Onondaga County Department of
WATER
ENVIRONMENT
PROTECTION

Onondaga Lake Ambient Monitoring Program

2003 Annual Report
Final - November 2004

Onondaga County, New York
Nicholas J. Pirro, County Executive

ONONDAGA LAKE AMBIENT MONITORING PROGRAM

2003 ANNUAL REPORT

REPORT AND APPENDICES 1-12

ONONDAGA COUNTY, NEW YORK

FINAL – November 2004

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ONONDAGA COUNTY, NEW YORK

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2003 AMP REPORT

PART I: RESULTS, COMPLIANCE, AND TREND ANALYSIS

CHAPTER 1: INTRODUCTION

1.1. PURPOSE AND ORGANIZATION OF THIS DOCUMENT

This report presents the results of Onondaga County Department of Water Environment Protection's (OCDWEP) 2003 monitoring program of Onondaga Lake, the Lake's tributary streams, permitted discharges, and segments of the Three Rivers system (the Seneca, Oneida, and Oswego Rivers). The County's monitoring program is referred to as the Ambient Monitoring Program (AMP) and includes both water quality and biological monitoring. Extensive data were collected in 2003 to evaluate physical, chemical, and biological conditions of this surface water system. These data are reported and analyzed in the context of inputs to the aquatic system and its water quality and biological response. Within this broad context of inputs and response, the report discusses trophic state, regulatory compliance, trends over time, response to reductions in external loading, and progress towards improved water quality and habitat conditions.

The 2003 report is presented in two parts. Part One, which includes Chapters 1 and 2, is submitted for formal approval by New York State Department of Environmental Conservation (NYSDEC). Chapter 1 is an introduction to the AMP and a description of the environmental setting. Chapter 2 is a summary of the major findings of the 2003 program with a focus on compliance and trends. Part Two is submitted for review and discussion by Onondaga County and the Onondaga Lake Technical Advisory Committee. Chapter 3 is an integrated discussion of water quality conditions and lake biology. Chapter 4 provides a summary of progress towards lake improvement as measured by a series of specific metrics. Chapter 5 presents recommendations for future monitoring and assessment. An executive summary of the 2003 annual report prepared for the interested public is bound separately and is available from OCDWEP and will be posted on the Onondaga County web site (www.ongov.net).

Appended to the Annual AMP Report are results of the entire 2003 monitoring program including results of storm events, Seneca River monitoring, fish community sampling, and analyses of the phytoplankton and zooplankton communities. Analytical methods are appended, as are results of the County's QA/QC program. Other appendices include a trend analysis, bibliography of historical and recent publications related to Onondaga Lake, and a summary of the 2003 zebra mussel assessment. Finally, plots of lake water quality of the upper and lower layers of Onondaga Lake from 1985 - 2003 are appended.

1.2. HISTORY AND OBJECTIVES OF THE AMP

The 2003 monitoring program represents the 34th consecutive year of Onondaga County's lake monitoring effort. The program began in 1970 as a baseline evaluation of the "state of the lake", and evolved into an annual monitoring effort designed to track water quality conditions of the lake and its watershed. Over the years the monitoring program has increased in scope and complexity in response to emerging regulatory issues, improvements in analytical methods, and growing public concern over the health of lakes and watersheds.

Onondaga County has convened a group of engineers and scientists (known as the Onondaga Lake Technical Advisory Committee or OLTAC) to provide guidance regarding program design, methods, and data interpretation. Current members of OLTAC along with their affiliation and area of expertise are listed below.

Dr. Raymond Canale, EnginComp Software Inc. (water quality modeling, Seneca River)
Dr. Charles Driscoll, Syracuse University (aquatic chemistry)
Dr. James Hassett, SUNY College of Environmental Science and Forestry (water resources engineering and hydrologic modeling)
Dr. Edward Mills, Cornell University (phytoplankton and zooplankton ecology)
Dr. Elizabeth Moran, EcoLogic LLC (limnology, monitoring program)
Dr. Lars Rudstam, Cornell University (fish ecology)
Dr. Kenton Stewart, SUNY Buffalo, Professor Emeritus (physical limnology)
Dr. William Walker, Jr., Consultant (statistics, loading estimates, mass balance)

Onondaga County's monitoring program has provided important information regarding the state of the resource and the need for controls on point and nonpoint sources of pollution to bring water quality conditions into compliance with state standards and federal requirements. In January 1998, Onondaga County signed an Amended Consent Judgment (ACJ) committing to a phased 15-year program of upgrades and improvements to the County's wastewater collection and treatment system. The ACJ includes three major elements:

1) Changes to the wastewater and stormwater collection systems to abate Combined Sewer Overflows (CSOs).

2) Improvements to the Metropolitan Syracuse Wastewater Treatment Plant (Metro) to provide a higher level of treatment to wastewater prior to discharge.

3) Monitoring Onondaga Lake, the lake tributaries, and the Seneca River to track their response to the pollution abatement actions.

The County's long-term monitoring program was evaluated and modified to ensure that the data collected would be adequate to evaluate the response of the lake, streams, and river to the planned improvements to the CSOs and Metro. This process of evaluation and modification was a collaborative effort of Onondaga County, OLTAC, U.S. Geological Survey (USGS), New York State Department of Environmental Conservation (NYSDEC), Environmental Protection Agency (EPA) and Atlantic States Legal Foundation (ASLF). Modifications were made to focus the monitoring program on a series of hypotheses related to the effectiveness of the County's improvements to the wastewater collection and treatment system. A revised monitoring program, known as the Ambient Monitoring Program (AMP) was initiated in August 1998.

The AMP is specifically designed to provide data and information regarding the effectiveness of the improvements to the County's wastewater collection and treatment system. Effectiveness is measured in terms of progress on two fronts: (1) compliance with water quality standards and guidance values, and (2) restoration of a balanced ecological community of plants and animals. In most cases, the AMP was designed to supplement, not replace, the historical program. A significant change was the greatly expanded focus on the biology of the aquatic system. The AMP assesses the status of the fish community, macroinvertebrates, vascular aquatic plants, algae, and zooplankton. Both abundance and community structure of these organisms can provide important information regarding health of the water resources.

Because the AMP will continue over an extended time period, the parties designing and approving the program consider flexibility to be an important consideration. Findings of the AMP and the implications of the results of the monitoring program regarding water quality and ecological status of the lake and watershed are reviewed by engineers and scientists associated with NYSDEC, ASLF, EPA, the Onondaga Lake Partnership, USGS, and members of OLTAC. The overall objectives and structure of the AMP are summarized in Table 1-1.

TABLE 1-1

Objectives and Structure of the Ambient Monitoring Program

AMP Program Objective	**Monitoring and Assessment**	**Comments**
Quantify External Loading	Monitor streams and point sources for flow, nutrients, solids, indicator bacteria, metals, salts. Calculate load using software customized by Dr. William Walker. Estimate inflow and outflow (mass balance) of nutrients.	Regular (biweekly) sampling supplemented with storm and high flow event monitoring.
Define compliance and trends in lake water quality	Physical characteristics: temperature, light penetration, water clarity Chemical characteristics: nutrients, salts, dissolved oxygen, ammonia, pH, metals. Biological characteristics: chlorophyll-*a*, phytoplankton, zooplankton, indicator bacteria. *Additional biological parameters are summarized below*. Trophic status: phosphorus, chlorophyll-a, Secchi disk transparency, deep water dissolved oxygen, phytoplankton community	Profiles through water column, supplemented by buoys at fixed depths. Water quality monitoring buoy at deepest location (profile sampling). Biweekly monitoring (open water season), winter as possible. Water clarity and indicator bacteria monitoring at nearshore stations: suitability for water contact recreation.
Determine tributary water quality, biota, and habitat conditions	Water quality: Annual program for flow, nutrients, solids, bacteria, metals, salts, oxygen-demanding material, and carbon fractions. Habitat and biota: Every 2 years: monitor stream macroinvertebrate community. Stream mapping: based on the National Resource Conservation Service (NRCS) Visual Assessment Protocol (baseline assessment in 2000 and 2002, to be repeated in 2008 and 2012). Additional evaluation of stream segments possible following improvements and/or major hydrologic events.	Focus is on the CSO-affected tributaries (Ley Creek, Harbor Brook, Onondaga Creek).
Assess the biological community in Onondaga Lake	Fish community: annual assessment of nests, larval fishes, juveniles, adults using multiple sampling gears and techniques. Macrophytes: annual aerial photography for percent cover of littoral zone (limited ground truthing). Detailed field survey every 5 years. Littoral macroinvertebrates: every 5 years, community structure and abundance. Zebra mussels: habitat mapping and sampling at reference locations (lake and river)	Focus on metrics of community structure, food web dynamics. Biological sampling of littoral zone, sediment texture analysis.

1.3. 2003 PROGRAM ELEMENTS

Improvements to Metro and the CSOs are being implemented in a phased program, with final completion dates in the year 2012. Loading reductions of wastewater related pollutants (ammonia, phosphorus, solids, floatables and bacteria) will be accomplished as discrete step improvements, not gradual reductions in loading. The ACJ includes specific milestone dates for assessment of progress and evaluation of the need for additional treatment or controls. The County's AMP includes both annual elements, designed to evaluate compliance and establish trends, and special elements timed to follow these construction-related milestones. Consequently, each year the AMP is slightly different. The structure of the 2003 monitoring program with respect to the ACJ-required objectives is summarized in Table 1-2.

TABLE 1-2
Elements of the 2003 AMP in Relation to ACJ-Required Monitoring Objectives

<table>
<tr><td colspan="3">ACJ Statement of Required Program Objective: <i>Quantify external loading of phosphorus, nitrogen, suspended solids, indicator bacteria, and salts. Assess the reduction in loading achieved by the CSO improvements. Design program to evaluate the relative contribution of point and nonpoint sources of pollution to the lake.</i></td></tr>
<tr><td>2003 Program Elements</td><td>Data Used To</td><td>Location in 2003 Report</td></tr>
<tr><td>(Annual program)
• Tributary monitoring: biweekly, high flows and storm events - Includes locations upstream and downstream of CSOs, urban and rural segments of subwatersheds.</td><td>Estimate annual external loading to Onondaga Lake</td><td>• Loading tables: Chapter 2
• Storm event analysis: Appendix 3
• Executive summary
• Mass balance (estimates of point and nonpoint contribution) last updated in 2002 Annual Report, dated Sept. 2003</td></tr>
<tr><td colspan="3">ACJ Statement of Required Program Objective: <i>Assess the tributaries' physical habitat and macroinvertebrate community</i>.</td></tr>
<tr><td>2003 Program Elements</td><td>Data Used To</td><td>Location in 2003 Report</td></tr>
<tr><td>(Every 6 years following baseline evaluation)
• Stream mapping using NRCS Visual Stream Assessment Protocol in CSO-subwatersheds: Onondaga Creek, Ley Creek and Harbor Brook</td><td>Quantify baseline conditions and provide basis to measure change</td><td>Not completed in 2003; most recent survey in 2002 Onondaga Lake Tributary Mapping report, dated April 2003</td></tr>
<tr><td>(Every 2 years)
• Macroinvertebrate surveys of CSO-affected subwatersheds</td><td>Quantify baseline conditions and provide basis to measure change</td><td>Not completed in 2003; most recent survey in 2002 Onondaga Lake Tributaries Macroinvertebrate Monitoring report, April 2003</td></tr>
<tr><td colspan="3">ACJ Statement of Required Program Objective: <i>Gather data on an adequate temporal and spatial scale to assess compliance with ambient water quality standards.</i></td></tr>
<tr><td>2003 Program Elements</td><td>Data Used To</td><td>Location in 2003 Report</td></tr>
<tr><td>(Annual program)
• Lake monitoring program: <i>South Deep Station, eight nearshore stations</i>
• Tributary monitoring program
• Seneca River monitoring program</td><td>Assess compliance with numerical and narrative standards</td><td>• Compliance tables: Chapter 2
• Executive summary</td></tr>
<tr><td colspan="3">ACJ Statement of Required Program Objective: <i>Evaluate changes in the water quality and trophic state of Onondaga Lake in response to reductions in external loading achieved by the improvements to Metro and the CSOs.</i></td></tr>
</table>

2003 Program Elements	Data Used To	Location in 2003 Report
(Annual program) - Lake monitoring - Tributary monitoring - River monitoring - Watershed analysis	Assess conditions in relation to inputs and trends	- Chapter 3: Integrated assessment - Trend summary: Chapter 2 - Executive summary - Appendix 4: trends

ACJ Statement of Required Program Objective: *Expand the chemical monitoring program to include other indices of ecological integrity: biological data, contaminant burden, and physical habitat.*

2003 Program Elements	Data Used To	Location in 2003 Report
Annual biological program: (1) Fish: nesting, larvae, juveniles, and adult communities (2) Lower trophic levels: phytoplankton and zooplankton - Contaminant data collected by NYSDEC	Assess current trophic state, abundance and diversity of species, importance of exotic species, reproductive success	- Chapter 2: summary of major findings - Chapter 3: integrated assessment, - Chapter 4: metrics of ecological integrity - Fish community: Appendix 8 - Phytoplankton and zooplankton: Appendix 2

ACJ Statement of Required Program Objective: *Through interaction with NYSDEC and appropriate peer reviewers, coordinate data collection and analysis to provide data at an adequate spatial and temporal scale to use in existing or revised lake models.*

2003 Program Elements	Data Used To	Location in 2003 Report
- Program reviewed by Technical Advisors and NYSDEC	Define lake response to external loading	- Chapter 2: Major Findings - Chapter 3: Integrated Assessment

ACJ Statement of Required Program Objective: *Define ambient water quality conditions in the Seneca River between Cross Lake and the Three Rivers junction.*

2003 Program Elements	Data Used To	Location in 2003 Report
(Annual program) - Surveys during low flow conditions at Seneca River Buoy 316	Assess current conditions, provide data for model validation	- Chapter 2: Major findings - Seneca River: Appendix 1

ACJ Statement of Required Program Objective: *Evaluate and quantify the assimilative capacity of the Seneca River and quantify effects of zebra mussels.*

2003 Program Elements	Data Used To	Location in 2003 Report
(Annual program) - Water quality surveys during low flow conditions	Assess current conditions, provide data for model verification (scheduled for 2005)	- Chapter 2: Major findings - Seneca River: Appendix 1 - Three Rivers Water Quality Model (TRWQM) applications to estimate assimilative capacity will be reported separately
- Zebra mussel assessment (survey completed in October 2003)	Assess current conditions, compile data for model verification (scheduled for 2005)	- Zebra mussels: Appendix 9 - Seneca River: Appendix 1

1.4. ONONDAGA LAKE AND ITS WATERSHED

1.4.1 Physical Features

Onondaga Lake is located immediately northwest of the City of Syracuse in Onondaga County, New York, USA (43° 06’ 54” N, 76° 14’ 34” W). The outlet of Onondaga Lake flows into the Seneca River, which joins with the Oneida River to become the Oswego River, which flow north on its route to Lake Ontario.

The Onondaga Lake drainage basin encompasses approximately 725 km^2 (285 square miles) and, with the exception of 2 km^2 in Cortland County, lies almost entirely in Onondaga County (Figure 1-1). The drainage basin includes six natural subbasins: Ninemile Creek, Harbor Brook, Onondaga Creek, Ley Creek, Bloody Brook, and Sawmill Creek.

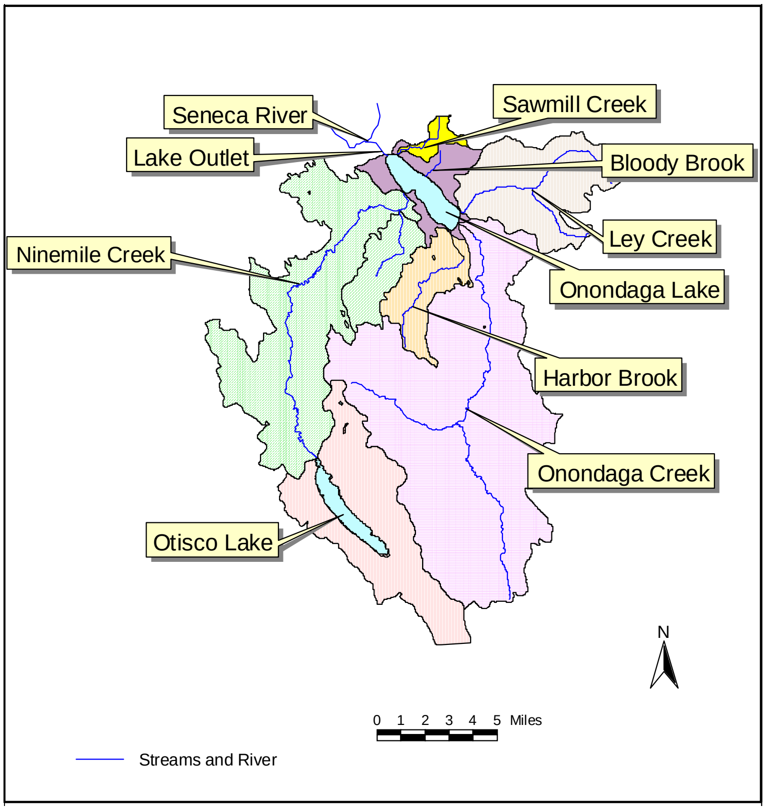

Figure 1-1. Onondaga Lake Watershed and 7 sub-basins. (Note: No GIS layer is available for Bloody Brook. Area shown in solid purple includes Bloody Brook watershed and areas of direct drainage to Onondaga Lake.

The climate of the Onondaga Lake basin is continental humid, strongly influenced by proximity to Lake Ontario and the presence of the Appalachian upland in the southern part of the drainage basin.

Lake Ontario moderates temperature extremes but contributes high amounts of cloudiness and snowfall. The summer months are drier on average, but high year-to-year variation is typical.

Climate Statistics for Onondaga Lake Basin

o	Mean daily maximum temperature (Aug. 2003):	81.5 ºF
o	Mean daily minimum temperature (Jan. 2003):	11.8 ºF
o	Annual precipitation (30—year average):	40.05 in
o	2003 precipitation:	37.60 in (-2.45 in)

Source: National Climate Data Center, Asheville NC

Onondaga Lake is relatively small, with 7.6 km maximum length, 2 km maximum width, 11.7 km^2 surface area, 131 x 10^6 m^3 volume, 10.9 m mean depth, and 19.5 m maximum depth. A bathymetric map (Figure 1-2) shows two minor depressions in a fairly uniform profile. The littoral zone is quite narrow. The Onondaga Lake shoreline is highly regular, with few bays.

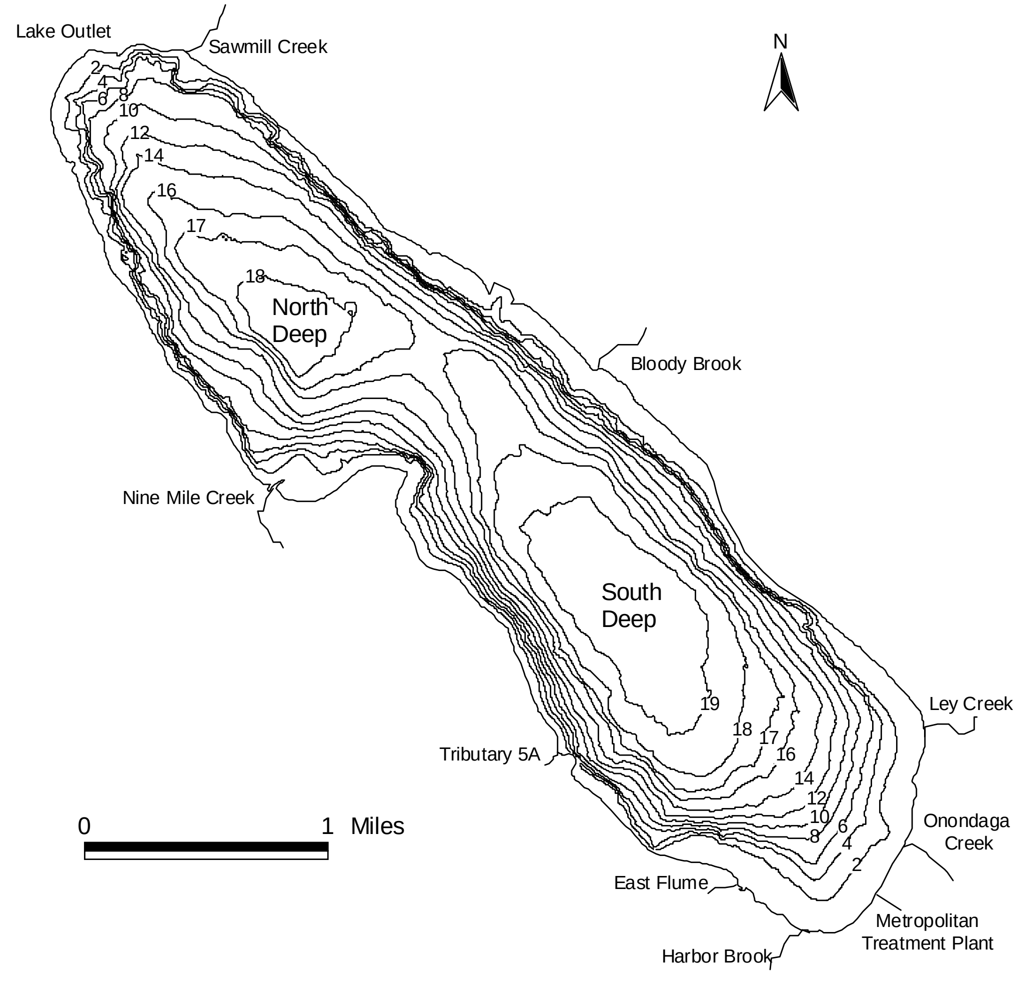

Figure 1-2. Bathymetric map of Onondaga Lake. (Note: Contour lines are in meters.)

Thermal stratification

At temperate latitudes, lakes and reservoirs with a maximum depth greater than about 10 meters develop relatively predictable annual patterns of water temperature with depth. In the spring, lakes begin to gain heat and the upper waters begin to warm. Heating causes water to expand; warmer less dense water floats on top of the cooler water. More work is needed for winds to overcome the developing density gradient. Depending on solar radiation and wind, Onondaga Lake alternates between isothermal and weakly stratified conditions in April through early May.

By late May 2003, Onondaga Lake waters stratified into the three layers associated with classic thermal stratification: warm upper waters (epilimnion), cool lower waters (hypolimnion) and a transition layer between the two (metalimnion). Density differences during thermal stratification were strong enough to impede most wind-induced mixing between the epilimnion and hypolimnion.

By August 2003, Onondaga Lake ceased gaining heat and the waters began to cool. The cooling process was manifested in a steady deepening of the epilimnion and gradual decrease in its temperature. Less and less wind energy was required to entrain the metalimnetic waters. Heat loss continued through the fall. Eventually, the temperature of the upper water cooled to the temperature of the lower water layer, and there was no density impediment to wind mixing of the water column. In 2003 fall mixing occurred in mid-October (around October 14th). Despite some variability caused by specific meteorological conditions, fall mixing typically occurs between October 15 and 31 each year.

Development of thermal stratification in winter is variable, depending on the extent and persistence of ice cover. OCDWEP staff maintains an ice diary noting dates of ice cover and sketching the surface area of the lake covered. Limited measurements of ice thickness, mostly in the northern basin, have been made. Observations are summarized in Table 1-3. There were 73 days of lakewide ice cover during the winter of 2003-2004.

TABLE 1-3
Onondaga Lake Ice Cover

Winter	Date Ice First Reported	Approximate Days of Ice Cover, North Basin	Approximate Days of Ice Cover, Lakewide *(diary notes >90%)*
87-88	12/31/87	70 days	20 days
88-89	12/14/88	75 days	9 days (4+5)
89-90	12/6/89	90 days	30 days (26 + 4)
90-91	12/27/90	54 days	6 days
91-92	12/19/91	59 days	19 days (14+5)
92-93	12/14/92	76 days	13 days
93-94	12/23/93	78 days	18 days
94-95	12/12/94	53 days	5 days
95-96	12/13/95	32 days	11 days (9+2)
96-97	1/9/97	47 days	19 days
97-98	12/31/97	15 days	0 days
98-99	12/23/98	62 days	12 days (6+6)
99-00	1/17/00	42 days	28 days
00-01	12/26/00	66+ days	54 days
01-02	1/8/02	2 days	2 days
02-03	1/4/03	42 days	40 days
03-04	1/09/04	61 days	73 days

Water residence time

Onondaga Lake has a short water residence time. Using 2003 streamflow data and Metro discharge, and a lake volume of 131 x 10^6 m^3, the water residence time is estimated at 0.25 years. This simple calculation assumes that the water column of the lake is consistently well mixed. However, Onondaga Lake is dimictic, with two periods of complete mixing separated by periods of thermal stratification. During summer stratification periods, upper waters are replaced by tributary and effluent inflows (warmer and less dense), while the cooler, denser lower waters are not. The replacement rate of the upper waters during summer stratification is rapid. Based on a detailed analysis of the volume of the upper waters and tributary inflows over the three year period from 1987 – 1989, Effler and Whitehead (1996) concluded that the water in the lake's upper layer is replaced about three times between May and September of an average hydrologic year.

1.4.2 Tributary Inflows

Five natural tributaries, three effluent discharges, and the lake outlet were monitored in 2003. Data summarizing the nature of the tributaries and point source inflows to the Lake are summarized in Table 1-4. Discharges from the major tributaries and Metro are gauged; approximately 93% of the hydrologic input to the lake is measured and sampled throughout the year.

TABLE 1-4
Summary of Monitoring Locations: Tributaries and Inflows

Tributary/ Inflow Gauged and Monitored in 2003	Drainage Area (km^2)	Gauge Site(s)	Percent of Lake Water Budget (2003)
Ninemile Creek	298	Lakeland (Rt. 48)	31%
Onondaga Creek	285	• Rt. 20, Lafayette • Dorwin • Spencer • Kirkpatrick	34 %
Metro: *Outfalls 001 and 002*	Syracuse service area	Post treatment, at outfall to Lake	18.3%
Ley Creek	77.5	Park St.	8.5%
Harbor Brook	29.3	• Velasko Rd. • Hiawatha Blvd.	2.3%
East Flume *(includes Honeywell International complex)*	<3	At weir	0.1%
Tributary 5A (*includes Crucible Specialty metals*)	<8	Downstream of facility outfall	0.3%
Direct precipitation and ungauged drainage area (including Bloody Brook and Sawmill Creek)	Lake surface area 11.7 Direct drainage < 30	None	Approx. 5.5%
Total	725 km^2	--	100%

1.4.3 Land Use

The Onondaga Lake watershed is highly urbanized compared with other lakes in the Seneca-Oneida-Oswego river basin. Approximately 22% of the watershed is classified as urban, 43% as forest, and 32% as agricultural. A watershed land use map is included as Figure 1-3. A watershed modeling initiative by the USGS is underway; the USGS and partners are compiling more detailed land use data from various sources for a more accurate breakdown within the tributary subwatersheds.

The majority of the lake shoreline is owned by Onondaga County and is maintained as part of a popular park and trail system. The lakeside park is currently used for recreation, shoreline fishing, and cultural entertainment. The lake is used for secondary water contact recreation activities such as boating.

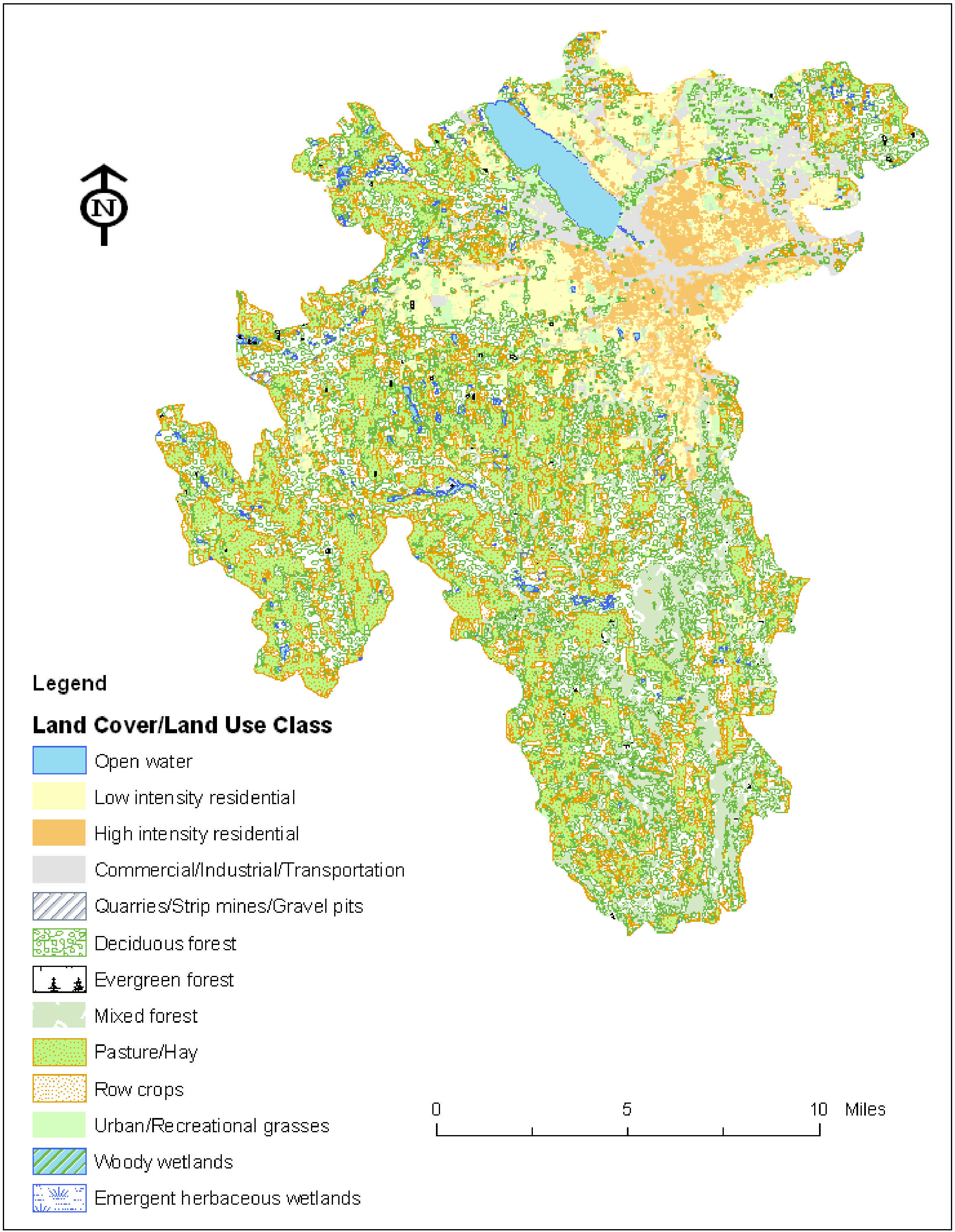

Figure 1-3. Land use within the Onondaga Lake watershed. *Source: Syracuse Onondaga County Planning Agency (SOCPA)*

1.4.4 Water Quality Classification and Designated Use

The NYSDEC is responsible for managing the State’s surface water resources. Lakes and streams are classified according to their designated best use (for example, water supply, swimming, fish propagation, aesthetic enjoyment, and fish survival).

Onondaga Lake is classified as B and C waters. The Class B segment encompasses the northern basin; the Class C segments include much of the southern basin and a small area around the mouth of Ninemile Creek. Both B and C waters must exhibit water quality conditions suitable for fish survival and propagation. Class B waters are to be suitable for primary water contact recreation (such as swimming). Class C waters are to be suitable for secondary water contact recreation (such as boating).

The main stems of the lake tributaries are classified mostly as C (suitable for fish propagation and secondary water contact recreation) but several small segments are Class B. The Seneca River segment in the vicinity of the Onondaga Lake outflow and downstream is Class B. As summarized in Table 1-5, several Class C stream segments within the subwatersheds are required to comply with Class C (T) water quality standards, meaning that dissolved oxygen and ammonia levels shall be suitable for salmonids. NYSDEC stocks several streams within the watershed with various species as summarized in Table 1-6.

TABLE 1-5

Summary of Regulatory Classification of Streams within Onondaga Lake Watershed

Stream	Description of Stream Segment	Regulatory Classification	Standards
Onondaga Creek	From mouth 0.85 miles to upper end of barge canal	C	C
	Upper end of Barge Canal 1.7 miles to Temple St.	C	C
	Temple Street 4.4 miles to Tributary 5B	B	B
	From Tributary 5B 1.9 miles to Commissary Creek	C	C
	From Commissary Creek to source	C	C(T)
Ninemile Creek	From mouth 3.4 miles to point mid-way between Airport Rd and Rt. 173	C	C
	From point mid-way between Airport Rd and Rt. 173 to Otisco Lake	C	C(T)
Harbor Brook	From mouth 1.9 miles to upper end of underground section	C	C
	From upper end of underground section 1.3 miles to City of Syracuse Line	B	B
	From City of Syracuse City line to source	C	C(T)
Ley Creek	From mouth to sewage treatment outfall	C	C
	From sewage outfall to South Branch of Ley Creek	B	B
Bloody Brook	From mouth to first tributary (approximately 0.37 miles from mouth)	B	B
	From first tributary to source	C	C

Source: NYSDEC (classifications as of July 2004)

TABLE 1-6

NYSDEC Fish Stocking in Waters Connected to Onondaga Lake, 2003

Stream Segment	Species Stocked	Number Stocked
Ninemile Creek	Brook Trout	1,900
	Brown Trout	6,676
	Rainbow Trout	302
Geddes Brook	Brown Trout	75
	Rainbow Trout	151
Onondaga Creek	Brook Trout	300
	Brown Trout	675
West Branch Onondaga Creek	Brown Trout	536
Seneca River	Tiger muskellunge	106,000
Otisco Lake	Brown Trout	3,370
	Tiger muskellunge	12,500
	Walleye	45,000

Source: NYSDEC

1.4.5 Priority Waterbodies Listing within the Watershed

New York State has an extensive program of monitoring and reporting to assess the extent to which designated uses for lakes and streams are being met. Water bodies that may not consistently meet their designated best use, or for which changes in land use may threaten water quality, are placed on a Priority Waterbodies List (PWL) that is updated periodically. Agencies and stakeholder groups including Environmental Management Councils, Soil and Water Conservation Districts, NYSDEC, watershed groups, and Water Quality Coordinating Committees provide input into the PWL. A subset of the PWL list is the 303(d) list, named for the section of the federal Clean Water Act that requires states to report to EPA those waterbodies requiring a watershed approach to water quality protection or restoration. This list is developed by NYSDEC and subject to a public comment period. A final list is forwarded to EPA for approval.

1.4.5.1 PWL Segments

Various stream and lake segments in the Onondaga Lake watershed were included on the October 2000 PWL for the Seneca-Oneida-Oswego basin, which is scheduled to be updated in 2004 following analysis of the data NYSDEC collected during their most recent Rotating Intensive Basin Surveys.

1.4.5.2 2004 303(d) list

The draft 2004 303(d) list (posted at http://www.dec.state.ny.us/website/dow/303dcalm.pdf.) includes the Seneca River as a “High priority for Total Maximum Daily Load (TMDL) development by NYSDEC”. According to the listing, “oxygen demand” is the cause/pollutant of water quality impairment in the Seneca River and “agriculture” is listed as the source. The listing stated that NYSDEC would complete a Total Maximum Daily Load (TMDL) allocation for the impaired region of the Seneca River and submit the documentation to EPA by March 31, 2006.

Geddes Brook and Ninemile Creek are placed in Part 3 of the 2004 303(d) list: “Waters requiring reassessment based on new methodology”. A footnote explains that the reassessment of these two streams will consider the impacts of the Onondaga Lake Watershed Management Plan on water quality. This plan is under development by the Onondaga Lake Partnership, lead agency Army Corps of Engineers.

Onondaga Lake and Lake Outlet were placed in a category of “multiple segment/categorical TMDL waters” on the 303(d) list. This category includes groups of waters affected by similar causes, or sources where a single TMDL may be able to address multiple waters with the same issue. Listed contaminants affecting fish consumption in Onondaga Lake and the outlet include PCBs, dioxin, and mercury.

1.5 POINT AND NONPOINT SOURCE DISCHARGES

As of 2003, remaining point source discharges to Onondaga Lake include treated effluent (outfall 001) and partially-treated flows (outfall 002) from Metro. Metro receives and treats wastewater and some stormwater from industrial, commercial, and residential sources within the Syracuse service area, which includes two Villages, six Towns and the City of Syracuse. The State Pollution Discharge Elimination System (SPDES) permit for Onondaga County also includes the outfalls of the CSOs.

There are other point source discharges within the watershed. Crucible Specialty Metals has a permit to discharge treated wastewater to a tributary to the lake (Tributary 5A). Noncontact cooling water from Trigen Syracuse Energy Corp and the Onondaga Cogeneration facility are returned to the lake via tributary 5A. The East Flume directs seepage from the former Honeywell International industrial complex and storm water from the Village of Solvay to the lake.

Onondaga County has a pretreatment program for industrial facilities connected to the publicly-owned sewer system. The most significant industrial user has been the pharmaceutical production facility of Bristol Myers-Squibb (BMS). A pretreatment facility for the pharmaceutical industry to remove BOD and convert ammonia to nitrate nitrogen was constructed and brought on line in the 1990s. Performance of the pretreatment facility was inconsistent through 1999. The 2003 data indicate that the BMS facility continues to achieve consistently high removal of ammonia; this pretreatment has significantly reduced the ammonia loading to Metro.

The ACJ, signed in January 1998, commits the County to implementing a phased 15-year program of upgrades and improvements to Metro and the CSOs. The ACJ specifies a compliance schedule for Metro to comply with staged effluent limits for ammonia and phosphorus (Table 1-7). Note that the County is projected to meet the Phase III ammonia effluent limits of 1.2/2.4 mg/l (summer/winter limits) by mid- 2004, eight years ahead of the original schedule.

TABLE 1-7
Phased Effluent Limits Specified by the ACJ

PARAMETER	PHASE	EFFLUENT LIMIT (Note seasonal limits for ammonia)	REQUIRED COMPLIANCE DATES	PROJECTED COMPLIANCE DATE
Ammonia Nitrogen	I	8,700 ppd (7/1 – 9/30)	January 1998	**MET**
		13,100 ppd (10/1 – 6/30)		
	II	2 mg/l (6/1 – 10/31)	May 1, 2004	Will proceed directly to Phase III limits
		4 mg/l (11/1 – 5/31)		
	III	1.2 mg/l (6/1 – 10/31) *	December 1, 2012	Mid- 2004
		2.4 mg/l (11/1 – 5/31) *		
Phosphorus	I	400 ppd	January 1998	**MET**
	II	0.12 mg/l	April 1, 2006	Late 2004 – early 2005
	III	0.02 mg/l *	December 1, 2012	December 1, 2012

ppd = pounds per day

* Final effluent limits for ammonia and phosphorus (effective December 1, 2012) may be modified based on revised TMDL for Onondaga Lake. NYSDEC anticipates promulgating revised TMDLs for Onondaga Lake on or about January 2009, subject to EPA approval as provided pursuant to section 303(d) of the Clean Water Act.

In order to comply with the effluent limits, Onondaga County is required to design, test and construct modifications and additions to the Metro facility that enable year-round nitrification of ammonia and filtration for phosphorus removal. The ACJ includes language requiring the County to modify the Metro discharge so that compliance with ambient water quality standards in the Lake is achieved, even if diversion of Metro effluent to the Seneca River is necessary to achieve compliant water quality conditions. The decision whether additional measures are required to bring the lake into compliance is scheduled for the year 2009. Engineering alternatives that fully comply with water quality standards must be implemented by December 1, 2012.

Nonpoint sources of nutrients, sediment, and bacteria enter the lake through the tributaries and the CSOs. CSOs are considered point sources of pollution, as they are piped into the tributary streams at defined points. As noted above, the discharge points are listed on the Metro SPDES permit.

Industrial residuals in the watershed continue to reach to the lake through surface runoff and infiltrating groundwater. Honeywell International’s upland sites, including the Semet Ponds, Willis Ave, LCP Bridge St. Facility, West Flume, and Wastebed B, are an ongoing source of mercury and organic contamination via runoff and groundwater infiltration. The wastebeds, including those located along the western shoreline, are also a continuing source of ionic waste (i.e., enriched in calcium and chloride). Lake sediments contain elevated concentrations of mercury and organic chemicals; the lake bottom is listed on the National Priorities List as a Superfund site.

For the combined sewers, the ACJ requires the County to design, construct, maintain, and modify and/or supplement as necessary, a CSO control and upgrade program. The program must meet requirements established in State and federal policy and guidance. Specifically, the County's CSO control and upgrade program must achieve three criteria:

(1) elimination or capture for treatment of no less than 85% by volume of the combined sewage collected on a system-wide annual average basis,
(2) elimination or minimization of floating substances in Onondaga Lake attributed to the CSOs,
(3) achievement of water quality standards for bacteria in all Class B portions of Onondaga Lake.

The release of untreated sewage through combined sewer overflows contributes to conditions where the bacterial levels in Onondaga Lake exceed the coliform standards promulgated in New York State's ambient water quality standards (6 NYCRR Part 703.4). CSOs also contribute to the presence of floating solids in violation of New York State's ambient water quality standards (6 NYCRR Part 703.2).

By the end of 2003, Onondaga County completed 16 CSO related projects required under the ACJ (Table 1-8). To meet the terms of the Amended Consent Judgment, the County will ultimately complete approximately 20 individual projects: five regional storage and treatment facilities, five or more sewer separation projects, five floatable control facilities, and four or more storage and transport projects. The planning and design of regional storage and treatment facilities for Onondaga Creek (Midland and Clinton Streets) and Harbor Brook are underway.

The Midland Avenue Regional Treatment Facility (RTF) and Conveyances project will significantly improve water quality conditions of Onondaga Creek and Onondaga Lake and will reduce human health risks associated with discharge of untreated sewage into the Creek and Lake. When completed, the project will exceed requirements of the ACJ in terms of the volume of combined sewage captured and the efficacy of the floatables controls. The proposed project will utilize underground capture and storage of combined sewage overflow in abating 9 CSOs in the area. The RTF will be used only during peak wet weather conditions that exceed the volume and/or intensity of flow in the system design. This project was scheduled to come on-line in May 2007 but the County has proposed a revised date of May 2008 due to delays in local approvals.

Table 1-8

Status of CSO Abatement Projects as of December 2003

Project	Status
Regional storage and treatment facilities	
Project	*Status*
Midland CSO Abatement Facility	In design.
Clinton CSO Abatement Facility	In facility planning stage.
Harbor Brook CSO Abatement Facility	In facility planning stage.
Newell St. disinfection pilot demo	Complete
Hiawatha Overflow, Interceptor, RTF	Complete
Sewer separation	
Project	*Status*
Sewer separation at Tallman-Taylor, Onondaga Ave	Underway 2004
Sewer separation near Brighton Ave.	Completed 2003
Sewer separation at Water St (024)	Completed 2001
Sewer separation on West St.	Completed 1999
Sewer separation at West St (057, 058, 059)	Completed 1999
Floatables control facilities	
Project	*Status*
CSO toxicity evaluation report	Complete
Maltbie St. FCF	Complete
Franklin St. FCF	Complete
Harbor Brook FCF	Complete
Teall Brook FCF	Complete
Onondaga Creek FCF	Complete
Storage and transport capacity	
Project	*Status*
Siphon rehabilitation	Complete
Erie Blvd. storage	Complete
Midland Phase 1 pipeline	Complete
Kirkpatrick St. Pump Station upgrade & force main	Complete

Source: Lake Improvement Project Office

The service area that contributes to the Clinton Street project is the second largest in the County's combined sewer system. It encompasses approximately 970 acres of urban residential and commercial areas. There are 10 permitted CSOs within the service area. Completion of this project will provide significant water quality benefits as part of the County's overall CSO control and upgrade program. The start of operations for the proposed facility is scheduled for May 2012.

The 1,287-acre combined sewer area within the urbanized portion of the Harbor Brook basin constitutes approximately 20% of the combined sewer area tributary to Metro. A total of 18 CSOs discharge into Harbor Brook. This project has not yet selected a final design alternative.

Evaluation of alternatives is based on engineering and operational considerations, environmental and community effects, and cost. Execution of this project is complicated by the presence of industrial contamination near the mouth of Harbor Brook. Because of these complications, the original deadline for the project may be altered. The assessment and decision-making process is now underway.

Performance reports for facilities that have gone on-line are satisfactory. As of first quarter 2004, these facilities are working as designed with no major problems reported.

1.6 A NOTE ON NOMENCLATURE

The annual pattern of thermal stratification of Onondaga Lake causes water quality conditions to vary with depth. The AMP is designed to characterize the lake's upper and lower waters by analyzing an extensive list of water quality parameters. Some parameters are analyzed from water samples collected at discrete depths, while other parameters are analyzed from two composite water samples created in the field. The composite samples are meant to characterize the lake's upper mixed layer (UML) and the lower water layer (LWL). The AMP sampling technicians select depths for compositing based on the lake's thermal profile as measured in the field at the start of the sampling event. Various terms have been used to refer to the samples of the upper and lower waters, which has led to confusion. To clarify the nature of the samples and the lake strata, modifications in nomenclature were adopted during 2004 and are reflected throughout this report:

- The composite samples of the lake's upper waters are referred to as the UML (upper mixed layer) samples. The term "epilimnion" is not technically correct during periods when the lake is not stratified. The term has been used historically to refer to the upper waters year round.

- The composite samples of the lake's lower waters are referred to as the LWL (lower water layer) samples. The term "hypolimnion" is not technically correct during periods when the lake is not stratified. The term has been used historically to refer to the lower waters year round.

1.7 REFERENCES

Effler, S. W. and K. A. Whitehead. 1996. Tributaries and discharges. pp.97–199 in S.W. Effler {ed.} Limnological and engineering analysis of a polluted urban lake. Prelude to environmental management of Onondaga Lake, New York. Springer-Verlag. NY.

CHAPTER 2: MAJOR FINDINGS

2.1 LOADING

2.1.1 Precipitation and Streamflow

Each year, the total amount and timing of precipitation affect delivery of materials to the Onondaga Lake ecosystem. Below-average rainfall throughout the year, except for a wet period during May and June, contributed to a total precipitation in 2003 of 37.6 inches (95.5 cm), slightly below the 30-year average of 40.05 inches (101.7 cm) (Figure 2-1). This continued a series of years of below-normal precipitation in evidence since 1994, as displayed in Figure 2-2. A significant water deficit remains with respect to cumulative departure from a 30-year rolling average precipitation measured by National Oceanic and Atmospheric Administration (NOAA) at their Syracuse Hancock Field airport monitoring station.

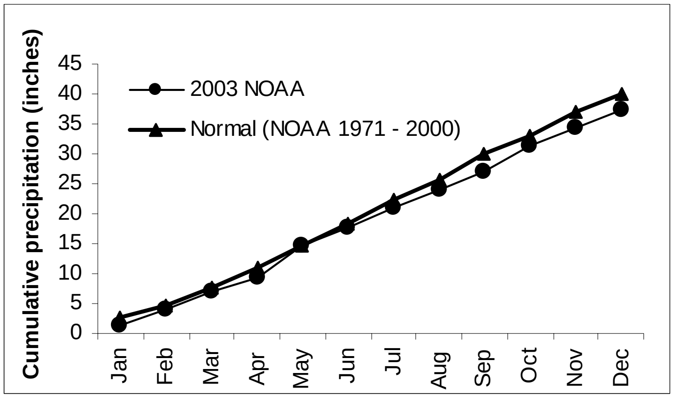

Figure 2-1. Cumulative precipitation in 2003 compared with the historical average for Syracuse, NY.

Source: National Climate Data Center, Ashveille NC

Hydrographs of the major tributary streams are plotted in Figure 2-3. Sampling dates for the AMP tributary program (including storm events on Ley Creek, Onondaga Creek, Bloody Brook and Sawmill Creek) are also indicated on the hydrographs. In 2003, the biweekly program was supplemented with one additional sampling event on all tributaries

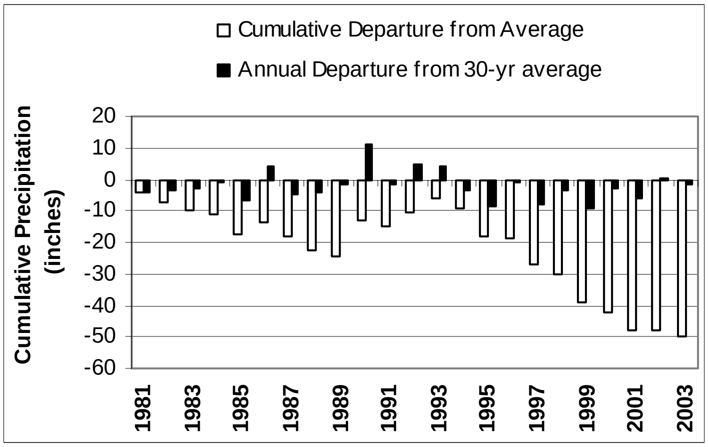

Figure 2-2. Cumulative precipitation for Syracuse, New York (Hancock Airport station) in relation to 30-year average. *(Source: National Climate Data Center Asheville, NC)*

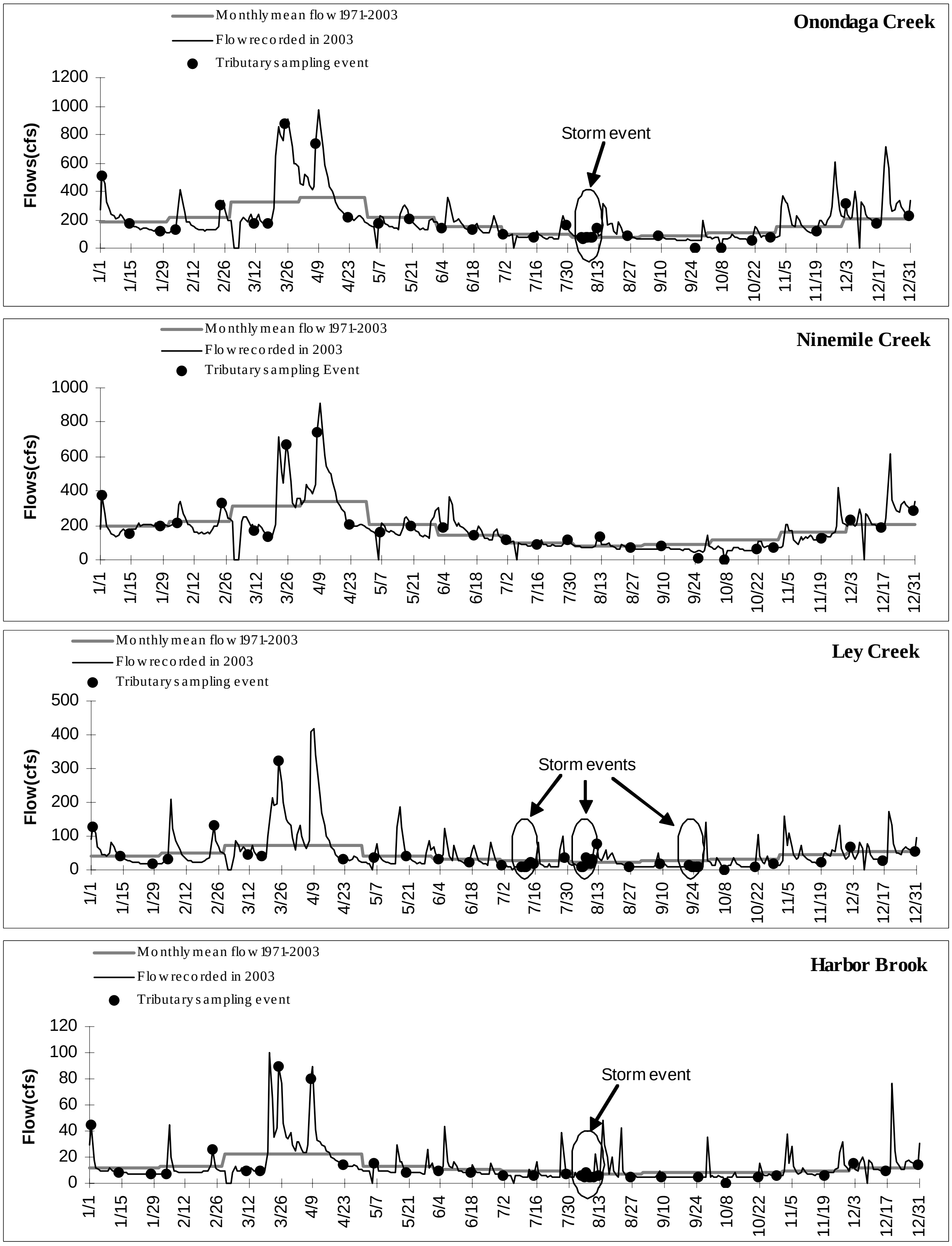

Figure 2-3. Observed tributary flows in 2003 compared with the long-term average flow record.

during high flow periods. A total of 11 sampling events in 2003 met or exceeded the threshold definition of a high flow event (defined as one standard deviation above the monthly average flow), well above the program goal of a minimum of five events sampled each year. The 2003 tributary monitoring program captured representative samples throughout the flow regime as shown by the number of samples during both high flow and low flow regimes.

2.1.2 Metro Performance

The Metropolitan Syracuse Wastewater Treatment Plant (Metro) is a major source of nitrogen, phosphorus, bacteria, and organic (oxygen-demanding) material to the lake. Major projects to upgrade the Metro facility and increase removal of wastewater-related contaminants continued through 2003.

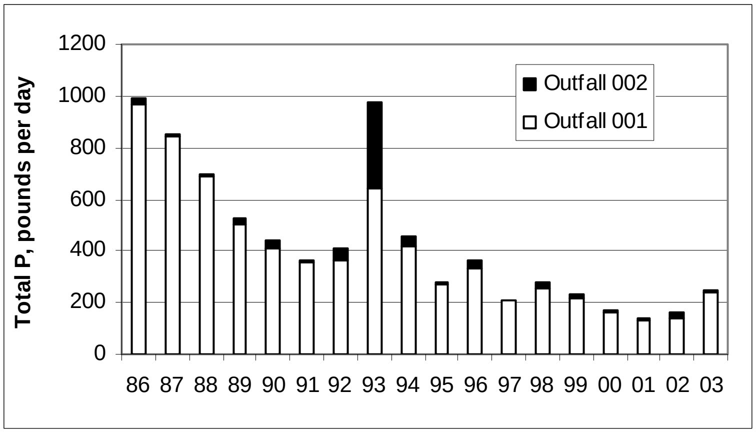

Figure 2-4. Annual phosphorus discharge from Metro outfalls 001 and 002, 1986 - 2003***. Elevated levels in 1993 due to construction-related bypass.***

Removal of a significant fraction of the phosphorus in wastewater is currently achieved using ferric chloride (iron salt). Because of the importance of phosphorus to lake ecology, its removal from wastewater has been a central focus of the engineering improvements at Metro. The phosphorus load from Metro (outfall 001) averaged 240 pounds per day in 2003 (Figure 2-4), below the Phase I effluent limit of 400 pounds per day. The secondary Metro discharge point (outfall 002, which is operational during high flow periods, and discharges effluent after primary treatment and disinfection) averaged an additional 14.5 pounds per day of phosphorus in 2003. Average effluent total P concentration from Metro Outfall 001 was 0.42 mg/l (Figure 2-5). In contrast, effluent discharged through Outfall 002 averaged 1.1 mg/l total phosphorus. The difference in the TP concentration reported for Outfalls 001 and 002 is attributed to the secondary treatment process and effectiveness of the addition of iron salts in reducing wastewater phosphorus.

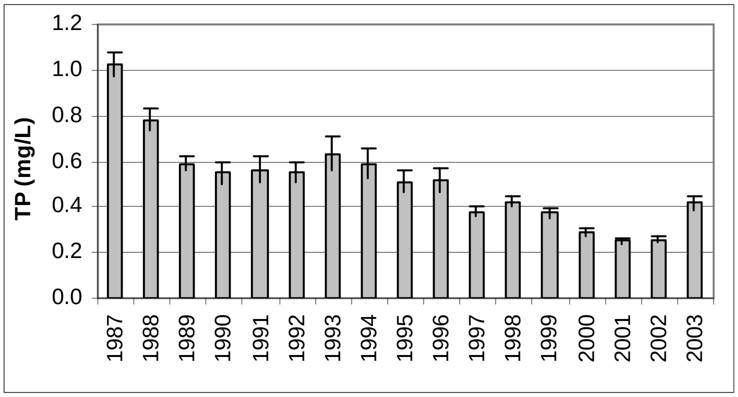

Figure 2-5. Average monthly total phosphorus concentration of Metro effluent (Outfall 001) *Note: Error bars are one standard error of the mean.*

The concentration and loading of Total P in Outfall 001 were higher in 2003 than measured in 2002. According to the engineering staff at OCDWEP, no single factor accounted for the higher TP concentration in the treated effluent in 2003 as compared to 2002. Additional reductions in effluent P concentration and loading to the lake will be achieved as the High Rate Flocculated Settling (HRFS) process is brought on line in late 2004 – early 2005 to meet the Phase II effluent phosphorus limit of 0.12 mg/l. Evaluation of the need for and feasibility of the Phase III limit of 0.02 mg/l will be completed in the context of a revised phosphorus TMDL allocation for the lake prior to the compliance deadline of December 1, 2012 (refer to Table 1-7).

Treated wastewater from Metro is the largest external source of ammonia to the lake, contributing an estimated 84% of the external load in 2003, including discharges from both Outfalls 001 and 002. Significant reductions in the ammonia loading to Onondaga Lake were achieved between 1995 and 1999 (Figure 2-6) as the aeration system of Metro's secondary clarifiers was upgraded. Since 1999, the ammonia concentration in the Metro effluent has been relatively consistent from year-to-year, although highly variable within each year between winter and summer; a result of seasonal nitrification. Major reductions in effluent ammonia N concentrations have been measured as of February 2004 when the Biological Aerated Filter (BAF) system came on line to achieve year-round nitrification and compliance with Phase III effluent limits (refer to Table 1-7).

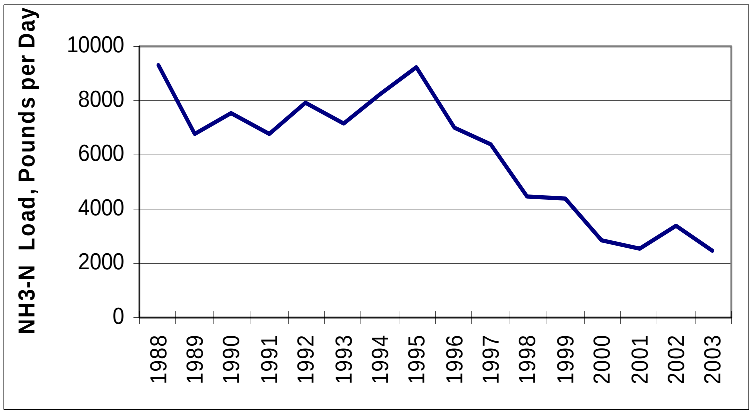

Figure 2-6. Average ammonia-N load from Metro (outfall 001), 1988 - 2003.

2.1.3 Concentrations and Loads of Inflows (Tributaries and Metro)

2.1.3.1 Methods

External loads of chemicals, solids, and microorganisms to Onondaga Lake are calculated using a custom software program developed by OLTAC member Dr. William Walker Jr. Prior to the 2003 analysis and annual report, the loading calculation method evaluated the relationships between flow and concentration of constituents in each tributary, stratified data into two flow regimes, and used the relationship between flow and concentration to project the concentration of constituents over the unsampled period of the hydrologic record. The results of this estimation technique (referred to as AUTOFLUX Method 2) were reported, along with the standard error of the annual estimate. Storm event samples were reduced to a single daily average flow-weighted concentration and included in the analysis.

In mid-2004, Dr. Walker refined his program used to estimate loading to Onondaga Lake. The 2003 loads were recalculated using the improved estimation technique; historical loads were re-calculated as well using the improved method (to be called “Method 5”). This change was implemented in conjunction with the compilation of the OCDWEP long-term integrated water quality database and supporting software in April 2004. The new technique was developed to support estimation of daily loads (required for lake modeling), to support development of monthly and seasonal lake mass balances, and to improve the accuracy and precision of the annual load estimates. A detailed review during the September 16, 2004 OLTAC meeting provided the basis for recommending this change in calculation method.

Method 5 differs from AUTOFLUX Method 2 in several ways. Data are stratified by flow regime (similar to AUTOFLUX Method 2) and are also stratified by season using a multiple regression technique. Higher-frequency measurements collected during storm events were incorporated into the calculations. Conditions during the unmonitored period are projected using a residual interpolation method that includes a flow derivative term. This term was included to account for the potential effect of differences in the flow: concentration relationship depending on whether data were taken during periods of rising vs. falling flows. Consideration of the flow factor was found to influence suspended solids and total phosphorus loads from Onondaga Creek and some others, but generally had little effect for other stations and parameters.

2.1.3.2 2003 Loading Estimates and Historical Results

Flow-weighted average concentrations of the lake inflows (tributaries and point sources) are summarized in Table 2-1. This table also reports the relative standard error (RSE) of the annual means, a reflection of the variability in measurements. Note the high RSE associated with suspended sediment (TSS) measurements in the natural tributaries; this result reflects the variability of TSS over the flow regime. Contaminants associated with the sediment fraction are also variable. Average concentrations of heavy metals are based on quarterly measurements. Bacteria concentrations were also extremely variable between sampling events, as would be expected in sources affected by combined sewer overflows and urban stormwater.

The 2003 external load of materials to Onondaga Lake is summarized in Table 2-2. The annual monitoring program samples more than 90% of the water flowing into the lake (runoff from nearshore areas and precipitation onto the lake surface are not monitored). As discussed in the sections related to storm event sampling, limited sampling of Bloody Brook and Sawmill Creek, two small streams directing runoff from nearshore areas, was conducted in 2003. This program was designed to assess whether these small drainage basins contribute disproportionate loads of material to the lake.

Loading varies each year depending on precipitation and streamflow conditions and the effectiveness of controls on point and nonpoint sources of pollution. Loading data from 1989 - 2003 are summarized in Table 2-3. Reductions in the loading of ammonia, nitrite, and TKN are evident, reflecting the enhanced nitrification of wastewater at Metro. Related to this change in technology is the increase in loading of nitrate, the oxidized form of nitrogen. Another notable reduction in external loading is evident in total P and soluble reactive phosphorus (SRP), although loads in 2003 were higher than those reported in 2002. This was a result of both more water (outfalls 001 and 002 combined to discharge 97.2 million cubic meters of treated wastewater in 2003, as compared to 92.2 million cubic meters in 2002) and higher effluent total phosphorus concentrations (outfall 001 averaged 265 µg/l in 2002 and 417 µg/l in 2003).

The relative contribution of each source to the 2003 materials and water budget for Onondaga Lake is summarized in Table 2-4. Note the importance of Metro as a source of nitrogen and oxygen-demanding material. Treated effluent from Metro is also a major source of total P, contributing approximately 40 - 60% of the external load to the lake each year.

2.1.3.3 Phosphorus Load

Total phosphorus loadings to the lake declined from the late 1980s to the late 1990s, from about 120,000 kg/yr in 1989 to about 50,000 kg/yr (Figure 2-7). From 1999 to 2002, total phosphorus loads remained relatively constant. The 2003 data indicate an increase in TP (to 70,000 kg/yr) and SRP (to 15,000 kg/yr) loading to the lake, primarily due to an increase in loading from Metro, which was due in turn to an increase in both total flow and concentration.

Temporal trends in phosphorus species from Metro during 2003 are plotted in Figure 2-8 along with measured concentrations at South Deep. Note that while TP from Metro exhibited some spikes during wet weather periods, the annual loading was relatively constant. In contrast, SRP loading from Metro exhibited distinct seasonality in 2003.

As in past years, of the major tributaries, Onondaga Creek contributed the greatest amount of phosphorus to the lake on an annual basis, followed by Ninemile Creek, Ley Creek and Harbor Brook (Figure 2-9). This pattern has not changed appreciably since the late 1980s. The same order of importance has been observed during storm events. The consistency of this pattern implies that there have been no major changes in contributions from the various portions of the watershed over this period. This is likely due to the relatively stable land use patterns in the watershed over this period.

TABLE 2-1

FLOW-WEIGHTED AVERAGE LIMNOLOGICAL PARAMETERS IN ONONDAGA LAKE TRIBUTARIES
AND STANDARD ERROR OF ESTIMATE, USING METHOD 5

		Ninemile Creek @ Lakeland		**Harbor Brook @ Hiawatha Blvd**		**Onondaga Creek @ Kirpatrick Street**		**Ley Creek @ Park St**	
Parameter	**Units**	Concentration	***RSE***	Concentration	***RSE***	Concentration	***RSE***	Concentration	***RSE***
5-day BOD	mg/l	2.4	*17%*	2.6	*43%*	2.5	*18%*	2.7	*21%*
Total Alkalinity	mg/l	187	*2%*	234	*4%*	210	*2%*	198	*4%*
Total Organic Carbon	mg/l	5.5	*24%*	2.2	*9%*	2.6	*7%*	6.5	*5%*
TOC-filtered	mg/l	2.9	*9%*	2.0	*9%*	2.4	*7%*	6.1	*4%*
Total Inorganic Carbon	mg/l	48.9	*2%*	61.0	*4%*	55.0	*3%*	56.0	*6%*
Total Kjeldahl Nitrogen as N	mg/l	0.71	*11%*	0.59	*24%*	0.59	*12%*	0.95	*11%*
Organic Nitrogen as N	mg/l	0.43	*16%*	0.50	*30%*	0.50	*16%*	0.55	*16%*
Ammonia as N	mg/l	0.26	*25%*	0.10	*20%*	0.10	*13%*	0.37	*14%*
Nitrate as N	mg/l	1.23	*7%*	1.71	*5%*	1.18	*6%*	0.52	*17%*
Nitrite as N	mg/l	0.02	*10%*	0.01	*26%*	0.01	*31%*	0.02	*15%*
Arsenic	ug/l	2.0	*0%*	2.0	*0%*	2.0	*0%*	2.0	*2%*
Total Phosphorus	ug/l	56.6	*13%*	78.7	*29%*	60.3	*23%*	83.9	*22%*
Soluble Reactive Phosphorus	ug/l	7.7	*28%*	33.2	*26%*	8.9	*32%*	13.5	*10%*
Silica	mg/l	4.0	*5%*	4.8	*5%*	4.8	*5%*	6.0	*5%*
Calcium	mg/l	188	*2%*	190	*4%*	101	*2%*	107	*5%*
Sodium	mg/l	114	*4%*	158	*19%*	248	*4%*	213	*23%*
Sulfate	mg/l	186	*1%*	352	*3%*	111	*1%*	120	*2%*
Chloride	mg/l	343	*4%*	292	*15%*	407	*5%*	362	*20%*
Total Suspended Solids	mg/l	18	*26%*	19	*48%*	26	*27%*	19	*58%*
Total Dissolved Solids	mg/l	1139	*3%*	1232	*6%*	1046	*3%*	998	*13%*
Zinc	ug/l	12.3	*37%*	23.6	*30%*	14.1	*33%*	19.0	*7%*
Copper	ug/l	6.8	*22%*	4.9	*47%*	5.5	*69%*	3.2	*24%*
Chromium	ug/l	1.1	*31%*	2.3	*64%*	1.3	*51%*	1.3	*34%*
Cadmium	ug/l	0.4	*26%*	0.4	*6%*	0.4	*13%*	0.4	*17%*
Lead	ug/l	4.6	*19%*	7.6	*23%*	4.7	*31%*	4.5	*28%*
Iron	mg/l	0.6	*15%*	0.5	*40%*	1.0	*68%*	0.9	*35%*
Magnesium	mg/l	27.8	*1%*	37.0	*4%*	22.2	*2%*	21.7	*5%*
Manganese	ug/l	64.3	*10%*	29.5	*33%*	52.7	*18%*	112.1	*10%*
Nickel	ug/l	2.8	*28%*	2.5	*21%*	2.6	*17%*	4.6	*13%*
Fecal Coliforms	cells/100m	170	*221%*	1,370	*329%*	1,755	*60%*	571	*51%*

RSE = relative standard error of the concentration estimate. ** METRO BOD5, NH3-N, TP, TSS based on observations made daily,
Metro TKN based on observations made 5 times each 2 week period. Other values are based on data collected bi-weekly, Mar - Nov, 2003
Calculations use the laboratory limit of detection when observations were below that limit.

[#] Computation method has been updated, see text for details

TABLE 2-1 (CONTINUED)

FLOW-WEIGHTED AVERAGE LIMNOLOGICAL PARAMETERS IN ONONDAGA LAKE TRIBUTARIES
AND STANDARD ERROR OF ESTIMATE, USING METHOD 5

		Trib. 5A		**METRO Effluent ****		**METRO By-Pass**		**East Flume**	
Parameter	**Units**	Concentration	***RSE***	Concentration	***RSE***	Concentration	***RSE***	Concentration	***RSE***
5-day BOD	mg/l	2.6	*11%*	16.2	*3%*	61.2	*9%*	3.5	*12%*
Total Alkalinity	mg/l	143	*2%*	210	*3%*	174	*13%*	168	*6%*
Total Organic Carbon	mg/l	3.8	*4%*	11.8	*4%*	20.0	*30%*	5.5	*5%*
TOC-filtered	mg/l	3.5	*4%*	9.2	*4%*	13.8	*31%*	5.0	*5%*
Total Inorganic Carbon	mg/l	37.4	*3%*	55.6	*3%*	43.9	*17%*	40.7	*6%*
Total Kjeldahl Nitrogen as N	mg/l	0.49	*10%*	6.62	*2%*	10.02	*8%*	1.20	*8%*
Organic Nitrogen as N	mg/l	0.34	*14%*	2.48	*13%*	3.89	*23%*	0.77	*15%*
Ammonia as N	mg/l	0.14	*8%*	4.30	*3%*	5.80	*12%*	0.42	*11%*
Nitrate as N	mg/l	0.96	*12%*	5.28	*8%*	1.56	*47%*	4.18	*9%*
Nitrite as N	mg/l	0.03	*19%*	0.41	*11%*	0.17	*64%*	0.77	*9%*
Arsenic	ug/l	2.0	*10%*	2.0	*5%*	2.0	*3%*	3.3	*11%*
Total Phosphorus	ug/l	104.6	*7%*	417.6	*2%*	1056.5	*10%*	161.5	*13%*
Soluble Reactive Phosphorus	ug/l	38.9	*11%*	114.4	*14%*	124.0	*75%*	76.4	*24%*
Silica	mg/l	7.6	*5%*	5.4	*4%*	4.4	*11%*	9.9	*7%*
Calcium	mg/l	124	*3%*	120	*8%*	88	*29%*	117	*7%*
Sodium	mg/l	187	*4%*	260	*14%*	343	*32%*	430	*9%*
Sulfate	mg/l	121	*3%*	189	*1%*	125	*5%*	383	*4%*
Chloride	mg/l	382	*4%*	414	*14%*	555	*38%*	582	*9%*
Total Suspended Solids	mg/l	14	*79%*	15	*4%*	64	*13%*	14	*33%*
Total Dissolved Solids	mg/l	1035	*4%*	1181	*3%*	1239	*28%*	1676	*7%*
Zinc	ug/l	22.6	*43%*	21.2	*8%*	36.50	*16%*	34.6	*36%*
Copper	ug/l	19.9	*36%*	11.2	*7%*	24.95	*110%*	2.6	*32%*
Chromium	ug/l	38.8	*40%*	2.4	*10%*	6.60	*29%*	2.1	*47%*
Cadmium	ug/l	0.4	*48%*	1.5	*11%*	1.42	*13%*	0.4	*81%*
Lead	ug/l	5.1	*23%*	3.4	*7%*	5.40	*6%*	3.9	*17%*
Iron	mg/l	0.9	*48%*	0.7	*6%*	3.2	*18%*	0.3	*27%*
Magnesium	mg/l	16.5	*2%*	23.2	*3%*	18.1	*17%*	26.8	*7%*
Manganese	ug/l	71.9	*25%*	47.0	*7%*	64.9	*23%*	24.3	*21%*
Nickel	ug/l	72.7	*19%*	11.3	*6%*	11.4	*23%*	3.0	*22%*
Fecal Coliforms	cells/100m	33	*540%*	5,259	*62%*	138,498	*53%*	70	*33%*

RSE = relative standard error of the concentration estimate. ** METRO BOD5, NH3-N, TP, TSS based on observations made daily,
Metro TKN based on observations made 5 times each 2 week period. Other values are based on data collected bi-weekly, Mar - Nov, 2003
Calculations use the laboratory limit of detection when observations were below that limit.

[#] Computation method has been updated see text for details

TABLE 2-2
2003 Loading of Major Water Quality Parameters to Onondaga Lake

Parameter	Units	Onondaga Creek	Ninemile Creek	Metro Outfall 001	Metro Outfall 002	Ley Creek	Harbor Brook	Trib 5A	East Flume	Total Monitored
Water	$10^6\ m^3$	183	167	95	2.19	45	12	1.7	0.63	507
Total P	10^3 kg	11	9.5	40	2.3	3.8	0.93	0.18	0.10	67
SRP	10^3 kg	1.6	1.3	11	0.27	0.61	0.39	0.07	0.05	15
TKN	10^3 kg	108	119	632	22	43	7.0	0.8	0.8	932
Nitrate-N	10^3 kg	218	205	503	3.4	23	20	1.6	2.7	977
Nitrite-N	10^3 kg	2.4	3.7	39	0.37	0.75	0.17	0.05	0.49	46
Ammonia-N	10^3 kg	18	44	410	12.7	16.5	1.2	0.24	0.26	504
Organic-N	10^3 kg	91	72	236	8.5	24.9	5.8	0.59	0.49	439
Ca	10^3 kg	18,450	31,509	11,497	193	4,814	2,245	211	74	68,993
Cl	10^3 kg	74,603	57,521	39,543	1,213	16,320	3,449	649	369	193,667
Na	10^3 kg	45,394	19,146	24,628	494	9,462	1,888	318	273	101,605
TSS	10^3 kg	4,745	2,949	1,426	140	855	221	24	8.8	10,369
Fecal Coli (annual)	10^{10} cells	321,351	28,451	501,806	302,619	25,754	16,171	56	44	1,196,252
Fecal Coli (May - Sept)	10^{10} cells	89,208	21,464	1,832	50,633	12,284	8,340	6	22	183,791
BOD -5 day	10^3 kg	453	403	1,548	134	212	31	4.5	2.2	2,788
T-Alk	10^3 kg	38,481	31,243	20,041	381	8,921	2,761	243	106	102,177
TOC	10^3 kg	473	922	1,128	44	295	26	6.5	3.5	2,898
TIC	10^3 kg	10,075	8,181	5,304	96	2,526	720	64	26	26,991

NOTES

Values have been revised from previous years due to revision in computation method (see text for details)
Metro Outfall 001 calculated loads of BOD5, NH3-N, TP, TSS are based on daily measurements; METRO TKN based on 5 measurements/2 wks
Metro Outfall 002 estimates based on periodic grab samples when outfall is active (high flow events)
Natural tributaries, East Flume and Tributary 5A calculations based on biweekly program, plus high flow events and storms
Tributary BOD samples include a large percentage of observations below the limit of detection

TABLE 2-3

2003 Annual Tributary Loadings to Onondaga Lake , 1990 - 2003 and Compariosn of 2003 Load to Long-term Average Conditions

Parameter	Units	Annual Load 1990	Annual Load 1991	Annual Load 1992	Annual Load 1993	Annual Load 1994	Annual Load 1995	Annual Load 1996	Annual Load 1997	Annual Load 1998	Annual Load 1999	Annual Load 2000	Annual Load 2001	Annual Load 2002	Annual Load 2003	Average Load 1990-2002	% Change 2003 from Average
5-day BOD	10^3 kg	2,835	2,109	4,059	4,226	2,928	2,433	3,300	2,134	2,220	1,745	1,981	1,734	2,325	2,696	2,618	3%
Total Alkalinity	10^3 kg	127,204	86,082	104,777	107,504	92,308	64,728	101,576	75,112	83,375	59,355	90,576	75,898	85,765	102,176	88,789	15%
Total Organic Carbon	10^3 kg	5,836	4,531	3,324	4,344	2,558	2,369	3,867	2,269	2,072	1,682	2,224	1,895	1,975	2,897		
Total Inorganic Carbon	10^3 kg	32,160	21,471	26,846	26,429	23,876	16,533	26,113	18,466	22,173	15,202	23,876	19,667	22,533	26,992	22,719	19%
Total Kjeldahl N	10^3 kg	1,907	1,745	1,880	2,003	1,927	1,883	2,081	1,494	1,274	907	982	824	1,018	932	1,533	-39%
Ammonia-N	10^3 kg	1,364	1,265	1,287	1,321	1,408	1,541	1,498	1,118	833	614	571	499	643	503		
Nitrate-N	10^3 kg	779	488	485	515	476	295	534	465	869	625	772	667	463	978	572	71%
Nitrite-N	10^3 kg	84	88	61	53	49	46	44	62	46	41	52	38	31	47	54	-12%
Organic-N	10^3 kg	551	436	584	666	514	324	580	376	413	276	403	319	332	441	444	-1%
Total Phosphorus	10^3 kg	149	83	126	140	83	65	112	50	68	54	53	46	48	68	83	-18%
Soluble Reactive P	10^3 kg	29	24	22	30	20	19	24	12	12	9	7	8	7	15	17	-11%
Calcium	10^3 kg	98,242	72,741	77,957	76,011	67,176	50,443	72,581	57,271	61,176	49,141	64,405	55,497	60,308	68,993		
Sodium	10^3 kg	88,765	75,504	76,862	91,093	82,787	58,656	77,378	65,721	76,469	76,777	90,648	85,662	88,817	102,096	79,626	28%
Chloride	10^3 kg	220,065	182,969	180,697	196,525	164,121	119,322	156,452	138,290	156,970	144,909	171,896	167,645	168,406	193,666	166,790	16%
Total Suspended Solids	10^3 kg	24,975	13,120	22,603	15,568	11,670	5,694	19,230	5,404	10,396	11,341	14,034	9,567	9,109	10,368		
Fecal Coliform	10^{10} cells	1,120,878	1,099,838	3,040,649	5,519,621	1,103,861	9,182,161	3,254,615	1,833,174	2,849,623	3,957,168	1,629,549	1,957,600	2,635,985	1,196,253	3,014,209	-60%
Total inflow	**hm^3**	627	407	496	511	454	298	510	348	434	316	465	387	420	507	436	16%

Note: values have been revised from previous years due to revision in compilation method from a flow-weighted mean concentration to a flow strata (from AutoFlux Method 2 to Method 5).

TABLE 2-4

2003 Percent Contribution by Source of Gauged Inflow

	Onondaga Creek	Ninemile Creek	Metro		Ley Creek	Harbor Brook	East Flume	Trib 5A
			Outfall 001	Bypass 002				
Water	36%	33%	18.8%	0.4%	8.9%	2.3%	0.1%	0.3%
Total P	16%	14%	59%	3%	6%	1%	0.2%	0.3%
SRP	11%	8%	72%	2%	4%	3%	0.3%	0.4%
TKN	12%	13%	68%	2%	5%	1%	0.1%	0.1%
Nitrate-N	22%	21%	51%	0%	2%	2%	0.3%	0.2%
Nitrite-N	5%	8%	83%	1%	2%	0%	1.0%	0.1%
Ammonia-N	4%	9%	82%	3%	3%	0%	0.1%	0.0%
Organic-N	21%	16%	54%	2%	6%	1%	0.1%	0.1%
Ca	27%	46%	17%	0%	7%	3%	0.1%	0.3%
Cl	39%	30%	20%	1%	8%	2%	0.2%	0.3%
Na	44%	19%	24%	1%	9%	2%	0.3%	0.3%
TSS	46%	28%	14%	1%	8%	2%	0.1%	0.2%
Fecal Coli (annual)	27%	2%	42%	25%	2%	1%	0.0%	0.0%
Fecal Coli (May-Sept)	49%	12%	1%	28%	7%	5%	0%	0%
BOD -5 day	17%	15%	57%	5%	4%	1%	0.1%	0.2%
T-Alk	38%	31%	20%	0%	9%	3%	0.1%	0.2%
TOC	16%	32%	39%	2%	10%	1%	0.1%	0.2%
TIC	37%	30%	20%	0%	9%	3%	0.1%	0.2%

Note: Approximately 93.5% of flow to Onondaga lake is from gauged sources. The remainder of flow is attributed to non-point ungauged sources and precipitation.

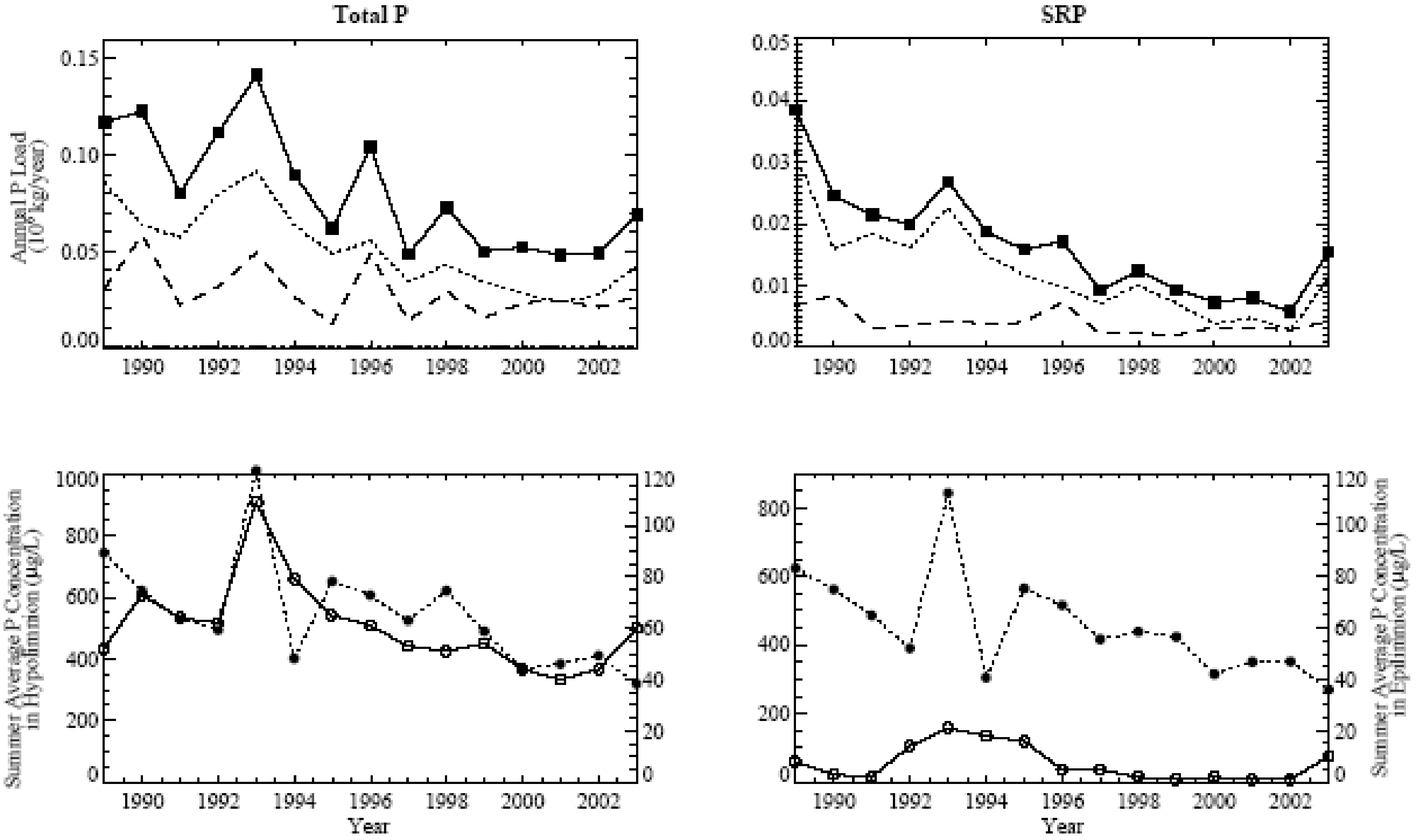

Figure 2-7. Year to year trends in phosphorus species in loads to Onondaga Lake and at the South Deep station.

Note: Load values have been revised from previous years due to revision in computation method from a flow-wtd-mean conc, 2 flow strata (~AUTOFLUX method 2), to multiple regression vs. flow, season, & date with residual interpolation method (~AUTOFLUX method 5).

Data Sources: Loadings - Table 2-3 rev hist load 2003.xls; Conc. - VA Tables Only_2-25 Revision1.xls + p&n_loads_1986_2002_rev_5.xls

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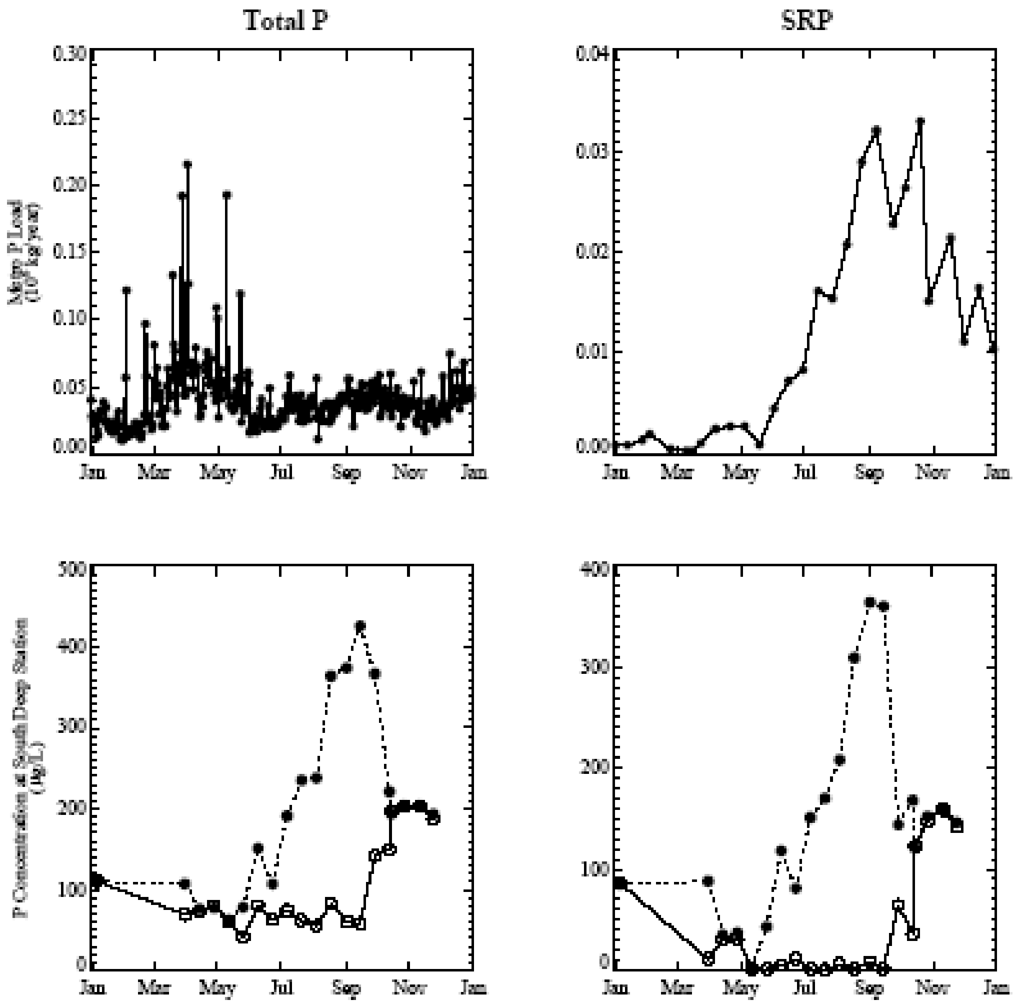

Figure 2-8. Temporal trends in phosphorus species in Metro loads to Onondaga Lake and at the South Deep station in 2003.

Note: Load values have been revised from previous years due to revision in computation method from a flow-wtd-mean conc, 2 flow strata (~AUTOFLUX method 2), to multiple regression vs. flow, season, & date with residual interpolation method (~AUTOFLUX method 5).

Data Sources: Loadings - Table 2-3 rev hist load 2003.xls; Conc. - 2003 Onondaga Lake Data (All QA included).xls

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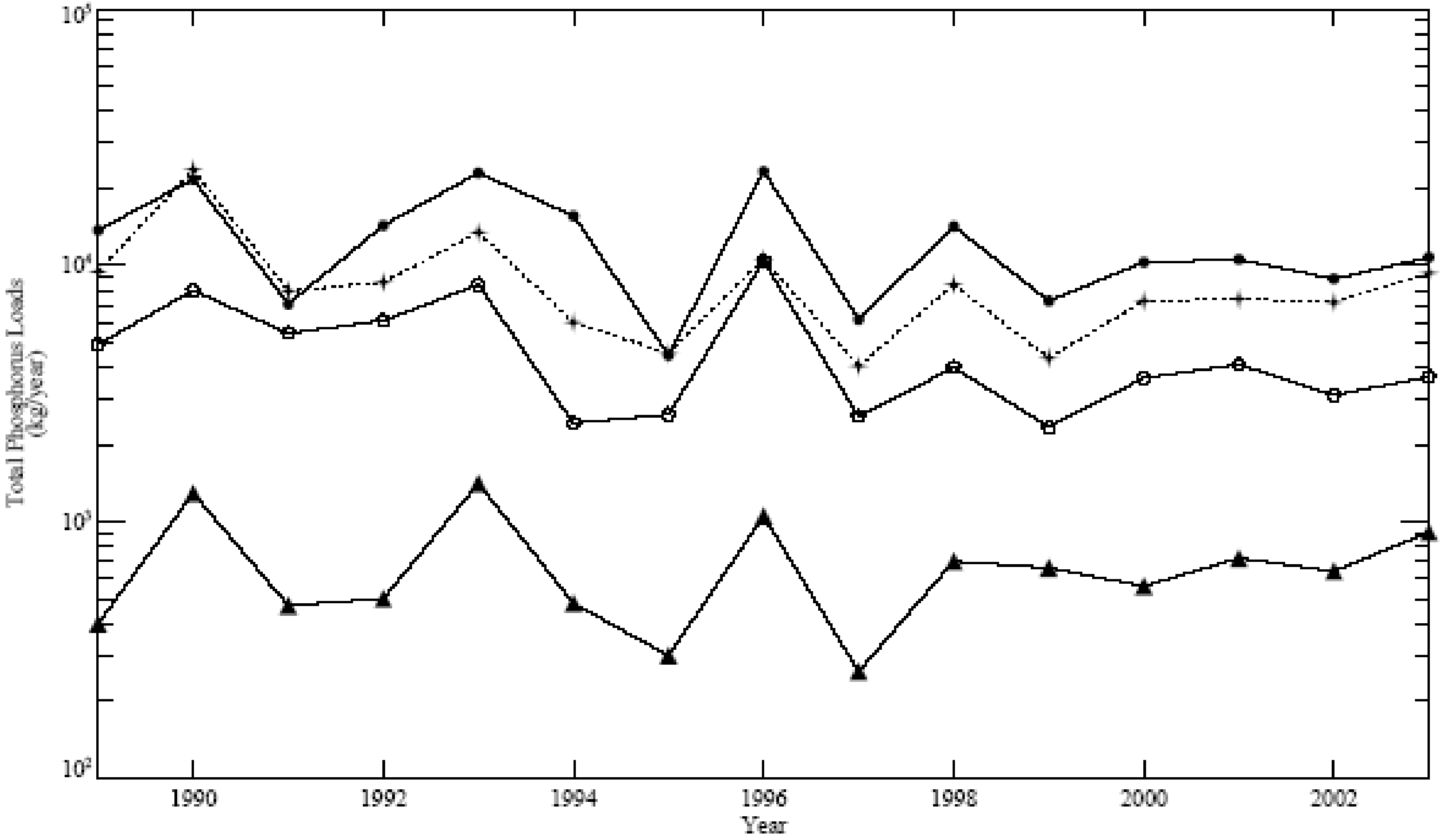

Figure 2-9. Total phosphorus loads to Onondaga Lake from the major tributaries.

Note: Load values have been revised from previous years due to revision in computation method from a flow-wtd-mean conc, 2 flow strata (~AUTOFLUX method 2), to multiple regression vs. flow, season, & date with residual interpolation method (~AUTOFLUX method 5).
Data source: Table 2-3 rev hist load 2003.xls

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Fri May 28 14:15:22 2004

2.1.3.4 Nitrogen Load

In the late 1990s, annual ammonia loads from Metro declined, resulting in a parallel decline in ammonia concentrations in both the upper mixed layer and lower waters (Figure 2-10). Major reductions in ammonia load are anticipated in 2004 as the Biological Aerated Filter (BAF) technology comes on line and year-round nitrification at Metro is achieved.

Metro effluent represented the largest source of ammonia to the lake in 2003 (on an annual basis, refer to Table 2-2, Figure 2-10). Note that the majority of the load enters the lake in the fall, winter and spring; because the ammonia load from Metro is lower during the summer due to nitrification (see below; Figure 2-11). As in previous years, Ninemile Creek and Onondaga Creek represented the largest non-Metro sources of ammonia to the lake (9% and 4%, respectively). Loading from all sources in 2003 was sufficiently low to bring the lake waters into compliance with ambient water quality standards for ammonia, as discussed in Section 2.2.6.

The seasonal patterns of ammonia loading and concentration in 2003 were similar to 2002. The seasonal effect of improved nitrification during the summer months is clearly demonstrated in Figure 2-11. In 2003, nitrification began at about the same time as in 2002 (late June), but continued longer into the fall (through November in 2003 and through October in 2002).

2.1.3.5 Bacteria Load

Disinfection of the treated wastewater is required between May 15 and October 15 to protect recreational use of the lake. The percent contribution of Metro effluent to the annual load of fecal coliform bacteria is notable; these values are calculated both on an annual basis and during the May through September time period. However, the annual loading estimates are associated with a very high standard error, due to the high numbers during the period when Metro does not chlorinate its effluent and the episodic nature of the loading events. The seasonal loading estimates should be considered better estimates. Outfall 002, operational only during periods when high flows are reaching the treatment plant from the combined service area, is a source of bacteria far out of proportion to its annual flow contribution. Under extremely rare conditions of high flows wastewater is bypassed at the head of the plant. This did not occur in 2003.

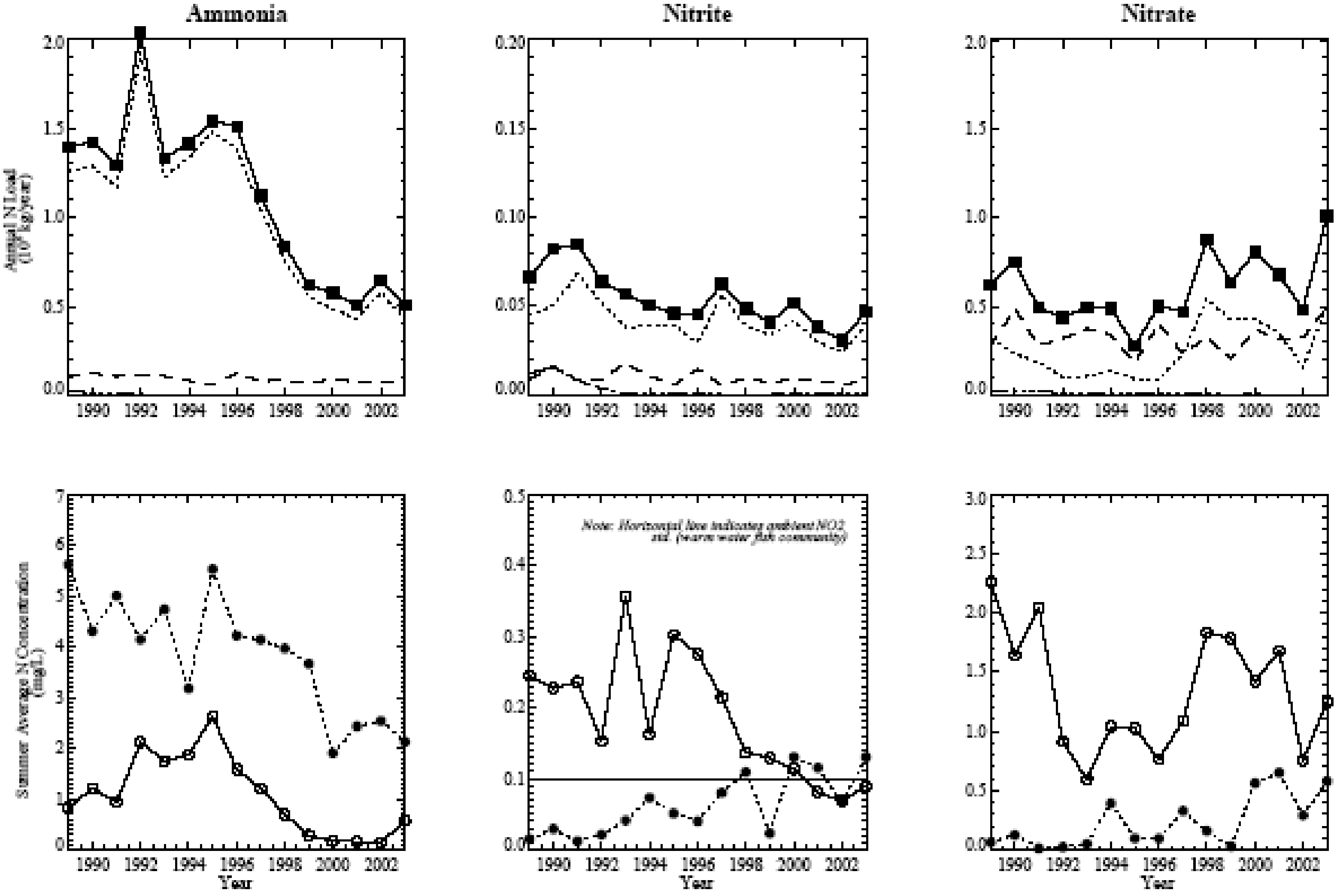

Figure 2-10. Year to year trends in nitrogen species in loads to Onondaga Lake and at the South Deep Station.

Note: Load values have been revised from previous years due to revision in computation method from a flow-wtd-mean conc, 2 flow strata (~AUTOFLUX method 2), to multiple regression vs. flow, season, & date with residual interpolation method (~AUTOFLUX method 5).

Data Sources: Loadings - Table 2-3 rev hist load 2003.xls; Conc. - VA Tables Only_2-25 Revision1.xls + pdxn_loads_1986_2002_rev_5.xls

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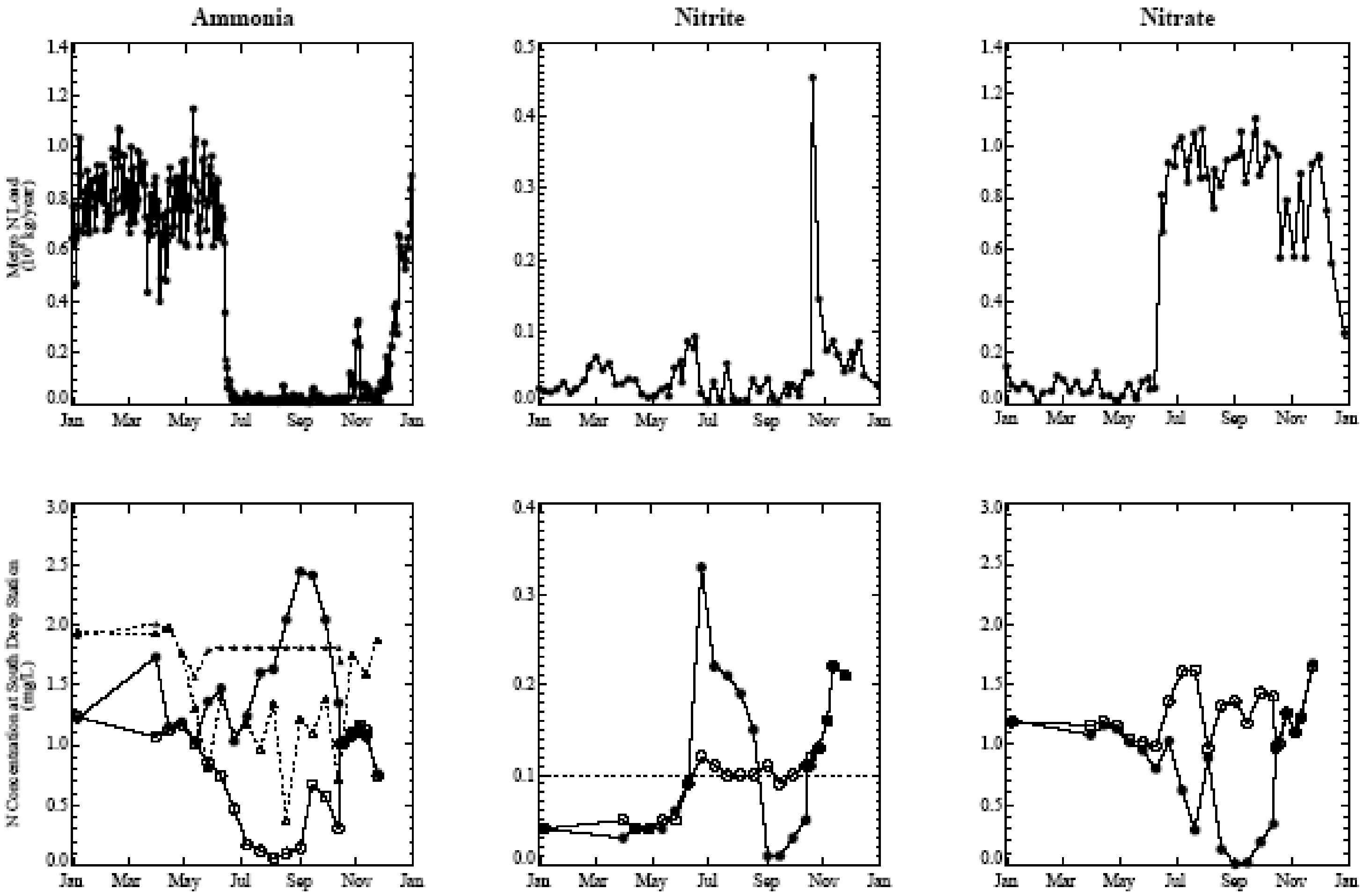

Figure 2-11. Temporal trends in nitrogen species in Metro loads to Onondaga Lake and at the South Deep station in 2003.

Note: Load values have been revised from previous years due to revision in computation method from a flow-wtd-mean conc, 2 flow strata (~AUTOFLUX method 2), to multiple regression vs. flow, season, & date with residual interpolation method (~AUTOFLUX method 5).

Data Sources: Loadings - Table 2-3 rev hist load 2003.xls; Conc. - 2003 Onondaga Lake Data (All QA included).xls

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Fri May 28 14:12:44 2004

2.1.4 Storm Events

OCDWEP has conducted a storm event monitoring program since 1999. The purpose of this monitoring effort is to quantify the impacts of combined sewer overflow (CSO) abatement efforts on constituent loadings to Onondaga Lake. The specific purpose of the monitoring period was to establish baseline conditions prior to completion of CSO abatement efforts in accordance with the Amended Consent Judgment (ACJ). The storm event monitoring program will continue through 2012 as the measures to abate CSOs are implemented.

The 2001 AMP Annual Report includes a chapter documenting and analyzing eight complete storm events collected in 1999-2001. The goals of the analysis presented in that chapter were: 1) to evaluate the sufficiency of the 1999-2001 data for characterizing the baseline condition, and 2) to establish a series of specific metrics for the purpose of comparing baseline conditions with future storm events. In 2002, the County decided to supplement the baseline data set with one additional storm event. This event was documented in Appendix 4 of the 2002 AMP report. In 2003, three additional storm events were sampled. The 2003 storm event program included water quality and flow measurements in two small tributaries: Bloody Brook and Sawmill Creek. These streams do not receive CSOs.

For the three streams with CSOs, Onondaga Creek, Ley Creek, and Harbor Brook, results of the 2003 sampling program were generally consistent with the results of the 1999-2002 storm event monitoring effort. These new data were incorporated into the previously developed rating curves. Ninemile Creek was not sampled in 2003, and hence the rating curves for Ninemile Creek are unchanged.

In July 2001, the Hiawatha RTF began operation. This facility captures combined sewer overflows from a portion of the Ley Creek watershed (upstream of the storm water quality sampling station). The facility is designed to send the captured water to Metro for treatment and to discharge flows that exceed the capacity of the facility directly into Ley Creek (downstream of the water quality and flow rate sampling stations). As of summer 2004, there were two small releases from this facility into the creek (approximately 281,000 gallons on June 14, 2002 and approximately 545,000 gallons on May 24, 2004). Each of these overflow events lasted for under two hours. All other CSO flows were fully captured and piped to Metro for treatment. The OCDWEP storm event program has captured one storm (August, 2003) when the RTF facility activated, but no flows were released to the stream. Based on the instream and nearshore water quality data for this storm, there is no discernible impact of the RTF on reducing contaminant concentrations. This is probably because the RTF flows are much smaller than the flows in the creek.

In 2003, both Bloody Brook and Sawmill Creek were sampled during two storms. The maximum concentrations measured at these locations lie well within the range of maximum concentrations measured in other tributaries. Due to an equipment malfunction, flow rates are not available for one storm on Sawmill Creek. Hence, two estimates of loading from Bloody Brook, and one estimate of loading from Sawmill Creek, are available. For storms with total precipitation between 0.5 and 1.5 inches (the approximate range of the 2003 storms), Bloody Brook is estimated to contribute less than 1% of the average storm nonpoint source loads of TP, TSS and fecal coliform bacteria (FCOLI) to the lake. Sawmill Creek also contributes a minimal amount to the external load, estimated at less than 1%. Based on these 2003 results, the storm loads from Bloody Brook and Sawmill Creek are not expected to have an important influence on lake-wide water quality in the foreseeable future. However, these small streams have the potential to affect water quality conditions in nearshore areas as they flow into Onondaga Lake.

The conclusions drawn from the full 1999-2003 data set remain consistent with those presented in the 2001 and 2002 AMP reports. Detailed data for the storm event programs from 1999 – 2003 are included in Appendix A. Corrected figures from 2001 and 2002 are included in this Appendix; an error in the calculated bacteria loads was discovered and corrected during analysis of the 2003 data. The metrics developed here can be used to evaluate the reductions in loading achieved with the planned reductions in point and nonpoint sources of phosphorus, suspended sediment, and bacteria.

2.2 LAKE CONDITIONS: WATER QUALITY

OCDWEP staff measure many characteristics of Onondaga Lake and its adjacent streams to assess water quality conditions. Results of these measurements help determine whether the lake is safe for water contact recreation, and whether conditions are adequate to protect the health of the lake's community of plants and animals. These concerns reflect the national goal for all surface waters, often referred to as the "swimmable fishable" goal. The County monitors indicators of human health and safety, such as sewage-related coliform bacteria and water clarity, along with ecological conditions, such as dissolved oxygen and nutrient levels, abundance of plant life, and the success of fish reproduction. A summary of the status of these indicators is included as Chapter 4. Highlights of the major findings of the 2003 monitoring program are summarized below.

2.2.1 Stratification and Mixing

Selected physical and chemical characteristics of Onondaga Lake are recorded at frequent intervals using specialized water quality monitoring instrumentation deployed in the lake. Two monitoring buoys moored at the South Deep station provide near real-time measurements of lake water quality conditions. The Onondaga County buoy is designed to record water temperature, pH, specific conductance, dissolved oxygen, chlorophyll-*a*, and turbidity at frequent time intervals (every 15 minutes) at fixed depths. Results are transmitted to a computer at the OCDWEP offices on Hiawatha Boulevard where they are uploaded to the County’s web site. The buoy is in operation from early spring to late fall. Data can be viewed through http://www.ongov.net.

A second buoy moored at South Deep is operated by the Upstate Freshwater Institute of Syracuse NY with funding from the U.S. Environmental Protection Agency. This buoy collects data at multiple depths once or twice daily. Data are processed using a graphic application; color plots may be viewed on-line at a web site maintained by the University of Minnesota http://www.wow.nrri.umn.edu/wow/data/java/dvt2/NYLakes.html

Taken together, data from the buoys moored at South Deep enable lake managers to examine conditions at both frequent time intervals and multiple depths. OCDWEP routinely conducts side-by-side examinations of data reported by the two buoys, and compares the buoy data with results of samples collected in the field. To date, no systematic differences have been noted in temperature, DO, pH or specific conductance between the buoys or as compared with field measurements. Chlorophyll-*a* data collected by either buoy do not correlate well with laboratory analysis of the pigment.

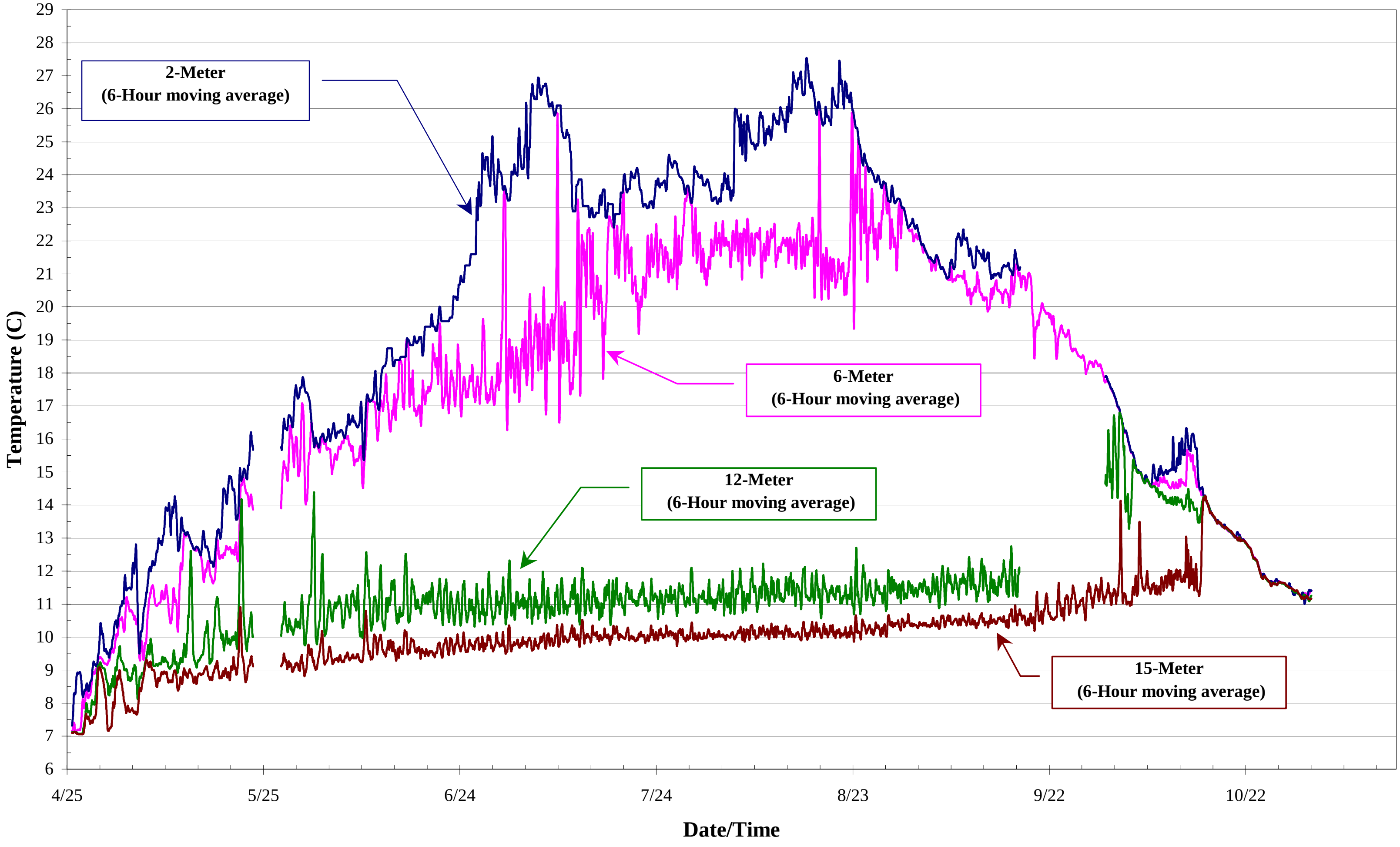
Lake water temperature measurements from 2003 are displayed in Figure 2-12. This figure was prepared using data from the OCDWEP buoy. Note that thermal stratification was evident at the beginning of the record (mid-June) and that the lower waters remained essentially isothermal until early in October, when stratification began to break down and warmer water was mixed deeper into the lake. The dynamic nature of the lake's thermal structure is remarkable; note how the water temperature recorded by the buoy placed at 6 m can oscillate by more than 5 degrees over short time intervals, on the scale of hours. This is interpreted to represent the effects of wind-induced internal seiche activity.

Based on paired sampling results from the North Deep and South Deep stations on four dates, the lake is laterally well mixed. There is no systematic gradient in ambient water quality conditions from the south, where most of the inflows enter the lake, to the north. Results of the four paired sampling events during 2003 are included as Tables 2-5, 2-6, 2-7, and 2-8.

2.2.2 Phosphorus and Trophic State

In 2003, the total phosphorus (TP) concentration in the lake's upper waters averaged 66 µg/l during the summer recreational period, June – September. The time period for averaging and the sampling depth was selected to be consistent with the NYSDEC guidance value for phosphorus in lakes.

Figure 2-12. Metro South Deep YSI Monitoring Buoy
2003
Temperature (C)



Phosphorus is naturally present in all waters and is an essential nutrient for life. In most lakes, P is the limiting nutrient for algal growth; that is, P concentration is positively correlated with algal abundance. Until recently, P concentrations in Onondaga Lake were so high that algal growth was likely limited by other factors, such as light levels. Average TP and SRP concentrations in the UML declined in the late 1990s and have been relatively stable since about 2000 (Figure 2-7). A small increase was observed in TP and SRP concentrations in the UML in 2003, probably in response to the increase in TP loading from Metro. Summer average concentrations in the lake's upper waters have ranged from 35 - 70 µg/l since the late 1990's (Figure 2-13). Despite the loading reductions, Onondaga Lake remains a eutrophic system, as summarized in Table 2-9.

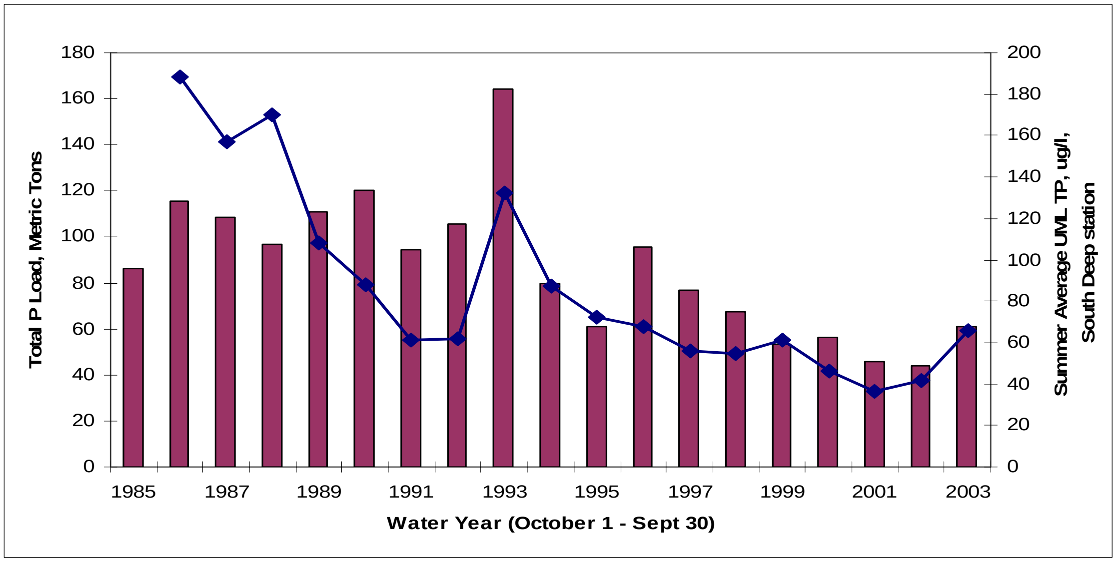


Figure 2-13. External Load of Total Phosphorus (water year) and summer average TP in Upper Mixed Layer, South Deep station, Onondaga Lake .

1985-1990 calculated with Method 2. 1991-2003 calculated with Method ***5.*** *See text for details.*

Table 2-5. COMPARISON OF NORTH AND SOUTH DATA
April 15-16, 2003

		EPILIMNION		HYPOLIMNION	
PARAMETER	UNITS	SOUTH	NORTH	SOUTH	NORTH
Secchi Disc Depth	m	1.8	2.0	NA	NA
pH	Std. Units	7.42	7.49	7.34	7.38
Temperature	C	5.3	6.1	4.4	4.7
Specific conductance	umho/cm	1782	1794	1854	1877
Dissolved Oxygen	mg/l	11.72	11.16	10.28	9.97
5-day BOD	mg/l	< 2.0	2.0	< 2.0	< 2.0
Total Alkalinity	mg/l	194	193	194	196
Total Organic Carbon	mg/l	3.7	3.5	3.7	3.8
TOC-Filtered	mg/l	3.4	3.4	3.4	3.3
Total Inorganic Carbon	mg/l	49	49	50	50
Total Kjeldhal Nitrogen	mg/l	1.7	1.6	1.6	1.7
TKN-Filtered	mg/l	1.5	1.4	1.5	1.6
Organic Nitrogen	mg/l	0.55	0.53	0.36	0.34
Ammonia-N	mg/l	1.13	1.07	1.27	1.35
Nitrite-N	mg/l	0.04	0.04	0.04	0.03
Nitrate-N	mg/l	1.19	1.17	1.16	1.14
Arsenic	ug/l	< 2.0	< 2.0	< 2.0	< 2.0
Total Phosphorus	mg/l	0.075	0.076	0.087	0.085
Soluble Reactive Phosphorus	mg/l	0.031	0.031	0.048	0.052
Silica	mg/l	3.9	3.9	4.0	3.9
Calcium	mg/l	106	114	118	115
Sodium	mg/l	197	200	202	210
Potassium	mg/l	5.1	4.0	3.7	3.8
Sulfate	mg/l	133	148	138	152
Sulfides	mg/l	NA	NA	NA	NA
Chloride	mg/l	396	386	400	405
Total Solids	mg/l	1070	1081	1138	1118
Total Volatile Solids	mg/l	130	173	134	171
Total Suspended Solids	mg/l	2.0	2.0	2.0	< 2.0
Volatile Suspended Solids	mg/l	< 2.0	< 2.0	< 2.0	< 2.0
Total Dissolved Solids	mg/l	1034	1015	1054	1017
Zinc	ug/l	12.8	< 2.0	7.2	9.8
Copper	ug/l	1.5	0.8	1.4	0.9
Chrominum	ug/l	< 0.50	< 0.50	< 0.50	< 0.50
Cadmium	ug/l	< 0.40	< 0.40	< 0.40	< 0.40
Lead	ug/l	3.4	3.3	3.1	3.3
Iron	mg/l	0.096	0.113	0.087	0.0705
Magnesium	mg/l	21.4	21.7	21.0	21.6
Manganese	mg/l	0.034	0.030	0.055	0.056
Nickel	ug/l	4.5	4.5	< 2.5	3.6
Selenium	ug/l	< 2.0	< 2.0	< 2.0	< 2.0
Phaeophytin-*a* (1)	mg/m^3	0.83	1.12	NA	NA
Chlorophyll-a (1)	mg/m^3	3.47	7.48	NA	NA
Fecal Coliforms	cells/100ml	< 2.0	< 2.0	NA	NA
E.Coli	cells/100ml	5	20	NA	NA

Data are volume-weighted when appropriate.
Calculations use the laboratory limit of detection when an observation is below that limit.
NA: Not Analyzed
(1) value represents a composite sample observation.
(2) sample taken from the photic zone.
South Deep sampled on the 15th. North Deep sampled on the 16th.
Revision: 10/27/04

Table 2-6. COMPARISON OF NORTH AND SOUTH DATA

June 24, 2003

		EPILIMNION		HYPOLIMNION	
PARAMETER	UNITS	SOUTH	NORTH	SOUTH	NORTH
Secchi Disc Depth	m	1.8	2.2	NA	NA
pH	Std. Units	7.83	7.79	7.29	7.28
Temperature	C	18.6	18.1	10.6	9.8
Specific conductance	umho/cm	1852	1857	1865	1873
Dissolved Oxygen	mg/l	7.08	6.95	0.24	0.10
5-day BOD	mg/l	2.0	2.0	8.0	8.0
Total Alkalinity	mg/l	179	178	190	196
Total Organic Carbon	mg/l	4.3	4.3	3.5	3.7
TOC-Filtered	mg/l	3.8	3.9	3.4	3.4
Total Inorganic Carbon	mg/l	49	50	56	55
Total Kjeldhal Nitrogen	mg/l	1.4	1.3	2.0	2.3
TKN-Filtered	mg/l	1.2	1.1	1.7	2.1
Organic Nitrogen	mg/l	0.79	0.64	0.59	0.51
Ammonia-N	mg/l	0.63	0.67	1.39	1.78
Nitrite-N	mg/l	0.12	0.12	0.33	0.30
Nitrate-N	mg/l	1.36	1.27	1.03	0.72
Arsenic	ug/l	< 2.0	< 2.0	< 2.0	< 2.0
Total Phosphorus	mg/l	0.052	0.048	0.178	0.282
Soluble Reactive Phosphorus	mg/l	0.012	< 0.013	0.146	0.224
Silica	mg/l	1.6	1.7	2.8	3.6
Calcium	mg/l	136	127	130	123
Sodium	mg/l	202	199	213	193
Potassium	mg/l	3.8	4.1	4.1	4.2
Sulfate	mg/l	179	162	164	168
Sulfides	mg/l	NA	NA	< 0.20	< 0.2
Chloride	mg/l	385	383	390	391
Total Solids	mg/l	1250	1214	1244	1263
Total Volatile Solids	mg/l	245	213	245	259
Total Suspended Solids	mg/l	< 2.5	< 2.0	2.0	< 2.0
Volatile Suspended Solids	mg/l	< 2.0	< 2.0	< 2.0	< 2.0
Total Dissolved Solids	mg/l	1178	1168	1145	1154
Zinc	ug/l	9.4	< 2.0	10.4	9.5
Copper	ug/l	1.2	1.5	1.2	1.4
Chrominum	ug/l	0.60	< 0.50	0.70	< 0.50
Cadmium	ug/l	< 0.40	< 0.40	< 0.40	< 0.40
Lead	ug/l	3.6	3.5	3.9	3.9
Iron	mg/l	0.053	0.033	0.046	0.075
Magnesium	mg/l	25.5	25.4	25.0	25.0
Manganese	mg/l	0.016	0.013	0.116	0.261
Nickel	ug/l	2.6	2.6	< 2.5	< 2.5
Selenium	ug/l	< 2.0	< 2.0	< 2.0	< 2.0
Phaeophytin-*a* (1)	mg/m^3	2.24	3.1	NA	NA
Chlorophyll-a (1)	mg/m^3	7.48	5.87	NA	NA
Fecal Coliforms	cells/100ml	< 5	< 5	NA	NA
E.Coli	cells/100ml	< 5	< 5	NA	NA

Data are volume-weighted when appropriate.

Calculations use the laboratory limit of detection when an observation is below that limit.

NA: Not Analyzed

(1) value represents a composite sample observation.

(2) sample taken from the photic zone.

Revision: 10/27/04

Table 2-7. COMPARISON OF NORTH AND SOUTH DATA

September 16, 2003

PARAMETER	UNITS	EPILIMNION		HYPOLIMNION	
		SOUTH	NORTH	SOUTH	NORTH
Secchi Disc Depth	m	1.5	1.1	NA	NA
pH	Std. Units	7.87	8.24	7.26	7.27
Temperature	C	19.9	20.4	10.8	10.9
Specific conductance	umho/cm	2047	2005	1901	1904
Dissolved Oxygen	mg/l	6.99	9.16	0.02	0.05
5-day BOD	mg/l	< 2.0	5.0	5.0	6.0
Total Alkalinity	mg/l	140	119	208	212
Total Organic Carbon	mg/l	4.6	4.9	3.6	3.4
TOC-Filtered	mg/l	4.0	4.1	3.3	3.3
Total Inorganic Carbon	mg/l	34	30	56	58
Total Kjeldhal Nitrogen	mg/l	1.0	1.1	3.4	3.4
TKN-Filtered	mg/l	0.8	0.8	3.3	3.2
Organic Nitrogen	mg/l	0.51	0.66	0.17	0.10
Ammonia-N	mg/l	0.52	0.40	3.22	3.13
Nitrite-N	mg/l	0.09	0.08	< 0.01	0.01
Nitrate-N	mg/l	1.18	1.19	0.02	< 0.01
Arsenic	ug/l	< 2.0	< 2.0	< 2.0	< 2.0
Total Phosphorus	mg/l	0.070	0.066	0.578	0.537
Soluble Reactive Phosphorus	mg/l	< 0.003	< 0.007	0.484	0.463
Silica	mg/l	1.4	1.5	4.0	4.2
Calcium	mg/l	116	124	131	130
Sodium	mg/l	247	240	230	228
Potassium	mg/l	4.4	5.2	4.3	4.4
Sulfate	mg/l	196	198	156	160
Sulfides	mg/l	NA	NA	2.95	3.41
Chloride	mg/l	485	469	431	437
Total Solids	mg/l	1406	1305	1255	1222
Total Volatile Solids	mg/l	323	253	203	226
Total Suspended Solids	mg/l	3.5	5.0	< 2.0	< 2.0
Volatile Suspended Solids	mg/l	2.5	4.5	< 2.0	< 2.0
Total Dissolved Solids	mg/l	1247	1218	1148	1144
Zinc	ug/l	< 2.0	8.7	< 2.0	8.5
Copper	ug/l	< 2.0	< 2	< 2	< 2
Chrominum	ug/l	< 0.50	< 0.50	< 0.50	< 0.50
Cadmium	ug/l	< 0.40	< 0.40	< 0.40	< 0.40
Lead	ug/l	2.6	2.6	3.2	2.8
Iron	mg/l	0.031	< 0.020	0.066	0.199
Magnesium	mg/l	25.6	26.0	23.6	23.6
Manganese	mg/l	0.027	0.008	0.504	0.507
Nickel	ug/l	< 10.0	< 10	< 10.0	< 10
Selenium	ug/l	< 2.0	< 2.0	< 2.0	< 2.0
Phaeophytin-*a* (1)	mg/m^3	2.83	4.27	NA	NA
Chlorophyll-a (1)	mg/m^3	19.22	33.11	NA	NA
Fecal Coliforms	cells/100ml	< 5	5	NA	NA
E.Coli	cells/100ml	< 5	8	NA	NA

Data are volume-weighted when appropriate.

Calculations use the laboratory limit of detection when an observation is below that limit.

NA: Not Analyzed

(1) value represents a composite sample observation.

(2) sample taken from the photic zone.

Revision: 10/27/04

Table 2-8. COMPARISON OF NORTH AND SOUTH DATA
November 12, 2003

		EPILIMNION		HYPOLIMNION	
PARAMETER	UNITS	SOUTH	NORTH	SOUTH	NORTH
Secchi Disc Depth	m	1.7	2.1	NA	NA
pH	Std. Units	7.81	7.81	7.81	7.80
Temperature	C	9.8	9.9	9.7	9.5
Specific conductance	umho/cm	2025	2028	2031	2025
Dissolved Oxygen	mg/l	8.16	8.14	8.09	7.78
5-day BOD	mg/l	5.0	6.0	6.0	5.0
Total Alkalinity	mg/l	171	169	171	175
Total Organic Carbon	mg/l	4.0	3.9	3.9	4.3
TOC-Filtered	mg/l	3.6	3.6	3.7	3.7
Total Inorganic Carbon	mg/l	46	45	45	45
Total Kjeldhal Nitrogen	mg/l	1.8	1.6	1.6	1.5
TKN-Filtered	mg/l	1.4	1.5	1.4	1.5
Organic Nitrogen	mg/l	0.65	0.50	0.56	0.47
Ammonia-N	mg/l	1.12	1.14	1.08	1.07
Nitrite-N	mg/l	0.22	0.20	0.22	0.19
Nitrate-N	mg/l	1.22	1.13	1.23	1.08
Arsenic	ug/l	< 1.0	< 1.0	< 1.0	< 1.0
Total Phosphorus	mg/l	0.202	0.201	0.202	0.193
Soluble Reactive Phosphorus	mg/l	0.159	0.162	0.160	0.154
Silica	mg/l	4.2	4.2	4.2	4.2
Calcium	mg/l	130	138	138	145
Sodium	mg/l	239	237	243	227
Potassium	mg/l	5.0	5.0	5.0	5.0
Sulfate	mg/l	180	176	173	198
Sulfides	mg/l	NA	NA	NA	NA
Chloride	mg/l	458	452	456	447
Total Solids	mg/l	1270	1256	1254	1296
Total Volatile Solids	mg/l	175	166	163	175
Total Suspended Solids	mg/l	4.0	3.5	3.8	3.2
Volatile Suspended Solids	mg/l	2.5	< 2.0	2.0	< 2.0
Total Dissolved Solids	mg/l	1237	1203	1225	1228
Zinc	ug/l	< 2.0	< 2.0	< 2.0	< 2.0
Copper	ug/l	1.5	< 2	2.4	< 2
Chrominum	ug/l	< 0.50	< 0.50	< 0.50	< 0.50
Cadmium	ug/l	< 0.40	< 0.40	< 0.40	< 0.40
Lead	ug/l	3.4	3.3	3.72	3.45
Iron	mg/l	0.103	0.040	0.066	0.075
Magnesium	mg/l	24.6	24.9	24.6	25.7
Manganese	mg/l	0.078	0.080	0.086	0.119
Nickel	ug/l	< 10.0	< 10	< 10.0	< 10
Selenium	ug/l	< 2.0	< 2.0	< 2.0	< 2.0
Phaeophytin-*a* (1)	mg/m^3	1.23	1.01	NA	NA
Chlorophyll-a (1)	mg/m^3	5.87	5.34	NA	NA
Fecal Coliforms	cells/100ml	920	360	NA	NA
E.Coli	cells/100ml	1420	420	NA	NA

Data are volume-weighted when appropriate.
Calculations use the laboratory limit of detection when an observation is below that limit.
NA: Not Analyzed
(1) value represents a composite sample observation.
(2) sample taken from the photic zone.
Revision: 10/27/04

TABLE 2-9

Trophic State Indicator Parameters Compared With Onondaga Lake 2003 Water Quality

	Oligotrophic	**Mesotrophic**	**Eutrophic**	**Onondaga Lake 2003**
Summer average total phosphorus, upper waters (µg/l)	<10	10-35	35 -100	**66**
Summer average chlorophyll-*a*, upper waters (µg/l)	<2.5	2.5 – 8	8 – 25	**30.4 (Jun-Aug)**
Peak chlorophyll-*a* (µg/l)	<8	8-25	25-75	**114**
Average Secchi disk transparency, m	>6	6-3	3-1.5	**1.27 (Jun-Sep)**
Minimum Secchi disk transparency, meters	>3	3-1.5	1.5-0.7	**0.6**
Dissolved oxygen in lower waters (% saturation)	80 – 100	10-80	Less than 10	**Zero**

(Source: Trophic state ranges from Janus and Vollenweider 1981)

Similarly, the summer average concentrations of TP and SRP in the LWL generally declined in the late 1990s and have been relatively stable since about 2000. In contrast to the UML, 2003 values were the lowest since 1989. The decline in the late 1990s occurred concurrently with a decline in ammonia, an increase in nitrite and nitrate, and a decrease in the volume-days of anoxia. It is possible that these trends are linked to the availability of oxygen. The biomass of phytoplankton, which settle to the lower waters and exert oxygen demand as they are decomposed, exhibited a decreasing trend over this period (Figure 2-14). The total external loading of oxidizable material to Onondaga Lake, including both carbonaceous and nitrogenous material has also

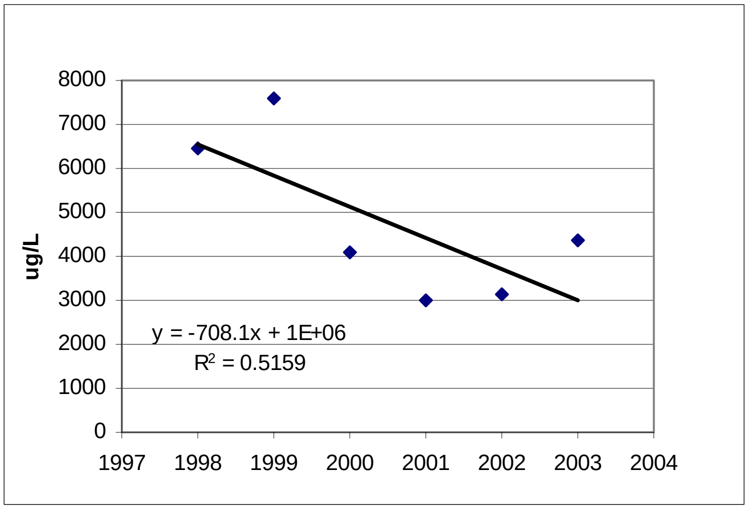


Figure 2-14. Annual average phytoplankton biomass in Onondaga Lake, South Deep Station, 1998-2003

shown a declining trend since the late 1980s (Figure 2-15). The concomitant decrease in volume days of anoxia (Figure 2-16) implies a direct linkage between algal biomass and sediment oxygen demand. Note that all of these parameters have remained relatively constant since 2000.

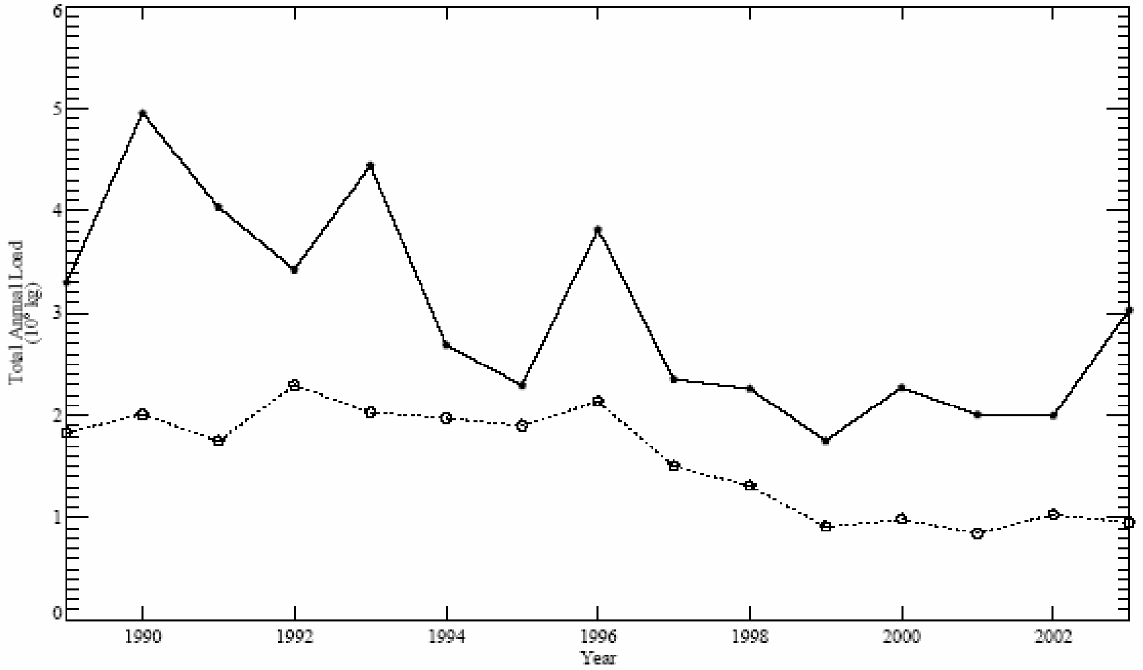


Figure 2-15. Historical total loading of oxidizable material to Onondaga Lake: organic carbon and total Kjeldahl nitrogen.

Note: Load values have been revised from previous years due to revision in computation method from a flow-wtd-mean conc, 2 flow strata (~AUTOFLUX method 2), to multiple regression vs. flow, season, & date with residual interpolation method (~AUTOFLUX method 5).

Data source: Table 2-3 rev hist load 2003.xls

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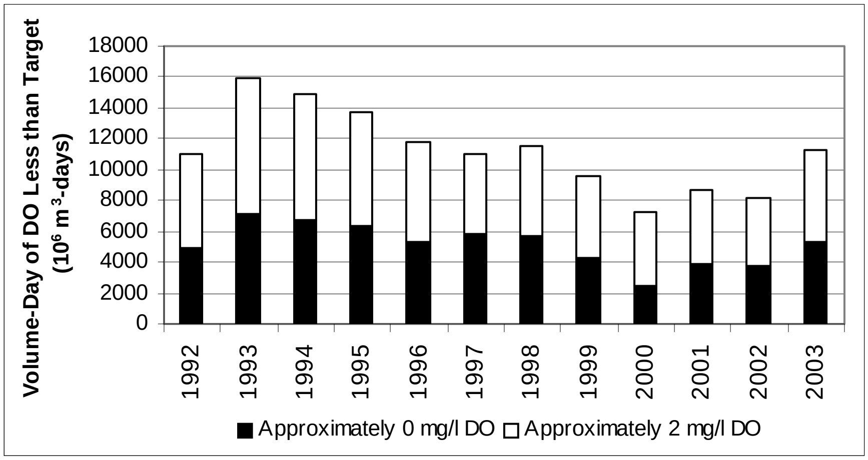

Figure 2-16. Volume-days of anoxia in Onondaga Lake, South Deep Station, 1992-2003.

2.2.3 Chlorophyll–*a*

By any standard, chlorophyll-*a* concentrations were high during 2003, indicating an increase in algal biomass. Chlorophyll-*a* concentration in the upper waters (photic zone) of Onondaga Lake averaged 30.4 µg/l during the period of June 1 – September 30, 2003. Notably, the clear water phase that had been characteristic of spring water quality conditions throughout the 1990s was reduced in magnitude and duration in 2003. A spring algal bloom was followed by a brief clear water phase in late May. Algal standing crop biomass increased through June and by late July had once again increased to bloom conditions. The annual peak was measured at 114.3 µg/l on August 5, 2003. Approximately 30% of the measurements obtained during the summer of 2003 were in excess of 30 µg/l. The fall bloom persisted through mid-September when the algal biomass gradually declined through the remainder of the monitoring period.

2.2.4 Water Clarity

The 2003 Secchi disk transparency results measured at the deepest point in Onondaga Lake (South Deep station) are plotted in Figure 2-17. Note the seasonal changes in water clarity; Secchi

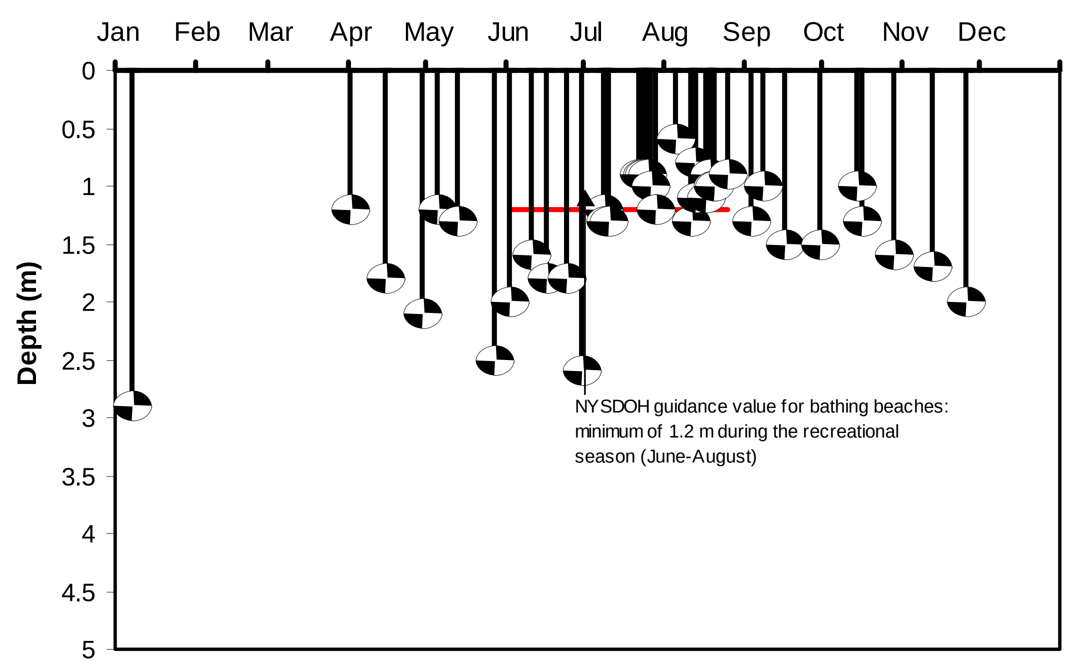

Figure 2-17. Secchi disk transparency in the upper waters of Onondaga Lake, South Deep Station, 2003.

disk transparency was low during the spring period of high algal abundance, increased somewhat in late May as the phytoplankton community declined (although not to the extent recorded in previous years) and fluctuated around 0.5 – 1.5 m during the summer and early fall. The annual minimum was recorded on August 5, 2003 with a Secchi disk transparency of only 0.6 m. A gradual increase in water clarity occurred as algal abundance declined through the late fall.

An interesting feature of the long-term Secchi disk data is the development and loss of the “clearing event” a period in the late spring when water clarity increased in response to zooplankton abundance. As displayed in Figure 2-18, high water clarity during the spring period was evident during the 1990s.

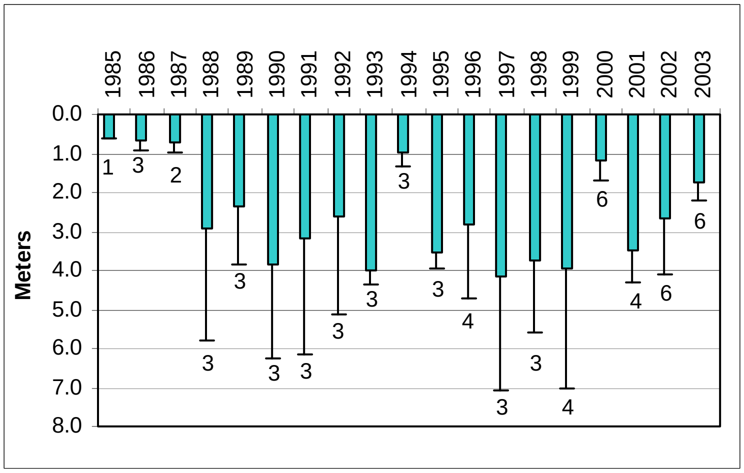

Figure 2-18. Mean Secchi Disk transparency from May 1 - June 15, South Deep Station, Onondaga Lake. Lines at the end of the bars represent one standard deviation. Numbers equal observations included.

As part of the AMP’s focus on indicators of recreational use attainment in Onondaga Lake, Secchi disk transparency measurements are also obtained at nearshore lake stations during the summer. The nearshore areas frequently exhibited low water clarity during the 2003 monitoring period (Figure 2-19). Reduced water clarity in the nearshore areas was caused by algal abundance, sediment resuspension, and the presence of macroalgae (large filamentous algae).

2.2.5 Dissolved Oxygen Concentrations

The dissolved oxygen (DO) status of Onondaga Lake is closely coupled with the lake’s annual thermal 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. As a consequence, no oxygen production occurs. Primarily bacteria and fungi use the DO content of the lake’s lower water; these organisms decompose organic material settling to the lake bottom from the sunlit layers above. As algal abundance increases in the upper waters, activity of the decomposers increases and DO is used up in the lower waters. When the supply of DO is depleted

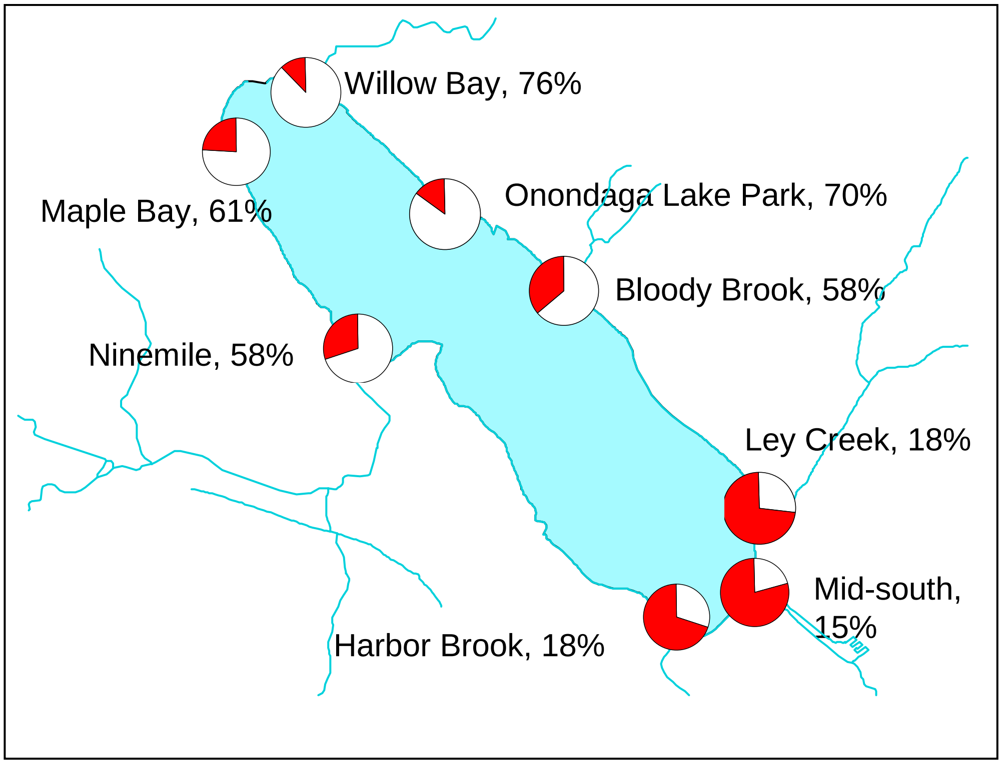

Figure 2-19. Nearshore Secchi violations in 2003. Percent shown in figure indicates compliance. Shaded area of pie charts indicates percent of samples where Secchi depth was less than 1.2 m (4 ft).

the waters become anoxic. Other chemicals such as iron, ammonia, hydrogen sulfide, and methane accumulate in the anoxic lower waters as decomposition continues in the absence of oxygen.

When the lake cools in the fall, temperature differences that keep the water layers isolated begin to break down. The deep anoxic waters gradually mix with the upper waters. Chemical reactions with iron, ammonia, hydrogen sulfide, and methane can remove oxygen in the upper waters as anoxic lower waters are entrained. As a consequence, DO concentrations are 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 during fall mixing. Compliance with minimum DO standards during fall mixing is one of the restoration goals for Onondaga Lake.

The DO content of the lake's upper and lower waters during 2003 is plotted in Figure 2-20. Note the rapid decline of DO in the lower waters at the onset of thermal stratification. The upper waters remained well-oxygenated until October when thermal stratification broke down rapidly.

Complete mixing occurred around October 14, 2003. Concentrations of DO gradually increased as the waters continued to mix and gain oxygen from the atmosphere.

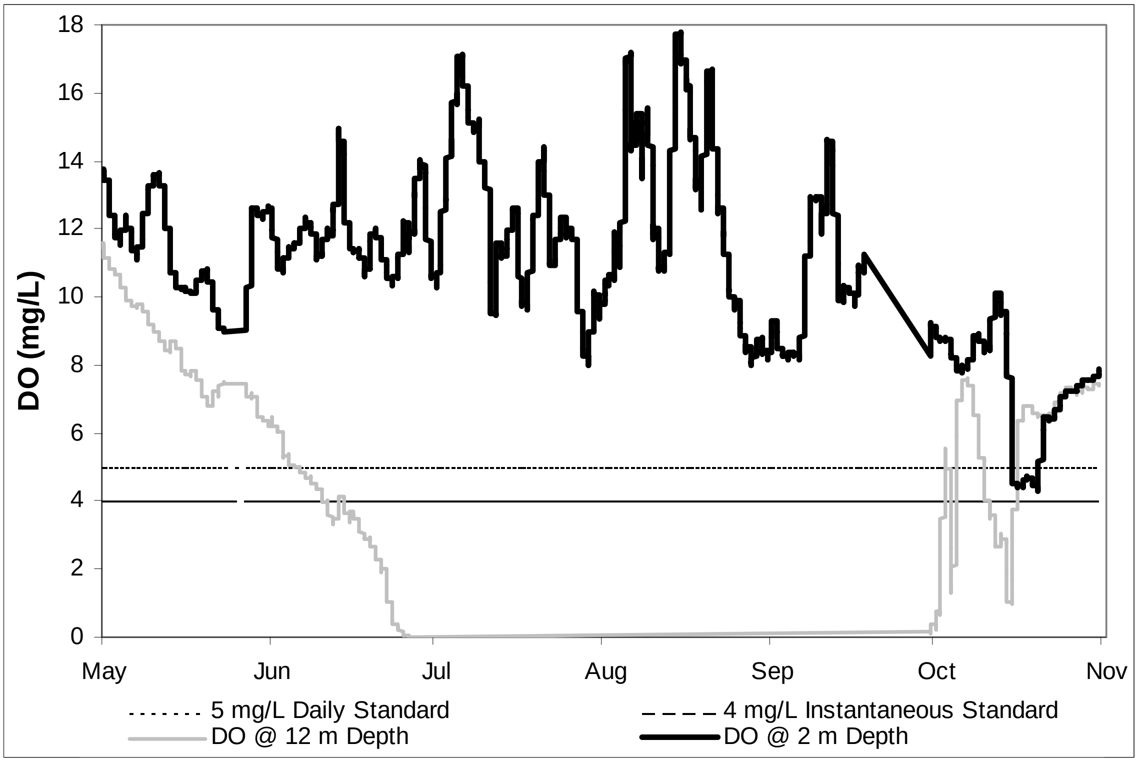

Figure 2-20. Temporal pattern of DO at 2 and 12 m depths in Onondaga Lake, South Deep Station in 2003. Data collected from OCDWEP high frequency monitoring buoy. Note: data were smoothed using a 192 point moving average which corresponds to two days of data collection. 5 and 4 mg/L lines designate NYS standards. Gap in data in mid-September due to probe replacement.

2.2.6 Ammonia Nitrogen

The water quality benefits of improved ammonia treatment at Metro were evident in the lake in 2003. As displayed in Figure 2-21, ammonia concentrations met the current NYS ambient water quality standard in the lake's upper waters (where oxygen levels are adequate for fish). NYSDEC is in the process of revising the state's ambient water quality standard for ammonia to be consistent with the federal criteria, which are also plotted in Figure 2-21. Onondaga Lake was also in full compliance with the federal criteria for ammonia throughout the 2003 sampling period.

Concentrations of ammonia in the lake waters and compliance with NYS standards and the federal criteria are variable from year to year depending on factors such as weather and algal abundance. The single most important factor governing ammonia nitrogen in the lake is Metro

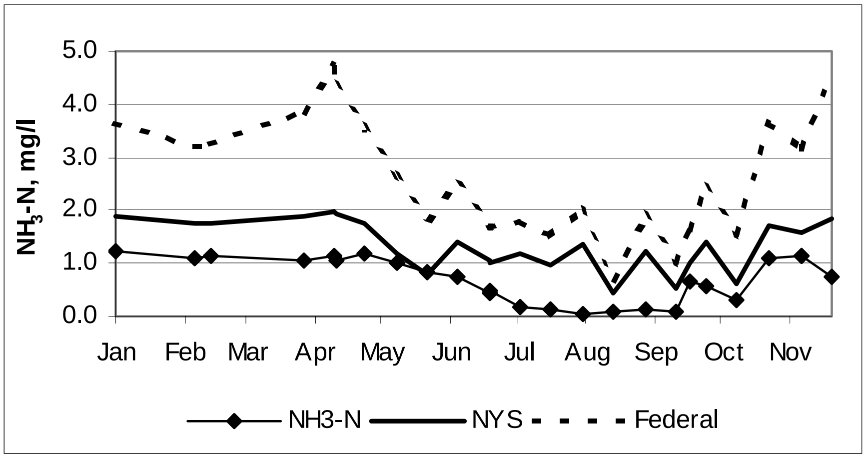

Figure 2-21. Ammonia concentrations at 3 meter depth, Onondaga Lake South Deep Station, 2003, compared with NYS standards and federal criteria.

performance; recall that Metro Outfalls 001 and 002 have historically contributed more than 90% of the external ammonia load to the lake. In 2003 the Metro contribution was reduced to 84% and additional reductions will be evident beginning in 2004 as the Biological Aerated Filters (BAF) system comes on line. This technique filters wastewater with a special micro-sand media while adding air and has been widely used in Europe. Nitrification occurs in chambers containing billions of tiny polystyrene beads that provide surface area for attachment of microorganisms. A pilot test of the technology demonstrated its effectiveness in treating the large flows and cold wastewater temperatures characteristic of Metro influent.

As displayed in Figure 2-22, improved wastewater treatment has resulted in reduced external ammonia loading and improved water quality conditions. The number of days of violation of the NYS ammonia standard in the upper waters each year is plotted in Figure 2-23. The effectiveness of the improved level of wastewater treatment is evident.

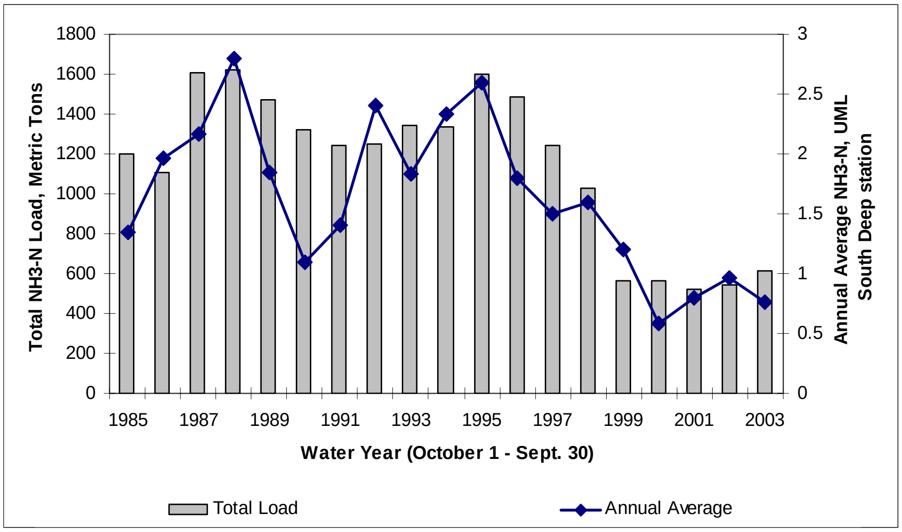

FIGURE 2-22. Annual External Ammonia Load to Onondaga Lake, 1985 - 2003 and UML Average Concentration at South Deep station.
1985-1990 calculated with AuroFlux Method 2. 1991-2003 calculated with Method 5. See text for details.

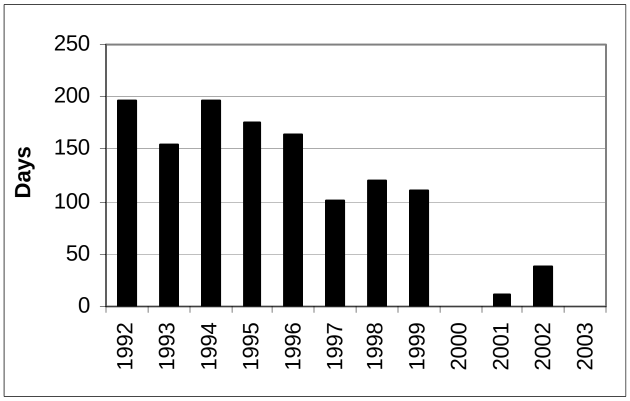

Figure 2-23. Estimated days of violation (April 1 - December 1) of NYS ammonia standard in UML (0-9m) of Onondaga Lake, South Deep station, 1992-2003. Note: Based on limited historical data, winter concentrations are assumed to exceed standard. There were no days of violation in 2000 and 2003.

The seasonal patterns of ammonia loading and concentration in 2003 were similar to 2002. The seasonal effect of improved nitrification during the summer months is clearly demonstrated in Figure 2-11. In 2003, nitrification began at about the same time as in 2002 (late June), but continued longer into the fall (through November in 2003 and through October in 2002). As in previous years, the decrease in loading produced a parallel decrease in the measured concentrations in the lake's UML during summer. The concentration of ammonia in the LWL increased during the summer as in previous years, generally responding independently of the changes in loading and reflecting the decay of settled organic matter (e.g., phytoplankton) into ammonia, the lack of nitrification due to lack of oxygen, and release of ammonia from the sediments, all of which serve to increase the concentration of ammonia in the LWL during the summer period of thermal stratification.

At fall turnover, the ammonia that had accumulated in the LWL mixed throughout the water column, coming into contact with oxygen present in the upper waters (refer to Figure 2-11). Some of this material was probably nitrified prior to exiting the lake.

2.2.7 Nitrite Nitrogen

The summertime average nitrite concentrations in the UML and LWL increased somewhat from 2002 to 2003, although the 2003 average fell within the range of values measured in the past several years (refer to Figure 2-10). The increase in UML nitrite concentrations constituted the first interannual increase in several years. The cause of the increase from 2002 to 2003 is not clear, although somewhat higher Metro loads in 2003 may have contributed. LWL nitrite concentrations increased during the 1990s and have remained relatively stable since about 2000.

The 2003 dataset did not exhibit spikes of nitrite in Metro effluent during the summer, as have been observed intermittently in previous years (e.g., 2002). The UML concentration of nitrite increased at the beginning of summer, probably due in part to nitrification (Figure 2-24); ammonia-N exhibited a simultaneous decrease. Levels were relatively stable over the summer. The LWL concentration exhibited greater variability within the growing season. The concentration of nitrite in the LWL increased dramatically in late June, concurrent with the

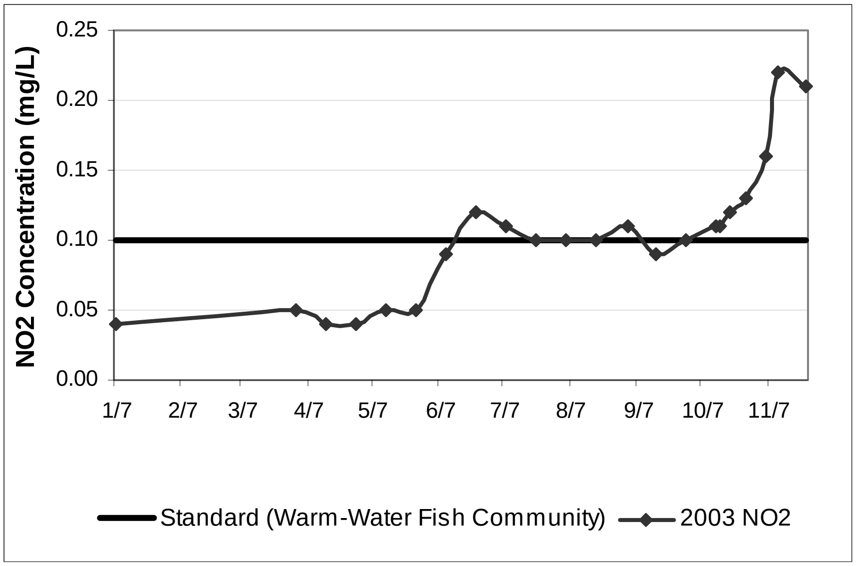

Figure 2-24. Averaged UML (0-9m) nitrite-N concentrations, Onondaga Lake South Deep Station, 2003.

decline in DO, and then decreased through July and August, presumably as the redox potential of the LWL continued to decrease. Finally, nitrite concentrations rose during and after fall turnover, likely due to the mixing of oxygenated upper waters with bottom waters rich in ammonia, providing conditions suitable for nitrification. These patterns were similar to the observations from 2002.

Nitrite concentrations in the UML and LWL were above the 0.1 mg/L standard at times. The UML remained at, or above, the standard through much of the summer and the LWL exceeded the standard in the middle of the summer and late fall. Overall, nitrite violations were more prevalent in 2003 than in 2002, which may be a consequence of the higher algal production (i.e., more biomass to be decomposed in the lower waters). Because of the linkage between ammonia and nitrite, improvements to the Metro treatment plant to reduce ammonia are expected to reduce nitrite concentrations in the lake as well.

2.2.8 Nitrate Nitrogen

Concentrations of nitrate-N in the UML have exhibited considerable variability since the late 1980s. Nitrate concentrations in the UML have not tracked external loads as well as UML ammonia, in part due to the fact that nonpoint source loads of nitrate have been significant contributors to total loads; in contrast, Metro has provided the dominant ammonia load. Nonpoint source nitrate loads have not exhibited a trend, but do vary from year to year.

LWL nitrate concentrations increased in the 1990s and have remained relatively stable in recent years, similar to nitrite concentrations. The cause of the increase in the 1990s is not clear, but may be associated with progress towards phosphorus limitation of algal productivity. Reduced algal activity would be associated with a reduction in the incorporation of N into biomass and eventual settling to the lower waters.

UML nitrate concentrations rose in early summer 2003, probably in response to increased nitrate loading from Metro as modifications to the treatment plant came on line. The UML achieved higher nitrate levels in 2003 than in 2002. Following a decline at fall turnover, due to mixing with nitrate-poor lower waters, nitrate concentrations rose again, probably due to a combination of loading from Metro and nitrification.

The LWL concentration of nitrate decreased in early summer 2003. Levels were below the detection limit in early September. The decline occurred as oxygen was depleted in the lower waters. These are conditions under which nitrification is minimal and denitrification is favored. During and following fall turnover, nitrate concentrations increased in the LWL due to mixing, nitrification and dispersion of the continuing Metro load through the water column.

2.2.9 Bacteria

Fecal coliform bacteria levels are measured at multiple sites in Onondaga Lake to assess whether the water is safe for contact recreation. Fecal coliform bacteria are used as indicators of the potential presence of pathogenic (disease-causing) microorganisms. This class of bacteria is currently used by NYSDEC as an indicator of microbiological purity. However, EPA is strongly encouraging states to change their ambient water quality standards to base their assessment of recreational suitability of freshwater on the presence and abundance of a second indicator organism, *E. coli*. Studies have shown that *E. coli* levels are more closely associated with human health impacts of contact recreation, particularly incidence of gastrointestinal illness (EPA 2002). Onondaga County is currently monitoring and reporting both classes of indicator organisms in Onondaga Lake.

The 2003 data indicate that indicator bacteria levels in the lake's southern basin, near the CSOs and major streams, are occasionally elevated in response to storms of sufficient intensity and duration to cause the combined sewer system to overflow. This finding highlights the need for continued progress with the CSO abatement projects. However, water quality improves in the northern basin. Water quality in Willow Bay, Maple Bay, and Onondaga Lake Park showed no violations of bacteria standards for safe swimming during 2003 (Figure 2-25).

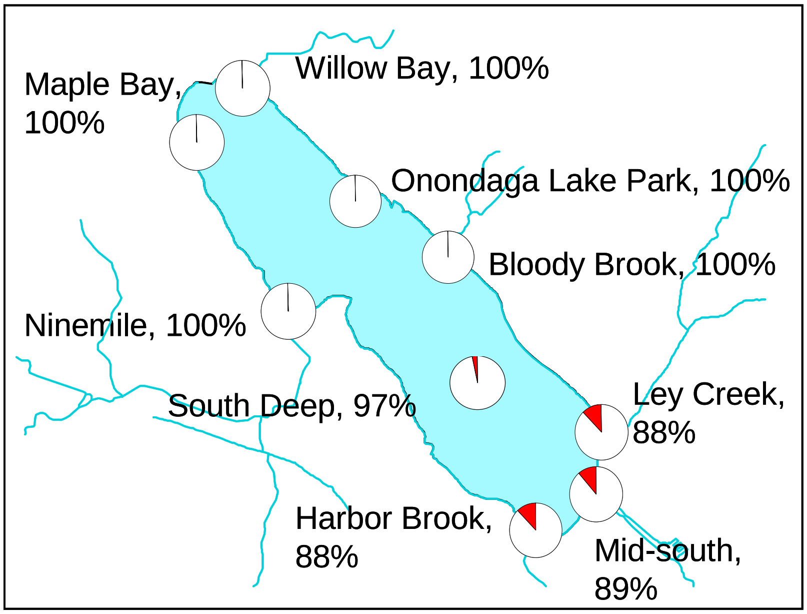

Figure 2-25. Nearshore F coli violations in 2003. Percent shown in figure indicates compliance. Shaded area of pie charts indicates percent of samples that exceeded 200 cells per 100 ml.

2.2.10 Mercury Concentrations

OCDWEP used special trace metal sampling techniques (referred to as the clean hands/dirty hands methodology) to collect water samples from Onondaga Lake for analysis of total and methyl mercury concentrations during 2003. The water samples were shipped to a specialized laboratory (Brooks Rand LLC) for measurement using analytical techniques capable of detecting trace concentrations of mercury in water. The AMP specifies a minimum of three low-level mercury sampling events to be completed each year based on the lake's stratification regime (April, August, and October). Samples are collected at both North Deep and South Deep stations from water depths of 3 and 18 meters during the events.

The contract laboratory analyzes these special samples using EPA Method 1631, which measures mercury in water by oxidation, purge and trap, and cold vapor atomic fluorescence. Method 1631 has a method detection limit of approximately 0.1 ng/l. Brooks Rand analyzes methyl mercury using a specialized method listed as BRL SOP BR-0011. Prior to 1998, the Metro Environmental Laboratory routinely analyzed water samples for mercury using EPA Method 245.2, a cold vapor atomic absorption method with a detection limit of 200 ng/l (0.2 µg/l). Improvements in analytical technology and increasingly stringent federal criteria and state ambient water quality standards for mercury led the County to use a specialized laboratory to measure mercury in Onondaga Lake waters.

The field team and laboratory implement extensive quality assurance/quality control measures to comply with the requirements of the analytical method, including equipment blanks, matrix spike/matrix spike duplicates, method blanks, and laboratory control samples. Duplicate analysis is not currently part of the program. As noted in the recommendations section (Chapter 5), analysis of method duplicates (split in the laboratory) or field duplicates (two samples collected in the field from the same station and depth) would provide an additional measure of variability.

Results of the 2003 low-level mercury sampling program are summarized in Table 2-10. The first set of samples was collected on April 29, 2003 prior to development of thermal stratification. During the April 2003 sampling event, concentrations of total mercury were remarkably consistent at the two stations and two sampling depths. This result was expected as the water column was fully mixed. Total mercury concentrations were in the range of 2 – 2.7 ng/l. Methyl mercury concentrations were about 10% of the total concentrations (0.2 – 0.28 ng/l).

A second set of samples was obtained on August 19, 2003 when Onondaga Lake was thermally stratified. In August, total mercury concentrations in the lower waters at both stations increased to approximately 7 ng/l. Methyl mercury concentrations were also at their seasonal peak during this

TABLE 2-10
Low Level Mercury Sampling
Onondaga Lake

April 29, 2003 Sampling Event
Lake fully mixed

Location and Depth	Total Hg (ng/l)	Methyl Hg (ng/l)
South Deep 3 m	2.24	0.237
South Deep 18 m	2.69	0.28
North Deep 3 m	2.06	0.205
North Deep 18 m	2.13	0.203

August 19, 2003 Sampling Event
Stratified

Location and Depth	Total Hg (ng/l)	Methyl Hg (ng/l)
South Deep 3 m	4.68	0.946
South Deep 18 m *	7.41	7.92
North Deep 3 m	1.63	0.398
North Deep 18 m	6.46	5.3

October 28, 2003 Sampling Event
Lake fully mixed

Location and Depth	Total Hg (ng/l)	Methyl Hg (ng/l)
South Deep 3 m	7.8	1.74
South Deep 18 m	8.11	1.84
North Deep 3 m	5.94	1.94
North Deep 18 m	7.75	2.2

* Methyl mercury slightly higher than total mercury in this sample. Both results should be considered estimated.

event, with concentrations in the lower waters approaching or equivalent to the total fraction. This pattern of peak mercury levels in late summer and early fall is typical of data collected since 1999, and is consistent with the conceptual model of mercury cycling in productive lakes (e.g. USGS fact sheet on mercury and lakes: water.usgs.gov/wid/FS_216-95/FS_216-95.html).

Mercury concentrations were again essentially uniform through the water column during the fall event, which was completed on October 28, 2003. Consistent with results of previous years, concentrations of methyl mercury after mixing are at their highest concentrations in the upper waters of the three annual events. Mercury concentrations throughout the water column in the October samples were substantially higher than concentrations measured in April.

2.3 PHYTOPLANKTON AND ZOOPLANKTON COMMUNITY

The AMP includes a detailed analysis of the structure and abundance of the phytoplankton and zooplankton communities of Onondaga Lake. These lower trophic levels demonstrate large seasonal fluctuations in species composition and abundance; year-to-year variability is also pronounced. Researchers have begun to try to define the mechanisms, both biotic and abiotic, that influence community structure of the lower trophic levels in the lake environment. While no simple factors have emerged, it is clear that nutritional factors (i.e., the rate of supply of nitrogen and phosphorus) and ecological factors (food web structure) interact to control the species richness of phytoplankton and zooplankton (Leibold and Wilbur, 1992).

The interactions of water quality conditions and the lake’s lower trophic levels are discussed in detail in Chapter 3 of this AMP report. A summary of the major findings of the phytoplankton and zooplankton analysis prepared by Dr. Edward Mills and colleagues at Cornell Biological Field Station is included in the following section. (Complete data set included in Appendix 2.)

2.3.1 Phytoplankton and Zooplankton

Onondaga Lake remains a productive aquatic system as evidenced by its high levels of algal biomass. The duration of the cyanobacterial blooms in Onondaga Lake declined from 1996-2000 and have been variable in the early years of this century. Cyanobacteria (blue-green algae) were present in the 2003 phytoplankton community, but were not present in significant numbers or biomass until late in the summer recreational season. Cyanobacteria appeared in the phytoplankton community in mid-August in relative abundance, and persisted through the end of October. The declining or limited cyanobacteria productivity documented prior to 2002 could indicate an improvement of water quality, but this recent resurgence may reflect changes in the food web that favors blooms of cyanobacteria.

The relative importance of cyanobacteria is of concern to lake managers because these organisms can proliferate and become nuisance algae, degrading water quality and the aesthetic environment. The 2003 phytoplankton samples were examined to identify and enumerate the organisms and estimate their biomass. As displayed in Figure 2-26, blue-greens represented approximately 15% of the phytoplankton biomass in 2003.

The biomass and size structure of the zooplankton community in 2003 show some interesting patterns. Average total zooplankton biomass in nearby Oneida Lake (Cornell Biological Field Station unpublished data) was 246 µg/L for a single deep site (February - September 2003), while it averaged 321 µg/L in all of Onondaga Lake for the same time period (all values are wet weight). Although this difference is not as pronounced as in previous years, this finding is expected given the high productivity of Onondaga Lake.

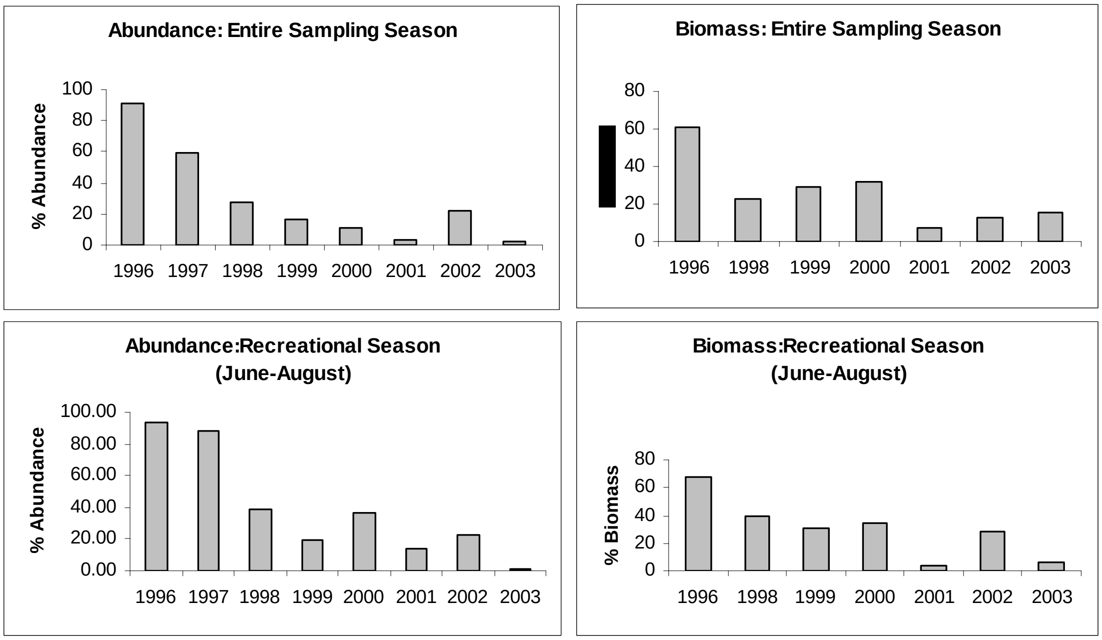

Figure 2-26. Percent contribution of Cyanobacteria (blue-green algae) to the phytoplankton community from 1996 to 2003, Onondaga Lake South Deep Station. *Note: 1997 data were not analyzed for biomass.*

The average size of animals in the Onondaga Lake zooplankton community was significantly smaller in 2003. Moreover, unlike previous years the temporal patterns in average zooplankton size showed little similarity between Onondaga and Oneida Lakes. The consistently small average size of the total zooplankton community throughout the seasons in 2003 (0.35mm (winter) and 0.33mm (fall)) was in stark contrast to 2002, which showed more variation – 0.92mm (winter) to 0.27mm (fall). Associated with this change in size structure is the dominance of the small cladoceran *B. longirostris*, but also a striking lack of *Daphnia* and total absence of mature calanoid copepods throughout the entire 2003 season.

These findings suggest a lengthy period of intense planktivory by plankton-eating fish in 2003. Populations of *Daphnia* have a tremendous capability to exert strong influence on the phytoplankton community (Mills *et al*. 1987). The striking absence of *Daphnia* species in Onondaga Lake in 2003 was likely linked to the increased density/biomass and drastically different composition of the phytoplankton community in 2003 when compared to previous years. *Cercopagis pengoi* again appeared in the lake in the 2003 season. Interestingly, the periods of *Cercopagis* detection in the lake also represent periods of decreased dominance by *Bosmina longirostris* and a fall season low in average adjusted size that coincides with the smallest adjusted average size of zooplankton in the lake for the entire 2003 season, suggesting possible predatory impacts by *Cercopagis* leading to a restructuring of the zooplankton community.

2.4 FISH COMMUNITY

In 2003, OCDWEP staff completed their fourth year of monitoring the lake's fish community. The monitoring program is designed to assess different life stages and habitats. The number and locations of fish nests are enumerated and identified to species (when possible). Larval fishes are collected both in the open waters (pelagic zone) and the nearshore areas (littoral zone). Juvenile fish are collected in the littoral zone. Adult fish are captured by electrofishing along the shoreline, by gill nets set offshore and by anglers participating in the diary program.

Significant findings of the 2003 results are presented in this section. Detailed data summaries are included in Appendix 8. A baseline analysis of the fish community was presented as the special focus chapter in the 2002 Annual AMP Report, which is available at the County web site (http://www.ongov.net/WEP/wepdf/we15e.pdf).

2.4.1 Summary of Findings and Metrics

A total of 9,875 fish representing 28 species were collected as part of the 2003 monitoring effort. Young-of-the-year seining captured 4,347 fish, electrofishing captured 3,935, larval seines 1,397, gill netting 157 and larval trawls 39. No new species were collected during the 2003 program. The total number of species captured in Onondaga Lake since 2000 remains at 36.The adult community in 2003 closely resembled the community documented in the past three years with nine key species dominating the catch (Figure 2-27). In addition, a tenth dominant species was present in the 2003 electrofishing catch; the alewife. Alewives were much more abundant in 2003 than in previous years, representing about 39% of the electrofishing catch in 2003 compared with a maximum of 0.6% of the annual catch from 1990 - 2002. Analysis of alewife length frequency suggests that most of the alewives captured in 2003 were probably one or two years old. It is not known if these fish were the result of successful reproduction within in the lake or if they originated elsewhere and moved into the lake as adults.

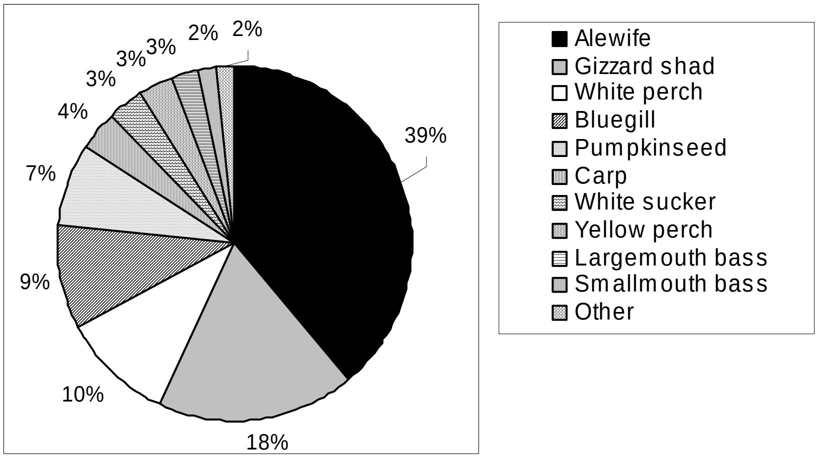

Figure 2-27. Relative abundance based on CPUE of fish captured during littoral zone electrofishing in 2003 (June and September sampling combined). CPUE for gamefish is calculated from all 24 transects. CPUE for non-gamefish are calculated from only the one-half of the transects where all fish are collected (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.

Alewives are a potentially important addition to the Onondaga Lake community. This species is a planktivore. By definition, the preferred food source of a planktivore is plankton (e.g. zooplankton, ichthyoplankton) although the alewife, like most fishes, is opportunistic and other foods may be consumed. Alewives have a well-documented ability to dramatically alter zooplankton community structure. Alewives selectively feed on large-bodied zooplankton such as *Daphnia* and can essentially eliminate these species from the zooplankton community. The loss of larger zooplankton, which are more efficient grazers of phytoplankton, can result in more algae and diminished water clarity. Understanding these biological interactions is essential when trying to distinguish changes to lake water quality that are a result of improvements to wastewater collection and treatment.

Some notable changes in catch rates of some fishes have occurred since 2000. These include the continuing increase in bluegill and pumpkinseed, the decline in gizzard shad and carp, and the dramatic increase in alewives (Figure 2-28). Shad are near the northern extent of their range and tend to undergo periodic high winter mortality. A similar crash in the shad population was observed in Onondaga Lake in the early 1990's (Gandino 1996). The carp decline may be related to a virus present in the Seneca-Oswego system in 2001, according to regional fisheries biologists

(Mark Arrigo, *personal communication October 2004*). The increase in both bluegill and pumpkinseed abundance is coincident with increases in year class strength from 2000 to 2002 and could be related to increased habitat for these species in response to expanded macrophyte cover it the lake's littoral zone.

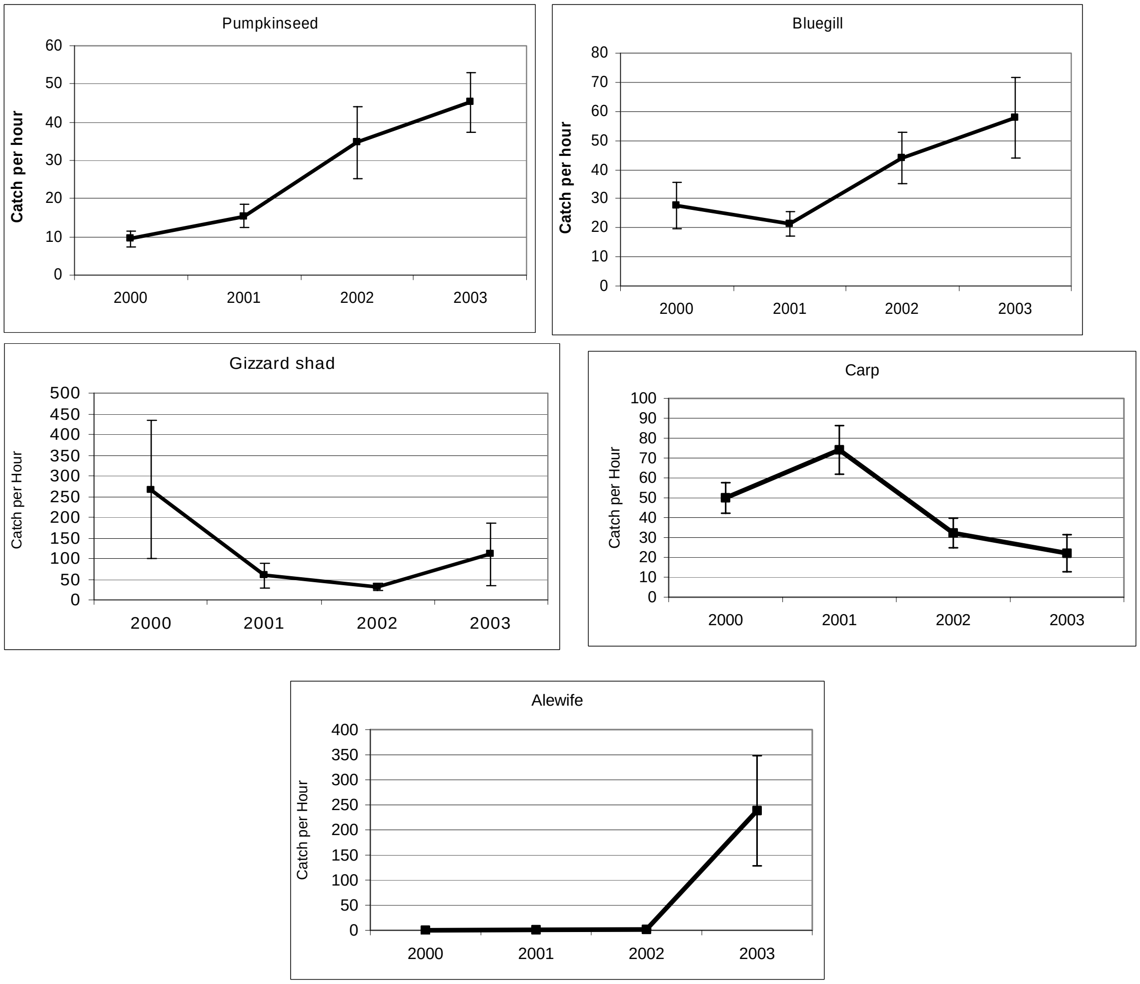

Figure 2-28. Catch per unit-hour (CPUE) from littoral zone electrofishing. Plots show the increase in pumpkinseed, bluegill and alewives as well as the decline in abundance of gizzard shad, and carp. Error bars are one standard error. CPUE based on both "all-fish" and "gamefish-only" transects. Gamefish species have CPUE calculated for all 24 transects, all other species have their CPUE calculated from only the 12 "all fish" transects. 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.

In 2003, most summary metrics were very similar to results calculated since 2000. The following metrics were essentially no unchanged: species richness, diversity, pollution tolerance, thermal guilds, proportional stock density (PSD), relative stock density (RSD), and relative weight. However, trophic guilds have shown some change (Figure 2-29). Refer to Appendix 8 for definitions of the trophic guilds. Most notable is the dramatic increase in planktivores in 2003;

this is due entirely to the increase in abundance of alewives, an obligate planktivore. Benthic invertivores (such as suckers and carp) have declined in relative abundance since 2000; this is due primarily to the decline in the carp catch since 2001.

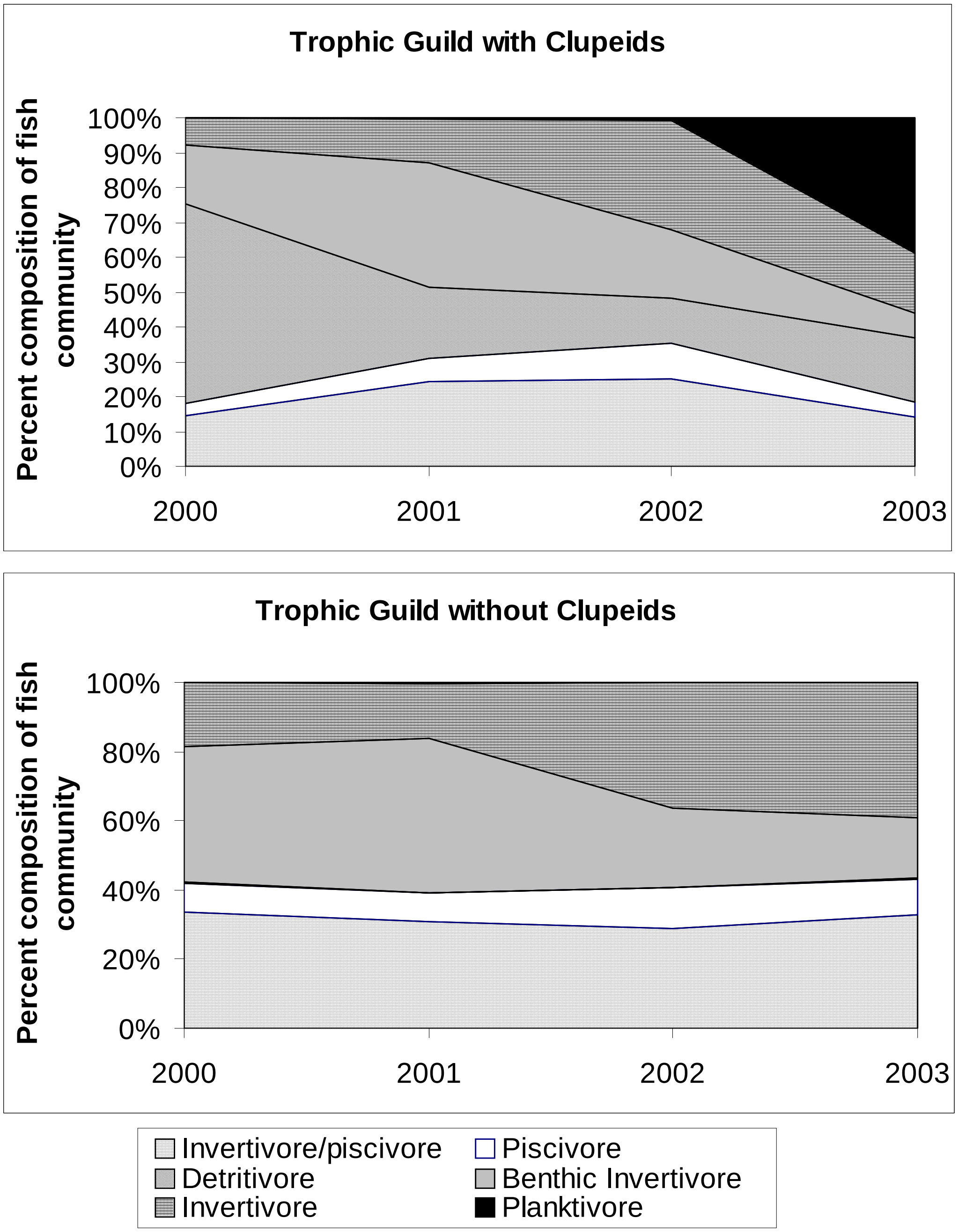

Figure 2-29. Relative proportion (based on CPUE from electrofishing) of trophic guilds from 2000-2003 shown with clupeids included and excluded.

Field observations of the number and species of fish afflicted with deformities, erosions, lesions, tumors, fungal infections, and multiple abnormalities (referred to collectively as DELTFM) were recorded in 2003. Systematic examination of all fish captured during the AMP sampling programs will begin in 2004. Eleven fish comprised of six species were noted to have some form of DELTFM in 2003 (Table 2-11).

TABLE 2-11
DELTFM Occurrence for Fish in Onondaga Lake in 2003*

Species	DELTFM Type	Number of fish with DELTFM
Brown bullhead	Melanoma on side	1
	Missing one barbel	1
	Burnt chin barbels	1
Channel catfish	Burnt chin barbels	2
Shorthead redhorse	Anal fin worn	1
	Tumor on mouth	1
Largemouth bass	Lesion on jaw, hook scar	1
	Mark on top of head	1
White sucker	Anal fin damaged	1
Yellow perch	Right operculum missing	1

* Note that systematic evaluation for DELTFM began in 2004.
These data summarize comments recorded on field sheets

2.4.2 Reproduction

Of the 28 species documented in the lake in 2003, 18 (64%) showed some evidence of successful reproduction either through the catch of larvae or young-of-the-year (Table 2-12). Of the ten species that did not show signs of reproduction in 2003, five (white, redhorse, and northern hog sucker, freshwater drum, and channel catfish) showed some evidence of reproduction in the lake from 2000 to 2002.

Lepomis spp., probably a combination of pumpkinseed and bluegill, continued to dominate the YOY community in 2003 representing 88% percent of the catch (Figure 2-30). The catch of *Lepomis spp*. and largemouth bass was down from the levels documented during the past two years. These taxa seem to generally track together over the first four years of the program indicating that relative success or failure of these taxa may be related at least partially to the same major variables (Figure 2-31). Gizzard shad and white perch YOY catch remained low in 2003, as in 2002, and down substantially from 2000 for both species. The number of carp young produced in the lake has apparently increased, although it is still low compared to other species. Smallmouth bass YOY abundance, an important gamefish in Onondaga Lake, has remained largely unchanged.

TABLE 2-12

Life Stages of Fish Captured During 2003 in Onondaga Lake Sampling

	Species	**Life Stages Present**
1	Banded killifish	L/Y/A
2	Bluegill	L/Y/A
3	Brook silverside	L/Y/A
4	Carp	L/Y/A
5	Gizzard shad	L/Y/A
6	Golden shiner	L/Y/A
7	Pumpkinseed	L/Y/A
8	Alewife	L/A
9	Black crappie	L/A
10	Yellow perch	L/A
11	Bluntnose minnow*	Y/A
12	Brown bullhead	Y/A
13	Emerald shiner*	Y/A
14	Largemouth bass	Y/A
15	Logperch*	Y/A
16	Smallmouth bass	Y/A
17	Tessellated darter*	Y/A
18	White perch	Y/A
19	Bowfin	A
20	Channel catfish	A
21	Freshwater drum	A
22	Northern hog sucker	A
23	Northern pike	A
24	Rock bass	A
25	Shorthead redhorse	A
26	Tiger muskellunge	A
27	Walleye	A
28	White sucker	A

A= Adult stage present, L= Larvae present (captured during larvae sampling), Y= YOY present (captured during YOY seining).

* denotes species that are small sized as adults making differentiation of YOY and adults difficult, these species are assumed to be reproducing in the lake if they are caught in the YOY seines.

Yellow perch larvae were caught in littoral larval seines at a rate nearly three times higher than the previous maximum (1.8/haul in 2003). However, no YOY yellow perch were captured in 2003, indicating a possible failure of larvae to recruit to the YOY stage. Alewives prey upon yellow perch larvae and have shown the ability to decimate yellow perch year classes in Lake Michigan (Shroyer and McComish 1999) and Conesus Lake (Matt Sanderson-NYSDEC, *personal communication*). The dramatic increase in adult alewife abundance in the lake in 2003 may have resulted in a year class failure of yellow perch, even though initial reproductive success was apparent.

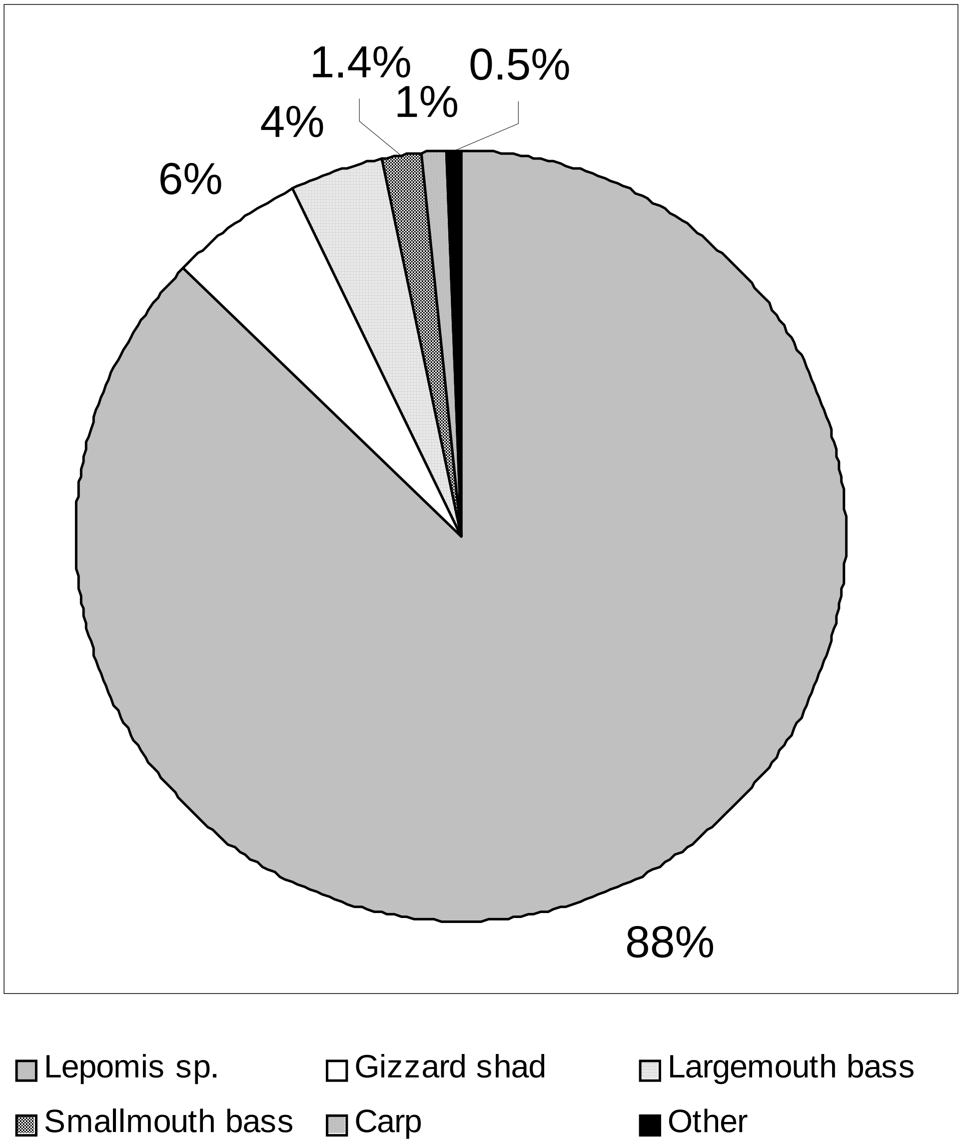

Figure 2-30. Relative abundance of YOY fish captured during littoral zone seining in 2003.

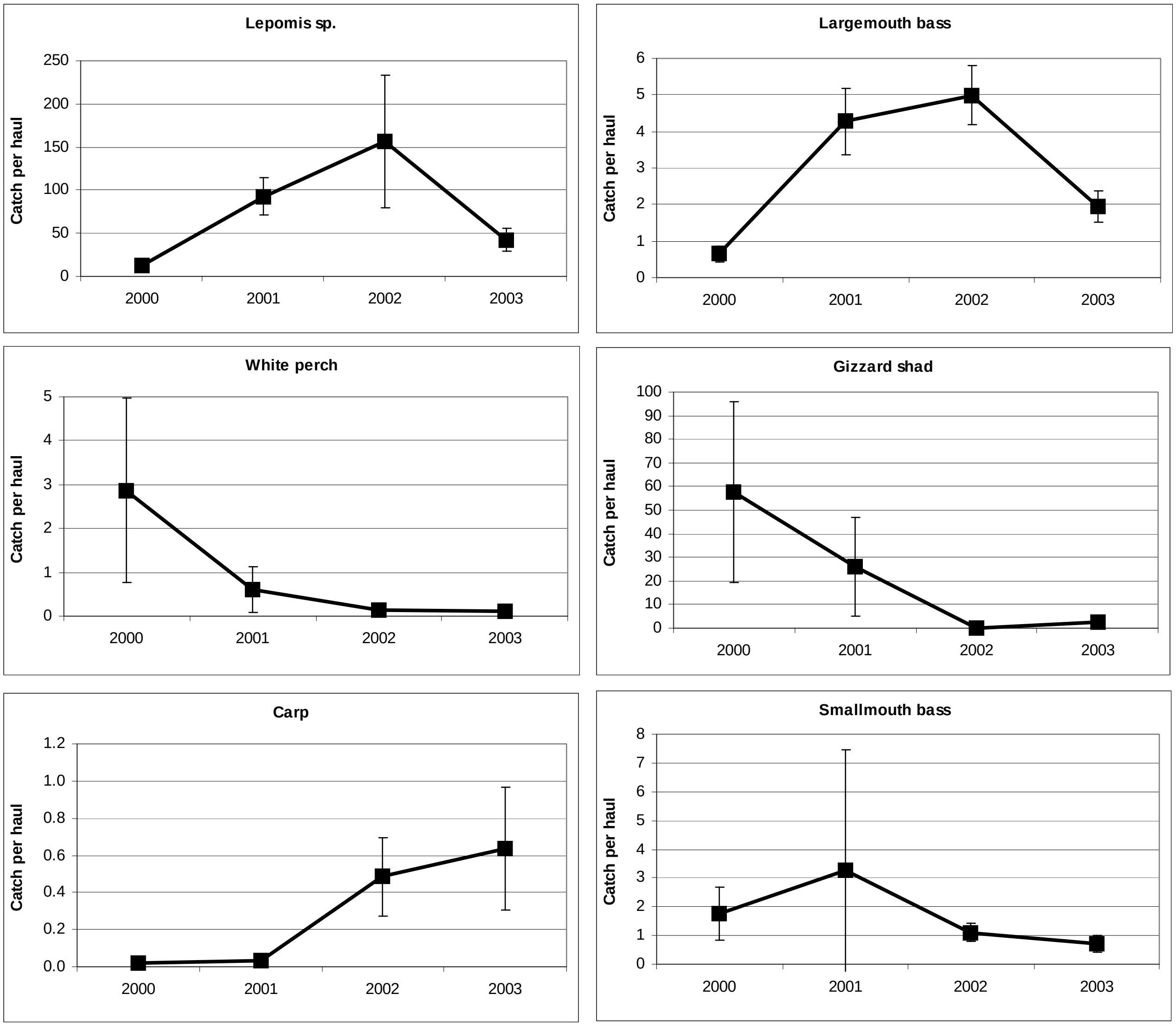

Figure 2-31. Catch per haul from littoral zone YOY seining, 2000 - 2003. Plots show trends in catch. Error bars are standard error.

2.4.3 Angler Diaries

The number of hours that cooperating anglers fished in Onondaga Lake in 2003 was about 64% of their cumulative 2002 effort and 48% of their 2001 effort. Smallmouth and largemouth bass continued to be the most frequently caught species in the lake based on the angler diaries. Catch rates for both species of bass were slightly higher in 2003 than in 2002. Smallmouth bass were caught at a rate of about 0.60 fish per hour in 2003 compared to about 0.40 fish per hour in 2002. Both these estimates are substantially lower than 2001 when about 2.8 smallmouth bass were caught per hour. Catch rates of largemouth bass are typically lower than those of smallmouth bass in Onondaga Lake. Largemouth bass angler catch rates were about 0.43 bass per hour in 2003 compared with 0.31 in 2002 and 0.28 in 2001.

2.5 SENECA RIVER CONDITIONS

The AMP team routinely monitors water quality conditions of the Seneca River at Buoy 316. In 2003, OCDWEP also completed three water quality surveys of multiple stations along the Seneca River to provide data for the Three Rivers Water Quality Model (TRWQM). These river surveys occurred on July 24th, August 21st, and September 11th, 2003 and were targeted for warm water, low flow conditions. During each survey, grab samples of bottom and top waters (1 m above the bottom and 1m below the surface) were collected and analyzed for a large number of water quality parameters. Grab samples of mid-depth waters (center location between the top and bottom of the water column) were also collected and analyzed in the three buoys located in deeper regions of the river (Buoys 269, 260, and 255). In addition, a profile of field parameters (DO, salinity, redox, pH, and temperature) was collected at each station during each survey. The complete data set from the 2003 Seneca River program may be found in Appendix 1.

The year 2003 was characterized by a wet spring (mid-March to mid-April), and few low-flow periods in the summer. The flow rates in the Seneca River on the three dates of the full water quality surveys were 3330, 1630, and 541 cfs. The average flow rates in the rivers from July to September were 2,065 cfs in the Seneca River and 1,162 cfs in the Oneida River, as compared to 863 cfs and 554 cfs, respectively, in 2002. The flow rate in the Seneca River in 2003 did drop below the 7-day average low flow with a recurrence interval of ten years (7Q10) value of 350 cfs (QEA, 2000) on October 13th, 14th, and 19th (188, 221, and 282 cfs respectively), although flow rates in the surrounding days precluded a seven-day average from reaching the 7Q10.

As in past years, the quality of Seneca River water in 2003 can be understood in light of several major factors: the loading of algal biomass from Cross Lake, flow rates, time of year, zebra mussel activity, effects of inflow from the more saline and eutrophic Onondaga Lake, and the presence of an anomalous region of the Seneca River downstream of the lake outlet called the “deep hole” which may be influenced by groundwater discharge.

During all three sampling events, the waters just downstream of Cross Lake were stratified. On two days, relatively low DO concentrations (6-8 mg/L) were measured in the bottom layers of the Seneca River at the upstream end of the study area, near the State Ditch Cut. These bottom water layers were entrained into the upper layers by Station 397, thereby increasing the DO concentrations in the bottom and decreasing the concentrations in the top waters. Zebra mussel respiration and sediment oxygen demand reduced DO concentrations as the water moved downstream to Baldwinsville. Consistent with previous years, DO levels in the vicinity of Baldwinsville were lowest in July and August: DO values below 5 mg/L were observed in the Baldwinsville area in the July and August events, but not in the September event.

In the Seneca River, since the zebra mussel invasion, river water quality has shifted from a system in which nutrients such as phosphorus and nitrogen were largely tied up in phytoplankton standing crops to one in which dissolved forms are more prevalent (Figure 2-32). In 2003, the average NH_3–N concentration in the river upstream of the lake (0.2 mg/L) was less than the concentration in the lake's LWL (generally greater than 1.0 mg/L), but was greater than the concentration in the UML at times (below 0.1 mg/L in the middle of summer). Thus, UML concentrations of ammonia may increase during flow reversals in the outlet due to the influx of river water. However, this phenomenon is probably limited primarily to the vicinity of the lake outlet and is unlikely to have a large impact on lakewide ammonia-N concentrations.

In 2003, SRP levels generally increased in the Seneca River from near zero in the vicinity of Cross Lake to approximately 30 ug/L near the lake outlet, because of filtration and nutrient release by the zebra mussels (refer to Figure 2-33). Levels were relatively constant going further

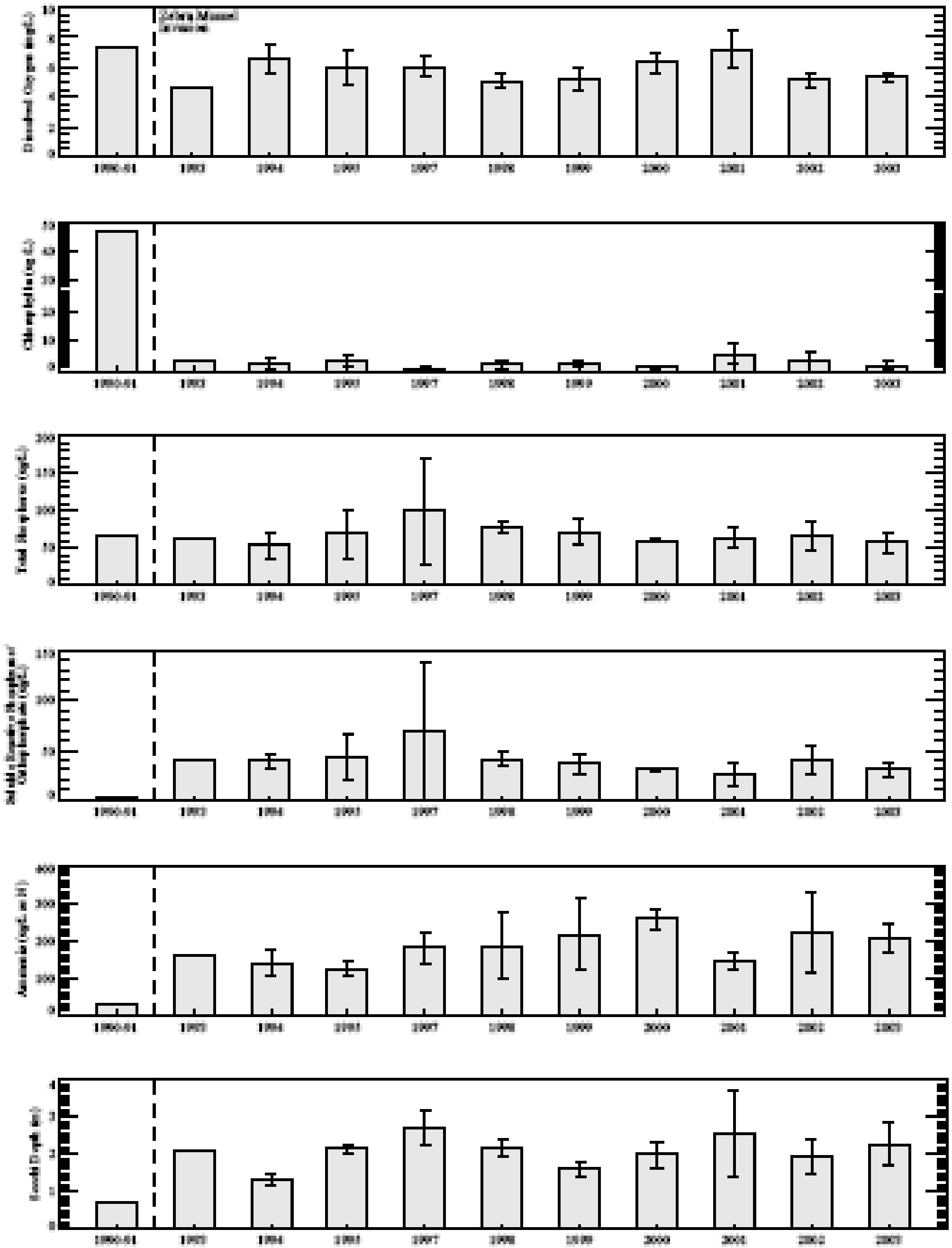

Figure 2-32. Water Quality Parameters Measured near Baldwinsville Before (1990-91) and After the Zebra Mussel Invasion of the Seneca River.

Note: 1990-91 & 93 data from Effler et al. (1996); 1994-03 data from County AMP; results are from 1 m below water surface at Buoy-316; plotted values represent yearly arithmetic mean +/- 2 standard errors of the mean

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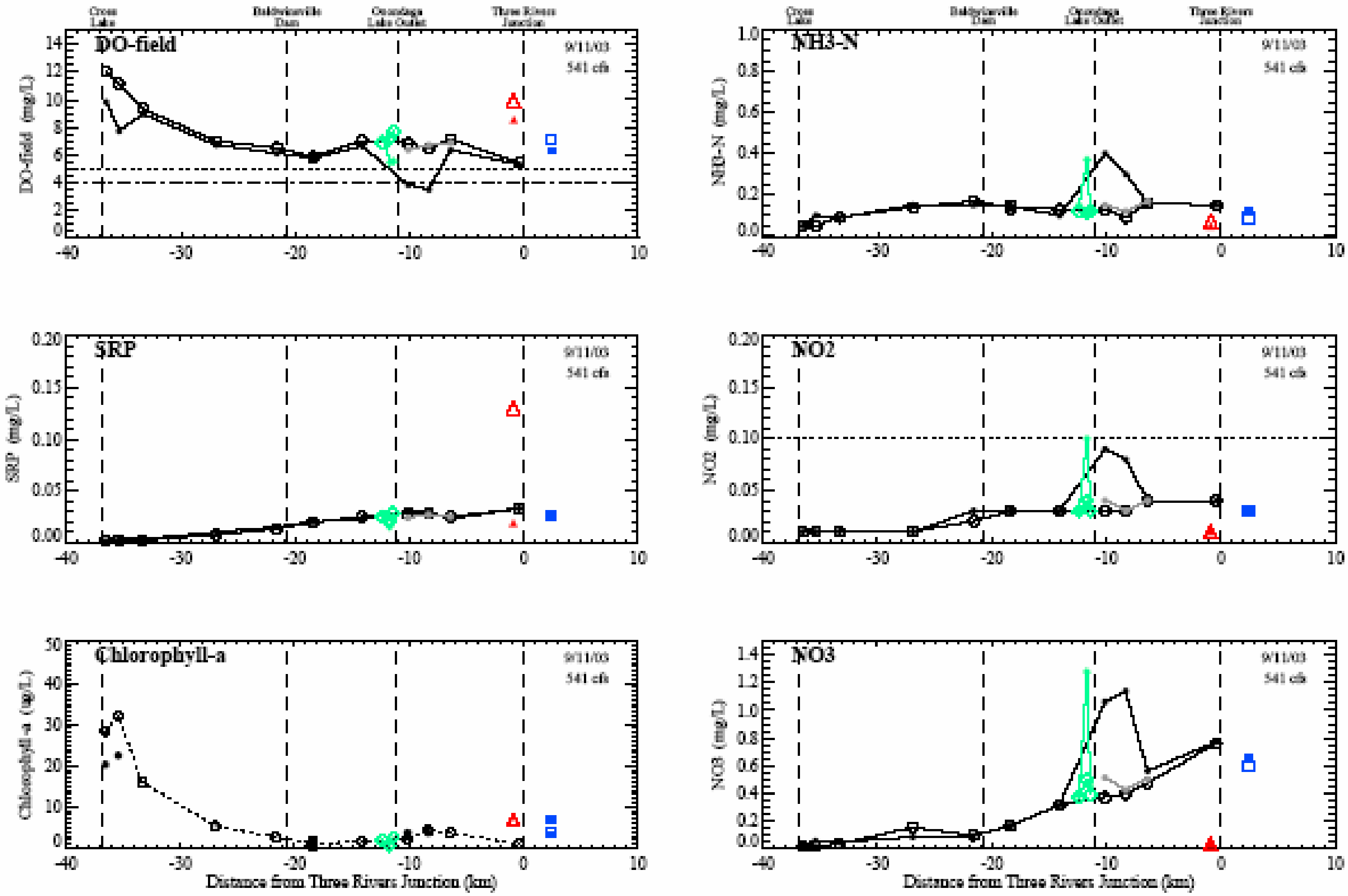

Figure 2-33. Spatial profiles of water quality parameters on 9/11/03.

Notes: (1)River km measured from Three Rivers Junction, upstream (-) for Seneca and Oneida / downstream (+) for Oswego; (2)Open symbols represent surface samples, filled symbols represent bottom samples, gray circles represent mid-depth samples, and open symbols with dots represent composite samples; (3)Baldwinsville flow on sampling dates shown in each panel.

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downstream, probably due to balancing of algal growth with filtration of the remaining algae. The SRP concentration upstream in the Seneca River (about 30 ug/L in the September 11, 2003 survey) was intermediate between the concentration in the UML of the lake (about 10 ug/L) and the LWL (about 300 ug/L). Thus, in mid-summer, the river may contribute some SRP to the lake's upper waters during periods of river inflow. These patterns are consistent with previous years.

Zebra mussel filtration led to a dramatic decrease in chlorophyll-*a*, from levels ranging from 10 to 60 ug/L at Cross Lake, to levels below 5 ug/L at Baldwinsville. Nutrient release by the mussels led to increases in NH_3-N and SRP concentrations in the river.

Elevated salinity and lower temperatures were observed downstream of the outlet, probably reflecting the influx of lake water: the temperature and salinity of the bottom waters of the river were similar to data collected in the bottom waters of the lake outlet. Dissolved oxygen levels in the bottom waters downstream of the outlet also appeared to be largely influenced by Onondaga Lake. The 2003 data exhibited overall higher DO in the bottom layers of the deep hole area than many previous surveys. This may be due to the relatively high flow rates of the July and August surveys of 2003.

Results of a sampling event along the Seneca River on Sept. 11, 2003 are plotted in Figure 2-33. The spatial profiles clearly demonstrate the decline in DO from Cross Lake to the Onondaga Lake outlet, and the stratification of the upper and lower waters of the river that developed during this low flow sampling event. The outlet of Onondaga Lake provides a clear signal in its elevated concentrations of inorganic nitrogen. Also of note is the marked decline in chlorophyll-*a* between Cross Lake and the Baldwinsville Dam; this decline is attributed to the grazing by zebra mussels.

In summary, the river water quality in 2003 was comparable to data collected from 1994 to 2002. The introduction of zebra mussels in the early 1990s resulted in dramatic changes in water quality in the river; since then, the dominant patterns and mechanisms do not appear to have changed significantly.

2.6 REGULATORY COMPLIANCE

2.6.1 Tributaries

The monitored segments of the Onondaga Lake tributaries are classified C (suitable for fish propagation and secondary water contact recreation). Compliance with the ambient water quality standards is summarized in Table 2-13. Overall, the lake tributaries were in compliance except for the following:

- As in previous years, the natural tributaries were consistently out of compliance with the current state ambient water quality standard for iron of 300 µg/l. Following an evaluation of the scientific basis for the standard, NYSDEC is expected to propose a revision to 1000 µg/l as a guidance value. This change would be consistent with the 1976 federal criterion for iron. Between 75% and 100% of the tributary iron measurements were below 1000 µg/l during the 2003 monitoring period.

- The East Flume occasionally violated ambient water quality standards for DO and regularly violated standards for cyanide, ammonia and pH during 2003. Nitrite N concentrations in this stream consistently exceeded the ambient water quality standard (0.1 mg/l to protect a warmwater fish community). Elevated levels of inorganic N have characterized this stream since the beginning of the County's monitoring program, more than 30 years ago.

- Cyanide concentrations in Ley Creek exceeded the ambient water quality standards on 50% of the measured samples in 2003.

- Heavy metal concentrations, measured quarterly, generally met the ambient water quality standards in 2003 with minor exceptions. One sample for copper in Tributary 5A (which includes the Crucible Specialty Metals outfall) exceeded the Class C standard. Three streams: Onondaga Creek, Harbor Brook, and Bloody Brook each had one sample with lead concentration over the Class C standard.

TABLE 2-13

Regulatory Compliance in Onondaga Lake Tributaries, 2003

All 2003 data are reported for each tributary. Samples were obtained at several sites on certain streams.

NM=Ninemile Creek @ Lakeland Rt48, OC=Onondaga Creek @ Kirkpatrick St and Dorwin Ave; LC=Ley Creek @ Park St.; HB=Harbor Brook @ Velasko Rd and Hiawatha Blvd; 5A=Trib 5A; EF=East Flume; BB = Bloody Brk @ Onondaga Lake Parkway ; SM = Sawmill Crk @ Onondaga Lake Rec. Trail

Parameter (units)	**NYSDEC Standard (Class C)**[1]	**Average of 2003 measured concentrations**	**Measurements in Compliance**
pH	Shall not be less than 6.5	NM : 7.85	100%
(standard units)	nor more than 8.5	OC : 7.86	100%
		LC : 7.45	100%
		HB : 7.68	100%
		5A : 7.67	100%
		EF : 8.69	11%
		BB : 7.75	100%
		SM : 7.52	100%
Dissolved Oxygen	Minimum daily average	NM : 11.77	100%>4, 100%>5
(mg/l)	5.0 mg/l, at no time shall DO	OC : 11.79	100%>4, 100%>5
	be < 4.0 mg/l	LC : 9.00	100%>4, 96%>5
		HB : 11.13	100%>4, 100%>5
		5A : 6.48	90%>4, 63%>5
		EF : 12.00	100%>4, 93%>5
		BB : 10.95	100%>4, 100%>5
		SM : 8.70	100%>4, 100%>5
Fecal Coliform[2]	Percent individual observations < 200 cells.	NM : > 349	85%
(cells/100 ml)		OC : > 845	67%
		LC : 578	74%
		HB: > 1007	74%
		5A : 140	93%
		EF : 76	89%
		BB : 267	50%
		SM : 25	100%
Ammonia-N	Varies with pH and temperature.	NM : 0.30	100%
(mg/l)		OC : 0.09	100%
		LC : 0.38	100%
		HB : 0.08	100%
		5A : 0.14	100%
		EF : 0.41	33%
		BB : 0.08	100%
		SM : 0.10	100%
Arsenic[3,4]	190 µg/l	NM : < 2.0	100%
(µg/l)		OC : < 2.0	100%
		LC : < 2.0	100%
		HB : < 2.0	100%
		5A : 2.3	100%
		EF : 3.3	100%
		BB : < 2.0	100%
		SM : < 2.0	100%
Cyanide[4]	5.2 µg/l (Free CN)	NM : < 2.0	100%
(µg/l)		OC : 2.3	100%
		LC : 5.5	50%
		HB : 2.6	89%
		5A : 2.0	100%
		EF : 4.8	75%
		BB : 2.5	100%
		SM : 2.0	100%
Nitrite-N	100 µg/l (Warm water fishery)	NM : 31.7	100%
(µg/l)		OC : 12.0	100%
		LC : 17.6	100%
		HB : 13.0	100%
		5A : 31.7	100%
		EF : 893.8	0%
		BB : 15.0	100%
		SM : 15.0	100%

●

TABLE 2-13 *(cont.)*

Regulatory Compliance in Onondaga Lake Tributaries, 2003

All 2003 data are reported for each tributary. Samples were obtained at several sites on certain streams.

NM=Ninemile Creek @ Lakeland Rt48, OC=Onondaga Creek @ Kirkpatrick St and Dorwin Ave; LC=Ley Creek @ Park St.; HB=Harbor Brook @ Velasko Rd and Hiawatha Blvd; 5A=Trib 5A; EF=East Flume; BB = Bloody Brk @ Onondaga Lake Parkway ; SM = Sawmill Crk @ Onondaga Lake Rec. Trail

Parameter (units)	**NYSDEC Standard (Class C)**[1]	**Average of 2003 measured concentrations**	**Measurements in Compliance**
Copper [4]	0.96 exp (0.8545 [ln (ppm hardness)] - 1.702)		
(µg/l)	Standard Range (µg/l):		
	NM: 26.1	NM : 6.6	100%
	OC: 16.1-26.1	OC : 4.5	100%
	LC: 23.5-26.1	LC : 3.5	100%
	HB: 20.9-26.1	HB : 2.4	100%
	5A: 22.8-26.1	5A : 18.4	75%
	EF: 16.5-26.1	EF : 2.7	100%
	BB : 12.2-26.1	BB : 4.0	100%
	SM : 19.6-26.1	SM : 1.1	100%
Mercury * [4]	0.0007 µg/l	NM : 0.02	50% (see note)
(µg/l)		OC : < 0.02	0% (see note)
		LC : 0.09	100% (see note)
		HB : 0.05	44% (see note)
		5A : 0.04	25% (see note)
		EF : 0.05	50% (see note)
		BB : 0.04	25% (see note)
		SM : 0.03	25% (see note)
Lead [4]	(1.46203 - [ln (hardness) 0.145712]) exp (1.273 [ln (hardness)] - 4.297)		
(µg/l)	Standard Range (µg/l):		
	NM: 14.3	NM : 4.6	100%
	OC: 7.9-14.3	OC : 6.3	87%
	LC: 12.6-14.3	LC : 5.6	100%
	HB: 10.9-14.3	HB : 6.1	89%
	5A: 12.1-14.3	5A : 5.0	100%
	EF: 8.1-14.3	EF : 3.9	100%
	BB : 5.6-14.3	BB : 4.8	75%
	SM : 10.1-14.3	SM : 3.6	100%
Cadmium [4]	0.85 exp (0.7852 [ln (ppm hardness)] - 2.715)		
(µg/l)	Standard Range (µg/l):		
	NM: 5.6	NM : < 0.4	100%
	OC: 3.6-5.6	OC : 0.7	100%
	LC: 5.1-5.6	LC : < 0.4	100%
	HB: 4.6-5.6	HB : < 0.4	100%
	5A: 4.9-5.6	5A : < 0.4	100%
	EF: 3.7-5.6	EF : < 0.4	100%
	BB : 2.8-5.6	BB : 1.0	100%
	SM : 4.3-5.6	SM : < 0.4	100%
Zinc [4]	exp (0.85 [ln (ppm hardness)] + 0.50)		
(µg/l)	Standard Range (µg/l):		
	NM: 240	NM : 12.5	100%
	OC: 148-240	OC : 10.4	100%
	LC: 216-240	LC : 18.4	100%
	HB: 192-240	HB : 14.5	100%
	5A: 219-240	5A : 20.8	100%
	EF: 151-240	EF : 34.3	100%
	BB : 113-240	BB : 22.0	100%
	SM : 180-240	SM : 11.0	100%

*Note: Limit of detection 0.02 µg/l, which is not adequate to measure compliance if samples are less than limit of detection (LOD). Table summarizes percent of samples with detectable concentrations (thus exceeding standard).

TABLE 2-13 (cont.)

Regulatory Compliance in Onondaga Lake Tributaries, 2003

All 2003 data are reported for each tributary. Samples were obtained at several sites on certain streams.

NM=Ninemile Creek @ Lakeland Rt48, OC=Onondaga Creek @ Kirkpatrick St and Dorwin Ave; LC=Ley Creek @ Park St.; HB=Harbor Brook @ Velasko Rd and Hiawatha Blvd; 5A=Trib 5A; EF=East Flume; BB = Bloody Brk @ Onondaga Lake Parkway ; SM = Sawmill Crk @ Onondaga Lake Rec. Trail

Parameter (units)	**NYSDEC Standard (Class C)**[1]	**Average of 2003 measured concentrations**	**Measurements in Compliance**
Chromium [4]	0.86 exp (0.819 [ln (ppm hardness)] + 1.561)		
(µg/l)	Standard Range (µg/l):		
	NM: 497	NM : 1.2	100%
	OC: 311-497	OC : 0.9	100%
	LC: 450-497	LC : 1.8	100%
	HB: 400-497	HB : 1.2	100%
	5A: 435-497	5A : 35.5	100%
	EF: 319-497	EF : 2.1	100%
	BB : 240-497	BB : 1.2	100%
	SM : 377-497	SM : 0.5	100%
Iron	300 µg/l (current) ; 1000 µg/l (proposed)	NM : 610	12% ; 88%
(µg/l)		OC : 652	31% ; 89%
		LC : 840	0% ; 78%
		HB : 576	75% ; 91%
		5A : 1133	4% ; 81%
		EF : 304	78% ; 93%
		BB : 583	25% ; 75%
		SM : 539	50% ; 100%
Nickel [4]	0.997 exp (0.846 [ln (ppm hardness)] + 0.0584)		
(µg/l)	Standard Range (µg/l):		
	NM: 150	NM : 2.8	100%
	OC: 93-150	OC : 2.7	100%
	LC: 135-150	LC : 6.5	100%
	HB: 120-150	HB : 2.8	100%
	5A: 131-150	5A : 70.7	100%
	EF: 95-150	EF : 3.0	100%
	BB : 71-150	BB : 3.3	100%
	SM : 113-150	SM : < 2.5	100%

(1) Standard values are derived from NYSDEC Ambient Water Quality Standards and Guidance Values, 1993, for Class B and C surface waters and 6NYCRR Part 703, with Jan. 1994 updates for bacteria and zinc; and 1998 updates for metals.

(2) The bacteria data presented compare individual measurements to the standard of 200 cells/100mL. Compliance is assessed as the geometric mean of a minimum of 5 samples a month. Therefore, the table represents the worst case. Compliance would always be greater than or equal to percentages noted.

(3) Standard value applies to dissolved fraction, though currently only acid soluble, total recoverable fraction is measured within the monitoring program. Standard values for all other metals apply to acid soluble, total recoverable fraction.

(4) Averages derived from observations made during quarterly sampling. All other averages derived from observations made during the bi-weekly sampling program supplemented with high flow and storm samples. Calculations use the laboratory limit of detection when observations are below that limit .

Compliance calculations are made using a maximum hardness value of 350 ppm, which is the maximum value allowed by NYSDEC for these calculations.

2003 Average Hardness for tributaries (from lab) is as follows (units ppm).
NM-708
OC-352
LC-403
HB-720
5A-378
EF-419
BB-438
SM-498

2.6.2 Metro Effluent

Metro compliance with its SPDES permit limits is summarized in Table 2-14. During 2003 there were a total of 38 permit exceedences; most were related to settleable solids (33 observations).

TABLE 2-14
Metro SPDES Limit Exceedances 2003*

SPDES PERMIT LIMITS	TOTALS
Flow	0
BOD5 (30 Day Average) Concentration	0
BOD5 (30 Day Average) Loading	0
BOD5 (7 Day Average) Concentration	0
BOD5 (7 Day Average) Loading	0
BOD5 (% Removal)	0
Suspended Solids (30 Day Average)	2
Suspended Solids (7 Day Average)	1
Suspended Solids (% Removal)	2
Fecal Coliform (30 Day Average)	0
Fecal Coliform (7 Day Average)	0
pH	0
Settleable Solids	33
Total Phosphorus	0
Cyanide	0
Total residual chlorine	0
Bypass settleable solids	0
Cadmium	0
Lead	0
Zinc	0
CBOD (5 Day)	0
Total	**38**

* Exceedances based on effluent limits.
Outfall 001

2.6.3 Onondaga Lake

Compliance of Onondaga Lake's upper and lower waters with applicable ambient water quality standards is summarized in Table 2-15. The lake is Class B in the northern basin and Class C in the southern basin. Water quality in both classes must be suitable for fish survival and propagation. Class B waters are to be suitable for primary water contact recreation (such as swimming). Class C waters are to be suitable for secondary water contact recreation (such as boating).

Similar to previous years, Onondaga Lake waters were not in full compliance with ambient water quality standards for dissolved oxygen, nitrite-N, and total dissolved solids. Fecal coliform bacteria occasionally exceeded the NYSDEC standard of 200-cells/100 ml at South Deep and at the southern nearshore stations. However, the standard is for a geometric mean value of a minimum of five samples collected over a 30-day period. The NYSDEC narrative guidance value for phosphorus (20 µg/l at 1 m depth, mid-lake sample, biweekly average from June 1 – Sept. 30) was not met, nor was the NYSDEC narrative standard for phosphorus. In addition, the Department of Health's swimming safety guidance value requiring a minimum of 1.2-meter (4 ft) visibility was not consistently met during the recreational period.

TABLE 2-15

Regulatory Compliance in Onondaga Lake Waters, 2003

Parameter (units)	**NYSDEC Standard (Class B,C)**[1]		**2003 Average**	**2003 Measurements in Compliance**
pH	Shall not be less than 6.5	UML:	7.7	97%
(standard units)	nor more than 8.5	LWL:	7.4	100%
Dissolved Oxygen	Minimum daily average	UML:	8.8	85%>4; 83%>5
(mg/l)	5.0 mg/l, at no time shall DO	LWL:	4.4	49%>4; 47%>5
	be less than 4.0 mg/l			
Dissolved Solids	Shall be kept as low as practicable	UML:	1178	0%
(mg/l)	to maintain the best usage of waters	LWL:	1177	0%
	but in no case shall it exceed			
	500 mg/l.			
Fecal Coliform [2]	Percent individual observations < 200 cells.	0 m:	81.8	93%
(cells/100 ml)		*Nearshore (nine stations):*	83.0	96%
Ammonia-N	Varies with pH and temperature.	0 m	0.64	96%
(mg/l)		3 m	0.71	96%
		6 m	0.79	100%
		9 m	1.06	100%
		12 m	1.49	80%
		15 m	1.99	56%
		18 m	2.39	48%
Arsenic [3,4]	190 µg/l	UML:	<2.0	100%
(µg/l)		LWL:	<2.0	100%
Nitrite-N	100 µg/l (Warm water fishery)	UML:	102	55%
(µg/l)		LWL:	113	50%
Copper [4,5]	0.96 exp (0.8545 [ln (ppm hardness)] - 1.702)	UML:	1.31	100%
(µg/l)	Standard: 26.1 µg/l	LWL:	1.38	100%
Lead [4,5]	{1.46203 -[(ln hardness) 0.145712)]}	UML:	3.3	100%
(µg/l)	exp (1.273 [ln hardness)] - 4.297	LWL:	3.5	100%
	Standard: 14.34 µg/l			
Cadmium [4,5]	0.85 exp (0.7852 [ln (ppm hardness)] - 2.715)	UML:	< 0.4	100%
(µg/l)	Standard: 5.60 µg/l	LWL:	< 0.4	100%
Zinc [4,5]	exp (0.85 [ln (ppm hardness)] + 0.50)	UML:	8.4	100%
(µg/l)	Standard: 240 µg/l	LWL:	7.9	100%
Chromium [4,5]	0.86 exp (0.819 [ln (ppm hardness)] + 0.6848)	UML:	0.53	100%
(µg/l)	Standard: 497 µg/l	LWL:	0.55	100%
Iron	300 µg/l (current) ; 1000 mg/l (proposed)	UML:	61	100% ; 100%
(µg/l)		LWL:	60	100% ; 100%

TABLE 2-15 *(cont.)*

Regulatory Compliance in Onondaga Lake Waters, 2003

Parameter (units)	**NYSDEC Standard (Class B,C)**[1]		**2003 Average**	**2003 Measurements in Compliance**
Nickel [4,5] (μg/l)	0.997 exp (0.846 [ln (ppm hardness)] + 0.0584) Standard: 248 μg/l	UML:	3.8	100%
		LWL:	3.0	100%
Total Phosphorus (μg/l)	None in amounts that will result in growths of algae, weeds, and slimes that will impair the waters for their best usages. Guidance value of 20 ug/l *UML summer (June - Sept.) average.*	UML:	73.7	0%
Secchi Disk Transparency (m)	NYSDOH guidance for bathing beaches 1.2 m June - Aug.	UML:	1.2	48%

UML = upper mixed layer; LWL = lower water layer (field determined)

(1) Standard values are derived NYSDEC Ambient Water Quality Standards and Guidance Values, 1993, and 6NYCRR Part 703, with January 1994 updates for bacteria and zinc, and 1998 updates for metals.

(2) Bacteria compliance reported by comparing individual measurements to the standard of 200 cells/100 ml. Since the standard is a geometric mean of at least 5 samples, compliance will always be equal or greater than the percent listed.

(3) Standard value applies to dissolved fraction, though currently only acid soluble total recoverable fraction is measured within the monitoring program. Standard values for all other metals apply to acid soluble total recoverable fraction.

(4)Averages derived from observations made during quarterly sampling. All other averages derived from observations made during the bi-weekly sampling program from January 7 to November 25, 2003. Calculations use the laboratory limit of detection when observations are below that limit.

(5) Compliance calculations were made using a hardness value of 350 ppm, which is the maximum value allowed by NYSDEC for these calculations. Average hardness for Onondaga Lake South Basin waters was 417 ppm in 2003.

2.6.4 Seneca River

Violations of ambient water quality standards for dissolved oxygen and nitrite were detected at several locations and dates during the 2003 program. The instantaneous dissolved oxygen standard (4 mg/L) was not met at station LO1 (the lake outlet) during the August event and Buoys 269 and 260 during the September event. Dissolved oxygen concentrations below the daily average standard (5 mg/L) were measured at the above locations and times, as well as at Buoys 334, 294, 269, 260, 255, and Stations LO2 and LO3 during the July event; Buoy 294 during the August event; and Buoys 269 and 260 during the September event. Nitrite concentrations equaled or exceeded the regulatory limit (0.1 mg/L) at Station LO1 during all three sampling events. A map displaying the sampling locations is included in Appendix 1 (refer to Figure A1-1).

2.7 TRENDS IN WATER QUALITY

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 tracking changes in water quality and relating these changes to the ACJ 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 over a ten-year period. With a longer period, results would be strongly influenced by historical data that are not representative of current conditions with respect to municipal and industrial wastewater inputs. With a shorter period, results would be increasingly influenced by short-term variations in hydrology and other random factors. Trends are analyzed using the seasonal Kendall test accounting for serial correlation. Detailed results of the trend analysis for the period 1994 – 2003 using software prepared by Dr. William Walker are included as Appendix 4.

Table 2-16. Ten Year Trends in Concentration (1994-2003) - Summary

Symbol	= Description
I	= increasing trend ($p2 < 0.1$)
D	= decreasing trend ($p2 < 0.1$)
blank	= no trend indicated ($p2 >= 0.1$)
p2	= significance level, two-tailed, seasonal kendall test accounting for serial correlation.

VARIABLE	SOUTH_U	SOUTH_L	NORTH_U	NORTH_L	OUTLET12	OUTLET2	METRO	BYPASS	DORWIN	SPENCER	KIRKPAT	VELASKO	HIAWATHA	PARK	RT48	TRIB5A	EFLUME
ALK	D	D	D							D		D			D	I	
BOD5							D	D		I		I					D
CA	D	D	D	D	D							D			D		D
CHLA	I																
CL				D			I						I		D	I	
COND	D	D	D	D			I							I	D	I	
DO_F	I		I		I	I				I	I	I	I	I	I	D	I
FCOLI		I				D						D		D	D		D
FE	D	D	D		D	D					D	D	D	D	D		
MG						I						D			D	I	D
MN	D														D		D
NA							I			D	D	I	I	I	D		
NH3N	D	D	D	D	D	D	D	D	D			D	D				D
NO2N					D									D		D	D
NO3N		I					I				I	I				D	
ORGN	D	D	D	D	D	D	D	D	I								D
PH_F	I		I								I	I			I	D	I
SECCHI																	
SIO2					D	D	D		D	D		D	D			I	D
SO4																D	
SRP	D	D	D	D	D	D	D		D			D		D		I	D
TEMP	I											I			I		
TIC																I	D
TKN	D	D	D	D	D	D	D	D		I				D	D		D
TOC	D	D		D			D	D									D
TOC_F	D	D		D			D	D								D	D
TP	D	D	D	D	D	D	D	D				D	I			I	D
TSS			D			I						D				I	I

Trends in concentration of inflows to the lake vary by tributary (Table 2-16). Onondaga Creek at Spencer St exhibited a decreasing trend in concentration of alkalinity, sodium, and silica. At the same time an increasing trend was detected in BOD, dissolved oxygen, and TKN. The upstream site on Onondaga Creek, Dorwin Ave, showed evidence of a decreasing trend in ammonia, silica and SRP. Ninemile Creek continued to show a decreasing trend in dissolved salts (total alkalinity, Ca, Mg, Na, Cl, specific conductance), iron and manganese, TKN, and fecal coliform bacteria. This tributary also showed an increasing trend in pH, temperature and dissolved oxygen. Tributary 5A, which includes treated effluent from Crucible Specialty Metals, showed increasing trends in several water quality parameters including total alkalinity, Cl, specific conductance, and pH. East Flume trends were consistent with improved water quality in this small tributary draining the former Honeywell International industrial site; decreasing concentrations of NH_3-N and nitrite were notable. Decreases in the average concentration of materials from Metro (outfalls 001 and 002) continued to be significant. Improved wastewater treatment has resulted in decreased effluent concentrations of carbonaceous materials (alkalinity, BOD_5, TIC, TOC), reduced nitrogen species (NH_3-N, TKN), phosphorus (TP, SRP), and SiO_2. The increased concentrations of salts (as tracked by sodium, chloride, and specific conductance) in Metro effluent may be related to changes in chemical addition during the treatment process, changes in the volumes of stormwater reaching the plant, or effects of infiltration of saline groundwater to the sewer collection system.

The trend analysis also examines water quality conditions in the lake's upper and lower waters at North and South Deep stations. From 1994 to 2003 the upper waters exhibited decreasing trends in concentration of nutrients (TP, SRP, TKN, NH_3-N), Ca, Mn, Fe, SiO2, total alkalinity, and TOC. Increasing trends were noted in DO, pH, and chlorophyll-*a*. Trends in the lower waters were generally similar. A significant increase in chlorophyll-*a* concentration over the ten-year period, first noted in 2002, is coincident with decreasing nutrient loads and the invasion of zebra mussels. As discussed in Chapter 3, this result appears to be the end result of significant changes in the zooplankton community (induced by fish predation). Recent loss of larger zooplankton has removed efficient grazers of phytoplankton from the aquatic ecosystem, leading to increased algal density.

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2003 AMP REPORT
PART II: DATA INTERPRETATION

CHAPTER 3:
INTEGRATED ANALYSIS OF WATER QUALITY AND ECOSYSTEM RESPONSE

3.1 INTRODUCTION

The assessment of changes in Onondaga Lake in response to the reductions in external loads is a multifaceted problem involving physical, chemical, and biological processes. The plants and animals comprising the food web of Onondaga Lake both influence and are influenced by water quality conditions. With the expansion of the AMP in 1998, the County's annual monitoring program encompasses abiotic (physical and chemical) as well as biotic (biological) monitoring of Onondaga Lake, its tributary streams, and the Seneca River. As outlined in Table 1-1 in Part One of this report, the County program assesses, in addition to a suite of water quality parameters, elements of the lake's food web, including phytoplankton, zooplankton, macrophytes, macroinvertebrates, zebra mussels, and various life stages of fish.

The major findings of the 2003 monitoring program, as presented in Chapter 2, indicate that the external phosphorus load has remained relatively stable since 2000. The lake is progressing towards phosphorus limitation of algal productivity, as evident from decreasing SRP concentrations during the summer and long-term declining trends in organic carbon. Water quality improvements from enhanced nitrification at Metro are evident. Yet, chlorophyll-*a* concentrations and algal blooms increased in 2002 and 2003. In this chapter the trophic interactions affecting the quality of the lake are examined. A close examination of the data indicates that shifting trophic interactions within the lake's food web, put in motion by the sudden increased abundance of the alewife, may be responsible for the increased algal abundance and diminished water clarity. The key to understanding the basis for this statement rests with the species composition and size structure of the zooplankton community. The following sections describe the species composition of the phytoplankton, zooplankton and fish communities and how these communities interact to affect measurable elements of the lake ecosystem.

3.2 ABUNDANCE AND STRUCTURE OF THE PHYTOPLANKTON COMMUNITY

A lake's phytoplankton community, defined in terms of both abundance and composition, is the consequence of a number of processes that act simultaneously. Some processes exert a positive influence on the community while others exert a negative influence. Seasonal changes in community structure and abundance result from changes in illumination, temperature, nutrients, and grazing pressure. Some of the seasonal patterns are predictable, others are not.

Reynolds *et al.* (2002) proposed a method of analyzing changes in the phytoplankton community of a water body over time based on “functional groups”, defined as a community of phytoplankton composed of specific species with similar adaptive features and requirements. Thus, species that are well adapted to certain environments, such as high nutrients or low light, are expected to be more successful in those environments than are other species. This type of analysis offers an innovative way of looking at the natural dynamics of the phytoplankton community in relation to changing environmental variables. A complicating factor is the extent to which conditions in the system of interest are at equilibrium. Onondaga Lake is a dynamic system, with large hydrologic and nutrient inputs and significant wind-induced mixing of the upper layer.

To date, thirty-one (31) functional groups have been classified in various lakes throughout the world, based on specific habitat types, tolerances and sensitivities. Typical representative species for each of these groups are listed in Reynolds *et al.* (2002). However, most of the species identified in Onondaga Lake since 1998 are not yet classified into any of the functional groups presented in the Reynolds *et al.* publication. For this reason, an analysis of the Onondaga Lake phytoplankton community based on assignment to functional groups identified in other lakes is not possible at this time. However, the approach of defining the community based on the dominant species and tracking changes over time appears to offer a useful long-term strategy for analyzing the Onondaga Lake phytoplankton data. Shifts in major taxa occur in response to nutrient reductions and other biologically-induced changes (such as invasions by exotic organisms).

Reynolds *et al.* (2002) have invited other plankton scientists to assist in the identification of functional groups using data from additional systems. Cooperation in this effort could be a very productive endeavor that might assist in the management and forecasting of the Onondaga Lake phytoplankton community, especially as nutrient concentrations decline with reductions in point source loads. The County has an extensive database of detailed phytoplankton data with enumerations and identifications performed by the same expert since 1996 (Dr. Ann St. Amand of PhycoTech Inc.).

3.2.1 Phytoplankton Biomass: Seasonal Patterns and Trends

3.2.1.1 Cell Counts and Biomass Estimates

Total phytoplankton biomass was calculated for each of the sampling events from 1998 to 2003 and plotted in Figure 3-1, together with chlorophyll-*a* concentrations for the corresponding dates. Two findings are notable: (1) chlorophyll-*a* concentrations measured in the photic zone and UML of Onondaga Lake track each other quite closely; (2) phytoplankton biomass shows a fairly good agreement with chlorophyll-*a* concentrations. Occasionally, chlorophyll-*a* concentrations were reported as low at the same time the biomass data indicated that the algal community was at its annual peak. These discrepancies are likely due to sampling problems; some phytoplankton species tend to concentrate at or near the water surface and it is challenging to collect a representative sample.

3.2.1.2 Species Composition

The phytoplankton community of Onondaga Lake is comprised of species distributed among the Divisions Bacillariophyta, Chlorophyta, Chrysophyta, Cryptophyta, Cyanophyta (Cyanobacteria), Euglenophyta, Pyrrhophyta, and Xanthophyta (yellow-green algae, documented only in 2002). A category of "miscellaneous microflagellates" is also used to enumerate the tiny cells for which a taxonomic identification is not practical. Cell counts, measurements, and identifications are performed by PhycoTech, Inc. of St. Joseph MI. Biovolume is converted to biomass by a factor of 10^{-3} (biomass equals biovolume multiplied by 0.001).

Dr. Ann St. Amand of PhycoTech Inc. identified and enumerated the 2003 phytoplankton samples and estimated algal biomass. The two dominant cyanobacteria present in the Onondaga Lake samples in 2003 were *Oscillatoria agardhii* (biomass) and *Aphanizomenon flos-aquae* (abundance). However, none of the 2003 algal blooms were dominated by cyanobacteria. Additional details are provided in Appendix 2.

The most frequently occurring algal species of other taxonomic groups, determined by the highest annual average abundance and/or biomass in 2003 were:

Division	**(Biomass)**	**(Concentration)**
Bacillariophyta	*Navicula spp.*	*Diatoma tenuis*
Chlorophyta	*Spirogyra spp.*	*Nephroselmis spp.*
Chrysophyta	*(Unidentified spp.)*	*Erkenia subaequiciliata*
Cryptophyta	*Cryptomonas erosa*	*Rhodomonas minuta*
Pyrrhophyta	*Gymnodinium sp.1*	*Amphidinium spp.*

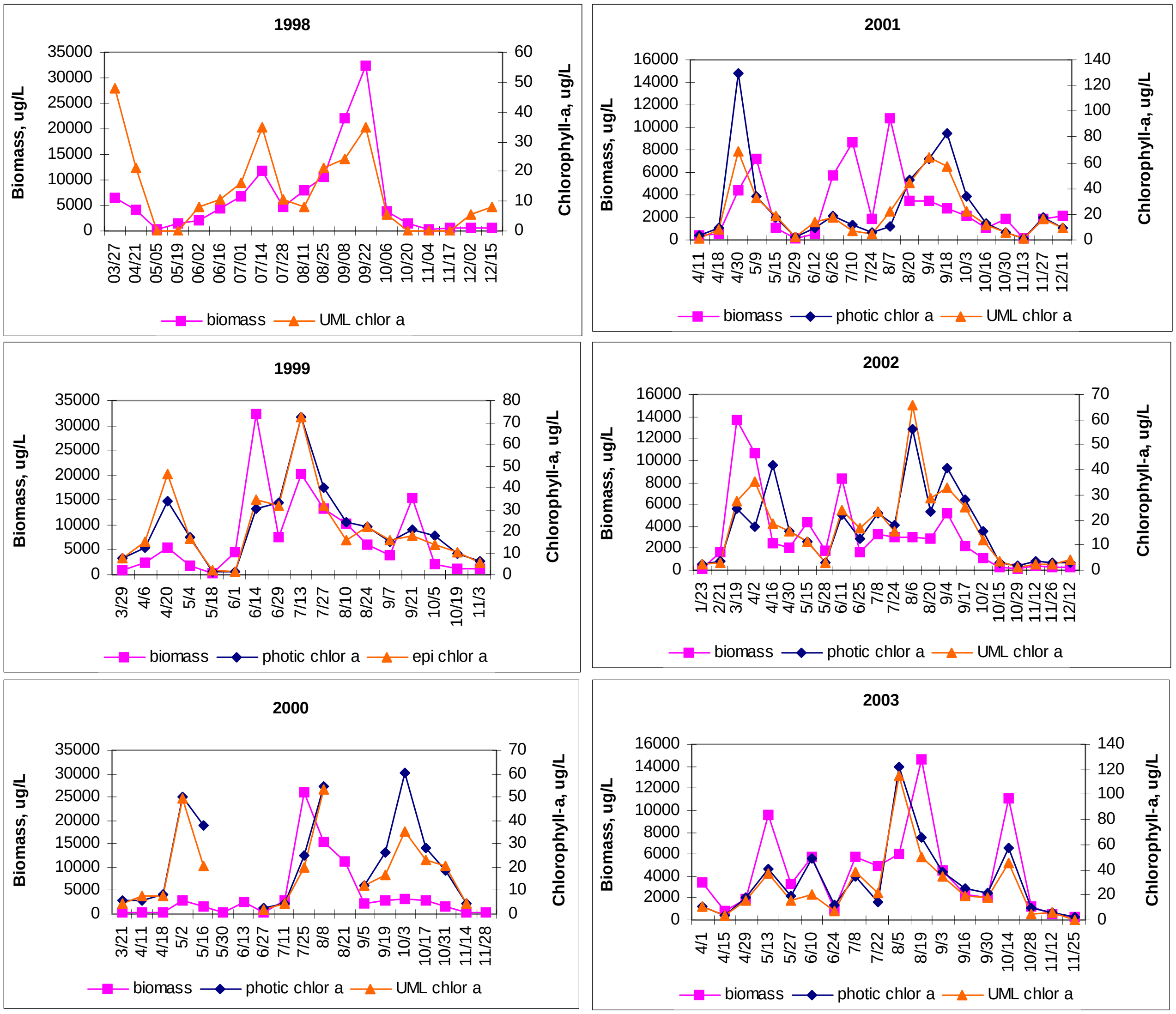

Figure 3-1. Total phytoplankton biomass vs. chlorophyll-*a* concentration in Onondaga Lake, South Deep Station, 1998-2003.

The 2003 season was characterized by three peaks in algal abundance, the first occurring in mid-May (7.44 x 10^6 cells per liter; dominated by bacillariophytes, or diatoms), the second in mid- August (7.37 x 10^6 cells per liter dominated by chlorophytes, or green algae), and the third occurring in mid-October (5.88 x 10^6 cells per liter dominated again by bacillariophytes). The timing of algal blooms in 2003 was essentially the same as recorded in previous years, with only minor differences that may reflect natural variability in weather conditions.

Biomass data from 1998 to 2003 show that peak algal biomass during the 2001-2003 period was approximately 50% of peaks evident during the 1998 – 2000 period (Figure 3-1). This reduction in biomass of algae produced within the lake occurred during a period when external phosphorus loading was relatively constant (Figure 3-2).

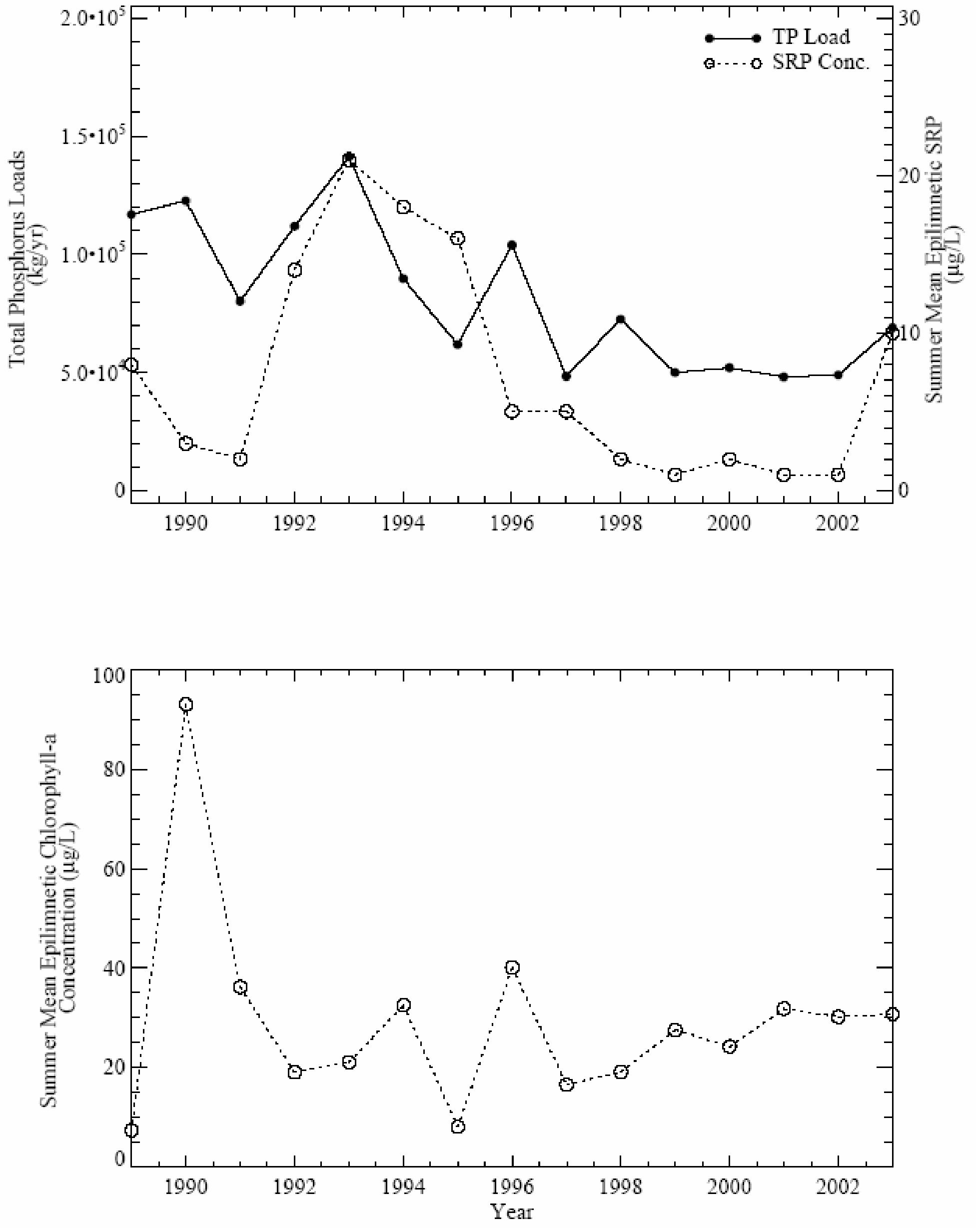

Figure 3-2. Total phosphorus loads, SRP concentrations, and chlorophyll-a concentrations in Onondaga Lake.

Note: Load values have been revised from previous years due to revision in computation method from a flow-wtd-mean conc, 2 flow strata (~AUTOFLUX method 2), to multiple regression vs. flow, season, & date with residual interpolation method (~AUTOFLUX method 5).

Data Sources: Loadings - Table 2-3 rev hist load 2003.xls; Conc. - VA Tables Only_2-25 Revision1.xls + p&n_loads_1986_2002_rev_5.xls

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The relative importance of cyanobacteria (blue-green algae) is of concern to lake managers because these organisms can proliferate and become nuisance algae, degrading water quality and the aesthetic environment. As displayed in Figure 2-26 (in Part 1 of this report), blue-greens represented approximately 15.6% of the annual phytoplankton community (biomass) in 2003 but only 2.6% in numbers (abundance).

Changes in the phytoplankton community over the past six years are evident in Table 3-1. This table shows all phytoplankton species identified in Onondaga Lake from 1998 – 2003. Annual relative abundance of species is indicated by a double "x" for species with over 1,000 unit count in any one sample.

Determining whether species that are no longer present have been replaced by species of the same or different division is difficult. However, Figures 3-3 (entire sampling season) and 3-4 (recreational season) also show changes in major taxonomic groups over the six year period (1998-2003). Pyrrophytes have declined dramatically while bacillariophytes, chlorophytes and cryptophytes have increased. A more significant question might be if the species that are no longer present in Onondaga Lake have been replaced by species in the same functional group, which are not necessarily in the same taxonomic group (Reynolds *et al.* 2002). A shift in functional groups would indicate a change in environmental conditions such as nutrient concentration.

Differences between dominant species in the North vs. South Deep Station, on same dates, are evident in Table 3-2. Although most are relatively small percentage differences, some are quite large, such as 9/21/99, 11/13/01, and 11/12/02. These differences might be due to sampling differences, or actual environmental differences such as nutrient levels or grazing pressure.

TABLE 3-1

Phytoplankton Species Found in Onondaga Lake, 1998 - 2003

Division		FunctGrp	1998	1999	2000	2001	2002	2003
Chlorophyta	Pyramichlamys dissecta		x			xx	xx	xx
Cryptophyte	Cryptomonas erosa	Y	x	xx	xx	xx	x	xx
Cryptophyte	Rhodomonas minuta		x	x	xx	xx	x	xx
Diatom	Cyclotella meneghiniana		x	xx	xx	x	x	xx
Diatom	Diatoma tenuis		x	xx	x	x	x	xx
Chlorophyte	Coelastrum microporum	J	x	x	x	x	x	xx
Chlorophyte	Eudorina elegans	G	x	x	xx	x	x	xx
Chlorophyte	Monoraphidium capricornutum	X1	x	x	x	x	x	xx
Chlorophyta	(unidentified genus species)						x	xx
Diatom	Stephanodiscus medius		x	x	x	x		xx
Cyanophyta	Aphanizomenon issatschenkoi	H1						xx
Chlorophyta	Nannochloris sp							xx
Bacillariophyta	Melosira sp							xx
Bacillariophyta	Stephanodiscus hantzschii	D	x	xx				xx
Chlorophyte	Chlamydomonas platystigma		x	x	xx	xx	xx	x
Cyanophyte	Oscillatoria amphibia		x		xx	x	xx	x
Cyanophyte	Oscillatoria limnetica		x	xx	xx	x	xx	x
Dinoflagellate	Gymnodinium sp. 3		x	x	x	xx	x	x
Diatom	Stephanodiscus parvus			xx	xx	xx	x	x
Cyanophyte	Aphanizomenon flos-aquae	H1	x	xx	x	xx	x	x
Chlorophyte	Chlamydomonas globosa		x	x	xx	xx	x	x
Chlorophyte	Schroederia judayi		xx	xx	x	xx	x	x
Dinoflagellate	Gymnodinium sp. 1			x	x	x	x	x
Dinoflagellate	Gymnodinium sp. 2		x	x	x	x	x	x
Dinoflagellate	Peridinium umbonatum	Lo	x	x	x	x	x	x
Diatom	Achnanthes minutissima		x	x	x	x	x	x
Diatom	Amphora pediculus		x		x	x	x	x
Diatom	Anomoeoneis vitrea			x	x	x	x	x
Diatom	Asterionella formosa	C	x	x	xx	x	x	x
Diatom	Gomphonema parvulum			x	x	x	x	x
Diatom	Navicula sp.		x	x	x	x	x	x
Diatom	Nitzschia acicularis		x	x	x	x	x	x
Diatom	Nitzschia gracilis				x	x	x	x
Diatom	Nitzschia palea		x	x	x	x	x	x
Diatom	Stephanodiscus niagarae		x		x	x	x	x
Diatom	Synedra tenera		x	xx	xx	x	x	x
Cyanophyte	Anabaena augstumalis				x	x	x	x
Cyanophyte	Anabaena flos-aquae	H1	xx	x	xx	x	x	x
Cyanophyte	Aphanocapsa delicatissima	K	x	xx	x	x	x	x
Cyanophyte	Merismopedia tenuissima	Lo	x	x	x	x	x	x
Cyanophyte	Oscillatoria tenuis		xx	x	x	x	x	x
Cyanophyta	Oscillatoria agardhii					x	x	x
Cryptophyte	Cryptomonas rostratiformis	Y	x	x	xx	x	x	x
Cryptophyta	Cryptomonas lucens	Y	x	x		x	x	x
Chrysophyte	Mallomonas sp.	E	x	x	x	x	x	x
Chlorophyte	Ankistrodesmus falcatus		x	x	x	x	x	x
Chlorophyte	Chlamydomonas incerta		x	x	x	x	x	x
Chlorophyte	Closterium moniliferum		x	x	x	x	x	x
Chlorophyte	Closterium sp.		x	x	x	x	x	x
Chlorophyte	Monomastix astigmata		x	x	x	x	x	x
Chlorophyte	Mougeotia sp.	T			x	x	x	x
Chlorophyte	Oocystis lacustris	F	x	x	x	x	x	x
Chlorophyte	Oocystis parva		xx	xx		x	x	x
Chlorophyte	Pandorina morum			x	x	x	x	x
Chlorophyte	Pediastrum boryanum	J	x	x	x	x	x	x
Chlorophyte	Quadrigula lacustris		x	x	x	x	x	x
Chlorophyte	Scenedesmus acutus	J		xx	x	x	x	x
Chlorophyte	Scenedesmus bijuga	J	x	x	x	x	x	x
Chlorophyte	Scenedesmus dimorphus	J	x	x	x	x	x	x

TABLE 3-1 (*continued*)

Phytoplankton Species Found in Onondaga Lake, 1998 - 2003

Division		FunctGrp	1998	1999	2000	2001	2002	2003
Chlorophyta	Deasonia gigantica		x	x		x	x	x
Bacillariophyta	Diatoma vulgaris					x	x	x
Bacillariophyta	Gomphonema olivaceum		x			x	x	x
Pyrrhophyta	Glenodinium quadridens						x	x
Dinoflagellate	Amphidinium sp			x	x		x	x
Dinoflagellate	Peridinium sp.	Lo		x	x		x	x
Diatom	Cyclotella sp. 1		x		xx		x	x
Diatom	Synedra ulna		x	x	x		x	x
Cyanophyta	Cylindrospermopsis raciborskii	Sn	x				x	x
Cyanophyta	Microcystis aeruginosa	Lm					x	x
Cyanophyta	Microcystis wesenbergii	Lm					x	x
Chrysophyte	Erkenia subaequiciliata		x	xx	x		x	x
Chrysophyta	Uroglena sp	U					x	x
Chlorophyte	Actinastrum hantzschii			x	x		x	x
Chlorophyte	Chlamydomonas sp.			x	x		x	x
Chlorophyte	Scenedesmus sp.	J		x	x		x	x
Chlorophyta	Ankistrodesmus convolutus			x			x	x
Chlorophyta	Closterium gracile						x	x
Chlorophyta	Franceia droescheri						x	x
Chlorophyta	Golenkinia radiata	J					x	x
Chlorophyta	Kirchneriella lunaris						x	x
Chlorophyta	Kirchneriella obesa						x	x
Chlorophyta	Pediastrum sp	J					x	x
Chlorophyta	Scenedesmus semipulcher	J		x			x	x
Bacillariophyta	Cocconeis placentula		x				x	x
Bacillariophyta	Entomoneis sp.		x	x			x	x
Bacillariophyta	Fragilaria construens		x				x	x
Bacillariophyta	Navicula capitata						x	x
Cryptophyte	Rhodomonas minuta v. nannoplanctica		x	xx	xx	xx		x
Diatom	Navicula cryptocephala		x	x	x	x		x
Diatom	Synedra delicatissima					x		x
Cyanophyte	Anabaena spiroides				x	x		x
Cyanophyte	Synechococcus elongatus	Z	x	xx		x		x
Cyanophyta	Anabaena aphanizomenoides					x		x
Chlorophyte	Crucigenia tetrapedia			x	x	x		x
Chlorophyte	Scenedesmus quadricauda	J		x	x	x		x
Chlorophyte	Selenastrum minutum		x		x	x		x
Chlorophyte	Sphaerocystis schroeteri		x	x	x	x		x
Chlorophyte	Tetracystis pulchra					x		x
Chlorophyte	Tetraedron minimum			x	x	x		x
Bacillariophyta	Achnanthes exigua					x		x
Miscellaneous	(unidentified genus species)							x
Diatom	Cymbella tumidula				x			x
Cyanophyte	Aphanocapsa elachista	K	x	x	x			x
Cyanophyte	Chroococcus minimus		x	x	x			x
Cyanophyte	Lyngbya sp.				x			x
Cyanophyte	Aphanocapsa incerta	K						x
Cyanophyta	Microcystis flos-aquae	Lm						x
Cyanophyta	Pseudanabaena sp.	S1		x				x
Chrysophyta	(unidentified genus species)							x
Chrysophyta	Chrysolykos planctonicus							x
Chrysophyta	Dinobryon spp.	E						x
Chlorophyte	Coelastrum pseudomicroporum	J			x			x
Chlorophyte	Lobomonas sp.				x			x
Chlorophyte	Pediastrum tetras	J		x	x			x
Chlorophyte	Scenedesmus abundans	J		x	x			x
Chlorophyte	Scenedesmus serratus	J	x		x			x
Chlorophyte	Schroederia setigera			x	x			x
Chlorophyta	Asterococcus limnecticus							x
Chlorophyta	Didymogenes anomala							x

TABLE 3-1 (*continued*)

Phytoplankton Species Found in Onondaga Lake, 1998 - 2003

Division		FunctGrp	1998	1999	2000	2001	2002	2003
Chlorophyta	Gonium sociale	W1						x
Chlorophyta	Lagerheimia ciliata							x
Chlorophyta	Nephroselmis sp.		x	x				x
Chlorophyta	Phacotus sp							x
Chlorophyta	Scenedesmus opoliensis	J						x
Chlorophyta	Scenedesmus parisiensis	J						x
Chlorophyta	Staurastrum cingulum							x
Chlorophyta	Staurastrum hexacerum			x				x
Chlorophyta	Tetraedron muticum							x
Bacillariophyta	Achnanthes lanceolata		x					x
Bacillariophyta	Diploneis puella							x
Bacillariophyta	Fragilaria brevistriata			x				x
Bacillariophyta	Gomphonema sp.		x	x				x
Bacillariophyta	Nitzschia fonticola							x
Bacillariophyta	Nitzschia reversa							x
Bacillariophyta	Nitzschia sp.	D	x					x
Bacillariophyta	Synedra filiformis							x
Diatom	Fragilaria crotonensis	P	x	x	x	xx	x	
Euglenophyte	Euglena sp.		x	x	x	x	x	
Dinoflagellate	Ceratium hirundinella	Lm	x	x	x	x	x	
Diatom	Amphora ovalis					x	x	
Diatom	Aulacoseira sp.		x			x	x	
Diatom	Cymbella microcephala		x	x		x	x	
Diatom	Cymbella sp.					x	x	
Diatom	Navicula pelliculosa					x	x	
Diatom	Navicula viridula		x	x	x	x	x	
Diatom	Nitzschia inconspicua			x		x	x	
Cyanophyte	Anabaena macrospora		x			x	x	
Cyanophyte	Aphanothece nidulans	K	x	x		x	x	
Cryptophyte	Cryptomonas gracilis	Y				x	x	
Chlorophyte	Characium limnetcum		x	x		x	x	
Chlorophyte	Cosmarium sp.	N	x	x		x	x	
Chlorophyte	Dictyosphaerium pulchellum			x	x	x	x	
Chlorophyte	Lagerheimia quadriseta			xx		x	x	
Chlorophyte	Micractinium pusillum			x		x	x	
Chlorophyte	Pyramichlamys sp.			x	x	x	x	
Chlorophyta	Spermatozopsis exsultans					x	x	
Chlorophyta	Spirogyra sp.					x	x	
Bacillariophyta	Rhoicosphenia curvata			x		x	x	
Bacillariophyta	Synedra nana					x	x	
Xantophyte	Pleurogaster lunaris						x	
Diatom	Cyclotella pseudostelligera			x			x	
Diatom	Stephanodiscus hantzschii 8-11um	D		x			x	
Diatom	Stephanodiscus minutulus						x	
Diatom	Stephanodiscus niagarae (Job 60)			x	x		x	
Diatom	Surirella minuta						x	
Diatom	Synedra arcus v. arcus						x	
Diatom	Thalassiosira sp.						x	
Cyanophyte	Dactylococcopsis irregularis			x			x	
Cyanophyte	Anabaena crassa						x	
Cyanophyte	Anabaena sp						x	
Cryptophyte	Cryptomonas ovata	Y	x	x	x		x	
Chrysophyte	Dinobryon cylindricum	E					x	
Chrysophyte	Dinobryon divergens	E					x	
Chlorophyte	Coelastrum astroideum	J		x	x		x	
Chlorophyte	Oocystis borgei			x			x	
Chlorophyte	Oocystis pusilla		x	x			x	
Chlorophyte	Scenedesmus acuminatus	J					x	
Chlorophyte	Scenedesmus intermedius	J		x			x	
Chlorophyte	Scenedesmus quadricauda v. quadrispina	J			x		x	

TABLE 3-1 (*continued*)

Phytoplankton Species Found in Onondaga Lake, 1998 - 2003

Division		**FunctGrp**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Chlorophyte	Scenedesmus sp. 2	J		xx			x	
Chlorophyte	Treubaria setigerum						x	
Chlorophyte	Carteria globulosa						x	
Chlorophyte	Chloromonas pumilio						x	
Chlorophyta	Scenedesmus producto-capitatus	J					x	
Chlorophyta	Selenastrum sp						x	
Chlorophyta	Tetraedron caudatum						x	
Bacillariophyte	Entomoneis cf ornata						x	
Bacillariophyte	Gomphonema minutum						x	
Bacillariophyte	Navicula cryptotenelloides						x	
Bacillariophyte	Navicula erifuga						x	
Bacillariophyte	Navicula radiosafallax						x	
Bacillariophyte	Nitzschia linearis						x	
Miscellaneous	Misc. microflagellate		xx	xx	xx	xx		
Chlorophyte	Non-motile Chlorococcales-spherical		x	x	xx	xx		
Miscellaneous	Gonyostomum ovatum	Q		x		x		
Euglenophyte	Euglena gracilis			x		x		
Dinoflagellate	Ceratium sp.	Lm				x		
Dinoflagellate	Peridinium cinctum	Lo		x	x	x		
Diatom	Achnanthes lanceolata ssp. biporoma					x		
Diatom	Actinocyclus normanii					x		
Diatom	Amphora veneta			x		x		
Diatom	Caloneis westii					x		
Diatom	Cocconeis pediculus					x		
Diatom	Cocconeis placentula v. lineata			x	x	x		
Diatom	Cyclotella comensis	A				x		
Diatom	Cyclotella sp.					x		
Diatom	Cymbella affinis					x		
Diatom	Cymbella cistula					x		
Diatom	Cymbella silesiaca					x		
Diatom	Diatoma vulgaris morph. distorta					x		
Diatom	Diatoma vulgaris morph. vulgaris					x		
Diatom	Fragilaria capucina		x	x	x	x		
Diatom	Fragilaria capucina v. vaucheriae				x	x		
Diatom	Fragilaria construens f. venter				x	x		
Diatom	Gomphonema pumilum					x		
Diatom	Meridion circulare		x	x		x		
Diatom	Navicula capitata v. capitata					x		
Diatom	Navicula cf. lacunolaciniata					x		
Diatom	Navicula gregaria			x		x		
Diatom	Navicula halophila					x		
Diatom	Navicula tenelloides					x		
Diatom	Navicula tripunctata					x		
Diatom	Nitzschia constricta					x		
Diatom	Nitzschia intermedia					x		
Diatom	Nitzschia perminuta					x		
Diatom	Nitzschia sociabilis					x		
Diatom	Stauroneis smithii					x		
Diatom	Synedra ulna v. acus					x		
Diatom	Synedra ulna v. ulna					x		
Cyanophyte	Anabaena oscillarioides					x		
Cyanophyte	Anabaena planctonica					x		
Cyanophyte	Merismopedia minima	Lo		x		x		
Cyanophyte	Microcystis aeruginosa-colony form	Lm	x	xx	x	x		
Cyanophyte	Microcystis sp. (single)	Lm				x		
Cyanophyte	Non-motile blue-greens (>1 UM)			xx		x		
Cyanophyte	Pseudanabaena galeata				x	x		
Cyanophyte	Surirella brebissonii					x		
Chrysophyte	Cyst (Chrysophyte)			xx		x		
Chrysophyte	Dinobryon cylindricum (single)	E				x		

TABLE 3-1 (*continued*)

Phytoplankton Species Found in Onondaga Lake, 1998 - 2003

Division		FunctGrp	1998	1999	2000	2001	2002	2003
Chrysophyte	Dinobryon divergens (colonial)	E			x	x		
Chrysophyte	Dinobryon divergens (single)	E	x		x	x		
Chrysophyte	Dinobryon monads	E			x	x		
Chrysophyte	Dinobryon sertularia (colonial)	E		x		x		
Chrysophyte	Dinobryon sertularia (single)	E	x			x		
Chrysophyte	Erkenia sp.					x		
Chrysophyte	Kephyrion gracilis					x		
Chrysophyte	Mallomonas caudata	E				x		
Chrysophyte	Synura sp. (single)	E, W1		x		x		
Chrysophyte	Synura uvella/sphagnicola	E, W1				x		
Chrysophyte	Uroglena sp. (single)	U		x	x	x		
Chlorophyte	Botryococcus braunii	F				x		
Chlorophyte	Closterium gracile v. tenue		x	x	x	x		
Chlorophyte	Coelastrum cambricum	J				x		
Chlorophyte	Coelastrum sp.	J		x	x	x		
Chlorophyte	Cyst (Chlorophyte)		x	x	x	x		
Chlorophyte	Elakatothrix gelatinosa		x			x		
Chlorophyte	Lobomonas cf. verrucosa					x		
Chlorophyte	Monomastix sp.				x	x		
Chlorophyte	Monoraphidium sp.	X1				x		
Chlorophyte	Nephroselmis olivacea					x		
Chlorophyte	Non-motile Chlorococcales (spherical, >10UM)					x		
Chlorophyte	Oedogonium sp.					x		
Chlorophyte	Pediastrum duplex	J	x	x	x	x		
Chlorophyte	Pyramimonas sp.					x		
Chlorophyte	Quadrigula chodatti					x		
Chlorophyte	Scenedesmus quadricauda v. longispina	J		x	x	x		
Chlorophyte	Sphaerellopsis sp.					x		
Chlorophyte	Ulothrix sp.		x		x	x		
Chlorophyte	Zygnema sp.					x		
Chlorophyte	Pediastrum simplex	J				x		
Chlorophyta	Staurastrum paradoxum			x		x		
Chlorophyta	Tetrastrum staurogeniaeforme		x	x		x		
Diatom	Achnanthes sp.		x	x	x			
Cyanophyte	Aphanocapsa koordersi	K	x	x	x			
Chrysophyte	Ochromonas sp.		x	x	x			
Chlorophyte	Chlamydomonas gracilis		x	x	x			
Chlorophyte	Gloeocystis gigas		x	x	x			
Cyanophyte	Aphanizomenon gracile	H1		x	x			
Chlorophyte	Cystomonas starrii			x	x			
Chlorophyte	Gloeocystis ampla			x	x			
Chlorophyte	Gloeocystis sp.			x	x			
Chlorophyte	Kirchneriella subsolitaria			x	x			
Chlorophyte	Stichococcus bacillaris			x	x			
Dinoflagellate	Gymnodinium sp.		x		x			
Diatom	Cyclotella cf ocellata		x		x			
Diatom	Fragilaria pinnata		x		x			
Diatom	Neidium sp.		x		x			
Chlorophyte	Coelastrum proboscideum	J	x		x			
Chlorophyte	Colonial chlorophyta - type 2		x		x			
Diatom	Cocconeis placentula v. pseudolineata				x			
Diatom	Cyclotella ocellata				x			
Diatom	Nitzschia sp. 1 (Job 55)				x			
Diatom	Staurastrum sp.				x			
Diatom	Stephanodiscus hantzschii 22um	D			x			
Diatom	Stauroneis sp.				x			
Cyanophyte	Cylindrospermopsis philippinensis	Sn			x			
Cyanophyte	Lyngbya circumcreta				x			
Cyanophyte	Oscillatoria chlorina				x			

TABLE 3-1 (*continued*)

Phytoplankton Species Found in Onondaga Lake, 1998 - 2003

Division		FunctGrp	1998	1999	2000	2001	2002	2003
Cyanophyta	Synechocystis sp				x			
Chrysophyte	Chlorocloster sp.				x			
Chlorophyte	Chlorogonium sp.				x			
Chlorophyte	Protoderma viride				x			
Chlorophyte	Westella linearis				x			
Diatom	Cyclotella radiosa		x	xx				
Cyanophyte	Coelosphaerium naegelianum-single cells		x	xx				
Diatom	Cyclotella atomus			xx				
Cyanophyte	Microcystis aeruginosa-single cells	Lm		xx				
Cyanophyte	Oscillatoria lemmermanni			xx				
Dinoflagellate	Dinoflagellate cyst		x	x				
Cyanophyte	Anabaenopsis circularis		x	x				
Cyanophyte	Coelosphaerium naegelianum-colony form		x	x				
Chlorophyte	Chlamydomonas pumilio		x	x				
Chlorophyte	Closterium acutum v. linea		x	x				
Xantophyte	Tribonema sp	T		x				
Euglenophyte	Euglena acus			x				
Dinoflagellate	Peridinium polonicum	Lo		x				
Diatom	Aulacoseira granulata	P		x				
Diatom	Bacillaria paradoxa			x				
Diatom	Melosira granulata			x				
Diatom	Nitzschia pumila			x				
Diatom	Nitzschia sigmoidea			x				
Cyanophyte	Lyngbya contorta			x				
Cyanophyte	Oscillatoria lacustris			x				
Cyanophyta	Chrysococcus minutus	X3		x				
Chrysophyte	Desmarella sp.			x				
Chlorophyte	Asterococcus sp.			x				
Chlorophyte	Carteria platyrhyncha			x				
Chlorophyte	Chlorella vulgaris			x				
Chlorophyte	Chlorococcales autospore			x				
Chlorophyte	Closterium acutum v. variabile			x				
Chlorophyte	Closterium lineatum			x				
Chlorophyte	Coelastrum reticulatum	J		x				
Chlorophyte	Coelastrum reticulatum v. duplex	J		x				
Chlorophyte	Crucigenia rectangularis			x				
Chlorophyte	Elakatothrix viridis			x				
Chlorophyte	Lagerheimia subsalsa			x				
Chlorophyte	Stigeoclonium sp.			x				
Chlorophyte	Treubaria schmidlei			x				
Cyanophyte	Non-motile blue-greens (>2 UM)		xx					
Miscellaneous	Cysts, Statospores, Zygotes		x					
Dinoflagellate	Ceratium cyst	Lm	x					
Diatom	Aulacoseira italica		x					
Diatom	Cymbella sinuata		x					
Diatom	Fragilaria sp.		x					
Diatom	Gyrosigma sp.		x					
Diatom	Navicula agrestis		x					
Diatom	Navicula salinarum		x					
Diatom	Pleurosigma sp.		x					
Cyanophyte	Anabaena circinalis		x					
Cyanophyte	Chroococcus limneticus		x					
Cyanophyte	Lyngbya subtilis		x					
Chrysophyte	Polygoniochloris circularis		x					
Chrysophyte	Synura sp	E, W1	x					
Chlorophyte	Chloromonas sp.		x					
Chlorophyte	Oocystis solitaria		x					
Chlorophyte	Palmella sp.		x					
Chlorophyte	Pediastrum duplex v. clathratum	J	x					
Chlorophyte	Scenedesmus smithii	J	x					
Bacillariophyte	Surirella visurgis		x					

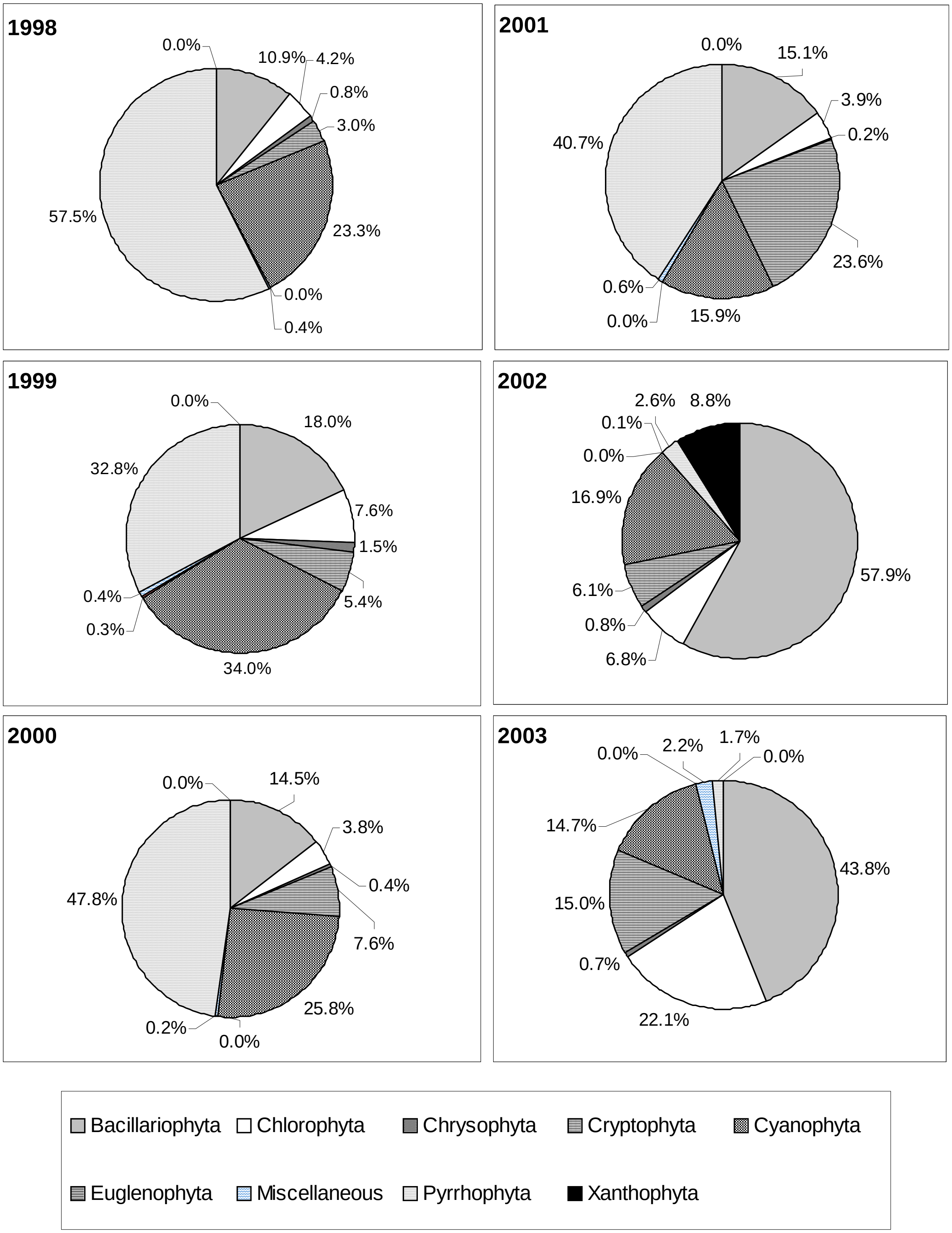


Figure 3-3. Phytoplankton community structure for entire sampling season in Onondaga Lake, South Deep Station, 1998 - 2003. Charts show biomass for major taxa groups.

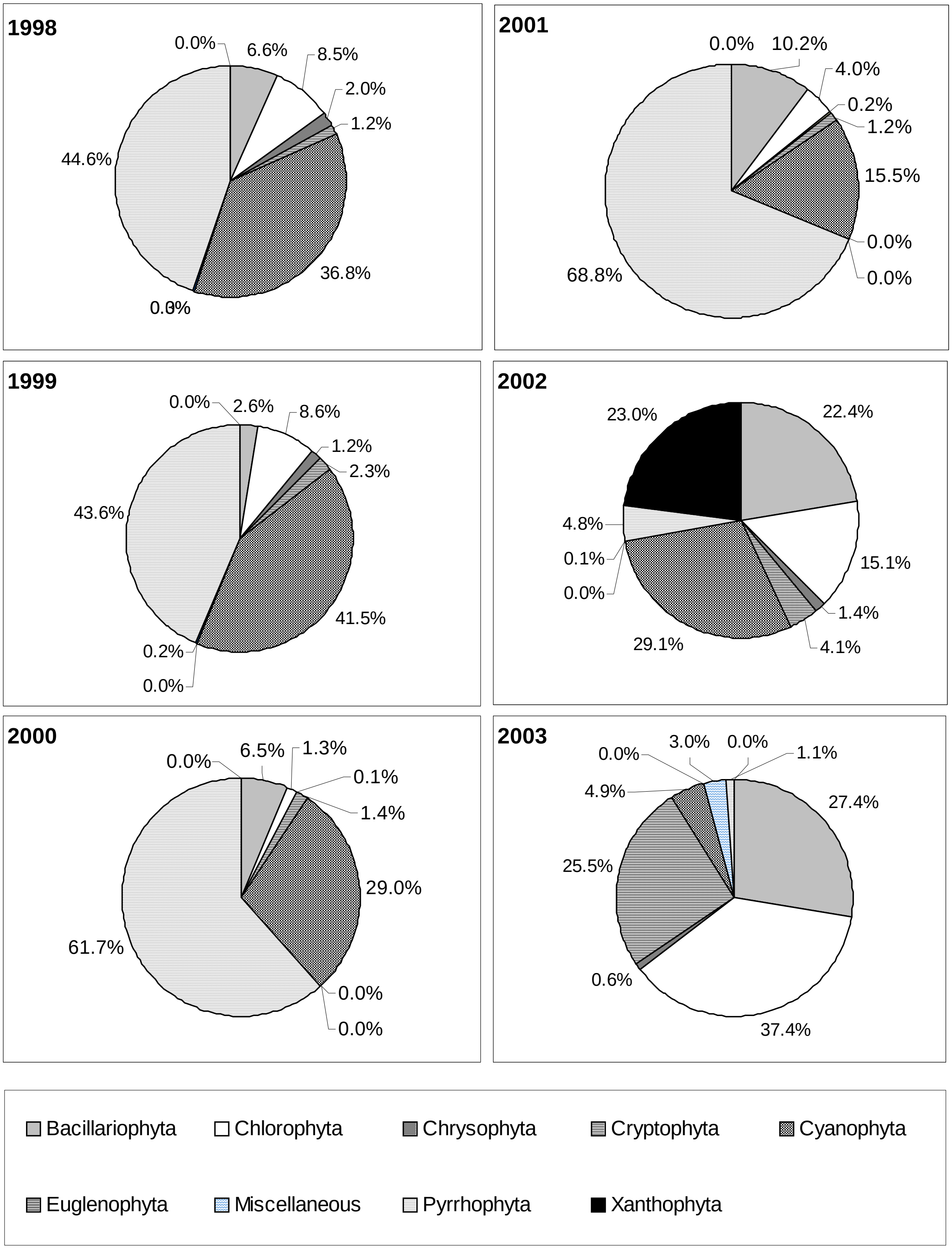


Figure 3-4. Phytoplankton community structure from June to August in Onondaga Lake, South Deep Station, 1998 - 2003. Charts show biomass for major taxa groups.

TABLE 3-2

Dominant Phytoplankton Species - Paired Samples, North and South Deep Stations
Onondaga Lake, 1998 - 2003

	North Station		**South Station**	
1998	1-Jul		1-Jul	
	Ceratium hirundinella	56%	Ceratium hirundinella	44%
	Oocystis parva	29%	Oocystis parva	21%
	Aphanizomenon flos? aquae	4%	Fragilaria crotonensis	12%
	22-Sep		22-Sep	
	Ceratium hirundinella	79%	Ceratium hirundinella	87%
	Ceratium cyst	12%	Oscillatoria tenuis	10%
	Oscillatoria tenuis	7%	Aphanizomenon flos? aquae	3%
	17-Nov		17-Nov	
	Cryptomonas rostratiformis	59%	Cryptomonas rostratiformis	68%
	Cryptomonas erosa	11%	Closterium sp.	12%
	Closterium sp.	11%	Cryptomonas erosa	7%
1999	6-Apr		6-Apr	
	Stephanodiscus niagarae	57%	Stephanodiscus hantzschii	37%
	Stephanodiscus hantzschii	17%	Cryptomonas rostratiformi	17%
	Entomoneis sp.	7%	Euglena acus	13%
	13-Jul		13-Jul	
	Ceratium hirundinella	75%	Ceratium hirundinella	64%
	Rhodomonas minuta v. nann	12%	Microcystis aeruginosa-co	8%
	Oocystis parva	3%	Aphanizomenon flos-aquae	8%
	21-Sep		21-Sep	
	Oscillatoria limnetica	36%	Cyclotella radiosa	86%
	Cryptomonas erosa	18%	Oscillatoria limnetica	4%
	Cryptomonas rostratiformi	12%	Chrysococcus minutus	3%
2000	11-Apr		11-Apr	
	Rhodomonas minuta v. nannoplanctica	13%	Gymnodinium sp. 2	30%
	Gymnodinium sp. 2	12%	Rhodomonas minuta v. nannoplanctica	16%
	Rhodomonas minuta	11%	Rhodomonas minuta	14%
	27-Jun		27-Jun	
	Cystomonas starrii	45%	Fragilaria crotonensis	21%
	Ceratium hirundinella	21%	Ulothrix sp.	21%
	Fragilaria crotonensis	10%	Oocystis lacustris	13%
	19-Sep		19-Sep	
	Aphanizomenon flos-aquae	26%	Ceratium hirundinella	22%
	Cryptomonas rostratiformis	14%	Synedra tenera	17%
	Synedra tenera	13%	Aphanizomenon flos-aquae	16%
	14-Nov		14-Nov	
	Cyclotella meneghiniana	18%	Fragilaria crotonensis	20%
	Fragilaria crotonensis	9%	Asterionella formosa	19%
	Mougeotia sp.	8%	Mougeotia sp.	11%

TABLE 3-2 (cont.)

Dominant Phytoplankton Species - Paired Samples, North and South Deep Stations
Onondaga Lake, 1998 - 2003

2001	18-Apr		18-Apr	
	Synedra ulna v. ulna	16%	Cryptomonas erosa	21%
	Stephanodiscus medius	16%	Rhodomonas minuta v. nannoplanctica	16%
	Navicula viridula	12%	Rhodomonas minuta	13%
	9-May		9-May	
	Rhodomonas minuta v. nannoplanctica	38%	Cryptomonas rostratiformis	54%
	Cryptomonas rostratiformis	36%	Rhodomonas minuta v. nannoplanctica	22%
	Rhodomonas minuta	8%	Rhodomonas minuta	7%
	26-Jun		26-Jun	
	Ceratium hirundinella	47%	Ceratium sp.	42%
	Fragilaria crotonensis	31%	Fragilaria crotonensis	26%
	Aphanizomenon flos-aquae	15%	Aphanizomenon flos-aquae	21%
	18-Sep		18-Sep	
	Aphanizomenon flos-aquae	33%	Aphanizomenon flos-aquae	55%
	Spirogyra sp.	31%	Oscillatoria agardhii	11%
	Oscillatoria agardhii	10%	Pyramichlamys dissecta	11%
	13-Nov		13-Nov	
	Spirogyra sp.	97%	Fragilaria crotonensis	26%
	Cyclotella meneghiniana	1%	Cryptomonas rostratiformis	19%
	Zygnema sp.	1%	Cryptomonas erosa	11%
2002	2-Apr		2-Apr	
	Stephanodiscus niagarae	96%	Stephanodiscus niagarae	95%
	Fragilaria crotonensis	1%	Fragilaria crotonensis	2%
	Cryptomonas rostratiformis	1%	Cryptomonas rostratiformis	1%
	25-Jun		25-Jun	
	Aphanizomenon flos-aquae	52%	Pandorina morum	30%
	Fragilaria crotonensis	22%	Aphanizomenon flos-aquae	29%
	Tribonema spp.	9%	Fragilaria crotonensis	21%
	17-Sep		17-Sep	
	Cyclotella meneghiniana	36%	Stephanodiscus parvus	18%
	Synedra tenera	16%	Synedra tenera	13%
	Stephanodiscus parvus	16%	Oscillatoria limnetica	13%
	12-Nov		12-Nov	
	Closterium sp.	74%	Rhodomonas minuta v. nannoplanctica	33%
	Stephanodiscus niagarae	7%	Stephanodiscus medius	20%
	Rhodomonas minuta v. nannoplanctica	7%	Rhodomonas minuta	15%
2003	15-Apr		15-Apr	
	Stephanodiscus hantzschii	32%	Stephanodiscus hantzschii	49%
	Cryptomonas erosa	20%	Gymnodinium sp. 1	13%
	Gymnodinium sp. 1	10%	Cryptomonas erosa	6%
	24-Jun		24-Jun	
	Cryptomonas erosa	49%	Cryptomonas erosa	76%
	Stephanodiscus medius	13%	Nannochloris spp.	9%
	(Chlorophyta)	11%	Cryptomonas rostratiformis	5%
	16-Sep		16-Sep	
	Aphanizomenon flos-aquae	22%	Aphanizomenon issatschenkoi	40%
	Aphanizomenon issatschenkoi	21%	Mougeotia spp.	15%
	Oscillatoria agardhii	17%	Oscillatoria agardhii	7%
	12-Nov		12-Nov	
	Oscillatoria agardhii	49%	Oscillatoria agardhii	48%
	Cryptomonas rostratiformis	11%	(Chlorophyta)	9%
	Entomoneis spp.	7%	Cryptomonas erosa	6%

3.2.2 Effects of grazing organisms on the phytoplankton community

Phytoplankton will grow as long as environmental conditions such as temperature and light are favorable and nutrients are available. In a balanced food web, maximum possible growth is controlled, to a certain extent, by predation. In the aquatic environment, large-sized zooplankton are the most effective grazers of phytoplankton and exert a major control on the standing crop. Zooplankton also release nutrients back to the water column; these soluble forms of N and P are then available to microbes and phytoplankton. Herbivorous zooplankton excrete widely varying ratios of N and P; these variable release rates are produced when zooplankton (the consumer organisms) retain the element in least supply and discard elements that are in excess (Elser and Urabe 1999). Detailed investigations of the magnitude of phosphorus excretion by the Onondaga Lake zooplankton community and its potential significance on phytoplankton productivity have not been completed.

Since late 2002, large-sized species have disappeared from the Onondaga Lake zooplankton community. The loss of the efficient grazers appears to be a contributing factor to the recent increase in algal biomass and the loss of the springtime clearing event. Data for 2003 show an increase in algal biomass as compared with 2001 and 2002 (refer to Figure 3-1); note the absence in 2003 of the low levels of algal biomass that had been characteristic of May and early June during the 1990s and early 2000s. Peak biomass during the sampling season was higher than in either of the two preceding years but within range of recent observations. Potential reasons for the loss of the larger zooplankton from the community are discussed in detail in later sections; this significant shift in zooplankton appears to be related to the recent (mid 2002 and 2003) proliferation of the alewife.

Average annual biomass for phytoplankton and zooplankton are plotted in Figure 3-5. Note the inverse relationship; phytoplankton biomass is high when zooplankton are low and vice versa. Average phytoplankton biomass showed an increasing trend from 1999 to 2002. Zooplankton biomass showed a decreasing trend over the same period. However, in 2003 zooplankton biomass increased while phytoplankton decreased. It is too early to know if this trend reversal will continue.

Zebra mussels were first detected in Onondaga Lake in 1992 (Spada *et al.* 2002). Populations in the lake remained very limited through the 1990's despite the availability of appropriate substrate and food, near-optimal temperature and water chemistry, and continuing inputs of veligers (Spada *et al.* 2002). Rapid expansion of the population occurred from 1999-2000. It is believed that decreases in concentrations of

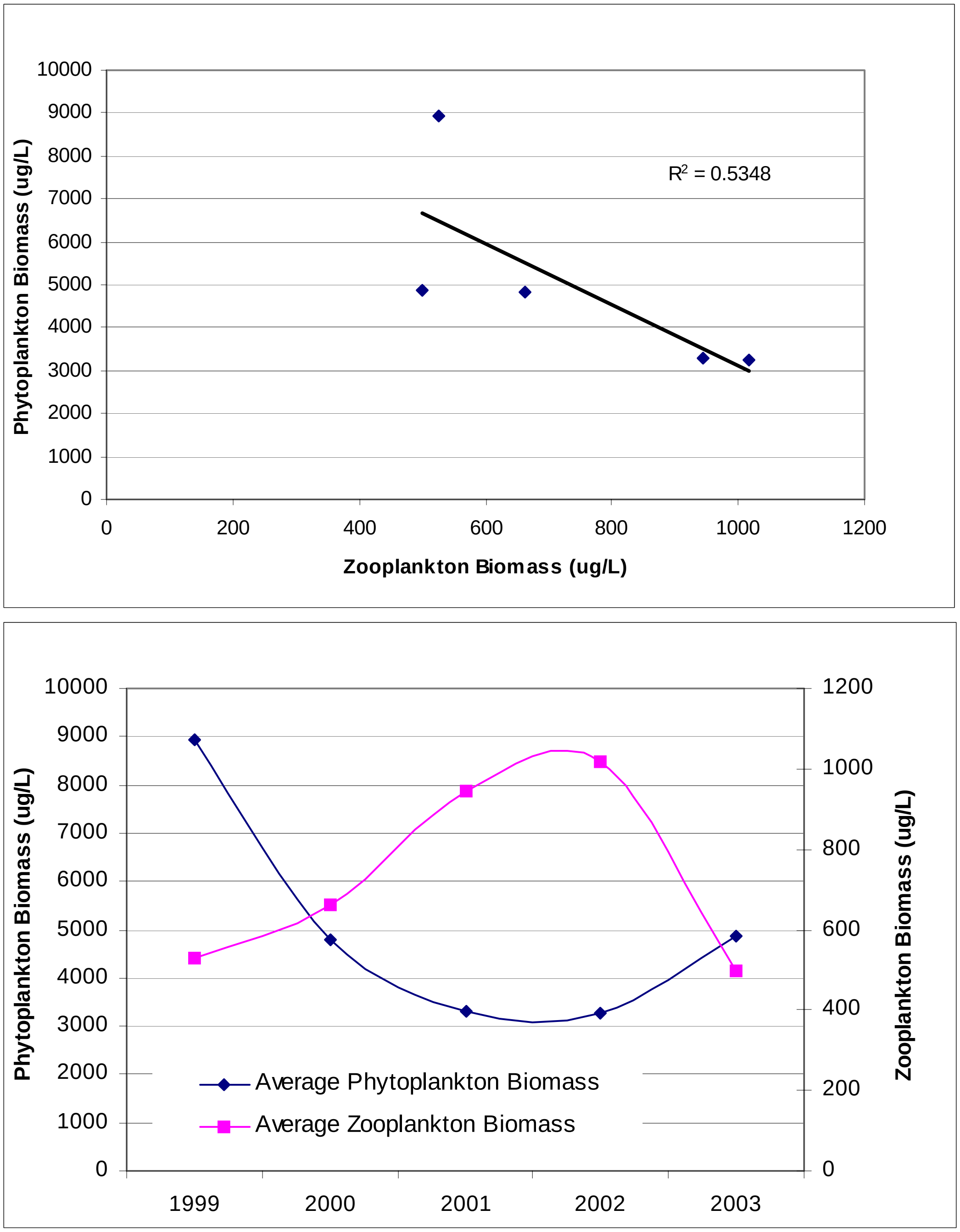


Figure 3-5. Phytoplankton biomass vs. zooplankton biomass (top) and plotted by year (bottom). Onondaga Lake, South Deep Station, 1999-2003.

ammonia N associated with increased treatment at Metro increased survival of sensitive life stages including veligers and allowed the population to expand (Spada *et al.* 2002). The continued presence of dense populations of zebra mussels may complicate the understanding of the cause and effect relationships between water quality and lower trophic levels.

Zebra mussels, if present in sufficient densities, can alter the cycling of nutrients and energy through the lake food web and may affect the distribution of organic material and light (Mayer *et al.* 2002). In particular zebra mussels can: 1) increase structural complexity and provide invertebrates with refuge from predation, 2) filter particulate matter from the water column and deposit it around their shells, thereby providing additional food for other invertebrates; and 3) increase depth to which light penetrates, likely increasing benthic primary production (Mayer *et al.* 2002). The increase in water clarity associated with invasions by zebra mussels has been demonstrated to increase benthic algal production and macrophyte growth (Mayer *et al.* 2002). This increased benthic primary production may result in increases in benthic consumers, particularly grazers such as amphipods and gastropods (Mayer *et al.* 2002). If these changes occur in Onondaga Lake they could alter the fish community by providing an advantage to species that favor macrophyte habitat, and those that feed primarily on benthic and macrophyte-dwelling invertebrates.

3.3 ZOOPLANKTON: COMMUNITY STRUCTURE AND ABUNDANCE

3.3.1 Plankton Biomass and Abundance

Average biomass of zooplankton in Onondaga Lake increased 11-fold from 1997 to 2002 then decreased in 2003 (Figure 3-6 a and b). There does not appear to be one single factor responsible for the increased biomass; contributing factors are likely to include reductions in ammonia concentrations, shift in the community of zooplankton, and dynamics of the lake's fish community. Increases in *Daphnia galeata*, a species that contributes a high portion of the biomass in most years, between 1997 and 2002 appears to be an important component of the overall increased biomass. Other prominent taxa also show some increase in biomass, indicating that the increase over this period was not attributable to a single species (Figure 3-6b). There are no fish data available for the 1997-1999 period, so it cannot be determined if decreasing planktivory by fishes was a contributing factor during that time period.

Extirpation of large-sized zooplankton (*Daphnia galeata* and diaptomids) from the zooplankton community was evident in late summer 2002 and continued through the 2003 sampling season. The elimination of the larger organisms from the community caused the decrease in total zooplankton biomass observed in 2003.

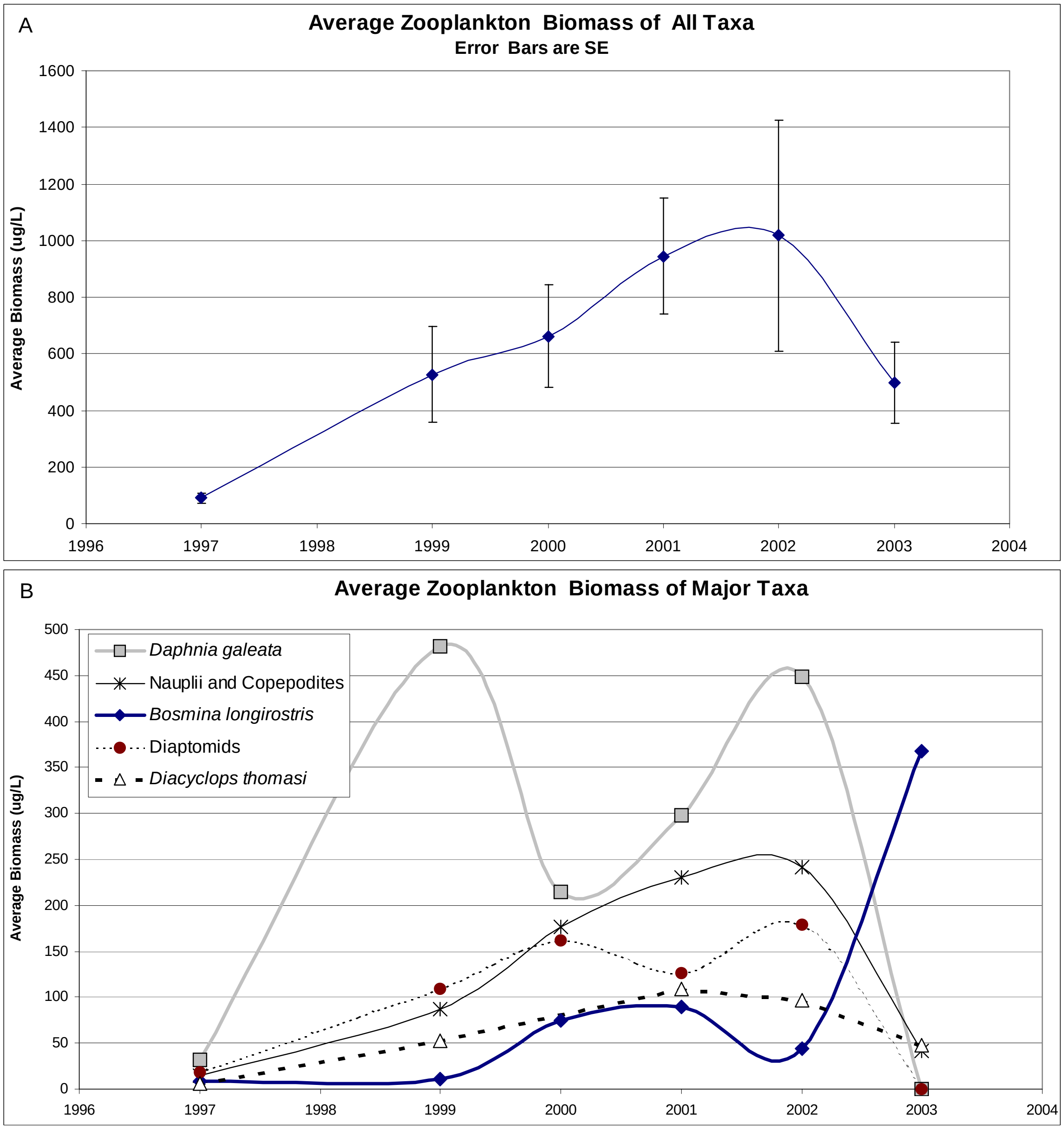


Figure 3-6. Average biomass of zooplankton (all taxa combined) and major taxa in Onondaga Lake from April until October in 1997 to 2003. Note: in 1998 data was only available until early August so no averages were calculated in that year.

Reduced ammonia concentrations in Onondaga Lake may have resulted in improved reproductive success of zooplankton and increased biomass similar to the effect described above for *Dreissena* veligers. Ammonia concentrations in spring decreased substantially from 1997 to 2000, and have remained nearly constant in recent years (Figure 3-7a). A regression of spring ammonia and zooplankton biomass shows an inverse relationship; note, however, that the regression is controlled by two ammonia peaks (Figure 3-7b). If ammonia concentrations remained below threshold levels of toxicity to zooplankton, increased biomass may have resulted. Arthur *et al.* (1987) reported that the geometric mean LC50 (concentration that is lethal to 50% of the test population) for a cladoceran was 1.7 mg/L NH3-N, comparable to measured values in Onondaga Lake between 1997 and 1999. This could be a contributing factor to the increase in biomass from 1997 to 2000, but would less likely have been a significant source of change from 2000-2003 since ammonia concentrations were similar in those years

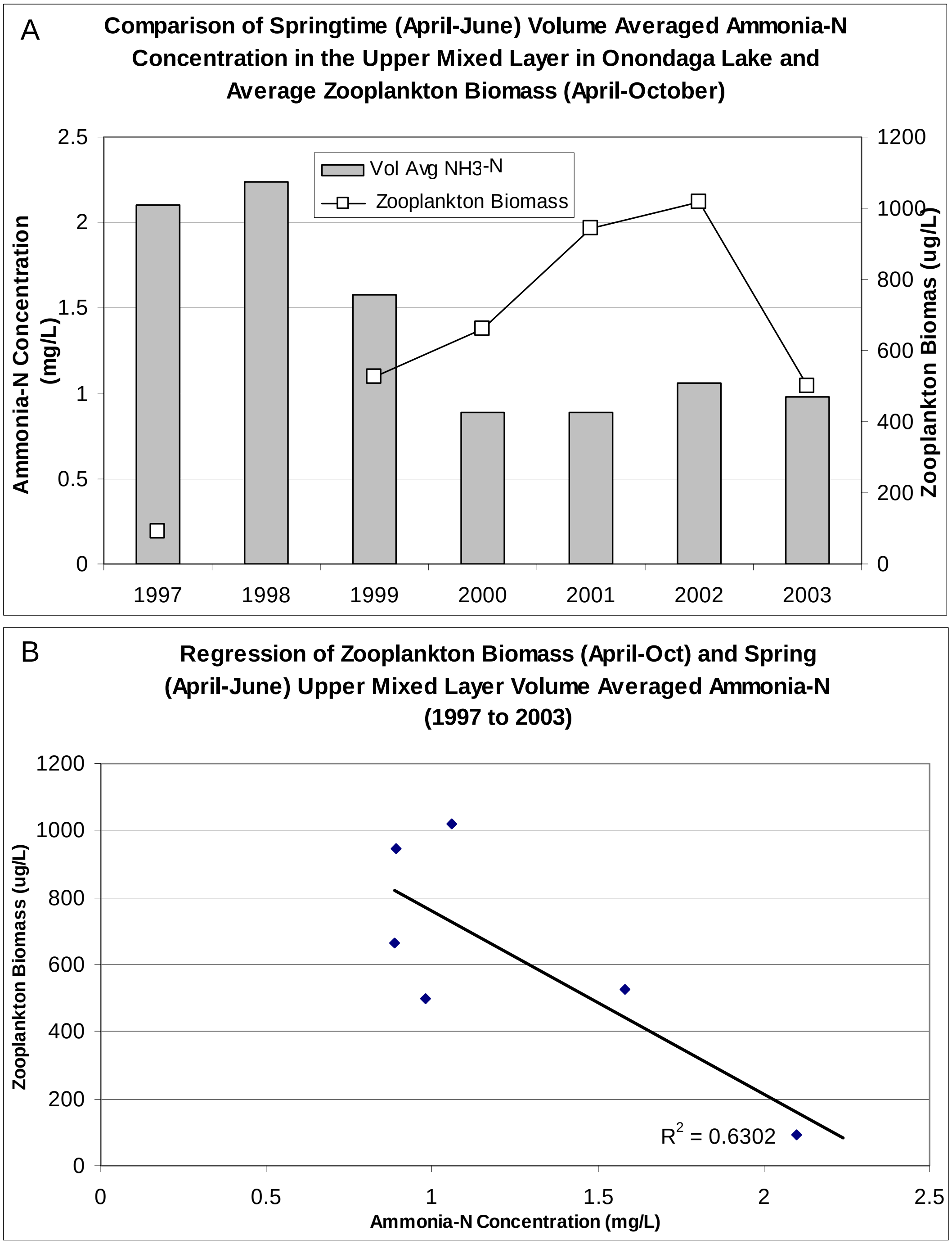


Figure 3-7. Comparison of ammonia-N concentration Onondaga Lake and zooplankton biomass. Note: Zooplankton data in 1998 was only collected until early August so were not used.

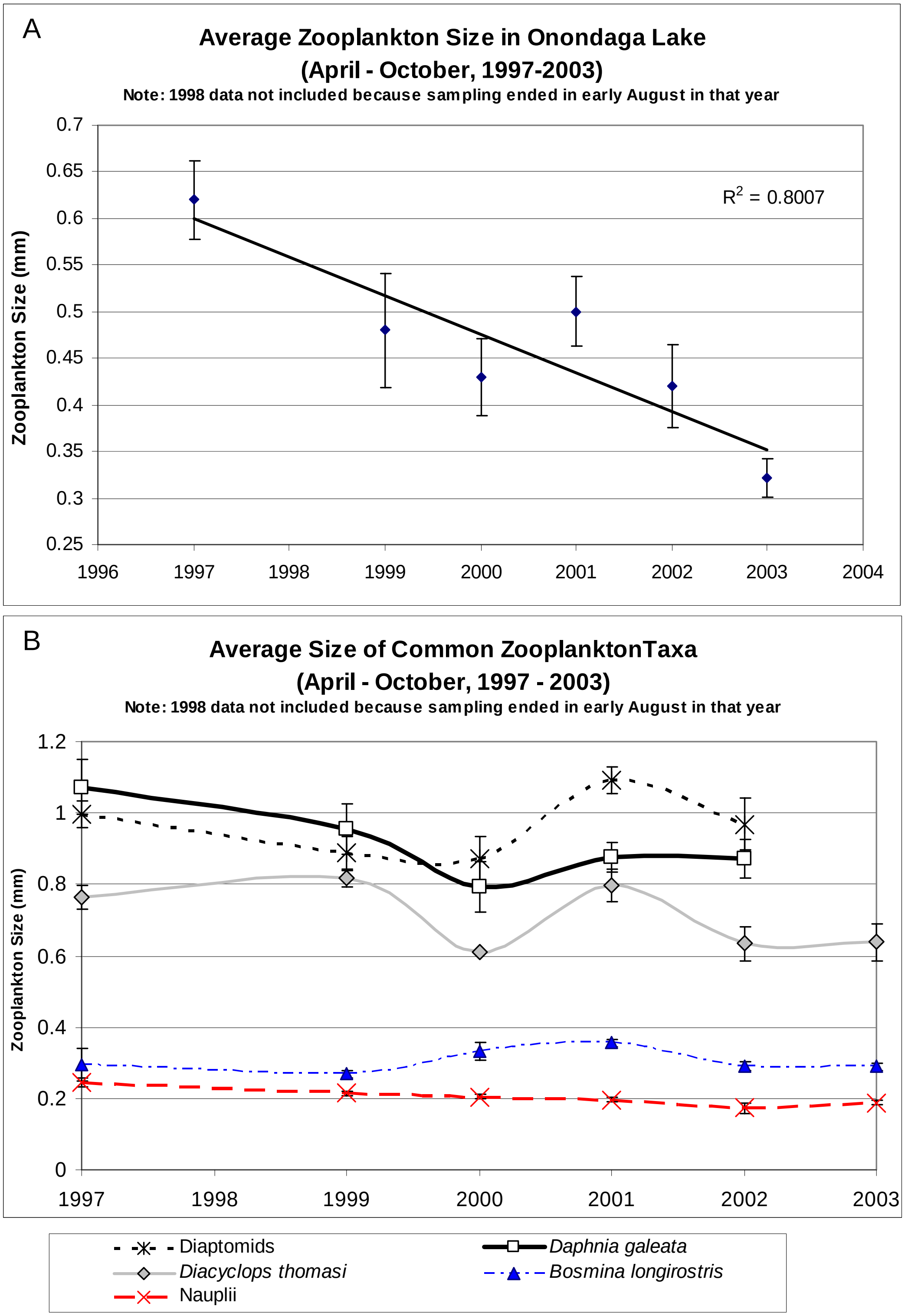
3.3.2 Size of Zooplankton Organisms

Size structure of zooplankton communities may be influenced by the relative degree of planktivory, which can cause a distinct shift favoring survival of smaller species as planktivorous fish prefer to graze on the larger organisms (Wetzel 1983). Mean zooplankton size in Onondaga Lake has shown a substantial decline since 1997 (Figure 3-8a). Zooplankton in 2003 were only about half as large as zooplankton in 1997 (0.32mm compared to 0.62mm). Although there has been an overall decrease in zooplankton size over time, mean size between 1999 and 2002 remained fairly constant (0.42mm - 0.5mm). The decrease experienced from 2002 to 2003 was due to the loss of the large-sized zooplankton, *Daphnia galeata* and diaptomids, from the community (Figure 3-8b).

Seasonal shifts in the average size of the individual organisms comprising the zooplankton community are common. Researchers at Cornell's Shackelton Point Field Station have tracked these seasonal shifts and compared them to Oneida Lake data. Because the sampling in Onondaga Lake utilizes a net with smaller mesh size, the small sized nauplii are excluded from the comparisons in order to approximate what would be captured in the Oneida Lake samples.

The temporal pattern between Onondaga and Oneida lakes is generally similar but some differences were noted (Figure 3-9). The zooplankton community in Oneida Lake exhibits very consistent size patterns from year to year. Dominated by larger organisms from late spring through mid-summer, the community shifts to smaller plankton when newly-hatched fish begin to graze. The average size of organisms tends to remain low until fall when it begins to recover.

The temporal pattern of average size of the Onondaga Lake zooplankton community tracked the Oneida Lake pattern very closely in 1999 and somewhat closely in 2002. In 2000 and 2001, zooplankton size in Onondaga Lake did not decrease nearly as much in late-summer possibly because of lower grazing pressure. Notably, the 2003 data show very different size structure between the two lakes. Onondaga zooplankton were substantially smaller throughout the sampling period, due to the loss of larger-sized organisms.


A Average Zooplankton Size in Onondaga Lake (April - October, 1997-2003)

Note: 1998 data not included because sampling ended in early August in that year

B Average Size of Common ZooplanktonTaxa (April - October, 1997 - 2003)

Note: 1998 data not included because sampling ended in early August in that year

Figure 3-8. Average size of zooplankton (all taxa combined) and major taxa in Onondaga Lake from April until October in 1997 to 2003. Note: 1998 data only through early August.

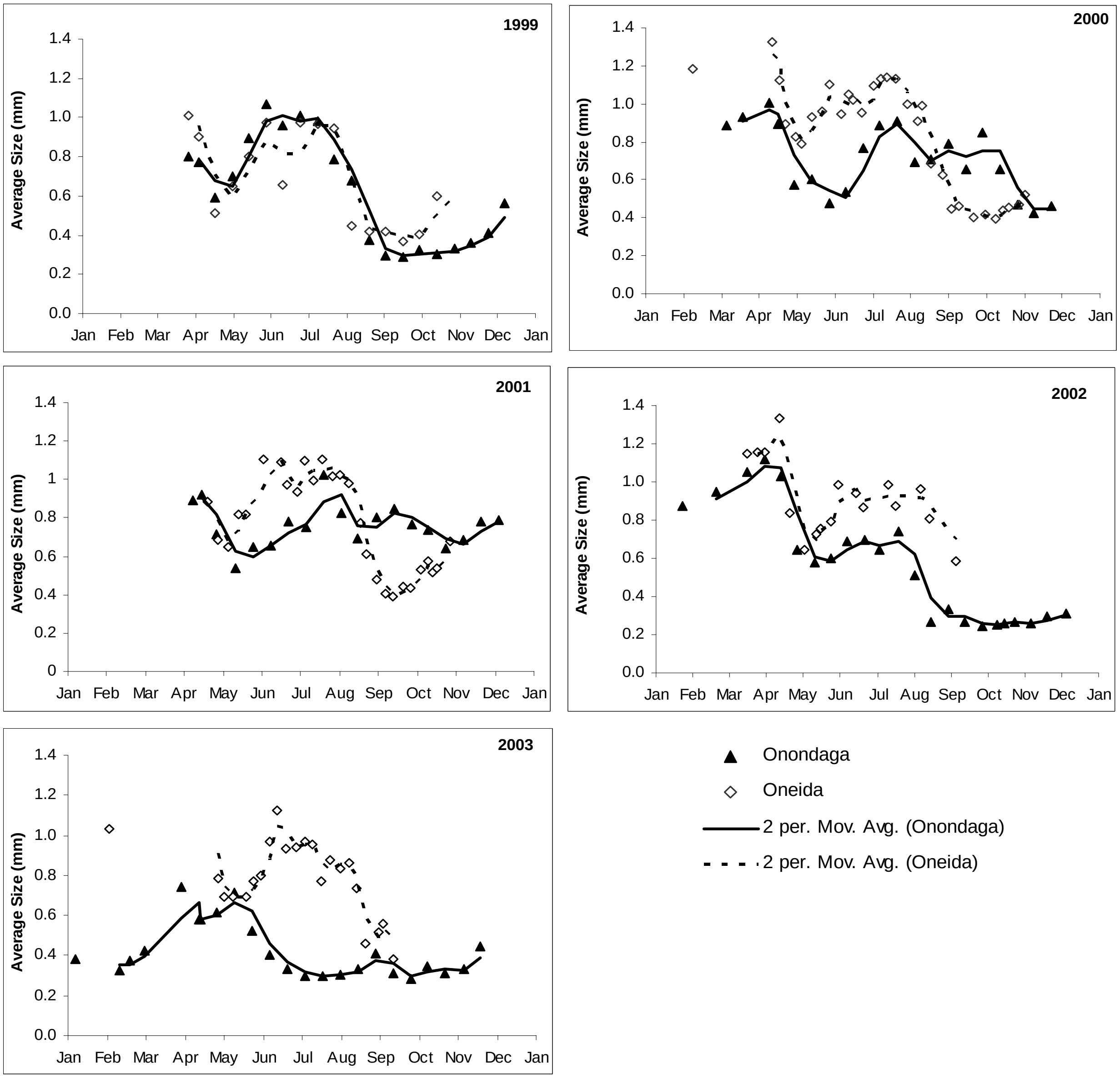


Figure 3-9. Adjusted average zooplankton (excluding nauplii) lengths (mm) in both Oneida and Onondaga Lake, 1999-2003. Trend lines reflect averages between adjacent data points. Averages represent a composite off all samples for each date.

3.3.3 Species Composition

A total of 9 cladoceran and 8 copepod taxa have been identified in Onondaga Lake since 1997; rotifers are not enumerated as part of the monitoring program (Table 3-3). Based on numerical abundance, the small-sized nauplii are the most common taxa. *Bosmina longirostris*, *Daphnia galeata* and the diaptomids are also common. However, the large-sized organisms tend to dominate the biomass analysis, with *Daphnia galeata* being the dominant species and *Bosmina longirostris, Diacyclops thomasi* and nauplii being common.

In 2003 *Daphnia galeata* and diaptomids were not found in the samples (Figure 3-10, Table 3-3). This is the only year these taxa were absent from the samples.

3.3.4 Temporal Patterns of Species Composition and Biomass

Annual seasonal trends in biomass seem to follow two general patterns (Figure 3-11). In 1999, 2000, and 2002 biomass peaked from May through July then dropped suddenly in August. These spring and summer increases in biomass appear to be largely due to increases in *Daphnia galeata*. These blooms of *Daphnia* were likely the major contributor to clearing events that had, until recently, been observed in May and June. In 1997, 2001, and 2003, zooplankton biomass was variable throughout the year.

The temporal biomass patterns may be controlled by fish planktivory. In years with high planktivory, biomass is severely reduced by mid-summer. The interactions within the fish community that largely control the relative degree of planktivory are a combination of species composition and abundance of planktivores and age-0 fish (Dettmers and Stein 1992, Carpenter *et al.* 2001).

Temporal area plots of relative zooplankton biomass by taxa (Figure 3-12) show that the progression of species was generally consistent from 1997 to 2002. In most years between 1997 to 2002, the mid-spring samples are dominated by a combination of diaptomids, nauplii and copepodites, *Diacyclops thomasi*, and *Daphnia galeata.* In 2000 *Acanthocyclops vernalis* represented an unusually large portion of the community from March to early May. *Daphnia galeata* tended to dominate the community from May to July. From July to late fall the zooplankton community varies from year to year with the major taxa shifting in relative abundance. The most consistent zooplankton taxa appear to be the diaptomids, which represent 10 - 20% of the community throughout most of the sampling season in most years.

TABLE 3-3

Zooplankton Assemblage of Onondaga Lake 1997-2003 Based on Biomass and Abundance.

Biomass

Taxa	1997	1998	1999	2000	2001	2002	2003
CLADOCERA							
Alona sp.	r					r	r
Bosmina longirostris	**VC**	P	C	C	C	C	**VC**
Ceriodaphnia quadrangula	r						r
Chydorus sphaericus	r		r	r		r	r
Daphnia galeata	C	C	C	C	C	C	
Diaphonasoma sp.	r	r	r	r	r	r	
Eubosmina coregoni			r	r	P	r	
Holopedium sp.			r				
Leptodora kindtii				r		r	
COPEPODA							
Acanthocyclops vernalis	r			C	r	r	
Calanoid copepodid					P	C	
Cercopagis pengoi				r		r	r
Cyclopoid copepod			P	C	P		r
Diacyclops thomasi	C	C		r	C	C	C
Diaptomids	C	C	C	C	C	C	
Mesocyclops edax	P	r	r	r	P	r	
Nauplii	C	**VC**	**VC**	**VC**	**VC**	**VC**	C

Key
VC=Very Common (>25%)
C= Common (5-24.99%)
P= Present (1-4.99%)
r = Rare (<1%)
Blank = Absent

Abundance

Taxa	1997	1998	1999	2000	2001	2002	2003
CLADOCERA							
Alona sp.	r					r	r
Bosmina longirostris	C	R	P	C	C	C	**VC**
Ceriodaphnia quadrangula	r						r
Chydorus sphaericus	r		r	r		r	r
Daphnia galeata	**VC**	**VC**	**VC**	**VC**	**VC**	**VC**	
Diaphonasoma sp.	r	r	r	r	r	r	C
Eubosmina coregoni			r	r	P	r	r
Holopedium sp.			r				
Leptodora kindtii				r		r	
COPEPODA							
Acanthocyclops vernalis	P			C	P	r	
Calanoid copepodid					P	P	
Cercopagis pengoi				r		r	P
Cyclopoid copepod			P	C	P		r
Diacyclops thomasi	C	C	C	r	C	C	C
Diaptomids	C	C	C	C	C	C	
Mesocyclops edax	C	P	P	r	C	r	
Nauplii	C	C	C	C	C	C	C

Key
VC=Very Common (>25%)
C= Common (5-24.99%)
P= Present (1-4.99%)
r = Rare (<1%)
Blank = Absent

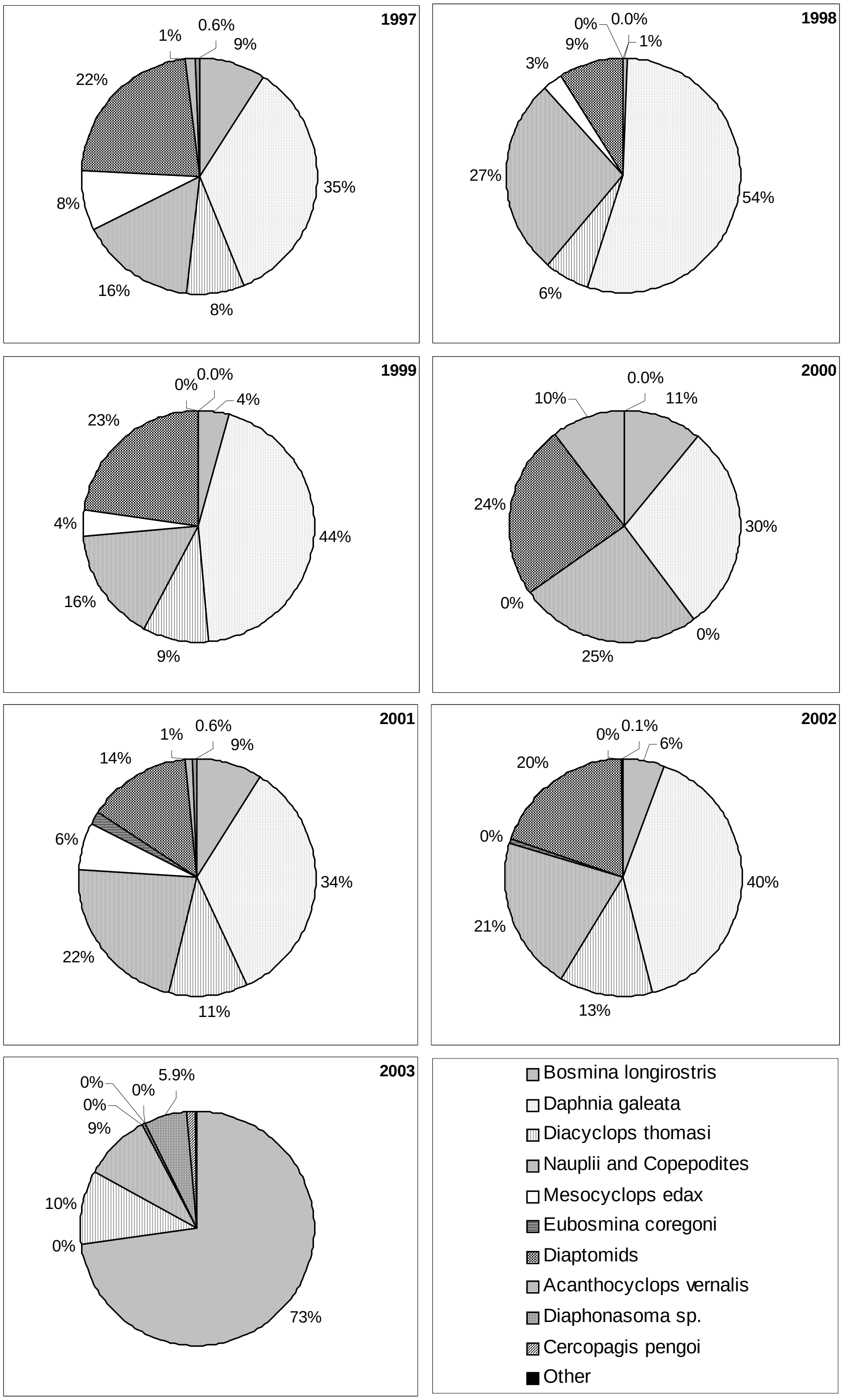


Figure 3-10. Species composition of zooplankton based on total annual biomass in each year from 1997 to 2003. Note: 1998 represents only the time period from April until early August, other years include data until at least November.

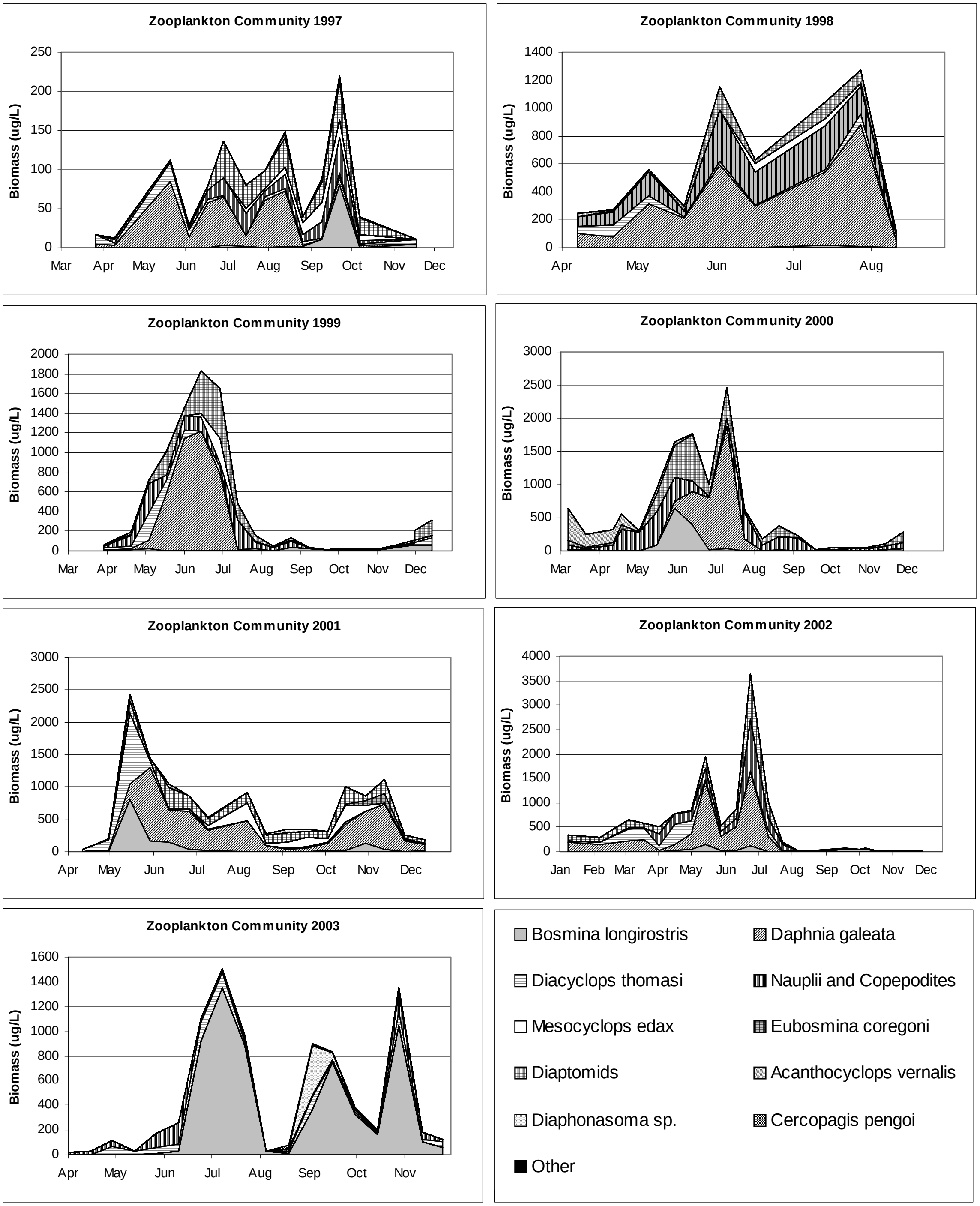


Figure 3-11. Seasonal species composition of zooplankton based on biomass in each year from 1997 to 2003.

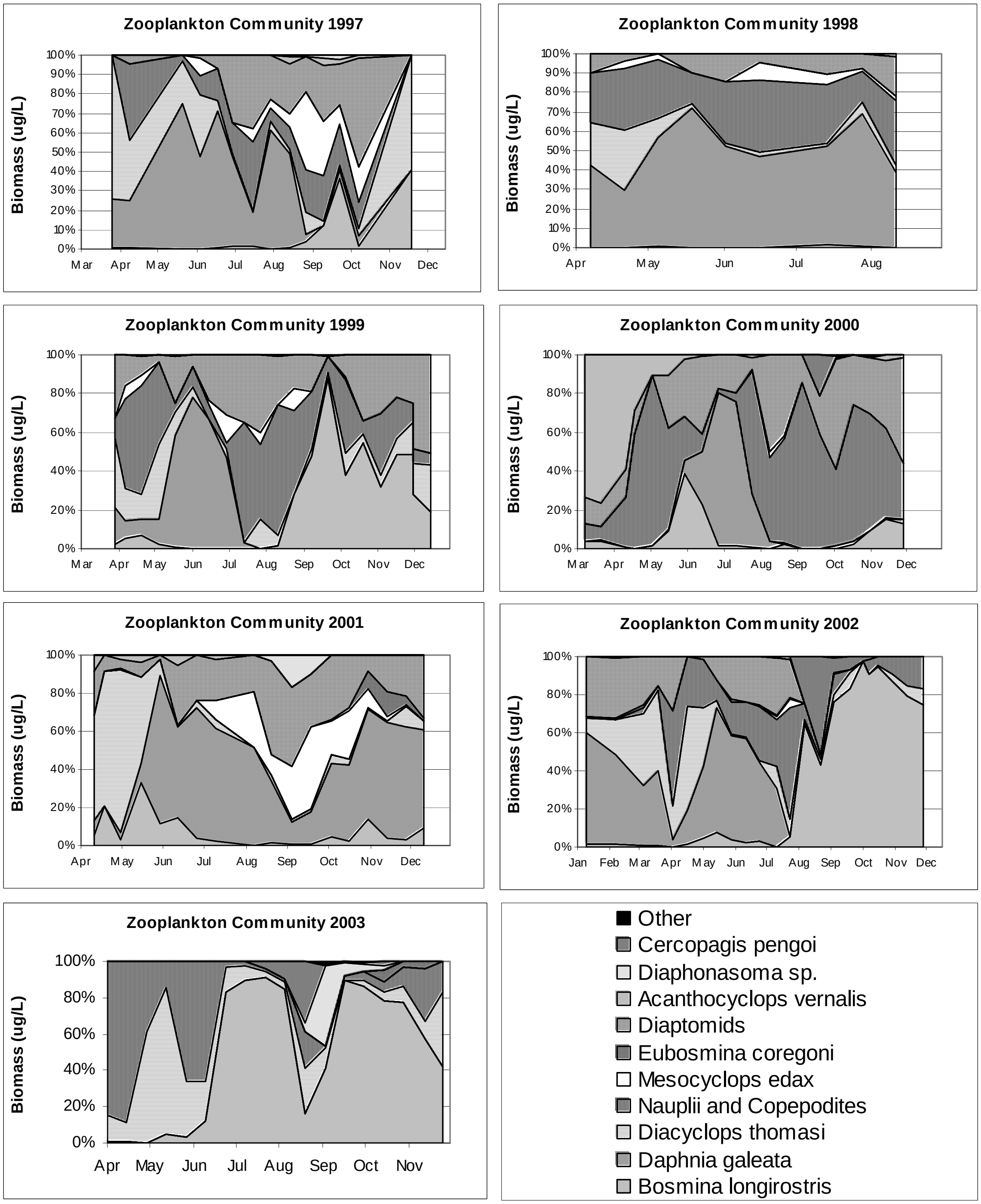


Figure 3-12. Seasonal relative species composition of zooplankton based on biomass in each year from 1997 to 2003.

The invasive predatory zooplankton *Cercopagis pengoi* was first detected in Onondaga Lake in 2000. It was not found in the 2001 samples, but was again reported as present in 2002 and 2003. *Cercopagis pengoi* biomass has steadily increased since its first reported presence in Onondaga Lake in 2000 (Figure 3-13a). The number of *Cercopagis pengoi* present is variable with peak biomass evident in late July to early September (Figure 3-13b). The 2002 and 2003 data showed double peaks in abundance of *Cercopagis pengoi* about one month apart.

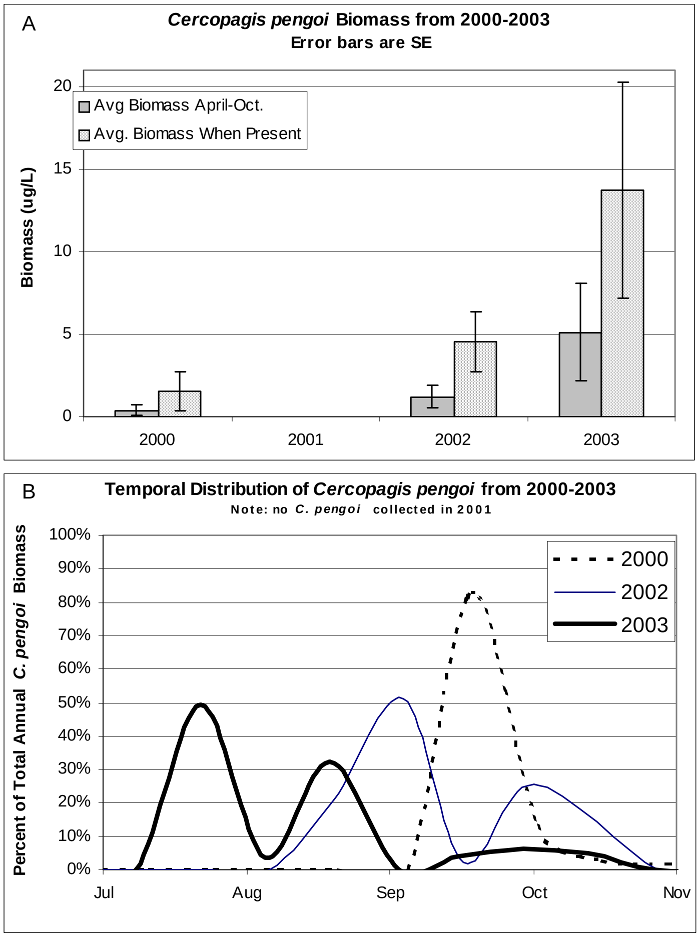


Figure 3-13. *Cercopagis pengoi* biomass and seasonal abundance pattern in Onondaga Lake since their initial discovery in 2001.

The temporal progression of species discussed above breaks down beginning in late summer 2002, when most taxa, with the exception of *Cercopagis pengoi* and *Bosmina longirostris*, underwent rapid population declines (refer to Figure 3-11 and 3-12). Diaptomids and *Daphnia galeata*, which had consistently been a significant portion of the community since 1997, were no longer found. A similar relationship was observed during the same time period in 1999, when *Bosmina longirostris* increased in relative importance and diaptomids showed a rapid decline. However, unlike in 1999-2000, diaptomids and *Daphnia galeata* did not recover in 2003 and were not collected in Onondaga Lake.

The 2003 zooplankton community composition was unlike any of the previous six years (refer to Figures 3-10 to 3-12). The early season community was composed almost entirely of nauplii and copepodites, and *Diacyclops thomasi*. From June to the end of the sampling season, *Bosmina longirostris* was the dominant taxa. The only exception to this occurred in August when *Cercopagis pengoi* was most dominant.

3.4 FISH COMMUNITY

3.4.1 Trophic Guilds

Trophic guilds are used to aggregate the adults of various fishes according to their feeding habits. The categories and species designations developed by Goldstein and Simon (1999) were used as the primary source for trophic guild categorization. The U.S.EPA and Ringler *et al*. (1996) trophic guild designations were used as a secondary source when information from the primary source was not available. Included in Appendix 8, Table A8-2 is a list of species and their designated trophic guild.

The trophic cascade hypothesis suggests that an inverse relationship between piscivore and planktivore biomass should be expected (Carpenter *et al*. 2001). Proportionally, planktivores have decreased while piscivores have increased since 2000 (Figure 3-14). However, this pattern is due entirely to the decrease

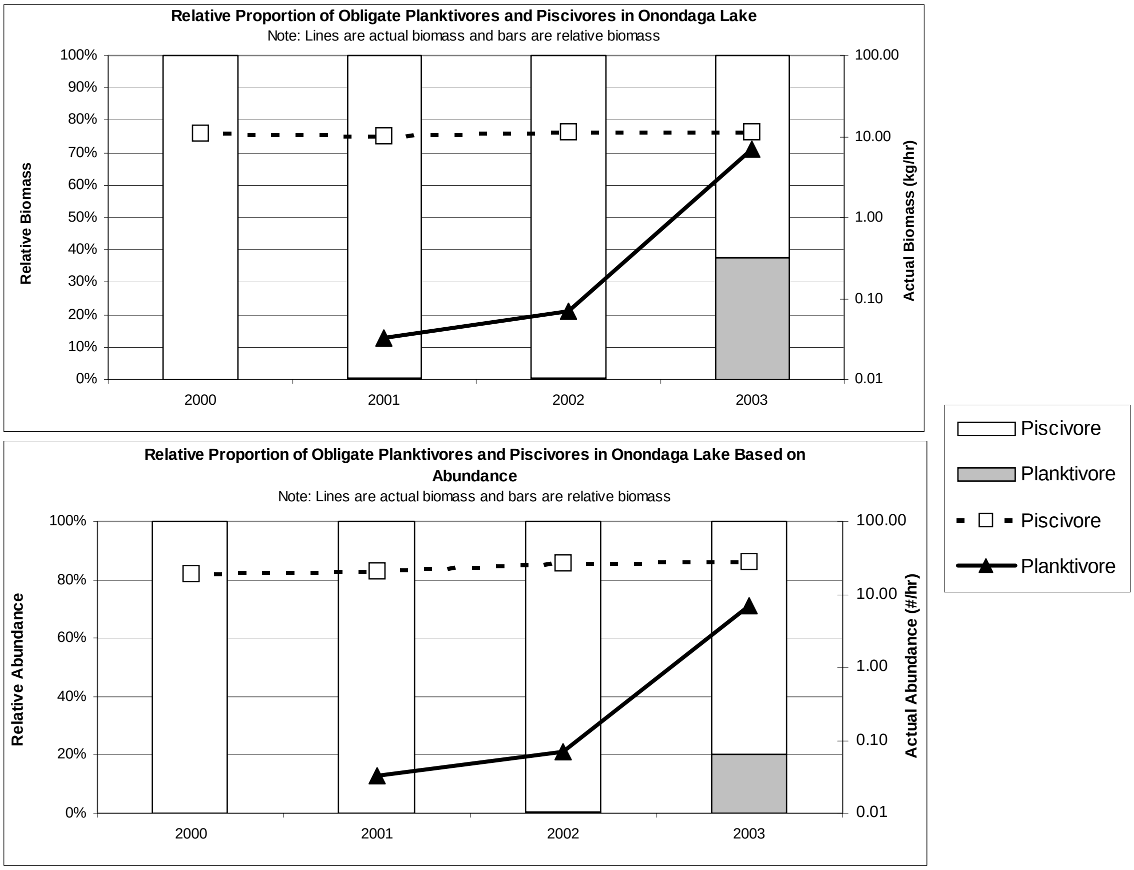


Figure 3-14. Relative proportion of planktivorous and piscivorous fish in Onondaga Lake based on biomass and abundance.

in planktivores, as piscivore biomass and abundance has remained nearly stable over the monitoring period. It must be noted that the AMP is not designed to estimate total biomass of the trophic levels, reliance on the electrofishing data may limit our ability to draw conclusions.

3.4.2 Effects on Lower Trophic Levels

According to the trophic cascade hypothesis the dramatic increase in an obligate planktivore (the alewife) in 2003 should result in decreased zooplankton size and biomass as predation on large-bodied zooplankton increases (Carpenter et al 2001). This should diminish grazing pressure on the phytoplankton community, causing increased phytoplankton abundance and decreased water clarity. Changes appear to have occurred as predicted. The 2003 relationship between zooplankton community characteristics and alewife biomass is striking (Figure 3-15). The dramatic increase in alewife coincides with drastic declines in zooplankton biomass and size. As discussed earlier in this chapter the relationship between phytoplankton biomass and zooplankton biomass in the lake is strong (refer to Figure 3-5). The increase in phytoplankton biomass in 2003 is notable (refer to Figure 3-5 bottom). This increase likely resulted in decreased water clarity, as measured by Secchi disk (Figure 3-16). Interestingly there is a strong positive relationship between mean zooplankton size and water clarity in Onondaga Lake from 2000-2003, indicating that zooplankton may be strongly influential in determining water clarity. Other interactions between the fish community and lower trophic levels may be taking place, but their influence is less obvious.

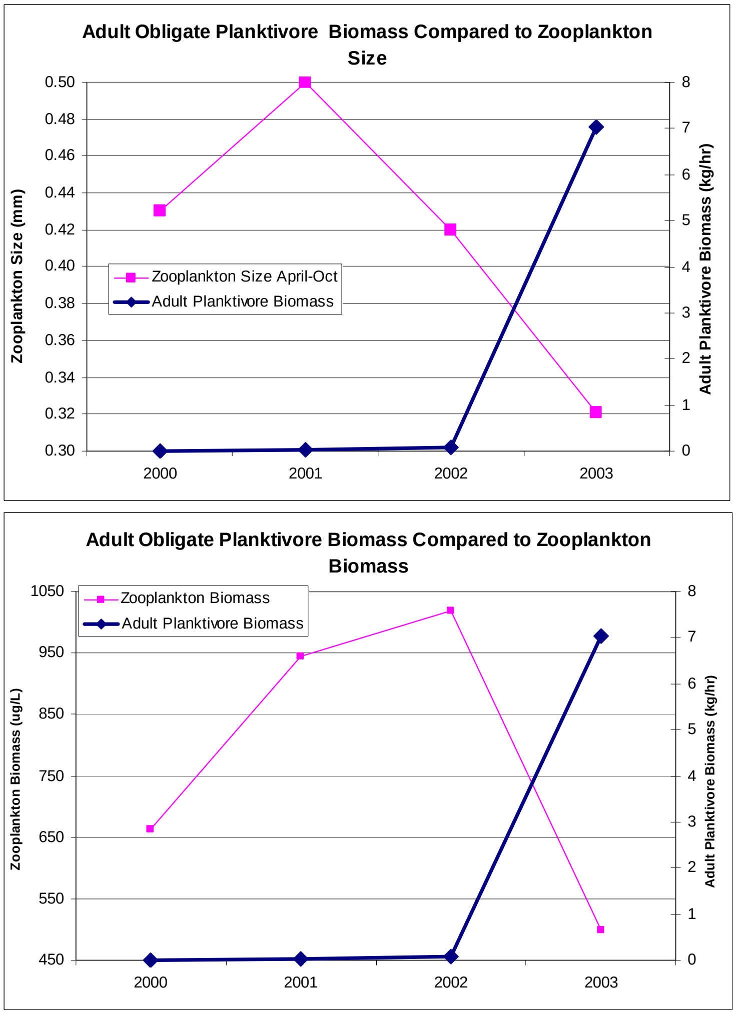


Figure 3-15. Comparisons of adult obligate planktivore catch (alewives) and biomass and size of zooplankton in Onondaga Lake from 2000-2003.

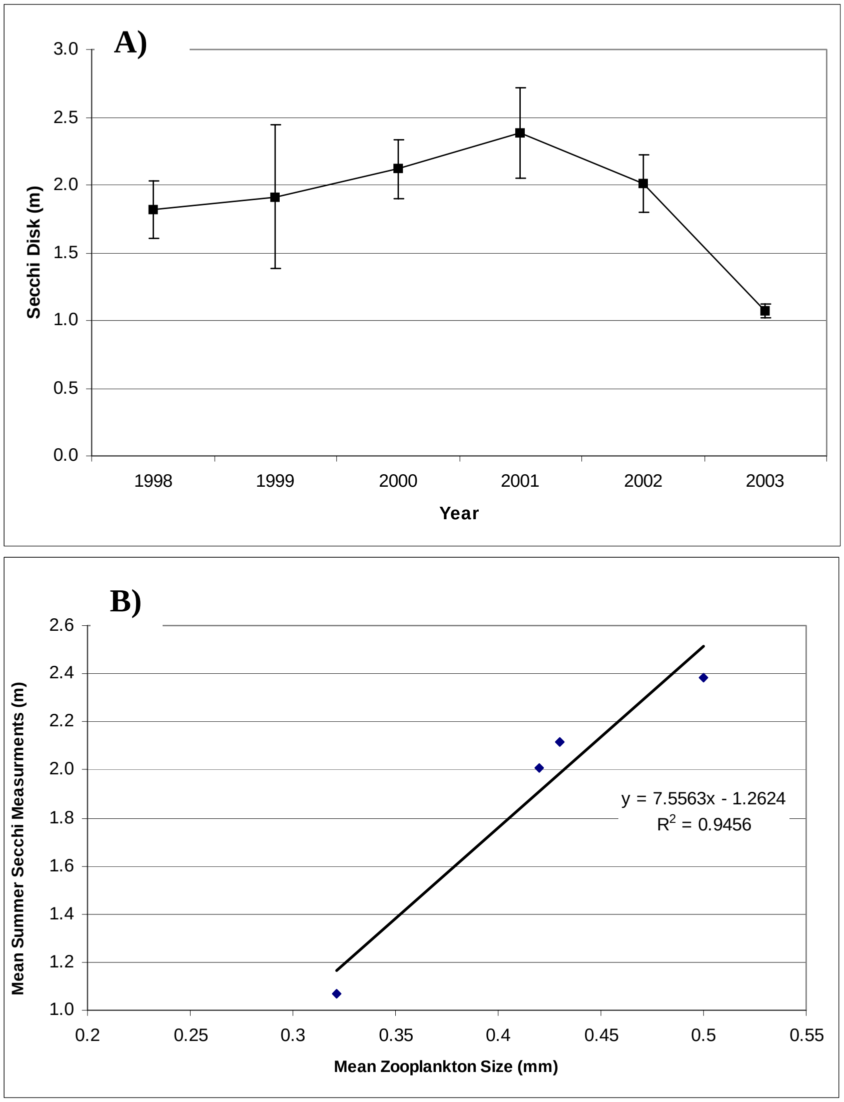


Figure 3-16. A) Mean summer secchi disk measurments from Onondaga Lake, 1998 to 2003. Error bars are standard eror. B) Regression of mean summer Secchi disk measurments and mean zooplankton size in Onondaga Lake 2000 to 2003.

Because of their direct interactions with zooplankton, phytoplankton and nutrients, shad may regulate lake communities via a complex “middle-out” process that affects both higher and lower trophic levels (Dettmers and Stein 1996). Gizzard shad, as well as other benthic and detrital feeding fishes, may have dramatic effects on internal nutrient loading, sediment resuspension, and fish productivity (Schaus *et al.* 2002). When feeding on detritus, gizzard shad mobilize nutrients from the sediments to the water column via their excretions, thereby potentially stimulating phytoplankton growth (Schaus et al 2002, Dettmers and Stein 1992). Gizzard shad may be particularly influential in the transport of nutrient from the sediments to water column as they typically excrete at a low N:P ratio relative to other species of fishes

(Schaus and Vanni 2000; Schaus *et al.* 1997). Consequently, it may be possible for detritivorous shad to maintain high phytoplankton productivity in lakes even after external nutrient loading is reduced (Schaus *et al.* 2002).

Population biomass and size structure of the fish community may influence the magnitude of nutrient transport from sediment. Smaller fish tend to have higher mass-specific excretion rates (Schaus *et al.* 2002); thus, a population dominated by smaller individuals would likely have a greater impact on nutrient and phytoplankton dynamics than would an equivalent biomass of larger individuals. These interactions, if they occur in Onondaga Lake, may have profound effects as nutrient loads decrease as a result of improved wastewater treatment.

3.5 INTERACTIONS

3.5.1 Phytoplankton and Zooplankton

The disappearance of large-sized zooplankton from Onondaga Lake since late 2002 has considerable implications for the future of the phytoplankton community. Large-sized zooplankton are very effective grazers; a healthy population of these organisms can keep phytoplankton in check. Consequently, their disappearance from the lake will affect phytoplankton standing crop.

3.5.2 Zooplankton and Fish Community

Zooplankton communities go through predictable temporal changes throughout the year that are largely controlled by grazing pressure from fishes. Typical patterns of zooplankton biomass and size compared to age-0 fish, calculated from Onondaga Lake data collected from 2000-2003, are displayed in Figure 3-17. Early summer declines in zooplankton size and biomass correspond to typical peaks in fish larvae abundance. As larval fish grow to young-of-the-year (YOY) size, grazing pressure continues causing sustained declines in zooplankton size and biomass through September. By October grazing pressure decreases and zooplankton size and biomass begin to recover due to combination of decreasing temperature, shifts in YOY diet away from zooplankton, and mortality of YOY. The intensity of these changes from year to year is largely a function of age-0 year class strength and species composition of the age-0 fish community. When obligate planktivores are present, the level of planktivory from those species is dependent on population size and water temperature. These levels may be somewhat stable from year to year depending on population size and species composition.

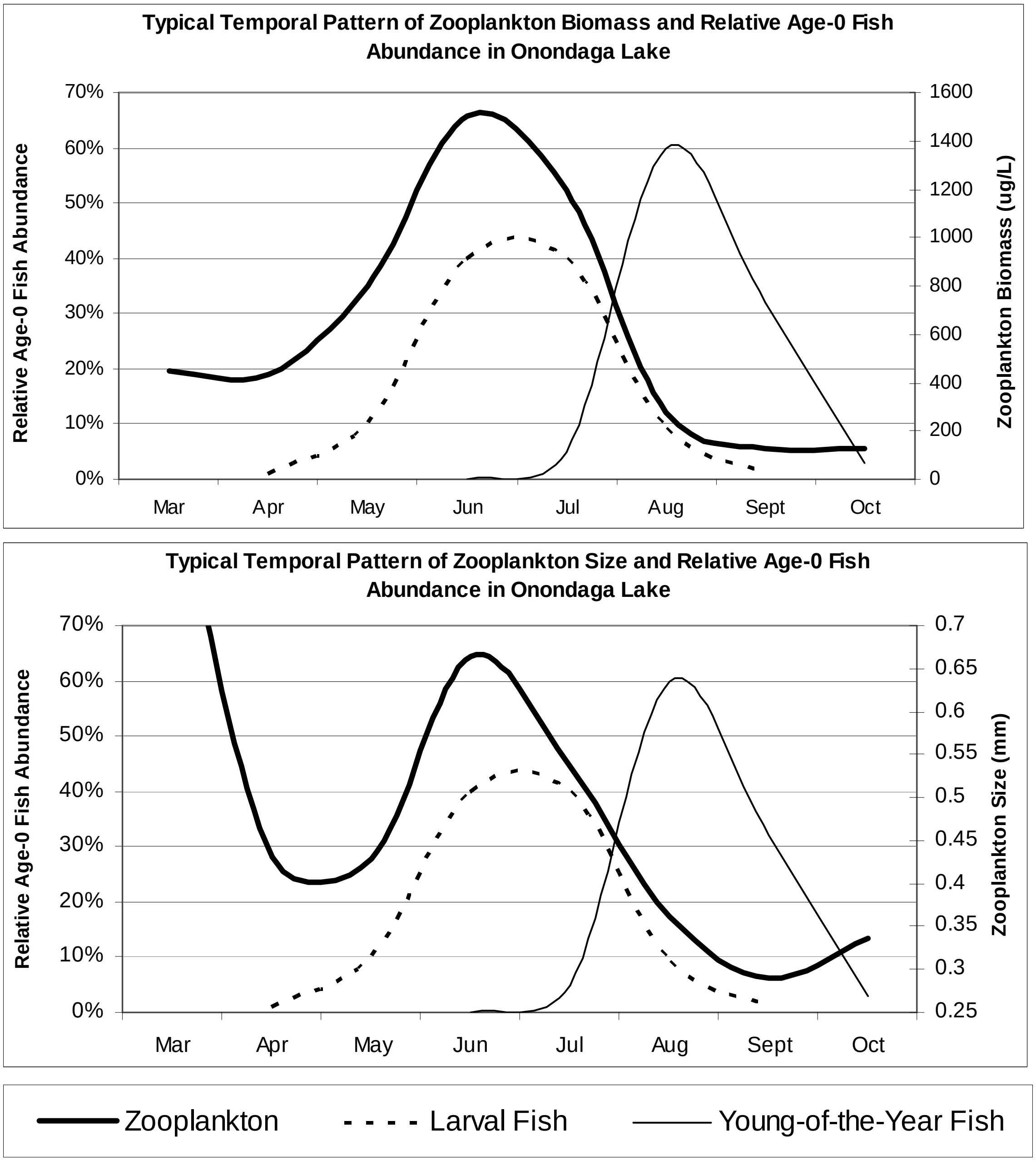


Figure 3-17. Typical temporal pattern of zooplankton size and biomass compared to relative Age-0 fish abundance in Onondaga Lake.

Extensive modification to the zooplankton species assemblage was noted in 2003. Large-bodied *Daphnia galeata* and diaptomids were extirpated from the lake. This phenomenon seems to have begun in late summer 2002. The fish community data from 2000-2003 were reviewed to determine if any relationships existed between the fish community and observed changes to the zooplankton community.

3.5.2.1 Adult Planktivores

The estimated abundance and biomass of planktivorous fishes in Onondaga Lake declined during the period of 2000 – 2003. As illustrated in Figure 3- 18, this decline is primarily related to reduction in the abundance of the gizzard shad. A change in the composition and abundance of the fish community can affect other trophic levels and, ultimately, water quality conditions.

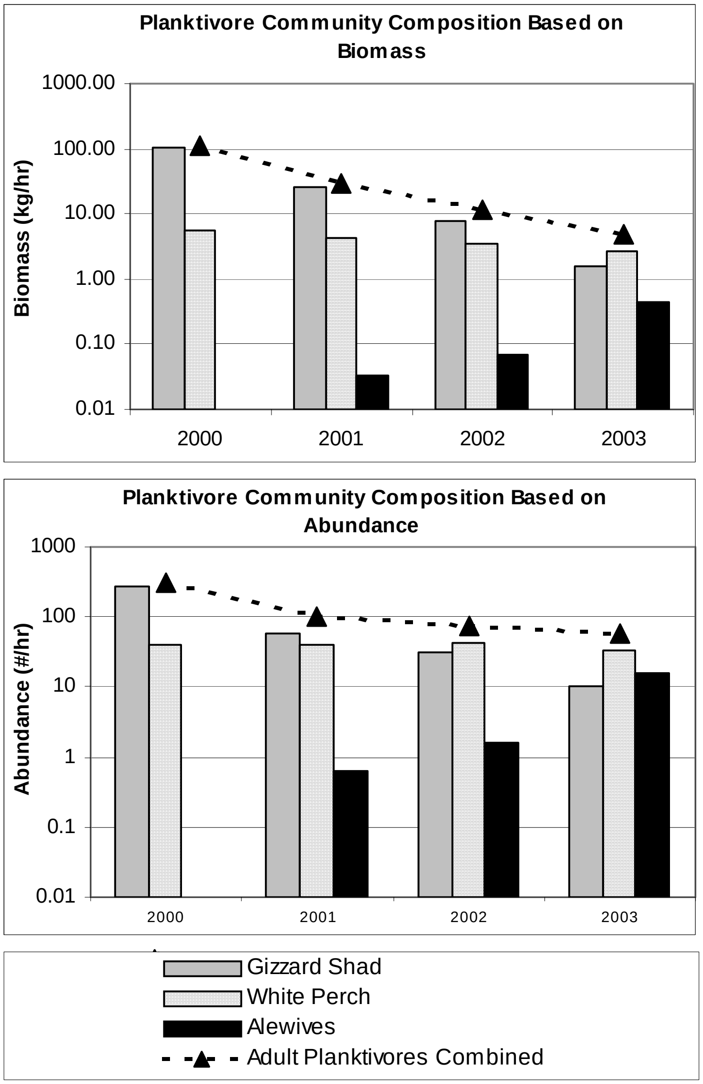


Figure 3-18. Adult planktivore community composition changes in Onondaga Lake from 2000-2003.

Adult planktivores can exert tremendous pressure on the zooplankton community if biomass is high. Based on Ringler *et al.* (1996), gizzard shad, white perch and alewives are categorized as planktivores in Onondaga Lake. However, most fish will change food sources based on availability. For example, white perch can be a planktivore, omnivore or piscivore. Smith (1985) states that white perch are mostly piscivorous once they exceed 200 mm. Diet analysis of adult and young white perch in the early 1990's in Onondaga Lake found that they ate primarily zooplankton (based on abundance) but, on a dry weight basis, fish and fish eggs were also important in their diet (Ringler *et al.* 1996). Yellow perch in Oneida Lake are planktivores but also feed on fish and benthic invertebrates (Mayer *et al.* 2000). In the early 1990's in Onondaga Lake, juvenile yellow perch ate primarily combinations of zooplankton and midge larvae (Ringler *et al.* 1996). Gizzard shad have been classified in the literature as an omnivore, planktivore, and herbivore. It is likely that these species feed on zooplankton in Onondaga Lake but they are unlikely to be as influential as the alewife.

At times, gizzard shad may exert a significant influence on the Onondaga Lake zooplankton community due to their periodic high abundance and foraging behavior as larvae. Shad feed almost exclusively on zooplankton until they reach a size of about 30 mm (Yako *et al.* 1996; Shepherd and Mills 1996). If present in high enough densities, larval and age-0 shad can severely deplete zooplankton (Yako *et al.* 1996). As shad grow larger they tend to become more omnivorous, feeding on zooplankton, phytoplankton, and detritus (Yako *et al.* 1996; Schaus *et al.* 2002), although in some systems adult shad apparently can feed primarily on zooplankton (Drenner *et al.* 1982).

Because of the variability in feeding behavior of adult gizzard shad they are best described as a facultative planktivore, or omnivore (Dettmers and Stein 1996; Schaus *et al.* 2002). Shad have been shown to be capable of depleting available zooplankton; once this occurs they switch to a diet primarily composed of detritus and phytoplankton (Dettmers and Stein 1992). When zooplankton abundance recovers, shad then increase their intake of zooplankton and can again suppress zooplankton (Yako *et al.* 1996). Consequently, gizzard shad can severely reduce available zooplankton yet still maintain their own population by supplementing their diet on detritus (Dettmers and Stein 1992). This can potentially affect recruitment success of all fishes with zooplanktivorus young (Dettmers and Stein 1992). However, this type of interaction appears to be more common in southern reservoirs where shad are not as susceptible to winter mortality and where population can probably grow to levels much higher than in Onondaga Lake.

3.5.2.2 Alewives

Alewives are obligate planktivores, feeding mostly on zooplankton and occasionally on other invertebrates, larval fish and fish eggs. Their first branchial arch is modified with closely spaced gill rakers that act as a plankton sieve (Wetzel 1983).

Alewives can severely reduce zooplankton size and biomass leading to reduced water transparency (Brooking *et al.* 1998; Kohler and Ney 1981). Alewives were rarely caught in Onondaga Lake for the first three and half years of the current monitoring program, although they apparently have been abundant in the lake in the past (Ringler *et al.* 1996; Smith 1985). CPUE of alewives in electrofishing ranged from zero to 0.9 from 2000 through 2002. In 2003 alewife catch rates suddenly went up to 215 in the spring and 261 in the fall indicating that either a year class already present in the lake became large enough to be routinely captured by the electrofishing sampling or that a population of alewives had moved into the lake from elsewhere. Because alewives are primarily an open water species their catch in the littoral zone electrofishing may be disproportionately less than other species, so their actual abundance may be even higher than observed.

Length frequency analysis of alewives in 2003 shows that there appears to be two distinct year classes present; a dominant cohort in the 140-180 mm range, and a minor cohort in the 200-220 mm range (Figure 3-19). If the prominent cohort are yearlings (in 2003) that would mean that they would have been produced in 2002 and likely began to have impacts to the zooplankton community late in the summer of 2002, precisely when impacts were observed. However, the primary cohort observed in 2003 were larger than age-1 alewives from Lake Ontario and Otisco Lake and were more in line with age-2 or possibly even age-3 fish from those lakes (O'Gorman et al 1997; David Lemon NYSDEC Region 7 Fisheries Biologist, personal communication). Onondaga Lake provided a food rich environment for alewives in 2002, with a high abundance of large sized zooplankton. This would have sustained higher growth rates than in most lakes, thus allowing zooplankton to reach sizes observed in 2003 in only one year. The

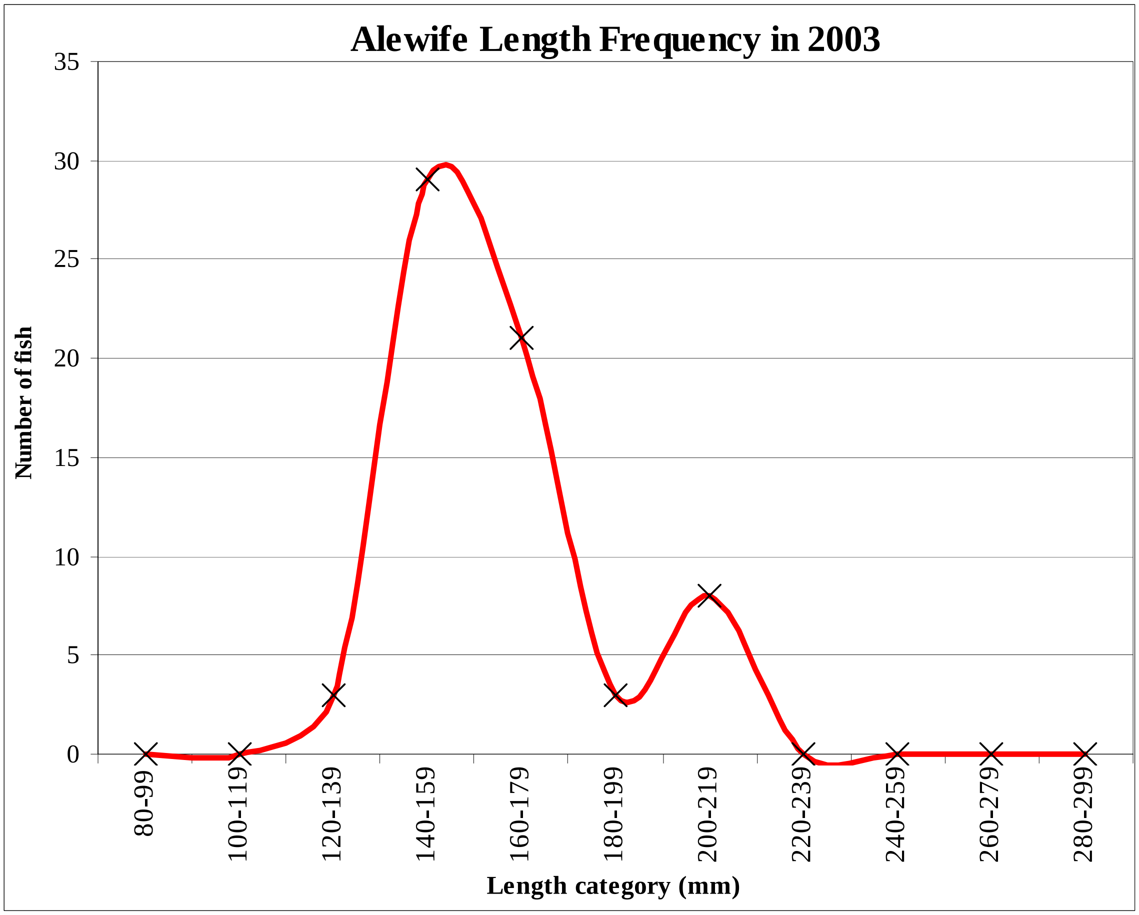


Figure 3-19. Alewife length frequency distribution in Onondaga Lake in 2003.

alewife size observed in Onondaga Lake in 2003 has been documented as age-1 in Oneida and Canadarago Lakes (Dr. Lars Rudstam, Cornell Biological Field Station, personal communication).

3.5.2.3 Age-0 Fish

Because many age-0 fish are planktivores for at least part of their early life stage they can have extensive effects on zooplankton communities, particularly if large numbers of age-0 gizzard shad are present (Dettmers and Stein 1992; Shepherd and Mills 1996). Larval gizzard shad feed almost exclusively on zooplankton (Yako *et al*. 1996; Shepherd and Mills 1996). High densities of larval shad can deplete zooplankton depending on zooplankton size structure and production (Dettmers and Stein 1992; Yako *et al*. 1996; Shepherd and Mills 1996). Mills *et al.* (1987) found that mean zooplankton size decreased as the abundance of age-0 fish increased. Gape (mouth) size may play an important role in how shad larvae structure zooplankton communities (Dettmers and Stein 1992). Small larvae (5-17 mm) predominately consumed small zooplankton such as nauplii and copepodites (Dettmers and Stein 1992). Larger larvae (18-24 mm) and juveniles primarily consume cladocerans (Dettmers and Stein 1992).

Annual patterns of age-0 fish were reviewed (Figure 3-20). Larval shad were at their highest density in 2000 and then show a substantial decrease from 2001-2003. In 2003, larval shad were at their lowest level

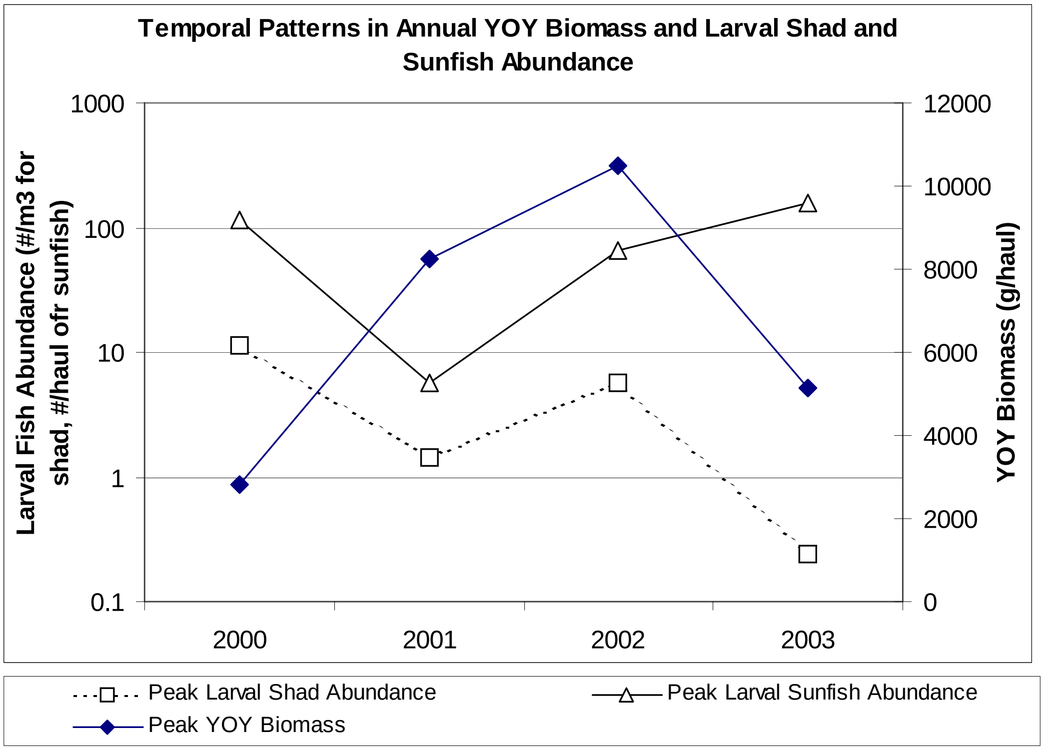


Figure 3-20. Changes in age-0 fish abundance in Onondaga Lake from 2000-2003. Note: larval fish are represented as abundance measures while YOY fish are represented by biomass.

of the four-year monitoring program. If larval shad were present in high enough densities to structure the zooplankton community then the most obvious impacts would have been in 2000 when larval density was highest. The fact that zooplankton community changes occurred in late 2002 and all of 2003, when larval shad was low, makes it highly unlikely that predation by age-0 gizzard shad played a significant role in the zooplankton community change.

Larval sunfish abundance was analyzed because they tend to be one of the dominant age-0 fish in the lake. If their density was high enough, they may be capable of affecting the structure of the zooplankton community. Larval sunfish show a steady increase from 2001 to 2003; however levels in 2002 and 2003 were generally comparable to 2000 when no shift in zooplankton community dynamics was observed. It seems unlikely that the observed pattern in sunfish larval abundance could account for the dramatic zooplankton changes starting in late summer 2002.

YOY biomass shows a steady increase from 2000 to 2002 then, in 2003, drops to levels intermediate between those documented in 2000 and 2001. It would be expected that if YOY were the cause of the zooplankton community change that there would be unusually strong year classes produced either in 2002, 2003 or both. This is not the case. There appears to be no pattern consistent with YOY fish causing the zooplankton community change.

Since the changes in zooplankton population began in 2002 and continued through 2003, it is unlikely that age-0 fish alone could have restructured the community. It is more likely that changes were influenced by alewives late in 2002 and again throughout 2003.

3.6 DISCUSSION

3.6.1 “Top-down” vs. “Bottom-up” Factors Affecting Lake’s Ecosystem

Top-down control is the result of cascading trophic effects; in this case, the pressure exerted by grazing zooplankton, which are in turn controlled by planktivorous fish. Bottom-up control refers to the resources available for primary production, namely nutrients, light, and adequate temperature conditions. Under current conditions, Onondaga Lake is not yet nutrient limited; consequently, top-down controls may have the larger effect on the phytoplankton community. Once the additional phosphorus removal at Metro comes on line, nutrients may control phytoplankton productivity.

Since late 2002, the zooplankton community of Onondaga Lake has experienced the disappearance of large-sized organisms, which are the most effective phytoplankton grazers. Given this scenario, an increase in phytoplankton biomass would be expected. Indeed, annual average biomass data for 2003 shows an increase when compared to 2001 and 2002 (refer to Figure 3-5). Peak biomass during the sampling season is higher than in either of the two preceding years but still within the range of recent data (refer to Figure 3-1).

3.6.2 Implications for Improvements

It is possible that, unless phosphorus inputs are reduced and reach limiting concentrations in the upper waters, the disappearance of large-sized zooplankton in Onondaga Lake will result in higher standing crops of phytoplankton and reduced water clarity. Since this is not a desired outcome, efforts to understand the interactions of the zooplankton-fish community should be pursued with the goal of restoring the large-sized zooplankton in the lake.

3.6.3 Implications and Recommendations for the AMP

It is evident from this discussion that the biological interactions play a significant role in structuring the phytoplankton community. In order to quantify the abundance of alewives in Onondaga Lake, it may be necessary to conduct open-water gill netting in conjunction with hydroacoustical sampling. Littoral electrofishing is not as reliable in estimating the abundance of pelagic schooling species such as the alewife.

No recent diet analysis of planktivores in Onondaga Lake has been conducted so it is not certain if facultative planktivores such as shad and white perch are feeding primarily on zooplankton or other food items. Limited diet analysis of at least alewives is warranted given their potential for drastically altering the zooplankton community. A limited diet analysis of gizzard shad may also be warranted. Gizzard shad are a particularly problematic species to conduct diet analysis on due to the poor condition of food items in their stomach. It is possible to determine the relative dietary proportion of zooplankton versus detritus for gizzard shad by means of multiple stable isotope analysis. The cost and feasibility of this analysis should be reviewed if shad again become a dominant species.

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CHAPTER 4

PROGRESS TOWARDS IMPROVEMENT

The primary objective of the County's monitoring effort is to provide the data and information needed to assess the effectiveness of the improvements to the wastewater collection and treatment system that are underway. Each year, water quality and habitat conditions are reviewed in context of compliance with ambient water quality standards and progress towards use attainment. A series of metrics or indicators are used to summarize current conditions related to specific uses (Table 4-1). These metrics share several specific properties: they relate directly to an impairment of the lake and watershed; they relate to a resource of interest; they correspond to a regulatory limit that, in turn, reflects the requirements of public health or the aquatic biota; and they can be measured and interpreted with relative ease. Indicators that help answer basic questions of the community: is the lake getting better, is it safe for my family to swim here, can we eat the fish, are of great value in public outreach.

Quantitative metrics are proposed for four categories of use attainment:

(1) water contact recreation;
(2) aesthetics;
(3) aquatic life protection; and
(4) sustainable recreational fishery

Note that these categories describe human use of the resource as well as attributes of the ecosystem itself. These categories were defined to be consistent with public perception and regulatory determinations of use attainment.

Metrics for water contact recreation are straightforward: New York State Dept. of Health and EPA have standards and guidance values for indicator bacteria and water clarity that are designed to be protective of human health and safety. Selecting metrics for aesthetics is slightly more judgmental, as they relate to perceived attributes such as water color and clarity, odors, and the visible extent of weed and algal growth.

TABLE 4-1

Summary of Metrics: Onondaga Lake Report Card

Desired Use	Metrics	Measured By
Water contact recreation	Indicator Bacteria	Fecal coliform bacteria at nearshore and South Deep station
	Water Clarity	Secchi disk transparency at nearshore stations
Aesthetics	Water clarity	Secchi disk transparency at South Deep
	Bloom frequency and magnitude	Percent of chlorophyll-*a* measurements greater than 15 µg/l (moderate bloom)
		Percent of chlorophyll-*a* measurements greater than 30 µg/l (intense/nuisance bloom)
	Algal community structure	Percent non-blue green taxa.
Aquatic Life Protection	Ammonia N	Percent of measurements in compliance with standards.
	Nitrite N	Percent of measurements in compliance with standards.
	Dissolved Oxygen	DO at fall mixing.
Fish Reproduction	Indicator species with documented successful reproduction	Compare with list developed by Onondaga Lake Technical Advisory Committee and other experts based on habitat and nature of open system.
	Species found in the lake	Percent intolerant or moderately intolerant
	Habitat quality	Percent cover of macrophytes: scaled to optimal level for largemouth bass (40 - 60% cover is target).

Water quality conditions needed to support aquatic life are fairly well defined in federal criteria and state standards. The metrics consider water quality conditions both throughout the year, and during critical periods for reproduction and early life stages. Also included are indices related to habitat quality for reproductive success of a warmwater fish community. Other indices related to the recreational fishery include the number of nests, and the presence and abundance of various life stages of warmwater fish. Calculations for these metrics using the 2003 AMP data are presented in Table 4-2.

In addition to these summary tables, detailed tables are prepared each year to tie together the design of the AMP and the specific hypotheses to be tested with recent results, trends, and tools used for analysis. Detailed tables (Tables 4-3 through 4-14) are included in this chapter that address nutrients (N and P) and lake response, including trophic status indicators, compliance with standards, and structure of the biological communities.

TABLE 4-2

2003 Results Onondaga Lake Water Quality and Habitat Metrics

Issue: Water Contact Recreation		
Metric (using June - September data)	**Goal**	**2003 Results**
Percent of water clarity measurements > 4 ft; (1.2 m) Segment B nearshore stations	100%	66%
Percent of water clarity measurements > 4 ft (1.2 m) Segment C nearshore stations	100%	27%
Percent of *E. coli* bacteria samples in compliance; Segment B nearshore stations	100%	98%
Percent of *E. coli* bacteria samples in compliance; Segment C nearshore stations	100%	83%
Percent of F. coli bacteria samples in compliance; Segment B nearshore stations	100%	100%
Percent of F. coli bacteria samples in compliance; Segment C nearshore stations	100%	92%
Metric (using all data)	**Goal**	**2003 Results**
Percent of *E. coli* bacteria samples in compliance; Segment B nearshore stations	100%	98%
Percent of *E. coli* bacteria samples in compliance; Segment C nearshore stations	100%	82%
Percent of F. coli bacteria samples in compliance; Segment B nearshore stations	100%	100%
Percent of F. coli bacteria samples in compliance; Segment C nearshore stations	100%	92%
Issue: Aesthetics		
Metric	**Goal**	**2003 Results**
Water clarity > 5 ft (1.5 m) at mid-lake station (South Deep)	100 %	45%
Algal abundance low in summer (chlorophyll-*a* < 15 µg/l in 85% of measurements)	>85%	31%
Lake is free of nuisance algal blooms 90% of time (nuisance algal bloom = chlorophyll-*a* > 30 µg/l)	>90 %	46%
Blue-green algal abundance is low (< 10% of community biomass)	<10%	15%
Issue: Aquatic Life Protection		
Metric	**Goal**	**2003 Results**
Dissolved oxygen > 5 mg/l during turnover; (daily average) >4 mg/l (minimum)	>5 mg/l; >4mg/l	Yes
NH_3-N meets standards in 100% of measurements throughout the year	100%	98%
Nitrite meets standards in 100% of measurements throughout the year	100%	55%
Issue: Fish Reproduction		
Metric	**Goal**	**2003 Results**
Reproduction of target species in the lake: • largemouth bass, smallmouth bass, and sunfish • yellow perch • black crappie and rock bass • walleye and northern pike	• Occurring • Occurring • Occurring • Occurring	• Occurring • Variable • Limited • None
Percent intolerant or moderately intolerant species in Lake	>25%	10%
Percent macrophyte cover of littoral zone, based on optimal habitat for largemouth bass {note: most recent survey data are from 2000}	40%	10%

TABLE 4-3

PROGRESS TOWARDS WATER QUALITY IMPROVEMENT: AMMONIA-N
Onondaga Lake 2003 Annual Report
Onondaga County, New York

(Water Quality Standard)

AMP Program Objective	
Compliance with the applicable ambient water quality standard in the upper waters and/or removal of ammonia toxicity as impairment to designated best use for survival and propagation of a warmwater fish community.	
Baseline Conditions	
Major Sources	Metro effluent. 1988-2003 mean contribution: 89.9% (S.D. 3.6) 2003 contribution: 84.2%
Upper waters concentration	Annual mean 1988-2003: 1.6 mg/l (S.D. 0.68) 2003: 0.76 mg/l Decreasing trend 1990–1999; relatively stable since 2000
Compliance with NYS Ambient Water Quality Standard in Upper Waters (April 1 – December 1)	Annual mean 1992 – 2003: 106 days of non-compliance (S.D. 76) 2003: 0 days of non-compliance during sampling period *(no winter sampling in 2003)*
Factors Affecting Compliance	Hydrology, Metro performance, pH and temperature of receiving water
Planned Load Reductions (1998 – 2012)	
Metro SPDES Permit Requirement ***NOTE: The County is currently projected to meet the Stage 3 limits by May 1, 2004, 8 years ahead of schedule***.	Stage 1 Limit: Cap on Loading (effective Jan. 1998) • July 1 – Sept. 30: 8700 ppd (as NH_3) • Oct. 1 – June 30: 13,100 ppd (as NH_3) Stage 2 (effective May 1, 2004): • June 1 – Oct. 31: 2.0 mg/l (as NH_3) • Nov. 1 – May 31: 4.0 mg/l (as NH_3) Stage 3: (effective Dec. 2012) • June 1 – Oct. 31: 1.2 mg/l (as NH_3) • Nov. 1 – May 31: 2.4 mg/l (as NH_3) Or as required by a revised TMDL (anticipated in 2009)
Monitoring and Assessment Program	
Hypothesis to be tested (H_0)	Implementation of load reductions will have no impact on compliance with the ambient water quality standard.
Loading estimates	Annual County monitoring program • Biweekly tributary monitoring, supplemented with samples collected during high flow conditions • Daily measurements of Metro effluent
Lake Monitoring	Annual County monitoring program • Biweekly profiles in Lake, April –Nov; additional sampling during fall mixing (mid Oct – mid-Nov) • Winter sampling as weather allows
Related Biological Monitoring	• Assessment of fish community began in 2000 • Annual zooplankton monitoring
Tools for Decision Making	
Models	• Upstate Freshwater Institute's nitrogen model dated 4/1/93 (prepared for NYSDEC). • Proposal for new model under review (11/04)
TMDL Allocations	NYSDEC Phase I TMDL 8/27/97 Phase II TMDL by January 2009
Ambient Water Quality Criteria and Standards	NYSDEC to review and revise of ammonia standards to be consistent with federal criteria.

TABLE 4-4
PROGRESS TOWARDS WATER QUALITY IMPROVEMENT: NITRITE-NITROGEN
Onondaga Lake 2003 Annual Report
Onondaga County, New York

(Water Quality Standard)

AMP Program Objective	
Compliance with the applicable ambient water quality standard in the upper waters and/or removal of toxicity as an impairment to designated best use for survival and propagation of a warmwater fish community.	
Baseline Conditions	
Major Sources (NO2-N)	
Upper waters concentration	Annual mean 1992-2003: 0.131 mg/l (S.D. 0.048) 2003: 0.102 mg/l Decreasing trend 1990–1999; relatively stable since 2000
Compliance with Ambient Water Quality Standard in Upper Waters	Percent of observations in violation of standard 1992 – 2003: 50.8% 2003: 46% (peak in fall)
Factors Affecting Compliance	Hydrology, Metro performance, pH and temperature of receiving water
Planned Load Reductions (1998 – 2012)	
Metro SPDES Permit Requirement	No numerical limit for nitrite in SPDES permit Monitor only (one sample per week)
Monitoring and Assessment Program	
Hypothesis to be tested (H_0)	Implementation of nitrification of Metro effluent and other loading reductions will not affect compliance with the ambient water quality standard for nitrite.
Loading estimates	Annual County monitoring program • Biweekly tributary monitoring, supplemented with samples collected during high flow conditions • Daily measurements of Metro effluent
Lake Monitoring	Annual County monitoring program • Biweekly profiles in Lake, April –Nov • Additional sampling during fall mixing (10/15 – 11/15) • Winter sampling as weather allows
Related Biological Monitoring	• Assessment of fish community, beginning in 2000 • Annual zooplankton monitoring
Tools for Decision Making	
Models	• Upstate Freshwater Institute's nitrogen model dated 4/1/93 (prepared for NYSDEC). • Proposal for new lake model under review (11/04)
TMDL Allocations	None planned
Ambient Water Quality Criteria and Standards	Standard is 100 μg/l (0.1 mg/l)

TABLE 4-5
PROGRESS TOWARDS WATER QUALITY IMPROVEMENT: TOTAL PHOSPHORUS
Onondaga Lake 2003 Annual Report
Onondaga County, New York

(Guidance Value)

AMP Program Objective	
Reduction in phosphorus sufficient to reduce the frequency and duration of nuisance algal blooms. Eliminate turbidity as an impairment to use of the lake for secondary water contact recreation (Class C segment) and primary water contact recreation (Class B segment). Compliance with narrative standard and site-specific guidance value appropriate for this urban lake considering all watershed sources of phosphorus.	
Baseline Conditions	
Major Sources	Metro effluent: 1988-2003 average contribution: 62.4% (S.D.11.3) 2003:62.9% (outfalls 001 and 002) Nonpoint sources
Upper waters concentration (summer average)	1986 – 2003: 0.076 mg/l (S.D. 0.035) 2003: 0.066 mg/l
Compliance with Ambient Water Quality Standard and Guidance Value	Narrative standard for phosphorus not met Guidance value (0.020 mg/l summer average upper waters) not met
Factors Affecting Compliance	Hydrology, Metro performance, land use in watershed, CSO performance
Planned Load Reductions (1998 – 2012)	
Metro SPDES Permit Requirement ***NOTE: The County is currently projected to meet or exceed the Stage 2 limits by end of 2004 or early 2005***	Stage 1 Limit: Cap on Loading (effective Jan. 1998) • 400 pounds TP per day (ppd) 12 month rolling average Stage 2 (effective April 2006): • Metro effluent TP 0.12 mg/l Stage 3: (effective Dec. 2012) • Metro effluent TP at 0.020 mg/l • Watershed nonpoint source reduction of approximately 50% (includes CSOs)
Monitoring and Assessment Program	
Hypothesis to be tested (H_0)	The point and nonpoint source control program will not reduce phosphorus concentrations in Onondaga Lake to meet a site-specific guidance value based on recreational water use.
Loading estimates	Annual County monitoring program • Biweekly tributary monitoring, supplemented with samples collected during high flow conditions • Daily measurements of Metro effluent • Storm event monitoring in tributaries
Lake Monitoring	Annual County monitoring program • Biweekly profiles of P fractions (TP, SRP, TDP), plus N species, DO and carbon species, April – Nov • Chlorophyll *a* and Secchi disk transparency, LiCor measurements • Winter sampling as weather allows
Related Biological Monitoring	• Annual phytoplankton and zooplankton monitoring • Macrophyte survey every five years (began in 2000)
Tools for Decision Making	
Models	• Upstate Freshwater Institute (UFI) phosphorus model dated 4/1/93 • Mass balance model of W. Walker predicts concentration of P, N, C and LWL oxygen depletion rate. Model includes empirical relationships between nutrients and trophic state indicators. • Eutrophication model by HydroQual for PTI (AlliedSignal RI/FS) • USGS watershed model for Onondaga Lake Partnership • Proposal for new lake model under review (11/04)
TMDL Allocations	NYSDEC Phase I TMDL 8/27/97, Phase II TMDL by January 2009
Ambient Water Quality Criteria and Standards	Guidance value for TP in lake upper waters

TABLE 4-6
PROGRESS TOWARDS WATER QUALITY IMPROVEMENT: DISSOLVED OXYGEN (DO)
Onondaga Lake 2003 Annual Report
Onondaga County, New York

(Water Quality Standard)

AMP Program Objective	
• Reduce volume-days of anoxia (i.e., improve temporal duration and spatial extent of aerobic habitat) • Maintain daily average DO > 5 mg/l throughout the water column during fall mixing. • Maintain DO > 3.0 mg/l above the LWL at least 80% of the time to provide suitable habitat for cool water fish such as walleye and tiger musky.	
Baseline Conditions	
Major Sources	Oxygen depletion in the LWL is primarily due to decomposing algal biomass (excess algae is caused by phosphorus load). Other sources include ultimate oxygen demand from organic material and reduced nitrogen species (primarily ammonia from Metro)
UML concentration during fall mixing	Average minimum concentration (1988 – 2003 data) 3.9 mg/l (S.D. 1.4) 2003 instantaneous minimum: 3.9 mg/l (1/14/03, duration <6 hours)
Volume-days of anoxia	**Anoxia**: Average 1992 – 2003: 5134 10^6 m^3-days (S.D.1359) **Less than 2 mg/l**: Average 1992 – 2003: 6106 10^6 m^3-days (S.D.1394) **2002 conditions**: 5325 10^6 m^3-days anoxia; 5966 10^6 m^3-days ≤ 2 mg/l
Factors Affecting Compliance	- Meteorology, algal abundance (related to phosphorus load) - NH3-N concentration and dynamics
Planned Load Reductions (1998 – 2012)	
Metro SPDES Permit Requirement	See staged effluent limits for TP BOD limit through 2001: 21 mg/l (30 day average)
Monitoring and Assessment Program	
Hypothesis to be tested (H_0)	Implementation of improvements at Metro, including reduction in load of phosphorus and ultimate oxygen demand, will not achieve compliance with the ambient water quality standard for DO during fall mixing, or reduce the volume-days of anoxia.
Loading estimates	Annual County monitoring program • Biweekly tributary monitoring, supplemented with samples collected during high flow conditions to estimate TP, N and BOD inputs • Daily measurements of Metro effluent • Storm event monitoring in tributaries
Lake Monitoring	Annual County monitoring program • Biweekly DO profiles in Lake, April – Nov • Intensive sampling in fall, included nearshore areas and mouths of tributaries • Monitoring buoy installed at South Deep for near-continuous data logging including DO (April – Nov) • Winter sampling as weather allows
Related Biological Monitoring	• Annual phytoplankton monitoring • Annual zooplankton monitoring • Limited tracking of fish movement during fall mixing • Fish tagging program
LWL Oxygenation Demonstration Project	• Began in summer 2003 with detailed workplan preparation • Feasibility report by ENSR fall 2004
Tools for Decision Making	
Models	• UFI oxygen model dated 4/1/93 • HydroQual preliminary eutrophication model for PTI • Dr. Walker mass-balance models and link to empirical eutrophication (including LWL oxygen depletion rate) • Proposal for new lake model under review (11/04)
TMDL Allocations	NYSDEC Phase I TMDL for phosphorus 8/27/97 Phase II TMDL for phosphorus by January 2009
LWL Oxygenation Demonstration Project	Analysis of approach, feasibility, risk, and environmental benefits

TABLE 4-7
PROGRESS TOWARDS WATER QUALITY IMPROVEMENT: BACTERIA
Onondaga Lake 2003 Annual Report
Onondaga County, New York

(Water Quality Standard)

AMP Program Objective Compliance with the standards for water contact recreation in the Class B segment and for secondary water contact recreation in Class C segment of Onondaga Lake	
Baseline Conditions	
Major Sources	Combined sewer overflows (major), sanitary sewer overflows (rare) Urban runoff (stormwater) Metro effluent (chlorination period April 1– Oct 15) and by-pass (Outfall 002) Other sources (wildlife, birds, etc.)
Upper waters concentration	Fecal coliform: 1988 – 2003 annual average: 90 cells/100 ml (S.D. 53) (Measured in surface waters, South Deep) 2003 average: 82 cells/100 ml No trend
Near shore stations (2003 F. coli average)	Maple Bay 12 cells/100 ml (S.D.12); summer compliance: 100% Willow Bay 11 cells/100 ml (S.D.9); summer compliance: 100% Ninemile Cr. 15 cells/100 ml (S.D. 15); summer compliance: 100% Eastside 13 cells/100 ml (S.D. 17); summer compliance: 100% Bloody Brook 21 cells/100 ml (S.D.34); summer compliance: 100% Mid-south: 160 cells/100 ml (S.D. 466); summer compliance: 89% Ley Creek: 235 cells/100 ml (S.D. 826); summer compliance: 88% Harbor Brook : 75 cells/100 ml (S.D. 122); summer compliance: 88%
Compliance with Ambient Water Quality Standard	South Deep Station: 2003 results: 97% compliance during summer; 93% compliance overall
Factors Affecting Compliance	Metro disinfection, extent of CSO and Sanitary Sewer Overflow (SSO) Meteorological conditions (rainfall, temperature, sunlight, winds) Lake water quality (turbidity); Abundance of waterfowl
Planned Load Reductions (1998 – 2012)	
Metro SPDES Permit Requirement Staged CSO remediation	Seasonal disinfection (4/1 – 10/15) of Metro effluent required CSO phased plan to capture combined sewage and stormwater: • Stage 1 captures 62% of volume through best management practices • Stage 2 eliminates and/or captures 85% of volume and provides equivalent of primary treatment.
Monitoring and Assessment Program	
Hypothesis to be tested (H_0)	Implementation of Stage 1 and 2 improvements to the wastewater collection and treatment system (including CSO projects) will have no effect on concentration of indicator organisms in Onondaga Lake (nearshore and South Deep) and tributaries.
Loading estimates	Annual County monitoring program • Biweekly tributary monitoring supplemented with samples collected during high flow conditions (fecal coliform bacteria) • Daily measurements of Metro (001 and 002 if active) for fecal coliform • Storm event monitoring in tributaries, (Fecal coliform)
Lake Monitoring	Annual County monitoring program (fecal coliform, E. coli) • Weekly monitoring at South Deep, Class C segment (May – Sept.) • Eight nearshore stations weekly (summer) and following storms
Tools for Decision Making	
Models	• UFI/Canale bacteria model (input loads, model routes bacteria using hydrodynamic routine, simulates bacteria die-off based on light and temperature, predicts bacteria concentration in lake cells). • Storm Water Management Model (simulates bacteria loads in tributaries from collection system given rainfall conditions)
TMDL Allocations	Based on presumptive approach: percent capture of combined storm and wastewater. Must account for urban stormwater.
Ambient Water Quality Criteria and Standards	NYS indicator bacteria standards include total and fecal coliform. EPA criteria now use *E. coli* (freshwater) and *Enterococcus* (marine water) as indicators; states encouraged to adopt *E. coli*

TABLE 4-8
PROGRESS TOWARDS WATER QUALITY IMPROVEMENT: CHLOROPHYLL-*a*
Onondaga Lake 2003 Annual Report
Onondaga County, New York

(Narrative Standard, Assessment Measure)

AMP Program Objective	
Reduction in average and peak algal biomass and frequency and duration of bloom conditions. Less than 10% chlorophyll *a* measurements exceed 30 µg/l (threshold for nuisance blooms) and Less than 25% chlorophyll *a* measurements exceed 15 µg/l	
Baseline Conditions	
Major Sources	Internal algal production based on nutrients (P approaching limiting conditions by late 1990s), light, temperature
Upper waters concentration Summer average (mid-May through mid-September) 1992 – 2003 data	1992 – 2003 20% observations >30 µg/l; 47% observations >15 µg/l Mean 18.2 µg/l (S.D. 18.2) Peak 114 µg/l (August 2003) Increasing trend 1993 – 2003 at South Deep 2003: 31 % observations >30 µg/l; 69 % observations >15 µg/l 2003 summer mean 30.4 µg/l; summer peak 114.3 µg/l (8/05/03) Annual peak 114.3 µg/l (8/05/03)
Compliance with Ambient Water Quality Standard and Guidance Value	No NY State standard or guidance value for chlorophyll *a.* Narrative P standard references algal abundance at nuisance levels Federal guidance based on ecoregion and reference lakes.
Factors Affecting Compliance	Nutrients, light, temperature, grazing pressure
Planned Load Reductions (1998 – 2012)	
Metro SPDES Permit Requirement	• See planned reduction in TP from Metro • Staged reductions in CSOs
Monitoring and Assessment Program	
Hypothesis to be tested (H_0)	Implementation of load reductions at Metro and improvements to the wastewater collection system (CSO remediation) will have no impact on the concentration of chlorophyll *a* in Onondaga Lake.
Lake Monitoring	• Weekly measurements at S. Deep, April – November
Related Biological Monitoring	• Phytoplankton community measurements biweekly April and October – November; weekly May – September • Zooplankton community measurements biweekly April-November
Tools for Decision Making	
Models	• HydroQual eutrophication model for AlliedSignal, not complete • UFI lake models (phytoplankton is not modeled, chlorophyll is based on measured conditions in 1989, increased or decreased proportionally based on TP concentrations). • Dr. William Walker's mass balance TP framework and linked empirical eutrophication model.
TMDL Allocations	See discussion of TP

TABLE 4-9
PROGRESS TOWARDS WATER QUALITY IMPROVEMENT: SECCHI DISK TRANSPARENCY
Onondaga Lake 2003 Annual Report
Onondaga County, New York

(Guidance Value)

AMP Program Objective Summer average Secchi disk transparency at South Deep at least 1.5 m (for aesthetic quality); transparency at nearshore stations at least 1.2 m daily during recreational season (bathing beach swimming safety guidance value).	
Baseline Conditions	
South Deep Station (June 1 – Sept 30 average)	Mean 2.0 m (1990 – 2003, N=195) Standard deviation 1.218 m Increasing trend.
Compliance with Ambient Water Quality Standard and Guidance Value	**South Deep Station** 80% of observations during this 12-year period met or exceeded swimming safety guidance value of 1.2 m ; 64 % met or exceeded 1.5 m (associated with NYSDEC aesthetic guidance of 20 ug/l TP) 2003 conditions: 1.3 m June – Sept. average (S.D. 0.38 m) 67 % $\geq$ 1.2 m 44 % $\geq$ 1.5 m **Nearshore Stations**: track compliance with 1.2 m (swimming) Bloody Brook: summer compliance: 64% Eastside: summer compliance: 85% Harbor Brook : summer compliance: 30% Ley Creek: summer compliance: 27% Maple Bay: summer compliance: 76% Nine Mile Creek: summer compliance: 70% Mid-south: summer compliance: 21% Willow Bay summer compliance: 88%
Factors Affecting Compliance	• Algal abundance (depends on light, temperature, nutrients and grazing pressure) • External loading of suspended solids • Resuspension of bottom sediments • Precipitation of calcite
Planned Load Reductions (1998 – 2012)	
Metro SPDES Permit Requirement	• Staged reduction in TP load from Metro • Staged implementation of CSO projects
Monitoring and Assessment Program	
Hypothesis to be tested (H_0)	Implementation of load reductions at Metro and improvements to the wastewater collection system (CSO remediation) will have no impact on the water clarity of Onondaga Lake as measured by Secchi disk transparency.
Lake Monitoring	• Biweekly measurements of Secchi disk at South Deep (increased to weekly between 6/1 and 9/30) • Nearshore Secchi disk measurements: baseline, summer weekly and following storm events
Related Biological Monitoring	Phytoplankton and zooplankton abundance and community composition
Tools for Decision Making	
Models	• Empirical relationship between TP and Secchi disk transparency, in UFI TP management model • Dr. William Walker's mass balance TP framework and linked empirical eutrophication model. • Proposal for new lake model under review (11/04)

TABLE 4-10
PROGRESS TOWARDS WATER QUALITY IMPROVEMENT: PHYTOPLANKTON
Onondaga Lake 2003 Annual Report
Onondaga County, New York

(Assessment Measure)

AMP Program Objective	
Abundance and composition of the algal community typical of a eutrophic lake in the same geologic and climatic setting. Decreased importance of cyanobacteria (blue-green algae).	
Baseline Conditions	
Biomass and Community composition	• 1968 – 1996 (Dr. Philip Sze, Georgetown University) Abundance of major groups • 1997 – present (Dr. Edward Mills, Cornell Biological Field Station and Dr. Anne St. Armand, PhycoTech Inc.), Biomass and biovolume • Qualitative discussion of trends in annual lake reports, also in Effler (ed.) 1996 • Chapter 3 of 2003 AMP report presents detailed evaluation of lower trophic levels
Forcing functions	Nutrients, light, temperature, grazing pressure
Monitoring and Assessment Program	
Hypothesis to be tested (H_0)	Implementation of load reductions at Metro and improvements to the wastewater collection system (CSO remediation) will have no impact on the phytoplankton community (as tracked by duration, frequency, intensity of blooms and percent composition of blue-green algae) of Onondaga Lake
Lake Monitoring	<u>Biweekly sampling events</u>: • Phytoplankton abundance (number per liter) • Biomass (µg/l) • Composition of the algal community (7 major groups) • Cell size divisions (nannoplankton and netplankton) <u>Metrics to track over time</u>: • Percent of major taxa • Blue-green algae dynamics and shifts in N:P ratio of lake water • Number of taxa (1995 and later) • Diversity (1995 and later) • Percent dominance (1995 and later)
Tools for Decision Making	
Models	Proposal for new lake model under review (11/04)

TABLE 4-11
PROGRESS TOWARDS WATER QUALITY IMPROVEMENT: ZOOPLANKTON
Onondaga Lake 2003 Annual Report
Onondaga County, New York

(Assessment Measure)

AMP Program Objective	
Abundance and composition of the zooplankton community are comparable to reference eutrophic lake in same geologic and climatic setting.	
Baseline Conditions	
Biomass and Community composition	Density (numbers per ml for major types) documented since late 1960's (Sze, 1968 – 1996; Mills 1997 – present) Qualitative discussion in annual reports, also in Effler (ed.) 1996 Since 1995, biomass of organisms reported
Forcing functions	Food supply (algal abundance) grazing pressure (fish community structure), water quality (ammonia, chlorides, extent of aerobic habitat)
Monitoring and Assessment Program	
Hypothesis to be tested (H_0)	Implementation of load reductions at Metro and improvements to the wastewater collection system (CSO remediation) will have no impact on the zooplankton community of Onondaga Lake (as tracked by abundance, species composition, and average size).
Lake Monitoring	• Biweekly monitoring for density (organisms per ml) and biomass (μg/l), April – November/December *Metrics to track over time* • Average size in spring (June 1 – 15) and fall (Sept. 1 – 15) • Relative biomass of major cladoceran types • Relative biomass of major copepod types • Number of crustacean taxa (1995 on)
Tools for Decision Making	
Models	None developed

TABLE 4-12
PROGRESS TOWARDS WATER QUALITY IMPROVEMENT: MACROPHYTES
Onondaga Lake 2003 Annual Report
Onondaga County, New York

(Assessment Measure)	
AMP Program Objective	
Expansion of the areal coverage and increase in diversity of macrophyte community. Number of species and biomass of macrophytes in the littoral zone comparable to other regional lakes. Increase percent cover of littoral zone to optimal levels for smallmouth bass (40 – 60%).	
Baseline Conditions	
Biomass	1991 survey (John Madsen, Army Corps of Engineers) reported number of transects with macrophytes present, no biomass or percent littoral zone coverage noted. 2000 survey (Onondaga County), species richness, percent cover, biomass, diversity
Community composition	Five species present in 1991 survey. In comparison, NY lakes average 18, Oneida has approx 16 species. Cross Lake has 5. No emergent or floating leaf species were present in Onondaga in 1991. In 2000, species richness doubled (to 10 species) but community dominated by only 3 plants. Percent cover about 12% of littoral zone. Distinct habitat zones present.
Forcing functions	• Sediment texture (oncolites are nutrient-poor and unstable, shifting with wind-driven waves in nearshore area) • Light penetration • Salinity levels • Harvesting by waterfowl
Monitoring and Assessment Program	
Hypothesis to be tested (H_0)	Implementation of load reductions at Metro and improvements to the wastewater collection system (CSO remediation) will have no impact on the macrophyte community of Onondaga Lake (as tracked by percent cover, species richness and depth to which plants grow).
Lake Monitoring	• Survey species composition and biomass every 5 years, beginning in 2000. • Annual aerial photographs of littoral zone to estimate percent cover (if water clarity and cloud cover conditions adequate) *Metrics to track over time* • Number of species (richness) • Percent cover • Biomass
Tools for Decision Making	
Qualitative and quantitative assessment	Compare to baseline survey in 2000 “Proof of technology” investigation to evaluate automated processing of aerial photos for use in estimating percent cover of the littoral zone was completed in 2003. This was a cooperative program between the SUNY-ESF NASA Affiliated Research Center (ARC), OCDWEP, and EcoLogic LLC.

TABLE 4-13
PROGRESS TOWARDS WATER QUALITY IMPROVEMENT: MACROINVERTEBRATES
Onondaga Lake 2003 Annual Report
Onondaga County, New York

(Assessment Measure)

AMP Program Objective	
The macroinvertebrate community is designated by NYSDEC Macroinvertebrate Biological Assessment Profile as slightly impacted or better at all sites.	
Baseline Conditions	
NYSDEC Biological Assessment Profile	Based on 2000 survey: • One site slightly impacted • Three sites moderately impacted • One site severely impacted
Community composition	Baseline conditions: more than 70 taxa in the lake's littoral zone. Communities dominated by oligochaetes and chironomids.
Forcing functions	• Sediment texture • Sediment contamination • Eutrophication • Ammonia
Monitoring and Assessment Program	
Hypothesis to be tested (H_0)	Implementation of load reductions at Metro and improvements to the wastewater collection system (CSO remediation) will have no impact on the littoral macroinvertebrate community of Onondaga Lake (as tracked by NYSDEC macroinvertebrate indices).
Lake Monitoring	A total of 180 littoral samples collected in 2000 (baseline monitoring was completed in 1999 to finalize program design). Sampling included 36 replicates from water depths 1.0 – 1.5 m in each of 5 strata (defined based on substrate composition and wind energy). Subsequent sampling (2005, 2010) to include 90 samples (18 replicates in 5 strata), following statistical evaluation of 2000 data.
Tools for Decision Making	
Metrics	• NYSDEC macroinvertebrate indices based on species diversity and presence/absence of pollution tolerant species. • Hilsenhoff Biotic Index • Percent oligochaetes

TABLE 4-14
PROGRESS TOWARDS WATER QUALITY IMPROVEMENT: FISH COMMUNITY
Onondaga Lake 2003 Annual Report
Onondaga County, New York

(Assessment Measure)

AMP Program Objective	
Expand habitat for fish community and promote water quality conditions that support diverse warmwater fish community. Self-sustaining sport fishery.	
Baseline Conditions	
Baseline Conditions	Community composed of pollution tolerant, warmwater species with a high proportion of planktivores. Many adult species show some evidence of reproduction in lake. Nesting mostly limited to north basin. Low incidence of deformities, erosions, lesions, tumors, and fungal infections.
Community composition	Warmwater fish community dominated by gizzard shad and carp. In 2003 saw re-emergence of alewife. Insectivorous sunfishes in littoral zone. Sport fish present (channel catfish, smallmouth bass, largemouth bass, walleye. Open connection with Seneca River important to community structure.
Forcing functions	• Ammonia toxicity • Extent of aerobic habitat • Abundance of preferred food sources • Habitat for spawning and juveniles
Monitoring and Assessment Program	
Hypothesis to be tested (H_0)	Implementation of load reductions at Metro and improvements to the wastewater collection system (CSO remediation) will have no impact on the fish community of Onondaga Lake (as tracked by species richness, diversity, relative abundance, pollution tolerance, trophic guilds, thermal guilds, location of nests, presence of early life stages, and angler catch rate).
Lake Monitoring	Annual monitoring, beginning in 2000 to assess reproductive success and community structure • Number and distribution of littoral nests • ID and enumerate larval fishes • ID and enumerate juvenile and YOY stages • ID and estimate (CPUE) of adult community using gillnets, electrofishing, and angler diaries • Assess and record DELT-FM anomalies
Tools for Decision Making	
Quantitative and qualitative analysis	Data collection techniques and data analysis comparable to standard procedures used throughout New York.

CHAPTER 5

RECOMMENDATIONS

1. NYSDEC and USEPA have selected Onondaga County to be the primary agency responsible for monitoring Onondaga Lake, the lake tributaries, and the Seneca River. The monitoring data will be used (along with other analyses) to update the state's Total Maximum Daily Load (TMDL) allocation for Onondaga Lake. Monitoring data will be used to evaluate the effectiveness of the improvements to Metro and the CSOs and the need for additional improvements. **Data screening and documentation of sampling and analytical procedures remain critically important and should remain a focus for DWEP.**

2. The success of the wastewater treatment plant improvements and progress towards recovery of Onondaga Lake are issues of great interest to many stakeholders, including state and local officials and the community at large. The AMP is designed and implemented with a commitment to high technical standards and an open process. Carefully designed methodologies, QA/QC protocols, and inter-laboratory comparisons have focused on maintaining the highest standards in laboratory data. In addition, the County has convened technical experts to review the program design, share data, and discuss findings. There is a parallel commitment to community outreach through the Onondaga County website, fact sheets, brochures, and user-friendly versions of the annual report. **Efforts to disseminate the findings of the AMP to the scientific community, water resources managers, and the interested public should continue.**

3. Several important initiatives have recently been completed that have greatly improved the collection, screening, handling and reporting of monitoring data. Two have directly affected preparation of the 2003 report:

   a) Creation and maintenance of an integrated database. Monitoring data are appended to the database following quality control review. The database was created by Dr. William Walker and is maintained by OCDWEP (status: completed March 2004).

   b) Refining the mass balance framework to generate daily load estimates. This refinement will support lake modeling, and maximize the use of the AMP tributary data that include routine (biweekly), high-flow, and storm-event sampling. Because the regression/

interpolation algorithm accounts for factors that are not considered in the loading algorithm used in previous years, this refined framework will improve the accuracy and precision of annual load estimates. {**Status: A draft product was completed by Dr. Walker in March 2004, modified in September 2004, and used to estimate the 2003 loads}.**

It is recommended that DWEP continue to work with Dr. Walker to verify the draft database, refine its user interface, and incorporate calculations of metrics designed to assess and report progress towards use attainment (for example, bloom frequency analyses). The possibility of incorporating the extensive phytoplankton and zooplankton data sets into the integrated database should be explored.

4. There are a number of significant initiatives underway in the Onondaga Lake watershed in addition to the AMP; many are funded and coordinated through the Onondaga Lake Partnership. Continued communications at the technical and policy levels will enhance the collective efforts to improve water quality and habitat conditions. For example, the U.S. Geological Survey (USGS) is investigating the sources and movement of saline groundwater and has documented discharge of brines to the Onondaga Creek bed. USGS is completing a watershed model of the lake. USGS regularly participates in the OLTAC meetings to report on their progress and coordinate data and information sources. **DWEP and OLTAC should continue to foster this collaborative approach to watershed management.**

5. Analysis of the 2003 biological data has resulted in several specific recommendations to further explore the impacts of the alewife on the lake's zooplankton community. **The Biological Working Group should convene to discuss approaches to estimating the size of the alewife population and its potential for impacting the Onondaga Lake food web {status: meeting held September 2004}.**

   Some specific suggestions are noted below.

   a) Set open water gill nets in late summer/early fall to determine if alewives are present and their relative abundance **{Status: completed October 2004}**
   b) Collect scales or otoliths from alewives to define the population's age structure. **{Status: completed October 2004}**
   c) Determine the feasibility of using hydroacoustics or other techniques to estimate the population of alewife in the lake. **{Status: completed October 2004}**

   d) Examine contents of fish stomach to confirm diet. **{Status: completed August 2004, results inconclusive, to be repeated}**

6. The trophic level assessment incorporated into Chapter 3 of the 2003 report provides evidence of a significant shift in the zooplankton community, with dramatic loss of larger organisms. **More frequent communication between the Cornell Biological Field Station personnel examining the zooplankton data and the AMP team is recommended as a way to respond more rapidly to new information and modify field efforts as needed to focus on the interaction of fish and zooplankton.**

7. Onondaga County has compiled highly detailed data describing the lake's phytoplankton community. There is a tremendous potential value for further exploration of the data, particularly from the perspective of functional groups as described by Colin Reynolds and other plankton ecologists. **It is recommended that the DWEP team work with Cornell University (or another suitable institution) and support a graduate student project exploring this rich data set with the ultimate goal of contributing to the scientific literature on environmental factors affecting structure and function of the lake's phytoplankton community.**

8. **The mass balance model for phosphorus should be updated using 2004 data and presented in the 2004 Annual Report** The mass balance model is an important tool that can provide guidance regarding some important issues related to lake management. For example, the relative contribution of internal sources of ammonia and phosphorus can be evaluated using the mass balance framework with the refined tributary loads that provide estimates on a seasonal or monthly, rather than annual, basis. Another example is the need to update the correlations between phosphorus, chlorophyll and water clarity. The recent increase in phytoplankton that appears to be related to the loss of larger zooplankton is not reflected in the empirical formulations that relate phosphorus to the probability of algal blooms. Dr. Walker recommends linking the spreadsheet containing the mass balance formulas to the database so that the calibration would be automatically updated each year.

9. The AMP is designed to provide data and information regarding existing conditions in the lake and watershed. In order to make informed decisions regarding the need for additional controls on point and nonpoint sources of pollution, a predictive model is needed. The

conceptual model summarized in Chapter 2 provides a foundation for a quantitative computer model of the lake to provide:

a) quantitative projections of the impacts of future reductions in Metro and nonpoint phosphorus and nitrogen loads on lake water quality,
b) projections of the impacts of Metro diversion on the lake,
c) support for the river model, in particular the critical linkage between the lake and Seneca River, in order to support evaluation of the impact of Metro diversion on the river,
d) a quantitative tool for assessing and managing bacterial contamination due to storm events (integrated with bacterial kinetics),
e) projections of the impacts of best management practices and land use changes in the watershed (linked with quantitative estimates of watershed nutrient loadings).

Ultimately a single, linked set of watershed/lake/river mathematical models will provide the most effective form of data integration and an efficient tool for developing long-term plans for both Metro operation and watershed management. Such a model is best developed using a phased approach as the costs and benefits associated with each component of the overall modeling effort must be evaluated as our understanding progresses: this conceptual model may be modified along the way, based on the accumulated knowledge and understanding of the system. **It is recommended that development of an integrated model begin, with full participation of the OLP and stakeholders.**

10. The storm event program is designed to assess the impacts of CSO abatement activities on loading and instream concentration of pathogens, phosphorus, and sediment. *Several specific recommendations have been developed:*
    a) **Continue to collect storm event data at the same locations, using comparable protocols to collect and analyze the samples.**
    b) **Monitoring of Bloody Brook and Sawmill Creek has confirmed that these small drainage areas contribute a negligible fraction of the storm-related loading of contaminants to the lake (each is <1%). It is therefore recommended that storm monitoring of these streams be discontinued. Inclusion of the two streams in the AMP quarterly and high flow tributary monitoring programs will enable the County to determine whether elevated concentrations of contaminants are affecting nearshore waters.**

    c) **Use comparable methods to calculate concentrations and loads of parameters of interest.**
    d) **Sample storms with comparable total precipitation as the baseline storms (0.2 to 3.6 inches).**
    e) **Focus monitoring efforts on larger storms.**
    f) **Include analysis of storm samples for NH3-N at the most downstream site of the tributaries to support TMDL development.**

11. The DWEP fish database continues to grow in size and complexity. *Several specific recommendations to improve its performance and reliability have been developed:*
    a) **Modify the database to track the date on which it was last modified.**
    b) **Modify the database to support revisions to data from the current year only. Historical data should be write-protected to avoid accidental change or deletion.**
    c) **Include data screening for outliers that will alert the data entry staff if parameters are outside of the expected range.**

12. Trace concentrations of mercury in Onondaga Lake waters are monitored using specialized sampling methods and an outside laboratory certified in meeting low limits of detection. **It is recommended that the QA/QC program for this effort be expanded to include field duplicate samples. This will provide an additional means to assess precision of the collection and analytical efforts.**