2002-2003
WATER QUALITY RESEARCH
FOR
CANANDAIGUA LAKE
AND
THE WATERSHED

by

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Executive Summary

1. The health of Canandaigua Lake remains good to excellent. Dissolved oxygen was available throughout the water column at all monitoring times. Seasonal temperature profiles fit historic patterns, with the exception that cold winter conditions did allow for the formation of complete ice cover, a situation that only occurs every one to two decades. This unusual winter lake stratification was followed by a spring turnover event. The lake pH was always above the neutral value of 7.00, a condition caused by the high buffer capacity of lake water. This condition helps protect the lake from the damaging effects of acidic precipitation events. Conductivity, a measure of ions dissolved in the water, averaged (ΦS/cm). Total phosphorus, the critical nutrient governing lake productivity and the element most responsible for lake eutrophication, averaged (Φg/L) during the April to November monthly sample period. Total phosphorus at the end of the winter season averaged (Φg/L). Algal productivity estimated by the concentration of chlorophyll *a* was Φg/L.

2. Previous watershed efforts have been directed towards perennial streams and understanding their contribution of sediment and nutrient to the lake during storm events, leaving unanswered the role of intermittent streams (i.e. rivulets). To provide new information, sixteen rivulets located within five direct drainage sub-basins were sampled this year. Although flow in these rivulets is not as frequent as in perennial streams, degradation of water quality was comparable during storm events. Mean total phosphorus concentrations were high, with most individual values exceeding the threshold of 100 Φg/L. Total suspended solids peaked at 1200 mg/L. Mean nitrite and nitrate levels often exceeded the critical value of 1 mg/L but seldom approached the NYS Department of Health drinking water standard of 10 mg/L. Concentration of pollutants in rivulets depended on storm character, antecedent conditions and land use practices within the direct drainage area.

3. Analyses of lake foam suggest that it originates from organic molecules within the lake; terrestrial runoff is not the source of the foam material. The foam is enriched with proteins and carbohydrates. The atomic enrichment of C^{13} over C^{12} relative to a standard was -19 ‰, more than would be expected for algae and similar to that expected for zooplankton and possibly zebra mussels. The atomic C/N ratio of the foam material was 17, falling between the benchmark values of fresh algal biomass (~10) and detritus (~20). This intermediate value may be due to the sample consisting of "old" foam with distortion caused by bacterial decay processes. Lipid analysis of the foam revealed a complex mixture of long chain fatty acids and alcohols that may come from waxes, suggesting a possible algal origin. The fatty acid chromatograph was extremely complex, however, and the origin of the fatty acids could not be determined. Zebra mussels can not be ruled out at this time and it would be instructive to compare these data to a fatty acid analysis of zebra mussels or the fatty acid abundance of their diet.

4. The annual road salt monitoring revealed higher than normal chloride concentrations (mg/L) in most tributary streams, with critical levels being exceeded in Sucker Brook and the stream entering the lake at Cook's Point. These data reflect the severity of the winter season and the subsequently higher amount of de-icing agents applied to highway surfaces.

5. Zebra mussels (*Dreissena polymorpha*) began a dramatic recovery following their die-off in the summer of 2001. Densities ranged from 29 to 11,079 individuals/m^2 among the fifteen samples taken from five locations. The lake "average" density was 3011.6/ m^2. Total mussel biomass ranged from 17 to 1085 g/m^2. The lake "average" biomass was 252.7 g/m^2. Individual mean weights were very small (0.0187 to 0.5867 g) and most shell lengths were less than 1 cm. These observations suggest a population structure dominated by the first year cohort.

Acknowledgments

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Outside organizations also contributed to this research. A winter 2002 sampling run was made possible through the generous donation of time and equipment by Webster Pearsall, Fisheries Scientist, Region 8 Office of the New York State Department of Environmental Conservation (DEC). DEC staff also assisted with summer sampling of zebra mussel populations. Limnology students at the college are recognized for their efforts in meticulously measuring shell length on hundreds of zebra mussels. The mysteries surrounding lake foam have been partially revealed through the volunteer efforts of Dr. Greg Boyer and Dr. Mark Teece, Chemistry Department at the College of Environmental Science and Forestry in Syracuse, New York. Kevin Schultz of the Ontario County Planning Department produced the GIS maps contained in this report. For the original aerial imagery, thanks are extended to Pictometry, International.

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Introduction

A recent publication (Carpenter et al. 1998) presents a general framework from which to view the historical use and subsequent modern condition of many North American water bodies. The authors report that from ancient times, people have chosen to live near water, settling in river valleys, besides lakes, or along coastlines. The attractions of clean water include its use as a crucial resource for drinking, irrigation, industry, transportation, recreation, fishing, support of biodiversity and sheer aesthetic enjoyment. Yet humans living near water bodies have also used them to wash away and dilute society's wastes and pollutants. Today, growing human populations can overwhelm the natural cleansing capabilities of the water. As pollutant inputs increase, degradation of water quality is evidenced by disruption of natural aquatic ecosystems, their component species as well as the amenities that these ecosystems once provided to society. Significant surface water degradation may be caused by nutrient enrichment (i.e. cultural eutrophication), siltation, acidification, toxins, exotic species and hydrologic changes. Point and nonpoint sources of pollution are well known for most water bodies but the relative significance among sources is not as clearly understood. Watershed wide sampling for pollutants and monitoring for other indicators of environmental degradation is an essential step in determining water condition and, thereby, helps in policy decisions and in the selection of watershed management practices designed to maintain high water quality.

Portions of the Canandaigua Lake ecosystem have been studied since the early 1900's, but there have often been large gaps of time between scientific research efforts. For the last decade, a regular sampling and monitoring program has reported on lake quality (Gilman 1993, Gilman 1994, Gilman 1995, Gilman 1996, Gilman 1997, Gilman 1998, Gilman 1999, Gilman 2000, Gilman 2002). The program provides a base-line assessment of lake health and over the years has indicated that the lake remains clean and relatively pollution-free. However, some legitimate concerns about the impacts of watershed activities on the lake have arisen. Therefore, monitoring of perennial tributary streams become a focus of recent research (Makarewicz and Lewis 1998, Makarewicz and Lewis 1999a, Makarewicz and Lewis 1999b, Makarewicz et al. 1999, Makarewicz and Lewis 2000, Makarewicz and Lewis 2001a, Makarewicz and Lewis 2001b, Makarewicz and Lewis 2001c, Makarewicz and Lewis 2002). In 2002, the current lake program was redesigned to be more responsive to emerging public concerns and broadened in scope to include special projects like watershed tributary stream sampling. Last year's stream data indicated that certain land use activities can increase nutrient, sediment and pollutant loading to the lake (Gilman 2002). Segment analyses of these streams helped to pinpoint the upland sources of contamination. Current work documenting watershed land cover will help predict where additional problems may occur and where preventative actions would be desirable.

Other impairments of lake water quality may result from foodweb disruption associated with the impacts of exotic species like the zebra mussel. Large populations of zebra mussels can improve water clarity but alter phytoplankton community structure, and when mussel numbers surpass the lake carrying capacity a population crash will occur. These population dynamics are thought to be related to the persistent foam observed on the surface waters of Canandaigua Lake since August 2001.

To better understand the health of Canandaigua Lake and its tributary streams, the following water quality tests, sampling frequencies and synthetic indices were selected. A brief explanation for each parameter is provided.

1. **lake temperature** - heat condition of a water body. Expressed in Centigrade degrees (EC). It is important to water circulation patterns in the lake (e.g., seiches and timing of fall turnover), stability of lake stratification, prediction of winter ice cover, metabolic rate of poikilothermic organisms, buoyancy afforded to the planktonic community and habitat diversity. Profile sampling for temperature should be conducted on a monthly schedule.

2. **lake dissolved oxygen** - oxygen present as a gas (O_2) dissolved in the lake water. Essential for the respiration of most desirable aquatic organisms, particularly fish and invertebrates. Cold water has the potential to hold greater amounts. Relative content of dissolved oxygen (DO) is measured as percent saturation. It is desirable to at or near 100 % saturation. Absolute content of DO is measured as parts per million (ppm) or its equivalent, milligrams per liter (mg/L). It has low solubility in water, with maximum amounts seldom exceeding 14.6 mg/L. DO is positively correlated with atmospheric pressure. DO concentration is influenced by replenishment rates (contribution from aerated tributary streams, surface exchange with the atmosphere, amount of aquatic photosynthesis) and consumption factors (respiratory demands of lake biota, amount of oxygen demanding wastes). If DO levels drop to

zero, the lake water is anoxic, nutrients are released from bottom sediments and undesirable anaerobic biota will predominate.

3. **lake conductivity** - the ability of water to support an electrical current. Strongly influenced by ionic concentrations (Ca^{++}, Mg^{++}, Na^{+} and K^{+}) and water temperature. Expressed as micromhos/cm or its equivalent, microsiemens (ΦS/cm). Addition of suspended soil particles from storm runoff and watershed erosion activities will temporarily increase conductivity. Seiches that resuspend bottom sediments may locally increase conductivity readings.

4. **lake chlorophyll *a*** - an estimate of algal abundance and, therefore, an indication of plant growth conditions in a lake. Primary production refers to organic matter synthesized by plants according to the general formula given below:

$$6CO_2 + 12H_2O \;\; !!6 \;\; C_6H_{12}O_6 + 6O_2 + 6H_2O$$

Energy for this photosynthetic reaction is provided when solar radiation penetrates water in the photic zone. Plant pigments, especially chlorophyll *a*, are receptors for this incoming light. Because of rapid species turnover in the phytoplankton community, algal abundance should be estimated monthly. Measured as Φg/L or its equivalent mg/m^3.

5. **lake clarity** - the depth of light penetration in the surface waters of a lake. Determined with a secchi disk and expressed in meters. When compared with underwater photometer measurements, the secchi disk reading approximates the depth where 95% of the surface light is gone. This is the compensation level for most aquatic vegetation. For the Finger Lakes, it is estimated that the entire surface light is gone at two to three times the secchi disk reading. Lake clarity is influenced by suspended sediment and planktonic organisms. Sampling should occur at least monthly, and at several stations on the lake, in order to document the full range of underwater light conditions that characterize the lake=s photic zone.

6. **lake and stream nutrients** - measurements of substances that promote biological growth in water. While several elements are considered essential, the critical nutrients in freshwater lakes and streams are phosphorus and nitrogen compounds. Phosphorus is often considered the limiting factor for biological productivity in freshwater ecosystems. Phosphorus is a macronutrient needed for the production of energy compounds in all organisms. It is present as inorganic and organic compounds, including particulate and dissolved forms. Total phosphorus (TP) refers to both dissolved and particulate forms. Expressed as parts per billion (ppb) or its

equivalent, micrograms per liter (Φg/L). TP concentrations exceeding 100 Φg/L suggest polluted stream conditions. In lakes, up to ten percent of the TP is likely to be found in the dissolved form (referred to as soluble reactive phosphorus [SRP]) at any time. Most phosphorus is biologically absorbed or temporarily bound to bottom sediments from which it is released back to the water if benthic anoxia occurs. During rapid growth of aquatic vegetation, all of the SRP is rapidly absorbed. Then the lake ecosystem Aslows down@ until phosphorus again becomes available through biological decay, bottom release or watershed contributions. The turnover time for phosphorus in small lakes has been estimated to be a matter of days or weeks; for larger lakes a matter of months. Measurement of phosphorus should occur seasonally, with winter data, when biological activity is low, giving the best estimate of lake nutrient budget.

Also a macronutrient, nitrogen contributes to protein synthesis in lake organisms. Nitrogen compounds commonly enter lakes through fertilizer runoff and biological decay. Decomposition processes release ammonia (NH_3) which may be harmful to aquatic life in high concentrations. In most lakes, ammonia is oxidized to inorganic nitrite (NO_2) and then nitrate (NO_3). Their combined measure is expressed as milligrams of nitrogen per liter (mg N/L) and levels exceeding 1 mg/L suggest pollution from anthropogenic sources. Nitrogen, in its oxidized forms, should be sampled seasonally.

7. **lake trophic status** - a synthetic index that describes the overall lake condition by combining water clarity (secchi disk readings), winter total phosphorus levels and summer lake chlorophyll *a* according to modeling equations. Trophic status is related to lake morphometry, lake age and watershed activities. The modeling equations derived years ago need adjustment to take into account the significant impact of introduced organisms like the zebra mussel.

8. **lake and stream chloride** - measurement of a corrosive substance that may be found in water as a result of the application of de-icing agents to watershed highways, or from natural leaching of bedrock salts. Expressed in parts per million (ppm) or its equivalent, milligrams per liter (mg/L). A critical threshold of 250 mg/L is thought to be damaging to sensitive stream and lake biota.

9. **coliform bacteria** – a group of bacteria that may be found in soils or animal wastes. Determined with a total coliform test. A fecal coliform test is conducted to verify that water has been recently contaminated with fecal materials that originated in warm-blooded intestines (e.g.,

animal or human wastes). Coliform bacteria in surface waters are used as an indicator that other disease-causing agents may also be present. Expressed as number of colonies that grew after membrane filtration of 100 milliliters of sample water and 24 hours of incubation.

Methods

Canandaigua Lake and Lake Shoreline

Lake studies began on April 29 and concluded on December 5, 2002. Two mid-lake stations (Deep Run and Seneca Point) were visited monthly by boat. At each station, secchi disk depths were recorded, a YSI water chemistry profile was taken, and water samples were collected for chlorophyll *a* analyses. A second set of mid-lake water samples was collected for determination of monthly nutrient profiles. Four additional stations were sampled in the lake: near-shore at Hope Point and Vine Valley, and at the mouths of Fallbrook Stream and the West River. Samples were taken for chlorophyll *a* analyses and determination of nutrient levels. This monthly experimental design was consistent with previous lake monitoring conducted by Finger Lakes Community College. A winter visit was made on April 14, 2003 mid-lake off Black Point and the same water quality parameters were measured.

Sampling water clarity occurred through use of a secchi disk near noon (sun directly overhead), if possible, on a cloudless day. Readings were taken on the shady side of the boat to minimize glare from the water surface. Secchi disk depths were recorded as the average of when the disk disappeared from view while being lowered and when it reappeared while being retrieved. Readings were expressed to the nearest tenth of a meter.

For chlorophyll *a* analysis, integrated water column samples were collected with TYGON tubing that extended through the photic zone. Samples were stored on ice in 2 liter dark bottles to minimize changes in algal abundance. Samples were processed within 6 hours using the alkaline acetone procedure (Wetzel and Likens 1991).

A nonmetallic Van Dorn sampler was used to collect lake water at depths of 2, 25 and 50 meters. Sample water was transferred to bottles containing acid preservative, then stored on ice. Samples were tested for nutrient content following EPA analytical methods at the NYS certified (DOH ELAP # 10248) Life Science Laboratories, Inc., in Syracuse.

Profile analyses of the water column were taken with a YSI 6920 water quality sonde and 650 data logger). Instrument calibration was checked prior to each sampling. Canandaigua Lake was sampled at one meter intervals from the surface to a depth of fifteen meters, then at five meter intervals to a maximum depth of 60 meters. Boat drift on the surface often prevented reaching maximum depths.

On July 10, 2002, zebra mussels were collected with a Ponar dredge (229 mm x 229 mm) from near shore, mid-depth and deep water locations at five lake sites: near the mouth of Fallbrook Stream, near the City of Canandaigua Water Treatment Plant, off Black Point, in the bay at Vine Valley and north of the NYS Launch by Woodville. Water depth was recorded for each water depth transect position. All visible mussels were separated from their substrate and preserved in bottles. Later the number of mussels and their total biomass were determined. Up to 100 mussel shell lengths were measured by micrometer caliper for each of the 15 samples.

On August 28, 2002, lake foam was collected from a mid-lake location off Seneca Point. Weather was calm and the water was free of any visible algal blooms. An attempt was made to collect foam with a vacuum apparatus, but a foam-water mixture was really collected. At the SUNY Environmental Science and Forestry Chemistry lab, the foam was collapsed with distilled water, and then filtered through a 934 AH glass fiber filter to remove numerous small invertebrates that were trapped in the foam. The extract was lyophilized to dryness. This powder was then subjected to these tests: % organic material, BCA total protein analysis, Bradford assay for hydrophobic protein, total carbohydrate by phenol sulfuric method, isotopic C^{13} determination, % carbon by weight, % nitrogen by weight, atomic C/N ratio and GCMS fatty acid analysis.

Direct Drainages

Intermittent streams (i.e. rivulets) were sampled on April 3, April 15, May 2 and November 23, 2002, and March 17, 2003. These dates corresponded to storm events and/or significant snow melts. Water was collected by grab samples in sections of typical flow. Sample water was then transferred to bottles containing acid preservative and stored on ice. Samples were tested for nutrient content and total suspended solids following EPA analytical methods at the NYS certified (DOH ELAP# 10248) Life Science Laboratories, Inc., in Syracuse. This sampling program expanded on a preliminary survey conducted by SUNY Brockport (Makarewicz and Lewis 2002).

Tributary Streams

Tributary streams were visited on February 27, 2003 and stream water samples were analyzed for road salt contamination (chloride [Cl^-] concentration) at the Finger Lakes

Community College chemistry lab using the argentometric titration procedure (Standard Methods, 17th edition). This monitoring has been conducted since 1990.

Results and Discussion

Health of Canandaigua Lake

Canandaigua Lake is a warm monomictic lake that thermally stratifies during the summer and generally remains ice-free during the winter. However, the winter of 2002 was unusually cold and complete ice formation occurred. Background information on the limnology of the lake is found in Eaton and Kardos (1978), Sherwood (1993), Olvany et al. (1997) and previous reports by the senior author. The development of thermal stratification in the lake is presented in the temperature profiles (Figures XX, XX and the Appendix). Following ice-out, spring turnover establishes isothermal conditions. Then the lake gradually gains heat at the surface. The work of the wind displaces the surface heat downward 15 to 20 meters by the end of the summer. Strong winds will produce Langmuir circulation (wind streaking) and may blow off the top of waves creating white caps. Fall turnover occurs in late November or early December, and normally lasts about one week. Typically open water allows the wind to keep the lake well mixed during the winter months.

Dissolved oxygen increases with depth in Canandaigua Lake (an orthograde profile). For 2002, epilimnetic oxygen was always close to or just exceeding 100% of saturation. Actual values ranged from low readings 9.02 mg/L during October to high readings of 13.40 mg/L in April. In the hypolimnion during the summer, the dissolved oxygen was maintained between 10 and 13 mg/L. Fall turnover redistributed dissolved oxygen downward. High oxygen levels were present throughout the water column during the winter sampling. These seasonal dissolved oxygen patterns indicate that the lake is a high quality environment for aquatic organisms.

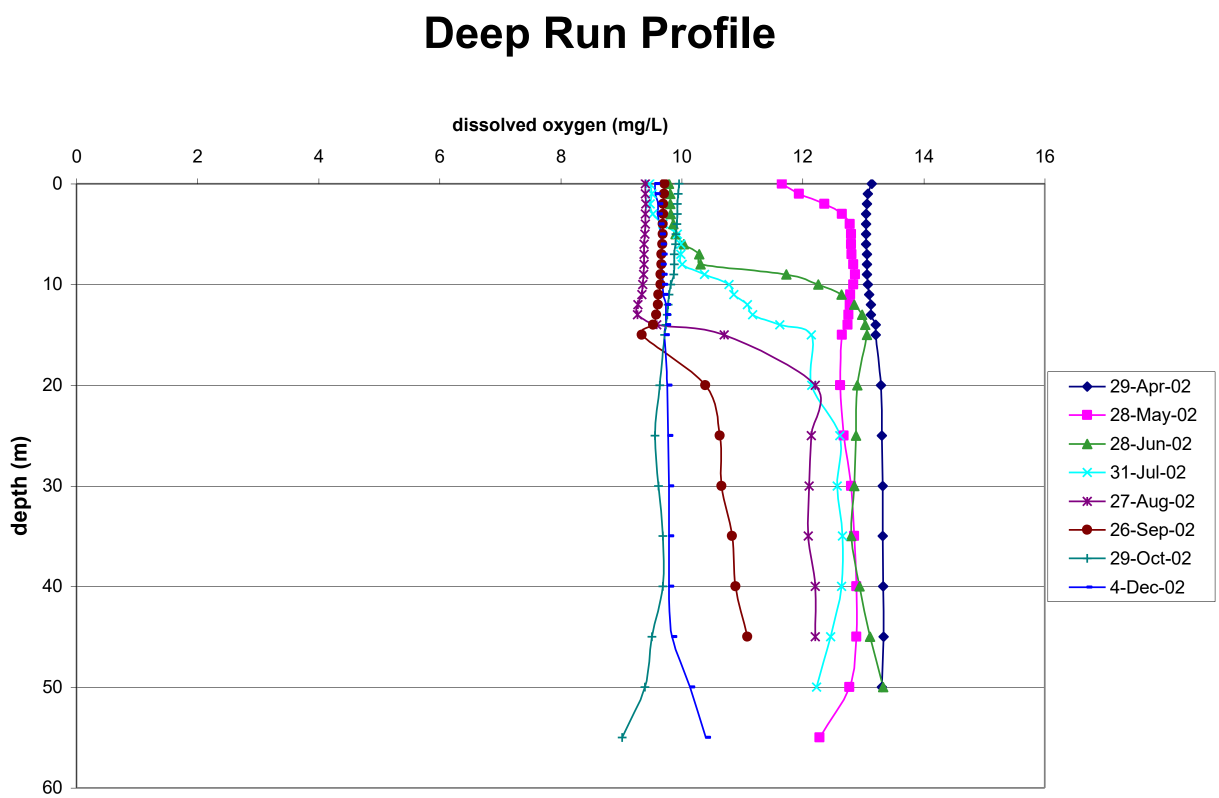

FIGURE XX - Development of 2002 thermal stratification in Canandaigua Lake, Deep Run Station.

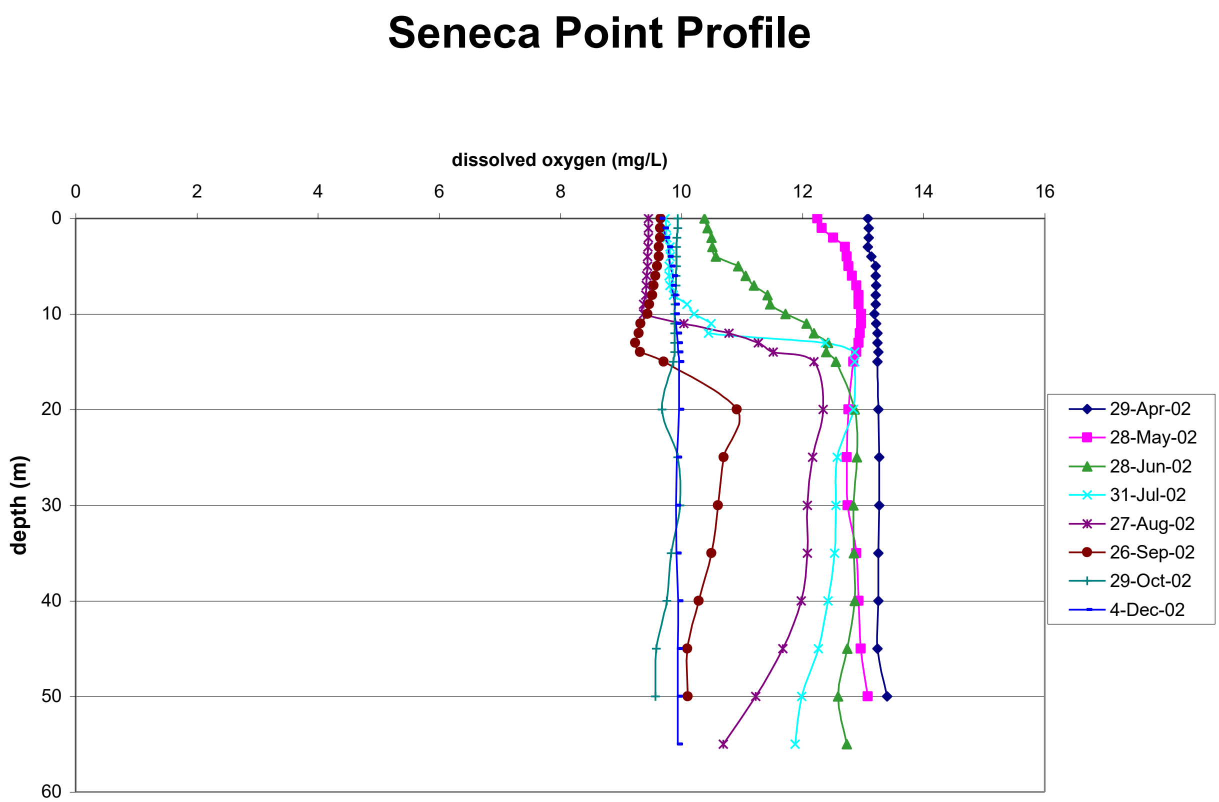

FIGURE 2 - Development of 2001 thermal stratification in Canandaigua Lake, Seneca Point Station.

In 2002, mean monthly specific conductance, integrated across the water column for both deep water stations, peaked during April (. 341.7 ΦS/cm) and reached its lowest in September (. 337.0 ΦS/cm). Conductivity showed very little fluctuation from month to month, and from top to bottom in the water profile. Based on Canandaigua Lake Sampling and Monitoring Program research by the senior author, the year 2002 eight month average was 340 ΦS/cm, compared to the 2001 average of 406 ΦS/cm, the 2000 average of 410 ΦS/cm, the 1999 average of 404 ΦS/cm, the 1998 average of 393 ΦS/cm, the 1997 average of 376 ΦS/cm, and the 1996 average of 362 ΦS/cm. These recent values represent an increase from 271 ΦS/cm in 1955 (Berg 1963), 285 ΦS/cm in 1973 (Oglesby in: Eaton and Kardos 1978), but now approximate the 350 ΦS/cm in 1993 (Gilman 1993) and are less than the level of 373 ΦS/cm noted in 1994 (Gilman 1994). The data had revealed a long-term trend of increasing conductivity in the lake, most likely associated with soil particles derived from watershed erosion. This year's significant decrease in conductivity may be related to the recovery of the zebra mussel population. Each animal absorbs calcium for shell formation.

Secchi disk readings for oligotrophic lakes are often greater than 5 meters. Readings are lower when light is blocked by suspended particles (organic and inorganic). Readings can also be affected by variability in cloud cover and surface wave action. Historic data on lake clarity are discussed in Gilman (2000). This year, clarity from April through November averaged 8.3 meters and reached a maximum of 10.4 meters. Lake clarity improved over last year, reversing a decline that began in 1999. Monthly data are presented in Table XX and Figure XX. Canandaigua Lake was also visited during the late winter on April 14, 2003 (just following ice-out) and had a secchi disk reading of 6.7 meters.

TABLE XX - Secchi disk readings (m) in Canandaigua Lake.

Date	Deep Run Station	Seneca Point Station	Mid-Lake Average
29 April 2002	7.7	9.0	8.4
28 May 2002	7.2	7.2	7.2
28 June 2002	9.4	8.5	9.0
31 July 2002	7.3	7.3	7.3
27 August 2002	8.5	8.5	8.5
26 September 2002	5.2	6.9	6.1
29 October 2002	10.0	9.0	9.5
4 December 2002	11.3	9.5	10.4

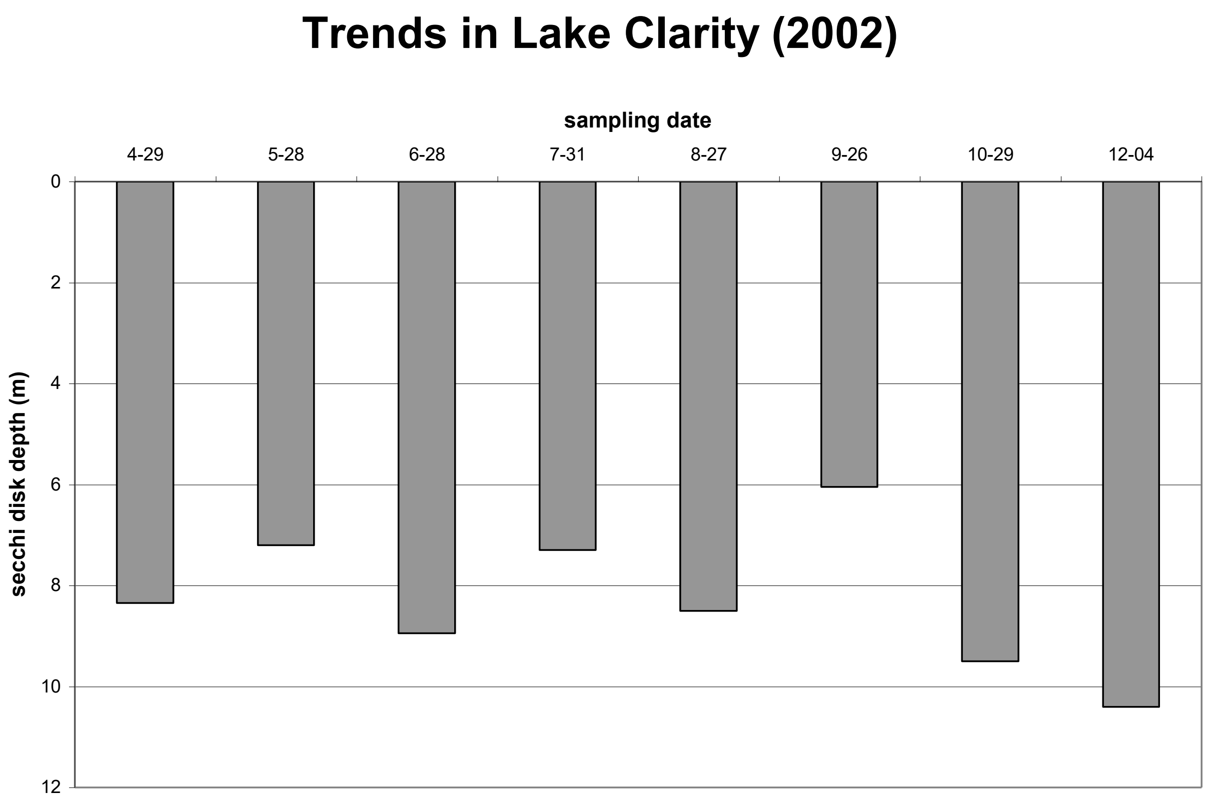

FIGURE XX - 2002 average secchi disk readings in Canandaigua Lake. See data in Table XX.

The levels of chlorophyll *a* during the 2002 sampling season are presented in Table XX and Figure XX. Algal populations develop quickly and species sequentially replace one another as lake conditions change during the growing season. Limnologists refer to this as a rapid species turnover. During 2002, a peak in algal abundance occurred in late May followed by a significant drop. This may be caused by rapid species turnover but may also be related to the onset of zebra mussel filter feeding in the warming waters of June.

Algal abundance estimated by the concentration of chlorophyll *a* based on all data except the West River station, averaged 2.45 Φg/L. This represents a 2.5% increase from last year's algal abundance and now approaches the historic levels reported in 1973 (Oglesby in: Eaton and Kardos 1978) and the pre-zebra mussel levels from the early 1990's. Algal abundance has been increasing since 1999. Indirect evidence suggests that zebra mussel populations crashed in August 2001. The increasing chlorophyll *a* levels suggest a recovery in the algal populations as they experience less predation by mussels, but this dynamic interaction may now be leveling off.

TABLE XX - 2002 chlorophyll *a* concentrations (Φg/L) in Canandaigua Lake. Adjusted mean graphically displayed in Figure XX.

Station	4-29	5-28	6-28	7-31	8-27	9-26	10-29	12-04
Fallbrook	3.64	1.13	3.35	2.09	4.22	5.34	0.88	0.75
Hope Point	3.84	1.02	1.36	3.59	2.06	6.87	1.84	1.46
Deep Run	3.81	2.34	1.44	3.05	2.12	2.94	1.67	1.52
Seneca Point	4.12	2.32	2.26	2.80	2.46	2.88	2.80	1.58
Vine Valley	5.09	1.10	1.10	1.70	1.38	2.03	1.05	1.00
West River	21.83	16.28	4.17	3.36	5.71	2.34	11.46	3.82
Mean	7.06	4.03	2.28	2.76	4.66	3.73	3.28	1.69
Adjusted Mean *	4.10	1.58	1.90	2.64	2.45	4.01	1.64	1.26

* adjusted mean = without West River values, this station is excluded because it more often reflects river conditions rather than lake quality.

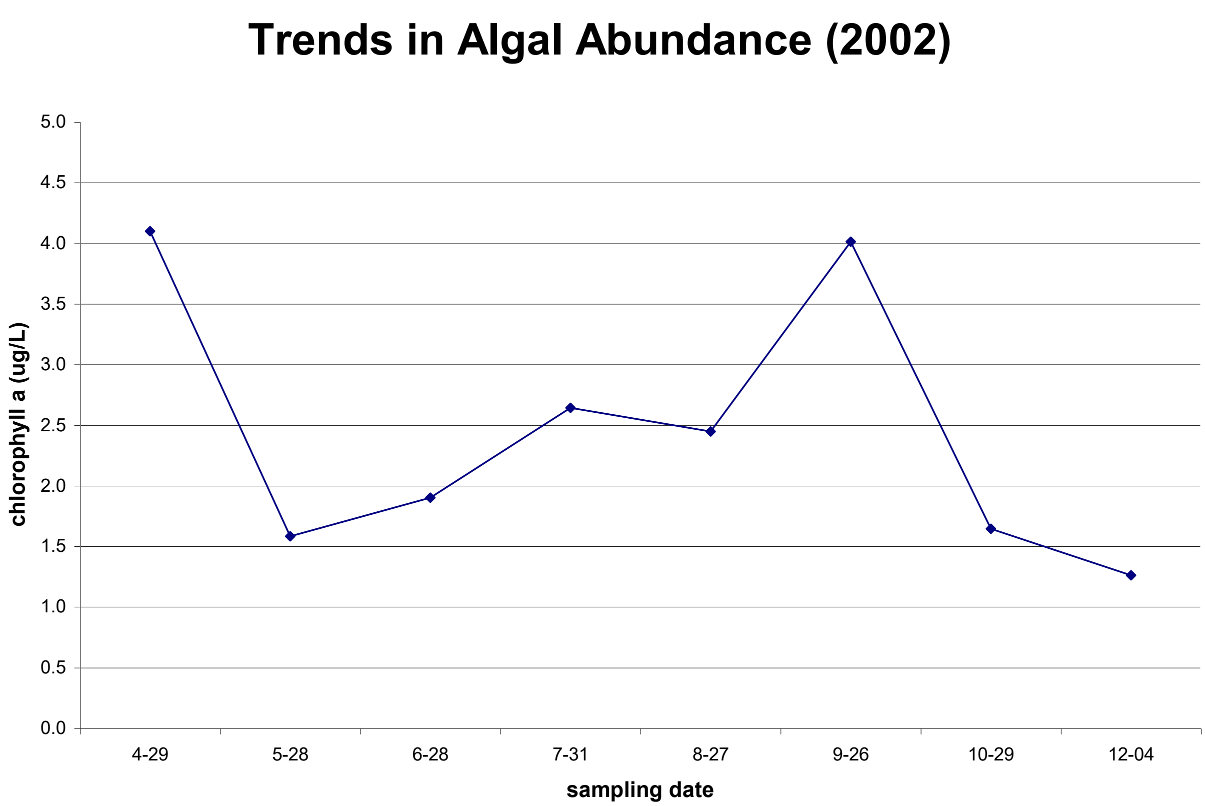

FIGURE XX – 2002 chlorophyll *a* concentrations among sample stations in Canandaigua Lake.

There has also been a change in the seasonal ratio pattern of chlorophyll *a* concentrations between shoreline and mid-lake stations (Table 3). Data from the West River station is excluded in this analysis. Ratios above 1.00 document more algal productivity along the shoreline. Conversely, when the ratio falls below 1.00, more algal productivity has been detected in the open water of the mid-lake stations. For a number of years, the ratio has favored less algal productivity along the shoreline and this effect has been attributed to filter feeding by zebra mussels in the shallow near-shore environment (Gilman 2000). Another process indirectly related to zebra mussels may also be at work. With improving water clarity along the shoreline, aquatic macrophyte communities have expanded outward. As this occurs, nutrients are absorbed by aquatic weeds, reducing the amount available for the suspended algae. Should the shoreline zebra mussel population die-off, suspended algae would increase and the ratio would return closer to 1.00. Algal ratios from 2001 supported this idea as three scores approached or exceeded a ratio of one. The 2002 ratios extend the pattern as four scores exceed a ratio of one and, notably, the September value reached 1.63. This occurred due to unusually high chlorophyll *a* concentrations along the northern shoreline of the lake (Hope Point and Fallbrook stations). Other Finger Lakes experienced similar fall algal blooms in their northern basins. This raises the question of whether this pattern is produced by fluctuations in the zebra mussel population (local lake effect) or induced by meteorological conditions like drought (regional lake effect).

TABLE 3 - Ratio between shoreline (n = 3) and mid-lake (n = 2) chlorophyll *a* concentrations. 1996-2000 samples were collected at a depth of 2 meters, 2001-2002 samples collected by integrated column method.

Year	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Mean ± 1 standard deviation
1996	1.05	1.13	0.84	0.75	0.87	0.79	0.77	0.94	0.89±0.14
1997	1.55	1.05	0.78	0.82	0.74	0.75	0.72	0.68	0.89±0.29
1998	0.90	0.54	0.57	0.50	0.86	0.77	0.83	0.77	0.72±0.16
1999	0.91	0.83	0.71	0.60	0.59	0.50	0.71	0.86	0.71±0.15
2000	0.94	0.66	0.80	0.59	0.72	0.57	0.47	0.67	0.68±0.15
2001	1.06	0.98	1.03	0.69	0.90	0.83	0.75	0.48	0.84±0.20
2002	1.06	0.46	1.05	0.84	1.11	1.63	0.56	0.69	0.93±0.37

An inverse relationship exists between chlorophyll *a* concentrations and secchi disk readings over the last six years (Figure 5). The graph provides further circumstantial evidence that zebra mussel populations and their impact on lake processes are subject to continual change.

FIGURE 5 - Recent water quality trends in lake clarity and algal abundance.

Nutrients in lake water fluctuate seasonally and vary with depth in the water column. Phosphorus is thought to be the limiting nutrient for lake productivity and total phosphorus has been measured since 1996. Based on 455 samples collected from different sites and depths during the growing season (April through November), the long term total phosphorus average has been 6.59 Φg P/L with the range running from undetectable to 200.0 Φg P/L. For the 84 samples collected in 2001, total phosphorus averaged 9.07 Φg P/L. Since 1996, there have been 55 instances (12.1%) when total phosphorus levels exceeded the desirable ecological threshold of 10 Φg P/L. This threshold is based on studies of hundreds of North American lakes; TP exceeding 10 Φg P/L move the trophic condition of the lake from oligotrophic to mesotrophic (Wetzel and Likens 1999). Twenty of these instances occurred between 1996 and 1999. Twenty-two occurred during the year 2000! That number was reduced to only 13 instances in 2001. Surprisingly, Deep Run at a depth of 50 meters exceeded the desirable TP threshold three times, including a value of 95.0 Φg P/L on July 24. These high phosphorus values at depth may in some way be related to organic decomposition along the lake bottom (note: samples from 50 meters at Deep Run are nearly at the bottom while samples from 50 meters at Seneca Point are still some distance off the bottom). Most of the other exceptionally high lake total phosphorus results over the past six years were from the mouth of the West River station either during the early spring when wetland vegetation is dormant or during late fall when wetland vegetation is senescent (Table 4), substantiating the seasonal role of the High Tor wetlands as a nutrient source to the lake.

During the summer of 1973, total phosphorus in the surface waters (mid-lake?) of Canandaigua ranged from 8 to 10 Φg P/L (Eaton and Kardos 1978). This was one year after Hurricane Agnes had brought tremendous rainfall that produced flooding throughout the watershed. Tributary streams contributed eroded sediment and nutrients to the lake and the highest lake levels on record were noted. During the last six years, total phosphorus levels have averaged significantly less. In fact, total phosphorus data were at the laboratory detection limits (2.4 Φg P/L for 1996-2000 [SUNY Brockport], 3.0 Φg P/L for 2001 [Life Science Laboratory, Inc.]) nearly 25% of the time since 1996. The 1997 winter mean total phosphorus values of 5.00 Φg P/L (range = 3.1 to 8.0 Φg P/L) for the two mid-lake stations fell below the historic 1973 data.

TABLE 4 - Total phosphorus data exceeding 10 Φg P/L, August 1996 through November 2001. Samples from the **West River** account for 24 (43.6%) of the instances.

Total phosphorus (Φg P/L)	Sampling site	Depth	Date
200.0	**West River**	2 m	September 30, 2001
141.2	**West River**	2 m	October 29, 1998
95.0	Deep Run	50 m	July 24, 2001
88.2	Fallbrook	2 m	April 30, 1997
52.0	**West River**	2 m	April 26, 2000
51.4	Seneca Point	50 m	May 30, 2000

46.0	**West River**	2 m	October 30, 2001
39.0	Hope Point	2 m	October 30, 2001
36.2	Hope Point	2 m	July 31, 2000
33.0	**West River**	2 m	May 30, 2001
31.7	**West River**	2 m	August 31, 1998
30.8	**West River**	2 m	October 27, 1999
28.8	**West River**	2 m	July 31, 2000
22.7	**West River**	2 m	September 30, 2000
22.0	Deep Run	2 m	July 31, 2000
20.0	Deep Run	50 m	June 26, 2001
20.0	**West River**	2 m	August 31, 1999
19.6	Vine Valley	2 m	July 31, 2000
19.0	**West River**	2 m	

			October 30, 1996
17.8	**West River**	2 m	October 26, 2000
17.8	Vine Valley	2 m	May 30, 2000
17.2	**West River**	2 m	November 28, 2000
17.0	West River	2 m	June 26, 2001
15.8	**West River**	2 m	August 28, 1996
15.5	Seneca Point	25 m	May 30, 2000
15.0	Deep Run	50 m	April 26, 2000
15.0	**West River**	2 m	July 24, 2001
14.9	**West River**	2 m	April 17, 1999
14.7	**West River**	2 m	June 26, 1997
14.0	Seneca Point	2 m	July 31, 2000
13.3	Vine Valley	2 m	April 26, 2000
13.2	**West River**	2 m	July 27, 1998

Total phosphorus (Φg P/L)	Sampling site	Depth	Date
13.0	**West River**	2 m	August 23, 2001
12.9	Seneca Point	2 m	August 31, 1999
12.8	Deep Run	50 m	July 31, 2000
12.8	Seneca Point	25 m	July 31, 2000
12.8	Fallbrook	2 m	April 26, 2000
12.6	Fallbrook	2 m	October 27, 1999
12.5	Hope Point	2 m	October 27, 1999

TABLE 4 (continued) - Total phosphorus data exceeding 10 Φg P/L, August 1996 through November 2001. Samples from the **West River** account for 24 (43.6%) of the instances.

Total phosphorus (Φg P/L)	Sampling site	Depth	Date
12.1	Deep Run	50 m	May 30, 2000
12.0	**West River**	2 m	April 25, 2001
11.6	**West River**	2 m	June 28, 2000
11.1	Hope Point	2 m	December 3, 1996

11.0	Deep Run	2 m	May 30, 2001
11.0	Deep Run	50 m	November 23, 2001
11.0	Vine Valley	2 m	May 30, 2001
10.8	**West River**	2 m	May 20, 1998
10.5	Deep Run	2 m	April 26, 2000
10.5	Deep Run	25 m	April 26, 2000
10.3	Seneca Point	50 m	July 31, 2000
10.3	Deep Run	50 m	September 30, 1998
10.2	**West River**	2 m	June 29, 1999
10.2	Seneca Point	25 m	December 3, 1996

The West River site had the highest total phosphorus levels in 29 of the 44 months of sampling (65.9%) conducted since August 1996!

The 2001 winter mean total phosphorus value was 3.6 Φg P/L (range = 3.1 to 4.3 Φg P/L) for mid-lake at Black Point. From a long-term watershed perspective, total phosphorus levels have declined since the restriction of phosphate builders in detergents, the watershed inspection program and the expansion of sewer lines. Continuing growth trends in the watershed population and an increase in impervious surfaces, however, represent threats to lake health that could significantly increase nutrient budgets unless proper landuse strategies are in place.

Table 5 presents mean monthly profiles of total phosphorus for the two mid-lake stations for the years of record, 1997-2001. Surface waters average the lowest near the end of the growing season (August through November). This may be associated with thermal stratification of the lake, frequent summer droughts, high rates of biological absorption and slower species turnover within the plankton communities.

TABLE 5 - Seasonal profiles for total phosphorus (Φg P/L) at the two mid-lake sampling stations. Data based on mean of monthly values, 1997 through 2001.

Deep Run Site

	Apr-Nov	
depth		Apr
	May	Jun
	Jul	Aug
	Sep	Oct
	Nov	mean
2		4.53
		6.46
	5.28	7.07
		2.94
		5.28
		3.59
		3.58
	4.84	
25		4.16
		4.10
		3.41
		3.86
		3.45
		5.19
		2.07
		2.52
	3.60	
50		5.16
		5.93
		7.54
	23.24	4.36

5.59
2.07
5.69
7.45
monthly mean 4.62 5.50 5.41
11.39 3.58 5.35
2.58 3.93

overall mean = 5.30 Φg P/L

Seneca Point Site

Apr-Nov
depth Apr
May Jun
Jul Aug
Sep Oct
Nov mean
2 3.57
5.08
4.92
5.46
5.56
4.51
2.68
3.57
4.42
25 5.21
5.82
4.64
4.10
2.15
4.54
2.70
2.52
3.96
50 4.36
13.42 4.56
4.04
2.73
3.76
2.40
3.33
4.83
monthly mean 4.38 8.11 4.71
4.53 3.48

4.27	2.59
3.14	

overall mean = 4.40 Φg P/L

Inorganic nitrogen (NO_3 and NO_2) had a mean of 0.29 mg N/L based on 498 samples collected from April 1996 through November 2001. Individual results ranged from 0.03 to 0.70 mg N/L. During the year 2001, inorganic nitrogen averaged 0.26 mg N/L. Eaton and Kardos (1978) report a mean of 0.31 mg/L NO_3-N for July 1972 based on 52 samples, and a mean of 0.32 mg/L NO_3-N for July 1973 based on 28 samples. Although not directly comparable, these findings suggest little change in the nitrogen compounds available for the support of biological activities during the last three decades. The ecological threshold for inorganic nitrogen is less than 1.00 mg N/L. Table 6 reveals a seasonal pattern of nitrogen depletion along the shoreline during the height of the growing season.

TABLE 6 - Monthly variation in mean inorganic nitrogen ($NO_3 + NO_2$ mg N/L) for mid-lake and shoreline sampling stations.

				2001
		average		
	Apr	May	Jun	Jul
			Aug	Sep
			Oct	Nov
shoreline		0.36	0.27	0.24
			0.17	0.06
			0.10	0.15
			0.21	
mid-lake		0.36	0.30	0.34
			0.25	0.27
			0.30	0.30
			0.32	

	long-term average, 1996-2001							
	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
shoreline	0.38	0.29	0.24	0.17	0.12	0.16	0.21	0.29
mid-lake	0.38	0.33	0.33	0.30	0.29	0.32	0.31	0.31

Near-shore lake water samples were collected for total coliform bacteria counts on May 30, June 26, July 24 and August 23. Results ranged from less than one colony to 60 colonies per 100 ml of water sample. These fall well below the standard of "not to exceed 2400 colonies" established for contact recreation in open waters. Individual data are in the Appendix.

Trophic status of Canandaigua Lake

Lake eutrophication is a natural process resulting from the gradual accumulation of sediments and organic matter. As a basin slowly fills, nutrient concentrations and productivity are increased. The rate of the eutrophication process and, hence, the life span of the lake, will depend on the morphometry of the basin and the stability of watershed soils. Human activities (e.g., land use changes, agricultural fertilization practices, waste water discharges) accelerate this process bringing about cultural eutrophication. Often changes in lake condition occur too fast for the adaptive capabilities of natural communities and their respective organisms. Species are lost from the basin and premature aging of the lake begins.

Typical lake succession passes through this series of trophic states:

Oligotrophy: nutrient-poor, biologically unproductive
Mesotrophy: intermediate nutrient availability and biological productivity
Eutrophy: nutrient-rich, highly productive
Hypereutrophy: extremely productive, "pea soup" conditions

Each trophic state is characterized by certain conditions. Oligotrophic lakes have low productivity due to low nutrient supplies. Water is exceptionally clear. These lakes are often deep and have steep basin walls. Water in mesotrophic lakes receives a moderate supply of nutrients from the watershed, which may be recycled several times within the basin. Primary productivity is enhanced despite water clarity being somewhat reduced by suspended sediment and plankton. Eutrophic lakes have a high nutrient supply and experience pulses of extremely rapid plant growth. Water clarity can be greatly reduced at times. Benthic depletion of dissolved oxygen is common.

Identification of a lake's trophic status is a useful way to determine overall lake "health". Comparisons can be made to other lakes, or from year to year in the same lake, to evaluate the effectiveness of lake restoration techniques. In earlier weedbed studies of Canandaigua Lake (Gilman and Rossi 1983, Gilman 1994a), results suggested that Canandaigua Lake was oligotrophic but nearing the mesotrophic state.

To update the trophic status of Canandaigua Lake, the Carlson Trophic State Index (TSI) is used. This index is based on values for chlorophyll *a* concentration, winter total phosphorus and summer water clarity. The variables are interrelated in complex ways. Equations have been developed for each variable used to estimate trophic state (Table 8). The TSI can be useful in determining the extent of eutrophication in any given lake but other factors should also be considered. Carlson's equations were based on data from lakes throughout the United States, and may not necessarily apply to the Finger Lakes. In fact, since the equations represent averages for many lakes, any one specific lake may not exactly follow the relationships described by the equations. In addition, each of these lake variables can be affected by other factors. For example, lake clarity can be influenced by highly colored water, non-algal turbidity (the addition of sediment from localized watershed erosion), the presence of zebra mussels which can filter out much of the plankton community thereby improving clarity, and depth to, and nature of, bottom sediments. Acidification of Adirondack lakes has altered the perception of their trophic status.

TABLE 7 - Information pertaining to the Carlson Trophic State Index (TSI).

Variable	Trophic State Oligotrophic	Mesotrophic	Eutrophic
total phosphorus	< 10 Φg/L	10 - 26 Φg/L	> 26 Φg/L
chlorophyll *a*	< 2 Φg/L	2 - 8 Φg/L	> 8 Φg/L
secchi disk depth	> 4.6 m	1.9 - 4.6 m	< 1.9 m
Carlson TSI	< 37	37 - 51	> 51

The TSI formulas are as follows:

TSI_{SD} = 60 - 14.41(ln secchi disk reading)

TSI_{Chl} = 30.6 + 9.8(ln chlorophyll *a* concentration)

TSI_{TP} = 4.15 + 14.42(ln total phosphorus level)

where ln = natural logarithm = $\log_{10}$ x 2.30

Highly acidic lakes are biologically sterile leading to low chlorophyll *a* concentrations and good water clarity, mimicking the conditions of a naturally oligotrophic lake. It is also important to remember that changes in trophic status are not a condemnation of human impacts on lakes. Each trophic state can support different uses. Eutrophic lakes often support excellent warmwater fisheries while oligotrophic lakes can provide an excellent source of public drinking water.

Summer (June, July, August) monthly mean secchi disk readings and chlorophyll *a* concentrations were used to calculate the TSI values in Table 9. The TSI total phosphorus value for Canandaigua Lake was also determined this year based on the winter sampling.

TABLE 8 - Carlson TSI values for Canandaigua Lake.

Trophic State Index	
	total

based on:	secchi disk	Chl *a*	phosphorus		
1995 data	36.9	46.3	36.0		
1996 data	33.0	39.1	46.5		
1997 data	30.2	40.6	27.4		
1998 data	29.1	36.8	-		
1999 data				28.6 -	35.6
2000 data				28.6 -	35.5
2001 data				33.3 22.7	37.9

2001 TSI values for Canandaigua Lake fall closest to the oligotrophic (<37) condition. TSI based on secchi disk readings and chlorophyll *a* concentrations had declined steadily since 1995 as a result of filter feeding by zebra mussels, but increased slightly this year possibly due to a zebra mussel die-off. The winter TP analysis produces a TSI that is relatively independent of zebra mussel effects and may provide a more realistic trophic status rating for Canandaigua Lake. While in general lake health has improved according to the Carlson TSI, there are localized nearshore instances that tell a different story. A significant dieback of Eurasian milfoil (*Myriophyllum spicatum*) was observed in August 2000 near the mouth of the West River. The macrophyte community collapse was remarkable and it was surmised that a biological control agent was at work. Spring 2002 monitoring at this site revealed an unusually heavy growth of curly-leaf pondweed (*Potamogeton crispus*) in the absence of Eurasian milfoil competition. This same effect was observed several years ago following an attempt to manage the aquatic plants through weedbed harvesting. Submerged aquatic plant communities are diverse and resilient!

water quality, trophic status

Pollutants in Direct Drainages

watershed area for direct drainages (?), area for individual rivulets (?), digital images (?)

Introduction:

For five years, twenty perennial streams flowing to Canandaigua Lake have been sampled for several water quality parameters including nitrates, phosphorus, total suspended solids and bacteria at one or more locations. These data sets encompassing thirty-six base line samples and twenty-seven storm events are described in reports by Makarewicz and Lewis (1998, 1999, 2000) and Gilman (2001). A substantial data set has been established for these streams. The overall stream monitoring program was continued in the year 2002, but the focus changed to study the smaller rivulets that had never been monitored. Bacteria samples were continued on the regular set of streams.

The Canandaigua Lake watershed consists of thirty-four defined drainage areas. Twenty-three of these drainages have one distinct outlet that drains to the lake. The remaining eleven drainage areas, known as direct drainages, literally have hundreds of small but distinct rivulets draining to the lake. The direct drainage areas encompass over 95% of the shoreline and near shore hillsides. Visually, many of the hills that ring Canandaigua Lake are within these direct drainage areas. Total direct drainage land area is 24,519 acres or 22% of the entire 110,000 acre Canandaigua Lake watershed. Although the direct drainages only make up one-quarter of the watershed area, their close proximity to the lake increases the possibility that pollution occurring in their respective drainage areas will end up in the lake. Additionally, several of these drainage areas (#22,31,32, 33,34) are just up hill of the five raw water in-take pipes (Newark, Palmyra, Gorham, Rushville and the City of Canandaigua) serving 50,000 people, further increasing their importance.

Most of the rivulets within the direct drainage areas have small drainage areas reducing the volume of water that is conveyed through respective drainage way to the lake. Thus, many of these rivulets are dry for most of the year. They will usually convey water at the surface during spring snow melt, large rain events and moderate rain events with high antecedent wetness conditions. The question the Watershed Council was looking to partially answer is what influence these rivulets have on the overall quality of Canandaigua Lake. We hope this portion of the report can help to answer this question.

Methods:

National, state and local monitoring programs have demonstrated that most non-point sources of pollution are carried into our waterways during precipitation events (i.e. rain or snow melt). Seventeen of the rivulets within five of the direct drainages (#22, 31, 32, 33, 34) were sampled on up to six events to measure the loss of phosphorus, nitrates and total suspended solids. Discharge measurements were also taken for qualitative comparisons. Due to the inaccuracy of discharge measurements in previous studies (where total annual discharge in many of the streams was measured to be greater than the total precipitation in the drainage area), the authors have decided to rely on concentration data rather than loading to make comparisons among the rivulets and regular set of streams. Major inaccuracies in discharge measurements will substantially impact conclusions utilizing loading data. Also, current water quality standards are also based on concentration data rather than loading allowing for easier comparison.

Samples bottles were pre-coded for accuracy. Samples were collected by the authors, stored in ice filled coolers until transport to Life Science Laboratories (LSI), a certified lab out of Syracuse, New York (NYS DOH ELAP #10248). Sample analysis by LSI, a certified lab, followed EPA standard methods.

Results and Discussion:

Characterization of storm events sampled:

The spring of 2002 was relatively wet with rain totals recorded at the Canandaigua Water Treatment Plant equaling 3.86 inches in April and 5.3 inches in May. Four precipitation events were sampled during these two months: April 3, 2002, April 15, 2002, May 2, 2002 and May 12, 2002. In contrast, the 2002 summer season was unusually hot and dry with most streams in the watershed completely drying up. Antecedent wetness conditions rapidly diminished with the occasional rainstorm being absorbed into the ground, filling ponds or utilized by plants. Due to conditions no events were sampled during the summer and early fall months. One fall event was sampled, November 22, 2002. One snowmelt event was sampled on March 17th, 2003 with a large snow pack and temperatures exceeding 60 degrees Fahrenheit for a second straight day. The table below provides the statistics and brief description of each event.

The Canandaigua Water Treatment Plant records daily precipitation at 8am each morning with that measurement being the amount recorded for the day. Storm events obviously cross this 8am time so additional information is provided in the third column describing rainfall measured the next day and the timing of that rainfall along with approximations of antecedent wetness to better document actual conditions and rainfall amounts.

Date	Rainfall totals	Additional information
April 3, 2002	0.93 inches	Some wet snow left from a previous snow storm
April 15, 2002	0.63 inches	0.82 inches fell the previous day. Antecedent wetness very high.
May 2, 2002	0.14 inches	High antecedent wetness and additional 0.25 inches fell between 8-11 am during the sampling run.
May 12, 2002	0.70 inches	Over an inch of rain fell in the previous four days building up antecedent wetness.
November 22, 2002	0.64 inches	1.3 inches of precipitation falling within the preceding five days. Some accumulating as snow. Partial snow melt with rain event.
March 17, 2003	0 inches	Major snow melt event.

Table 1. Review of weather conditions for each of the sampling events.

Site ID	Location	Site ID	Location
T-22A	Outfall from Lake side estates	T-33A	Dead end in Lake Dr.
T-22B	4076 W. Lake Rd	T-33B	Main trib along Lake Dr.
T-22C	Hope Pt.	T-33C	Trib coming from Hall Rd.- lake dr.

T-22D	3725 W. Lake Rd.	T-34A	Along Private Dr.- just north of Powell
T-22E	Drainage from Senior complex	T-34B	Shoal water point @364
T-22F	Drainage to Holiday Harbour	T-34C	3810 Private Drive- drains turner rd.
T-31A	5300 East Lake Rd.	T-34D	Thorndale Beach- wire mesh foot bridge
T-32A	Just South of Jones Rd.	T-34E	Sandy Beach Drive
T-32B	Just North of Church Camp		

Table-2 Location of each of the direct drainages sampled.

Phosphorus:

As stated previously in the limnology section of the report, Canandaigua Lake is an oligotrophic lake, having low productivity and good water quality. Phosphorus is the main nutrient that drives vegetative growth (algal and macrophyte) in the lake. Prolonged elevated loading of phosphorus through human activities can cause substantial changes in the lake environment including algal blooms and increased plant growth.

Mean concentrations of phosphorus for the six storm events document five locations as being substantially higher than the remaining rivulets. All five locations are above the 100 micrograms of Phosphorus per liter (ug/l) guidance value that documents polluted streams. T32B had the highest average phosphorus concentration of 298ug/l with five of the events sampled above 200ug/l. The second highest is T-34A (264ug/l) with four of the events sampled above 200ug/l. The next three highest rivulets are T-22F (167ug/l), T-34B (152ug/l) and T-22A (137ug/l).

The last three sampling locations each had one event that was substantially higher than the rest possibly skewing their averages higher than they actually should be. T-22F had a spike of 640ug/l on November 22, 2002 with four other events having phosphorus concentrations at this location being well below 100ug/l. T34B had a spike of 520ug/l also on November 22, 2002 with four other events below 100ug/l. T-22A, an active development site, had a spike of 390 on May 2, 2002 with three other concentrations below 100ug/l. Many variables influence phosphorus concentrations some man made and some natural. Trends showing fairly consistent high results are the best indicators of pollution.

There are solid trends in the highest two locations T-32B and T-34A that warrant further investigation as to the source of elevated levels of phosphorus. When comparing concentration data in these two streams to five years of data for the regular set of tributaries, these two streams stand out as having greater concentrations than the highest ranking stream, Sucker Brook at 212ug/l! It is important to note that the tributary data set is based on twenty-seven storm events as compared to the rivulets having six storm events. However, the preliminary trends do document possible pollution issues.

Preliminary investigations in the drainage areas for these two streams show that agriculture is the dominant land use in both drainage areas. There is also a lack of riparian buffers as the drainage way crosses through barnyard areas. Riparian buffers have the ability to filter out phosphorus and other nutrients and sediments before runoff enters the stream. The Watershed Program Manager will work with the Agricultural Program Committee and County Soil and Water Conservation District to further document the source and work with the landowners to remedy the situation.

Nitrate:

Mean event nitrate levels showed four rivulets as having substantially higher concentrations as compared to the rest T-33B (4.61mg/l), T-32B (3.48mg/l), T-32A (2.15mg/l) and T-34B (2.06mg/l). A general guidance concentration to determine if a stream is polluted with nitrates is approximately 1mg/l.

T-33B had three events greater than 6mg/l of nitrates showing a possible trend of elevated levels of nitrates in this drainage area. T-32B identified as having a possible phosphorus source also shows trends of having a source of nitrates with three of the events having levels greater than 3.5mg/l. T-32A and T-34B also have slightly elevated levels with further investigation warranted.

When comparing results from the rivulets to the regular set of streams these four streams are comparable to the long term averages for Gage Gully (4.26mg/l) and Deep Run (3.47mg/l) and are much higher than the other streams and rivulets sampled. Possible sources of nitrates include failed septic systems, row crops and animal operations.

Total Suspended Solids (TSS):

TSS is a measure of soil loss from a drainage area to the stream and ultimately the lake. Mean concentrations of TSS did not demonstrate any obvious trends among the seventeen rivulets sampled. Two streams that were generally low in TSS, T-22A and T-31A both had spikes well above the other events sampled at their respective locations possibly skewing their averages. T-22A is an active development site that has well established erosion control practices and will continue to be periodically monitored.

On March 17, 2003 T-31A had a concentration of 1200mg/l of TSS. This was the main snow melt of the season and the sample could have been taken during a pulse of soil being lost from the streambank. This drainage area is heavily forested with some agriculture at its headwaters. All other events at this location were well below 50mg/l. Statistically, the March 17, 2003 event and the May 2, 2002 event had the highest concentrations of suspended solids throughout the seventeen rivulets. Timing of samples collected and types of runoff events can impact the results.

When comparing TSS averages of the seventeen rivulets to the regular set of streams sampled the rivulets are comparable or even slightly lower than the regular set of streams. Possible causes of this could be a much smaller data set, but could also be caused by natural forces such as decreased runoff velocities and shear stress of in stream flows being less erosive in smaller drainage areas. Periodic comparisons to the regular set of streams are warranted to gain a better understanding of the influence of the rivulets on the amount of soil erosion entering the lake.

A special investigation of an active development site within the drainage area of T-22D took place on two events October 29, 2002 (0.39 inches of rain) and November 22, 2002 (0.64 inches of rain). Samples of TSS were collected just above the influence of the active development site and just below to measure the effectiveness of soil erosion management practices on the development site. The results are presented below.

Date	Location	Results TSS mg/l
10/29/02	T-22 Above	7mg/l
10/29/02	T-22 Below	2,200mg/l
11/22/02	T-22 Above	33mg/l
11/22/02	T-22 Below	580mg/l

Table-3. Special study of T-22D (Butler Rd Drainage).

During the fall and winter months the Town of Canandaigua began to take corrective action against the developer for not properly installing erosion control practices. Subsequent visual inspection by the Watershed Program Manager has documented no substantial change in clarity as the stream passes by the development site. Continued enforcement of existing erosion control measures along with periodic inspection of the stream will occur. Other active development sites will also be monitored throughout the watershed to document any water quality violations.

Conclusions:

After one full year of monitoring preliminary observations have been made regarding the seventeen rivulets within the five direct drainage subwatersheds studied. Possible sources of phosphorus and nitrates in the drainage area for T-32B, phosphorus in T-34A and nitrates in T-33B will be further investigated. Overall results demonstrate that the rivulets when compared to the more perennial streams contribute comparable levels of nutrients and slightly lower levels of sediment to the lake.

It is very important to point out that even these direct drainages are largely unable to scientifically document the nutrient, sediment and bacterial inputs from the dense ring of residential properties that surround Canandaigua Lake. The overwhelming majority of precipitation landing on these 1,200 plus properties will not enter a stream or rivulet where pollution levels can be isolated and measured before eventually entering the lake. Rain and snowmelt on these micro direct drainages overwhelmingly bypass any defined drainage way and directly enter the lake carrying with it all the signatures of human kind. Upland sources of pollution may be diluted by wetlands and in-stream processes, but lakeside pollution can only diluted by the lake itself. In lake dilution of pollution is not a long-term solution.

National, state and local studies have documented the negative impacts high density development can have on water quality. Elevated levels of heavy metals, hydrocarbons, nutrients and bacteria are just some of the types of pollution associated with suburban living. It is important that these critical lakeshore residents understand that they are part of the problem and hopefully ultimately the solution to protecting this treasured resource.

Bacteria:

Fecal coliform is used as an indicator bacteria of possible harmful pathogens in the water. Sources of bacteria include urban runoff, failed septic systems, broken sewer lines, pet waste, wild animals, and agricultural operations. Due to dry baseline conditions most of the regular streams either dried up or had extremely low flow by mid-summer making valid sample collection impossible. Results show that Sucker Brook, Vine Valley, Gage Gully and Fall Brook had the highest colonies of fecal coliform (colonies per 100 ml of water) over the five monthly samples. The June 17th sample date showed the highest levels of fecal coliform overall. Bacteria sampling continues this year with samples collected in May and June.

Sampling ID	Sample Location	4/11/02	5/16/02	6/17/02	8/7/02	10/30/02
T-1	Fall Brook	3	123	300	Dry	Dry

T-2	Deep Run	2	72	280	Dry	Dry
T-3	Gage Gully	7	58	200	312	Dry
T-4	Fisher Gully	4	20	153	Dry	Dry
T-5	Vine Valley	<1	34	TNTC	320	Dry
T-6	Upper Vine Valley		420	Dry	Dry	Dry
T-8	West R.	10	69	170	10	2
T-12	Naples		45	142	34	1
T-13	Cook's Point	8	28	128	56	Dry
T-14	Hick's Point	1	3	17	Dry	Dry
T-15	Seneca Point	1	18	43	32	30
T-15A	Upstream Bristol STP	1	16	38	Dry	Waterlogged sample
T-15B	Bristol STP	2	36	120	Dry	3
T-16	Barnes Gully	2	8	43	Dry	Dry
T-17	Menteth Point	2	28	54	37	<1
T-18	Tichenor Gully	14	36	174	Dry	Dry
T-20	Sucker Brook	16	652	TNTC	Waterlogged sample	5
T-B (misc.)	Grimes Ck. Rcwy@Ontario St.	18	96	212	65	1
T-C (misc.)	Grimes Creek Rcwy@46 E.St.	158	24	50	Waterlogged sample	<1
T-D (misc.)	Hope Pt.	16	76	264	Dry	Dry

Table- 4. Fecal Coliform results in colonies per 100ml.

Site ID	Location	4/3/02	4/15/02	5/2/02	5/12/02	11/22/02	3/17/02
T-22A	Outfall from Lake side estates	91	dry	390	37	150	19
T-22B	4076 W. Lake Rd	33	dry	51	dry	dry	180
T-22C	Hope Pt.	34	31	110	32	51	130
T-22D	3725 W. Lake Rd.	45	26	140	48	52	71
T-22E	Drainage from Senior complex	58	47	150	82	45	61
T-22F	Drainage to Holiday Harbour	51	37	140	51	640	83
T-31A	5300 East Lake Rd.	18	21	38	34	dry	260
T-32A	Just South of Jones Rd.	56	72	46	34	dry	190
T-32B	Just North of Church Camp	200	220	330	dry	dry	440
T-33A	Dead end in Lake Dr.	48	36	50	39	dry	54
T-33B	Main trib along Lake Dr.	33	46	29	22	20	170
T-33C	Trib coming from Hall Rd.- lake dr.	96	71	180	97	90	71
T-34A	Along Private Dr.- just north of Powell	250	dry	290	320	290	170
T-34B	Shoal water point @364	50	90	75	55	520	120
T-34C	3810 Private Drive- drains turner rd.	46	45	57	42	27	69
T-34D	Thorndale Beach- wire mesh foot bridge	40	52	110	35	dry	64
T-34E	Sandy Beach Drive	42	dry	120	59	dry	85

Table- 5. Phosphorus concentrations in ug/l

Site ID	Location	4/3/02	4/15/02	5/2/02	5/12/02	11/22/02	3/17/02
T-22A	Outfall from Lake side estates	110	dry	650	16	170	4
T-22B	4076 W. Lake Rd	41	dry	100	dry	dry	420
T-22C	Hope Pt.	26	18	210	33	9	240
T-22D	3725 W. Lake Rd.	15	7	260	44	4	69
T-22E	Drainage from Senior complex	23	6.5	130	53	4	24
T-22F	Drainage to Holiday Harbour	19	12	190	30	18	59
T-31A	5300 East Lake Rd.	5	5	42	29	dry	1200
T-32A	Just South of Jones Rd.	21	8	21	19	dry	200
T-32B	Just North of Church Camp	10	14	27	dry	dry	380
T-33A	Dead end in Lake Dr.	17	11	64	46	dry	49
T-33B	Main trib along Lake Dr.	9.5	38	42	19	4	230
T-33C	Trib coming from Hall Rd.- lake dr.	22	18	180	76	19	12
T-34A	Along Private Dr.- just north of Powell	27	dry	230	110	18	10
T-34B	Shoal water point @364	16	29	120	31	56	97
T-34C	3810 Private Drive- drains turner rd.	21	31	89	44	4	71
T-34D	Thorndale Beach- wire mesh foot bridge	21	39	140	37	dry	53
T-34E	Sandy Beach Drive	11	dry	120	39	dry	72

Table -6. Total Suspended Solids concentrations in mg/l

Site ID	Location	4/3/02	4/15/02	5/2/02	5/12/02	11/22/02	3/17/02
T-22A	Outfall from Lake side estates	0.5	dry	0.53	0.3	2	0.77
T-22B	4076 W. Lake Rd	0.074	dry	0.17	dry	dry	0.5
T-22C	Hope Pt.	0.67	0.094	0.089	0.03	0.43	0.43
T-22D	3725 W. Lake Rd.	1.4	1.5	0.087	0.074	0.14	1.4
T-22E	Drainage from Senior complex	0.25	0.16	0.17	0.054	0.15	0.33
T-22F	Drainage to Holiday Harbour	3.3	1.3	0.05	0.1	0.46	1.9
T-31A	5300 East Lake Rd.	0.5	0.23	0.27	0.15	dry	0.74
T-32A	Just South of Jones Rd.	2.3	4.4	1	0.93	dry	2.1
T-32B	Just North of Church Camp	3.5	4.7	1.4	dry	dry	4.3
T-33A	Dead end in Lake Dr.	0.95	0.84	0.26	0.5	dry	1.1
T-33B	Main trib along Lake Dr.	6.1	8.1	3.8	3.3	0.074	6.3
T-33C	Trib coming from Hall Rd.- lake dr.	0.34	0.37	0.26	0.12	1.1	0.48
T-34A	Along Private Dr.- just north of Powell	0.57	dry	0.45	0.16	0.97	0.91
T-34B	Shoal water point @364	2.0	4.3	0.88	0.55	1.8	2.8
T-34C	3810 Private Drive- drains turner rd.	2.0	3.7	0.71	0.82	0.21	2.3
T-34D	Thorndale Beach- wire mesh foot bridge	2.4	1.6	0.57	0.84	dry	1.4
T-34E	Sandy Beach Drive	0.074	dry	0.029	0.02	dry	0.1

Lake Foam

Road salt monitoring

Road salt contamination of tributary streams varies with location and winter severity (Table XX and Figure XX). The winter of 2002-2003 demonstrated the effects of a cold winter with high snowfall. In fact, this year only the Cook's Point stream and Hick's Gully fell below the long term average. Chloride levels were highest in Lower Sucker Brook (254 mg/L), followed by Upper Sucker Brook (168 mg/L), Gage Gully (141 mg/L) and the Cook=s Point

Stream (124 mg/L),. Only four streams had chloride concentrations exceeding 100 mg/L. The situation at Cook's Point appears better now, seven years after the construction of a building to cover the Town of South Bristol Highway Department=s salt pile. A segment analysis of the Cook=s Point stream on February 27, 2003 revealed high levels just below the historically contaminated soil (130 mg/L) but also high chloride levels upstream of the Highway Department Barns (95 mg/L) as well as in the small tributary flowing under the bridge in the driveway to the South Bristol Town Hall (101 mg/L). These data are lower when compared to last year, a relatively mild winter, suggesting that most of the salt in the historically contaminated soil has leached away. The chloride concentrations in the stream segments are related to the quantity of de-icing salt applied in the rugged terrain of this subwatershed. Low results at Clark's Gully and Conklin Gully document background levels typical of forested watersheds lacking major highway corridors.

TABLE XX – Chloride concentration (mg/L) in Canandaigua Lake tributaries, 2002 and 2003.

Sample location	27 February 2002	27 February 2003	1990-2003 mean	1990-2003 range
T21 Fallbrook	80	63	57	24 – 167
T20 Deep Run	86	88	60	22 – 179
T19 Gage Gully	109	141	93	17 – 343
T18 Fisher Gully	11	28	11	0 – 29
T17 Upper Vine Valley	86	35	31	14 – 86
T17 Lower Vine Valley	53	28	25	12 – 53
T14 Upper West River	70	61	51	26 – 106
T13 Lower West River	44	38	35	17 – 78
T16 Clark's Gully	2	1	1	0 – 4
T11 Conklin Gully	6	4	3	1 – 8
T12 Upper Naples Creek	25	24	22	11 – 50
T 12 Lower Naples Creek	32	26	22	12 – 47
T27 Cook's Point	173	124	149	75 – 322
T10 Tannery Creek	27	26	*	*
T09 Reservoir Creek	37	30	*	*

T08 Eelpot Creek	21	17	*	*
T06 Hick's Point	60	47	55	15 – 148
T05 Seneca Point Gully	42	49	43	21 – 94
T04 Barnes Gully	65	97	74	29 – 203
T03 Menteth Gully	76	76	57	27 – 109
T02 Tichenor Gully	74	78	55	27 – 104
T01 Upper Sucker Brook	129	168	138	54 – 489
T01 Lower Sucker Brook	160	254	168	35 – 607
Outlet	39	30	32	19 – 58

* new sites added to the road salt sampling program in February 2002

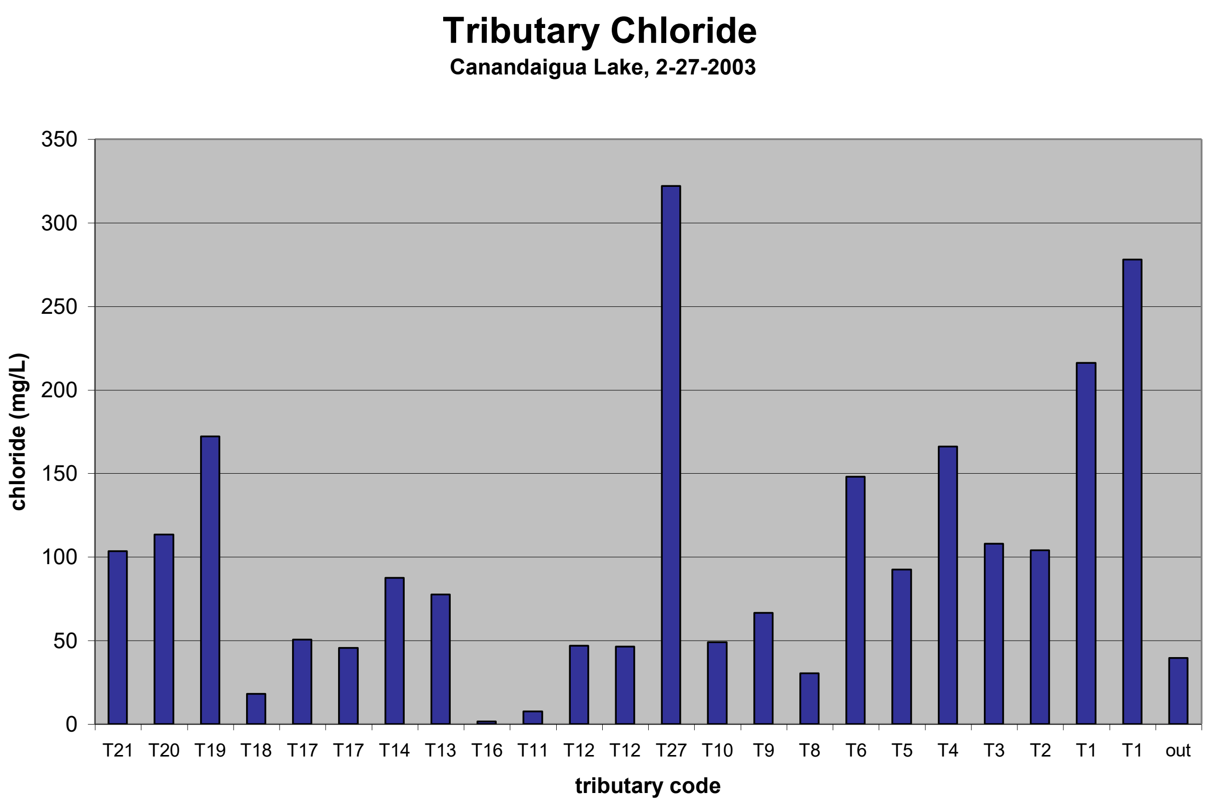

FIGURE XX - Road salt contamination in Canandaigua Lake tributaries.

Fourteen years of chloride record now exist for these tributary streams to Canandaigua

Lake. Figure XX presents a graphical summary where each year is represented by the mean chloride concentration in tributary streams. The years 2000 and 2003 stand out as harsh winters where more road salt was being applied during the month of February. While the winter cumulative road salt application totals may vary only slightly from year to year, the event-based application rates produce the significant differences captured in these data.

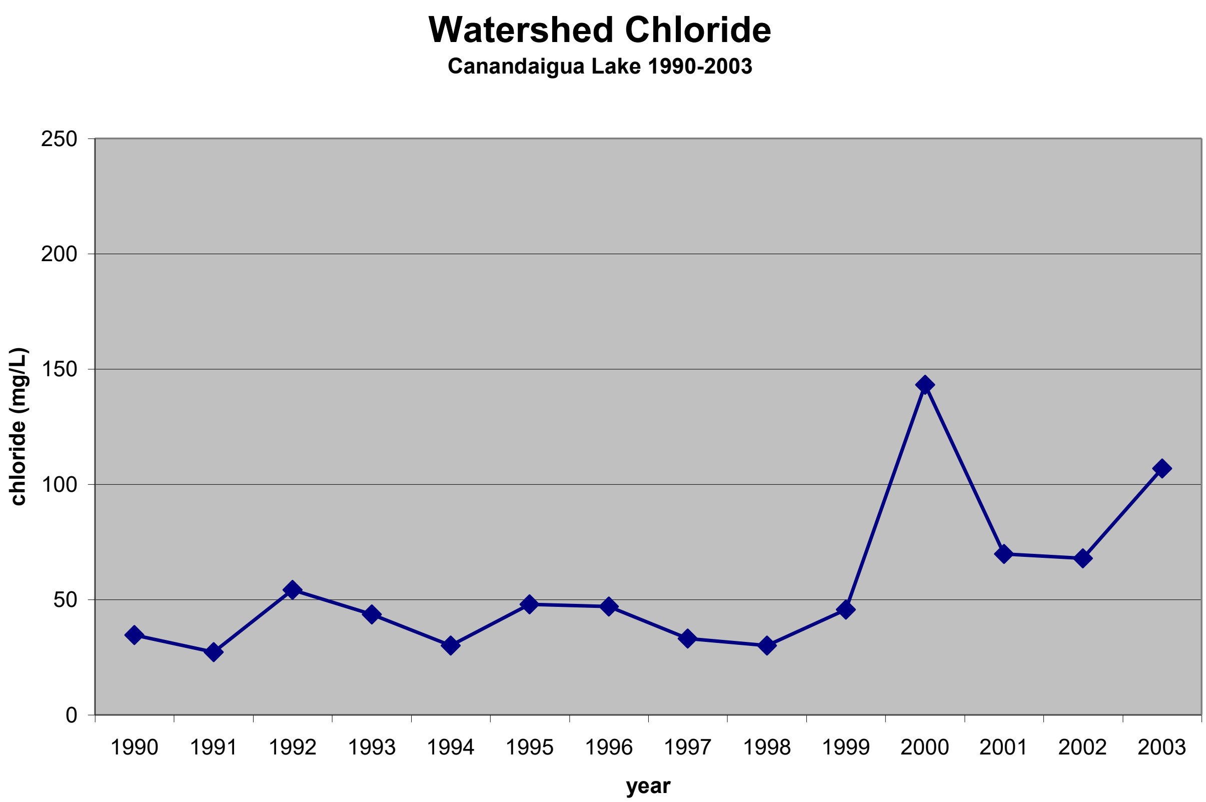

FIGURE XX - Long-term watershed chloride trends based on February sampling, 1990-2003.

Population status of zebra mussels

In last year's report (Gilman 2002), several observations were made that suggested a decline in the zebra mussel population in Canandaigua Lake. First, a decrease in lake clarity had been detected. Correspondingly, increases in chlorophyll *a* continued a three year trend. Finally, local residents mentioned seeing fewer and fewer mussels on the lake bottom and some reported large numbers of empty mussel shells along their shoreline (see feature article in local newspaper "Daily Messenger", November 15, 2001, section B, page 1). While no historical data exists for comparison, it was still considered important to gather information on the status of the zebra mussel population this year. These data will serve as an important baseline for future mussel research in the lake.

The density of zebra mussels varied with location (Figure XX). Greater numbers were found where macrophyte stems served as the principal substrate. The deep sample at the Woodville location contained 11,079 mussels/m^2. Most were attached to Eurasian milfoil (*Myriophyllum spicatum*). Mussels also occurred in high density in the near shore sample at the Water Treatment Plant, 6,369 mussels/m^2, where they attached to stonewort (*Chara vulgaris*). Fewer mussels were detected in coarse sandy bottoms where they seemed only to attach to large rocks. Only 29/m^2 and 57/m^2 were collected in the near shore samples at Fallbrook and Vine Valley, respectively. Other data on mussel monitoring is located in the Appendix.

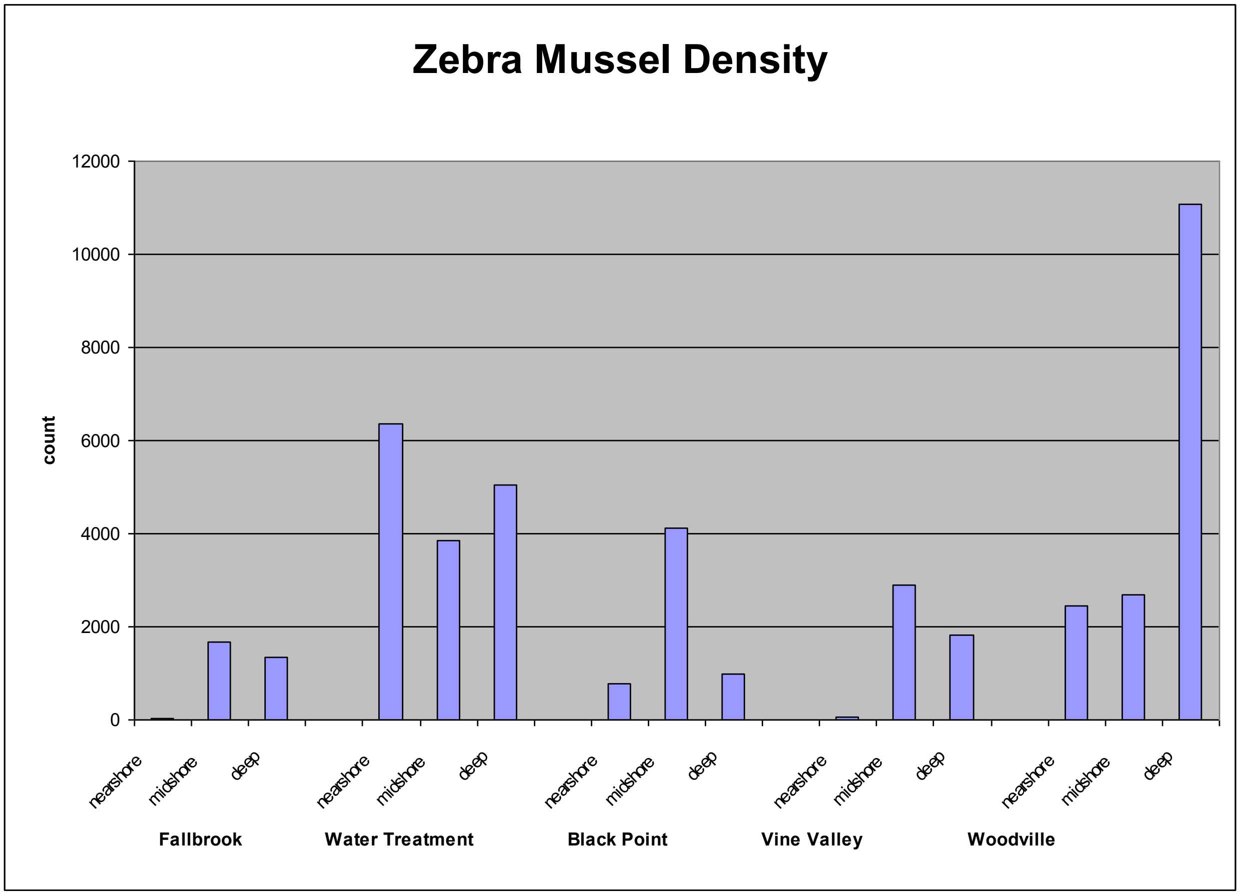

FIGURE XX – Zebra mussel density for 15 samples in Canandaigua Lake.

Mussels on macrophytes tended to be small while those on rocks were larger. Individual mean weight (Figure XX) serves as a proxy for age and reveals the obvious – zebra mussels attached to permanent substrates like large rocks live longer and grow larger than mussels attached to temporary substrates like seasonal shoots of macrophytes. It is from these permanent substrates that a population can recover following a general die-back brought on by lack of palatable algae. This cyclic population dynamic should play out in Canandaigua Lake over the next 3-5 years.

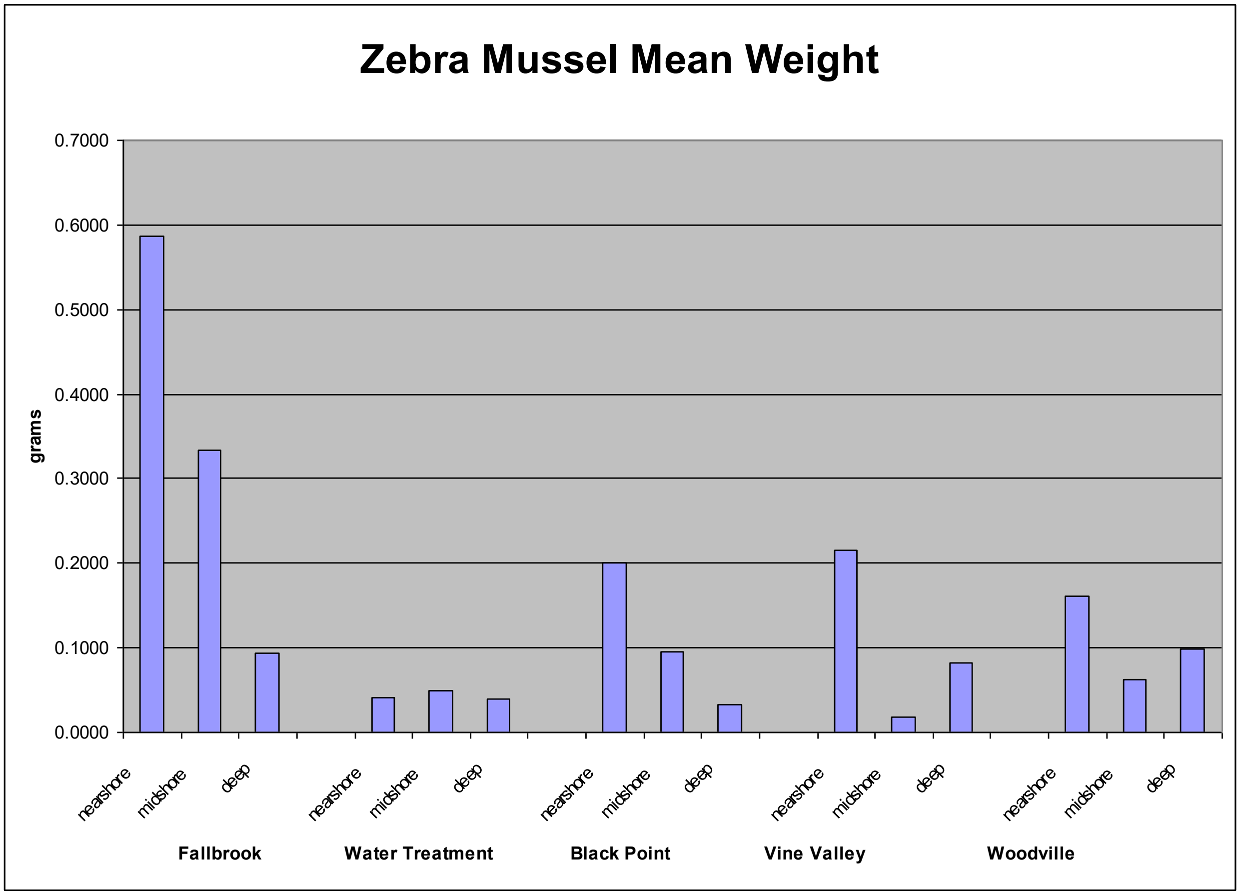

FIGURE XX – Zebra mussel mean weight for 15 samples in Canandaigua Lake.

Total zebra mussel biomass (Figure XX) was weakly related to density. Age and density together appear to control mussel biomass. Age is a function of substrate permanence and density is closely tied to food availability as well as the ability to mass in clumps (i.e. attach to each other with their byssal fibers).

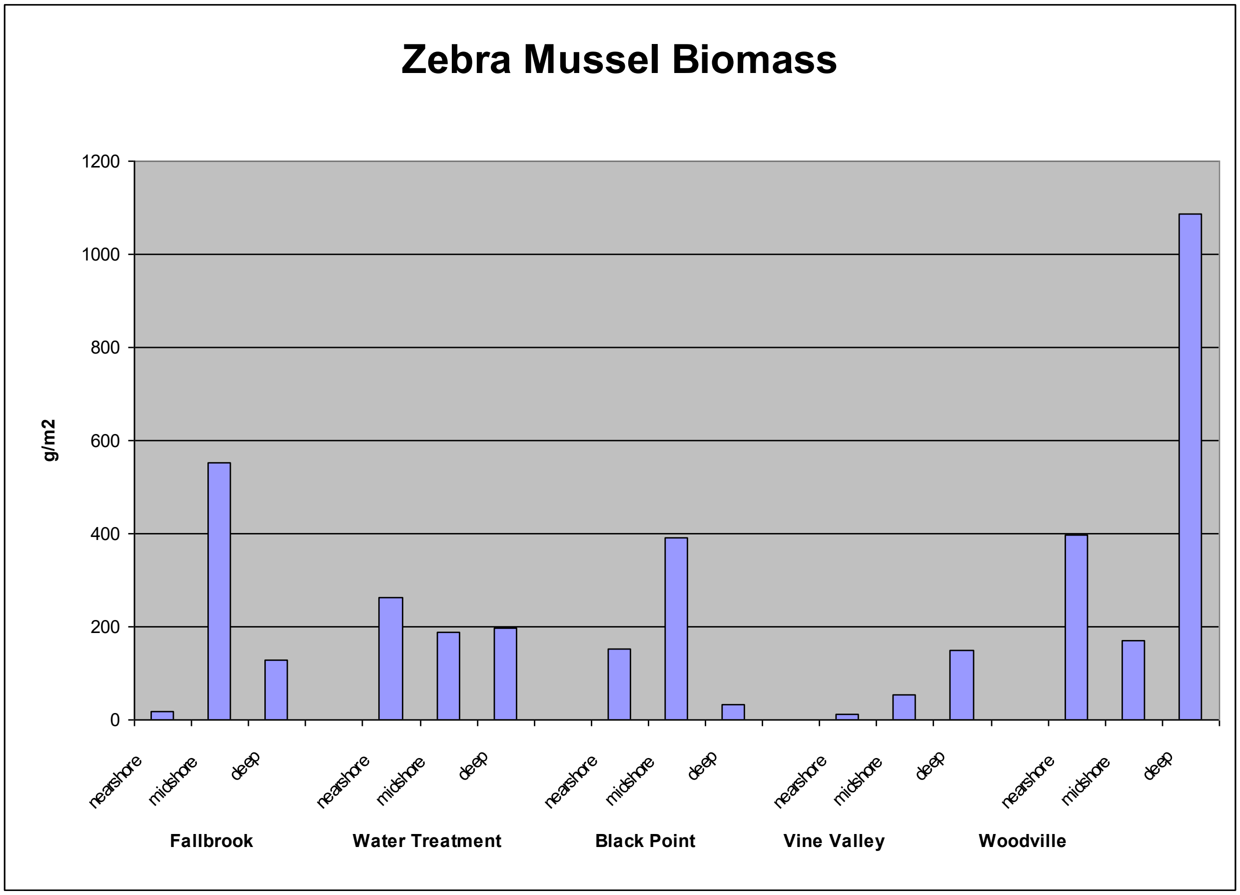

FIGURE XX – Total zebra mussel biomass for 15 samples in Canandaigua Lake.

Literature Cited

Berg, C.O. 1963. Middle Atlantic States in: Frey, D.G. (ed.) Limnology in North America. Univ. of Wisconsin Press. Madison, Wisconsin. pp 191-237.

Carpenter, S., N. F. Caraco, D.L. Correl, R.W. Howarth, A.N. Sharpley and V.H. Smith. 1998. Nonpoint pollution of surface waters with phosphorus and nitrogen. Issues in Ecology No. 3. 12 p.

Eaton, S.W. and L.P. Kardos. 1978. The limnology of Canandaigua Lake in: Bloomfield, J. (ed.) Lakes of New York State, Volume 1: Ecology of the Finger Lakes. Academic Press. New York, New York. pp 225-311.

Gilman, B.A. 1993. Summer monitoring of Canandaigua and Honeoye Lakes. Finger Lakes Community College. Canandaigua, New York. 39 p.

Gilman, B.A. 1994. 1994 water quality monitoring program for Canandaigua Lake and Honeoye Lake. Finger Lakes Community College. Canandaigua, New York. 54 p.

Gilman, B.A. 1996. 1996 water quality monitoring program for Canandaigua Lake. Finger Lakes Community College. Canandaigua, New York. 36 p.

Gilman, B.A. 1997. 1997 water quality monitoring program for Canandaigua Lake. Finger Lakes Community College. Canandaigua, New York. 26 p.

Gilman, B.A. 1998. 1998 water quality monitoring program for Canandaigua Lake. Finger Lakes Community College. Canandaigua, New York. 24 p.

Gilman, B.A. 1999. 1999 water quality monitoring and trend analyses for Canandaigua Lake. Finger Lakes Community College. Canandaigua, New York. 41 p.

Gilman, B.A. 2000. Year 2000 water quality monitoring and trend analyses for Canandaigua Lake. Finger Lakes Community College. Canandaigua, New York. 47 p.

Gilman, B.A. 2002. 2001-2002 water quality research for Canandaigua Lake and its watershed. Finger Lakes Community College. Canandaigua, New York. 87 p.

Gilman, B.A. and L. Rossi. 1983. Weedbed productivity at the south end of Canandaigua Lake. Community College of the Finger Lakes. Canandaigua, New York. 12 p.

Harris, G.P. and J.N.A. Lott. 1973. Observations of Langmuir circulations in Lake Ontario. Limnology and Oceanography 18(4):584-589.

Langmuir, I. 1938. Surface motion of water induced by wind. Science 87:119-123.

Makarewicz, J.C. and T.W. Lewis. 1998. Nutrient and sediment loss from watersheds of Canandaigua Lake. SUNY Brockport. Report to Canandaigua Lake Watershed Taskforce. 45 p.

Makarewicz, J.C. and T.W. Lewis. 1999a. The loss of nutrients and materials from the Naples Creek watershed. SUNY Brockport. Report to Canandaigua Lake Watershed Taskforce. 21 p.

Makarewicz, J.C. and T.W. Lewis. 1999b. Nutrient and sediment loss from watersheds of Canandaigua Lake: January 1997 to January 1999. SUNY Brockport. Report to Canandaigua Lake Watershed Taskforce. 46 p.

Makarewicz, J.C. and T.W. Lewis. 2000. Nutrient and sediment loss from watersheds of Canandaigua Lake: January 1997 to January 2000. SUNY Brockport. Report to Canandaigua Lake Watershed Taskforce. 52 p.

Makarewicz, J.C. and T.W. Lewis. 2001a. Canandaigua Lake subwatersheds: Time trends in event loading and the watershed index. SUNY Brockport. Report to Canandaigua Lake Watershed Taskforce. 32 p.

Makarewicz, J.C. and T.W. Lewis. 2001b. An addendum to segment analysis of Sucker Brook: The location of sources of pollution. SUNY Brockport. Report to Canandaigua Lake Watershed Taskforce. 19 p.

Makarewicz, J.C. and T.W. Lewis. 2001c. Stressed stream analysis of Deep Run and Gage Gully in the Canandaigua Lake watershed. SUNY Brockport. Report to Canandaigua Lake Watershed Taskforce. 76 p.

Makarewicz, J.C. and T.W. Lewis. 2002. Small intermittent rivulets versus major tributaries: The loss of soil and nutrients from selected small subwatersheds compared to the major subwatersheds of Canandaigua Lake. SUNY Brockport. Report to Canandaigua Lake Watershed Taskforce. 22 p.

Makarewicz, J.C., T.W. Lewis and S.S. Lewandowski. 1999. Segment analysis of Sucker Brook: The location of sources of pollution. SUNY Brockport. Report to Canandaigua Lake Watershed Taskforce. 45 p.

Napolitano, G.E. and J.E. Richmond. 1995. Enrichment of biogenic lipids, hydrocarbons and PCBs in stream-surface foams. Env. Toxicology and Chemistry 14(2):197-201.

Olvany, K. (editor). 2001. The Canandaigua Lake Watershed Management Plan: A strategic tool to protect the lifeblood of our region. Canandaigua Lake Watershed Council.

Olvany, K., M. Helms, E. Thingvoll and J. Terninko. 1997. The Canandaigua Lake Book: Your Personal Guide for Protecting our Vital Resource. Canandaigua Lake Watershed Taskforce. Canandaigua, New York. 68 p.

Sherwood, S.D. 1993. Report on the determination of existing and potential pollutants affecting the Canandaigua Lake watershed. Center for Governmental Research. Rochester, New York. 127 p.

Wetzel, R.G. and G.E. Likens. 1991. Limnological analyses. Springer-Verlag New York, Inc. 391 p.

Appendix

sampling locations, monthly *in situ* data, daily precipitation records

2002 Zebra mussel monitoring data

Location	Depth (m)	Density (m^2)	Mean weight (g)	Biomass (g/m^2)
Fallbrook				
Near shore	1.1	29	0.5867	17
Mid depth	2.7	1659	0.3329	552
Deep	4.4	1354	0.0942	128
Water Treatment				
Near shore	1.5	6369	0.0414	264
Mid depth	2.8	3852	0.0488	188
Deep	4.5	5034	0.0394	198
Black Point				
Near shore	0.9	763	0.2000	153
Mid depth	3.8	4119	0.0949	391
Deep	6.5	992	0.0328	33
Vine Valley				
Near shore	1.1	57	0.2150	12
Mid depth	3.2	2908	0.0187	54
Deep	5.0	1812	0.0826	150
Woodville				
Near shore	2.0	2460	0.1616	398
Mid depth	2.6	2689	0.0628	169
Deep	3.6	11079	0.0980	1085