Water Quality of Seneca Lake
1991-1998

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SUMMARY

The water quality of Seneca Lake has been studied since the early 1900's when secchi disk readings were first taken. At that time, the trophic state of Seneca Lake was classified as oligotrophic; that is, nutrient concentrations and primary production were low and transparency high. Water clarity remained approximately the same up through the early 1930s. In general, by the late 1970s water clarity had decreased, indicating the lake's trophic status was mesotrophic. Total phosphorus concentrations from the 1970s were into the mesotrophic range. Chlolophyll-a concentrations also illustrate the trend toward more productive waters in Seneca Lake in the early to mid 1970s. Similarly in the early 1970s, the transparency of Seneca Lake had decreased to within the eutrophic range. These low transparency values were observed into the early 1990s. Based on the sampling done by the Seneca County Soil and Water Conservation District in the 1990s, an improvement in water quality of Seneca Lake is suggested – at least at the north end where the samples were taken. Summer total phosphorus levels have decreased and perhaps as a result, phytoplankton levels have decreased slightly as indicated by the decrease in chlorophyll levels. However, it should be noted that the increase in transparency and the decrease in phytoplankton levels may well be the result of the high filtering capacity of the invading zebra mussels into Seneca Lake. The monitoring data do not provide an answer to this question. The trophic status of Seneca Lake is currently best described as oligotrophic. In conclusion, water quality of Seneca Lake appears to have improved since the early 1970s and within the 1991-1998 period of monitoring by the Seneca County Soil and Water Conservation District.

INTRODUCTION

Seneca Lake represents a major water resource of considerable economic, recreational and aesthetic value to central New York State. Maintenance of water quality, prevention of further deterioration of water quality and restoration of a lake's health are major concerns of the public. Monitoring the water quality of Seneca Lake has continued periodically from the early 1900's to the present. This report reviews data collected by the Seneca County Soil and Water Conservation District during the 1991-1998 period from the north end of Seneca Lake. The water quality data presented are the result of a new strategy to continually monitor Seneca Lake. Monitoring, as performed, provides the important function of documenting gradual improvements that may result from restoration efforts and remedial action plans. Similarly, monitoring provides evidence of deterioration of water quality and thus the opportunity for a management response and notification of the public of such changes. By considering nutrient and chlorophyll a concentrations and water clarity measurements, we review the current data from Seneca Lake using the previous historical measurements of the lake.

METHODS

General:

Seneca Lake was sampled once a week usually from late June or early July to September from 1991 to 1998 by personnel from the Seneca County Soil and Water Conservation District and by volunteers from Seneca County. All samples collected for water quality analysis were taken from Site #3 (Figure 1) with a Van Dorn water bottle. Secchi disk measurements were taken at three different sites along the center axis of Seneca Lake. Once samples were taken, they were packed in ice and transported to SUNY College at Brockport for water quality analysis within one day. A subsample was filtered on site for soluble nutrient analysis through a 0.45-µm membrane filter. Parameters analyzed included nitrate + nitrite, total phosphorus (TP), soluble reactive phosphorus (SRP), chlorophyll-a (Chl-a), and turbidity.

Water Chemistry:

Nitrate + Nitrite: Dissolved nitrate + nitrite nitrogen analyses were performed by the automated (Technicon Autoanalyser) cadmium reduction method (APHA 1999).

Total Phosphorus: The persulfate digestion procedure was used prior to analysis by the automated (Technicon autoanalyser) colorimetric ascorbic acid method (APHA 1999).

Turbidity: Turbidity was measured using a Turner nephelometer. The turbidimeter was calibrated with a known standard prior to measurements with routine verifications during analysis.

Soluble Reactive Phosphorus: Sample water was filtered through a 0.45-µm membrane filter. The filtrate was analyzed for orthophosphate using a Technicon Autoanalyzer II

(Technicon Industrial Method No. 15-71W). The formation of a phosphomolybdenum blue complex was read colorimetrically at 880 nm.

Chlorophyll a: Chlorophyll a was measured fluorometrically using a Turner Model 111 Fluorometer. Approximately 800 mL aliqouts were filtered through glass fiber filters and extracted with 90% alkaline acetone. Extracted samples were centrifuged and measured fluorometrically (Wetzel and Likens 1994).

Secchi Disk: The secchi disk depth was determined using a black and white 20-cm disk.

Quality Assurance Internal Quality Control: Multiple sample control charts (APHA 1999) were constructed for each parameter analyzed except chlorophyll. A prepared quality control solution was placed in the analysis stream for each sampling date. If the control solution was beyond the set limits of the control chart, corrective action was taken and the samples re-run.

External Quality Control: The Water Chemistry Laboratory at SUNY Brockport is certified through the New York State Department of Health's Environmental Laboratory Approval Program (ELAP - # 11439). This program includes biannual proficiency audits, annual inspections and good laboratory practices documentation of all samples, reagents and equipment. Table 1 is a summary of a proficiency audit.

RESULTS

Soluble Reactive Phosphorus (SRP):

Soluble reactive phosphorus provides information on the amount of phosphate ion present in the water column. Phosphate is the form of phosphorus that is readily taken up by phytoplankton and macrophytes and is generally considered the limiting factor to plant growth in lakes in New York. Since 1991, SRP summer average concentrations ranged from a minimum of 0.8± 0.1 µg P/L (mean±S.E.) in 1995 to a maximum of 3.0 ± 0.6 µg P/L in 1991 with an average concentration of 1.9 µg P/L for the study period (Table 2). There were no obvious trends during the study period (Fig. 2). However, concentrations were noticeably lower in the mid-1990s.

Total Phosphorus (TP):

Total phosphorus provides an estimate of the total amount of phosphorus potentially available to aquatic plants. For example, winter TP values are often a reliable prediction of summer chlorophyll a concentrations – that is the amount of phytoplankton present in the water column. Winter samples were not taken. Even so, summer TP concentrations do provide insight on trophic status; that is relative productivity of the lake. TP summer average concentrations ranged from a minimum of 5.3 ± 1.0 μg P/L in 1994 and 1995 to a maximum of 10.5 ± 2.1 μg P/L in 1993 (Table 2). As with SRP, there were no significant differences in TP concentrations or obvious trends over the study period (Fig. 2) except that total phosphorus concentrations were noticeably lower in the mid-1990s. Average total phosphorus concentration for the study period was 7.9 μg P/L.

Chlorophyll-a (Chl-a):

Chlorophyll a provides an estimate of algal abundance in lakes. Generally, algal abundance increases with increasing levels of phosphorus in the water column. In fact, a strong correlation (r=0.90) between TP and Chl-a concentrations was observed during the 1991-1998 period which suggests that phosphorus plays a role in controlling algal abundance in Seneca Lake. Over the study period, Chl-a concentrations were variable and ranged from an average summer minimum of 2.0 ± 0.2 μg/L in 1995 to a maximum of 5.0 ± 0.6 μg/L in 1992 with no upward or downward trends (Table 2, Fig. 2). Average chlorophyll-a concentration for the study period was 3.4 μg/L.

Nitrate (NO_3):

Figure 3 represents yearly average nitrate concentrations in Seneca Lake from 1991 to 1998. Temporal variability in nitrate concentration was similar to other nutrients and ranged from a minimum of 0.26 ± 0.02 mg N/L in 1991 to a maximum of 0.39 ± 0.01 mg N/L in 1994 (Table 2) with no obvious trends. Average concentration for the study period was 0.34 mg N/L.

Turbidity:

Figure 4 illustrates yearly average turbidity readings of samples taken from Seneca Lake from 1992 to 1998 (turbidity was not measured in 1991). Minimum mean yearly turbidity was observed in 1995 at 0.58 ± 0.08 NTU. Maximum yearly turbidity measurements occurred in 1997 at 1.30 ± .19 NTU. As with Cayuga Lake (Makarewicz et al. 1999), this resulted from high readings associated with a storm with strong southerly winds that mixed sediments into the water column. Mean annual turbidity for the study period was 0.80 NTU (Table 2).

Secchi Disk (Lake Clarity):

Figures 5a (Site 1), b (Site 2), and c (Sites 3) display monthly average secchi disk readings during the summer months from 1991 to 1998. The data suggest that the transparency or clarity of the lake has increased since 1991. At Sites 1, 2 and 3 transparency progressively increased from generally less than 3m in 1991 to 1993 to generally over 8m from 1994 to 1998. In 1997 and 1998, transparency reached as high 10m. Since, 1991 transparency has increased by a factor greater than 100% (<4m to 10m). The lake has become remarkably clearer over the pass decade.

DISCUSSION

A lake's health or water quality is often associated with its trophic status. A lake that is oligotrophic is biologically unproductive with high transparency and low nutrient concentrations while a eutrophic lake is biologically productive with low transparency and high nutrient concentrations. A mesotrophic lake is a lake with characteristics intermediate of oligotrophic and eutrophic. With time, soil particles from the watershed are gradually added to the lake, thus decreasing depth. Nutrients from the watershed are also constantly added, increasing concentrations of limiting nutrients such as phosphorus. Biotic productivity increases with the higher nutrient concentrations, sedimentation of dying plankton increases, and transparency of the lake decreases accordingly. This process is natural and is called eutrophication. However, the actions of man in a lake's watershed can increase the loss of soils and nutrients from the watershed into the lake. This cultural eutrophication accelerates the natural aging process often leading to deteriorating water quality. Reducing cultural effects by decreasing the rate of eutrophication and improving water quality is the goal of many environmental agencies concerned with the health of lakes. In the next few pages, we review the historical data available for three parameters often used to determine a lake's trophic status and to assess any changes in the lake over the past 50 years.

Phosphorus (Table 3)

The Environmental Protection Agency (1974) monitored Seneca Lake as part of the National Eutrophication Survey and reported a TP range of 7-14 μg P/L in the summer of 1972 with a mean of 9 μg P/L. Mills (1975) observed a similar set of TP concentrations for the summer of 1973 (mean=10.9, range=9-12.8). Oglesby and Schaffner (1975) analyzed TP concentrations in all of the Finger Lakes of New York State. They reported a winter TP concentration of 17.8 μg P/L. In summer of 1994, Pawlaczyk (1995) observed a summer TP average to be 7.8 ± 1.1 μg P/L. Statistically, Pawlaczyk concentration is statistically the same as the summer average found in this study. The average summer TP concentration from 1991 to 1998 as determined was 7.9 μg P/L with a range of 5.3 to 10.5. There were no clear trends in total phosphorus concentrations over the 1991 to 1998 period (Fig. 2). However, total phosphorus concentrations from the 1991-1998 period appear to be slightly lower than in those in the early 1970s (Fig. 7).

Chlorophyll-a (Table 4)

Chl-a concentrations in the summer of 1972 ranged from 0.2 μg/L to 10.4 μg/L, with the minimum being in May and the maximum being in July (EPA 1974). A 1973 synoptic survey (Bloomfield 1978) reported chl-a concentrations of 3 - 5.5 μg/L. Oglesby and Schaffner (1975) analyzed summer chlorophyll-a concentrations in all of the Finger Lakes of New York State and observed an average summer concentration of 7.1 μg/L for Seneca Lake. In 1995, Pawlaczyk (1995) observed summer average chl-a concentration to be 1.21 μg/L, which would be classified as oligotrophic. With an average of 3.4 μg/L during the 1991-1998 period (range of 2.0 – 5.0 μg/L), chlorophyll a levels were slightly lower than those observed in early and mid 1970s (Figs. 2 and 8).

Transparency (Secchi Disk)(Table 5)

Our early knowledge of Seneca's Lake's water quality dates from the early 1900s. Birge and Juday (1921) observed secchi disk readings averaging 8.3 meters in 1910. Similar high transparency readings were observed by Muenscher (1928) (9.1m). By 1973, the transparency of the lake had decreased dramatically. Oglesby and Schaffner (1975) observed a summer average of 3.6 meters in Seneca Lake in the early 1970s. Bloomfield (1978) reports a transparency range of 2-4.5m; also for the early 1970s (Fig. 6). In this study, transparency progressively increased from generally less than 3m in 1991 to 1993 to generally over 8m from 1994 to 1998. In 1997 and 1998, individual transparency values reached as high as 10m. Values not observed since the early 1900s. Since, 1991 transparency has increased by a factor greater than 100% (<4m to 10m) (Table 2). The lake has become remarkably clearer over the pass decade. This dramatic improvement in water clarity may be the result of management practices reducing nutrient losses from the watershed. However, the improvement in transparency does correlate with the invasion of zebra mussels (Dreissena polymorpha). Zebra mussels were first observed in 1991 in Seneca Lake and were widespread throughout the lake by 1993 (Jim Malyj, Personal communication). Zebra mussels are known to actively filter out particles from the water column. In the western basin of Lake Erie, transparency increased after the introduction of zebra mussels (Makarewicz et al. 1999).

Carlson's Trophic Status Index (TSI):

Carlson's TSI is used to assess the trophic state of a given lake by analyzing winter TP concentrations and summer Chl-a concentrations, and by measuring summer secchi disk depth. This index is one of several that can be used to evaluate the trophic status of a lake; that is, what is the overall productivity of the lake. Based on the average summer Chl-a concentrations and secchi disk readings for the entire 1991-1998 period, Carlson's total TSI was less than 37 (Table 2) suggesting an oligotrophic status for the lake even though, the Chl-a value is within the mesotrophic classification range. The conclusion of an oligotrophic status is reinforced by considering the general relationship of lake productivity with phosphorus, transparency and chlorophyll (Table 6). Chlorophyll and total phosphorus concentrations as well as transparency readings observed during the 1991-98 period also indicate an oligotrophic status for Seneca Lake. This is particularly evident for epilimnetic total phosphorus.

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Table 1. Results of the semi-annual New York State Environmental Laboratory Assurance Program (ELAP Lab # 11439, SUNY Brockport) Non-Potable Water Chemistry Proficiency Test, July 1998. Score Definition: 4 (Highest) = Satisfactory, 3 = Marginal, 2 = Poor, 1 = Unsatisfactory.

Analyte	**Mean/Target**	**Result**	**Score**
Residue			
Solids, Total Suspended	54.3 mg/L	53.3 mg/L	4
Hydrogen Ion (pH)			
Hydrogen Ion (pH)	4.63	4.69	4
Organic Nutrients			
Kjeldahl Nitrogen, Total	9.00 mg/L	8.92 mg/L	4
Phosphorus, Total	3.46 mg/L	3.54 mg/L	4
Total Alkalinity			
Alkalinity	429 mg/L $CaCO_3$	438 mg/L $CaCO_3$	4
Inorganic Nutrients			
Nitrate (as N)	7.08 mg/L as N	6.62 mg/L as N	4
Orthophosphate (as P)	1.92 mg/L as P	1.67 mg/L as P	3
Minerals			
Chloride	74.8 mg/L	74.0 mg/L	4
Wastewater Metals I and II			
Calcium, Total	51.5 mg/L	53.7 mg/L	4
Magnesium, Total	5.78 mg/L	6.02 mg/L	4
Potassium, Total	10.7 mg/L	11.3 mg/L	4
Sodium, Total	40.0 mg/L	39.6 mg/L	4

Table 2. Average summer values for total phosphorus (TP), nitrate, soluble reactive phosphorus (SRP), chlorophyll a (Chl a), turbidity (Turb) and transparency (secchi disk). Values are the average for Site 3. The standard error is in parentheses. TSI equals Carlson's Trophic Status Index (TSI). *Not measured.

Seneca Lake Averages (Site 3)						
Year	**Nitrate (mg N/L)**	**SRP (µg P/L)**	**TP (µg P/L)**	**Chl-a (µg/L)**	**Turb (NTU)**	**Secchi Disk (m)**
91	0.26 (0.02)	3.0 (0.6)	9.1 (2.0)	2.4 (0.5)	*	4.9(.55)
92	0.38 (0.01)	2.7 (0.6)	9.7 (1.1)	5.0 (0.6)	0.79 (0.12)	3.1 (.34)
93	0.32 (0.01)	2.4 (0.8)	10.5 (2.1)	4.1 (1.3)	0.65 (0.12)	3.9 (.50)
94	0.39 (0.01)	0.9 (0.3)	5.3 (0.9)	2.6 (0.4)	0.70 (0.12)	6.8 (.50)
95	0.31 (0.01)	0.8 (0.1)	5.3 (1.1)	2.0 (0.2)	0.58 (0.08)	8.9 (.33)
96	0.34 (0.03)	1.9 (0.5)	8.7 (1.7)	4.0 (1.3)	0.75 (0.14)	6.3 (.29)
97	0.36 (0.01)	1.1 (0.5)	6.1 (0.6)	3.3 (0.6)	1.30 (0.19)	8.4 (.60)
98	0.35 (0.02)	2.4 (0.7)	8.2 (0.7)	3.4 (0.6)	0.84 (0.15)	9.4 (.50)
Average	0.34	1.9	7.9	3.4	0.80	6.4
TSI				42.1 (1.1)		34.1 (2.1)

Table 3. Historical comparisons of total phosphorus (µg P/L) concentrations in Seneca Lake.

Year	**Mean**	**Range**	**Period**	**Author**
1972	9	7-14	Autumn	EPA (1974)
1973	10.9	9.0-12.8	July and August	Mills (1975)
1995	7.8	6.9-9.1	Summer	Pawlacyzk (1995)
1991-1998	7.9	5.3- 10.5	June-September	This study

Table 4. Historical comparisons of chlorophyll a (µg/L) concentrations in Seneca Lake. NA=Not available.

Year	Mean	Range	Period	Author
1972	5.33	0.2-10.4	Summer	EPA (1974)
1973	NA	3.0-5.5	Sampled once in April, June and August	Bloomfield (1978)
1969-72	7.1	NA	Upper 10m	Oglesby and Schaffener (1975)
1995	1.21	NA	July-October	Pawlaczyk (1995)
1991-1998	3.4	2.0-5.3	June-September	This Study

Table 5. Historical comparisons of transparency (secchi disk) in Seneca Lake. Data for 1991–1998 is the mean for Site 3. NA=Not available.

Year	Mean	Range	Period	Author
1910	8.3	One reading	Week in August	Birge and Juday (1921)
1928	9.1	Not available	Summer	Muenscher (1931)
1969-72	3.6	Not available	Summer	Oglesby (1975)
1970-74	Not available	2.0-4.5	June-September	Bloomfield (1978)
1991-1993	3.9	3.1-4.8	June-September	This study
1994	6.8		June-September	This study
1995-1998	8.3	6.3-9.4	June-September	This study

Table 6. General relationship of lake productivity in relation to phosphorus, nitrogen, transparency and chlorophyll a. Adapted from Wetzel (1983). Seneca Lakes values are from Site 3.

	Epilimnetic Total Phosphorus (µg P/L)	**Annual Total Phosphorus (µg P/L)**	**Chl a (µg/L)**	**Secchi Disk (m)**
Oligotrophic	5-10	3.0-17.7	0.3- 4.5	5.4-28.3
Mesotrophic	10-30	10.9-95.6	3-11.0	1.5-8.1
Eutrophic	30-100	16.0-386	3-78.0	0.8-7.0
Hypereutrophic	>100	750-1200	100-150	0.4-0.5
Seneca Lake (91-93) (95-98)	 9.8 7.1	 NA	 3.8 3.1	 3.9 8.3

Figure 1. Location of sampling sites on Seneca Lake, 1991-1998.

Figure 5. Average monthly transparency (secchi disk) measurements for Seneca Lake. All error bars represent plus or minus the standard error.

Figure 3. Average nitrate concentrations in Seneca Lake from 1991 to 1998. The error bars correspond to the standard error.

Figure 4. Average turbidity readings in Seneca Lake for each summer from 1991 to 1998. The error bars correspond to the standard error.

Figure 2. Average total phosphorus, soluble reactive phosphorus and chlorophyll a concentrations, Seneca Lake. The error bars correspond to the standard error. The black bar represents SRP concentrations, the gray bar represents TP concentrations, and the white bar represents Chl-a concentrations.

Figure 6. Historical transparency values for Seneca Lake. Error bars represent the range of values observed. Sources of these data are listed in Table 5.

Figure 7. Historical total phosphorus values for Seneca Lake. Error bars represent the range of values observed. Sources of the data are listed in Table 3.

Figure 8. Historical chlorophyll a concentrations for Seneca Lake. Error bars represent the range of values observed. Sources of the data are listed in Table 3.