State of Honeoye Lake Water Quality
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Introduction

The measurements of parameters that describe the condition of Honeoye Lake are valuable in assessing its state and are necessary to justify implementing any remediation technique. Everyone that uses the lake, or just observes it, has a subjective impression of the state of the lake: clarity, algae, weed beds, lake level, zebra mussels, etc. Appropriate objective measurements are valuable since they can be analyzed and correlate to some extent with these subjective impressions.

This report presents graphs of the change over time of a few of the measured parameters that best summarizes the state of the lake. This data is but a small fraction of the data collected on Honeoye Lake over the past thirty years by volunteers, state agencies, and local colleges. There are hundreds of graphs and tables related to these measurements, which in this report have been summarized with the most important results in about a dozen graphs and tables.

Summary

Honeoye Lake has always been highly biologically productive and has experienced algae blooms that have been documented as far back as the 1940s (Figures 1 & 2). High levels of phosphorus are the primary cause of this biological productivity. This phosphorus comes from both external sources, such as runoff, and internal sources, which come primarily from phosphorus released from the bottom sediment during periods of anoxia. **The depth of a lake is one of the most important factors in determining biological productivity due to its effect on internal loading. Honeoye Lake has similar water quality characteristics to other lakes of similar depth.**

The monitoring shows significant algae blooms every year since 2010, whereas prior to 2010 they were more sporadic. The cause of this every year occurrence is unknown. Algae blooms were minimal from 2007-2009, after an alum application in 2006 and 2007.

Rooted aquatic vegetation has experienced changes in species dominance and a moderate reduction in total biomass over the past 20 years. Zebra mussels which were first found in the lake in 1998 increased for many years, but are now declining.

The lake level has been very effectively controlled to minimize variability from its normal level. Some have blamed the weir as a contributor to increased algae blooms, which I do not believe to be the case and is addressed.

Summer Water Quality Sampling Program

The growth of phytoplankton, which includes green algae, diatoms, and cyanobacteria (blue green algae), are influenced by lake bottom sediment characteristics, nutrient availability, temperature, and sunlight. Phytoplankton requires a variety of nutrients in varying amounts with phosphorus and nitrogen being the likely limiting nutrients. A DEC study (Callihan 2001) states that if N/P>20 the lake is phosphorus limited and if N/P<10 it is nitrogen limited. Nitrogen is generally not measured as part of Honeoye's sampling program, but it was measured in 2015 resulting in an average N/P=27.9 making the lake phosphorus limited. The minimum N/P =13.4, in late June, indicates the lake is close to being nitrogen limited at certain times. If a lake is nitrogen limited, it could give a competitive advantage to cyanobacteria over other organisms, since cyanobacteria can obtain its nitrogen by fixing it from the atmosphere. Since phosphorus is the limiting nutrient, it is the reason for focusing on phosphorus reduction, since we have no control over other environmental factors.

The summer water quality sampling program (Starke 2015) includes the most important measurements that reflect the cause of, and magnitude of this growth of phytoplankton. Sampling is conducted on at least a bi-weekly basis at the deepest point in the lake. This sampling program measures temperature and dissolved oxygen profiles from the surface to the bottom of the lake, total phosphorus (TP) and soluble reactive phosphorus (SRP) at the surface and at 8 meters, chlorophyll-a at the surface, and water clarity using a Secchi disk. This sampling program was first done in 2003 by Dr. Bruce Gilman and was fully reinstituted in 2007 and continues to the present time. Prior to this, a more limited water quality sampling program was performed under the DEC-CSLAP program from 1996-2000 (Kishbaugh 2002), and most of this data is also included in this report. Some of the data from a Finger Lakes sampling program (Halfman 2015) is also included.

Results of Summer Water Quality Sampling Program

In this report only three of the measured parameters are reported that best assess water quality, surface TP which is a major contributor to algal growth and two parameters which reflect the resultant amount of algae, surface chlorophyll-a and Secchi water clarity. Chlorophyll-a is the green pigment in phytoplankton that allows them to photosynthesize. By measuring chlorophyll-a, you are indirectly measuring the amount of phytoplankton found in the lake. The Secchi disk is used to measure water clarity by lowering a black and white disk into the water and noting the distance at which it is no longer visible. Greater amounts of algae reduce the water clarity and hence reduce the Secchi depth reading.

Limnologists classify lakes based on their biological productivity from oligotrophic (little) to eutrophic (significant). This classification is based on measured levels of TP, chlorophyll-a, Secchi water clarity, and oxygen saturation which is shown in Table 1, and shows that Honeoye is a eutrophic lake.

Based on sampling results presented in Figures 3-5 it is apparent that since 2010 both TP and chlorophyll-a have been higher than in previous years with a corresponding lower values for Secchi water clarity. This is indicative of greater amounts of algae. **While historically algae blooms are not uncommon in Honeoye Lake, this consistent every year algae bloom since 2010 is unprecedented**. Since Secchi water clarity in Figure 5 has been collected for all years except two since 1996, it best shows the trend over time. The changes in chlorophyll-a in Figure 4 show the same trends as Secchi water clarity, and is a measure of phytoplankton which is a more sensitive parameter. Unfortunately it was not measured as often prior to 2007.

In 2002 Honeoye Lake experienced one of its worst algae blooms in history. It lasted most of the summer and resulted in the Honeoye Valley Association (HVA) hiring Princeton Hydro to perform a lake water quality evaluation, which resulted in an alum application in the fall of 2006 and 2007. This application was done in the hope of reducing internal phosphorus loading and hence reducing the severity of algae blooms. Unfortunately, there was no water quality sampling program in 2002, so there were no objective measures of its severity, only subjective impressions. Reasonably good water quality existed from 2007-2009 as evident from the low levels of chlorophyll-a and high Secchi clarity in Figures 4 and 5. Lacking good objective data from years prior to the alum application it is not possible to definitively state that the alum application was the reason for the better water clarity, but the good water quality from 2007-2009 is an indication of its success.

A possible reason for the apparent short lifetime of the alum application (2-3 years) was its low dosage. A study on the use of alum (Huser2015) analyzed its use in 114 lakes worldwide and found that alum dosage and lake morphology to be the most significant factors in how long it is effective. In this study, there were only two lakes with a lower dosage rate than that used in Honeoye, and the average dosage rate used in polymictic lakes was four times that used in Honeoye. A polymictic lake, such as Honeoye, is one that is too shallow to develop a strong thermal stratification, and thus the lake's water can mix from top to bottom throughout its ice-free period. Another finding of the study was that the average lifetime of alum's effectiveness in stratified lakes was 21 years, versus only 6 years in polymictic lakes.

Possible Causes for decrease in water quality since 2010

Climate change, intense storms the past two years, and the recent appearance of gleotrichia algae in 2007 have been proposed as possible causes for the decrease in water quality since 2010.

Whether climate change is the cause of the change in Honeoye Lake's water quality is not clear. Table 3 compares changes in air and water temperatures from before and after 2010. This data shows small and inconsistent changes and is insufficient to identify climate change as the cause. In addition, based on results in Figure 6 of eight of the Finger Lakes (Halman 2015), the large reduction in Secchi in Honeoye Lake is not seen in any of the other lakes which all have similar climate to Honeoye. Figure 10 shows that in 2014 and 2015 Honeoye experienced several severe storms, possibly related to climate change. Runoff from these storms provides an increased flow of nutrients into the lake, but again there is insufficient data over enough years to show that this is the reason for a decrease in water quality. **While climate change may well be a contributing factor to the decrease in Honeoye's water quality, there is insufficient data on Honeoye Lake to prove this thesis.**

Another reason often suggested as a cause for the decrease in water quality is the recent appearance of gleotrichia cyanobacteria in 2007, whose life cycle provides increased nutrient s for late summer algae blooms. However, for 2015 there was virtually no gleotrichia, which makes this as a causative factor questionable.

Comparison of Honeoye Lake to Other Lakes

Being one of the Finger Lakes, Honeoye is often compared to the other Finger Lakes. However, Honeoye is very different from the other Finger Lakes, particularly regarding its depth. This is a very important factor that affects how much internal phosphorus is released from the bottom sediment, which greatly influences algae blooms and reduced clarity. In Table 3, in which the Finger Lakes are sorted by depth, the importance of depth is confirmed, where the three shallowest of the Finger Lakes are eutrophic. It is more appropriate to compare Honeoye to the lakes shown in Table 4, which have depths comparable to Honeoye. These lakes often appear in the news related to algae blooms, confirming that the objective parameter of lake depth is highly correlated to the subjective impression of the frequency and severity of algae blooms. The reason that depth is so important is that shallow lakes fail to develop a strong thermal stratification, which allows periodic mixing of the nutrient rich bottom waters throughout the summer months.

Lake Aquatic Vegetation

Dr. Bruce Gilman has done a detailed inventory of the rooted aquatic vegetation in the lake by sampling along 20 transects around the lake at five distances from 10-400 feet from the shoreline. This is a very labor intensive effort that is conducted every ten years starting in the fall of 1984. Being every ten years, it gives a snapshot of the species present and their density at these times, and is to some extent showing long term trends. However, it cannot show short term changes.

Figures 7 & 8 summarize the change in biomass and dominant species over the past thirty year period. From Figure 7 it is evident that in 1984 most biomass was limited to water depths less than about 9' while in 1994 & 2004 aquatic vegetation had migrated out to about 15 feet, most likely due to clearer water due to the presence of zebra mussels.. In 2014 the biomass retreated to about 12 feet, probably due to the reduced water clarity since 2010, which was discussed above. The total lake biomass for each year was estimated to be:

Biomass dry weight (kg)

1984	525,000
1994	333,000
2004	464,000
2014	412,000

The study in 1994 was done later in the fall than the other years and may explain the decrease in biomass for this year that does not seem consistent with the overall trend.

Figure 8 shows a large peak in Eurasian milfoil in 1994 that was common during this period of time in many lakes throughout the northeast. Since that time it has steadily declined. Eelgrass and coontail are always present in moderate amounts with the dominant species changing from year to year. There were 26 different species of macrophytes found in the study.

Harvesting of aquatic vegetation has been done since 1987 with the goal of improving recreational use of the lake and at the same time removal of biomass and the phosphorus it contains. Figure 9 summarizes the results of the harvesting program over the years. Harvesting has at times been a controversial practice, since it does not capture all of the harvested fragments that can be a nuisance when they collect along the shoreline. However, there are other sources of fragments, such as from boat props and the natural die-off of aquatic plants. One undeniable fact is that the harvesting program has removed over 15,000 wet tons of aquatic vegetation along with their nutrients over the past 30 years.

Zebra Mussels

Dr. Bruce Gilman discovered the first zebra mussels in Honeoye Lake in 1998, which had likely already been there for more than a year at that time. They multiplied rapidly and consumed phytoplankton which increased water clarity. Blue green algae however are their least favorite phytoplankton. With their sharp shells they presented a hazard along the shoreline. In addition they changed the food chain causing other disruptions to the lake ecology. More recently, in 2014 residents noticed a decline in their population. A zebra mussel sampling program (Gilman 2014) measured their abundance and found that their density and total biomass had declined by about 27% and 35% respectively since a previous survey in 2002, proving the public's subjective impression to be correct.

Lake Level

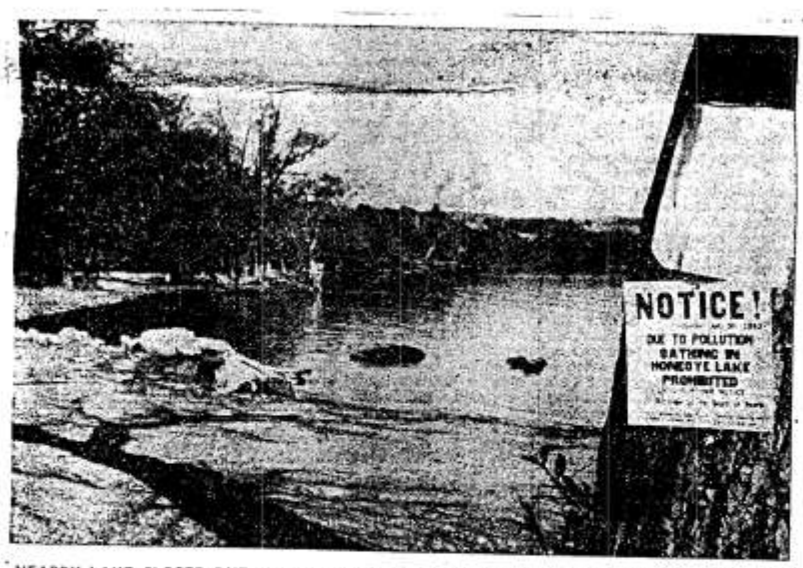
The earthen weir was replaced with a concrete weir in 1999 which was not significantly different except for the more uniform height of the concrete weir. From Figure 10 it is clear that the yearly peak values, which although variable from year to year, have not changed significantly over the years. This is not surprising since these peak values are caused by heavy rain events causing the lake level to rise rapidly. It then takes time for this excess water to drain from the lake. The highest level occurred during hurricane Agnes in 1971, and represents an anomaly. The minimum lake levels after installation of the new weir are about 6'' higher that before. This is due to a more uniform height of the new weir that prevents the lake level from dropping during dry periods. **The new weir is doing an excellent job of maintaining the lake level near its long term average height of 803.5 ft. above sea level, which was the objective of the new weir.**

Related to lake level and the weir, there have been suggestions by some that the new weir is increasing the severity of algae blooms by preventing flushing of the lake. Since the new weir was installed in 1999, if the weir was the cause of increased algae blooms, one would expect an increase in algal growth shortly after its installation, not ten years later.

Another reason that reduced flushing due to the weir is not valid is that the flushing would need to occur during July-August period when algal growth is at its peak. During this time period there is insufficient water south of the weir to promote the flow necessary to create this flushing effect. Some have suggested that removing the weir would accomplish this objective. However, if the weir were removed the increased flushing would occur during April, when the water levels are generally higher. By July-August when algae blooms typically occur the lake level would already be at a lower level with no water available to promote the intended flushing. This idea would just make the lake even shallower during the summer, which would exacerbate the problem of algal growth. In addition, it would allow the lake level to decrease to such an extent that boats could be grounded in their docks along the shoreline.

Figure 1 Aerial Photo of Honeoye Lake Showing Whole Lake Algae Bloom from 1940s

(N.Y.) Sun, Saturday, October 4, 1952 — 9



NEARBY LAKE CLOSED DUE TO POLLUTION — This empty beach at Honeoye Lake is mute testimony of what happens when the Health Department forbids swimming at a lake due to pollution. Just one week before the sign was posted, in right hand corner, this beach was crowded with fun seeking vacationists. Right up until the date the lake was closed local residents did not believe it was polluted. See story Page 20.

(Sun Photo by Nunn)

Figure 2 Honeoye Lake Closed by Department of Health in 1952

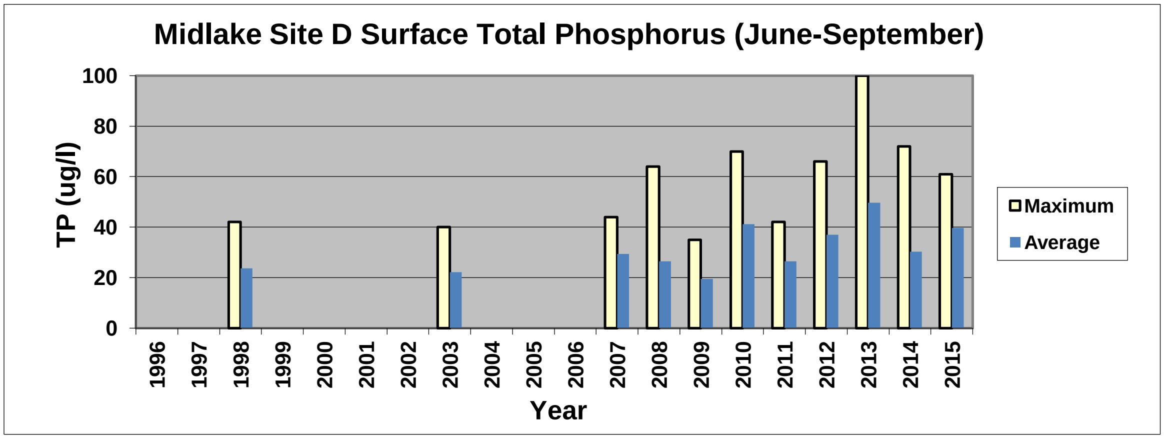


Figure 3 TP Summary

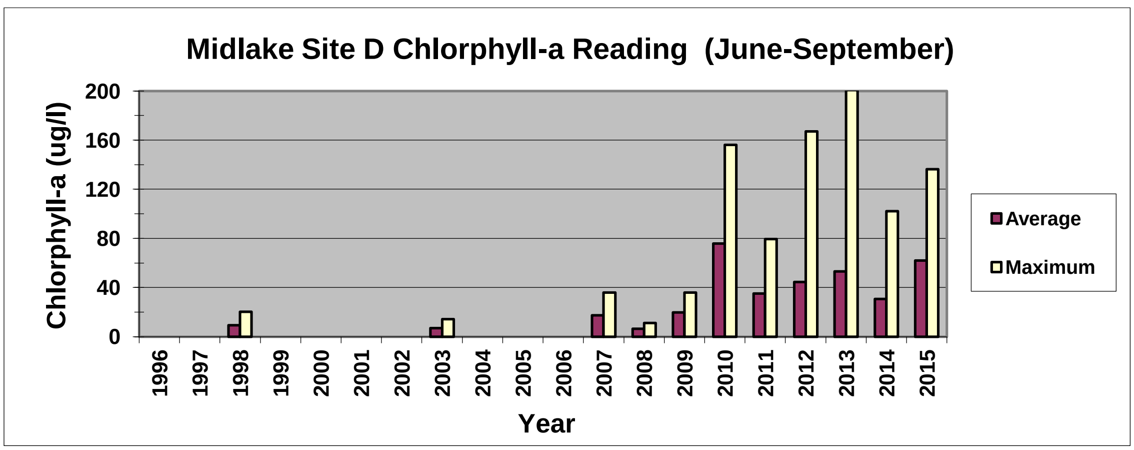


Figure 4 Chlorphyll–a Summary

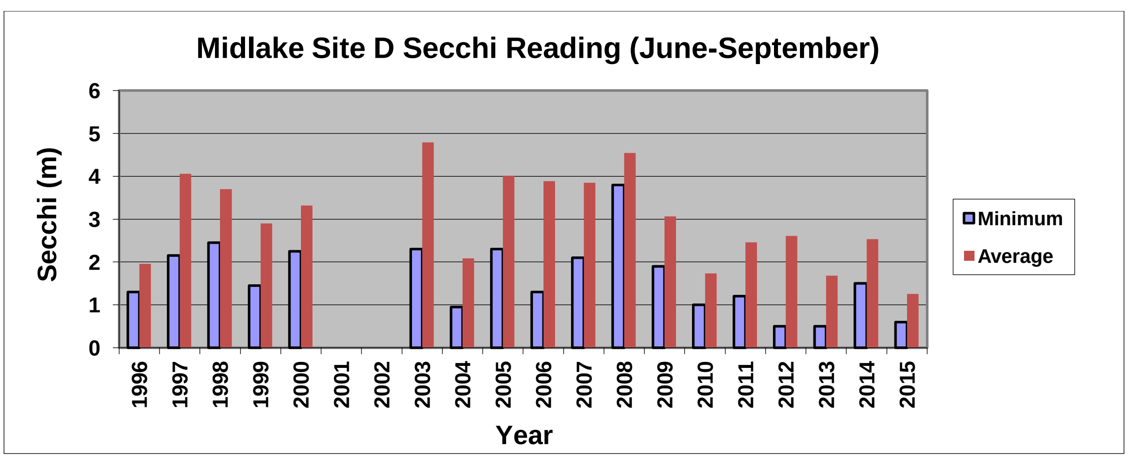


Figure 5 Secchi Disk Water Clarity Summaries

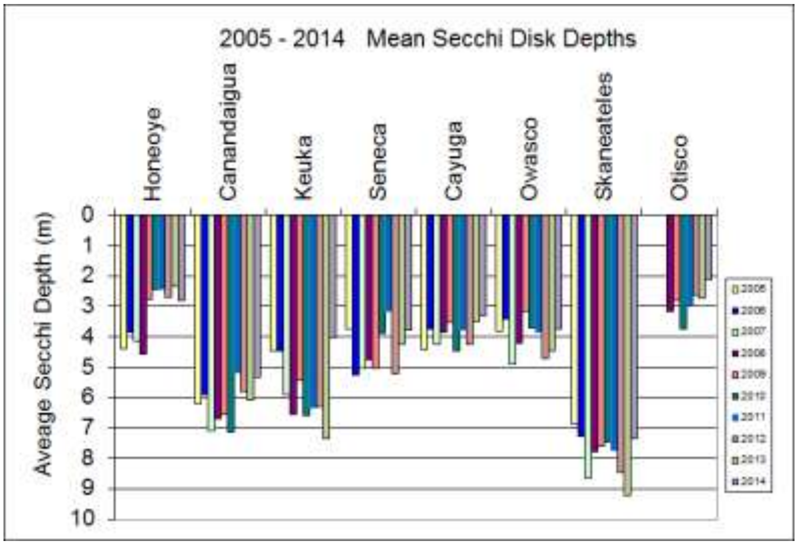


Figure 6 Secchi reading from Halfman Finger Lakes water quality monitoring

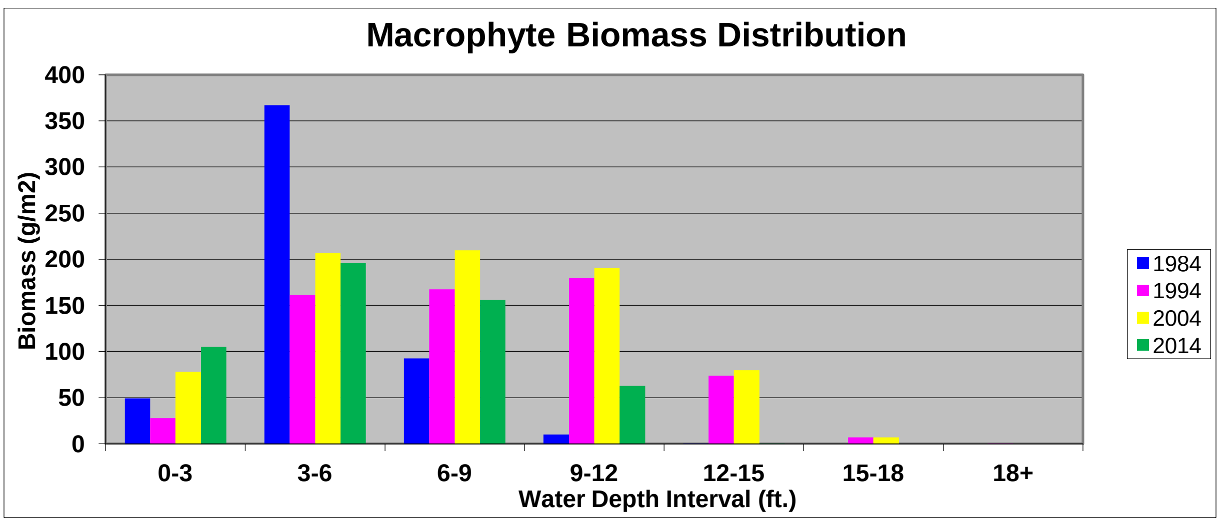


Figure 7 Macrophyte Biomass Distributions with Water Depth

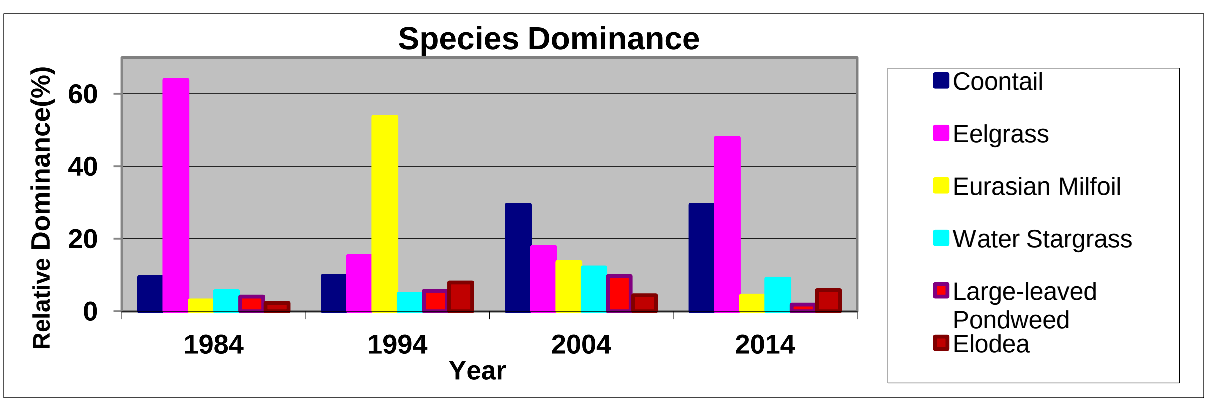


Figure 8 Species Dominance Change with Time

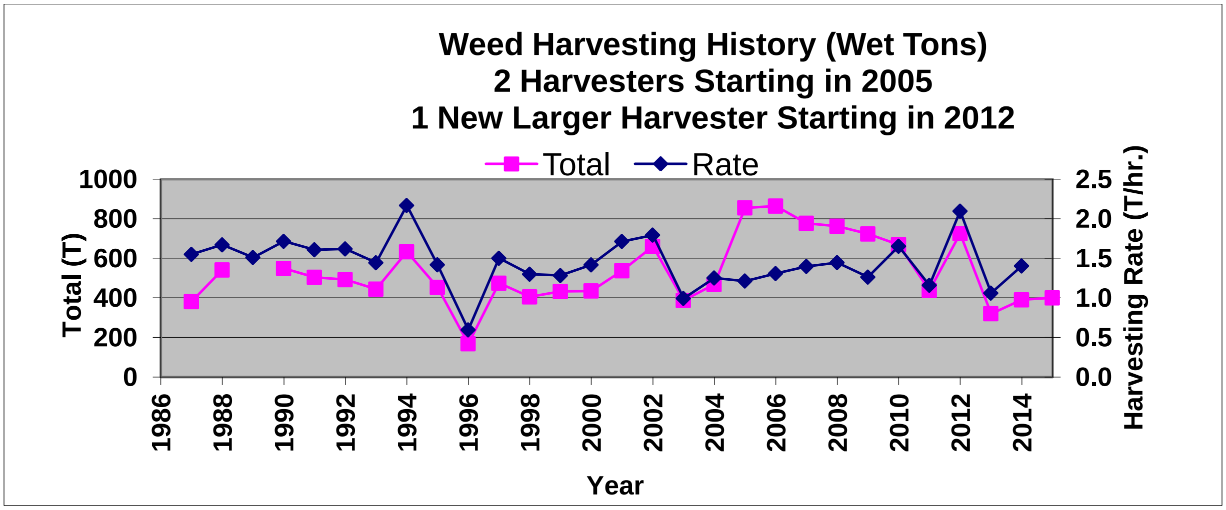


Figure 9 Aquatic Vegetation Harvesting History

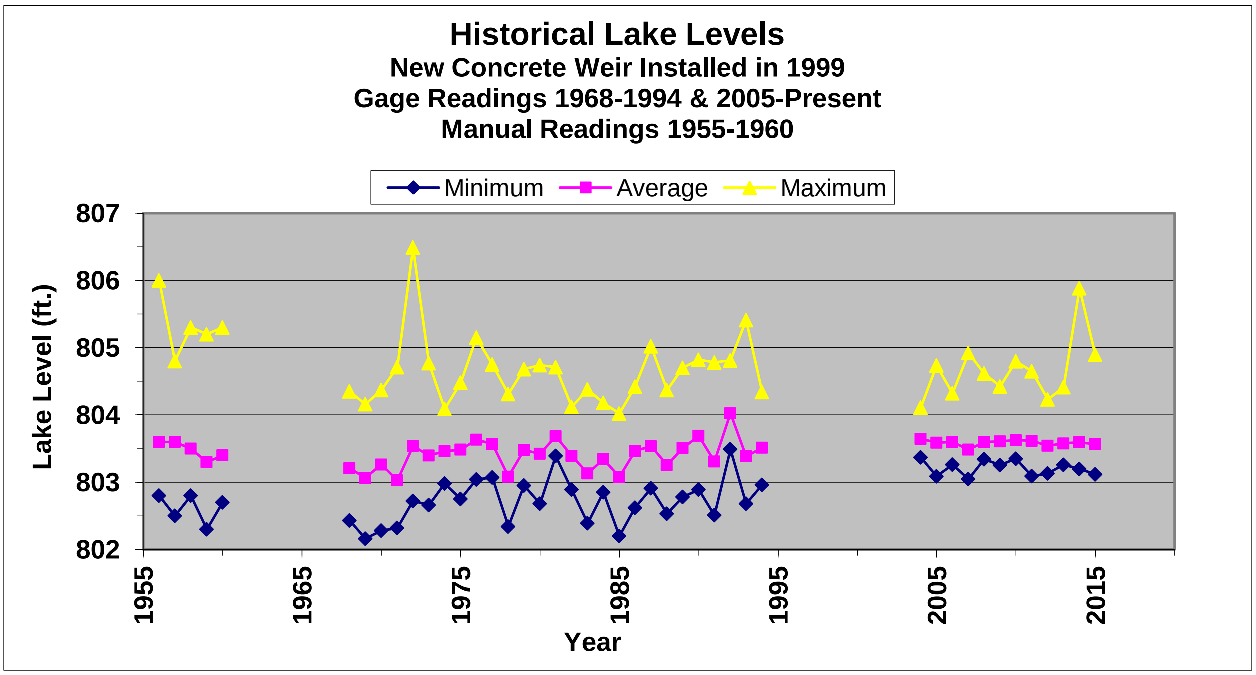


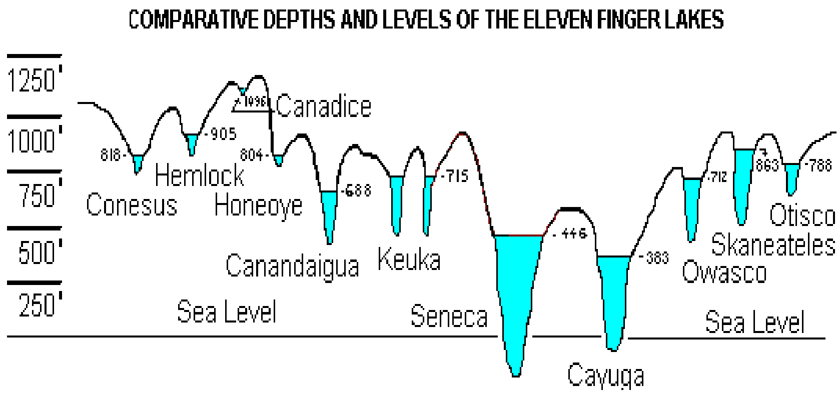
Figure 10 Historical Lake Level

Indicator	Oligotrophic	Mesotrophic	Eutrophic	Honeoye Average	Honeoye Min-Max
Total phosphorus (ug/L)	<10	10-20	>20	31.4	7.2-100
Chlorophyll-a (ug/L)	<4	4-10	>10	32.8	0.5-200.8
Water Clarity Secchi (m)	>4	2-4	<2	3.0	0.5-6.8
Hypolimnetic oxygen (% saturation)	>80	10-80	<10	20.4	0.6-100.0

Table 1 Definition of Trophic Classification of a Lake

	2003-2009	2010-2015
Average Summer Air Temperature (C)	67.8	67.4
Average Summer Surface Water Temperature(C)	23.1	23.3
Average Summer Maximum Surface Water (C)	26.1	25.9

Table 2 Factors Affected by Climate Change



	Max Depth(ft)	Length (mi)	Surface Area(acre)	Volume 10^3 gal.	Retention (yrs)	WS Area (10^3 acres)	Trophic Class
Honeoye	30.2	4.1	1,742	9	1.0	23.5	E
Conesus	59.1	7.8	3,378	41	2.0	44.6	E
Otisco	65.9	5.4	1,878	21	1.5	23.2	E
Canadice	83.3	3.2	642	11	4.0	7.9	O-M
Hemlock	90.2	6.7	1,779	28	2.5	23.8	O-M
Owasko	177.2	10.8	6,598	206	3.0	116.1	M
Keuka	183.1	19.6	11,614	379	8.0	100.0	O-M
Canandaigua	274.0	15.2	10,453	433	10.0	117.8	O
Skaneateles	296.9	15.0	8,871	413	14.0	38.1	O
Cayuga	435.0	38.2	42,527	2,478	10.0	283.0	O-M
Seneca	650.9	35.2	43,342	4,105	23.0	291.7	O-M

Table 3 Finger Lakes Morphology

Lake	Max Depth
Chatauqua South Basin	19
Waneta	29
Honeoye	30.2
Silver	37
Lamoka	40
Sodus Bay	48

Table 4 Depth of Nearby Shallow Lakes

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