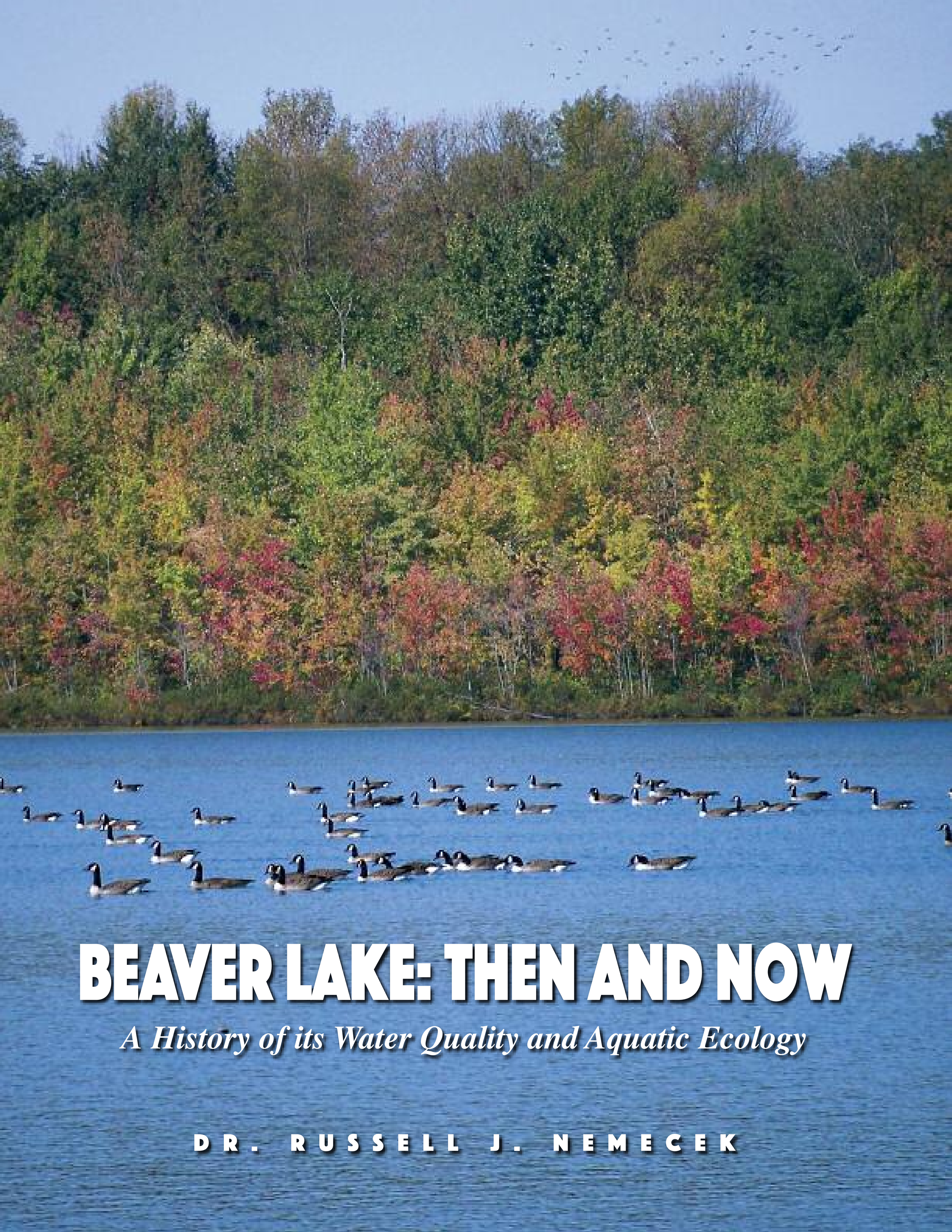

BEAVER LAKE: THEN AND NOW

A History of its Water Quality and Aquatic Ecology

DR. RUSSELL J. NEMECEK

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Dr. Russell J. Nemecek

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has been to provide the ISBN to facilitate Bowker registration of the book.
Responsibility for the content in all respects is that of the author.

Cover photos / Barbara E.R. Lucas

Table of Contents

A C K N O W L E D G E M E N T S

A number of individuals and organizations have provided assistance over the years not only making the work on Beaver Lake possible, but in the completion of this book.

I am especially grateful for the many years of support provided by Onondaga County government as well as from department commissioners and staff most notably from the Onondaga County Department of Health, Onondaga County Parks Department, the Onondaga County Department of Water Environment Protection, and the Onondaga County Soil and Water Conservation District.

A special note of appreciation is extended to the directors and staff of the Parks Department Beaver Lake Nature Center over the years for their special help including making boats, personnel and other equipment available as the collection of data and satisfying other frequent requests and whims.

The research and other studies conducted by the academic and consulting companies described in this summary provided invaluable information not only at the time the work was completed, but for the present to provide a chronology of how, when, and why conditions in Beaver Lake changed.

A number of volunteers have assisted me with data collections on the lake for which I am most grateful. In-kind services provided by County staff and most notably through laboratory analyses and fish collections done by the Onondaga County Department of Water Environment Protection staff were invaluable to this work over the years.

The Beaver Lake work, including the publication of this book, would not have been possible without funding made available through the Finger Lakes-Lake Ontario Watershed Protection Alliance which is a New York State Environmental Protection Fund appropriation.

I am also grateful to the Friends of Beaver Lake for their financial contribution to the publication of this work.

F O R E W O R D

Why a Volume about Beaver Lake?

Beaver Lake and the Nature Center that bears its name interested me almost upon my arrival to the Syracuse area in 1981. Despite our being blessed in Central New York with a lot of open space; at least to someone who grew up about 25 miles from New York City, Beaver Lake represents a respite from nearby suburbia and urban living. Before working for Onondaga County, I knew little of its history, but walks, cross-country skiing, and taking our young son to a maple syrup collection demonstration provided early and still lasting memories after so many years.

Literally any body of water short of a mud puddle always was a curiosity. Plus I was intrigued as to what might live or swim in whatever body or type of water under observation. Admittedly, marine or “saltwater” was my original focus that was undoubtedly due to growing up on Long Island and spending vacations and many days on the “East End” or “out east” as we referred to it.

That interest continued through my education years and in beginning a professional career as an environmental scientist and consultant. I had the grand opportunity to be involved with and/or conduct water quality and fisheries studies and assessments on projects both big and small in Alaska, Maine, and Florida, New Hampshire, New Jersey, Ohio, Pennsylvania, West Virginia, and throughout much of New York.

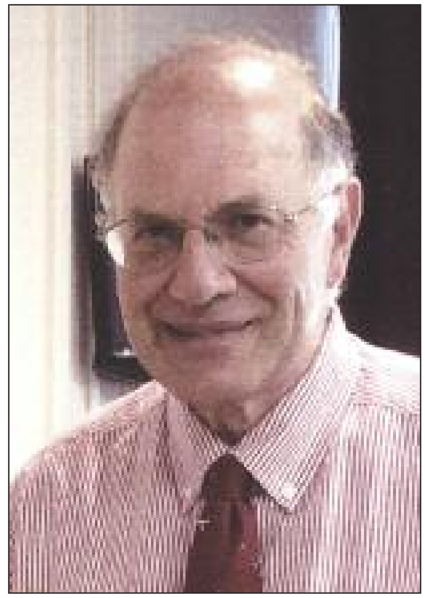
Water quality was my generic mission when I started working for Onondaga County. While drinking water supply sources had priority, the condition of all of our lakes, rivers, streams, etc. were also a focus. I soon learned about Beaver Lake’s changing condition and the work that had been done in prior years to determine what was happening.

Certainly important to the County due to the Beaver Lake Nature Center’s popularity, I also saw the situation at Beaver Lake, proper, as part mystery and part intrigue since being County property it was “ours” to study or ask to be studied. The lake had been virtually unmanaged or altered since the County acquired it, and it was small enough that figuring out what the problem was and what might be done about it seemed doable.

With the aid of grants and the support of many within and outside of County government, studies of the lake accelerated. It was during and after the 1988 investigations discussed in some detail in this publication, that my personal interest and involvement grew since we now had a better idea as to what was going on in Beaver Lake and hopefully what might be done to improve the situation. Over the years, Beaver Lake became a pet project and in keeping with the Nature Center’s environmental education mission, I felt all of those interested should hear the “Beaver Lake” story.

Dr. Russell J. Nemecek

ABOUT THE AUTHOR



Dr. Russell J. Nemecek was the Water Quality Management Program Coordinator in the Onondaga County Department of Health Division of Environment Health and previously in that position with the Syracuse-Onondaga County Planning Agency for over thirty years. He has personally been involved with water quality sampling, as well as with oversight and administration of projects at Beaver lake since the mid-1980s. Prior to employment with Onondaga County, Dr. Nemecek was an environmental scientist with Terrestrial Environmental Specialist, Inc. in Phoenix, New York. Dr. Nemecek holds a BA degree from Colgate University, a MS degree from Old Dominion University, and PhD from St. Bonaventure University.

Dr. Nemecek resides in Liverpool, New York with his wife, Mary Ann. They have two grown children.

Dr. Nemecek was honored with the Izaak Walton League's 2018 National Honor Roll Award. This award is in recognition of non-League members who have achieved outstanding accomplishments involving conservation, public education, or publicity efforts in keeping with the League's goals.

I N T R O D U C T I O N

Although serving as the geographical focal point and namesake of the Beaver Lake Nature Center (BLNC), the historical and present-day water quality and aquatic biological conditions of Beaver Lake, itself, have largely gone undocumented and not readily available to the interested reader.

Onondaga County has owned the BLNC property for more than fifty years. All of the known studies, investigations and data collection efforts on Beaver Lake have been either done by or for Onondaga County with the only exception being very limited narrative information from prior to the 1960s.

While never intended to be maintained as "forever wild", BLNC has been only passively managed from a natural resource standpoint. Nevertheless, "human interference" has been minimal despite the several hundred thousand visitors annually.

At first glance, a book on Beaver Lake water quality and aquatic ecology may seem to be of interest only to the science or nature enthusiast. However, exactly what Mud (Beaver) Lake and the property comprising the eventual BLNC would be used for after the County acquired it in 1963 was far from a foregone conclusion. Furthermore, the changes that have taken place in the lake over half a century and what may have caused them is fascinating in its own right.

- What can we expect Beaver Lake to be like in the future?
- What do we know about the condition of Beaver Lake in the 1960s and before Onondaga County owned it?
- Has Beaver Lake changed for better or for worse over the past five decades and if so, how, why and when?
- What is the present condition of Beaver Lake's water quality and aquatic ecology?

This study is intended to answer fundamental questions in a scientific, but also understandable format:

A compilation of the reports, documents, letters, data sources and other materials used are listed in appendix I. Hopefully, this information will be useful not only for the historical record, but for any future investigations done at Beaver Lake. Other appendices include lists generated from the studies discussed relating to phytoplankton, zooplankton, and fish species.

To avoid reading too much like a scientific publication, citations and footnoting have been avoided as much as possible with only direct reference to the organization or investigator (s) that did the work. English units of measure are used for reader familiarity, but metric units are included when data were collected or reported as such and conversion would be cumbersome.

A series of questions are included at the end of the narrative for use by school classes and other educational groups. These are arranged by chapter to serve as a review of the Beaver Lake "story" to help understand several key aquatic ecology and limnological terms and principles.

D E S C R I P T I O N

The Lake

Beaver Lake is located in the northwest corner of central New York's Onondaga County approximately 16 miles from Syracuse, NY (**Figure 1**). The lake is part of the 600–acre BLNC which is comprised of the lake and its immediate surrounding environs. The property was purchased by Onondaga County in 1963 and serves as a very popular environmental educational and nature recreation facility, with canoeing and kayaking the only forms of water-based recreation allowed on the lake. The BLNC is second only to Onondaga Lake Park in annual visits to an Onondaga County Park facility.

Beaver Lake is a small lake with a surface area of around 200 acres (198 acres to be more precise). Much of the lake is 5-6 feet deep with a maximum depth of about 11.5 feet. As the depth contour map in **Figure 2** shows, the immediate shoreline area is quite shallow with the lake's deepest part in its southern portion.

Geologically speaking, Beaver Lake is a kettle lake formed in a depression created by melting glacial ice buried under sand and gravel deposits. Nearby Tully Lake and its surrounding lakes along the Onondaga-Cortland county border are also examples of kettle lakes.

Surface water flows into Beaver Lake from three very small, unnamed tributaries (small streams) with one entering from the north and two from the west. However, two-thirds of the lake perimeter is covered by wetlands which contain even smaller and generally seasonal springs and feeder streams that provide inflow to the lake on its western and eastern margins.

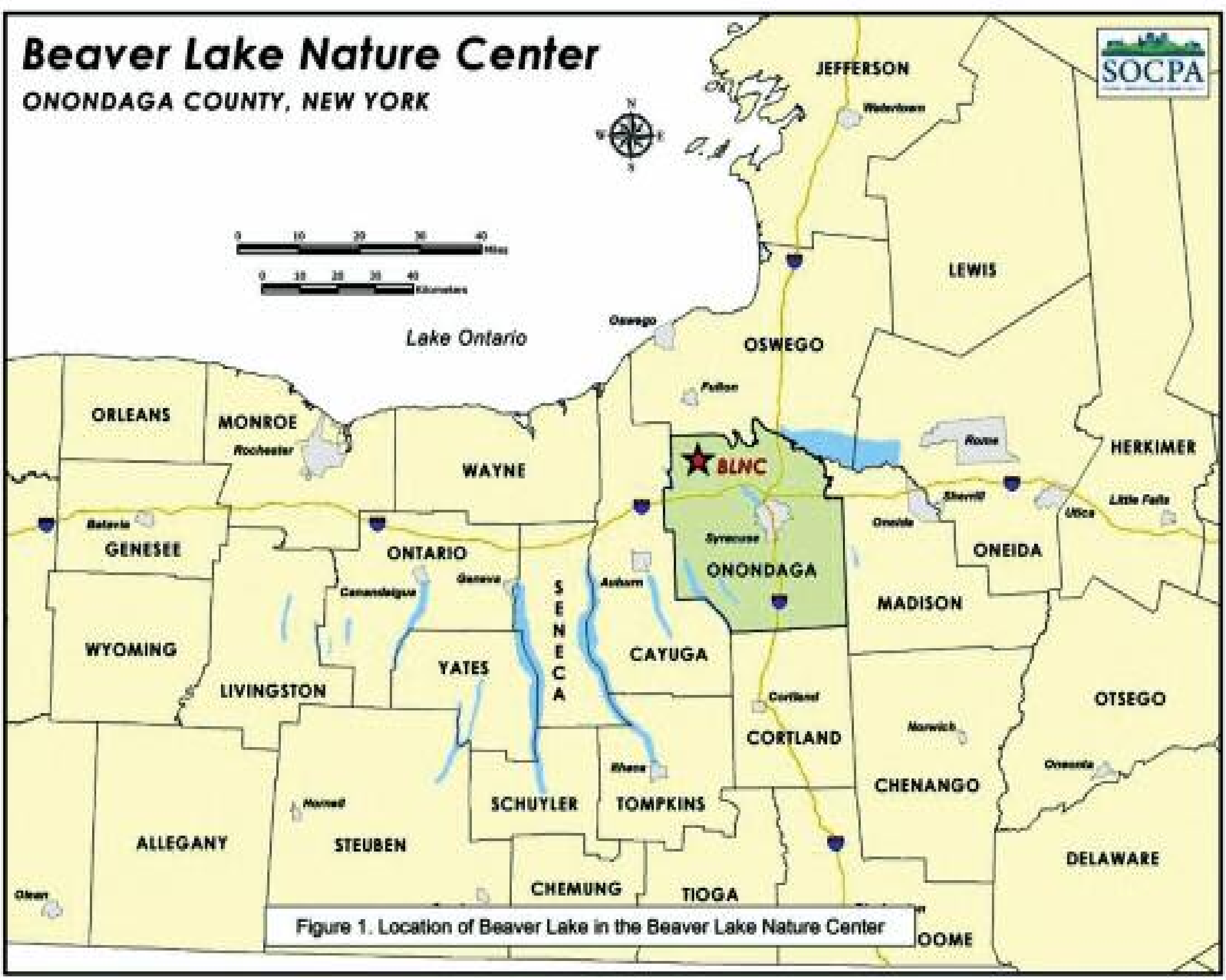


Figure 1. Location of Beaver Lake in the Beaver Lake Nature Center

The location of the Beaver Lake outlet relative to the incoming tributaries is a bit unusual since they are within about one half- mile of one another. Despite Beaver Lake's proximity to the Seneca River just to the south, the lake outlet flows northerly into the Ox Creek drainage which enters the Oswego River south of Fulton, New York.

Water flow patterns become more confusing with the movement of groundwater entering and leaving Beaver Lake. The lake receives groundwater from a roughly one-mile reach along its northeastern shore but loses water along an approximate one-mile long stretch on its southern shore in the direction of the Seneca River.

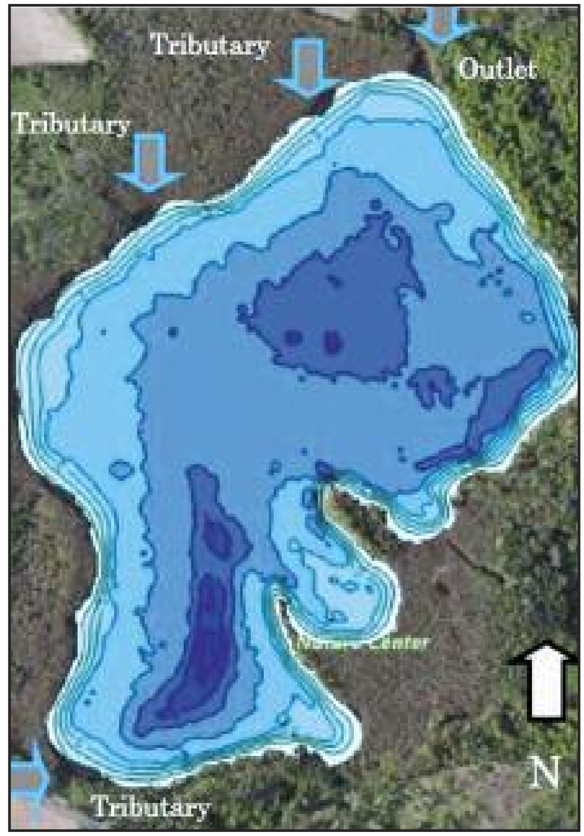


Figure 2. Bathymetric (Water Depth) Map of Beaver Lake (1 foot contours)

The Watershed

Lakes are not isolated "islands of water", but more of a reflection of what is around them. The surrounding area of land where rain or melting snow runs off and eventually enters the receiving lake is called the lake watershed. In the case of Beaver Lake, its watershed boundary (see Figure 3) is close to the lake for about two-thirds of the shoreline and then extends in a broad sweep to the northwest.

The Beaver Lake watershed is small; less than 2000 acres (1950 acres) with a watershed to lake ratio of about 10:1. To provide a frame of reference, watershed to lake ratios for nearby lakes include Skaneateles Lake (4:1), Otisco Lake (roughly 12.3:1), and Owasco Lake (20:1). The greater the watershed size relative to the lake, the more the characteristics of the watershed land uses can affect the quality of the lake water.

Land cover in the watershed is pasture/field and forested indicative of a land use which is largely a combination of agricultural, rural residential and rural open space **(Figure 3)**. Despite increasing residential development taking place to the east of the BLNC, the types and percentages of predominant land uses within the watershed have remained largely unchanged since at least the early 1980s.

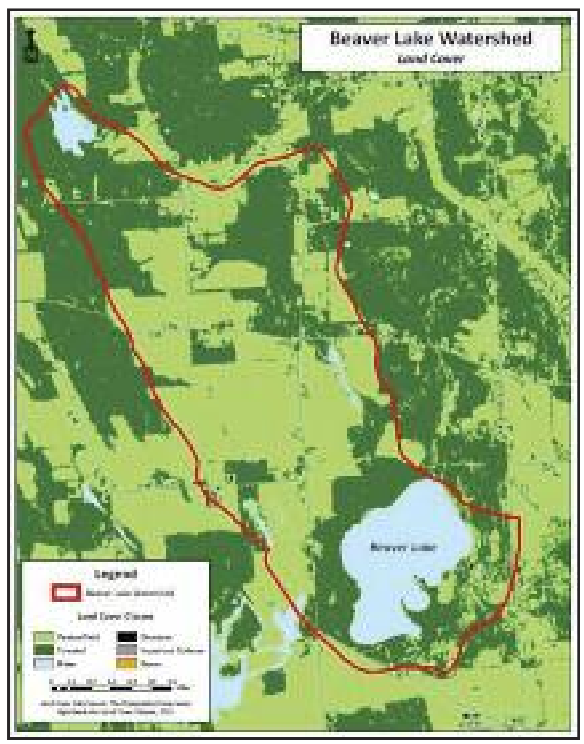


Figure 3. Land Cover Map for the Beaver Lake Watershed *(Land cover data source: The Chesapeake Conservancy High Resolution Land Cover Dataset, 2013. Map produced by the Syracuse-Onondaga County Planning Agency.)*

Mud Lake?

While known at one time as Beaver Lake due to the presence of beaver, locals changed the name to Mud Lake and topographical maps for the area still show it as that. Privately owned, the lake was maintained in a generally unaltered state with the exception of an attempt to attract waterfowl in 1924 by planting several species of plants including Sago Pondweed (*Potamogeton pectinatus*), Wild Rice (*Zizania aquatica*) and Wild Celery (*Vallisneria americana*). No other known information is recorded about the water quality or biological condition of the lake from 1924 until Onondaga County obtained ownership.

This was done by Clyde B. Terrell, a naturalist from Oshkosh, Wisconsin who was a self-proclaimed "Specialist in Wild Duck Foods, Aquatic Plants & Live Water Fowl" **(Figure 4)**.

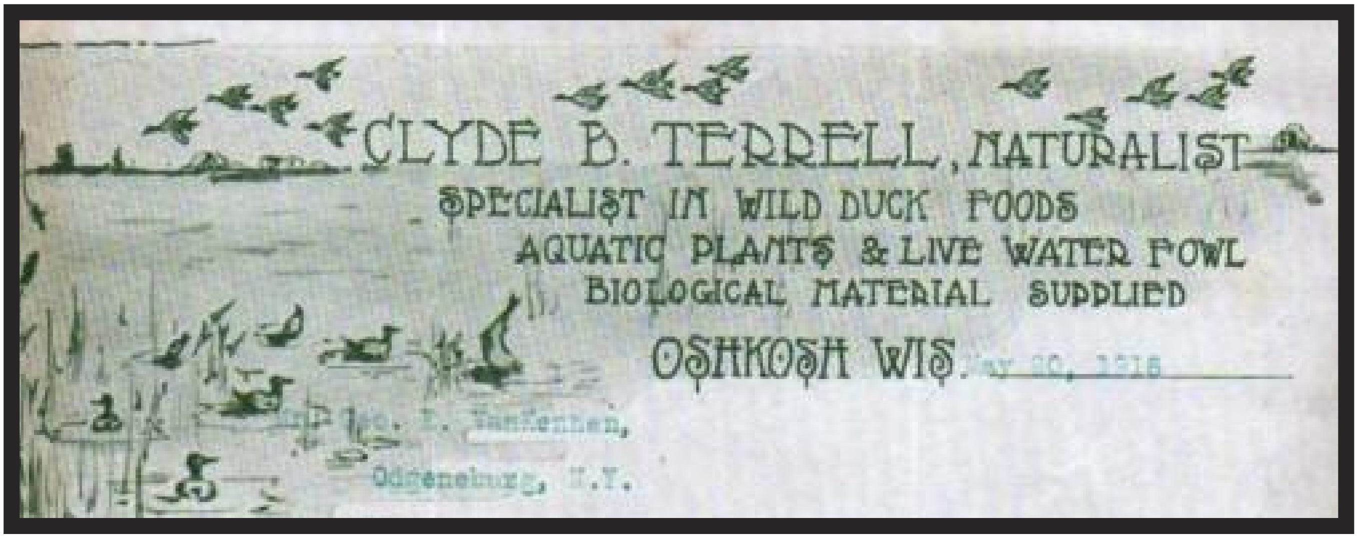


Figure 4 Clyde B. Terrell Advertisement" (Image taken with permission from David M Beach Collection - beach7@CFL.RR.com)

The Beaver Lake Nature Center is Born!

Largely through the efforts of the late J. Howard Shattuck, Deputy Commissioner of Parks and Conservation for Onondaga County, the County purchased the lake and its surroundings in 1963 and renamed it Beaver Lake. However, what the future uses of Beaver Lake would be were not defined.

In 1964, the Syracuse University Department of Civil Engineering was commissioned by Onondaga County to conduct a lake and biological survey of the Beaver Lake property with an emphasis placed on studies to ascertain possible future uses of the lake and surrounding property.

Dr. Daniel Jackson of the engineering faculty was the primary investigator and the recommendations revolved around five major uses thought to be compatible with one another:

i. serve as a waterfowl refuge,

ii. provide for picnicking, hiking, and nature study,

iii. boating and fishing,

iv. swimming, and

v. serve as an Onondaga County Conservation Center.

Dr. Jackson felt some of the proposed uses needed further investigation before being decided upon, but he did recommend that no motorboats be allowed and only boats provided by the County Parks Department be permitted. Dr. Jackson noted the lake was unsuitable for swimming, but ask that consideration be given to creating a "ground water pool" that could provide for swimming.

To a great extent much of what Dr. Jackson envisioned came to fruition with the opening of the BLNC as a county park in October of 1970 and Visitor Center constructed in 1974.

W H A T W A S B E A V E R L A K E L I K E ?

The 1960s - "No algae blooms and large beds of rooted aquatic plants"

Dr. Jackson gave a rather poetic description of Beaver Lake and its environs in a 1964 report entitled, "Beaver Lake – A Lake That Is" when he called it, " a lake, unpolluted by man, surrounded by beautiful woods, in which rare plants and animals abound, yet only 15 minutes driving time from a metropolitan area of 420,000 inhabitants."

Dr. Jackson noted Beaver Lake was one of the few lakes in Onondaga County at that time with "no algae problem" although he made reference to three "major" algal blooms reported during the summer and fall of 1964. An indication of the lake's abundance of submerged aquatic vegetation is found among the reasons given for recommending against the use of motorboats on Beaver Lake. "Care must be taken not to destroy the large beds of rooted aquatic plants which cover most of the lake's bottom," the report said.

This along with other measured parameters lead to the description of Beaver Lake as a fairly well-balanced ecological system characterized by high species diversity including the aforementioned rooted vegetation along with high levels of dissolved oxygen. The implication was the rooted vegetation kept algae populations in check by competing with algae for available nutrients. It is important to note here it was believed there was no shortage of available phosphorus, an important nutrient for plant growth.

In the 1964 report Dr. Jackson also described Beaver Lake as an "excellent fishing lake" though what exactly he meant is not really clear. In more biological terms Beaver Lake possessed an "excellent fish fauna" which implied the presence of a fairly large number of different species.

The following species were collected or observed: Black Bullhead, Northern Pike, Chain Pickerel, Banded Killifish, Yellow Perch, Largemouth Bass, Pumpkinseed Sunfish, and Brook Stickleback. Unfortunately, no mention was made of how abundant any of these were although many young-of-the year Northern Pike were observed. This implied that this predator species had a healthy presence in the lake which included reproducing successfully.

Jackson's water quality and biological survey work became noteworthy serving as a baseline to compare changes in the lake that would take place over the next several decades and provide valuable information to help explain why these changes took place.

The 1970s - "Lake vegetation abundant but not too much; more geese."

Data sheets from a 1973 New York State Department of Environmental Conservation (NYSDEC) fish survey of the tributaries coming into the lake characterized lake vegetation as "abundant" and distributed equally between 50% emergent (much of the plant growing out of the water) and 50% submergent (growing underwater) plants.

Two years later in 1975, County officials became increasingly concerned there was too much aquatic vegetation growing in Beaver Lake. In response, the NYSDEC did an assessment concluding there was no serious problem with abundant plant growth and commented on the biologically and ecological benefit plant growth provided to the lake.

The NYSDEC report noted an estimated 10,000-15,000 Canada Geese (*Branta canadensis*) on the lake during migration season. This was a dramatic increase from maximum spring migration numbers in the early 1960s estimated at 3,000-6,000 birds. Why was this of concern? The geese represented a significant source of nutrients to the lake since goose droppings are high in phosphorus.

Regarding fish, in addition to sampling the small tributaries, the lake, itself, was also sampled by the NYSDEC during the 1970s. Northern Pike, Pumpkinseed and Yellow Perch were collected as previously, but four species were reported for the first time: Brown Bullhead, Central Mudminnow, Bluegill, and Black Crappie. Largemouth Bass were observed along with "many" sunfish during the 1975 aquatic vegetation survey.

Of note is one identification from the 1960s, Black Bullhead, that was most likely Brown Bullhead. There are a couple of explanations for this reasoning. Black Bullhead is a relatively scarce species in New York State and has never been collected from Beaver Lake again. Furthermore, Brown Bullhead was one of the more common species collected in later studies.

Despite some differences in the species of fish collected, the differences were subtle and reflected a stable condition for Beaver Lake between 1963 and 1975.

To summarize, there was nothing to indicate Beaver Lake had changed for better or worse over the first decade or so since acquired by the county. There was an abundance of aquatic vegetation, but it provided for a balanced ecological system. Algal blooms were not a problem and water clarity was good. The overall fish population contained a good mix of species.

BEAVER LAKE WATER & ECOLOGICAL QUALITY

TIME FRAME	CHANGE IN CONDITIONS
mid 1960s – mid 1970s	unchanged

The 1980s

During the 1980s, visual conditions became more of a concern to BLNC staff and lake users, alike. By 1982, decreases in water clarity had accelerated with intense blue-green algae blooms1 having gotten progressively worse.

Conditions continued getting worse and in 1984 Onondaga County created a Beaver Lake Water Quality Task Force charged with the following tasks: i) determine whether there had been a significant change in the trophic state (biological productivity) of the lake since the 1960s and if so, ii) what strategies could be implemented to reverse the decline and get it back to its previous condition.

Much like a medical doctor taking "vital signs" to help diagnose what might be wrong with the patient, scientists studying lakes (called limnologists) look for signs indicative of an "unhealthy" lake. Three lake measurements, in particular, are measured to help describe the trophic or nutrient state of a lake: i) chlorophyll, ii) secchi disc depth, and iii) total phosphorus.

Chlorophyll is an indicator of how much algae is present while the secchi disc reading tells how transparent or clear the water column is. The amount of total phosphorus tells how much of this important nutrient for plant growth is present. The Onondaga County Department of Drainage and Sanitation (now called the Department of Water Environment Protection) measured these parameters in Beaver Lake during 1984 and 1985 (Table 1).

Table 1 ——Selected Water Quality Data –Beaver Lake 1984-1985

(Mean of three sampling locations unless otherwise noted)

* Single lake location

Date	Chlorophyll a (ug/l)	Secchi Disc (ft)	Total Phosphorus (ppm)
4/10/84	16.9	5.6	.06
5/22/84	10.7*	3.9	.07
8/28/84	14.3	1.6	.06
10/30/84	27.6	2.3	.08
9/12/85	44.6	.7	.2*

(Modified from Onondaga County Department of Drainage and Sanitation, 1984 - 1985)

Note: 1. Biologically they are called cyanobacteria. Although really bacteria, they are commonly referred to as blue-green algae and that term will be used throughout.

Values for these parameters can vary by season and from year-to-year, but there are some general guidelines. For example, chlorophyll a values greater than 30 µg/l indicate a major algae bloom is underway. Total phosphorus values shown here were all .06 parts per million (or 60 parts per billion= 60 µg/l) or greater and amounts this high are typical of nutrient-rich lakes.

Normally, there is a direct relationship between Secchi disc readings and the amount of algae present; the greater the amount of algae the lower the secchi disc reading. While this is true to some extent in Beaver Lake, there are other factors reducing water clarity and these will be discussed later. Needless to say, the August and September secchi disc readings when algae are typically most abundant were less than 2 feet (1.6 and .7 feet) indicating poor water clarity.

Average summer readings for these three parameters provide an indication of a lake's trophic or biological productivity: oligotrophic (low productivity), mesotrophic (moderate productivity), and eutrophic (high productivity) as shown in Table 2.

Taking the data results and comparing them to those in Table 2, Beaver Lake clearly fit into the eutrophic or high productivity category.

Table 2. Criteria Used to Designate Trophic State Designations for New York State Lakes.
(μg/1 = micrograms per liter or ppb= parts per billion)

	Trophic State		
	Oligotrophic	**Mesotrophic**	**Eutrophic**
Total Phosphorus	< 10 μg/l (ppb)	μg/l (ppb)	>20 μg/l (ppb)
Chlorophyll a	<2 μg/l (ppb)	2-8 μg/l (ppb)	>8 μg/l (ppb)
Secchi Disc Transparency	>5 meters (>16.4 ft)	2-5 meters (6.6-16.4ft)	< 2 meters (< 6.6 ft)

(Taken from, "Diet for a Small Lake-The Expanded Guide to New York State Lake and Watershed Management. New York State Federation of Lakes and New York State Department of Environmental Conservation. Second Edition 2009.)

A separate study was done in 1984 to identify the types of algae present and to get an estimate of the population size of the most abundant species.

Some species of algae called indicator species are typically found in nutrient-rich or eutrophic conditions. For example, the green algae, Microspora, numbered as high as 179,000 cells per liter in a sample taken on June 19, 1984. Later in the summer, Oscillatoria (a blue-green algae) had counts as high as 220,000 cells per liter.

Secchi disc readings were taken every two weeks during this 1984 investigation and remained a nearly constant .5 m (slightly over 1.5 feet) throughout the summer which was pretty much in line with the Onondaga County Department of Drainage & Sanitation.

Surveys of rooted and submerged aquatic vegetation done in June and August 1984 found many of the same species present as in 1965, but limited in distribution to areas very close to shore. Only a species called Coontail (*Ceratophyllum demersum*) shown in Figure 5 was found in deeper water since it doesn't require as much light to survive as many other submerged aquatic plants.

A follow-up algae study in mid-August 1985 included only one sample taken during a large bloom. The findings were, "The visual change in water quality is correlated with a far greater turbidity of the water which gives a "pea soup" appearance." A greater variety of species was found with several, if not most, indicative of very nutrient-rich conditions.

Clearly, this was a different lake from the one described twenty years earlier that had an expanse of rooted aquatic vegetation and "no algae problem." Something had caused this change, but what?

Figure 5. Coontail (*Ceratophyllum demersum*) *Picture courtesy of Douglas Fisher, Onondaga County Soil and Water Conservation District.*

BEAVER LAKE CHANGE – WHO WERE THE SUSPECTS?

Watershed Farming Practices

The general thinking of the Beaver Lake Water Quality Task Force was there must have been an increase in the amount of nutrients entering Beaver Lake than in the past. A couple of actions or activities were looked at to see if something may have changed over the years to cause this. Contaminants including nutrients can enter streams in runoff generated by rain events and snow melt. In areas that are farmed, the type and quantity of such contaminants from the watershed lands could change if there are more acres farmed, farming practices change, or if a different crop is planted.

The US Soil Conservation Service (now the Natural Resource Conservation Service) analyzed aerial photographs taken between 1966 and 1981 and also reviewed Agricultural Stabilization and Conservation Service crop reports. The findings were there had been a switch to corn (grown for grain) from vegetable crops and that may have been responsible for an increase in the number of Canada Geese **(Figure 6)** observed for longer periods of time in the area. However, it was concluded there had not been a significant enough change in agriculture within the watershed area to add appreciably to the nutrient enrichment of Beaver Lake .

Too Many Geese?

Figure 6

As noted above by the US Soil Conservation Service, Canada Geese were staying in the Beaver Lake watershed area for longer periods of time than in the past.

Recall that the NYSDEC report of 1975 also commented on the increase in Canada Geese on the lake during migration from an estimated 3,000-6,000 birds during the early 1960s to 10,000-15,000 in the mid-1970s.

Dr. Fritz Scheider, a local wildfowl expert, had been keeping records for at least 15 years prior to 1984 and agreed that goose numbers had increased, but added the recent (1984) numbers were in the 12,000-18,000 range and occasionally greater than 20,000. Dr. Scheider also noted there had been no significant shift in the duration of stay during the spring or fall migration time, but the increase in geese had apparently resulted in a small decline in the spring duck population.

If determined the geese were the culprits it would have created more than a slight dilemma. Canada geese were an integral component of BLNC's educational mission which in effect made them pretty much untouchable!

While not dismissing the role Canada Geese could be playing in adding excess nutrients to the lake, the fact remained the two to three-fold increase in the migratory goose population of the mid-1970s compared to the 1960s had not changed the visual appearance and clarity of the lake through the 1970s. It seemed something else had happened along the way.

What About The Fish?

Was there any obvious change in the types (species) of fish found in the lake or in their abundance over this same time period when water quality conditions had worsened?

In 1984, the NYSDEC conducted another fish investigation of Beaver Lake. Among the findings were that although Largemouth Bass were not collected, they were still thought to be common in the lake with their absence was attributed to the sampling method used.

Golden Shiner and Yellow Perch had replaced Brown Bullhead and Black Crappie as the most abundant species. This was of interest since Golden Shiner had not been collected during any previous sampling efforts.

Notable was the appearance of another species never collected before. This was the Common Carp (**Figure 7**) which was believed to have entered Beaver Lake after an earthen dam broke on a minor inlet to the lake outlet in the spring of 1976. This meant Common Carp had been part of the Beaver Lake fish assemblage for roughly a decade and enough time for it to become the fourth most abundant of the ten species collected.

Figure 7. Common Carp. *In the 1980s, Common Carp (Cyprinus carpio) became a dominant fish in Beaver Lake (photo by Onondaga County Department of Water Environment Protection).*

Fishery biologists like to see a proper balance between the number of food or prey species and predator species present in a lake. This is known as predator-prey balance. Simply said, there needs to be more prey than predators. However, if there are too few predators the prey populations can get too large in number causing them to have slower than expected growth rates. Therefore, growth rates can provide clues as to whether or not a lake has a proper predator-prey balance.

The NYSDEC study identified slow growth rates for Yellow Perch and Black Crappie of Age III+ and Age IV+ indicating too many prey fish compared to the number of predator fish in the lake.

So by 1985 Beaver Lake had a sizeable Common Carp population, too few predator fish, slow-growing prey fish, worsening algae blooms, and submerged rooted vegetation that had pretty much disappeared.

This was now far from the lake described twenty years earlier. The biggest change seemed to have been the Common Carp. Might they be the problem?

END OF THE 1980s: WERE THINGS GETTING EVEN WORSE?

Algae

In 1988, Onondaga County contracted with researchers from Syracuse University, State University of New York-College of Environmental Science and Forestry (SUNY-ESF) and the Upstate Freshwater Institute (UFI) to do a comprehensive study of Beaver Lake to identify what was contributing to its problems and suggest possible remedies to the algae blooms. The research team assessed surface and groundwater hydrologic conditions, water quality, and Algae populations, rooted aquatic vegetation presence and the fish population of Beaver Lake.

The results were rather discouraging since water quality and ecological conditions in Beaver Lake had deteriorated even further from just a few years previous. The warm and dry summer of 1988 likely made the algae blooms even worse.

While the rate of increase in algal cell counts had leveled off, the density measured in October of 1988 exceeded 12 million units per liter! This very large increase (more than 10-fold) over four years was telling **(Figure 8).**

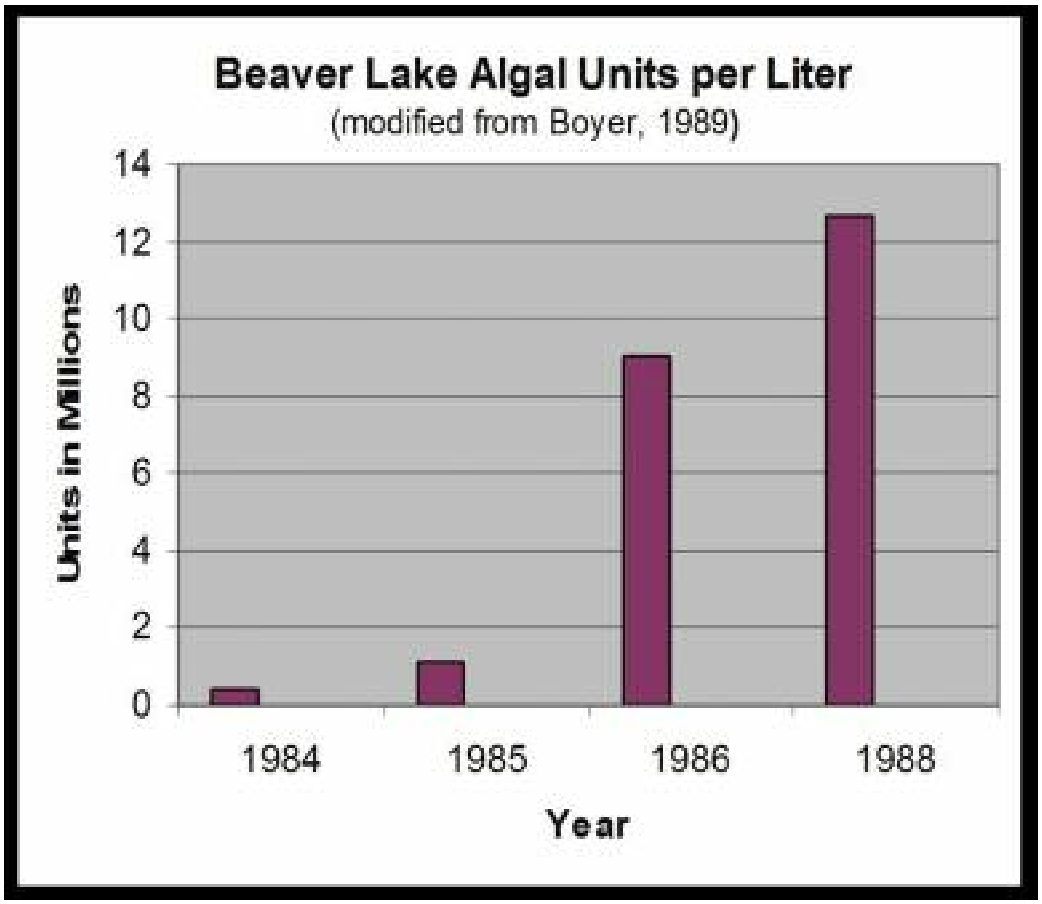


Figure 8. Beaver Lake Algal Units per Liter. *Increases in algae populations in Beaver Lake from 1984-1988.*

The chlorophyll a concentrations in late August of 1988 reached 560 mg/m3 (parts per billion) which approached some of the highest levels reported in the scientific literature. Remember values greater than 30 mg/m^3 (parts per billion) indicate a major algae bloom!

Species identifications were done on samples taken in late October 1988 and these were found to be indicators of waters high in nutrient content and characterized as "pollution tolerant."

The dominant seasonal algae changes taking place in Beaver Lake were characterized as shown in Table 3.

Table 3. Beaver Lake Algae Succession Pattern for 1988
(*From Boyer 1989)*

Season	Dominant Algae
Spring	weak diatom bloom
Mid-Summer	green algae bloom
Late Summer	blue-green algae dominant
Early Fall	blue-green algae population crash (die-off)
Fall	moderately strong diatom bloom

As the table shows, an early, but weak diatom bloom was followed by a green algae bloom in mid- summer. As summer and warmer temperatures prevail, blue-green algae became dominant before yielding to a pronounced diatom bloom in the fall.

Submerged Aquatic Vegetation - What's Left?

The aquatic vegetation study in 1988 assessed the current status of this community. This included the identification of the species present as well as where they were found and how abundant.

Few differences were found between this and the 1984 study as far as the locations where plants were found, but an obvious decline in the number of species and their abundance was noted. Species including Tapegrass, Waterweed, Northern Watermilfoil(Myriophyllum exalbescens), and Long-Leaved Pondweed (Potamogeton nodosus) were found, but only in the vicinity of the lake outlet and/or in what is called the canoe channel which is located along part of the lake's western shore.

Significant was the dramatic decline in the number of species found in water deeper than one foot. As was the case in the 1984 study, Coontail was essentially the only "underwater" plant or submergent found in water deeper than one foot. No submerged plants were found in water deeper than about 4.5 feet, which is a rather large portion of the lake.

Conclusion: the submerged aquatic plant situation had not improved and if anything had gotten worse.

A comment on Myriophyllum species is helpful at this point. At present, the invasive Eurasian Watermilfoil (*Myriophyllum spicatum*) is abundant in Beaver Lake as will be discussed later. However, only the native Northern Watermilfoil (*Myriophyllum exalbescens*) was reported during the 1988 study. At what point Eurasian Watermilfoil entered Beaver Lake is not known. Complicating definitive identification are the similarity of the two species in appearance and that they may also hybridize.

Fish 1988 - Anything New?

Thirteen species were identified during the 1988 fish survey. This was the largest number of species collected from the lake until that time and likely due to a larger sampling effort compared to previous investigations.

Brown Bullhead **(Figure 9)** continued its decline in numbers and this was attributed to competition with Common Carp which had now become well-established in Beaver Lake. Common Carp collected showed healthy and steady growth along with several age classes indicated successful reproduction.

Numbers of Yellow Perch **(Figure 10)** also increased as lake conditions became more favorable to them as well as for Black Crappie.

Figure 9. Brown Bullhead. *In the late 1980s the population continued to decline (photograph by the Onondaga County Department of Water Environment Protection).*

However, an indication of the “unhealthy” ecological state of the Beaver Lake fishery was seen in the overabundance of forage species such as Golden Shiner and Bluegill. Both had lower than expected condition factors known as K values. The K value is derived from a fish’s length and weight and provides an indication of its “well-being”.

One might think of it as a Body Mass Index for fish or simply a height and weight table in a doctor’s office.

The less than desirable condition factor values meant Beaver Lake lacked enough predator fish to keep forage fish populations from becoming too large. With so much prey available, one might assume the condition factor values for the few predator fish collected would be high since there would be plenty of food.

Figure 10. Yellow Perch *increased in number during the late 1980s. (photograph provided by David Lemon, New York State Department of Environmental Conservation).*

This was true as K values for Largemouth Bass and Northern Pike **(Figures 11 and 12)** were two to three times higher than what would normally be expected.

The lake’s very low transparency due mostly to excessive amounts of algae certainly played a role in this imbalance since these conditions made it hard for predator fish to feed.

So too many prey fish, too few predators to feed upon them, and murky water making it hard for predator fish to feed set up an unhealthy ecological situation. The result was forage fish were growing slower than they should have resulting in individuals of the population being stunted.

Another question was why were there so few Largemouth Bass in the lake? As mentioned earlier, researchers acknowledged the sampling methods used were probably not the most effective at catching Largemouth Bass so the population might be larger than collections indicated. Nevertheless, turbid water conditions, lack of submerged vegetation, and the loss of the small amount of spawning habitat historically present in Beaver Lake were likely responsible for the small Largemouth Bass population.

Another problem was the young bass found themselves competing with forage fish for a limited supply of microscopic animals known as zooplankton which are an important food source. Zooplankton will be discussed later on.

At this point, Common Carp was the dominant fish species in Beaver Lake and likely responsible for much, if not all, of the visual deterioration and ecological changes in the lake. But how?

Figures 11 and 12. *Largemouth Bass (left) and Northern Pike (right). Major predator fish in Beaver Lake, but too few to control the large numbers of prey fish that dominated the lake in the late 1980s. (photographs by the Onondaga County Department of Water Environment Protection)*

Common Carp - What's The Problem?

What might Common Carp have done to cause such changes? For one thing, bottom sediments of shallow lakes such as Beaver Lake often remain loose or what is called unconsolidated. Bottom feeding fish such as Common Carp when they are numerous keep sediments loose.

With loose bottom sediments, it doesn't take much in the way of wind and wave action to resuspend or stir up and transport both the nutrients and sediments that make up the lake bottom material. Common Carp can also physically stir-up bottom sediments. Nutrients such as phosphorus may then be available for use by algae. As algae populations increase, the sunlight needed by submerged vegetation to survive is blocked and these plants die.

Figure 13. Clear, but Brown Water. *The brownish color of Beaver Lake is more obvious when algae populations are low. (photo by Donald Gates).*

The situation can then worsen. As submerged vegetation dies off, more nutrients become available since the vegetation helps stabilize the bottom keeping the nutrient-rich sediments from resuspending in the water column. Removal of what little rooted vegetation might remain by organisms such as snapping turtles only adds to the problem. However, this is not to ignore that nutrients were being added to the lake from the geese.

Figure 14. Aquatic Vegetation: *Clear water allowing adequate levels of sunlight to penetration the water column is necessary to have a diverse, submerged aquatic plant community as shown here for Tully Lake.*

If all of this isn't enough to hinder light penetration in Beaver Lake, one other important factor is the presence of dissolved substances and other particulate material in the lake water. This is where the lake's original name, Mud Lake, comes from since the lake has a brownish coloration even when algae numbers are low (**Figure 13**).

In any lake, the presence and distribution of submerged aquatic plants is highly dependent upon the availability of light. As a general rule, the depth to which about 1% of the light available at the surface of the water can reach in the water column is the maximum depth submerged plants can survive at.

For 1988, calculations derived from data collected put the 1% level of light penetration between 1 and 3 ft deep. The submerged aquatic vegetation field data survey validated this quite well. Looking back at the depth contour map for the lake (Figure 1) water depths begin to exceed 3 ft very close to shore with only about 10% of Beaver Lake's surface area 3 ft or less in depth. So on the basis of light penetration alone it was no wonder so little submerged vegetation was present anywhere in Beaver Lake.

In contrast, an example of a healthier ecological situation is seen in this photograph of Tully Lake. **(Figure 14)**.

The End of the 1980s - In Conclusion…

Conditions in 1988 seemed to have become as bad as they could get. The findings of the SUNY-ESF, Syracuse University and UFI research team are summarized in Table 4:

Table 4. Status of Beaver Lake- 1988

1. Beaver Lake is a severely disturbed system.
2. Algae quantities or densities are unusually high and dominated by blue-green algae.
3. Algae are out-competing rooted plants for light and nutrients.
4. Common Carp have become the dominant fish in the lake.
5. Common Carp are exceptionally healthy and thriving at the expense of other forage fish.
6. Predator fish such as Largemouth Bass are not as abundant as one would expect…

Safe to say at this point in the "Beaver Lake Story" conditions had taken a turn for the worse.

BEAVER LAKE WATER & ECOLOGICAL QUALITY

TIME FRAME	CHANGE IN CONDITION
mid 1970s-1980s	⇩ worse

NOW WHAT?

The Research Team report outlined three primary lake restoration objectives for Beaver Lake (**Table 5**):

Table 5. Restoration Objectives for Beaver Lake

1. Re-establish the pre-carp fish population
2. Improve the water quality of the lake.
3. Restore the balance between algae and rooted macrophytes.

Note the objective dealing with Common Carp. This meant completely removing them from the lake, if possible, or at least reduce or prevented the current population from getting any larger. Yet how large was the Common Carp population in Beaver Lake? Was such a population control option feasible?

Fisheries biologists can get a "ball park" population estimate by tagging a number of individuals from a species of interest and compare the number of tagged individuals to the total number (tagged and untagged) individuals collected in a follow-up sampling.

Two different calculations were used in the 1988 study to estimate the population size of Beaver Lake Common Carp. What is known as the Peterson estimate gave a population size of 5,016 while the Chapman-Schnabel estimate was 5,220.

Using the higher estimate (Chapman-Schnabel) for the lake population and biomass value for the number of Common Carp actually collected, an estimate of the biomass of Common Carp for all of Beaver Lake was computed to be 215.6 kg/hectare, or about 192 pounds per acre.

On its own, this number doesn't mean very much. However, some perspective can be gained by looking at a successful Common Carp removal project recently done in Wisconsin's Lake Wingra.

Lake Wingra is of similar size (about 346 acres) and depth (mean depth slightly less than 9 feet) compared to Beaver Lake's average depth of about one-half that. During two collection efforts, 6,722 adult Common Carp were removed and computed to be 25,100 kg or 179 kg/hectare or just less than 160 (159.7) pounds per acre.

In retrospect, the biomass estimate for Beaver Lake in the 1988 study was reasonable and a removal effort similar to that done in Lake Wingra was needed and certainly feasible.

Remediation Plan For The Lake

While specific recommendations were made for each of the three lake restoration objectives by the research team, these and other options were evaluated by an environmental consulting firm, Ichthyological Associates, contracted to prepare an in-depth remediation plan for Beaver Lake.

The following factors were considered during the preparation of the remediation plan:

i) Advantages and disadvantages of each option (method).

ii) Suitability of the method to address the problem.

iii) Suitability for use in Beaver Lake.

iv.) Effectiveness.

v.) Useful life or duration.

vi) Short and long-term effects.

viii) Initial and continuing costs.

Remediation Step #1: Mother Nature Steps In!

The consultant's report reinforced the general consensus the Common Carp population had to be severely reduced and kept that way as part of almost any plan to bring Beaver Lake back closer to what it was like twenty plus years ago.

In the latter part of 1991, arrangements were made for a commercial carp fisherman to remove Common Carp from Beaver Lake, but Mother Nature decided to step in!

Earlier that year, (spring of 1991), Beaver Lake experienced one of its infrequent, though not unheard of, fish kills. This particular event included an undetermined "large number of panfish" and 889 Common Carp counted by BLNC staff.

Fish kills have a number of possible causes, but a drop (usually an abrupt one) in dissolved oxygen levels or in water temperature are often responsible. Shallow, high nutrient and algae-rich lakes with limited access for fish to go in or out of are prime candidates. Beaver Lake fits this description very well. A typical scenario in the fall is an abrupt drop in air temperature along with a corresponding decrease in the water temperature causing algae to suddenly die- off with oxygen in the water quickly used up as the dead algae decomposes.

Another scenario, under such conditions, is during winter or early spring if there had been an extended period of ice and snow cover. Algae do not get sufficient amounts of sunlight to produce enough oxygen during photosynthesis. In a shallow lake like Beaver Lake this might result in the entire or most of the water column having dissolved oxygen levels becoming too low for fish to survive.

Problems can also arise in the summer months with hot weather since water holds less dissolved oxygen as water temperatures increase. At night, algae use oxygen instead of producing it through photosynthesis and this can also lead to a lack of dissolved oxygen being available for fish.

During the "ice-free" time of the year, Beaver Lake's water temperature and dissolved oxygen levels remain much the same throughout the water column. Figure 15 shows a typical water temperature and dissolved oxygen profile for measurements on June, 2017. Occasionally, there are slightly more pronounced differences known as stratification in temperature as well as dissolved oxygen with depth.

Usually, water temperatures in Beaver Lake mimic the daily air temperature fluctuations that occur during the summer. and the water is normally well-oxygenated.

There was no way to know precisely what percentage of the Common Carp population died in the fish kill. Remember, the only population estimates to rely upon were in the 5,000 range and therefore it was believed plenty of Common Carp remained in the lake.

This turned out not to be the case. The Common Carp removal effort mentioned earlier netted only five individuals between 53.3cm (21 in.) and 64.8 cm (25.5 in) in total length. Boat electroshocking captured about another two dozen Common Carp of nearly the same length indicating they were of the same age or very similar age. Unlike the Common Carp collected only a few years earlier in 1988, these appeared to be under ecological stress since they were not as heavy and robust as they should have been.

It was reasonable to conclude a significant decrease in the Common Carp population had taken place, but two questions arose at this point: 1) had the population been reduced enough so the condition of the lake might improve? and 2) if so, could the population be kept at that level?

Remediation Step #2: Alum Treatment

One method used to reduce algae and improve lake water quality is to remove excess amounts of nutrients, namely phosphorus, from the water column. Known as nutrient deactivation or inactivation, this technique usually involves the application of aluminum sulfate or "alum" which binds to the phosphorus creating a heavier clump or aggregate which then settles out of the water column.

The idea is that by reducing the amount of phosphorus available the amount of algae will also be reduced since phosphorus is crucial for algal growth.

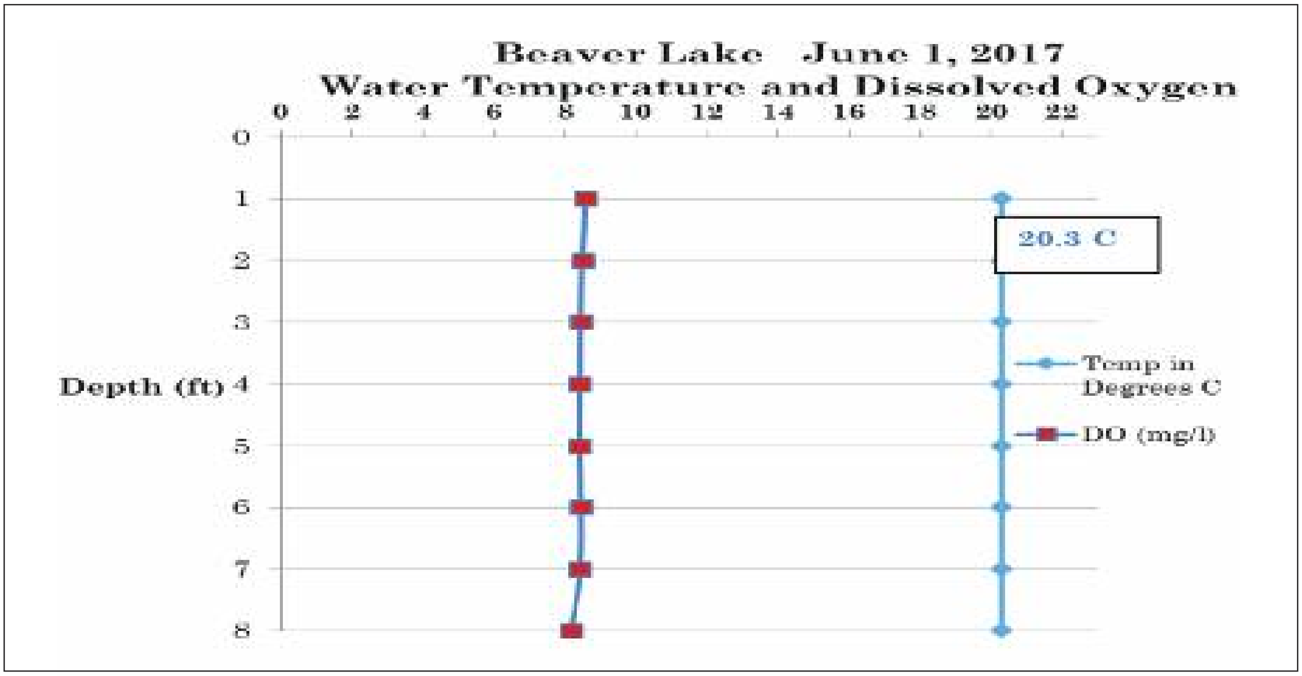


Figure 15. Beaver Lake June 1, 2017 water temperature and dissolved oxygen. *Water temperature (in blue) and dissolved oxygen (in red) readings with depth.*

There were basically two types of applications to choose from. One required smaller doses and used to address more immediate or short-term conditions while larger amounts of alum could be applied for long-term inactivation to "seal" bottom sediments and prevent the release of phosphorus to overlying waters.

A water column level treatment was selected for a couple of reasons including cost and the thinking that creating a "window" of clear water conditions during the early part of the growing season might allow submerged plant species to establish themselves.

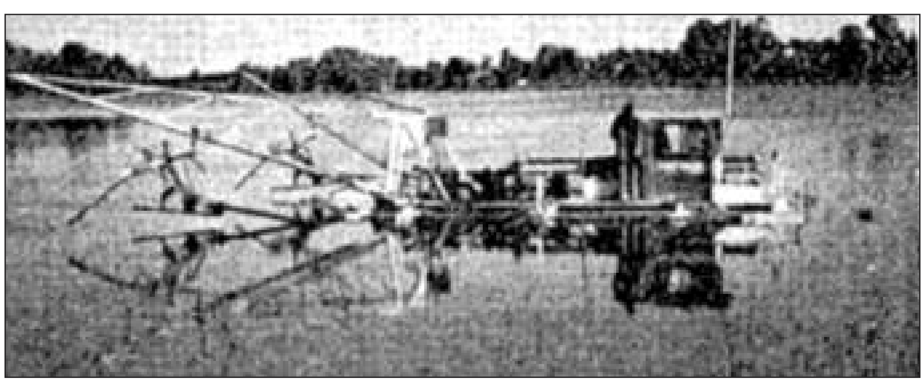
Remember Beaver Lake is very shallow with a well-mixed water column and without a bottom zone of water known as a hypolimnion lacking dissolved oxygen. Bottom waters with very low or no oxygen allow phosphorus to be released and made available for algae to grow. Such shallow lakes are not the best candidates for long-term inactivation since the bottom sediments can be stirred up (resuspended) rather easily.

Another determining factor was the cost of a long-term inactivation application which was far more expensive. It was also believed a multi-year benefit would result from a water column application.

The alum treatment was completed on June 9 and 10, 1992 by Sweetwater Technology Corporation (Figure 16). Alum was applied in the portion of the lake deeper than five feet (approximately 140 acres). This was about 70% of the surface area of the lake, but a considerably greater percentage by volume.

While the shallowness of the lake presented a challenge, a good aggregate or "floc" formed. Water pH remained above 6.0 which was important to prevent unwanted impacts to aquatic life. The treatment was believed to be among a very few implemented in New York State at that time.

Figure 16. **Boat and boom equipment used for alum application.** *(photo included in proposal from Sweetwater Technology, Inc.)*



POST-ALUM TREATMENT: IN THE SHORT TERM

A short-term benefit was clearly seen in the chlorophyll a data results shown in **Figure 17**. Readings remained below 20 µg/l through the growing season, but increased in the late September to mid-October time period due to a fall algae bloom.

Increased transparencies reflected in Secchi disc readings were seen almost immediately with readings around 1m (3ft); a substantial improvement over those taken during the summer of 1988 **(Figure 18)**. Like the chlorophyll a readings, the improved water visibility lasted through the summer until the onset of the above mentioned bloom before increasing again with the onset of cooler temperatures and decrease in algae in November.

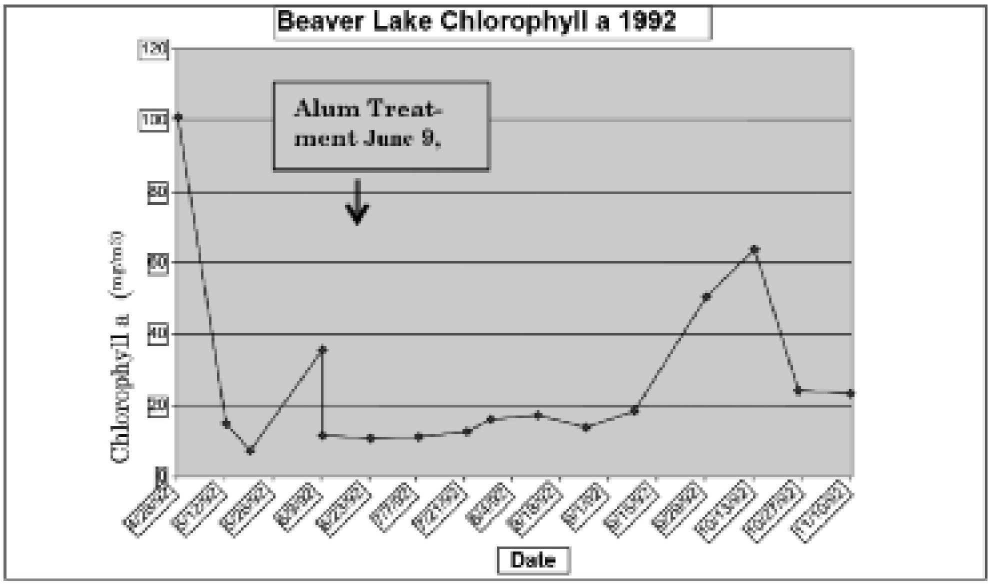


Figure 17. Chlorophyll a readings in 1992.
(data from PD Morse Master Thesis 1993 SUNY–ESF Syracuse, NY)

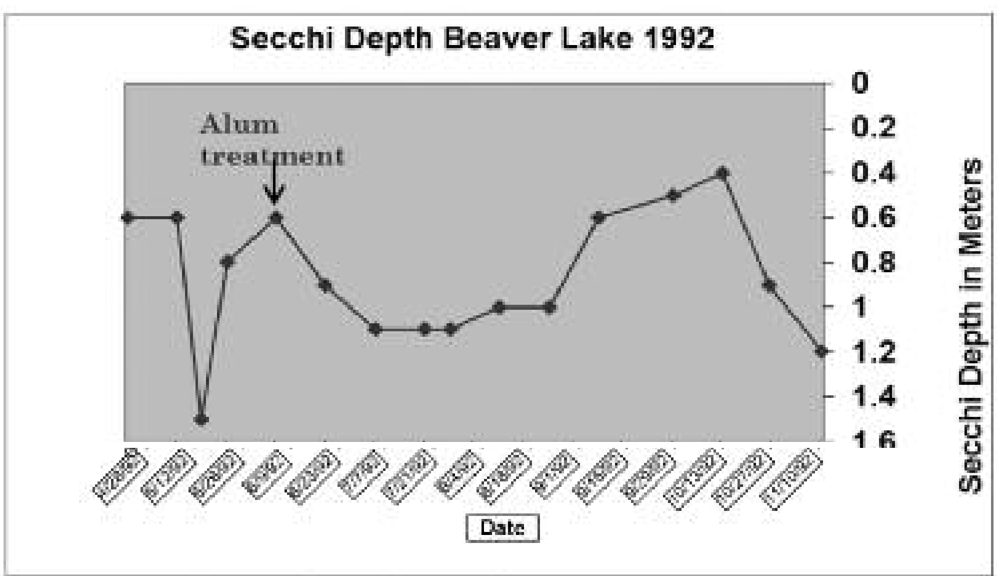


Figure 18. Secchi Depth Beaver Lake 1992.
(Data from PD Morse Master Thesis 1993 SUNY CESF Syracuse, NY).

POST-ALUM TREATMENT: LONG-TERM GAIN OR MORE PAIN?

Were there any other indications conditions in Beaver Lake were improving? Observations during the 1991 Common Carp removal effort made note of a general absence of young or juvenile fish of any species. About a year later, BLNC staff began seeing juvenile and forage fish in the shallow shoreline waters.

Juvenile Fish Survey

To better quantify this, Barnes and Williams Environmental Consultants conducted a juvenile fish shoreline netting survey in October, 1994.

Results indicated good numbers of juvenile fish were indeed present in shoreline habitats, although comprised largely of only two species: Bluegill and Yellow Perch. Bluegill was far more abundant. Two age classes of Bluegill were identified indicating at least some reproductive consistency and stability in that population. Other species collected included only adults. Significant was the absence of juvenile Common Carp providing further evidence their population had been reduced and not expanding.

Aquatic Plant Restoration Study

With seemingly improved conditions in the lake fish community and water clarity, was it possible to achieve a better balance between rooted submerged aquatic vegetation and algae as Dr. Jackson had described Beaver Lake over three decades ago?

In 1996, Terrestrial Environmental Specialists, Inc. implemented a pilot aquatic vegetation restoration project which included planting seven rooted, aquatic plant species that represented emergent, floating, and submerged types.

What are these three categories of plants? While somewhat of a simplification, emergent aquatic plants are rooted in the water with much of the plant growing in and above the water surface. Floating aquatic plants have a top portion that sits or floats on the water's surface. Submerged aquatic plants grow entirely underwater.

The plant species selected were either presently or historically found in Beaver Lake. An example of the latter was Wild Rice, discussed earlier, which had been purposely planted in the 1920s, but no longer present. All of the plantings were in water two feet or less in depth.

Figure 19 above. Plant Restoration Study. *Transect Number 8 – September 12, 1996. Pickerel Weed Planting Stock-July 12, 1996 (is seen on page 27). (photographs from Terrestrial Environmental Specialists, Inc.-Beaver Lake Aquatic Vegetation Restoration Study.)*

As expected, the emergent species, Pickerelweed, which was common along the shoreline, showed the best growth. Water Lily, a floating aquatic plant, grew well at all locations while the submerged species, Sago Pondweed and Tape Grass,

Figure 19b

grew successfully along 8 of 10 test transects. The emergent Wild Rice and Arrow Arum grew poorly as did Coontail, a submerged species. It is interesting to recall the 1988 study where Coontail was essentially the only submerged plant found growing in deeper water **(Figure 19 and 19b)**.

Along with the study, a list of aquatic plants found nearshore were identified indicating some improvement in species distribution since the 1988 study. For example, both Sago Pondweed and Tape Grass (two of the test species) were described as being "common" in shallow (1-1.5ft) water while Curly-Leaf Pondweed, Large-Leaf Pondweed and Naiad described as, "present."

Fair enough to say in the first half of the 1990s there were signs of an improving Beaver Lake!

BEAVER LAKE WATER & ECOLOGICAL QUALITY

TIME FRAME	CHANGE IN CONDITION
Early to Mid– 1990s	A little better

THE MID-1990s INTO THE NEW MILLENIUM

The water quality data base for 1994-2008 is not as complete as time frames before and after that. Nevertheless, much can still be said about whether or not conditions in Beaver Lake had changed. The best way of doing that is by looking at the data over this time period on a parameter-by-parameter basis.

Table 6. Beaver Lake Chlorophyll a (mg/m^3) (Years 1988-2002)

Year	Sampling	N	Mean	Range
1988	4/13 - 10/20	23	134	10-563
1991**	4/10 - 9/17	14	54.9	10-214
1992***	4/28 - 11/10	16	27	7.2-100.9
1998	3/30 - 10/23	7	17.6	10.7- 26.7
1999	4/12 - 12/9	9	15.1	6.4 - 35.6
2000	4/20 - 11/2	5	8.8	2.7- 24.0
2001	4/26 - 11/27	7	11.0	9.1 - 15.8
2002	6/4 - 9/26	4	12.7	5.3 - 12.0

** Reported as total chlorophyll which would be slightly higher readings than chlorophyll a, only (Morse 1993)

*** Alum treatment June 9, 1992.

Chlorophyll a

Table 6 shows mean chlorophyll a values along with minimum and maximum measurements (ranges) for the years 1998-2002. There are some differences in the number and seasonality of samples taken from year-to-year, but means and ranges were quite similar with the possible only exception being a 1999 reading of 35.6mg/m3, indicative of a major bloom. This sample was taken on July 28th of that year.

The numbers do show improvement over the “ultra-high” chlorophyll a readings for 1988 and 1991; especially with a decrease in maximum values from those two years (563 $mg/m^3$and 214 mg/m^3, respectively).

Thus, from the late 1990s into the early 2000s there were no large, summer-long algae blooms typical of the late 1980s and early 1990s. Maximum chlorophyll a values were typically no greater than “minor bloom status” of 15 mg/m3 or higher, and less than the 30 mg/m3 of value characterizing major bloom conditions. From 2003 to 2008, fewer chlorophyll a analyses were made as sampling narrowed to focus on capturing peak blooms (see Table 7). Results for the years 2003

BEAVER LAKE WATER & ECOLOGICAL QUALITY

TIME FRAME	CHANGE
1990s - early 2000s	A little better, again!

and 2004 were much like the previous two years (2001-2002). A whole of only four samples were taken but all readings were below 10mg/m3. However, major blooms were identified for 2005 and 2008 with chlorophyll a values 42.72 mg/m^3 and 58.74 mg/m3, respectively.

In 2009, increased seasonal sampling was reinstated fortuitously catching a major bloom as chlorophyll a readings including a maximum of 197.6 mg/m^3 (Table 7). This approached readings not seen since the early 1990s and late 1980s! Were things starting to get worse? It certainly seemed so, but one year does not make a trend!

A look at the chlorophyll a data collected from 2009 through 2016 **(Figure 20)** provided a different picture, with 2009 being more of an outlier than the start of a trend. That is not to say that Beaver Lake has not had large algae blooms in recent years. **Figure 20** clearly shows major blooms have taken place.

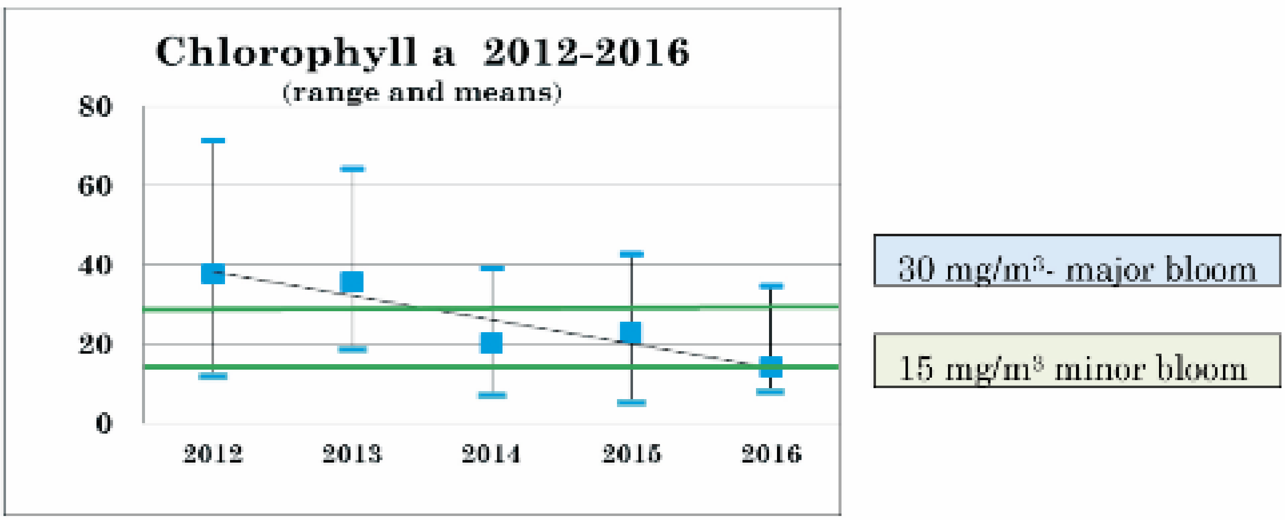


Figure 20. Chlorophyll a 2012-2016 range and means.
Beaver Lake 2012-2016 (April-October) showing frequent blooms occurring but a slight downward trend in the data.

Table 7. Beaver Lake Chlorophyll a (2003-2009)		
Year	**Sample Dates**	**Chlorophyll a (mg/m^3)**
2003	5/30	8.9
	7/25	7.91
2004	5/13	2.67
	8/24	5.34
2005	5/18	4.27
	8/10	42.72
2007	6/14	6.41
2008	6/30	12.28
	7/31	58.74
2009	**4/27-10/29 (n=7)**	**10.2-197.6 Mean=69.8**

Total Phosphorus

What about other parameters? Do they provide any clues whether the lake has changed?

Figure 21 shows mean total phosphorus readings for much the same period of record as for chlorophyll a. There are occasional years besides the 1988 benchmark such as 1999, 2009 and 2010 with very high mean values likely skewed by a single extremely high reading. Remember from Table 2 that New York State considers a mean summer season total phosphorus value of 20 µg/l as eutrophic or nutrient-rich.There is no obvious trend in the total phosphorus data though one might note there has not been a "spike" year since 2009. Nevertheless, Beaver Lake's total phosphorus readings are indicative of a eutrophic lake and even hypereutrophic as noted back in 1988.

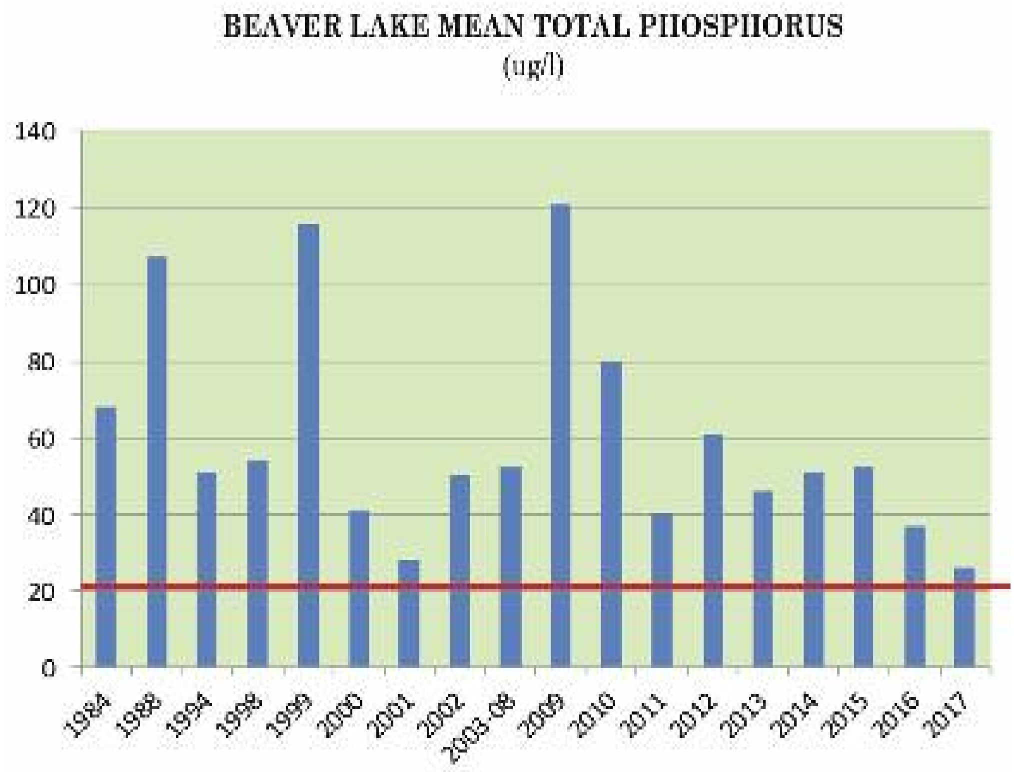


Figure 21. Beaver Lake Mean Total Phosphorus. *Readings shown for 1984-2016. There has been significant annual variability, but Beaver Lake has consistently been eutrophic and even characterized in past years as hypereutrophic.*

On the basis of the available data and narrative description discussed earlier, there is little doubt Beaver Lake was a nutrient-rich lake when acquired by the County and likely before thenas well.

Secchi Disc Transparency

As was said earlier there is not a good correlation or relationship between Secchi disc readings and algal abundance in Beaver Lake due to the coloration of the water due to "non-algae" components in the water column.

Figure 22 shows May to October mean values along with standard deviations for each year sampled (The standard deviation indicates how "spread out" the sample data are.)

Not surprisingly, there is no obvious trend in the secchi disc data showing either long-term improvement or degradation. The data, however, do have something else to say.

Perhaps most telling is that Secchi disc readings annually average less than a meter (3ft). This again says large areas of the lake consistently do not receive adequate amounts of sunlight for submerged macrophyte plants to grow and survive.

The years shown with a lower mean value and a "small" standard deviation indicate years where blooms were high and lasted much of the growing season. Recent examples include 2010, but also years 2012, 2013, and 2015. Still nothing has approached 1988 which serves as a "measuring stick" for the lake's "low point" in overall quality.

Notice results from 2017 show consistent, high visibility. Such conditions have not been seen since some years in the mid- 1990s. Overall conditions for 2017 and more recently will be discussed later.

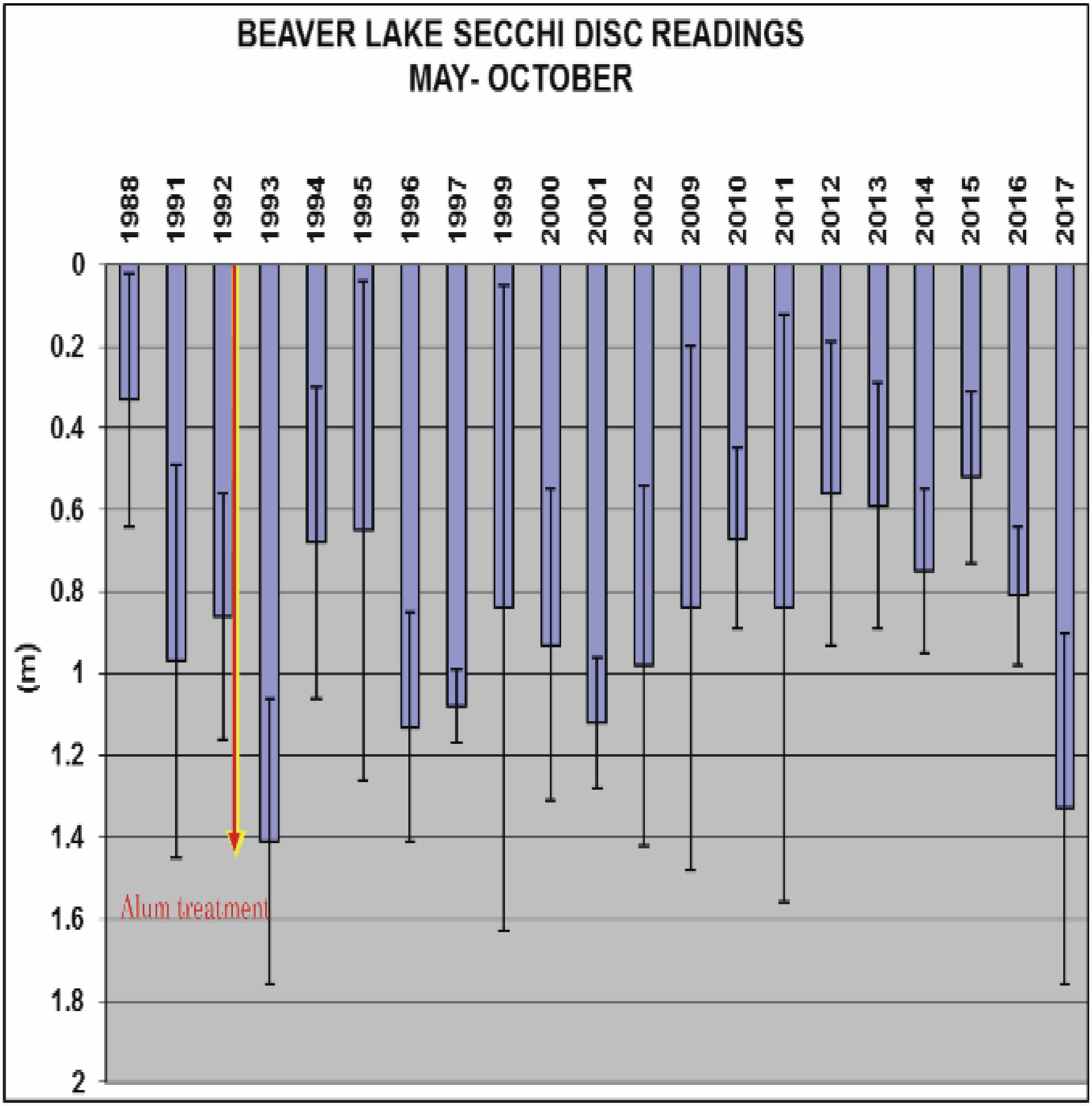


Figure 22 Beaver Lake Secchi Disc Readings May-October. *Secchi disc readings for Beaver Lake period of record.*

An abundance of nutrients (mainly phosphorus), suitable water temperatures and sufficient sunlight are the drivers for determining when algae blooms occur and how intense they will be. Simply said, seasonal algae growth and abundance patterns are weather dependent and vary from year to year and in Central New York, the only certainty concerning weather, is its uncertainty!

For example, in some years conditions are suitable in April for an early bloom which can be followed by a reduction or "clearing" before species preferring warmer temperatures become more numerous. In other years, fairly strong blooms have developed in April and early May and while the dominant species may change over the course of the growing season, bloom conditions have lasted for most, if not, all of the growing season.

O T H E R R E C E N T I N V E S T I G A T I O N S

Several investigations never done before at Beaver Lake or not for many years have recently been completed. These have helped provide a better understanding of the present ecological condition of Beaver Lake and provide helpful comparisons to past conditions.

Algae: What Species and How Abundant?

In 2012, algae samples were collected to identify species found in the lake along with determining which were most abundant and responsible for blooms. This work was completed by PhycoTech Inc. and was the first time such information had been collected from Beaver Lake since the 1988 study. Samples were taken during July, September and October in an attempt to capture peak blooms. The list of the species identified is found in **Appendix I**.

A rather large number of species were identified, but only a few (highlighted in bold in **Appendix I**) were found to be very abundant either by biovolume (amount of algae in a reported unit volume) or by relative count (number of organisms).

Table 8 - Dominant Algae Beaver Lake 2012 July-October

- *Microcystis viridis* (blue-green algae) dominant throughout though decreasing slightly in the fall (October) sample.
- In addition to *Microcystis virdis* (blue-green algae), another blue-green algae *Microcystis we senbergii* was abundant in early July. *Ceratium hirundinella* (dinoflagellate) and *Aulocoseria ambigua* (diatom) were abundant in early July and late July, respectively.
- *Microcystis virdis* (blue-green algae) and *Aulocoseria ambigua* (diatom) were equally dominant in the September sample.
- *Aulocoseria ambigua* (diatom) was dominant in the fall (October) sample.

The dominant species and the seasonal pattern of abundance are shown in Table 8 and as expected, the dominant algae types were those typically found in nutrient-rich lakes. Also take note that dominant algae were not always blue-green algae.

Table 9

Beaver Lake Phytoplankton 2012

Date	Est. Total Biovolume (mg/l)
July 9	4.92
July 26	4.16
September 10	5.24
October 26	3.77
Onondaga Lake (Apr-Oct 2012)	1.5 (peak 6 mg/l in May)
Onondaga Lake (Apr-Oct after 2007)	1.5
Onondaga Lake (1998-99)	8

-Wetzel (2001) regards 3-5 mg/l as mesotrophic

How large were the algae populations?

Table 9 shows computed biovolumes for samples from this study compared to historical and more recent numbers for Onondaga Lake. It should be noted the methods used in sampling and calculating the Beaver Lake and Onondaga Lake values were quite similar.

Beaver Lake biovolume measurements were in the 3-5 mg/l range which is characterized as mesotrophic or moderately nutrient-rich. The September value was indicative of eutrophic conditions and the July 9th reading very close to the 5 mg/l reference number for a eutrophic condition. Onondaga Lake, which has improved dramatically in recent years from a trophic status standpoint, has had biovolumes typically well below 3 mg/l; much less than values from the late 1990s.

Submerged Aquatic Vegetation

The 1988 study showed the ecologically important submerged aquatic vegetation having virtually disappeared from Beaver Lake with the exception being shallow water adjacent to portions of the shoreline. Likewise, observations made during the 1996 plant restoration study and over the next decade indicated little, if any, change in distribution or abundance of submerged plants.

In 2013, a lake wide survey of aquatic vegetation was done utilizing sonar transducer technology and computer data analysis developed by C-Map, Inc. Results were calculated as vegetative biovolume which is the percentage of the water column containing submerged vegetation as a percent of the water column depth. For example, if vegetation extended four feet high in five feet of water, biovolume would be reported as 80%.

Results are presented as a "heat" map in **Figure 23** and clearly show an increase in submerged aquatic vegetation presence and abundance in the lake; likely greater than any time since the late 1970s or early 1980s. The overall mapping included emergent species such as water lilies which had expanded their distribution in the lake's southeast corner as well as in an area along the western shore.

Not all of the dense areas of aquatic vegetation (red-orange) in the embayments are due to water lilies, but to submerged aquatic vegetation as well. Other "hotspots" for submerged vegetation included the eastern corner of the lake close to the boat dock and Nature Center building as well as near the outlet in the lake's northern extreme.

The presence of at least some submerged aquatic vegetation in depths of 5 feet or more (mid-portion of the lake) is worth noting despite it being still very much restricted to shallow areas of the lake usually sheltered from wind and wave action.

In general, another important factor affecting submerged aquatic vegetation distribution is bottom or substrate type. Hard bottoms such as those consisting of cobble and stone support less plant growth than softer bottoms comprised of silt or other small diameter material.

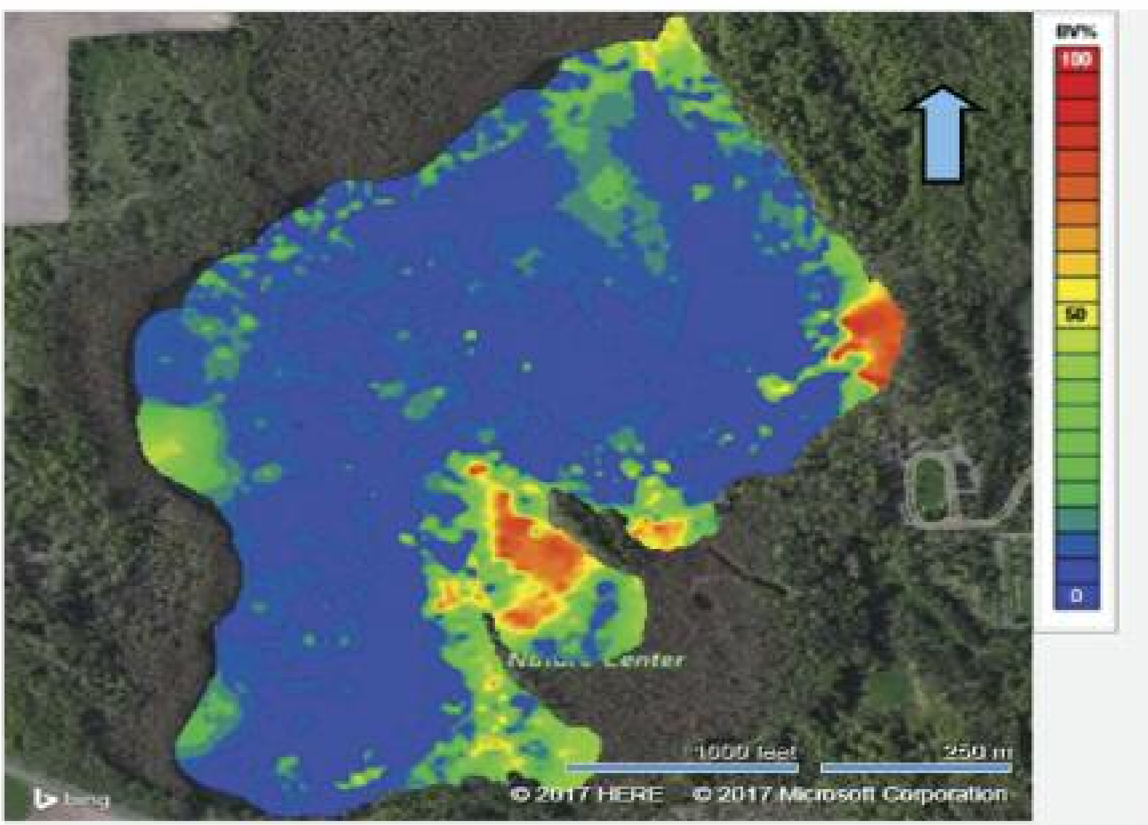


Figure 23. Beaver Lake Aquatic Vegetation Survey 2013. *Results tabulated as biovolume (percentage of water column containing aquatic vegetation). Note higher amounts (yellow-orange-red colors) of aquatic vegetation in embayments and sheltered areas along the eastern shore.*

Figure 24 helps explain why aquatic vegetation is largely absent from a portion of the eastern shore almost directly in line with the Visitor Center and extending southwesterly. This area shows a hard bottom composition (red-brown coloration) not conducive to submerged plant growth.

In contrast, the light gray color indicates a soft bottom composition and these are areas where aquatic vegetation is generally most abundant. This information also provides a clue as to what areas of the lake would likely be able to support larger amounts of submerged aquatic vegetation in the future if water column visibility improves.

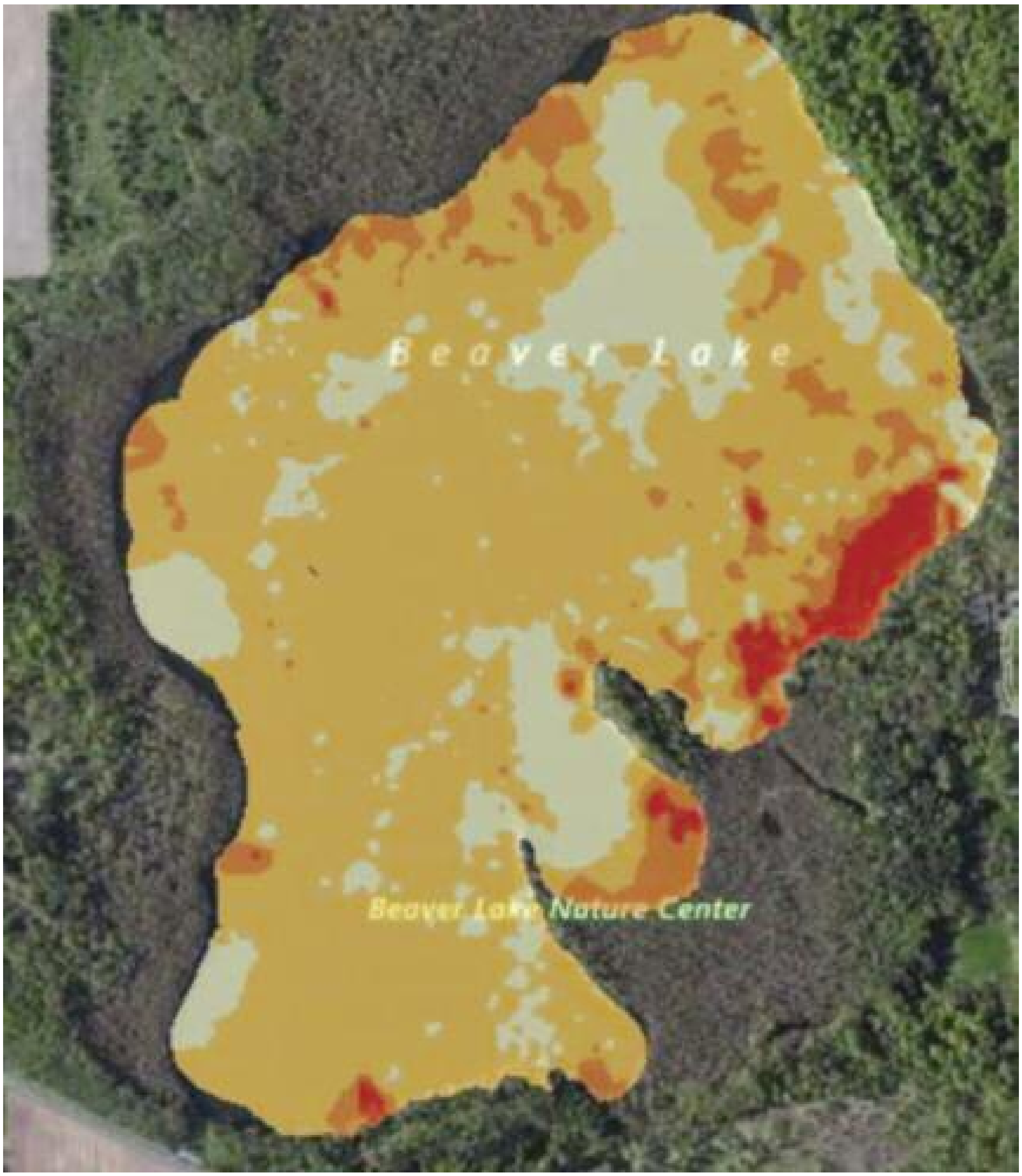


Figure 24. Beaver Lake Beaver Lake Bottom Type. *Bottom type characterization ranging from soft (light colors) to hard (darker colors) in Beaver Lake.*

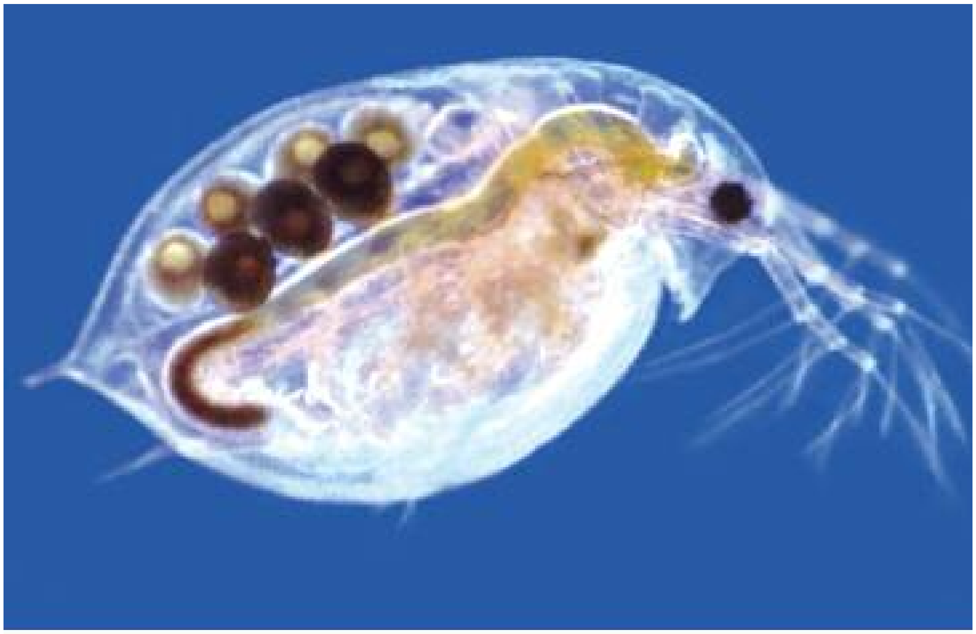


Figure 25 - *Zooplankton are important since they are critical component of a lake's ecosystem. Large sized Daphnia, one of the dominant zooplankton found in the lake. (photo by Onondaga County WEP).*

The "Forgotten" Zooplankton

The 1988 study made reference to Beaver Lake's small numbers of zooplankton. However, until 2012, no zooplankton community analyses had been done since Jackson's work in the 1960s (**Figure 25**).

Samples were collected on four occasions between July and October, 2012 with identifications, counts and computations done by the Cornell University Biological Field Station at Shackleton Point - Oneida Lake. Table 10 shows mean sizes and total biomass (as dry weight) for each of the four sample dates.

Like phytoplankton, species that are dominant can vary over the course of a growing season. These results must also be viewed cautiously since only four samples were taken and for just one year. For example, the overall mean biomass (75.6 µg/l) is skewed by the July 9th collection which was much larger (197.1 (µg/l) than that for the other three sample dates which had biomass values of 44.5 µg/l or less. Results were also affected by the small number of individual zooplankton in the samples.

How do these numbers compare to other lakes? The Cornell Biological Field Station has sampled and compiled zooplankton biomass data for Onondaga and Oneida lakes. While these are much larger datasets and compiled over many years (especially in the case of Oneida Lake) they provide a useful comparison as to the size of the Beaver Lake zooplankton community.

Onondaga Lake in 2013, had a growing season (April-October) mean biomass of 104 µg/l. For Oneida Lake, biomass has generally decreased in recent years, but its long-term (1975-2014) zooplankton biomass average is 207 µg/l. In some years during the 1990s values were at or above 300 µg/l. These numbers are much larger than the 75.6 µg/l biomass mean reported for Beaver Lake affirming the long-held assumption the lake has a small zooplankton population.

Mean sizes of zooplankton shown in Table 10 give an indication of the size of the dominant zooplankton present. For example, *Daphna*, *Ceriodaphnia* and *Diapanosoma* were dominant and these are larger-sized zooplankton resulting in an overall mean size about .5 mm (.49mm).

Table 10 Beaver Lake Zooplankton 2012
(Biomass and Mean Size)

	7/9/12	7/26/12	9/10/12	10/26/12	Mean
Biomass (ug/l)	197.1	44.5	27.7	32.9	**75.6**
Mean size (mm)	.56	.49	.52	.40	**.49**
number	107	104	103	111	

Onondaga Lake, in comparison, had a growing season mean zooplankton size in 2013 just less than .4 mm. For the 1999-2013 time period, the size range has been from around .25 mm to just less than .55mm.

What can we take from the zooplankton information? Small in quantity, the zooplankton population doesn't provide much of a food source for young fish in Beaver Lake and does little in the way of feeding or what is called "grazing" upon the lake's large algae population which could help keep those numbers down and blooms under better control.

And The Fish?

Fish sampling done in 2012 was the most extensive effort since the 1988 study. Actually, a greater variety of methods **(Figures 26, 27 and 28)** were used in this study than in any previous effort.

Figure 26. Electroshocking shoreline habitat. *Note the Water Willow (right), an emergent aquatic plant very common along portions of the lake shoreline. Note also the large algae bloom underway shown by the green coloration of the water (photo by Onondaga County WEP).*

Figure 27. Seining. *Seining in the shallow water close to shore (photo by Onondaga County WEP).*

Figure 28. Gillnetting. *Deeper water sampled by setting a gillnet (photo by Onondaga County WEP).*

More than one age class of Largemouth Bass **(Figure 32)** was collected, but few individual fish in total. This was also true of the lake's other major predator species, Northern Pike. Thus, continues the longstanding issue of a lack of top predator fish in Beaver Lake. However, though based upon a small sample size, prey fish aged by Onondaga County WEP staff gave no indication of showing stunted growth such as reported back in the 1970s.

Common Carp continued its absence as a major player in the lake which has been the case since the early 1990s. Only one adult was collected!

What Did The Fish Study Say?

Bluegill including many juveniles was by far the most common species **(Figure 29)** with the closely related Pumpkinseed and Black Crappie **(Figure 30)** also abundant. Multiple age classes of Yellow Perch and Golden Shiner **(Figure 31)** were collected indicating these species are successfully reproducing in the lake.

Figure 29. Bluegill. *Bluegill was by far the most common species (70% relative abundance) collected including many young fish indicating good reproductive success (photo by Onondaga County WEP).*

Figure 30. **Black Crappie**. *One of the species showing reproductive success in Beaver Lake (photo by Onondaga County WEP).*

Figure 31. Golden Shiner. *There are multiple age classes of Golden Shiner in Beaver Lake. A major forage fish in many lakes, the abundance of larger sized individuals indicates the long time problem of too few predator fish present in the lake. (photo by Onondaga County WEP).*

Figure 32. Young Largemouth Bass. *More than a single age class of Largemouth Bass were collected, but the overall number of fish was small. (photo by Onondaga County WEP).*

Results from the lake seining and gillnetting are summarized in **Figure 33** and **Table 11**.

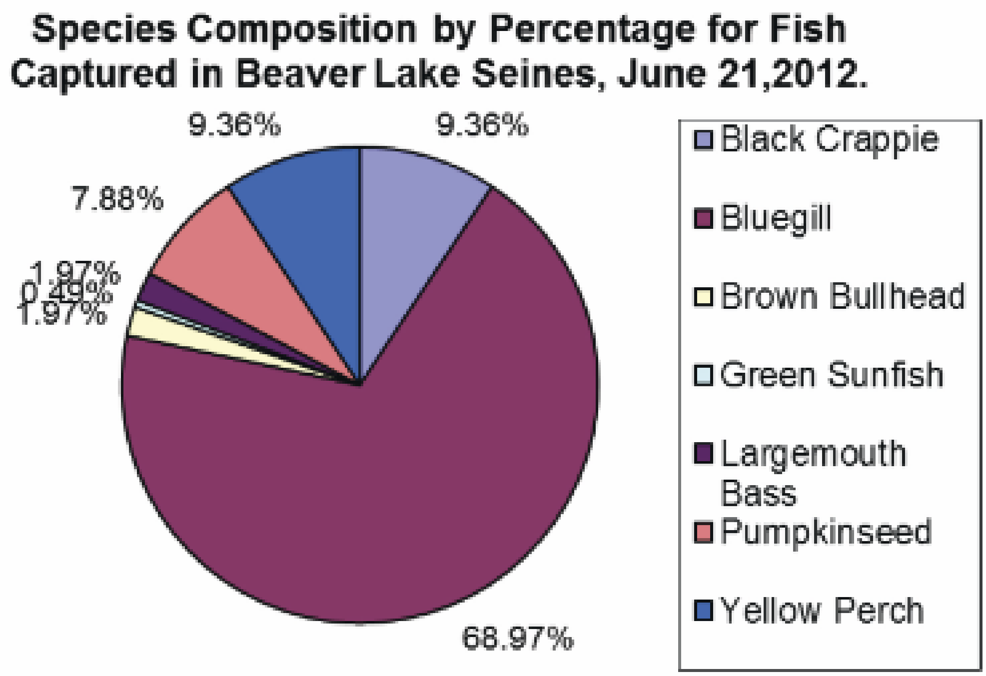


Figure 33. **Species Composition by Percentage for Fish Captured in Beaver Lake Seines, June 21, 2012**.
Note the overwhelming dominance of Bluegill (data compilation and graph provided by Onondaga County WEP.)

Table 11
Beaver Lake Gill Net Data August 22, 2012
(Onondaga County Water Environment Protection)

Species (Common Name)	Number*	Life Stage
Brown Bullhead	1	Adult
Common Carp	1	Adult
Northern Pike	2	Adult
Bluegill	5	Adult(4) Juvenile (1)
Golden Shiner	75	Adult
Black Crappie	3	Adult (2) Juvenile (1)
Yellow Perch	1	Adult

* Combined total from four gill net locations.

WHAT TO MAKE OF 2017 AND BEYOND?

Visual conditions and data results for 2017 were quite different from what has typically been the case for Beaver Lake and warrant a separate discussion.

Secchi disc results for 2017 have already been discussed, but it is worth mentioning no readings were below 3 ft during summer with one even exceeding 6 ft in mid-September.

A number of lakes in the Central New York region experienced large algae blooms known as Harmful Algal Blooms or HABs. In almost direct contrast, Beaver Lake was virtually "bloom free". *Remembering it is an indicator of algae abundance*, Chlorophyll a readings during the June through mid-September period were as low as 2.9mg/m3 and never exceeded 8.5mg/m3. Likewise, total phosphorus readings were lower than historically recorded including values below 30 µg/l.

Needless to say, such values over the course of an entire growing season are unprecedented at least as far back as the mid-1980s when lake monitoring began on a more consistent basis.

Algae blooms whether due to "true" algal species or blue-green algae (as explained previously these are really bacteria) have garnered a great deal of public attention in recent years. Harmful Algal Blooms, or HABS for short, may have impacts affecting health, recreational and ecological conditions.

Algae, however, are a natural and integral part of a lake's ecosystem and blooms or what we might refer to as an over-population of algae are nothing new and their basic causes are well known. In simple and basic terms, there must be adequate light (sunlight), warm enough water temperatures and enough nutrients. With ideal light and temperature conditions in place, it is usually the overabundance of nutrients, namely phosphorus is freshwater systems that essentially cause a population explosion.

Whether the number and duration of algal blooms have increased in recent years and why toxins are produced by some populations of certain species under particular conditions cannot be answered definitively and beyond the scope of this discussion.

Even more dramatic was the expansion in area coverage and abundance of submerged aquatic vegetation. While priority areas of Beaver Lake were surveyed in 2017, the expansion in aquatic vegetation presence and abundance along the lake's northern, western and southern shores is clearly seen in **Figure 34** in comparison to the whole lake survey done in 2013 shown in **Figure 23**.

Dense coverage of submerged aquatic vegetation extended approximately 125 ft from shore with Beaver Lake probably looking much like it did in the early 1960s and 1970s.

While Large-leaf Pondweed (*Potamogeton amplifolius*) is abundant in some of the areas closest to shore, but the not-so-good news is the vast majority of the expanded vegetation is Eurasian Watermilfoil (*Myriophyllum spicatum*), a dominating, invasive species **(Figure 35)**.

How did all of this happen? Among the most obvious possibilities was the above normal amounts of rainfall received that spring and early summer. The March, April, May "spring" season rainfall totaled for 2017 was the fourth highest on record for Syracuse, NY. As for temperatures, April averaged above normal, but a cooler than normal May might have helped minimize algal growth. [2]

Not surprisingly, Beaver Lake remained well above its normal level for much of the spring and summer. Typically, seasonally high rainfall results in tributaries bringing more pollutants and contaminants into a receiving lake and increases the likelihood of algae blooms. However, remember Beaver Lake's watershed is very small and the lake does not receive a great deal of surface inflow from its small tributaries.

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[2] Similar if not a nearly identical magnitude of rainfall above normal was probably the case for Beaver Lake though located 25 miles west of Hancock Field where precipitation data are recorded for Syracuse. Weather information retrieved August 16, 2017 from cnycentral.com)

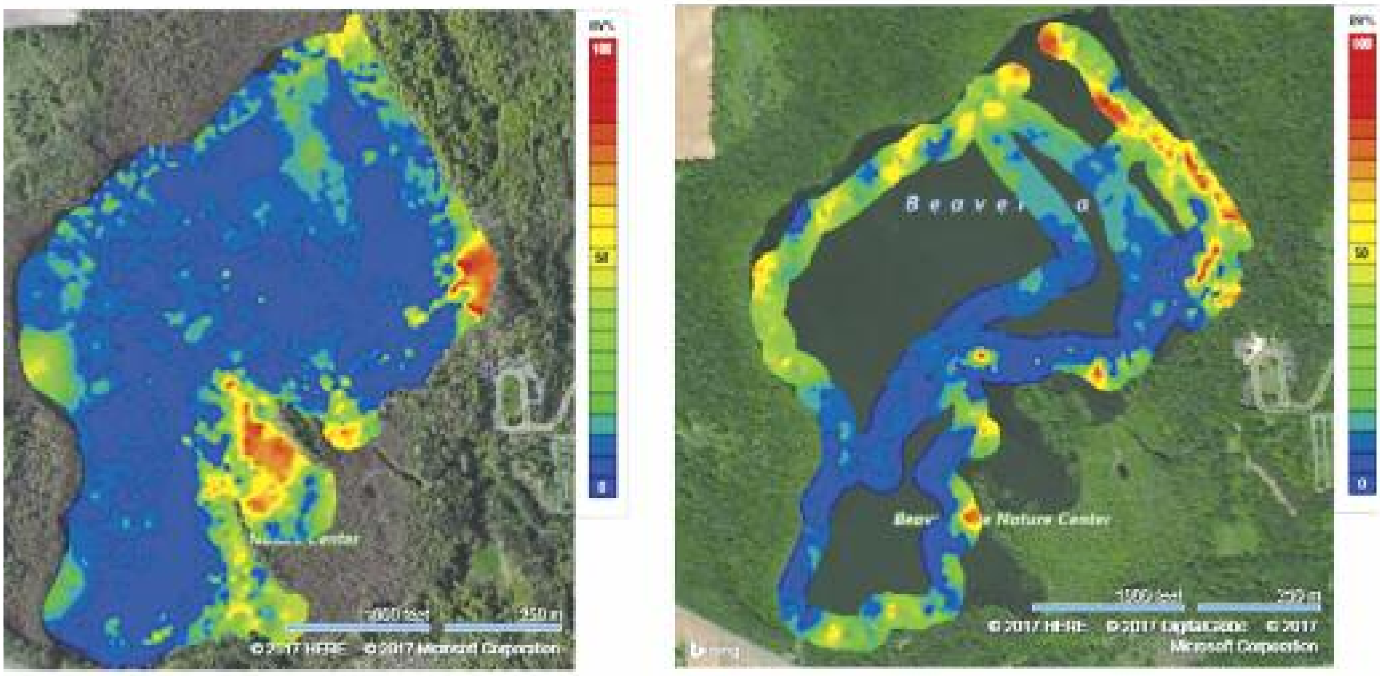

Figure 34 Aquatic Vegetation Abundance 2017. *Nearshore areas from a portion of Beaver Lake surveyed in 2017 (right). Note the greater amount of submerged vegetation present (orange to red) along the northern, western, and southern shoreline areas of the lake in comparison to those same areas in 2013 (Figure 23, repeated at right).*

Figure 35.
Eurasian Watermilfoil (*Myriophyllum spicatum*)
An invasive species and problematic in many lakes, Eurasian Watermilfoil has become increasingly abundant in Beaver Lake. However, it does provide submerged aquatic vegetation habitat and bottom sediment stability.

As for the lower than usual phosphorus levels? It may be the unusual volume of "cleaner" or lower nutrient water entering the lake from surrounding wetlands and rainfall directly falling on the lake having a dilution effect since Beaver Lake does not flush quickly despite its small size and volume. On the other hand, perhaps the larger volume of inflow to that lake increased flushing and outflow enough to reduce levels of phosphorus.

In 2018, lake water quality samples (five samples) were taken approximately monthly from mid-May through mid-September. Results were similar to 2017 for total phosphorus which were consistently around 30 µg/l **(Figure 36)**. Chlorophyll a readings were slightly higher than in 2017, with the two highest values being 19.2 mg/m3 and 14.0 mg/m3, respectively. These were indicative of being close to or at minor bloom conditions with the other three values at or less than 6.41 mg/m3 **(Figure 37)**.

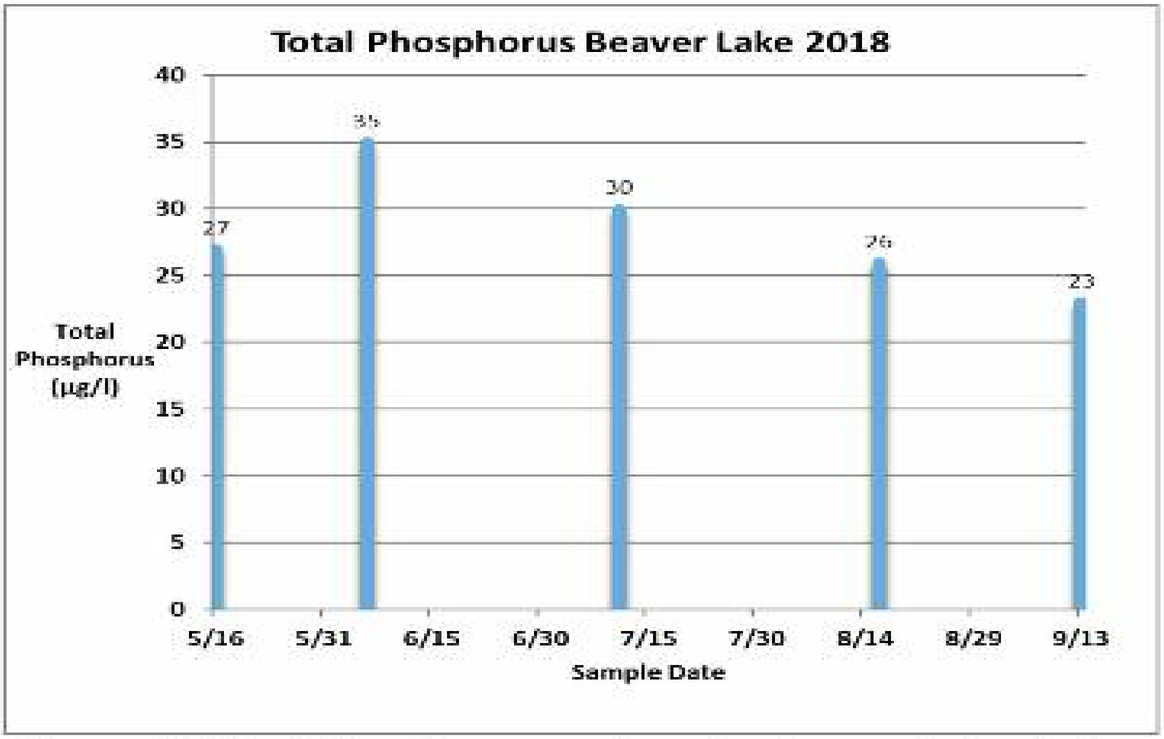

Figure 36. Total Phosphorus readings for Beaver Lake. *Values consistently around 30 ug/l which are eutrophic or nutrient enriched, but historically low.*

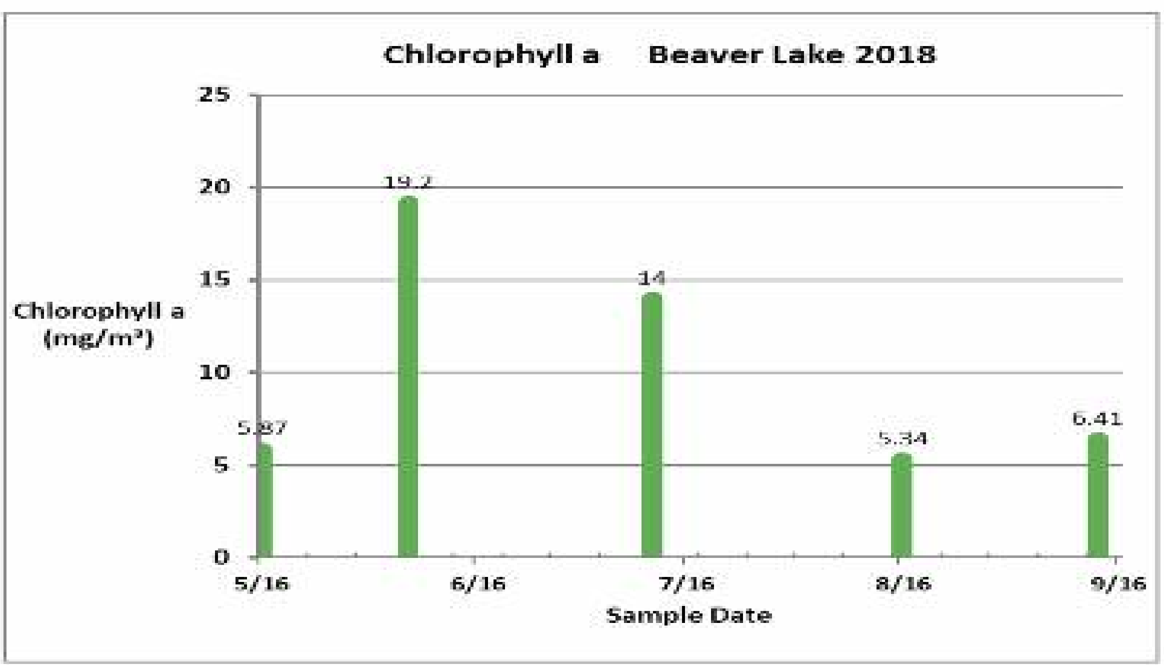

Figure 37. Chlorophyll a readings for Beaver Lake. *Mid-summer minor bloom conditions, but overall seasonal readings remained low by historical comparisons.*

These numbers confirmed visual observations of the lake. Secchi disc readings also showed a slight decrease indicating water clarity in 2018 was very good, but not exceptional as in 2017 **(Figure 38)**. Similarly, the submerged aquatic vegetation surveys in 2018 **(Figures 39 and 40)** showed abundant and widespread coverage of plants greater than in 2013, but not at 2017 levels; especially along the inshore areas on the northeastern shore of the lake **(see Figure 34 and 23)**. Conditions in 2019 largely mimicked those of 2017 and 2018 with Secchi disc readings between 4 1/2 feet to over 6 ft during the growing season, chlorophyll a readings below 15 mg/m3, and Total Phosphorus between 20 and 42 ug/l. Submerged vegetation, mostly Eurasian Watermilfoil, had spread even into some of the deeper areas of the lake.

How come? Weather conditions are most likely the cause. Rainfall in the late spring through mid-summer of 2018 was closer to average than in 2017. This gave submerged vegetation the opportunity to grow prior to the reduced light penetration resulting from algal blooms which while greater than in 2017 were still minor. However, Eurasian Watermilfoil benefited the most from these conditions and increased its dominance over the previous year.

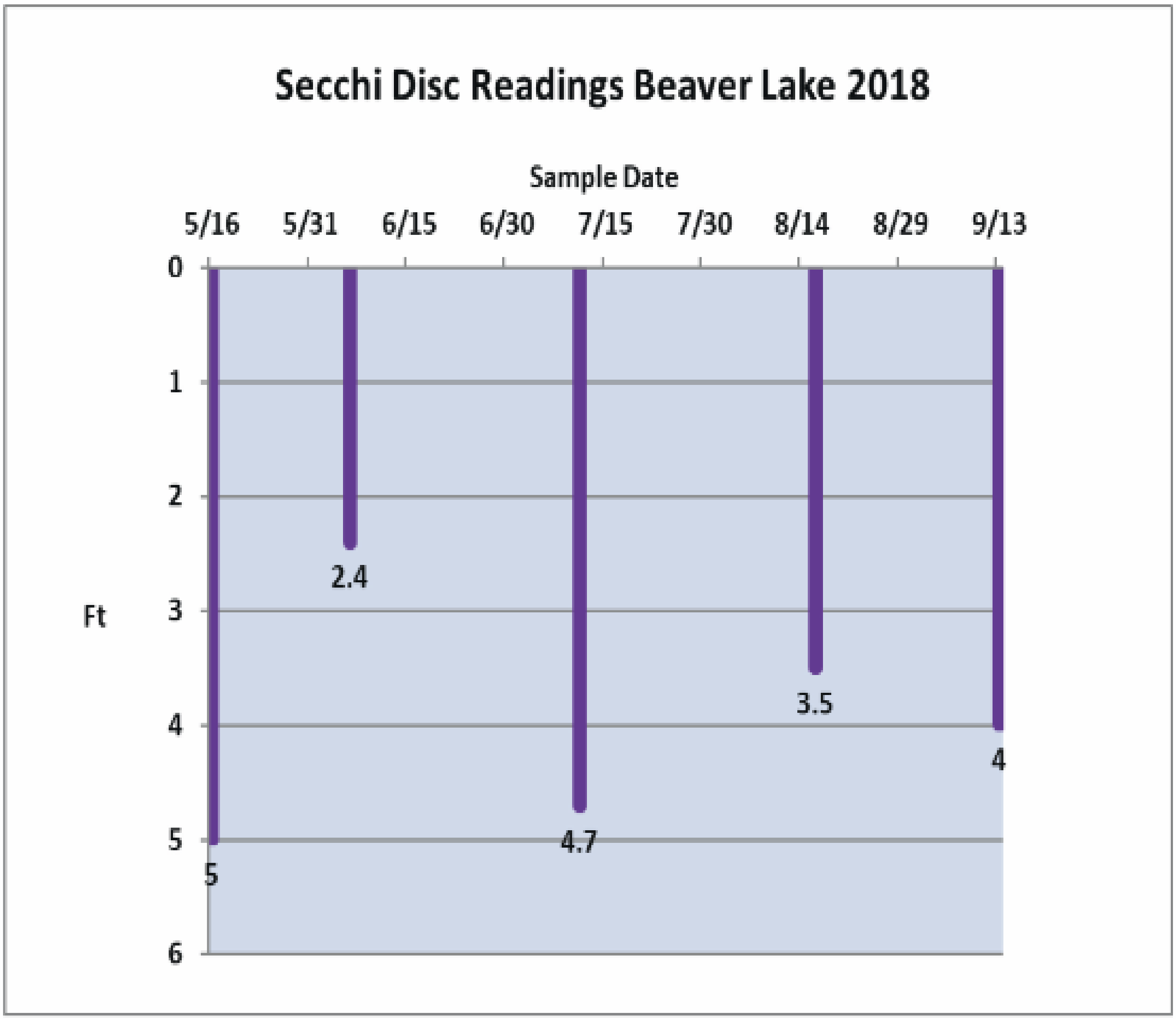

Figure 38. Secchi Disc Readings for Beaver Lake. *While not showing the unusual water clarity of 2017, values were still exceptional with the minimum still in excess of two feet during an algal bloom.*

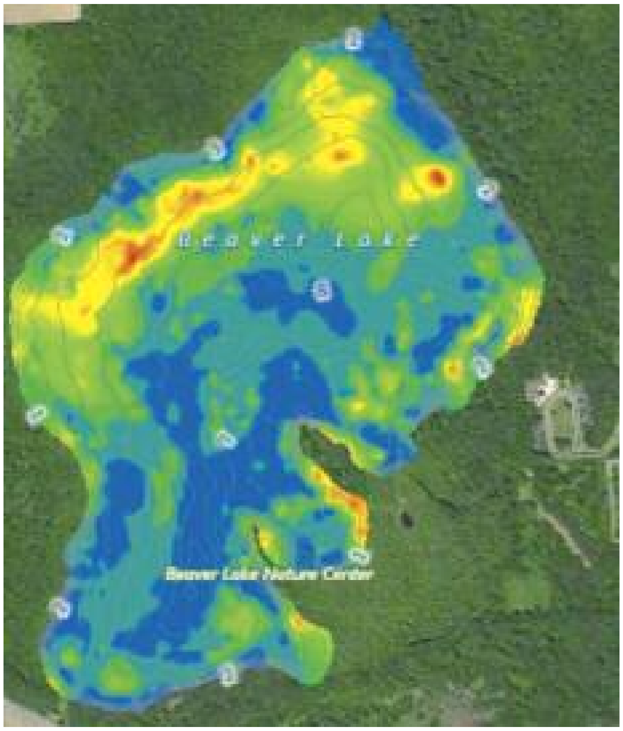

Figure 39. *Aquatic vegetation "heat-map showing plant abundance (biovolume) for 2018.*

Figure 40. *Satellite imagery of Beaver Lake July 2018 (C-MAP, Inc.) The bright green areas along the shoreline areas are largely lily pads and have been part of the overall aquatic vegetation community of Beaver Lake for many years. This includes the small area in the extreme lower left of the lake. The bright multi-colored area (upper right) is the Visitor Center complex.*

Along with the lower than usual nutrient levels in the lake water, those cooler spring and early summer temperatures along with a lack of sunshine during all of the cloudy and rainy weather likely suppressed algae growth.

Most likely the low algae numbers that continued through the summer allowed for sunlight to penetrate deeper into the water column than it normally does in Beaver Lake providing submerged vegetation a better chance to grow and expand its presence.

The increased amount of submerged vegetation also helps stabilize bottom sediments which reduces the resuspension of nutrients and other particles from going back into the water column. This helps reduce turbidity and increases light penetration for the benefit of submerged plants.

These are just possible explanations! What we can say, however, is that Beaver Lake has trended towards change for the better. What the future holds remains to be seen!

BEAVER LAKE WATER & ECOLOGICAL QUALITY

TIMEFRAME	CHANGE
Mid-2000s- present	Steady to better

A "Glistening" Beaver Lake (*photo by Donald Gates*)

IN SUMMARY...

While changes in the water quality and aquatic community of Beaver Lake have taken place over its five decades as part of BLNC, much has remained the same. Clearer and more visually appealing water conditions along with a biologically desirable amount of submerged vegetation was the rule in the 1960s through the 1970s. This became the benchmark to which any future changes over the decades would be compared.

Levels of the important nutrient phosphorus have fluctuated, but remained high. Contrary to concerns dating back to at least the early 1980s, Beaver Lake had been a nutrient-rich or eutrophic system since the County first acquired it and the limited historical information available indicates this was likely the case before that.

The dramatic change or shift during the 1980s to an algae-dominated system was defined by increasingly larger algae blooms resulting in very poor water clarity and the loss of virtually all of the lake's submerged aquatic vegetation. Conditions worsened through the decade of the 1980s. While likely due to several factors, the accidental entry of Common Carp into Beaver Lake in the mid-1970s and their subsequent population expansion over the ensuing years was the most important. Ironically, a naturally-occurring fish kill in the early 1990s significantly reduced the Common Carp population. Predation by bluegills on early life stages such as eggs provides a plausible, but unstudied, explanation as to why Common Carp numbers have remained low.

Only two sets of data collections have been done on the zooplankton population of Beaver Lake and these were done roughly fifty years apart. Nevertheless, those results and inferences during fish collections and other studies over the years consistently referred to Beaver Lake's zooplankton population size being much smaller than it should be.

It is very unlikely Beaver Lake could have sustained any appreciable amount of recreational fishing pressure which was discussed as a possible use when the County originally acquired it. However, the types of fish species collected from Beaver Lake over the years are very much like those found in similar Central New York lakes.

Certainly, the entry, expansion, and subsequent decline of the Common Carp is the most intriguing and important component of the Beaver Lake fish story. However, the long-term decline in the numbers of the once abundant Yellow Bullhead is of interest as well.

Today, the Beaver Lake fish population while not robust, is stable, largely self-sustaining (reproducing) and has improved since the late 1980s. Remaining is the long-standing lack in numbers of top level predators such as Largemouth Bass and Northern Pike.

While longer-term weather (climatic) changes are a separate consideration, annual variations especially in precipitation and temperature drive fluctuations seen in the duration and severity of algae blooms.

The year 2017 provided a marked improvement in lake conditions with the expansion of submerged vegetation and improved water column visibility supported by accompanying water quality parameters giving a sense of what Beaver Lake was like in the 1960s and 1970s. Beaver Lake remains a nutrient enriched system.

Conditions in 2017 were certainly a positive change for Beaver Lake, but will the expanded amount of submerged vegetation remain and become the status quo? Will it continue to expand or was it a temporary event that will be reduced or largely eliminated with a return to large algae blooms? Depending upon conditions over the next few growing seasons, these questions will likely be answered in the short-term.

While a more diverse macrophyte assemblage consisting of native species would be desired over a dominance of the invasive Eurasian Watermilfoil, this is unlikely unless extensive native plant restoration is undertaken. However, since it is now established in more areas of the lake, Eurasian Watermilfoil probably has the best chance to survive lower light conditions under any future large algae blooms.

There are other more long-term factors to be considered as well. For example, will the watershed land uses remain much the same as they have been or change dramatically such as becoming more residential? Will other invasive plant or animal species become established in Beaver Lake or might the Common Carp make a comeback and become a dominant fish species again?

Such changes would possibly have a profound impact upon the Beaver Lake of the future, but hopefully watershed land use remains much the same and invasive and/or unwanted species of plants and animals are prevented from establishing or re-establishing themselves.

A P P E N D I C E S

APPENDIX I

List of Common and Scientific Names Used

Plants

Coontail (*Ceratophyllum demersum)*
Sago Pondweed (*Potamogeton pectinatus*),
Wild Celery or Tapegrass (*Vallisneria americana*)
Wild Rice *(Zizania aquatica*)
Common Waterweed (*Elodea canadensis*)
Northern Watermilfoil (*Myriophyllum exalbescens*)
Long-leaved Pondweed (*Potamogeton nodosus*)
Eurasian Watermilfoil *(Myriophyllum spicatum*)
Water Willow *(Justica americana)*
Pickerelweed (*Pontederia cordata)*
White Water Lily *(Nymphaea odorata)*
Arrow Arum *(Peltandra virginica*)
Curly-leaf Pondweed (*Potamogeton crispus*)
Large-leaf Pondweed (*Potamogeton amplifolius)*
Naiad *(Najas flexis*)

Fishes

Black Bullhead (*Ameiurus melas)*
Northern Pike *(Esox lucius)*
Chain Pickerel, (*Esox niger)*
Banded Killifish *(Fundulus diaphanous)*
Yellow Perch (*Perca flavescens)*
Largemouth Bass (*Micropterus salmoides)*
Pumpkinseed Sunfish *(Lepomis gibbosus)*
Brook Stickleback (*Culaea inconstans)*
Brown Bullhead (*Ameiurus nebulosus)*
Central Mudminnow *(Umbra limi)*
Bluegill (*Lepomis macrochirus)*
Black Crappie (*Pomoxis nigromaculatus)*
Golden Shiner (*Notemigonus crysoleucas)*
Common Carp *(Cyprinus carpio*)
Green Sunfish (*Lepomis cyanellus)*

Birds

Canada Geese (*Branta canadensis*)

APPENDIX I

Beaver Lake Phytoplankton Species List 2012 (Summer-Fall)
(Identification by PhycoTech, Inc (2012)

Type	Genus/Species	Genus/Species
Bacillariophyta (Diatoms)	***Aulacoseira ambigua*** *Fragilaria construens* *Fragilaria crotonensis* *Synedra ulna*	
Chlorophyta (Green algae)	*Chlorococcaceae spp.* *Chalamydomonas spp.* *Lagerheimia ciliata* *Monomastix minuta* *Oocystis parva* *Oocystis pusilla*	*Scenedesmus spp.* *Scenedesmus abundans* *Scenedesmus bijuga* *Scenedesmus minuta* *Oocystis parva* *Oocystis pusilla*
Chrysophyta (Golden algae)	*Dinobryon spp.* (cyst) *Erkenia subaequiciliata* *Rhodomonas minuta*	
Cyanophyta (Blue-Green algae)	*Anabaena crassa* *Anabaena planctonica* *Anabaena spiroides* *Aphanocapsa delicatissima* *Aphanocapsa holsatica* *Aphanocapsa nidulans* *Chroococcus minutus* *Lyngbya limnetica* *Merismopedeia warmingiana*	*Microcystis aeruginosa* ***Microcystis viridis*** ***Microcystis wesenbergii*** *Oscillatoria spp.* *Planktolyngbya spp.* *Pseudanabaena mucicola* *Synechocystis spp.* *Woronichinia naegelian*
Pyrrhophyta (dinoflagellates)	***Ceratium hirundinella***	

Species in **bold** were very abundant.

APPENDIX III

Beaver Lake Zooplankton 2012*

Species/Classification		7/9 (%)	7/26(%)	9/10(%)	10/26
Bosmina longirostris	Bosminids	30	7	6	18
Ceriodaphnia sp.	Other Cladoceran	29	41	11	14
Diaphanosoma sp.	Other Caldoceran	12	17	30	0
Chydorus sphaericus	Other Caldoceran	0	4	0	40
Alona sp.	Other Caldoceran	0	0	0	5
Tropocyclops prasinus	Cyclopod	2	2	4	1
Diacyclops thomasi	Cyclopod	0	1	0	7
Cyclopoid copepodid	Cyclopod	0	1	0	0
Mesocyclops edax	Cyclopod	0	1	1	0
Nauplii		5	8	25	7
Daphnia mendotae	Daphnids	1	9	2	5
Daphnia retrocurva	Daphnids	15	0	0	0
Diaptomus minutus	Calanoids	3	8	17	3
Diaptomus oregonensis	Calanoids	4	0	5	1
Calanoid copepodid	Calanoids	0	2	0	0
TOTALS					
	Nauphlii	5	8	25	7
	Bosminids	30	7	6	18
	Other Cladocerans	41	62	41	59
	Cyclopods	2	5	5	8
	Calanoid copepods	7	10	22	4
	Daphnids	16	9	2	5

*Original identification and enumeration by Cornell Biological Field Station
900 Shackelton Point Road, Bridgeport, NY 13030-9747

APPENDIX IV - Beaver Lake Fish Species 1965-2012

Species		Jackson (1965)	NYSDEC (1970[a])	NYSDEC (1973)	NYSDEC (1985)	Kahn and Werner	Wiiliams (1994[b])	Onondaga Co WEP
Ameiurus natalis (Lesueur)	Yellow Bullhead				x	x		
Ameiurus nebulosus (Lesueur)	Brown Bullhead		x	x	x	x	x	x
Ameiurus melas (Rafinesque)	Black Bullhead	x						
Catostomus commersoni ((Lacépède)	White Sucker				x	x		
Culaea inconstans (Kirtland)	Brook Stickleback	x						
Cyprinus carpio (Linnaeus)	Common Carp				x	x		x
Esox lucius (Linnaeus)	Northern Pike	x	x	x	x	x		x
Esox niger (Lesueur)	Chain Pickerel	x						
Fundulus diaphanus (Lesueur)	Banded Killifish	x						
Lepomis cyanellus (Rafinesque)	Green Sunfish							x
Lepomis gibbosus (Linnaeus)	Pumpkinseed	x	x	x	x	x		x
Lepomis machrochirus (Rafinesque)	Bluegill			x	x	x	x	x
Micropterus salmoides (Lacépède)	Largemouth Bass	x				x	x	x
Notemogonius crysoleucas (Mitchill)	Golden Shiner				x	x		x
Pomoxis nigromaculatus (Lesueur))	Black Crappie			x	x	x	x	x
Perca flavescens (Mitchill)	Yellow Perch	x		x	x	x	x	x
Umbria limi (Kirtland)	Central Mudminnow		x			x		

a. Tributary collections.
b. Juvenile study, Ameiurus identified to genus, only. Unidentified "shiners" not listed

B E A V E R L A K E
Q U E S T I O N S

I. Description

Q. How big is Beaver Lake?

Q. How does its size compare to some other lakes in the area?

Q. What is a watershed?

Q. Does Beaver Lake have a small or a large watershed, especially in comparison to the size of the lake?

Q. How can the size of a lake's watershed affect the water quality of the lake?

The area known today as the Beaver Lake Nature Center (BLNC) has been owned by Onondaga County since 1963.

Q. How do you think the lake and the area surrounding it looked before Onondaga County bought it? For example, do you think there were many homes, farms, or was it forested? Do you think it looked a lot like it does today or very different?

II. What Was Beaver Lake Like?

In the 1960s through the 1970s Beaver Lake was considered to be a well-balanced aquatic ecosystem.

Q. What were some of the characteristics of the lake that are typical of a well-balance aquatic ecosystem?

Q. Why do you think there was a concern that Beaver Lake was getting or had too much aquatic vegetation in it?

Q. In the early to mid-1970s, the number of Canada geese on Beaver Lake during spring migration had increased by about three times the numbers in the early 1960s. Why might this have become a concern?

III. What Happened?

During the 1980s, lake conditions worsened noticeably

Q. What were the most obvious visual conditions indicating water quality had gotten worse?

Q. What basic parameters or "vital signs" were measured telling those studying the lake why the water looked the way it did?

Q. What is meant by the trophic state of a lake? By this time, what trophic state was Beaver Lake classified as and why?

Q. What is an indicator species?

IV. Beaver Lake Change - Who Were the Suspects?

There had to be some reason or reasons to explain why Beaver Lake had changed

Q. What were three possible explanations why Beaver Lake's condition had deteriorated?

Q. How had the make-up of the Beaver Lake's fish population change between the 1960s and 1980s?

Q. How might one change in the fish population been largely responsible for the change in the lake's appearance and condition?

Q. Do you think there was just one factor responsible for the change in Beaver Lake or might there have been several factors that caused it?

V. End of 1980s - Were Things Getting Even Worse?

A detailed study was done in 1988 to try and figure out what had happened to Beaver Lake.

Q. How had the algae population in the lake changed from 1984 to 1988?

Q. Why had rooted submerged aquatic vegetation essentially disappeared from Beaver Lake?

Q. By the late 1980s, had anything changed as far as the type (species) of fish found in the lake and which were most abundant?

Q. What fish in Beaver Lake are considered prey species and which are predator species?

Q. How are fish populations estimated in a pond or lake?

Q. Why was Beaver Lake considered an unbalanced aquatic ecosystem?
Q. What are the problems Common Carp could have created?

Q. What factors must be present for submerged, rooted plants to grow and be present in suitable numbers?

Q. How would you summarize the status of Beaver Lake by the end of the 1980s (see Table 4!)?

Q. What is the "ultra –nutrient rich" term assigned to describe Beaver Lake's trophic condition by this time?

VI. Now What?

The Beaver Lake study provided ideas as to what might be done to get it bring the lake closer to what it once was.

Q. What were the three major restoration objectives listed for Beaver Lake in the study?

Q. Which do you think would be the easiest or most practical objective to try and reach first?

A second report developed a remediation plan and evaluated the specific recommendations made to undertake the three major restoration objectives

Q. What seven primary factors were considered in preparing the remediation plan?

Q. What are the factors that can be responsible for a fish kill?

Q. What were the results of the fish kill in Beaver Lake?

Q. What was the purpose of the alum treatment?

VII. Post-Alum Treatment: In the Short Term

Q. Did it show any short-term benefit, if so, what (See Figures 17 and 18)?

VIII: Post-Alum Treatment: Long-Term Gain or More Pain?

Whether or not the alum treatment improved lake water quality conditions in future years, there were some signs the aquatic ecology of the lake was getting better.

Q. What were some of the indications of an improving Beaver Lake ecology?

IX. The Mid-1990s Into the New Millennium

Q. What parameters provide an indication that water quality conditions in Beaver Lake improved through the 1990s and into the 2000s?

X. Other Recent Investigations

Several studies done in Beaver Lake since 2012 are the first in decades to describe certain aspects of the lake including algae, zooplankton, and fish populations as well as aquatic plant distribution.

Algae

Q. What were the major algae types collected in the 2012 study and what are they an indicator of?

Q. What does biovolume measure?

Q. What do the biovolume results from Beaver Lake tell us?

Submerged Rooted Aquatic Vegetation

Q. What does the aquatic vegetation mapping tell us about the distribution and abundance of aquatic vegetation in Beaver Lake in 2013 (see Figure 23) compared to the late 1980s?

Q. Look at Figure 24 which provides information on the bottom type from soft to hard in the lake. How do the areas of soft bottom types (light gray) match up with areas of greatest plant abundance?

Zooplankton

Q. What are zooplankton and why are they important to a lake ecosystem?

Q. Although not a detailed study and done over only one summer-to-fall time period, what did the results say about the zooplankton population in Beaver Lake ?

Q. How did the biomass numbers compare to those for Onondaga Lake and Oneida Lake?

Fish

Q. What fish species were found to be the most plentiful?

Q. What does finding multiple age classes for at least some species say about the health of the fish population in Beaver Lake?

Q. Were the top predator species found in large numbers or were they uncommon as has been the case in Beaver Lake?

Q. What about Common Carp. Do they continue to be present in low numbers as they have since the early 1990s fish kill ? If so, why do you think this might be so?

XI. What to Make of 2017 and Beyond?

Q. What were some of the observations and collected data measurements indicating what the condition of Beaver Lake was in 2017, and also in 2018?

Q. How do these conditions compare to those from previous years even going back to descriptions from the 1960s?

Q. Do you think these conditions are temporary and if so, why?

Q. What do you think needs to be done to make or keep Beaver Lake a well-balanced, healthy biological system?

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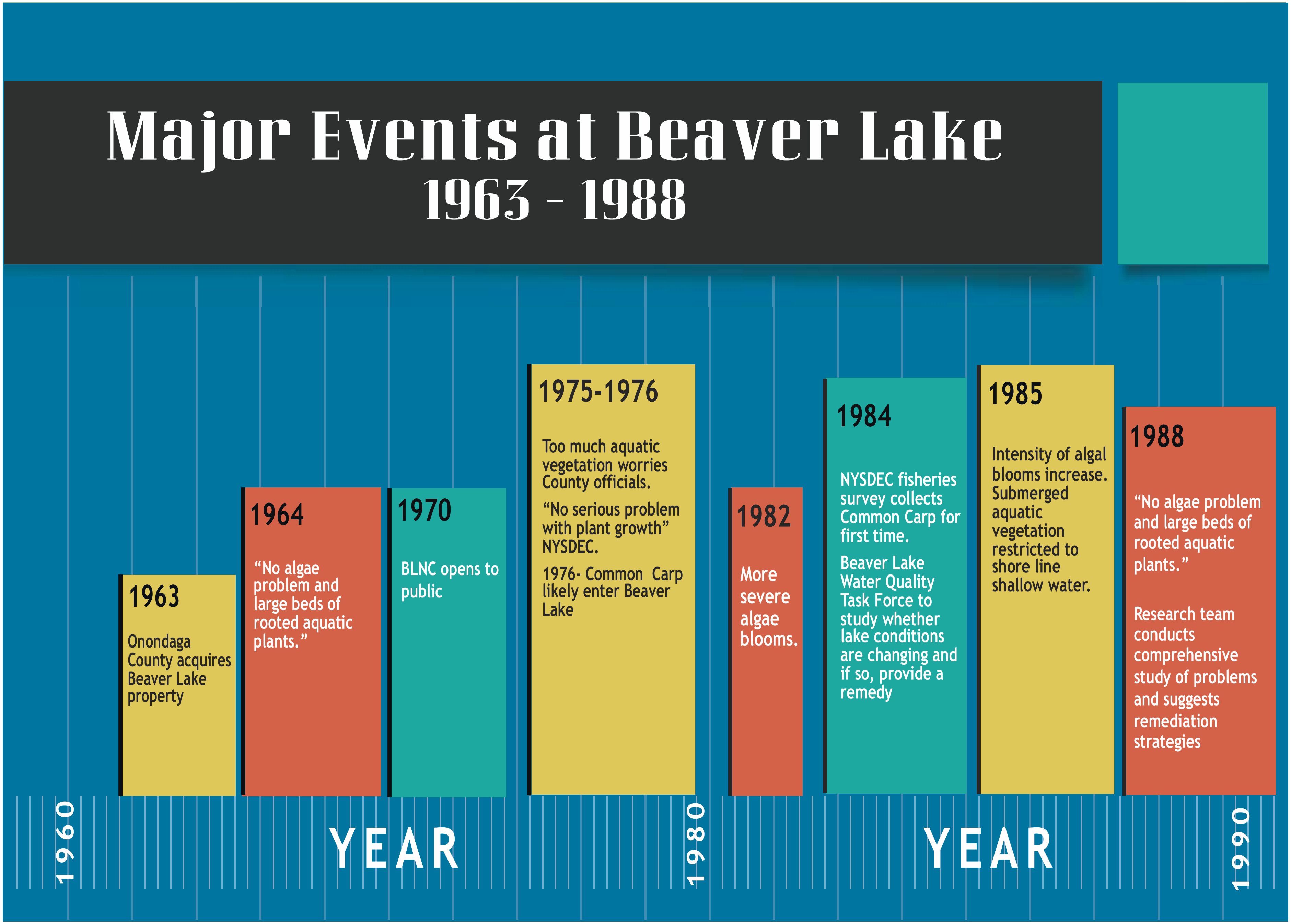

Major Events at Beaver Lake
1963 – 1988
1963
Onondaga County acquires Beaver Lake property
1964
"No algae problem and large beds of rooted aquatic plants."
1970
BLNC opens to public
1975-1976
Too much aquatic vegetation worries County officials.
"No serious problem with plant growth" NYSDEC.
1976- Common Carp likely enter Beaver Lake
1982
More severe algae blooms.
1984
NYSDEC fisheries survey collects Common Carp for first time.
Beaver Lake Water Quality Task Force to study whether lake conditions are changing and if so, provide a remedy
1985
Intensity of algal blooms increase. Submerged aquatic vegetation restricted to shore line shallow water.
1988
"No algae problem and large beds of rooted aquatic plants."
Research team conducts comprehensive study of problems and suggests remediation strategies
1960
YEAR
1980
YEAR
1990

Major Events at Beaver Lake
1989-Present

1991
Spring fishkill includes substantial numer of Common Carp

1992
Alum treatment completed in June

1996
Aquatic Vegetation Restoration Study completed

2000
Generally stable and improved conditions over the past decade

2010
Algae species identified and population estimate done for first time since 1988 severe algae blooms.

2012
Zooplankton species identified and population estimate done for the first time since 1960's

2013
First aquatic vegetation sonar and computer analysis mapping

2017
Water quality, algae and aquatic vegetation conditions closely resemble conditions in the 1960s and 1970s

Present
2018 - Water quality, algae and aquatic vegetation conditions slip from 2017, but remain very good by historical standards the past 50 years

1989 YEAR 2010 YEAR Present