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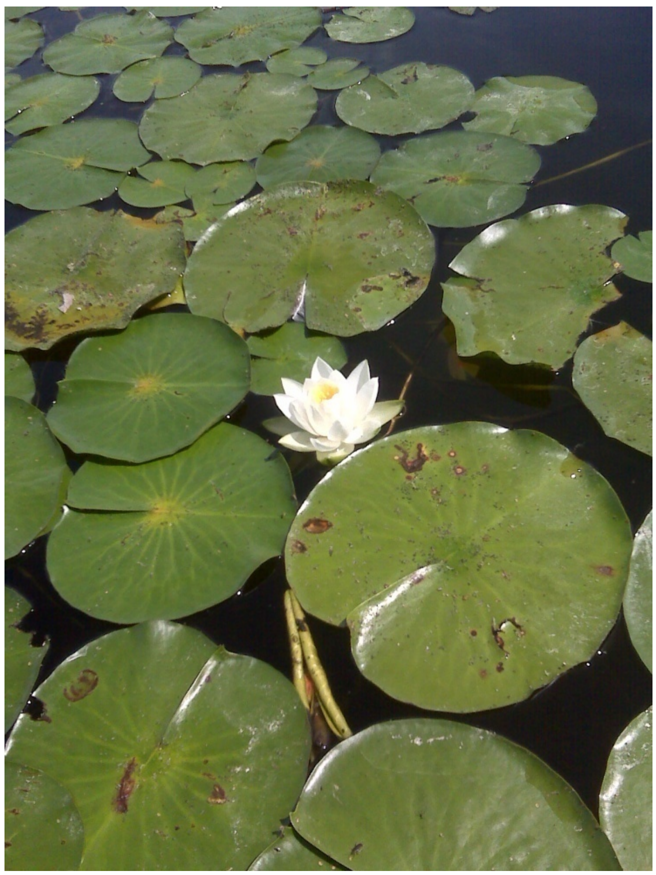
Tonetta Lake, Brewster New York

Synoptic Data Review

Based on the 2007, 2008, 2009 and 2010 sampling seasons



Nymphaea odorata: Tonetta Lake, June 2008

"A lake that has served many generations of men now can be destroyed by man in less than one"

-Lyndon B. Johnson (1908-1973) 36th U.S. President,
Special Message to Congress, "To Renew a Nation"
8 March 1968

Objective:

The objective of this data review is to outline the probable factors causing eutrophic conditions in Tonetta Lake and to recommend options to improve overall lake conditions going forward.

Site Observations:

Tonetta Lake is relatively shallow with a mean depth of 12.8 feet and a maximum depth of 21.5 feet. It has a watershed area of roughly 500 acres and a surface area of 75 acres. The full water capacity is just over 300 million gallons with a retention time of roughly 8 months.

While there is only one surface water outlet from the lake there are numerous inputs, most of which are ephemeral in nature.

The eastern, southwestern and southern portions of the watershed are comprised of relatively high density residential housing. The northern reaches of the watershed are occupied by a rare and distinctive Atlantic White Cedar (Chamaecyparis thyoides) swamp which comprises about one tenth of the overall watershed. This is the northern most inland White Cedar swamp in New York State.

Sampling and Nomenclature:

During the spring, summer and fall of 2007, 2008, 2009 and 2010 limnologic and tributary data were collected. Sampling generally began in May and continued through September. See *Table 1* for a general data collection schedule.

General Timeline for Tonetta Lake Data Collection																		
Activity:	**May**			**June**			**July**			**Aug.**			**Sept.**			**Oct.**		
Seasonal Inflow Water Quality																		
Sediment Sampling: Dredge																		
Monthly Inflow Field Analysis																		
Seasonal In-Lake Water Quality																		
Monthly In-Lake Water Quality Analysis																		
Synoptic Macrophyte Survey																		
Zooplankton Survey																		

Table 1: Tonetta Lake General Data Collection Timeline

Not all of the activities listed in *Table 1* were performed annually. Sediment sampling is typically performed every 5 years and macrophyte surveys are generally done on a 3 year cycle, as changes occur more slowly for both of these parameters. Sediments were last sampled in 2007 and a macrophyte survey was completed in 2008.

Six sampling points were chosen for data collection. The six locations are as follows: four tributaries, the singular outlet, and one area near the center of the lake where the deepest waters are found. Three of the tributaries are located on the eastern side of the Lake and one on the western side. They are named in the data according to their relative street address on Shore Drive (250-SD, 218-SD, 182-SD) and Tonetta Lake Way (75-TLW). These sampling locations are displayed below in figure 1.

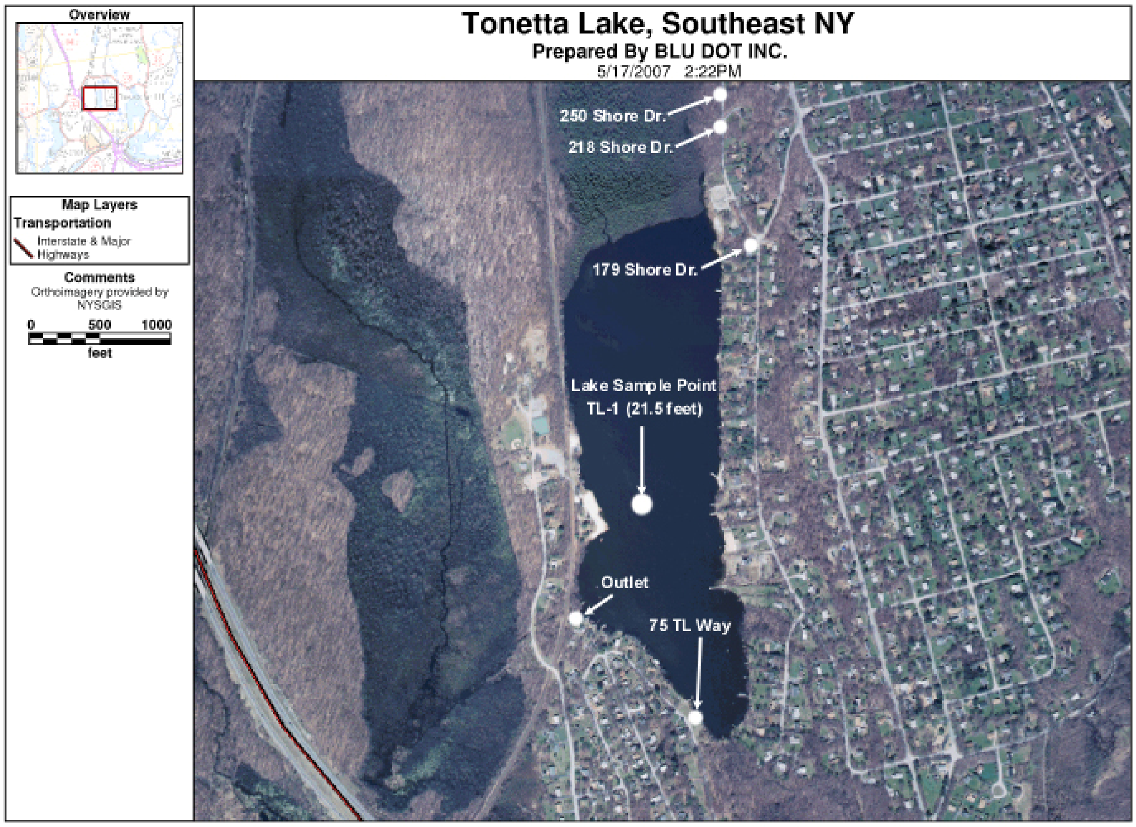


Figure 1: Tonetta Lake Sampling Nomenclature

Seasonal Inflow Water Quality Sampling consisted of lab testing for total phosphorus, dissolved phosphorus, nitrate, ammonium and Kjeldahl nitrogen. This was accompanied with field testing for conductivity, temperature, pH, turbidity and flow measurements for each of the four tributaries. Sampling occurred on the four tributaries as a "dry/wet" paired storm event.

Sediment Sampling was performed with the use of a Ponar dredge. Sediments were analyzed for Petroleum Hydrocarbons, Pesticides, Herbicides, PCB's, Metals and Phosphorus. This was last performed in 2007 and should be repeated in 2012.

Monthly Inflow Field Analysis consisted of monthly field testing for conductivity, temperature, pH, turbidity and flow rate for each of the four tributaries.

Seasonal In-Lake Water Quality sampling consisted of lab testing for total phosphorus, dissolved phosphorus, nitrate, ammonium and Kjeldahl nitrogen. This also included field testing for conductivity, temperature, pH, turbidity and dissolved oxygen. Samples were taken from the central lake sampling point in a three point vertical profile: near-surface, mid-depth and near bottom. Fecal coliform analysis was added in 2010.

Monthly In-Lake Water Quality sampling consisted of a dissolved oxygen and temperature vertical profile. Measurements were taken from the lake surface, progressing at half meter intervals, down to the lake bottom. Additionally, a Secchi disk reading was taken. All measurements were taken from the central lake sampling point.

Synoptic Macrophyte Survey entailed the mapping of plant types, cover and biovolume. This was last performed in 2008 and should be repeated in 2012.

Zooplankton samples were collected using a Turtox tow net, with a 12” mouth and Nitex, 80µm netting. Ten meter tow samples were collected near the center of the lake and generally taken in late summer. Two samples were collected in 2007 and single samples were collected in 2008, 2009 and 2010.

Data:

(See the four attached data sets for years 2007-2010)

Results:

- **pH:**

Tributary pH measurements on occasion appear to be slightly elevated. This would suggest point sources and may be a result of lime treatments on residential lawns. Lake numbers are generally consistent with the region. Overall, numbers look reasonable and are within an acceptable range.

- **Temperature:**

Higher temperatures equate to higher metabolic rates which ultimately means an accelerated eutrification process. While tributary and lake temperature measurements are higher than we would like to see, they are not surprising given the land use. Overall, numbers are within an acceptable range.

- **Conductivity:**

Tributary conductivity numbers are quite high even considering land use and suggest that water softeners may be common in the watershed or an excess in winter salt use on the roads. The readings generally rise with flow rates suggesting that at least some sources are point in nature. This is relatively good news for the underlying aquifer. However, it is only a matter of time before salinity levels will begin to rise there as well.

- **Turbidity:**

Tributary turbidity readings reflect a relatively stable watershed, even during storm events. Overall, turbidity numbers are within acceptable levels.

➢ Dissolved Oxygen:

Tonetta Lake is weakly stratified, but strong enough to create anoxic conditions at the lake's bottom during the summer months. The anoxic conditions cause nutrients to be leached out of the bottom sediments. When the reservoir turns, these nutrients are pulsed into the water column creating plant and algal growth issues.

Fortunately, it does not appear that Tonetta experiences multiple turn events other than the expected seasonal turns occurring in the spring and fall.

➢ Secchi Disk Transparency:

While there are no standards for Secchi disk measurements, higher readings indicate less growth and likely less suspended nutrients for future growth. In Tonetta Lake there is a distinct, declining trend in Secchi disk depth since 2007. Secchi disk measurements plotted over the past 4 years are shown in figure 2 below.

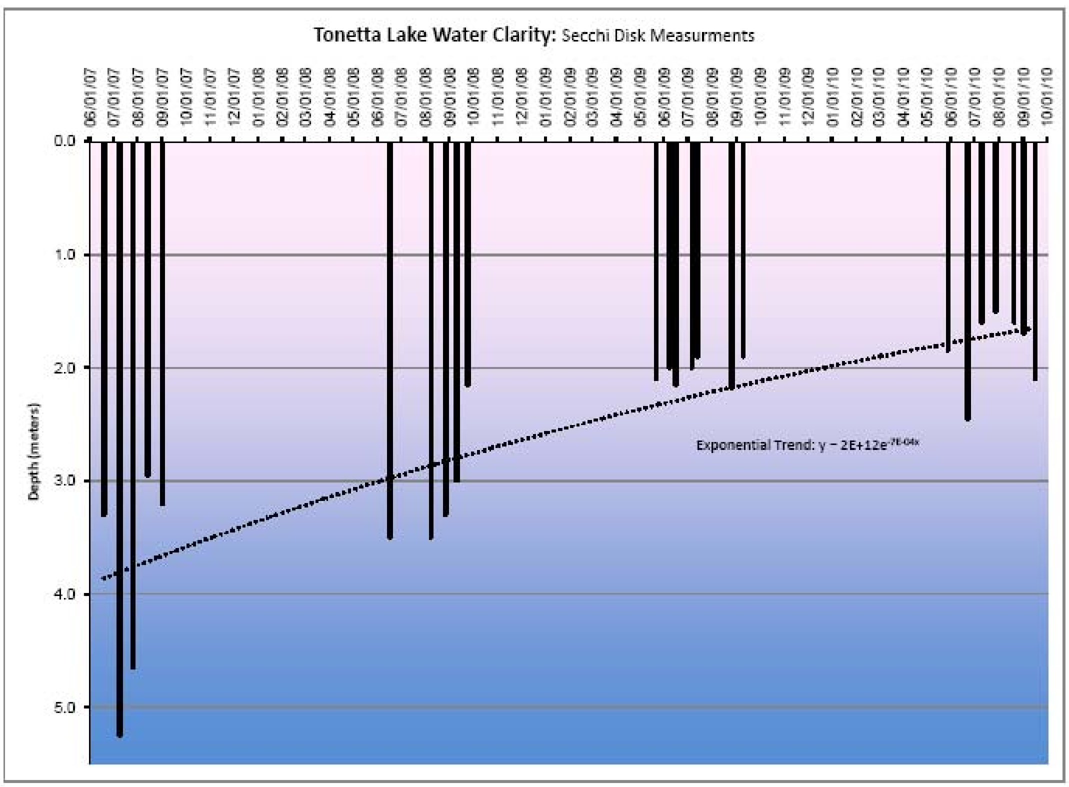


Figure 2: Dissolved Oxygen Profiles 2007-2010

Looking back at the sparse historical data set (1985-1990), it appears that 2007 Secchi disk readings are consistent with the historical numbers, suggesting a distinct systemic change in the past 4 to 5 years.

In 2006, triploid grass carp (Ctenopharyngodon idella) were introduced to Lake Tonetta. These fish were adolescent when stocked, ranging in size from 10”-12” inches in length. They grow rapidly and generally reach full size (3’-4’ feet and 30-50 lbs) within a few years of introduction. They feed almost exclusively on plant material, preferring rooted plants. It is likely that the reduction in water clarity is directly related to the feeding carp, as the reduction in water clarity corresponds closely with their introduction.

- **Ammonia (NH_3):**

The EPA does not publish a Maximum Contaminant Level (MCL) for Ammonia. Measurements less than 1.00 mg/l are generally considered acceptable in drinking water supplies. Watershed tributary and in-lake samples all fall well below this threshold.

Ammonia occurs as a breakdown product of nitrogenous materials in natural waters. Its presence could be indicative of contamination from domestic effluent or industrial waste water. Ammonia levels in the watershed tributaries are moderate to low. The only appreciable numbers are found in the anoxic deep waters, a typical scenario for a stratified water body.

- **Nitrate (NO_3):**

The EPA MCL for nitrate is set at 10 parts per million (ppm) or 10 mg/l. Nitrates are very soluble and do not bind readily to soil or sediments and therefore have a high potential to migrate to ground water. Because they do not evaporate, nitrates are likely to remain in suspension until consumed by plants or other organisms.

Most nitrogenous materials in natural waters tend to be converted to nitrate, so all sources of combined nitrogen, particularly organic nitrogen and ammonia, should be considered as potential nitrate sources. Primary sources of organic nitrate include human sewage and animal waste. The primary inorganic nitrates found in surface waters are potassium nitrate and ammonium nitrate both of which are widely used as fertilizers.

Lake Tonetta nitrate numbers are relatively low, while tributary input levels are moderate to high. The dynamic here is difficult to determine without a more comprehensive sampling program.

- **Total Kjeldahl Nitrogen:**

There is no EPA MCL for Total Kjeldahl Nitrogen (TKN). TKN is defined as the sum of the organic nitrogen, ammonia (NH_3), and ammonium (NH_4^+).

TKN combined with Nitrate can provide a sense of the total available nitrogen component in a lake system. It is generally this sum (TKN + Nitrate), that is used as the nitrogen component in the nitrogen to phosphorus ratios used to calculate the growth dependant variable.

Lake Tonetta TKN numbers are moderate, while tributary input levels are quite low. Again, it is difficult to determine the dynamic without a more comprehensive sampling program.

- **Total Phosphorus**

Phosphorus is an essential nutrient for the growth of aquatic plants and it is only needed in very small quantities relative to nitrogen. Additionally, Phosphorus is typically the limiting element of growth, especially in the north eastern U.S. . For this reason, minor changes in phosphorus concentrations can have dramatic effects on lake growth potential.

Taking into consideration the surrounding watershed, Lake Tonetta phosphorus numbers are moderate. Tributary input levels are high and inconsistent, suggesting potential point source contamination, likely from fertilizer use in the watershed.

Eutrophic lakes typically experience growth related problems including algal blooms. Total phosphorus (TP) results can be used as an indicator of trophic state using Carlson's Trophic State Index (TSI). The index uses a log transformation of total phosphorus values as a measure of algal biomass on a scale from 0 - 110. Each increase of ten units on the scale represents a doubling of algal biomass.

The index is useful for comparing lakes within a region and for assessing changes in trophic status over time. Thus it is often valuable to include an analysis of trophic state index values in reports.

The formula for calculating the Carlson Trophic State Index for total phosphorus is presented below. Ranges of trophic state index values are often grouped into trophic state classifications. The range between 40 and 50 is usually associated with mesotrophy (moderate productivity). Index values greater than 50 are associated with eutrophy (high productivity). Values less than 40 are associated with oligotrophy (low productivity).

Average Tonetta Lake (2007-2010) Surface Total Phosphorus = 25.7 ug/L

TSI = 14.42 (In Total phosphorus (ug/L)) + 4.15

TSI = (14.42) (3.25) + 4.15

Tonetta Lake Trophic State Index = 51.0

As seen from the above TSI calculations, Tonetta Lake can be classified somewhere near the border of mesotrophic and eutrophic.

It should be noted that similar TSI indices can be calculated using Secchi Disk measurements as well as chlorophyll a.

- **Total Dissolved Phosphorus:**

Total dissolved phosphorus measurements are taken by filtering samples to remove the particulate phosphorus fraction. Dissolved phosphorus measurements are often considered the "available phosphorus" as much of the particulates settle out, becoming unusable for immediate growth.

Lake Tonetta total dissolved phosphorus numbers are also moderate and correspond with the total phosphorus numbers as expected.

- **Bacteria:**

Bacterial analysis was performed on an ad hoc basis prior to 2010, making data analysis very difficult. That said, based on the available bacterial reports provided by the County and the Secchi disk data, there may be a correlation between algal growth (or decomposition) and bacterial activity.

Secchi disk measurements taken in mid to late July 2010 came in substantially lower than expected. Secchi disk measurements were in the 1.50 meter range, about 0.50 to 1.00 meter less than we have seen at this time over the past 4 years. After several repeat visits to the lake it became apparent that the lake was at the tail end of a small bloom. As the algal masses decomposed, their cell contents were released into the water as nutrients, creating ideal conditions for bacterial growth.

The Putnam County Board of Health closed the Tonetta Lake public beach on July 27th due to high fecal coliform levels (2100). The lake tested high again (2900) on July 29th and was finally reopened on August 2nd 2010. It is likely that the bloom that occurred in July of 2010 contributed to the bacterial hit. This, of course, does not speak to the source of the bacterial contamination.

- **Zooplankton:**

Zooplankton are microscopic water borne animals. They have two important roles in the health of a lake. They form an important part of the food chain for fish and fish fry and they eat algae and therefore can have a large effect on water clarity and quality.

Zooplankton samples were taken in each of the sampling years, 2007-2010. Lake Tonetta zooplankton results consistently lacked the larger zooplankton species. Tonetta mean zooplankton sizes fell in the 0.4 mm range (it is hard to get mean lengths lower than 0.3 mm). Ideal lengths are from 0.5-0.7 mm.

While the fry of most fish species will eat the smaller zooplankton during their development, only some fish are planktivores as adults. Planktivorous fish generally eat the largest zooplankton species like Daphnia, or water fleas, preferentially. Unfortunately, it is the larger species of plankton that are responsible for reducing algal levels as they are capable of consuming far larger amounts of algae than the smaller species.

When the bio-diversity of zooplankton is found to be lacking the larger species it is usually attributable to an imbalance in the fish community. Typically there are too many planktivorous fish such as Blue gill or crappies and not enough predatory fish.

While a fish survey has not been done in Lake Tonetta, site observations as well as conversations with anglers on the lake support this conclusion.

- **Macrophytes:**

Macrophytes are aquatic plants growing in or near water. A balanced plant population is necessary for a healthy lake. They can extend out of the water (emergent), remain totally submerged (submergent), or float. In lakes, macrophytes provide cover for fish and substrate for aquatic invertebrates, produce oxygen, and act as food for some fish and wildlife.

A survey of the macrophyte population in Lake Tonetta was done in June of 2008. Please see figure 3 below. Three main species dominate in the lake: Ceratophyllum demersum, the invasive Myriophyllum spicatum and Nymphaea odorata. The common names for these three species are Coontail, Eurasian Milfoil and Pond Lily, respectively.

The invasive Milfoil was found only in a few locations and did not appear to be aggressively spreading in the lake as of 2008. Coontail was by far the dominant species, making up about 80% of plant bio-volume in the lake.

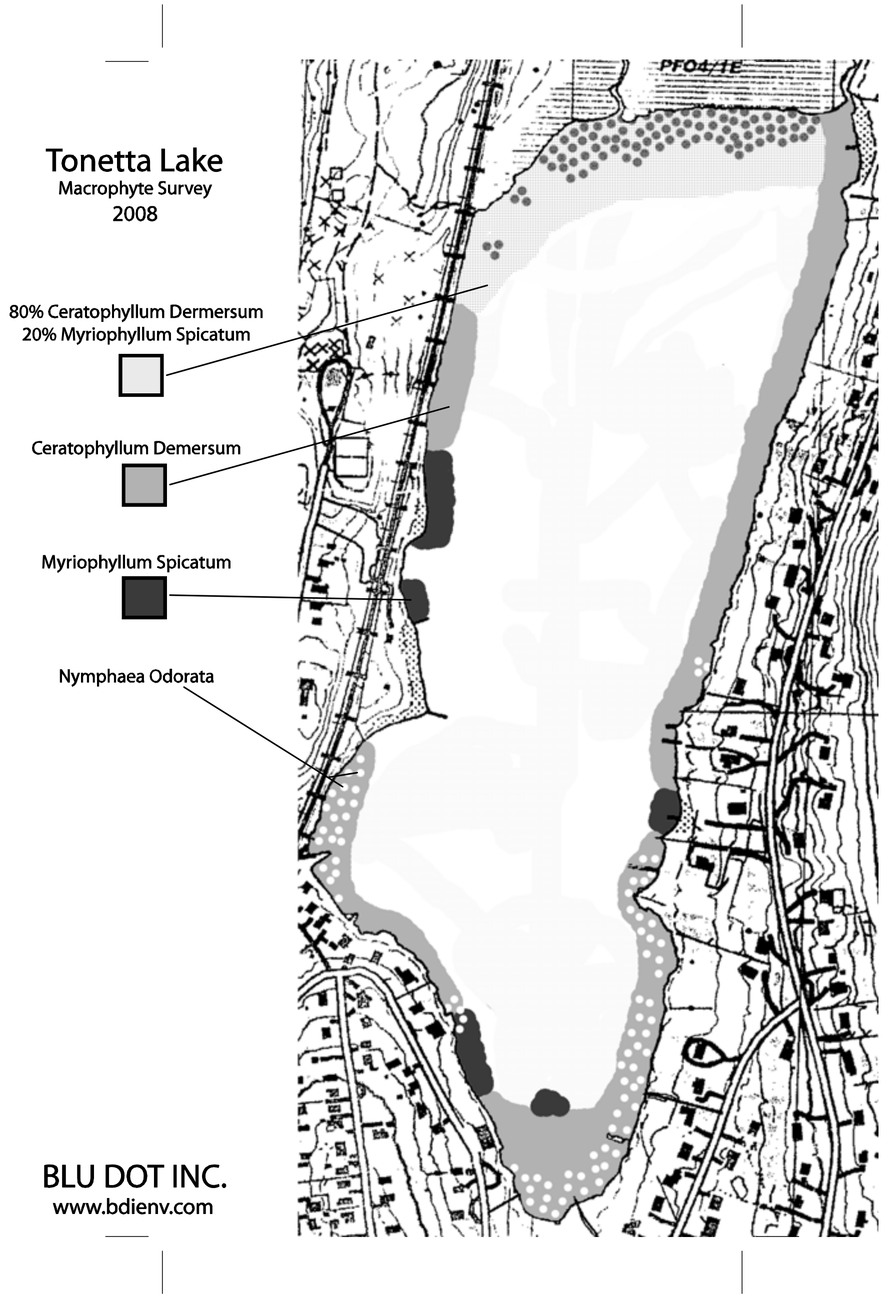


Figure 3

Looking back at the last macrophyte data provided by Michael Ciaiola, it appears that Coontail, Milfoil and Pond Lily were present in 1990. Also found at that time were Potamogeton foliosus and Najas flexilis. However, the distribution information from the Ciaiola study suggests that Milfoil was sparse as the report does not give it a designation on the map. Please see figure 4 below.

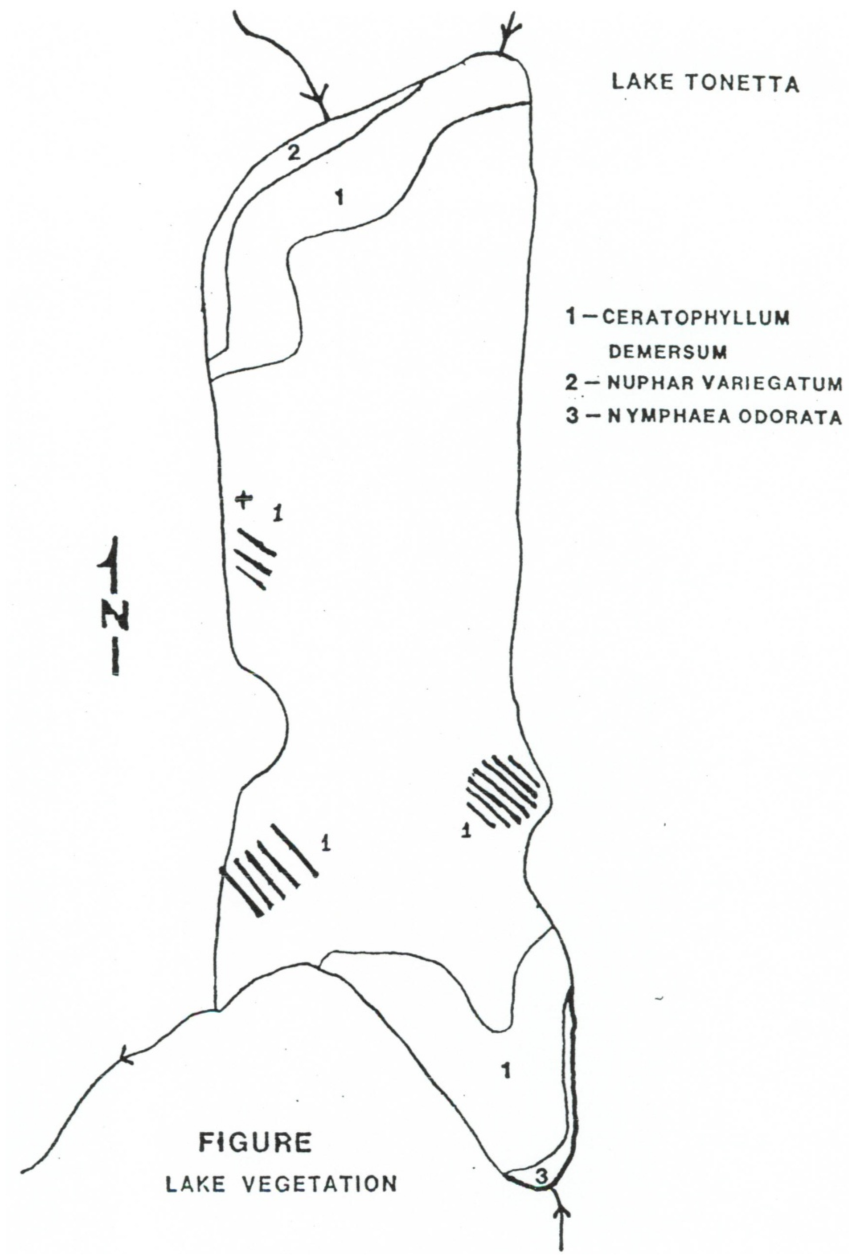


Figure 4: 1990 Ciaiola Macrophyte Map

The 1990 Ciaiola study also makes reference to a plant removal plan. A map of the proposed harvesting locations is shown in figure 5 below. In comparing the 2008 map with the 1990 harvest map, I found a striking correlation between Coontail harvesting and Milfoil proliferation. This would suggest that when the Coontail was removed it was replaced by a monoculture of the invasive Milfoil.

If removed Coontail is replaced by invasive Milfoil, the preferred diet of the triploid carp, introduced in 2006, may play a large role in macrophyte diversity and therefore the overall health of the lake. Triploid carp are thought to marginally prefer Coontail over Milfoil. If this is in fact the case, the next macrophyte survey will be critical in determining the effects the carp have had on macrophyte balance within the lake.

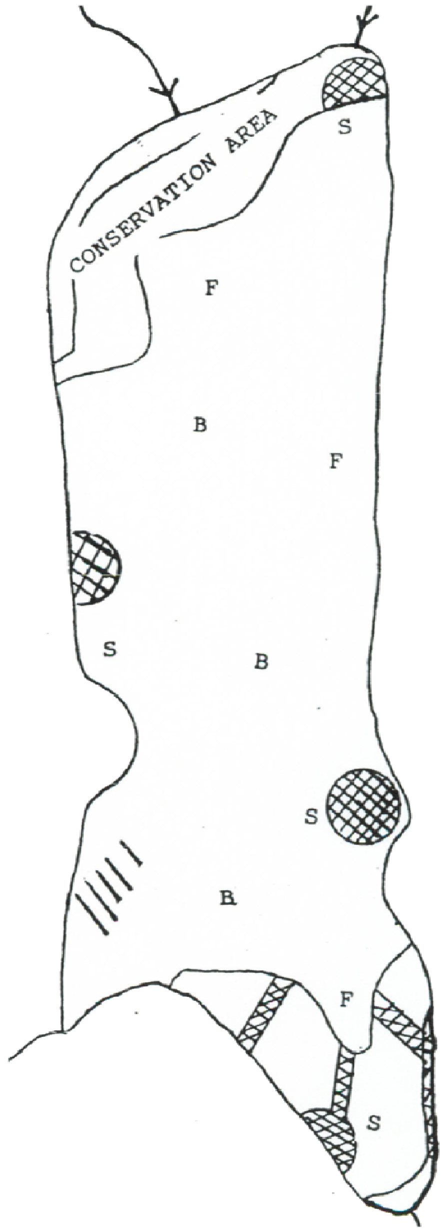


Figure 5: 1990 Ciaiola Map

Hashing represents proposed areas for vegetation removal

- **Sediments:**

Tonetta Lake sediment samples were collected in 2007 with the use of a Ponar dredge. Sediments were analyzed for Petroleum Hydrocarbons, Pesticides, Herbicides, PCB's, Metals and Phosphorus.

Results for Petroleum Hydrocarbons, Pesticides, Herbicides and PCB's all came in below the laboratory detection limits. The results for Metals and Phosphorus were compared with both the Commercial and Residential *New York State Restricted Use Soil Cleanup* parameters and were found to be below the limits for every element except for Arsenic. The State Arsenic levels are set at 16 ppm (mg/kg) and lake sediments were found to be18.8 ppm. In the northeast it is not uncommon for lake sediment arsenic levels to exceed 30 ppm. Arsenic at these concentrations pose no issues to the health of the lake or to the residents who recreate in and on the lake.

Data Observations and Discussion:

- **What Drives Growth in Tonetta Lake?**

In general, lake vegetation growth potential, algal or macrophyte, is determined by either nitrogen (N) or phosphorus (P). Lakes with an N to P ratio of less than 10 are decidedly nitrogen limited. This means that nitrogen is what drives growth. The addition of phosphorus to a nitrogen limited lake will have little effect on growth in the system.

Lakes with an N to P ratio of greater than 50 are decidedly phosphorus limited. Phosphorus is what drives growth here, and the addition of nitrogen will have little effect on growth in these systems. Lakes with N:P ratios falling in between the 10 to 50 range can be either P or N limited and often are driven by both elements depending on the conditions and season.

While Tonetta falls squarely in the middle with a 30:1 N to P ratio, it is safe to assume that it is predominantly driven by phosphorus in the spring and summer. In late summer, when available phosphorus is at a maximum (P is readily available during plant decomposition), it is likely that lake growth is driven by nitrogen. Because of this dynamic, late summer is when the lake is most susceptible to blue green (nitrogen fixing) algal blooms.

- **Is Internal Phosphorus Cycling an Issue In Tonetta Lake?**

Phosphorus levels near the lake bottom are consistently quite large and certainly have the potential to be a substantial factor in lake growth. This becomes a factor if the lake experiences multiple turn events outside the seasonal spring and fall turns.

Based on the temperature profile data we can conclude that Tonetta does not typically experience multiple turn events. We can therefore conclude that the majority of the nutrients responsible for lake growth come from the watershed.

- **Dissolved v.s. Particulate?**

The knowledge that the bulk of our nutrients come from the watershed is only part of the story. The format is of critical importance in understanding how to approach potential solutions. In this case, the data conclusively points to dissolved phosphorous as the main format versus particulate phosphorus.

Unfortunately, dissolved phosphorus is much harder to mitigate when compared with dissolved phosphorus. The settling time for particulates is quite small and specialized catch basins can often remove a large portion of the material. Dissolved phosphorus often requires treatments that provide long hold times or infiltration features to be effective.

Cyclonic catch basins will have virtually no effect on nutrient loading numbers if the bulk of the nutrients are dissolved.

Options to Consider:

Circulation: Use of water or air to keep water moving. (Cost: $75-180 K)

- Advantages: Will promote uniform appearance; minimization of algal scums on water surface. May disrupt the growth of some algae. Will minimize stratification and thereby minimize internal cycling of phosphorus as well as other undesirable elements. Will improve habitat for fish and invertebrates. Can have positive systemic effects.
- Disadvantages: Could spread local impacts (not likely in Tonetta). May increase oxygen demand at greater depths (again, not in Tonetta). Will minimally raise overall lake temperatures. Cost.

Phosphorus Inactivation: Use of salts of aluminum, iron or calcium are added to the lake to remove phosphorus from the water column and bind phosphorus in the bottom sediments. (Cost: $75-95 K)

- Advantages: Will have immediate effect on available phosphorus and therefore growth potential. May remove other nutrients as well.
- Disadvantages: May be toxic to fish and invertebrates. May cause fluctuations in water chemistry, especially pH, during treatment. Positive effects will be short lived if: 1) Internal cycling is not a factor. 2) Residence time is short (Tonetta is relatively short at 8 months). 3) Watershed is providing bulk of available nutrients (likely the case in Tonetta). Cost.

Dredging: Sediments are physically removed by wet excavation. (Cost: $1.5-2.5 million)

- Advantages: Removal of years of nutrient reserves. Reduction in oxygen demand. Iron and Manganese control (not an issue in Tonetta). Rooted plant control. Can control algae if internal cycling is main nutrient source (not likely in Tonetta). Increases water depth. Can reduce pollutants or toxins (not an issue in Tonetta). Can provide complete renovation of the lake ecosystem.
- Disadvantages: Will remove benthic invertebrates. May cause turbidity issues temporarily. Cost.

Introduction of Predatory Fish: Manipulation of biological components of lake system to achieve grazing control over algae. (Cost: $2-6 K)

- Advantages: Ultimately convert algae indirectly into harvestable fish. Zooplankton response to algal blooms can be very rapid. Natural method that can be accomplished with native fish species. Overall methodology is compatible with all fishery management goals (correcting an imbalance). Can provide exciting recreational opportunities for anglers. Small investment.
- Disadvantages: Variable success and response time. May involve non native species.

Detention, Infiltration and Sedimentation: The management of watershed tributaries and ephemeral culverts with features promoting soil infiltration to minimize nutrient loading to the lake. (Cost: Variable)

- Advantages: Highly effective in systems with relatively high dissolved nutrient levels (applies to Tonetta). Can help to reduce water temperatures. Can be inexpensive.
- Disadvantages: Require treatment areas that are often difficult to locate in developed watersheds. Maintenance costs can be high if waters are highly turbid. Can be expensive.

Outreach, Education and Legislation: Reduce watershed impact on the lake through educational programs and materials aimed at residents, the general public and law makers. Topics to include but not limited to point source control, and land use regulations such as septic testing/replacement programs. (Cost: Variable)

- Advantages: Tends to be very effective in watersheds with a relatively large residential population density like that of Lake Tonetta. This approach truly addresses root causes of problems versus treating the subsequent symptoms. Can be a very cost effective approach.

- Disadvantages: Can cause tension and division among residents.

Summary:

There is evidence that the triploid carp introduced in 2006 are responsible for the distinct reduction in water clarity. Unfortunately, the impact on water clarity is only the proverbial tip of the iceberg, as the stirring of bottom sediments translates directly into an increase in the availability of nutrients. Therefore, there is the distinct possibility that the carp are directly affecting the lakes growth potential and indirectly an increase in bacterial activity.

The data reflect a clear imbalance in the zooplankton community. The larger zooplankton have been depleted by an abundance of smaller "pan" fish such as the Blue Gill that seem omnipresent in the shallows of Lake Tonetta. The larger species of zooplankton can consume substantial amounts of algae and have the ability to quickly respond to an algal bloom. The introduction of predatory fish such as Walleye (*Sander vitreus*) and or Tiger Muskies (*Esox masquinongy*) will reduce the numbers of the plankton eating fish. Often, the temporary existence of large predatory fish promotes populations of larger native species, bringing a lasting balance to the lake. This is an inexpensive option that has little to no down side potential that I strongly recommend be given consideration.

The data suggests that the surrounding watershed is the primary source of available nutrients in the lake. Additionally, the bulk of these nutrients are in a dissolved format. This is an important realization in that it tells us both the best place and way to approach treatment. Cyclonic separators, like those already deployed near 75 Tonetta Lake Way and 250 Shore Drive will have little to no impact on lake water quality. Under these circumstances the key to nutrient reduction is infiltration.

Additionally, community outreach in the surrounding residential watershed promoting best management practices to reduce point source loading should be pursued actively. A septic maintenance and replacement program should be investigated for potential adoption by the town board. Changes from the community within the watershed are the best opportunity for positive changes within the lake.

Overall, considering the surrounding land use, Lake Tonetta is actually doing quite well. There is no doubt that the White Cedar Swamp at the North end of the lake plays a critical role in buffering the lake from the impacts of development. However, one of the most promising aspects of her current condition are the dedicated volunteers and willing town board members that have collaborated to preserve this invaluable resource for future generations.