Citizen-Led Environmental Observatory At Lake Lillinonah

2014 Annual Report

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Questions/Comments?

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Acknowledgements

The Citizen-Led Environmental Observatory (CLEO) at Lake Lillinonah is sustained by the volunteers who have dedicated their time and effort to the program. Special thanks go to the 2014 monitors: Bob Calder, Brian & Jeb Boodry, AJ Murphy, Denise Fitch, Ken Dougherty, Peter & Ally Anderson, Greg Bollard, Jeff & Samantha Marcus, Louise Trojanoski-Marconi, Rebekah White and Kendra Kilson. This program could not function without you!

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2. Executive Summary

The Citizen-Led Environmental Observatory (CLEO) (http://faculty.fairfield.edu/dockmonitoring/) was established in 2006 to monitor water quality on Lake Lillinonah, an impoundment on the Housatonic River, located in western Connecticut. The goals of the program are to

1) Provide credible information on water quality conditions to state and local agencies

2) Educate the public on water quality issues

3) Build a constituency of involved "citizen scientists".

The purpose of this report is to present the data collected during the summer of 2014. A brief summary of water quality conditions is presented here in the executive summary. The methods of collecting and results involving the data are presented in the main body of the report.

Across all sites, water temperature followed the standard trend with the water warming throughout the summer, peaking in June/July before beginning to decline. Most sites in 2014 had average secchi depths between 1-2 meters making most of the lake qualify as eutrophic. Lake color was recorded largely as green which is consistent with a eutrophic ecosystem. The number of days which reported a brown lake color was higher than in previous years. The overarching amount of data recorded some sort of particle present in the water column throughout the recreational period. Some were identified as algal in nature while others remained undefined. This did not seem to detract from the overall aesthetic of the lake as most of the days were reported as "beautiful" and a moderate amount were reported as having "minor aesthetic problems".

Surface algae varied greatly depending on the location in the lake. Of the percentage of days with surface algae varied from <10% to upwards of 40% depending on location. There was also significant variability in the algal toxin concentration levels depending on where and when they were taken. Concentrations in bloom samples were generally higher than in routine twice monthly samples.

Monitors observed little debris in 2014. The highest percentage of debris days observed was ~10%. Trash was a new variable which was introduced this year so volunteers would be able to distinguish between manmade and natural debris. Only 3 days were reported as having some trash. No days were reported as being recreationally impaired by manmade trash.

Multiple volunteers continued recording data past the Memorial Day-Labor Day time frame which provided valuable insight. During September, there were several algal blooms which were reported in the lake, one of which was recorded as the "worst bloom all year" by one of the volunteers.

This year we have decided to look at previous years and compare nutrient concentrations and secchi depth readings from various lake sites between 2011 and 2014. This will allow us to better analyze the changes that take place within Lake Lillinonah. From the preliminary analysis we were able to see that average secchi depths across all sites have remained nearly constant since 2011. The average nutrient concentrations have varied depending on site and year; at times showing little change from year to year and at others varying dramatically.

We recommend continued monitoring to track changes in water quality over time. Based on previous work on Lillinonah (Whitney and Klug 2012), we recommend stakeholders continue to emphasize the importance of decreasing nutrient loading from the upstream watershed. In addition, we recommend that stakeholders consider boat ramp signage or other outreach advising lake users to minimize contact with thick surface blooms of algae.

3. Introduction

Lake Lillinonah was created in 1955 as a result of the construction of the Shepaug Dam whose purpose was to pond water for hydroelectricity generation. Lake Lillinonah extends 12 miles in West Central Connecticut and is surrounded by six towns: Bridgewater, Brookfield, New Milford, Newtown, Roxbury and Southbury. Since its creation, Lake Lillinonah has been a eutrophic system, with high nitrogen and phosphorus concentration and large summer algal blooms (Whitney and Klug 2012). Lake Lillinonah's watershed is rather large and as such the point and non-point sources of nutrient input to the lake are numerous. Summer algal blooms can be severe enough to impair recreation and create an oxygen depleted environment in deeper parts of the lake. Additionally, there is increasing concern that secondary compounds produced by certain algal groups may pose a danger to dogs and humans using the lake (CTDPH and CTDEEP 2013).

The Citizen-Led Environmental Observatory (CLEO) was established in 2006 to monitor water quality in Lake Lillinonah. Friends of the Lake (FOTL), a non-profit organization along with faculty and students from Fairfield University's Biology Department jointly manage the monitoring program.

Friends of the Lake is a volunteer based organization that encourages "citizen scientists" to provide water quality information to state and local organizations and to educate the public. The primary goals of the organization are as follows;

1) To increase the recreation potential for those who use the lake
2) To work towards having the lake meet the standards of the Clean Water Act
3) To implement long-term environmental goals that protect the lake and its watershed.

FOTL works closely with many local and federal organizations including the Lake Lillinonah Authority, CT Department of Energy and Environmental Protection, First Light Power Resources and the Federal Energy Regulatory Commission. Through these relationships, they hope to promote the community awareness about lake pollution and debris issues. They welcome membership from those who are eager to help protect the lake. More information about Friends of the Lake can be found at www.friendsofthelake.org.

4. Methods

Volunteers collect data from dock locations on water temperature, secchi depth, water color, debris, recreation potential, trash, particle type and surface scum from Memorial Day through Labor Day. To facilitate comparison among sites and because values of many of the variables may change throughout the course of the day (e.g. temperature), data are collected between 3:00pm and 7:00pm. In addition, volunteers collect water samples for chemical analysis of total phosphorus, total nitrogen and algal toxin concentration. Detailed methods are presented in the individual variable sections. A copy of the data sheet used by volunteers is provided in Appendix A.

Volunteers are required to attend a training session each spring. In the classroom portion of the training session, volunteers are educated on proper technique for recording each measurement and on the basic ecological meaning behind each variable. In the field component of the training session, volunteers practice taking each measurement. In addition to the training program, program managers maintain contact with volunteers through email and occasional group meetings and presentations. Volunteers return their completed data sheets to Jen Klug via email, postal mail or in person. Fairfield University interns or research students enter the data and data analysis is completed by Fairfield University faculty and students. Results are compiled into an annual report and distributed to all interested parties.

For categorical variables (e.g. recreation potential, surface algae, color, debris, and trash) we calculate the % of total monitored days falling each category. For continuous variables (e.g. secchi depth) we present an average and time series for each site. In addition, we use a trophic status rubric outlines by the Department of Energy and Environmental Protection (DEEP) to classify sites based on total nitrogen, total phosphorus and secchi depth (Table 1, CTDEP 1991). The DEEP categories are oligotrophic, early mesotrophic, mesotrophic, late mesotrophic, eutrophic and highly eutrophic and represent the degree to which a lake is impaired due to excessive nutrient loading and/or poor water clarity.

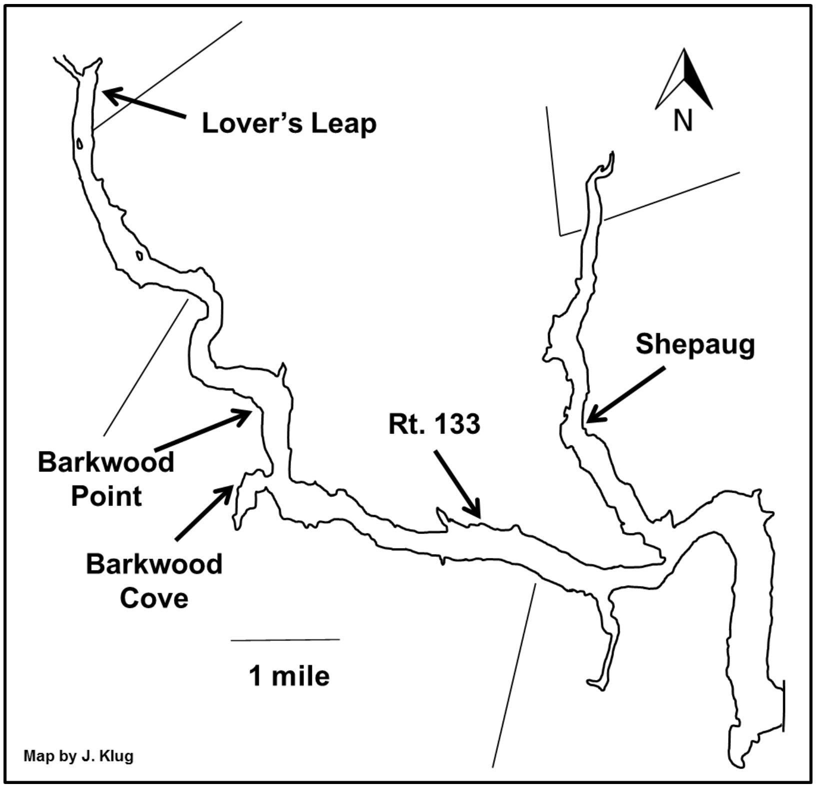

Figure 1: 2014 Site Locations on Lake Lillinonah

In 2014, there were five dock sites (Figure 1) on the lake and there were 1-3 volunteers at each dock. Data was recorded throughout the week. Some volunteers chose to record data more frequently and/or beyond the required Memorial Day through Labor Day timeframe. For the purpose of comparability across sites, summary data includes only the data collected from Memorial Day to Labor Day, May 26, 2014-September 1, 2014. The total number of days that data was collected at each site and the number of days that data was collected from Memorial Day to Labor Day is listed in Table 2. Water samples for nutrient concentration and algal toxin concentration were collected according to the schedule listed in Table 3.

To compare with in-lake samples, in 2013 and 2014, water samples were collected for toxin and nutrient analysis at the GMS Rowing Center along the main stem of the Housatonic River upstream of the confluence of the Still River. No other data were collected at this site.

Table 1: DEEP Water Quality Classification for Trophic Status

	Oligotrophic	Early Mesotrophic	Mesotrophic	Late Mesotrophic	Eutrophic	Highly Eutrophic
Secchi Depth (m)	>6	>4-6	>3-4	>2-3	>1-2	<1
Total Nitrogen (µg/L)	0-200	>200-300	>300-500	>500-600	>600-1000	>1000
Total Phosphorus (µg/L)	0-10	>10-15	>15-20	>25-30	>30-50	>50

Table 2: Number of Days Data was Collected and Number of Days from Memorial Day to Labor Day 2012

Site	Number of Days Data Collected	Number of Days Memorial Day-Labor Day
Barkwood Point	49	42
Rt 133	89	81
Shepaug	90	84
Barkwood Cove	46	40
Lovers Leap	39	34

Table 3: 2014 Water Sample Collection Dates.

Up to three extra toxin samples were collected during algal blooms.

Date	Nutrients	Toxins
May 31	X	X
June 14	X	X
June 28	X	X
July 12	X	X
July 26	X	X
August 9	X	X
August 23	X	X
September 6	X	X
September 20	X	X

5. Water Temperature

Water temperature in a lake is important in understanding the types of organisms that can survive, their biological activity and the amount of oxygen available (Dodds 2010). Predictable temperature changes occur at different depths of the lake, at different times of the day and at different times of the year. Water temperature is positively correlated to an increase in algal growth, as higher temperatures are optimal for algae growth. Related to this, water temperature affects the amount of oxygen that is available for organisms to use. As temperatures become warmer, the amount of available oxygen decreases because warm water holds less oxygen then cold water. Finally, temperature monitoring can be especially important in understanding the impact of storms and any other unusual weather patterns. Temperature variations are expected during and after storms.

At the beginning of the summer, the volunteer tied the provided thermometer to the dock so that the bottom of the thermometer was 1 meter below the water. Throughout the summer, once a month, the volunteer checked the depth of the thermometer to make sure that it was still at 1 meter. When sampling, he or she pulled the thermometer up and recorded the temperature to the nearest 0.5

degree Celsius. The volunteer quickly recorded the reading because of the temperature change that occurs once the thermometer is taken out of water.

Water temperature peaked at all sites by early July and were in steady decline by August (Figure 2). During the period from Memorial Day to Labor Day, the temperatures ranged from a minimum of 18℃ (at Lover's Leap and Barkwood Point) to a maximum of 29℃ (at Barkwood Cove, Rt.133 and Shepaug). Water temperature was consistently lower at Lover's Leap than at the rest of the sites.

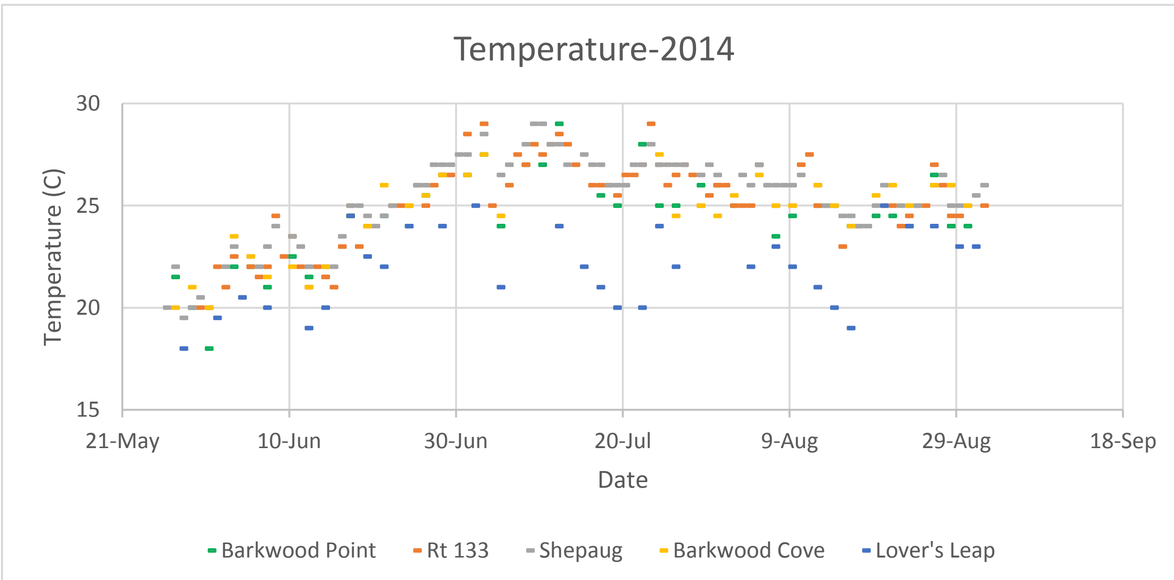

Figure 2: Water temperature across all sites

6. Secchi Depth Monitoring

Secchi depth is a common measure of water clarity. It is directly related to the presence or absence of algae and other particles such as sediment. This is due to the fact that when light enters a lake, it can either be transmitted, absorbed or reflected. Light is reflected off and absorbed by particles and as the number of particles increases, less light will be transmitted (Dodds 2010). Consequently, a lake with more particles has lower secchi depth. Secchi depth can help interpret information regarding particle content and recreation potential. Additionally, water color can be important in determining if algae or silt is the main factor behind a lower secchi depth. Changes in secchi depth follow seasonal changes that are most closely coordinated with temperature and algal growth. Typically, as the weather gets warmer in the summer, secchi depth decreases. It is generally lowest in mid-summer and then slowly begins to increase in the fall.

When taking a reading, the volunteers stood on the dock and lowered the secchi disk over the shady side of the dock. They slowly lowered the secchi disk into the water until they could no longer see it (no white glow). They then lowered it a little further and raised it to the point of which the white just reappears. The disk was slowly pulled up and down until the exact disappearing point was reached. The volunteers leaned over to see the disk but did not kneel or sit until they were ready to mark the rope. They then used their fingers to pinch or clip a clothespin to the rope at the point at which the rope hits the water. They pulled the disk up and recorded the depth to the nearest ¼ meter. They also noted whether the secchi disk hit the bottom of the lake and what depth it hit.

From Memorial Day to Labor Day in 2014, most sites had average secchi depths between 1 and 2 meters. (Figure 3). Lovers Leap was the only site whose average secchi depth was below 1m clarity making it qualify as a highly eutrophic site. The Barkwood Point, Barkwood Cove and Rt. 133 sites had average secchi depths from 1-2m classifying them as eutrophic. Shepaug had the highest water clarity with an average secchi depth of just over 2m meaning it qualified as a late mesotrophic site.

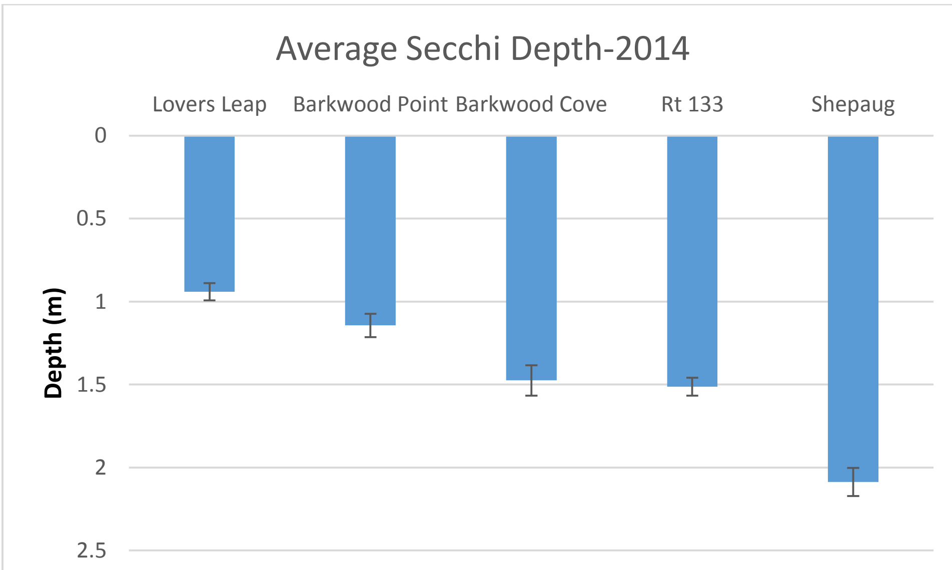

Figure 3: Average Secchi Depth across Sites

Figure 4 shows the time series of secchi depth at all sites. In general, Lover's Leap had the lowest water clarity and Shepaug had the highest water clarity throughout the year. The distinct high values in late spring (mid June for 2014) correspond to the clear water phase, a seasonal marker characterized by low algal concentration due to high zooplankton abundance (Dodds 2012).

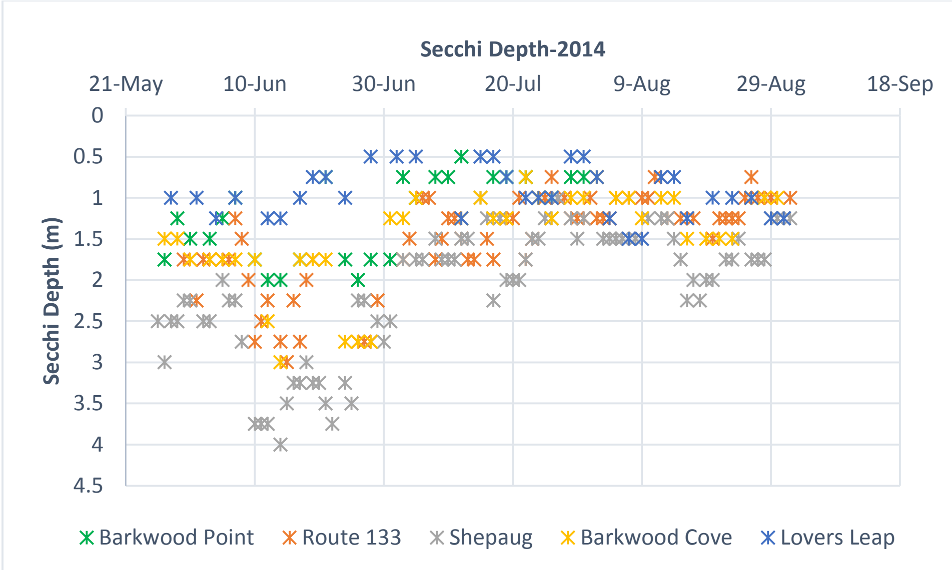

Figure 4: Secchi Depth over time

7. Debris Monitoring

The presence of large floating debris (trees, logs etc.) is a recurring problem in Lake Lillinonah. The debris poses a hazard to boaters and impairs recreation. Nonetheless, it can also provide shoreline habitat for many organisms, including fish (Dodds 2010). Floating debris is particularly prevalent during high water periods when wood floats off the shores or out of coves into the main channel of the lake. The purpose of debris monitoring is to observe the presence or absence of floating woody material at each sampling.

The volunteer looked around the general vicinity of the dock when judging the level of debris. They then used a rubric to classify the amount of debris present. The first category of the rubric says "No debris present". The second category says "Some debris present but not enough to affect boating". The third category says that water is "Boating impaired because of debris".

In Figure 5 we can see that the majority of lake days were free in terms of debris. Lover's Leap, Barkwood Cove and Rt. 133 reported the most days with debris (~10%). Between Memorial Day and Labor Day the overall state of the lack in terms of debris was very good with the majority of days being regarded as debris free and only a small percentage as either having debris or being boating impaired.

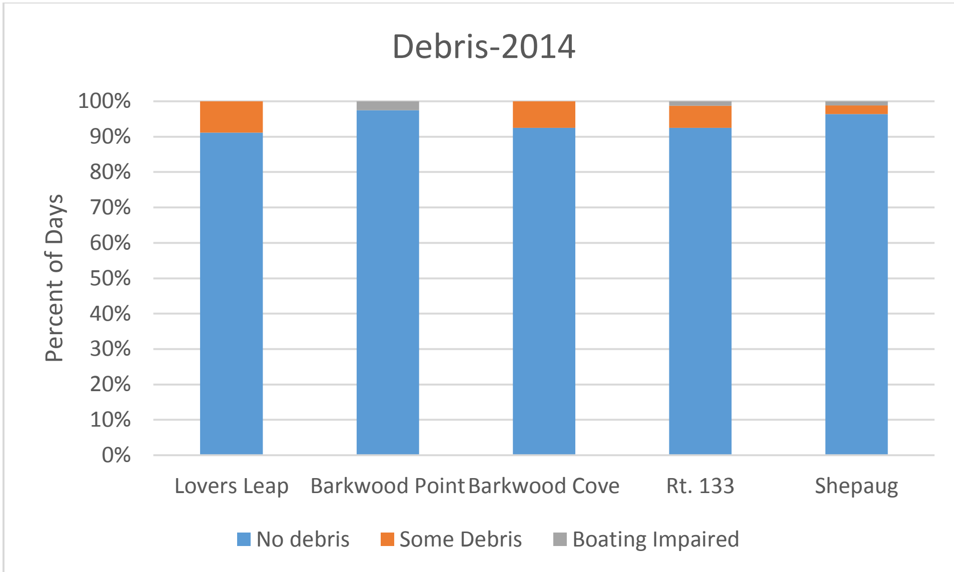

Figure 5: % of Days of Particular Debris Content from Memorial Day to Labor Day

8. Trash

This was the first year volunteers were asked to record observations of manmade trash on the lake. Volunteers were told to keep an eye out for bottles, tires, plastic bags etc. and to record their observations by putting either a 1, 2 or 3 in the trash column of their observations. The numbers respectively represent "no trash present", "some trash present but not enough to affect recreation" and "recreation impaired due to debris". There were only 3 days throughout the summer months which reported any trash presence, none of which impeded recreation.

9. Water Color Monitoring

Water color can be an important indication of water quality and can be especially important in determining what is in the water. Water color is not definitive but gives us an idea of what types of materials may be in the water. Using a chart provided by the Colorado Volunteer Lake Monitoring Program, specific guidelines were utilized for matching a certain water color with a particular lake condition. For example, brown can indicate the presence of sediment or diatom algae and blue-green can indicate cyanobacteria. The color categories are brown, blue-green, green, yellow-green, light blue and clear. Light blue is indicative of certain types of sediment that are not typically seen in Lake Lillinonah. Water color has been especially important in post-storm analysis where secchi depth was low due to sediment in the water column.

The volunteers recorded the water color and particle reading after taking the secchi depth reading. Using the same location that they took the secchi depth reading, they lowered the secchi disk into the water to one half of the secchi depth. E.g. If secchi depth is 1 meter, then the color reading was taken at 0.5 meters. This ensured that the color was observed at the same light level at each sampling period. They observed the water color against the white part of the disk and then chose the color on the color chart that most closely corresponded to the color observed. The volunteer kneeled or sat when taking the color and particle readings.

The color chart that the volunteers used has been widely used in other monitoring programs such as Colorado Volunteer Lake Monitoring Program. In this report however, we combined the green, blue-green and yellow-green categories into one general "green" category. The modification was used because difference in the shades of green may have been indistinguishable to some volunteers and we were most interested in whether the lake was green due to algae, brown due to sediment, or clear.

Green was the color that was most predominantly recorded across all sites. This color is indicative of the presence of a diversity of algae. All sites except for Barkwood Cove also reported several brown days. The percentage of brown days at Lover's Leap is higher than in past years. For example, in 2013 and 2012 this site reported 2.6% and ~3% brown days respectively. The relatively high number of brown days in 2014 suggests that some of the days with low secchi depth were caused by sediment in the water column rather than algae.

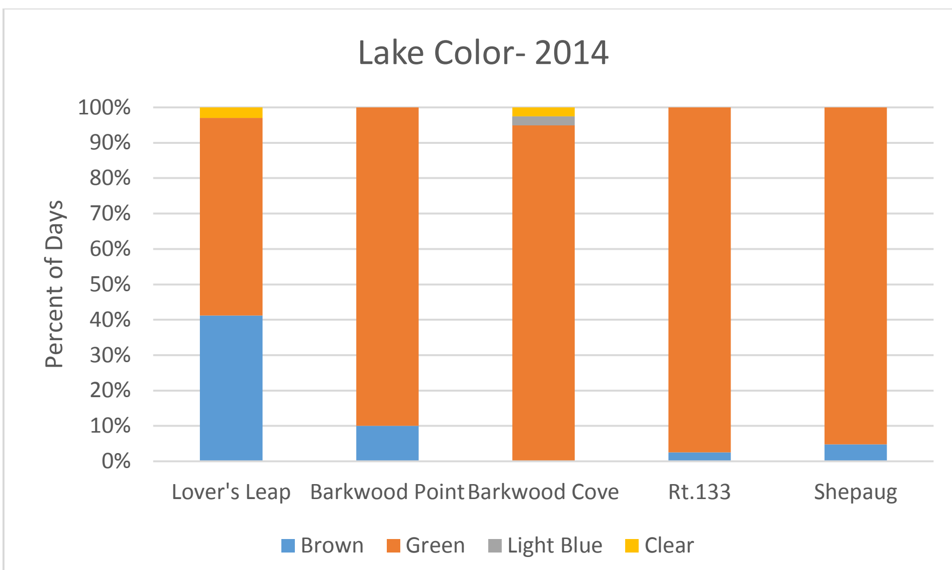

Figure 6: % of Days of Particular Color Across all Sites

10. Particle Monitoring

Particle type is important in knowing whether potential bloom forming algae are present and in what quantities. The assigned categories that volunteers could choose from were "none", "unidentified particles", "visible algae" and "algae bloom". The "none" category was chosen when the water had no visible particles.

The "unidentified particle" category was chose when the volunteers could see particles but couldn't tell whether they were sediment or algae. The "visible algae" category was recorded when they could see particles that were distinctly green. Here, they determined that there were clear patches between the algal particles. The "algal bloom" category was chosen when they could see green particles and there were no clear spots between the clumps. The water is typically determined to be cloudy and has been described as looking like pea soup.

In determining the presence or absence of particles, the volunteer kept the secchi disk in the water at ½ secchi depth. They looked at the white part of the disk and noted whether they could see particles in the water. They then chose the value on the particle chart that most closely corresponded to the particles that were observed in the water.

The overwhelming amount of data reported some sort of particle, whether it was identified as algal in nature or from an unknown source. Lover's Leap, Barkwood Point, and Barkwood Cove in particular had high instances of unknown particles. Rt. 133 and Shepaug had the highest incidences of visible algae. Only two sites reported thick algal blooms in 2014 (from Memorial Day-Labor Day).

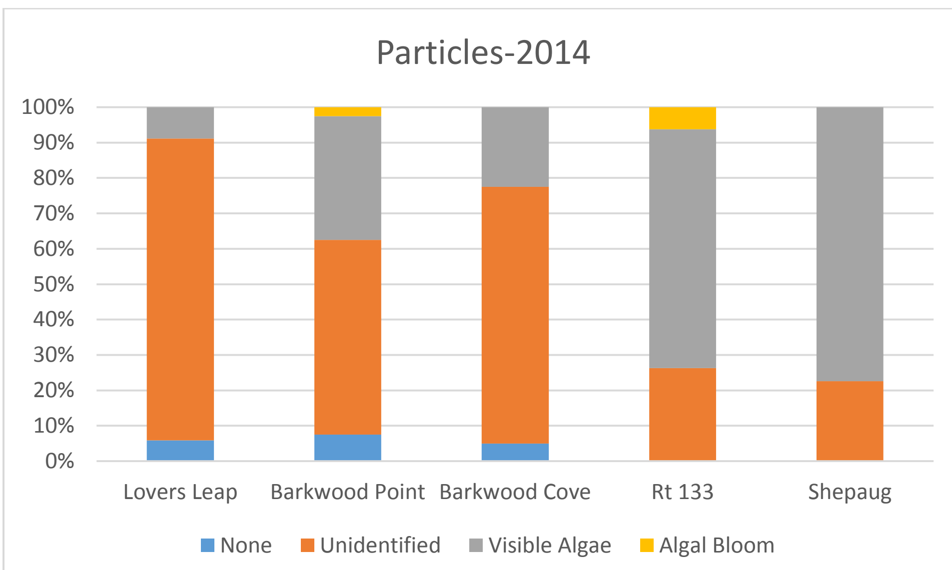

Figure 7: % of Days of Particular Particle Content Across all Sites

11. Recreation Potential Monitoring

Recreation potential relates lake conditions to the aesthetic qualities of the system and the ability of people to use the lake. Recreation potential of Lake Lillinonah is particularly important because the lake is highly utilized and enjoyed by both those that live on the lake and those that visit the area. Recreation potential is an important variable at Lake Lillinonah as it may either encourage or discourage boating, swimming and fishing. Recreation potential may be correlated with other variables, including algal levels and secchi depth. Documentation of poor recreation potential can be used to convince local officials that initiatives must be taken to better protect the lake and the people using it. Similarly, increased recreational use of the lake may subsequently lead to people having a greater incentive to protect the lake.

Recreation potential is based on the volunteer's opinion of general lake conditions with a specific focus on algal content. Four categories were establish with the best possible recreation potential being "beautiful could not be better" (Smeltzer and Heiskary, 1990). From there the categories go from "minor aesthetic problems due to algae, still good for swimming and boating", "desire to swim and enjoyment of lake substantially reduced because of algae (boating still ok)" and "swimming and aesthetic enjoyment of lake nearly impossible because of algae". Recreation potential may be the most influential category concerning citizen's use of the lake.

According to Figure 8, the greatest number of days were recorded as being "beautiful". No days were recorded as having "recreation impossible". All sites had a moderate amount of days with "minor aesthetic problems" with Rt. 133 having the greatest percentage (~50%). Each site had a small percentage of days which were regarded as being "recreationally impaired".

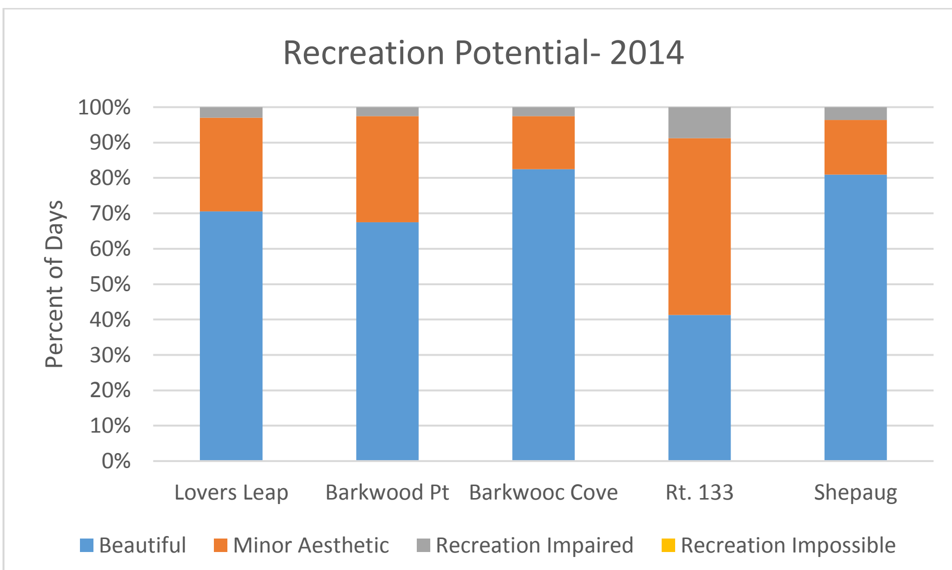

Figure 8: % of Days of Particular Recreation Potential Across all Sites

12. Surface Algae Monitoring

Algal scums represent a concentration of algae on the surface of water and may be indicative of high cyanobacteria concentrations. Scum is also related to weather as the presence of wind will cause the surface algae to mix more into the water column.

Volunteers observed the water surrounding their sample site and recorded what they saw. They knew that they may not see surface algae at the exact secchi depth location because they had disturbed that part of the water. They recorded that surface algae was present if they saw algae concentrated on the surface of the water in the general vicinity of their sampling site. They were given two categories to choose from. The first was "no algae concentrated on the surface of the water". The second was "algae concentrated on the surface of the water".

According to Figure 9, Lover's Leap and Rt. 133 had very few days with surface algae. Barkwood Point and Shepaug sites had a near 40:60 split between days which were regarded as not having surface algae compared to days which were regarded as having surface algae. Barkwood Cove fell between these two groups of sites.

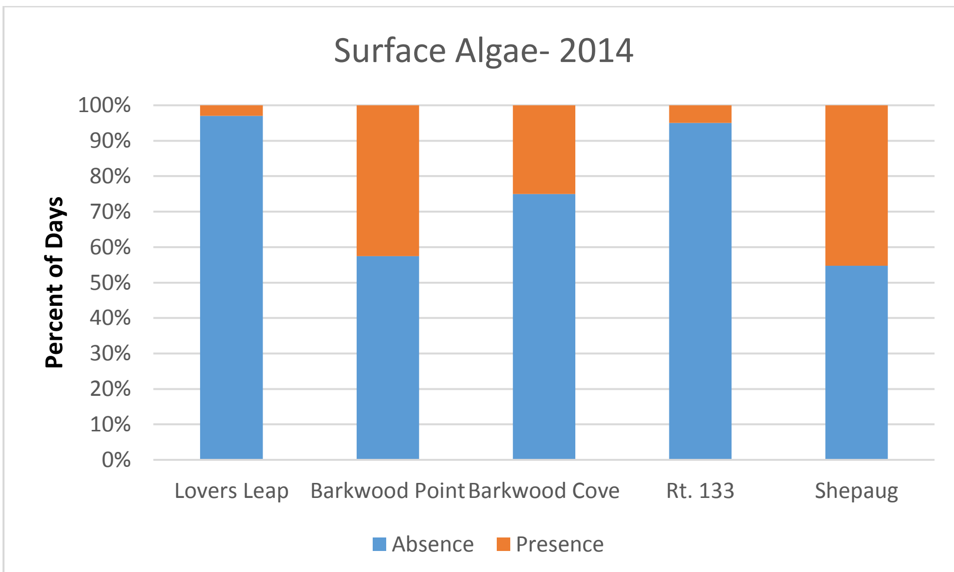

Figure 9: % of Days with Presence or Absence of Surface Algae Across all Sites

13. Nutrient Monitoring

Phosphorus and nitrogen are essential nutrients whose increased levels foster growth of plants and algae. As total phosphorus and total nitrogen levels increase, the presence of algal blooms also tends to increase. Lower secchi depth and thus lower water clarity, results from this increase in algal biomass. In many freshwater systems, phosphorus is considered the most important nutrient limiting algal growth but nitrogen also plays a role (Dodds 2010).

Nitrogen and phosphorus are transported to lakes from a variety of sources, including fertilizer runoff and wastewater treatment plants. Lake Lillinonah has a very large watershed and nutrients are collected from a large number of point and non-point sources. Understanding how nutrient concentration within the lake changes over time and across sites will help us evaluate how changes in watershed management have affected water quality.

Total phosphorus and total nitrogen concentration was measured at all sites. To collect nutrient samples, the volunteers were given bottles that were pre-labeled with date and location. They wrote the name of the collector with a permanent marker in the space provided. They then rinsed the bottle three times with lake water. From there, they submerged the bottle upside down until their wrist was in the water and then turned it right side up to fill it. They poured some of the water out until the bottle was 2/3 full and placed the bottles in the freezer. Samples were sent to the University of Connecticut's Environmental Research Institute for analysis.

In 2014 there was a noteworthy spike in nitrogen concentration at Barkwood Point. From June 28th to July 12th, the nitrogen concentration at this site had increased by 450%. Within the same time frame the phosphorus concentration at this site increased by 700%. Over the next month the levels of both phosphorus and nitrogen at Barkwood Point went into dramatic decline. There were other significant spikes as well at the Route 133, Shepaug and Barkwood Cove sites which followed the Barkwood Point spike (Figures 11 & 12).

There are many factors which could have resulted in the variability in total nitrogen (TN) and total phosphorus (TP) concentration. The analysis for TN and TP includes the nutrients dissolved in the water as well as nutrients within biological cells and sediment particles. If there was a particularly large amount of cellular life, like that which occurs in a bloom, it could have created such a dramatic increase in nitrogen and phosphorus. The 7/12 spike at Barkwood Point was on a day with low secchi and green water suggesting algal blooms.

Increased river discharge following storms can have a significant impact on various lake characteristics including nutrient concentration. Runoff from rainstorms is able to pick up many types of particles and debris as they flow into bodies of water. The summer of 2014 was particularly stormy with several large thunderstorms as well as numerous small scale storms leading to high variability in discharge (Figure 10). It is possible that the runoff of one or several of these storms could have carried a large amount of nutrients into the lake. The USGS gauging station used for these discharge measurements is located ~10 miles upstream from Lovers Leap. Given the size of Lake Lillinonah, the storm variability of the 2014 summer and the distance from the USGS gauging station to Lake Lillinonah, it is possible that Lillinonah experienced a storm that went unregistered. Discharge data is missing from early July but the Friends of the Lake weather station recorded nearly 4 inches of rain in the 10 days preceding the July 12th spike at Barkwood Point suggesting that loading from the watershed contributed to the increase in nutrients.

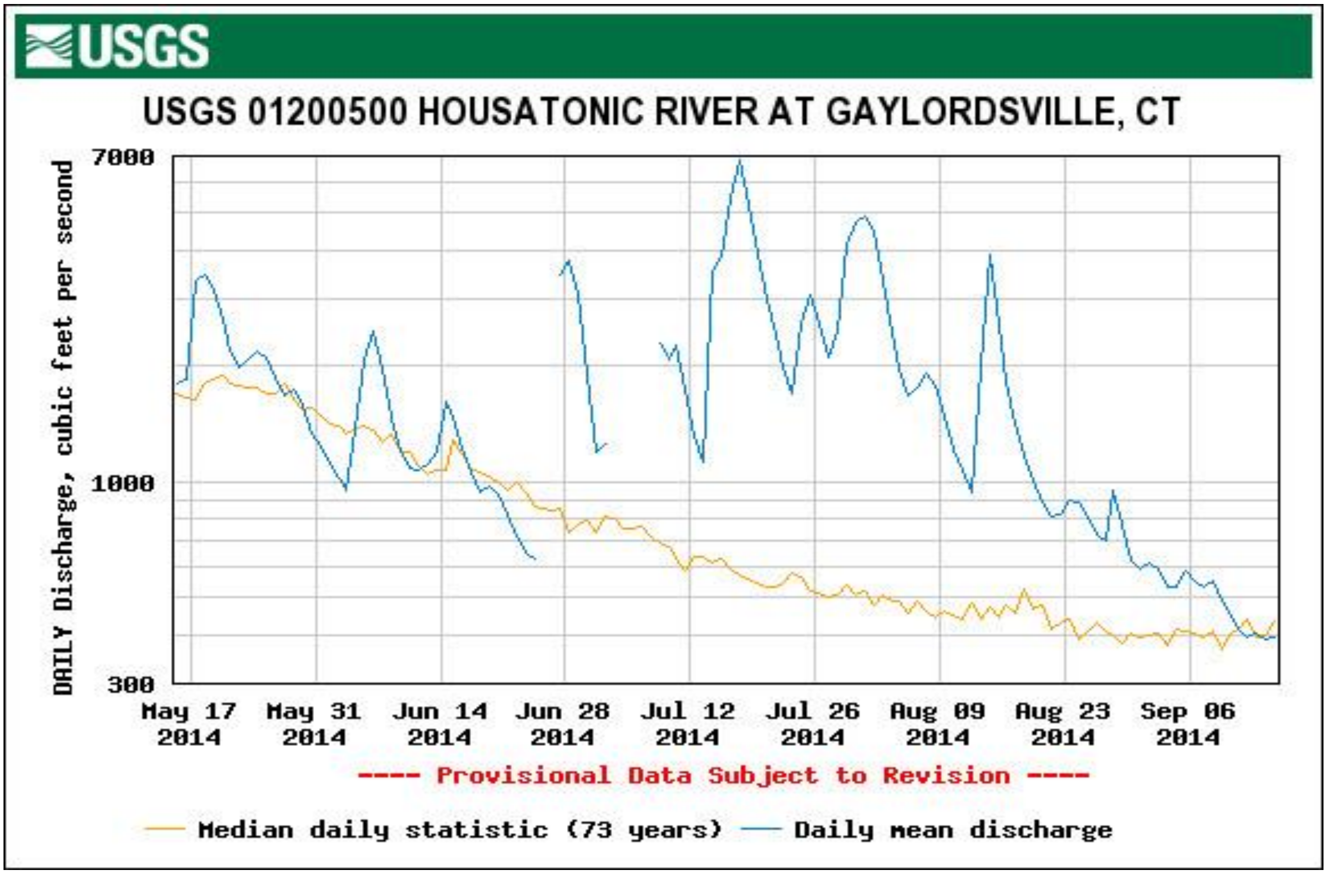

Figure 10: Housatonic River Discharge at Gaylordsville, CT

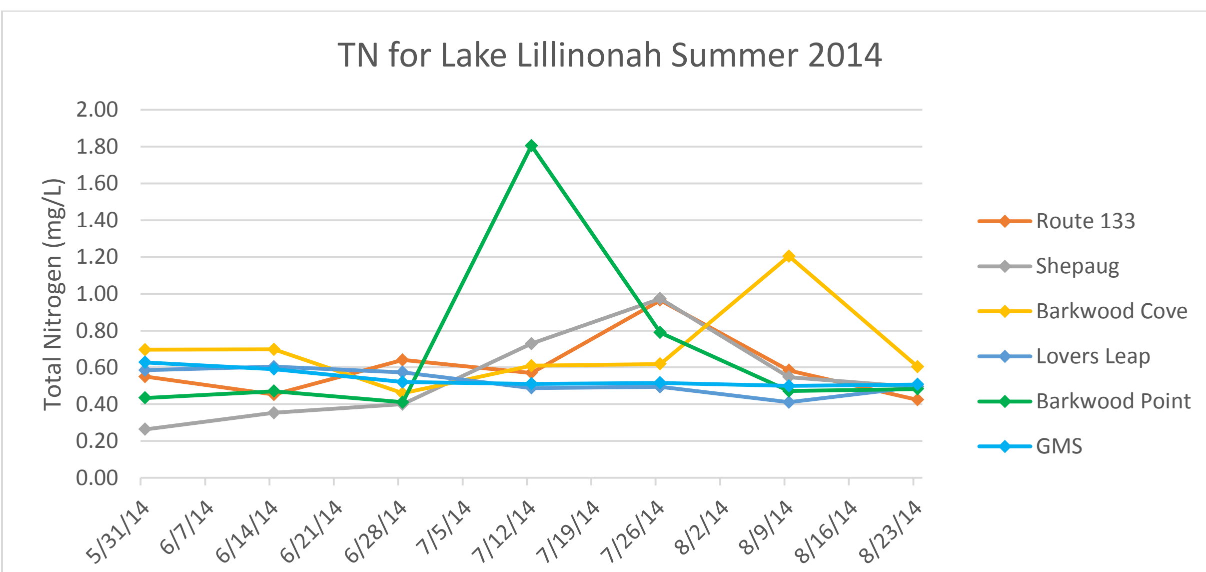

Figure 11: Total Nitrogen Concentration across all sites.

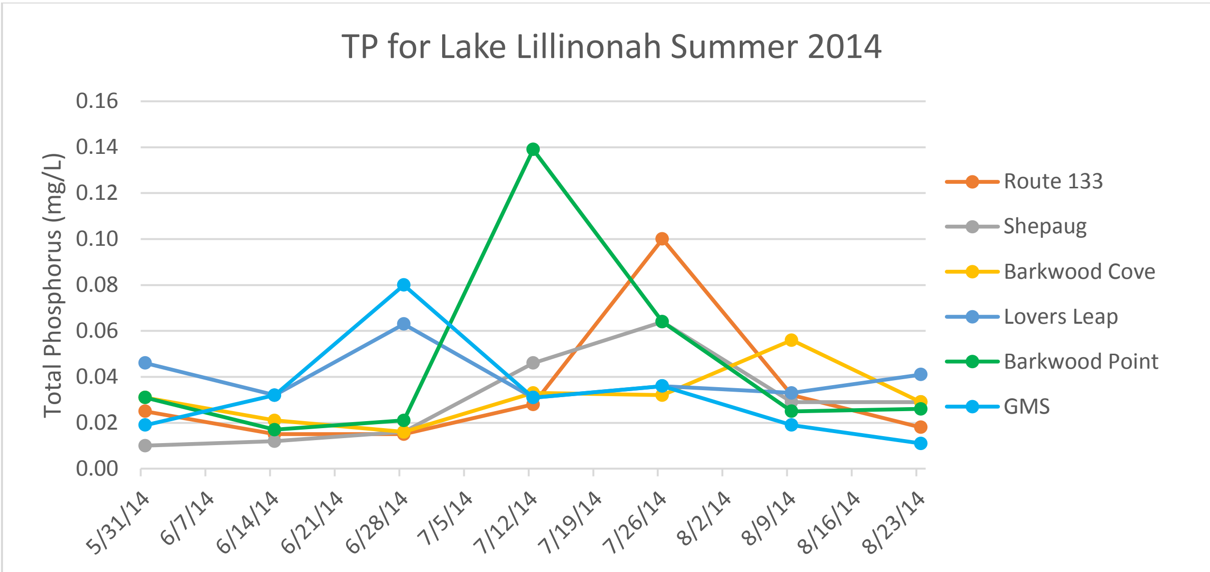

Figure 12: Total Phosphorus Concentration across all sites.

14. Algal Toxin Concentration Monitoring

The type of phytoplankton that forms the surface algal blooms that we see in Lake Lillinonah is called cyanobacteria. As their name suggests they are a form of bacteria, though they are typically grouped with algae because they are ecologically very similar. Many of the bloom-forming cyanobacteria produce compounds that may be harmful to aquatic organisms as well as other organisms, including humans, which drink or swim in the water. Several hypothesis exist for the ecological role of the toxins including

1. That they are a chemical defense against being eaten by zooplankton.
2. That they are chemicals that harm other algal competitors giving the cyanobacteria more access to light and nutrients
3. That they serve an unknown physiological purpose for the cyanobacteria cell.

Regardless of their ecological role, water quality managers have become increasingly concerned that during bloom conditions, toxin concentration may reach levels that could pose a threat to public health. Many of the species that are common in algal blooms in Lake Lillinonah have the potential to produce toxins. These include: *Anabaena, Aphanizomenon, Lyngbya and Microcystis*. Worldwide, the most well studied toxin is microcystin which is produced by two common Lake Lillinonah species, *Microcystis* and *Anabaena*.

The World Health Organization (WHO) guideline for microcystin in drinking water is 1 µg/L. Although water from Lake Lillinonah is not used for drinking, accidental ingestion of toxins through recreational contact is common and it is possible that repeated ingestion could lead to sub-lethal liver damage (Chorus

2001). In addition, microcystin has been implicated in a number of dog deaths in New England. The WHO does not have an official recommendation for recreational contact but states there is a "moderate probability of adverse health effects" when recreating in waters with microcystin concentration above 20μg/L. The Connecticut Department of Energy and Environmental Protection has recently published guidance for local health departments recommending that beaches in Connecticut be closed at microcystin concentrations greater than 15μg/L (CTDPH and CTDEEP 2013).

Samples for toxin analysis were collected fortnightly. Volunteers were given pre-labeled bottles which they were told to rinse the three times with water, submerge the bottle upside down until their wrist was in the water and then fill it up. They then poured out some of the water until the bottle was 2/3 full to allow room for expansion once the sample was frozen. Volunteers were given several extra bottles and instructed to take samples of algal blooms. There are a number of different types of microcystin. The most commonly measured is microcystin-LR (MC-LR). The data presented here are for MC-LR.

Water samples were analyzed using the EnviroLogix QualiTube Kit for microcystin by Fairfield University research assistants under the supervision of Jen Klug. The kit is used to detect levels of microcystin from 0.5-3.0 ppb. Microcystin concentrations were evaluated based on color development and an analysis of absorbance. The analysis allows us to place each sample into one of three categories: less than 0.5 ppb (not detectable), between 0.5 ppb and 3 ppb (low detect), and above 3 ppb (high detect).

The routine fortnightly samples show that the toxin concentration varies over time and location. The samples taken at GMS for instance were all within the "not detectable range" whereas those at Shepaug were all low or high detects. All other sites had either low or no detects for the routine sampling (Fig. 13). Volunteers also collected water samples on days other than the fortnightly samples if they noticed an algal bloom. In all cases except two, these spot samples had microcystin concentration greater than 3 ppb (Fig.14) suggesting that poor visual condition is associated with higher microcystin concentrations. The analysis does not allow us to assess whether samples are above the recreational guideline of 15 ppb but does show that microcystin concentrations are generally higher when visible blooms are present.

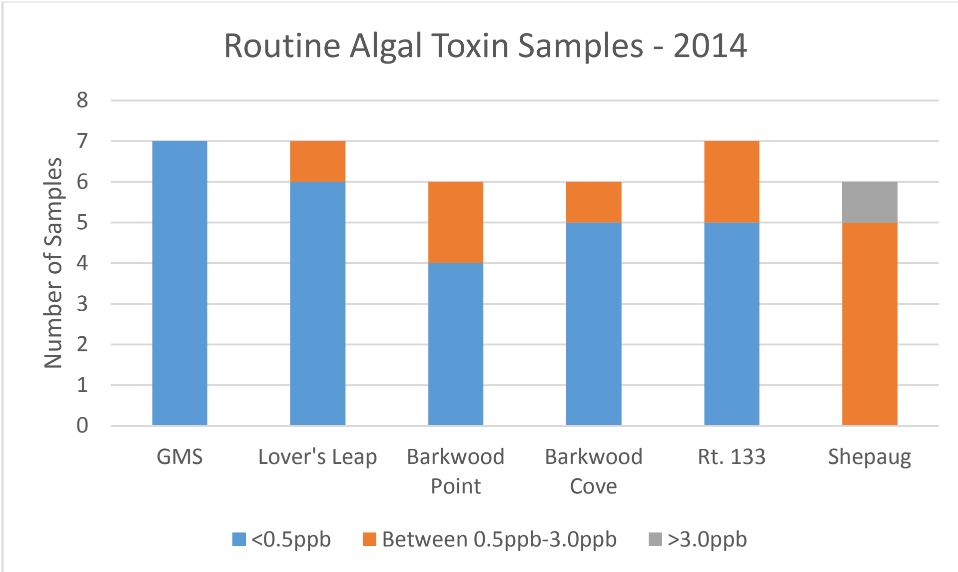

Figure 13: Routine Algal Toxin Samples- Summer 2014

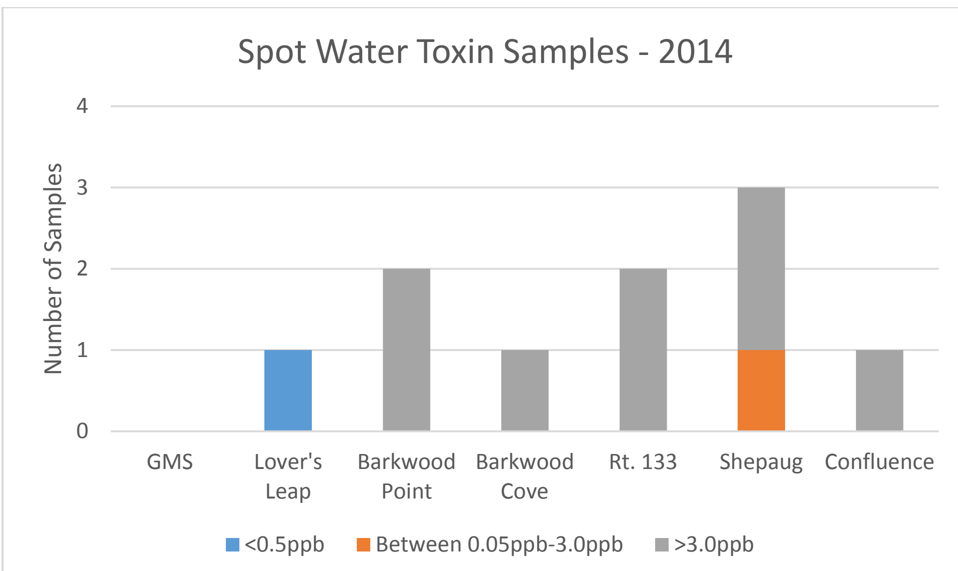

Figure 14: Spot Water Toxin Samples- Summer 2014

15. Cross Year Comparison

From 2011-present day, data has been collected by volunteers at Lake Lillinonah. The data collected has been used for year to year comparison and can now be used for moderate long term comparisons. For multi-year comparison we decided to look at secchi depth, nitrogen concentration and phosphorus concentration. We looked at the Lover’s Leap, Barkwood Cove, Route 133 and

Shepaug sites. We did not include GMS and Barkwood Point for this comparison because there have only been 2 years of data collection for those two sites. Between 2011-2014 there has been fluctuation between the average secchi depth of sites with Shepaug having the greatest secchi depth and Lover's Leap maintaining the least (Figure 14). Between 2013 and 2014 there was an overall increase in phosphorus concentration throughout the lake (Figure 18). Phosphorus concentration for Lovers Leap and Barkwood Cove, while higher than their 2013 levels, showed improvement from 2012 (Figure 15).From 2011-2013 nitrogen levels were in a steady state of decline but in 2014 there was a significant increase in all sites except for Lover's Leap. Looking at Figures 17 and 18 we can more clearly see these nutrient changes from 2013-2014. The error bars in these graphs show the variability within the data. When looking at the secchi depths we can see that the error bars are small indicating there was very little variability in the data gathered. When we look at the error bars on the nutrient graphs we see they are much larger. This is because there may have been greater variability during the time the data was collected. For example the large nitrogen increase in July of 2014 shows itself in that the error bar for Barkwood Point is significantly larger than other points.

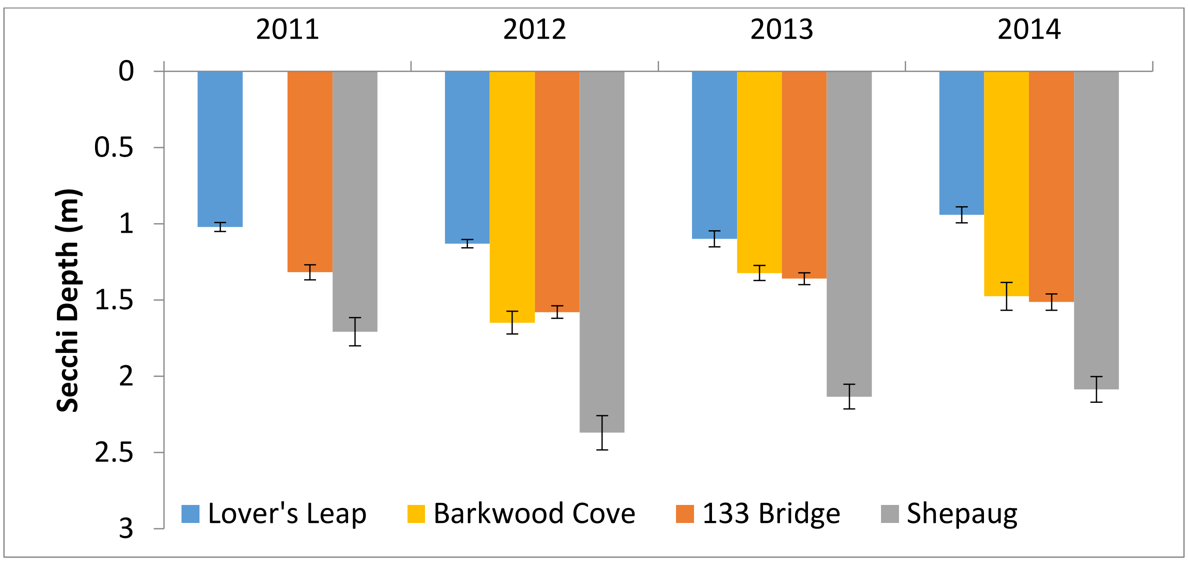

Figure 14: Cross Year Comparison of Secchi Depths across sites.

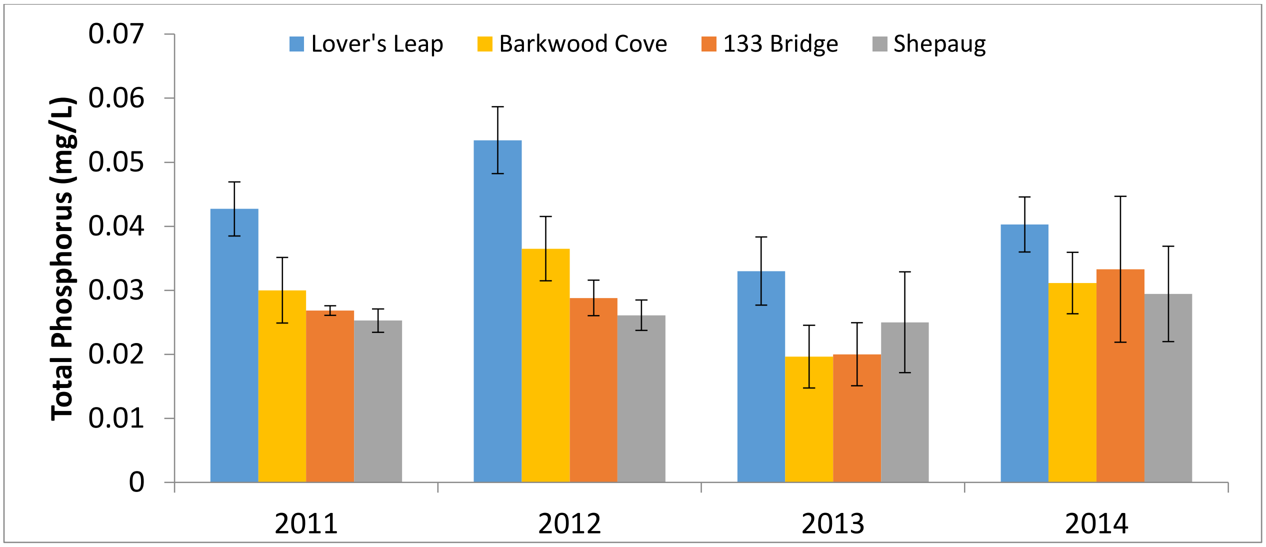

Figure 15: Cross year Comparison of Total Phosphorus across sites

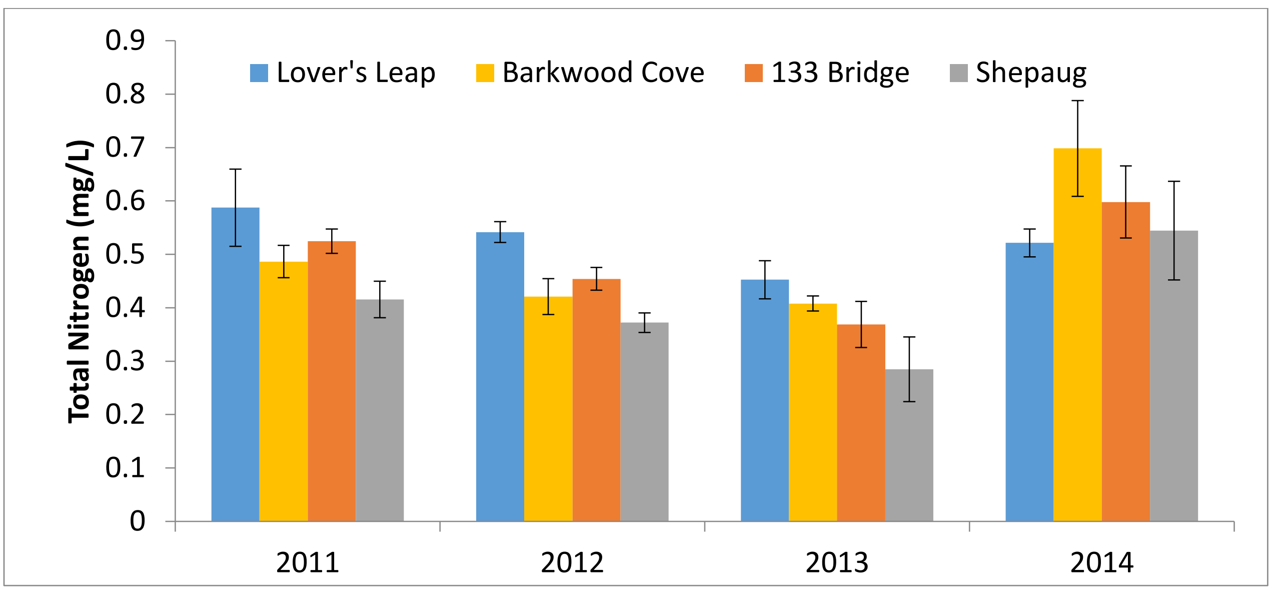

Figure 16: Cross year comparison of Total Nitrogen across sites

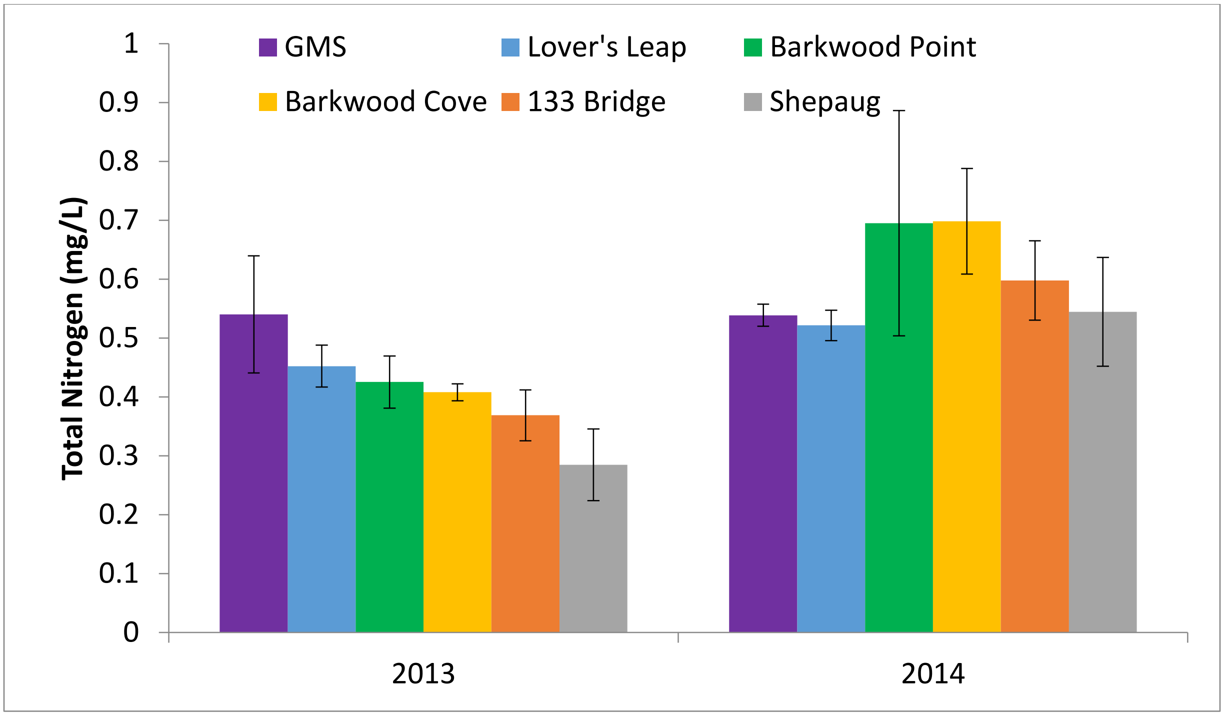

Figure 17: Comparison of Total Nitrogen at sites from 2013-2014

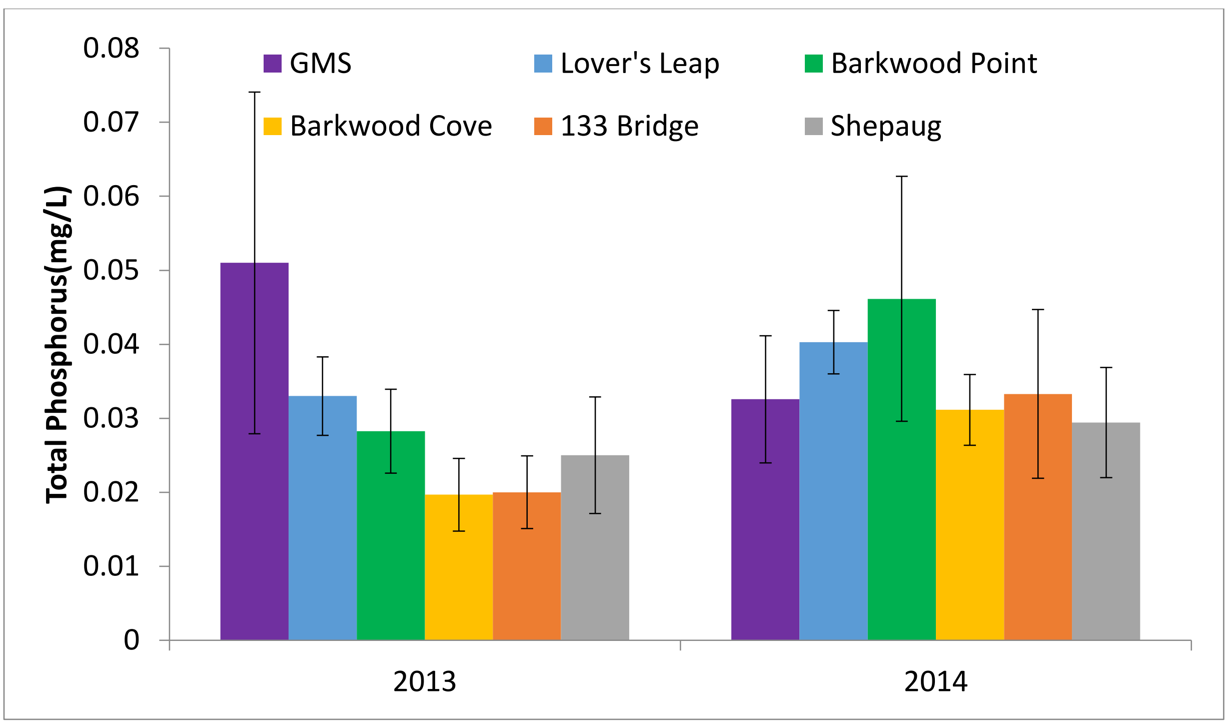

Figure 18: Comparison of Total Phosphorus at sites from 2013-2014

16. Conclusions

As in past years, the data collected from lake volunteers has allowed us to compile an overall assessment of Lillinonah's water quality. Using the ten variables discussed, we are able to better discuss what is happening to the lake environment and ecosystem. The various lake sites allow us to monitor the status of the lake as a whole which allows us to have a fuller understanding of Lake Lillinonah.

Table 4: Classification of Lake Sites Based on DEEP Trophic Level Classification (Table 1)

Site	Average Secchi Depth	Average Nitrogen Level	Average Phosphorus Level
Lovers Leap	Highly Eutrophic	Late Mesotrophic	Eutrophic
Barkwood Point	Eutrophic	Eutrophic	Eutrophic
Barkwood Cove	Eutrophic	Eutrophic	Late Mesotrophic
Rt. 133	Eutrophic	Late Mesotrophic	Late Mesotrophic
Shepaug	Late Mesotrophic	Late Mesotrophic	Late Mesotrophic

Based off of the secchi depths and nutrient concentrations, Lake Lillinonah would be classified as a late mesotrophic or eutrophic body of water. (Table 4). In relation to secchi depth, all sites except Shepaug were classified as eutrophic or worse. Shepaug just barely made it out of the eutrophic category with an average secchi depth of just over 2 meters classifying it as a late mesotrophic site. As seen in Figure 3, Lover's Leap had the lowest water clarity year round and Shepaug had the highest. Given that the overall color of the lake was green these secchi depth readings combined with visual color is indicative of high algal biomass. There were also numerous days where the secchi depth was low and the lake color was brown, indicating the secchi depth on those days was largely in part to sediment being stirred up into the water column or brought into the lake during periods of high flow. Sediment had a bigger impact on water clarity in 2014 than in past years.

The levels of nitrogen and phosphorus across the lake ranged from late mesotrophic to eutrophic. Many sites were on the divide between having a late mesotrophic or eutrophic categorization particularly in regards to phosphorus levels. Based on the combination of phosphorus levels, nitrogen levels and secchi depths throughout the lake, we can classify Lake Lillinonah as a eutrophic system.

The lake as a whole was relatively debris free throughout the entire summer with few days recording significant debris. There were almost no days recorded as being boating impaired due to debris on the lake. (Figure 5)

As mentioned above, the green color of the lake is indicative of the presence of algal life and is something that has been consistent with previous years. Despite this, the overall appearance of the lake appears to not have been detracted from. The majority of sites had a majority of days which were regarded as beautiful or having only minor aesthetic problems. All sites also reported some days where there was some recreation impairment (Figure 8).

The data presented in this report span the time frame from Memorial Day-Labor Day, traditionally defined as the recreational season. However, data collected by volunteers after Labor Day deserves consideration. For example, all of the 4 spot samples collected after Labor Day had microcystin concentrations greater than 3 ppb. In addition, 5 of 9 routine samples collected after Labor Day had concentrations between 0.5 and 3 ppb. Furthermore, almost half (44%) of the days collected after Labor Day reported recreational impairment due to algae. And 80% of the data collected reported visible algae or an algal bloom. These results suggest that we should consider extending the monitoring season into early fall, when recreational use is still high and water quality may be poor.

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