STATE OF THE LAKE REPORT 2015

Lake Warner, Hadley Massachusetts

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for the Town of Hadley, Massachusetts

Table of Contents

List of Tables

List of Figures

Friends of Lake Warner and the Mill River.

State of the Lake 2015

Report to the:

Hadley CPA Committee

Hadley Conservation Committee

Summary

The Friends of Lake Warner and the Mill River (FoLW) was formed in 2013 to save Lake Warner. FoLW spent much of 2013-15 involved in public education, advocacy and fund raising to ensure the repair of the Lake Warner Dam. Dam repair is scheduled beginning 1 July 2016.

Once the dam repairs and the continued existence of the lake were assured, FoLW turned its' attention to the health of the lake. Members of FoLW had been involved for many years in monitoring the lake and in invasive plant removal in and around the lake. FoLW began to focus, courtesy of Hadley CPA funds, on scientific measurement of the lake in 2014. We have, with the assistance of its membership, collected much of the equipment necessary to navigate, monitor and map the lake.

Members of FoLW developed more efficient methods of aquatic plant management, conducted original research, developed models and obtained tools that have enabled us to control Water Chestnut. This work is applicable to further noxious weed control in the lake in the future. FoLW's techniques and tools are being shared with other lake and river organizations in Western Massachusetts.

The FoLW Executive Director researched histories of and previous studies of Lake Warner in order to understand trends in the lake. Some of these studies will be repeated in 2016.

The dissolved oxygen levels in Lake Warner were below the Massachusetts minimum water quality criteria (5 parts per million) for warm water bodies on the August-September sample dates. Bacteria levels were elevated in the Mill River and tributaries but did not exceed primary or secondary contact levels in the lake. Water transparency, total phosphorus and Chlorophyll a samples in the lake, did not, with one exception, reach eutrophic thresholds but were well past mesotrophic levels. Excessive aquatic plant growth severely impacts and inhibits recreational boating and fishing. Uncontrolled aquatic plant growth, decomposing bottom vegetation, algal blooms, lake sediment nutrient levels and tributary Phosphorus levels all suggest a lake approaching a eutrophic crisis.

We plan to continue monitoring in 2016 to identify trends, improve our understanding of the role that sedimentary nutrients, aquatic plant management and sources of tributary pollution have on Lake Warner and the Mill River. We will continue to inform the public of our findings.

FoLW will develop an Aquatic Vegetation Management Plan, and a Drawdown Plan in 2016. These will be included in the Long Range Lake Management Plan for Lake Warner.

Introduction

The Hadley CPA Committee committed funds in 2013 for an assessment of Lake Warner. This financial support enabled FoLW to coordinate and conduct testing and monitoring of Lake Warner and the Mill River. This is the first attempt in over ten years to comprehensively measure the physical and biological parameters of the lake. The results of this testing show that while some conditions measured are within mesotrophic ranges, and even show improvement from the 2003/2004 study, trends indicate that by mid-summer *each year* the lake is in a eutrophic condition.

Background

Lake Warner is a reservoir of approximately 68 acres, located on the Mill River in Hadley, Massachusetts in the Connecticut River watershed.

The Mill River watershed covers 30.01 square miles and drains into Lake Warner. It encompasses portions of Amherst, Leverett, Shutesbury and Sunderland. The watershed is 58 percent forested, 20 percent agricultural, 14 percent rural, and 8 percent urban with high-density residential and commercial-industrial land use according the 2001 TMDL Report.

The last bathymetric map was made by Massachusetts Department of Fisheries, Wildlife and Environmental Law Enforcement (DFWELE) in 1952; the Lake had a mean depth of 3.5 feet and maximum depth of 10 feet.

The Massachusetts Department of Environmental Protection (DEP) placed Lake Warner on the 303d list of impaired water bodies in 2002, 2007, 2012 and 2014, as being impaired due to nutrients, organic enrichment, low dissolved oxygen, turbidity and noxious aquatic plants. The Mill River above the inlet to the lake was placed on the 303d list of impaired water bodies for excessive E. coli bacteria pollution in 2006, 2011 and 2014.

A 2002 Lake Warner Assessment Project, coordinated by DFWELE's Riverways Program involved visual survey of the lower portions of the watershed to identify potential nonpoint pollution sources and nutrient pathways into the lake.

A 2003/2004 Monitoring Report by the Massachusetts Water Watch identified sources of nutrients, characterized the extent and type of aquatic plant growth and characterized the general health of the lake. An attempt to assess bacterial contamination was dropped from the study.

A 2011 Study by Ann Capra of the Pioneer Valley Planning Commission (PVPC) found excessive levels of E. coli bacteria in the Mill River above the inlet to Lake Warner.

FoLW was formed in 2013 to preserve Lake Warner through public outreach and education and to advocate repair of the Lake Warner Dam.

FoLW achieved the following in 2015:

- In conjunction with the USF&WS, removed 2,200 pounds of invasive Water Chestnut (*Trapa natans*) from Lake Warner. This raised the FoLW total since 2013 to almost 10,000 pounds and signaled that this weed has been brought under control in Lake Warner, a singular achievement in Western Massachusetts.
- Established ten permanent transects of the lake running roughly magnetic North to South with 15M data sampling intervals. FoLW sampled roughly half of these data intervals in 2015 and collected data on water depth, temperature, transparency and plant species at each point. The remaining data points were also observed but not in full detail. Plant data indicates a lake in borderline eutrophic condition.
- Tested for dissolved oxygen, temperature and water transparency at selected points on a bi-weekly basis. Total phosphorus in the lake and at five tributary locations were sampled once. Sediment samples were collected from four locations and tested for nutrients and metals. Two samples were collected for PCB and VOC testing. Chlorophyll a was sampled once. Bacterial samples were collected from numerous sites.
- Produced a Landowner Assistance Guide for Mill River watershed residents.
- Produced Best Management Practices and Vegetative Buffers handouts focused on lake and river protection.
- Hired an Executive Director in 2015 to develop and oversee future planning for the lake.
- Initiated bathymetric mapping of the lake in 2015. The resultant map will be combined with species, temperature, sediment and pollutant mapping.
- Completed a current Data/Report Summary for Lake Warner and the Mill River
- Began to draft a Lake Management Plan for Lake Warner

Testing/Sampling Schedule:

FoLW conducted the following tests/activities in 2015:

Survey Type/Test	Indicators	Materials/Methods	Laboratory	Sample Locations Frequency
Plant Transects, Depths, temperature	Species type and relative dominance	Tape and Measuring Rod, , GPS		10 Permanently sited, similar to 2003/2004 study
Macrophyte Characterization	Macrophytes-map, collect samples	Throw rake, Plant I.D. Keys, GPS, lab thermometer		At 15m intervals along 5 transects in 2015
General Lake Health	D.O, Transparency, Temperature	YSI 200 Meter, Secchi Disc		Mid-Lake, June-October, and additional sites
Nutrient Source Evaluation	Total Phosphorus	100mL brown sample bottles. Lab supplied	EAL UMASS Amherst	Lake Warner, Mill River and 5 tributaries
Trophic evaluation	Total Phosphorus Chlorophyll a	Vacuum Pump, 200 micron glass filters	EAL UMASS Amherst	2 samples, mid-lake
Primary and Secondary Contact for Recreation	E.coli bacteria	100ml clear sample bottles Lab supplied	CRWC Lab Greenfield	11 samples, mid-lake, Mill River,5 Tributaries
Plant tissues/Soil Nutrients/Metals	Plant Nutrient Uptake, Soil Nutrients/Metals	Grab Samples, stainless steel trowel	Paige Soils Lab, UMASS Amherst	3 locations in Lake,1 at Mill River inflow
Soil	PCB's, VOC's	Grab samples, glass vials	Contest Laboratory	2 locations

Testing Results:

Vegetation Transects

FoLW surveyed (GPS) and established ten semi-permanently marked transects across Lake Warner. These are sited to correspond with the 2003/2004 study transects in order to track changes in plant community structure and dominance. FoLW used these transects to measure water depth, water temperature, water transparency, aquatic vegetation (macrophyte) species and dominant vegetation type at 15M (~50') GPS located intervals. Riparian species were documented at the terminus of transects. FoLW completed sampling of half of transects in 2015 and partial sampling of the remainder. We expect to complete the remaining transects in 2016. FoLW plans to repeat this sampling every year.

General Lake Health,

Temperature

Temperature and dissolved oxygen are principal indicators of aquatic habitat. Aquatic animals have habitat preferences and lethal tolerances to temperature. Temperature is a fundamental aspect of plant habitat. Temperatures were taken at many locations around the lake, ranging from 18.6C TO 23.2C at 2 meters, with a maximum of 26.1C at the surface. . Temperature results from all locations are in the raw data summery in the Appendix. Temperature data from the Mid-lake sample site at 1 meter are presented in Table 1.

Table 1. Transparency, Dissolved Oxygen and Temperature at 1 meter

Date	Transparency Secchi Depth (meters)	Dissolved Oxygen (ppm)	Temperature Degrees Celsius
6/10/15	2.0	7.3	21.4
6/17/15		6.85	20.6
6/20/15	2.5	5.9	21.6
6/30/15	1.8		19.0
7/2/15		8.56	20.7
7/25/15	1.8	7.56	24.6
8/11/15		8.39	22.5
8/19/15	2.4	7.51	26.1
9/12/15	2.3	3.36	22.3
9/17/15		4.57	19.5
10/2/15		5.05	16.2

FoLW has acquired the use of a Garmin GPS EchoMap device which continuously records water temperature. This will enable FoLW to map surface temperature throughout the lake in the future.

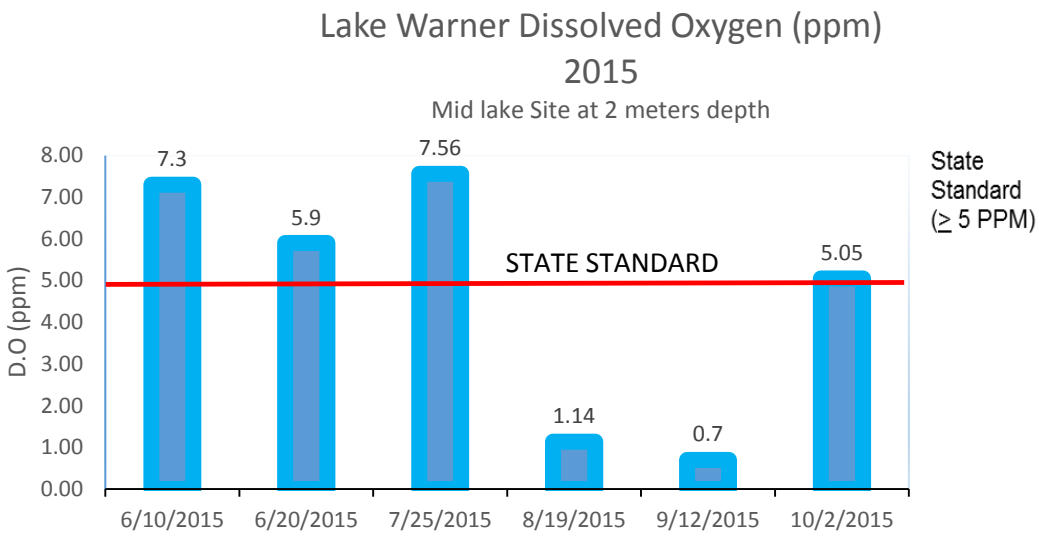
Dissolved Oxygen (DO)

FoLW purchased a YSI200 DO and temperature meter. FoLW ~~has~~ conducted 45 temperature and DO measurements throughout the lake, focusing on hypolimnetic oxygen levels and used the same mid-lake site used in the 2003/2004 study to determine trends in temperature and dissolved oxygen levels at depths of 1 meter and 2 meters throughout the summer and early fall.

All aquatic animals are dependent on dissolved oxygen. The state standard for dissolved oxygen (D.O.) in lakes is 5 parts per million (ppm). The lake is amply oxygenated in the spring. But by mid-August D.O. levels at 2.0 meters in depth decrease dramatically as light is cut off by excessive plant growth. The drop in D.O. is also influenced by the abundance of decomposing plant material at the peak of the growth of vegetation coupled by the reduction of highly oxygenated flow from the feeder tributaries. The very dry 2015 summer created a stressful environment for aquatic organisms. Lake Warner, fortunately, did not experience a fish kill. This may be

because there are areas of the lake where fish are finding refuge. Groundwater flow may be helping to maintain tolerable conditions. Dissolved oxygen values at 2m are shown in Figure 1.

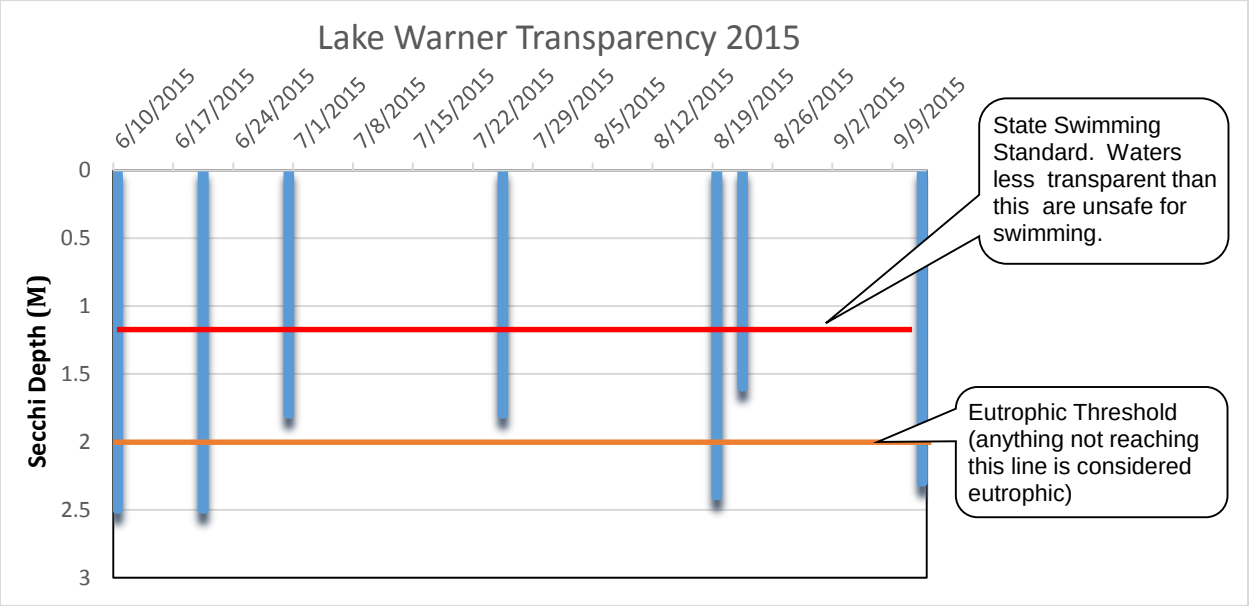
Figure 1. Dissolved Oxygen Levels in Lake Warner 2015



Transparency

Transparency is a measurement of light transmission into the water. Transparency data was measured using a Secchi disc, a black and white disc on a depth metered line that is lowered into the water until it can no longer be observed. Transparency readings this year exceeded those from prior studies a decade ago and, with one exception, exceeded the state swimming standard throughout the season are shown in Figure 2. The lowest measurements of 1.8m were observed in late June through late July, the state standard is 2.0m, anything less than that is considered eutrophic. Observations of 2.4m were made in late August, which was good, but by this time of year the majority of the lake surface was covered with floating vegetation or algae preventing light penetration and causing low D.O. readings.

Figure 2. Lake Warner Transparency Mid-Lake 2015



Plant Nutrient Results

A literature review of nutrient content of Water Chestnut (*Trapa natans)* documented that it is excellent at adsorbing toxins into its plant tissues, particularly heavy metals in polluted waters. FoLW have removed over four tons from Lake Warner over the past two years and thought it would be valuable to have an evaluation of what it contained. A sample of seeds and plant tissue was taken to the Paige Soil and Plant Lab at UMASS Amherst for nutrient and metals analysis. A copy of the laboratory report is provided in the attachments.

Water Chestnut, (*Trapa natans)* vegetation was tested for nutrients and metals. FoLW has not yet been able to obtain results for Mercury, Arsenic and PCB's. Nevertheless, preliminary indications are that the water chestnut plants and nuts collected from Lake Warner are safe to use as green manure.

Nutrient Source Evaluation

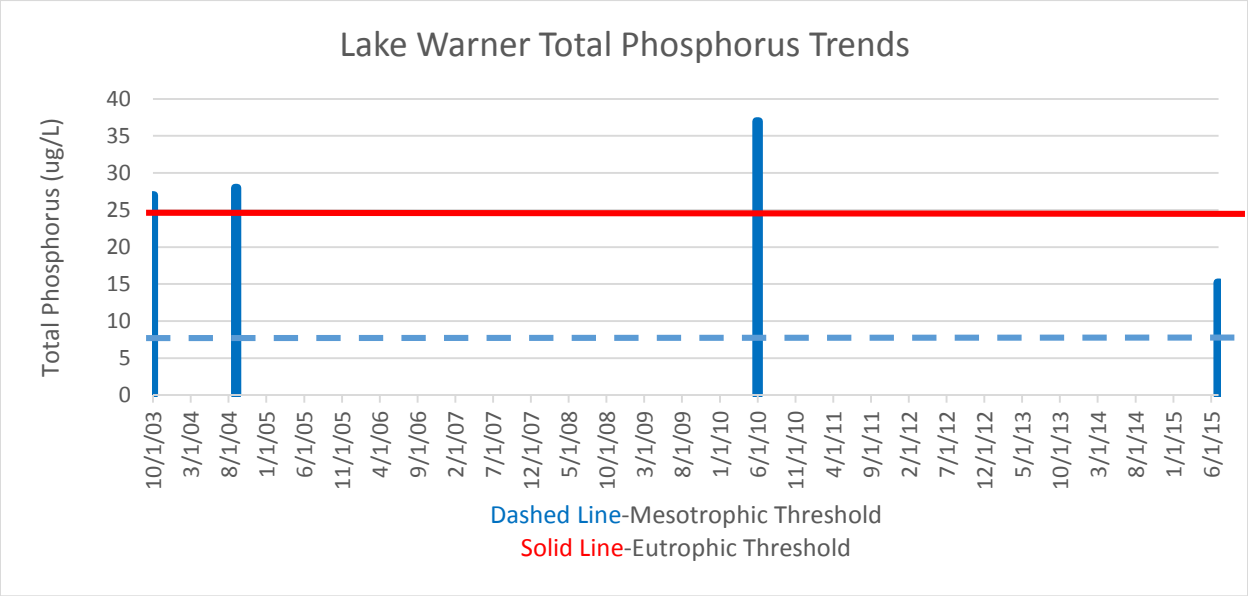
Phosphorus

Phosphorus is the limiting plant nutrient in lake ecosystems. Excessive amounts are a primary cause of eutrophication (nutrient enrichment). Phosphorus levels were measured at the mid lake site and upstream on the Mill river and other tributaries. Levels in the lake were very low, at times below levels of detection. Levels of Phosphorus were higher in the Mill River above the lake. The results are not refined enough to determine sources. Perhaps due to a relatively dry summer Phosphorus measurement from the lake was not elevated. However there are elevated inputs from tributaries and the Mill River was often higher than the EPA's threshold levels for streams and rivers. Phosphorus results can be found in Table 2, and Figures 3, 4 and 5.

Table 2. Mill River/ Lake Warner Tributary- Nutrient, Temperature and Dissolved Oxygen, 2015

Date	Phosphorus *Tributary* (ug/L)	Dissolved Oxygen (ppm)	Temperature (Deg. C)
7/27/15	*Eastman Bk. Amherst,* 13.6	8.97	20.1
7/27/15	*Brandywine Bk*. *Amherst*, 48.7	7.24	23.6
8/11/15	*Horse Farm Bk. Hadley*, 62.8	7.71	21.5
8/11/15	*Rocky Hill Road Bk. Hadley*, 61.3	3.6	21.0
8/11/15	*Knightly Bk, Hadley*, 180.4	7.35	15.5

Figure 3. Total Phosphorus Trends Lake Warner 2003-2015



Note on Fig 3: Values from 2003 and 2004 are geometric means of several samples during that season. 2010 value is a single sample taken by Ethan Needu during sampling for a Zebra Mussel Study. Similarly the 2015 value is from a single sample and may not be representative of the conditions during the rest of the year.

Figure 4. Mill River Tributaries, Total Phosphorus 2015

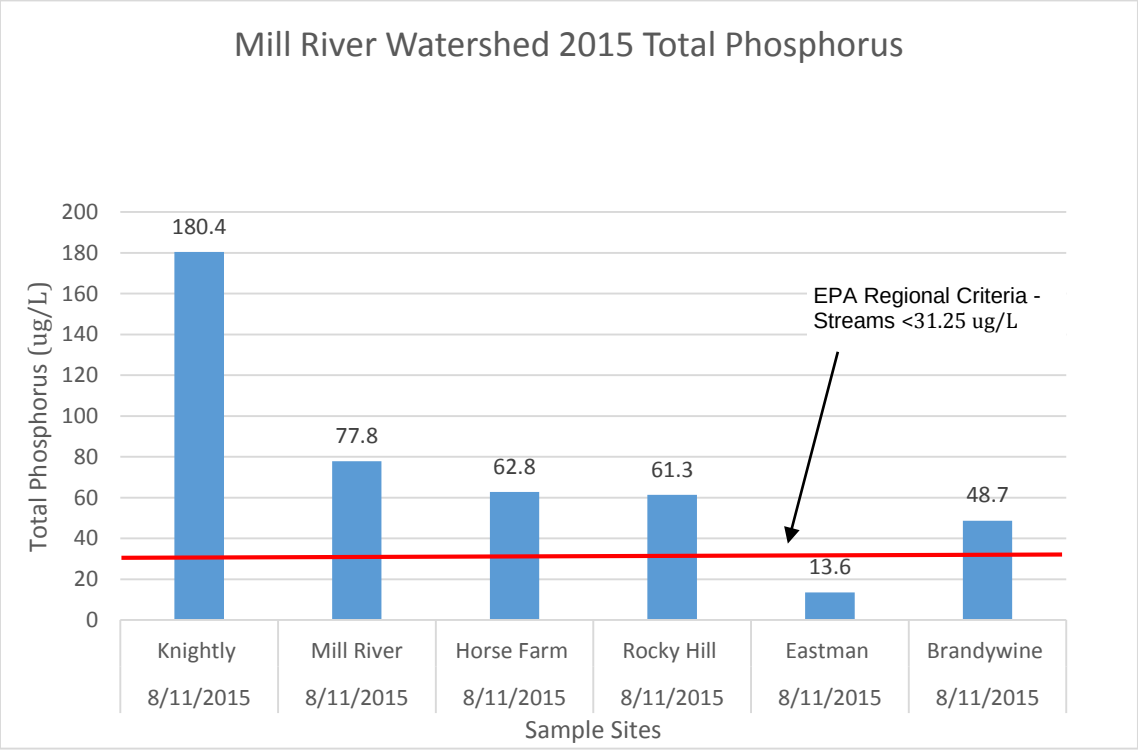
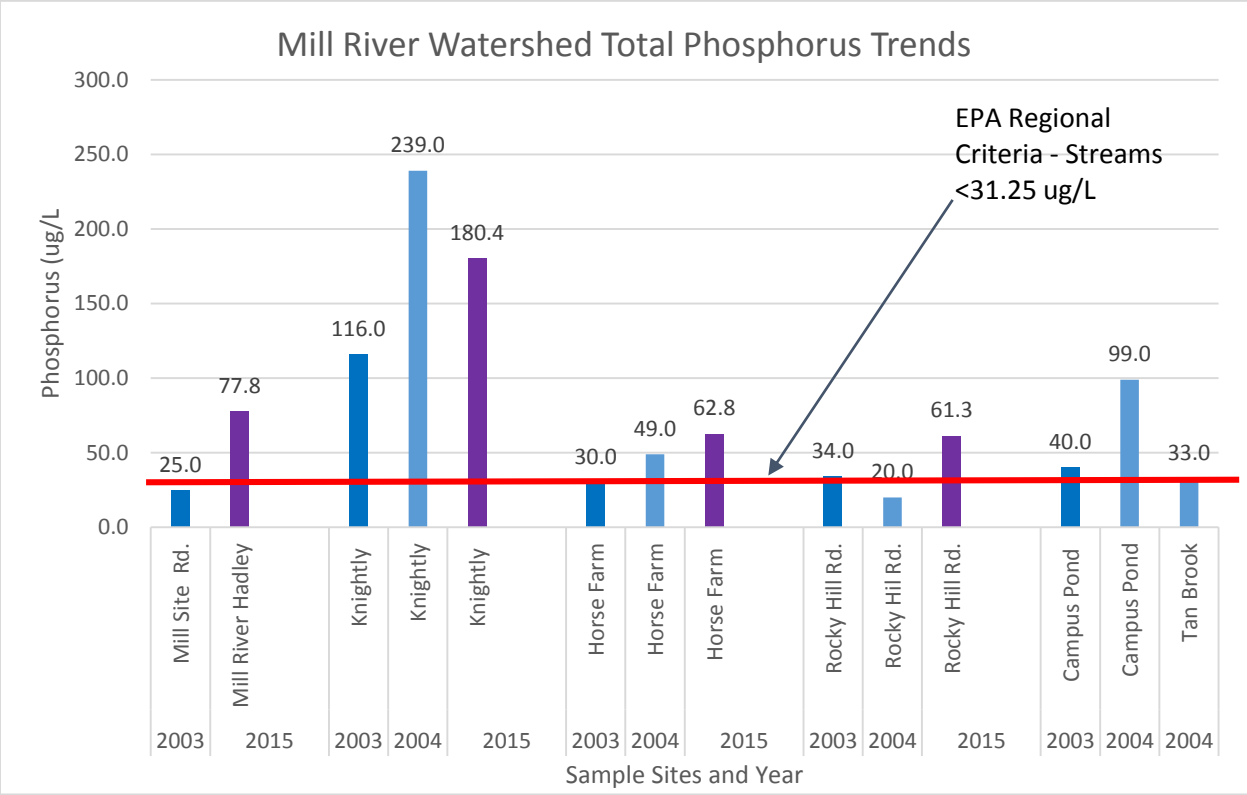


Figure 5. Mill River Tributaries Total Phosphorus Trends 2003, 2004, 2015



Note on Figure 5. Campus Pond was being drained during the sampling period in 2015. There was no baseline data for Eastman Brook and Brandywine Brook, both were sampled in 2015 for the first time and left off the tributary trend graph.

Chlorophyll a

Chlorophyll a are photosynthetic cells. They are measured by filtering a specific volume of water through a glass filter, dried, and then analyzed by a certified laboratory. The EPA nutrient criteria for our region is 2.9ug/L. Samples collected in early September were very low, 1-2ug/L. We don't have any explanation for this. There can be seasonal variability. Other water quality monitoring projects across the state were also getting below average values.

Bacteria

Bacteria samples were collected between June and September 2015. E. coli bacteria comes from animal waste or leaking septic systems. There are state standards for levels involving primary contact like swimming and secondary contact such as boating. Ponds and lakes used for swimming and other recreation should have single-sample maximums of 235 colonies of E. coli bacteria per 100 mL of water. The Mill River and Lake Warner have previously been areas where high levels of E. coli have been found. FoLW is pleased to report that the level of bacteria in the lake never

exceeded the primary contact level that would have required warnings to be posted. The Mill River above the lake did have levels that exceeded primary contact levels and nearly exceeded secondary contact levels in one sample. All results can be found in Table 3. Aging municipal sewer lines and septic systems, especially from large housing projects may be responsible for elevated levels of E.coli bacteria. More analysis needs to be done to try and determine the source of these high bacteria levels.

Table 3. Lake Warner and Mill River Nutrient and E.coli Bacteria, 2015

Date	Phosphorus Lake Warner (ug/L)	Phosphorus Mill River (ug/L)	Chlorophyll a Lake Warner (ug/L)	E. coli Bacteria Lake Warner (MPN/100mL)	E.coli Bacteria Mill River (MPN/100mL)
6/17/15				178.5	488.4
7/2/15	15.2	No Detection		42.0	547.5
7/30/15				5.2	387.3
8/11/15		77.8			
8/20/15				45.0	*Mill River Amherst,* 12.0 *Mill River Hadley,* 517.2
8/22/15			2, 1		
9/17/15				17.3	83.9

Sediment

Four locations were sampled for nutrient and metals; two additional locations for PCB and VOC's. A summary of results from Paige Soil Laboratory are provided in Table 4. We still have not received the results of a sediment core test conducted in 2014 by Worcester State College. The description of the sample was described in the following email correspondence with Professor Tim Cook in February of 2015:

"We are still working on developing a chronology for the sediment core that we collected in the fall so we aren't yet at a point where we can tell a very complete story. We collected about 80cm of sediment which in most lakes that I have worked on in New England, that would be more than enough material to get us through the last century. In the case of Lake Warner, I am not sure exactly how long the record is, but we are looking for the radioisotope Cesium-137 in the sediment which did not occur in the environment until nuclear weapons testing began in the 1940s. I know that the bottom of the core lacks Cs and that we do find it towards the top, so that implies that our record goes back at least through the 1940s. Given your recollection of a drawdown of the lake in the 1940s we did encounter material toward the bottom of the core that might reflect that event. There is also a pretty significant transition in the character of the sediment midway through the core that likely has to do with the timing of a change in water quality - although we are still trying to make sense of that as well. If you were to conduct nutrient analyses on the core I would think that sampling at the top of the core (most recent sediments) and then above and below the transition that I mentioned previously would provide some interesting insight. "

Soil Nutrient Results

Soil samples were taken at four locations in the Lake, these sites were recorded using a Garmin GPS Unit. The locations, along with a summary of results are provided in Table 4. Site No. 4 was taken close to the inlet of the Mill River and consisted mostly of fluvial sediments. Samples were taken to the Paige Soil and Plant Tissue Testing Laboratory at UMASS Amherst for analysis.

Phosphorus levels were elevated (15.0 ppm and 16.1ppm] in two of the lake sites and still within the optimum range at 4.4ppm at site No. 2, taken mid channel at the Kestrel peninsula. Nitrate levels were measured and ranged from 0-2 ppm. Nutrient levels all indicate very productive sediments.

Table 4. 2015 Lake Warner Sediment Sample Results

Location	MAFW	Kestrel Peninsula	Knightly Brook Outlet	**Lake Sediment**	Mill River Inflow
Sample Number	LKW Sed 1	LKW Sed 2	LKW Sed 3	**Averages**	LKW Sed 4
Macronutrients (ppm)					
Organic Matter	14.50%	2.3%	11.4%		0.3%
Nitrate (NO3-N)	2.0	0	2.0	**1.33**	1.0
Soil Ph (1:1, H2O)	5.2	5.5	5.3	**5.33**	5.9
Phosphorus (P)	15.0	4.4	16.1	**11.83**	1.7
Potassium (K)	48.0	16	66.0	**43.33**	5.0
Calcium (Ca)	1372.0	520	1910.0	**1267.33**	126.0
Magnesium (Mg)	112.0	41	128.0	**93.67**	12.0
Sulphur (S)	99.9	49	262.5	**137.13**	9.0
Micronutrients(ppm)					
Boron (B)	0.4	0.2	0.5	**0.37**	0.1
Manganese (Mn)	90.3	29.8	200.1	**106.73**	22.2
Zinc (Z)	30.7	3.3	23.6	**19.20**	1.9
Copper (Cu)	0.8	0.5	0.7	**0.67**	0.4
Iron (Fe)	320.5	45.2	305.5	**223.73**	15.2
Aluminum (Al)	239.0	68	131.0	**146.00**	15.0
Lead (Pb)	11.7	1.6	4.3	**5.87**	0.6

Macrophyte Characterization

As noted above, aquatic vegetation (macrophyte) species and dominant vegetation type were surveyed at 15M (~50') GPS located intervals.

Sixteen aquatic plant species were identified in the Lake in 2015. They are listed in Table 5 in order of abundance based upon transect data collected in 2015.

Table 5. Aquatic Macrophytes Observed and Frequency of Occurrence Transects 1,2,3,7,8 in Lake Warner, 2015

Common Name	**Latin Name**	**No. of Observations**	**Freq. in Group (%)**	**Freq. Overall (%)**
Emergent Species				
Swamp Loosestrife	*Decodon verticillatus*	12	**28**	**6**
Purple Loosestrife	*Lythrum salicaria*	7	**16**	**4**
Burreed	*Spargannium*	4	**9**	**2**
Arrowhead	*Sagitteria*	6	**14**	**3**
Cattail	*Thypha spp*	1	**2**	**1**
Rushes	*Scirpus spp*	3	**7**	**2**
Sedges	*Juncus spp*		**0**	**0**
Pickerelweed	*Pontederia*	10	**23**	**5**
		43		
Floating species				
Watermeal	*Wolfia*	34	**42**	**17**
Duckweed, Major	*Lemna1*	20	**25**	**10**
White Water Lily	*Nymphaea odorata*	17	**21**	**9**
Yellow Water Lily	*Nuphar variegata*	5	**6**	**3**
Duckweed, Minor	*Lemna2*	3	**4**	**2**
Water chestnut	*Trapa natans*	2	**2**	**1**
		81		
Submergent species				
Coontail	*Cerataphyllum*	35	**48**	**18**
Pondweed1 Big-leafed	*Potomogeton spp*	26	**36**	**13**
Waterweed	*Elodea*	8	**31**	**4**
Pondweed2 Curly	*Potomogeton spp*	2	**3**	**1**
Pondweed3 Ribbon	*Potomogeton spp*	1	**1**	**1**
Bladderwort	*Utricularia spp*	1	**1**	**1**
		73		
Total No. of observations		**197**		

Soil VOC's and PCB Results

Soil samples from two locations documented via GPS, bracketing the Kestrel Peninsula were taken to Con-Test Analytical Laboratories in East Longmeadow for analysis of Volatile Organic Compounds, Chlorinated Biphenyls and Metals Analysis. Mercury was also scheduled to be analyzed however the sample quantity provided to the lab was insufficient to perform the analysis. The mercury sample was dropped from the order at no charge.

Volatile Organic Compounds, and Chlorinated Biphenyls were not detected (ND) at either site. All reported results were within defined laboratory quality control objectives, unless listed below with the following *qualifications*. The explanations can be found in the case narrative on page 4 of the Con-Test report.

O-03 Two incompletely resolved aroclors were detected. The Aroclor with the closest matching pattern, found in sample 2, was reported as Aroclor 1260 [2C] in the amount of 0.40mg/Kg dry.

R-05 In sample 1 the laboratory fortified a blank duplicate RPD outside of the control limits. A reduced precision is anticipated for any reported value for the compound Bromomethane.

V-16 The response factor was less than the method specified minimum acceptable value. Reduced precision and accuracy may be associated with reported result for 1,4-Dioxane.

V-*20* Continued calibration did not meet method specifications and was biased on the high side. Data validation is not affected since sample result was ''not detected'' for the compounds Acetone and Carbon Disulfide.

Metals

Lead was found to be 27mg/Kg dry in sample 1, and 83mg/Kg dry in sample 2 analyzed by Con-Test Laboratory. These values were considerably higher than the values obtained from Paige Laboratory at UMASS and exceeded the optimum range of less than 22mg/Kg provided by Paige Laboratory. However, this range is provided by the lab and ''represents the normal range found in soils are for reference only.'' Lead is considered a hazard at 400ppm in bare soil in children's play areas and 1200 ppm average in residential yards according to the EPA Hazard Standards TSCA Section 403. The values measured in Lake Warner sediments are considerably lower.

Bathymetric Survey

A Garmin GPS/Depth Finder was used to collect depth measurements in sections of the lake in October/November 2015. Additional mapping of the lake bottom, combined with traditional survey methods for quality control, will be used to complete bathymetric mapping of the lake in 2016.

Discussion

Water Quality

Water quality measurements were affected by an abnormally dry spring and summer. The amount and timing of agricultural water withdrawn from the Mill River is undocumented. Sample sites and methods were chosen to allow comparison and trending with earlier studies. Results were subject to climatic conditions with regard to temperature, dissolved oxygen, and transparency. Temperatures were normal for a warm water lake, transparency improved from the 2003/2004 study. The significant reduction of dissolved oxygen compared to previous values from the same site and depth is the clearest indicator that overall lake health has declined over the last decade. Low oxygen levels can impair health and growth rates of fish and other aquatic organisms.

Phosphorus

Nutrients within the lake and tributaries were not sampled with the same frequency and quality assurance/quality controls as the 2003/2004 effort. Wet samples were difficult to obtain due to dry conditions. The time and effort involved to collect samples as well as attend to other components of the monitoring program affected the frequency of nutrient sampling. We are confident of the quality assurance of the sample collection process, performed by the same personnel consistently throughout the season. Funding limitations did not permit replicate sampling of previous sites. The dredging of UMASS Campus Pond made sampling there impossible.

Despite the limitations of the monitoring program, the data collected is within acceptable levels of variability when compared to the geometric mean of samples collected from the 2003/2004 study. Trends suggest, even with only one sample point at most locations, that phosphorus loading and bacterial pollution are coming from tributaries in the watershed. The relative increase or decrease of pollutant levels from 2003/2004 to 2015 is relative to the frequency of measurements taken. The relevance of the 2015 data is that in most cases these pollutants are still present at levels higher than state and federal thresholds. Three out of the five tributaries sampled had phosphorus levels twice as high as the EPA criteria for streams of less than 30ug/L. Knightly Brook, the only stream directly entering the lake has a phosphorus level almost six times the EPA criteria for streams, while this is a small tributary and actual loading rates may be low, this levels of Phosphorus in this brook are unusually high.

Lake Warner is located in the Eastern Coastal Plain ecoregion (region XIV) defined by US EPA for purposes of developing ecoregional nutrient criteria; more specifically, it is found in Level III Ecoregion 59: Northeastern Coastal Zone (source: USEPA Nutrients: Ecoregional Criteria http://www.epa.gov/sites/production/files/2014-08/documents/criteria-nutrient-ecoregions/).

EPA has established criteria for ecoregion XIV of 8ug/L Total Phosphorus for lakes and 31.25 ug/L for streams. According to the EPA, "The criteria are empirically derived to represent conditions of surface waters that are minimally impacted by human activities and protective of aquatic life and recreational uses. The information contained in this document represent starting points for States and Tribes to develop (with assistance from EPA) more refined nutrient criteria." The criteria shown here are given

as a general guideline for interpreting data from this study. They do suggest that most of the tributary sites exceeded protective levels during the sampling period in 2015. The single sample taken in June in Lake Warner was twice the protective levels established by EPA.

The MADEP 2001 Total Maximum Daily Loading Study suggests that a significant source of phosphorus available for plant growth is found in the lake sediments. Internal loading of phosphorus can be a significant source of nutrient loading in shallow, eutrophic lakes. We did make an effort to obtain sediment samples during the 2015 sampling season. A detailed analysis of phosphorus loading from the lake sediments is beyond the scope of this report.

A considerable amount of research has been done in recent years on sedimentary phosphorus, particularly focusing on environmental conditions influencing its availability to contribute to nutrient loading. Total Phosphorus can be a poor indicator of internal loading due to highly mobile and immobile phosphorus fractions. Al and Fe bound phosphorus can become soluble under anoxic conditions. Ca and Mg also bind phosphorus in lake sediments and are found to be more stable. Phosphorus release from lake sediments under natural conditions are therefor in a fluctuating state depending on the chemical makeup of the sediments and the amount of oxygen present at the water/sediment interface. Oxygen concentrations are dependent on inflow of fresh water and the hydrodynamics present due to lake morphometry (shape).

Determining how much phosphorus loading is occurring due to loading from the sediments is beyond the scope of this monitoring effort. We can make some deductions based on the literature and other water quality data we collected this year:

- The sediment samples show that Lake Warner sediments contain abundant Al, Fe, Mg and Ca, all effective at binding phosphorus.
- Lake Warner has anoxic conditions in portions of the lake and during portions of the year, depending on inflow, light transparency, and Biological Oxygen Demand (BOD) from decomposing plant material.
- Al and Fe bound phosphorus can become soluble under anoxic conditions and contribute to internal loading of Phosphorus.

Release rates of phosphorus under anaerobic conditions in Lake Warner could be more discretely measured and understood relative to their contributing to the overall phosphorus loading in the lake. Until then the focus of lake management activities should be on improving conditions in the lake to deter anoxic conditions.

While reduction of internal loading should not be ignored as a potential source of phosphorus to Lake Warner, recommended management strategies should focus on external loads (e.g. riparian buffer strips, on-farm comprehensive nutrient management plans, stormwater retention areas, and constructed wetlands/detention areas). These will likely have the greatest influence on reducing phosphorus loads to the Mill River and Lake Warner. Continued monitoring of all sources of phosphorus loading is encouraged to address and adapt methods to reduce eutrophication problems in the lake.

Vegetation

All ten vegetative transects were established this season. However FoLW was unable to perform detailed data collection at every 15M interval data point. This is a massive, time consuming undertaking performed solely by volunteers. A major limitation in 2015 was the inability to navigate on Lake Warner after August due to the massive, annual weed infestations that effectively close off two thirds or more of the lake. It then becomes impossible to navigate by motor, sail, paddle, oars or poles. FoLW has recently gained limited use of specialized vessels that can operate in this environment. Only limited analysis or presentation of the transect data can be made until the remaining transects are surveyed in detail. However, we have specifically sought answers in regard to the maturation, dominance and succession of various species and their mutual interactions. It is probable that FoLW will establish additional transects in 2016, specifically to collect information on riparian and terrestrial plant species on the edges of the lake.

Coontail *(Certaophyllum)* is the most abundant aquatic plant in the lake. Since it is rootless, it can be found anywhere there is sufficient light and nutrients for it to grow, whatever the water depth or conditions. It is frequently found intermixed with other plants such as Water Lilies, Water Chestnut or Big Leaf Pond Weed. It essentially forms a second canopy beneath many of the emergent plants. Technically a submergent, it grows so thickly in places that it pushes above the surface. It is the major hindrance to navigation, fishing and recreation in Lake Warner. It entangles propellers and clogs the cooling systems of outboard motors. It is impossible to paddle, row or pole through. It acts a nursery for Water Chestnut. It is the largest contributor to anoxic plant debris on the bottom. It is reducing the available fish habit. If an efficient way could be found to harvest Coontail from the lake it could provide a way to remove excess nutrients from the lake.

The upper or eastern reaches of the lake are dominated by Elodea, an invasive, possibly due to cooler and faster flowing water and sandy sediments. There is an infestation of Elodea in a cove in the western section of the lake which may indicate a lower temperature under water spring. It is difficult to navigate canoes and kayaks in Elodea infested areas.

There is intense plant competition at the edge of the light penetration zone. Big leaf pondweed *(Potamogeton spp.)* seems to outcompete Coontail where the depth exceeds 2m and there is limited light. Its stalks are fully developed and seeding by June. It entangles boat propellers and limits navigation and recreation.

Both Yellow Water Lily *(Nuphar variegata)*, and European White Water Lily *(Nymphaea alba)* get a substantial growth head start from well-established, nutrient laden rhizomes and large leaves that block out light penetration to the water immediately beneath the plant. It is difficult to navigate through areas of thick growth. The Leaves and fibrous stems inhibit rowing or paddling and fowl propellers. Water Chestnut apparently has a competitive edge in association with White Water Lily and Coontail. Elodea is found in many of these niches as well. These

plants, when not cluttered with rotting, anoxic debris, do provide nursery space for fish and other aquatic organisms.

Lake Warner suffers from large algal blooms every spring. Many of these persist late into the year, hidden beneath surface vegetation. The only way to effectively prevent this *in the short term* is to physically remove plant debris from the lake. Herbicides can be effective, but are only temporary solutions, are expensive and may have negative impacts on other species. A long term solution involves reduced nutrient loading from the watershed and Phosphorus binding in the sediment. The solution is to reduce nutrient loading to the lake from the watershed, and to utilize in-lake treatments

Volunteer Invasive Plant Removal and Monitoring

Cynthia Boettner, Invasive Plant Coordinator for the USFWS Conte Wildlife Management Refuge, with The Friends of Lake Warner and the Mill River listed as a cooperator filed a Request for Determination of Applicability (RDA) with the Hadley Conservation Commission in May, 2015. The Conservation Commission made a negative determination, indicating that a Notice of Intent (NOI) did not need to be filed. Hand pulling of water chestnut was permitted using volunteers under the guidelines outlined in the RDA for a period of three years, through 2017

FoLW removed a total of 2,218 pounds of Water Chestnut (WC) from Lake Warner in 2015. FoLW advertised and sponsored three public volunteer WC harvests in 2015. The USFWS Conte Wildlife Refuge participated in the July effort and also brought Youth Conservation Corps (YCC) members for another half day later in the season. FoLW trained volunteers, ran an informational table at the boat ramp. FoLW coordinated for and transported six to twelve canoes, two Jon boats and a Lund motorboat to use as a barge/ transport for bagged water chestnut and as an emergency support craft. FoLW provided personal flotation devices, bags, water, gloves and a hand washing station for the event. FoLW had approximately 45 volunteers participate in these events. Volunteers contributed over 205 hours during these three days. This does not include the planning and preparation time of the Executive Director and FOLW board members.

Previous removal totals have been estimates. The 2015 harvest of water chestnut was weighed to ensure accuracy. This is in keeping with FoLW efforts to manage the lake with greater scientific precision. The 2018lb. removed in 2016 is a third of the 2014 total. This is over a 65% reduction in weight from last year. FoLW attributes this to starting earlier in the season and to continuing with an aggressive program of weekly patrols by trained and equipped personnel well into the onset of cold weather.

Lake Warner may be the only lake of comparable size in Western Massachusetts where Water Chestnut may be said to be under control. While FoLW is very pleased with all the success controlling water chestnut in Lake Warner, we recognize the urgent need to also address the reduction of nuisance vegetation in the lake. It has become quite obvious that categorizing aquatic plants as native and invasive and trying to separately control only the invasive plants whilst leaving the native weeds uncontrolled actually hinders the development of a rational, coherent, integrated and effective strategy to return the lake to health.

Extreme plant growth in aquatic systems is referred to as nuisance aquatic vegetation. Controlling nuisance aquatic vegetation has been recommended in Lake Warner in every survey or evaluation of the pond since the 1950's. The next steps are to complete the documentation and mapping of the vegetative communities present in the lake, and to produce an Aquatic Vegetation Management Plan that is accepted by the Hadley Conservation Commission and DEP.

Terrestrial plants

Terrestrial invasive plant species can be found throughout the lake perimeter. These include Purple Loosestrife, Asiatic Bittersweet, Japanese Knotweed, Rosa multiflora and others. FoLW began cataloguing them with GPS locations in 2014. FoLW will begin reporting them on Outsmart, an online mapping and invasive data collection program in 2016. We would like to be able to address pioneer infestations within the lake perimeter before it becomes overwhelmed.

Additional Surveys conducted in 2015 by other entities

Fisheries

The Massachusetts Division of Fisheries and Wildlife conducted an electrofishing survey of Lake Warner in June. Figure 6 shows the 13 species collected during this survey. This sampling effort was not intended to provide a population estimation of the lake or to predict fisheries production in the lake. It provides a ''snapshot'' of lake conditions at this time. The high diversity of species collected, the large size of individual bass collected and quantity of forage fish indicate a very productive lake ecosystem, with a high diversity of native fish species and self-reproducing populations of historically stocked species. Lake Warner has not been stocked by MAFW since 1962 and 1963 when (1,345) and (1,100) Largemouth bass were stocked following the reclamation of the lake. Figure 7 shows the size and weight of the largemouth bass surveyed in the lake in 2015.

Jason Stolarski, Masswildlife Aquatic Ecologist with a Largemouth Bass from Lake Warner fisheries survey, June, 2015. (Photo by Leanda M. Fontaine Gagnon)

Figure 6. 2015 Fish Species Sampled in Lake Warner

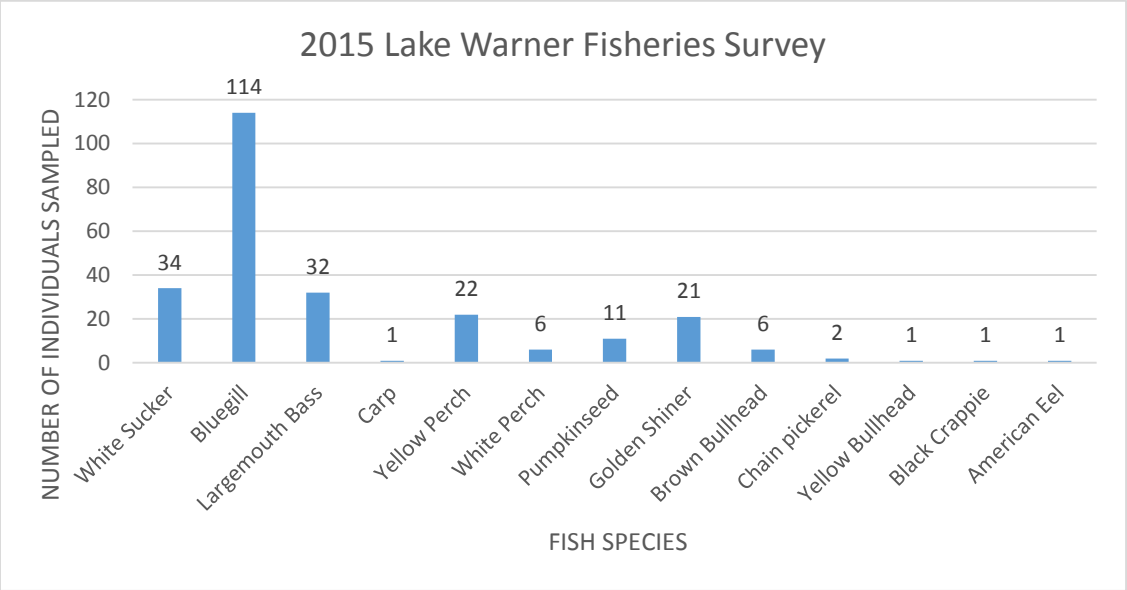
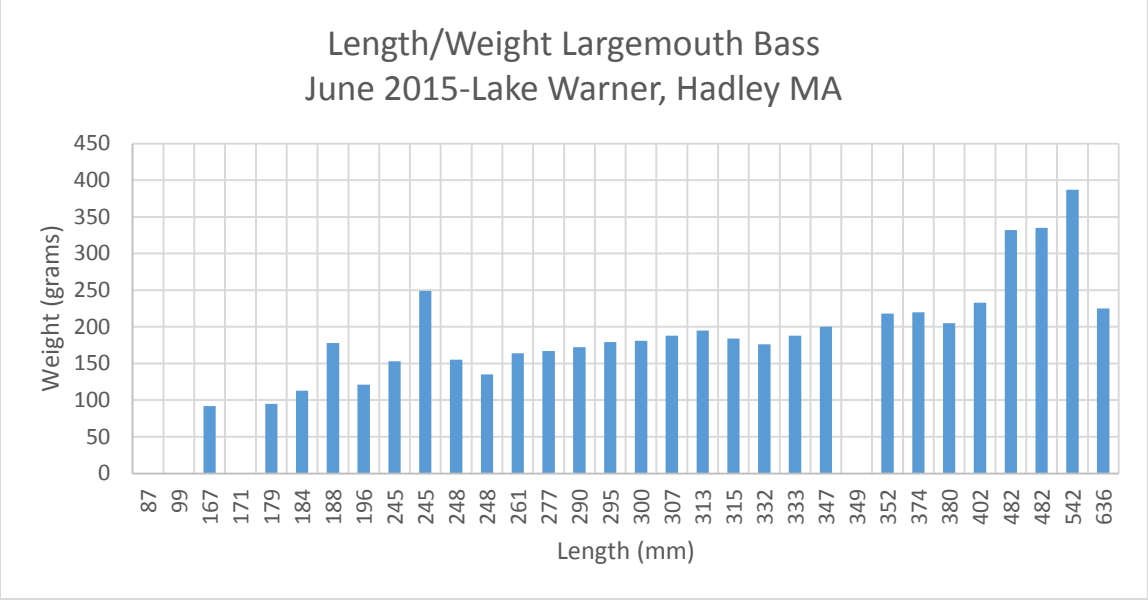


Figure 7. Length and Weight of Largemouth Bass, Lake Warner 2015



<u>Waterfowl</u>

Lake Warner's Mute swans produced five cygnets this spring. Three survived. There are at least two blue herons and a white egret was seen for several weeks in August.

A waterfowl survey is conducted at Lake Warner intermittently by the Massachusetts Division of Fish and Wildlife. Personal communication with Masswildlife staff revealed that they counted 42 wood ducks and 8 Mallards in 2015.

There was geese poaching in late November and abandoned kills were found in the lake.

Mammals

Beaver were trapped out on the Mill River some thirty years ago. But they have returned. They have been very active above the upper lake and on Mill River East of the lake. During the driest portion of the summer, nearly the entire Mill River channel was blocked by beaver dams. There are at least two active lodges in the lake and Mill River Inlet area. Muskrats were frequently observed during the sampling season. Evidence of their feeding activity including partially and fully consumed Water Chestnut seeds, as well as piles of roots and shoots observed throughout the upper lake.

Bathymetric Surveys and mapping

FoLW has obtained access to a Garmin GPS EchoMap instrument which is enabling us to make fine scale bathymetric (depth) and surface temperature maps of Lake Warner. Masswildlife has committed to helping produce the final map the completed map will then be made available to the public.

Summary/Conclusion

FoLW has gone to great effort to scientifically measure the condition of Lake Warner. This is the first effort to do so in many years and a great deal of work remains to be done.

Portions of Lake Warner are effectively dead at certain parts of the year. The lake is so choked with weeds and rotting vegetation that parts of it have zero dissolved oxygen. The weeds are so thick that over two thirds of the lake are un-navigable three or more months of the year, half the recreational summer season. It is impossible to motor, sail, paddle, row or even pole on over half the lake. The problem isn't just invasive species, the real problem is nuisance species that are out of control.

Changing land use issues will continue to affect the Mill River watershed. The loss of forests and wetlands and increasing urbanization and development are putting pressure on the water quality of the tributaries of the Mill River. More so than agriculture. If steps are not taken to address point-source and non-point source pollution and storm water, increasing nutrient and pollutant loading are going to cause more problems. None of this is new, much of it was documented in 2003. Recreational users of the lake, particularly those who enjoy boating and fishing, are have been experiencing the consequences of our inaction for years. Increased bacteria levels, algae filled waters, low dissolved oxygen and fish kills are all probable outcomes unless aggressive action is taken soon.

The good news is that the lake is still beautiful and the water is surprisingly pollutant free. Efforts must be made to support, improve, enhance wetland functioning along the Mill River above the lake, this wetland complex is a critical filter for the stormwater and non-point source pollution coming from urbanized portions of the watershed. We look forward to working with both the towns of Hadley and Amherst to improve the monitoring, assessment, and planning for non-point source and stormwater

pollution efforts in the supply areas of the watershed. Addressing the impaired portions of the Mill River, reducing bacteria levels and working toward meeting the TMDL goals for Lake Warner should be goals that we can all work together to achieve.

Recommendations and work plan for 2016:

FoLW will continue monitoring and scientific evaluation of the lake. We will complete and analyze the transect data. This will enable us to make an aquatic plant species map. FoLW will GPS depth survey the lake and produce an accurate bathymetric map. We will attempt to further pinpoint both E.coli bacteria and elevated nutrient sources in the Mill River watershed. We will expand sediment testing of the lake, particularly in the shallow coves along the northern shores. We will continue to evaluate nutrient contents, heavy metals, VOC's and PCB's. We will continue to measure transparency, DO and temperature from May-September. We will continue to refine our Water Chestnut Control Model. FoLW will expand its educational work within the community and engage in cooperative activities with other local lake associations.

There are regulations regarding impaired waters in which Total Maximum Daily Loads (TMDLs) of pollutants have been established. The research initiated by FoLW will contribute to this response. The Friends of Lake Warner and the Mill River have asked both the towns of Amherst and Hadley to cooperate to meet TMDL objectives and to commit to improving conditions in the Mill River and Lake Warner for the benefit of both the public and wildlife.

Dam repairs are scheduled to begin on 1 July 2016 and scheduled to be completed within six weeks.

Lake Warner in late summer during peak of aquatic vegetation growth. Uncontrolled nuisance aquatic vegetation and algae is preventing light transmission into the lake causing low dissolved oxygen levels that impair lake health. August, 2015
(Photo by Jason L. Johnson)

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Appendices