Lower Bolton Lake
Status Up-Date

Prepared for:

Town of Bolton

Bolton, CT

Prepared by:

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Mansfield, CT

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June 19, 2017

October 31, 2017

Purpose

This report is an update on three primary Threats to Lower Bolton Lake listed in NEAR 2016 report. Threats are defined as:

1. **Proliferation of Southern Naiad**

   Southern Naiad[1] was removed from the Threat List in 2016 based on all consecutive survey data showing continued lack of presence since application of the herbicide; Fluridone in 2013.

2. **Severe Cyanobacteria Blooms**

   (1) August 2012 cyanobacteria numbers reached 240,000 cells/mL[2]. Cyanobacteria cell density increases above about 20,000 begin to cause declines in water clarity.

   (2) Cyanobacteria numbers began increasing in deep water in early June 2013 prompting a preemptive copper sulfate on June 20, 2013; Cyanobacteria numbers immediately subsided. Green Alga and diatoms persisted for remaining part of the season.

   (3) Cyanobacteria increased in September 2015. Copper sulfate was added on September 2, 2015 causing cyanobacteria numbers to decrease rapidly to be replaced by very high numbers of Green Alga causing the lake to have dense cloudy green color.

   (4) The 2016 season showed clearer water dominated by Diatoms and Green Alga with very few cyanobacteria until a brief spike in numbers ~54,000 cells/mL in early September. The cyanobacteria rapidly disappeared from the lake after that to be replaced by very high numbers of Green Alga.

3. **Invasive Aquatic Plants**

   The invasive aquatic plant; variable-leaved milfoil was last seen in 2012, the invasive aquatic plant; fanwort was last seen in 2013. Curly-leaf pondweed first seen in August 2014, has developed a few established beds in the northeast sector of the lake and several isolated beds scattered around other parts of the lake. Early season treatments attempt to kill the plant prior to its reaching maturity.

[1] Najas guadalupensis

[2] mL = milliliter is a small unit of liquid measure equal to 0.034 ounces

Cyanobacteria Blooms

Increased **phosphorus** has been implicated as the principal driver of phytoplankton growth in Lower Bolton Lake, however secondary nutrients; **nitrogen** and **iron,** appear to be important causal agents of severe cyanobacteria blooms.

Targets and thresholds given here are used to assess Monitoring Data.

Primary and Secondary Causes

- **Phosphorus** – Total phosphorus is the nutrient limiting cyanobacteria growth.
  - Goal for total phosphorus in upper waters is <10ppb.
  - Upper tolerable level of phosphorus is 20ppb.
- **Nitrogen** – Nitrogen levels are linked to cyanobacteria increases.
  - Goal for total nitrogen <200ppb.
  - Upper tolerable level is 600ppb.
- **Iron** – Increased iron levels are linked to high cyanobacteria numbers and poor clarity.
  - Goal for total iron <50ppb.
  - Upper tolerable level is 150ppb.

Primary and Secondary Impacts

- **Water Clarity** – The Secchi disk depth is a measure of plankton density.
  - Goal for water clarity >3 meters.
  - Upper tolerable level is clarity 2m.
- **Cyanobacteria Cell Numbers and toxins** – Increasing cell numbers causes diminished water clarity and increased probability of presence of cyano-toxins.
  - Goal for cyanobacteria numbers <20,000 cells/mL.
  - Upper tolerable level is cyanobacteria of 75,000 cells/mL.
- **Dissolved Oxygen –** dissolved oxygen loss in bottom water is accelerated by dead phytoplankton settling to the bottom during dense blooms.
  - Goal for dissolved oxygen should be above 5ppm at all depths.
  - Dissolved oxygen below 1ppm should not occur above 5meters (16ft).

Cyanobacteria: Primary and Secondary Causes

Phosphorus

Goal for total phosphorus in upper waters is <10ppb. Upper waters are the 1 and 3 meter samples. Upper tolerable level of phosphorus is 20ppb.

Upper waters-------------------------------------

2011 =9 ppb _ one sample,

2012 =Average **18ppb**, max 26ppb,
No values of less than 10ppb,
33% of samples 20ppb or higher, (N=12)

2013 =Average **28ppb**, max 49ppb,
No values of less than 10ppb,
82% of samples 20ppb or higher, (N=28)

2014 =Average **22ppb**, max 32ppb,
No values of less than 10ppb,
70% of samples 20ppb or higher, (N=26)

2015 =Average **25ppb**, max 36ppb
No values of less than 10ppb,
76% of samples 20ppb or higher, (N=29)

2016 =Average (1) **19ppb**, 63ppb
Average (2) **17ppb**, max 26ppb (removing one high value of 63ppb)
No values of less than 10ppb,
47% of samples 20ppb or higher, (N=30),

Bottom waters------------------------

2011 =52ppb _ one sample

2012 =Avg. 26ppb, max 32ppb,

2013 =Avg. 43ppb, max 83ppb,

2014 =Avg. 29ppb, max 40ppb,

2015 =Avg. 37ppb, max 58ppb,

2016 =Avg. 33ppb, max 94ppb,

General pattern of phosphorus concentration:

1 –2013 and 2015, showed lowest phosphorus in spring with rapidly increasing concentrations during the season to reach maximum values in Oct/Nov.

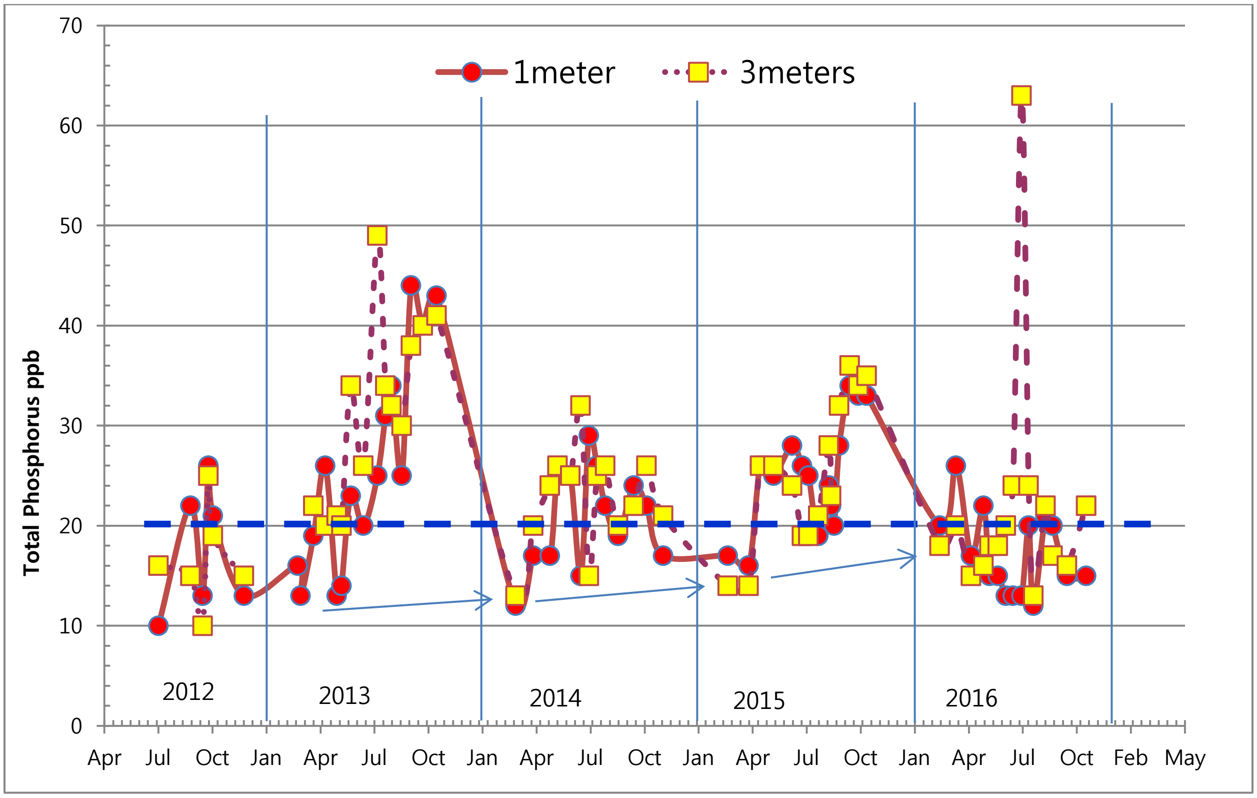
2 -2012 and 2014 also showed lowest phosphorus in spring but showed maximum values in August followed by declines in fall.

3 –2016 showed an opposite pattern with high values in the spring and declining concentrations during summer to reach lowest values in August.

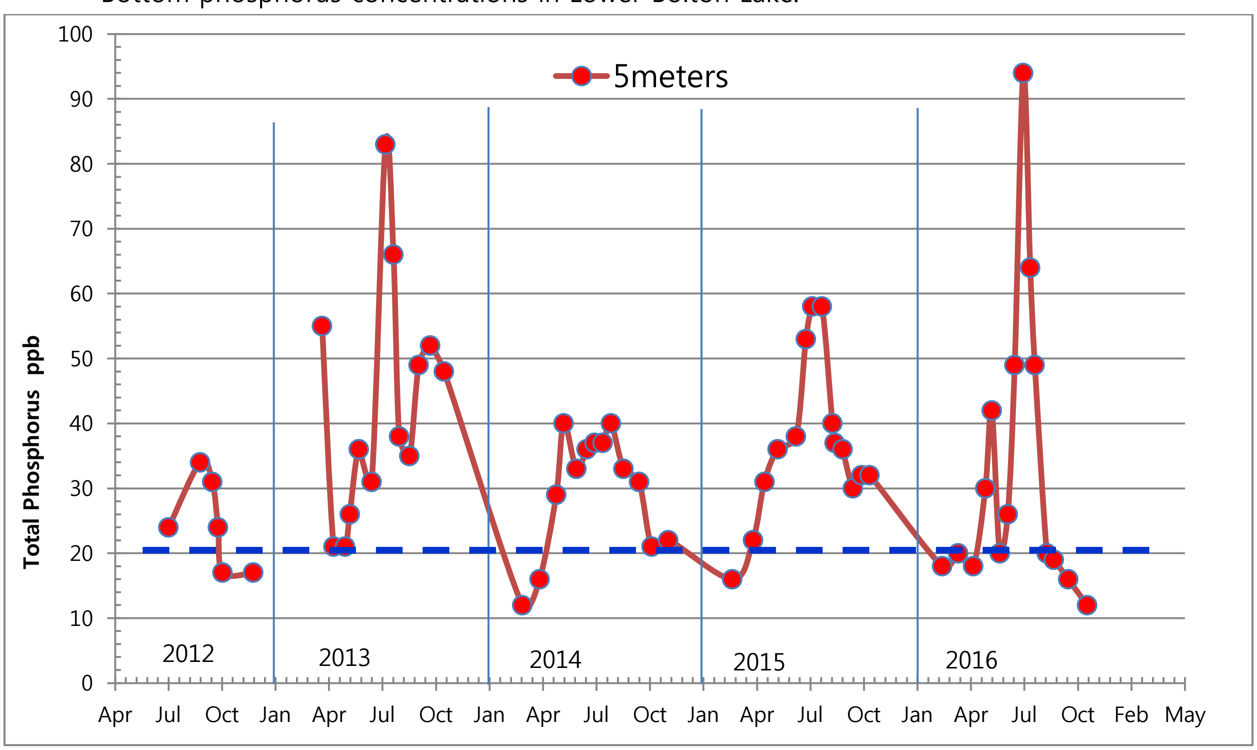
4 –Generally, 2016 phosphorus concentration at the 1 and 3 m depths were identical verifying that these depths represent the mixed layer of the lake. On two occasions 3m phosphorus exceeded 1m values due to increased concentrations at 5m.

5 –Bottom water phosphorus showed mid-summer increases each season. Duration of >20ppb in bottom water was considerable less in 2016 than in the prior three years.

Trend in 1m and 3m phosphorus concentration in Lower Bolton Lake:



Bottom phosphorus concentrations in Lower Bolton Lake:



Nitrogen

Goal for upper waters is total nitrogen <200ppb.

Upper tolerable level is 600ppb.

Upper waters--------------------------------------

2011 =307ppb _ two samples,

2012 =Average **835ppb**, max 2,150ppb,

No values of less than 200ppb,

75% of samples 600ppb or higher, (N=8)

2013 =Average **508ppb**, max 1,080ppb,

No values of less than 200ppb,

15% of samples 600ppb or higher, (N=26)

2014 =Average **323ppb**, max 435ppb,

1 value less than 200ppb,

0 samples >600ppb, (N=26)

2015 =Average **498ppb**, max 980ppb

No values of less than 200ppb,

27% of samples 600ppb or higher, (N=29)

2016 =Average **327ppb**, max 539ppb

No values of less than 200ppb,

0 samples >600ppb, (N=30),

Bottom waters-------------------------

2011 =934ppb _ one sample

2012 =Avg. 1,137ppb, max 2,360ppb,

2013 =Avg. 775ppb, max 1,496ppb,

2014 =Avg. 401ppb, max 742ppb,

2015 =Avg. 807ppb, max 1,679ppb,

2016 =Avg. 420ppb, max 768ppb,

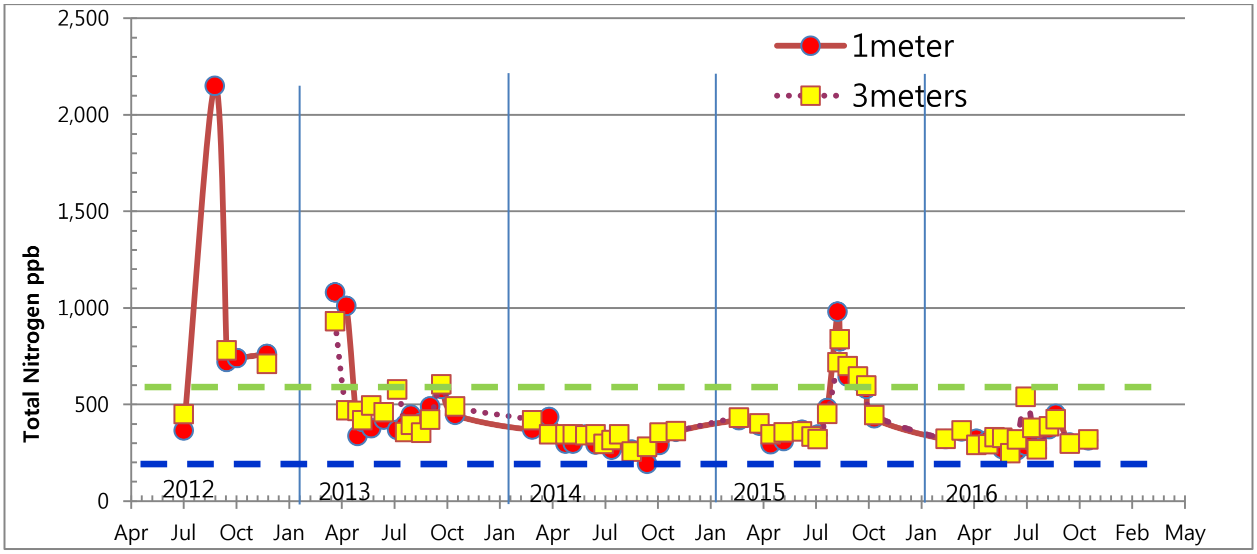
Total nitrogen trends in the mixed layer of Lower Bolton Lake between 2012 and 2016 are shown below, important aspects are:

1 - Total nitrogen was exceptionally high during the bloom in 2012, similar levels have not been seen in the lake since that time.

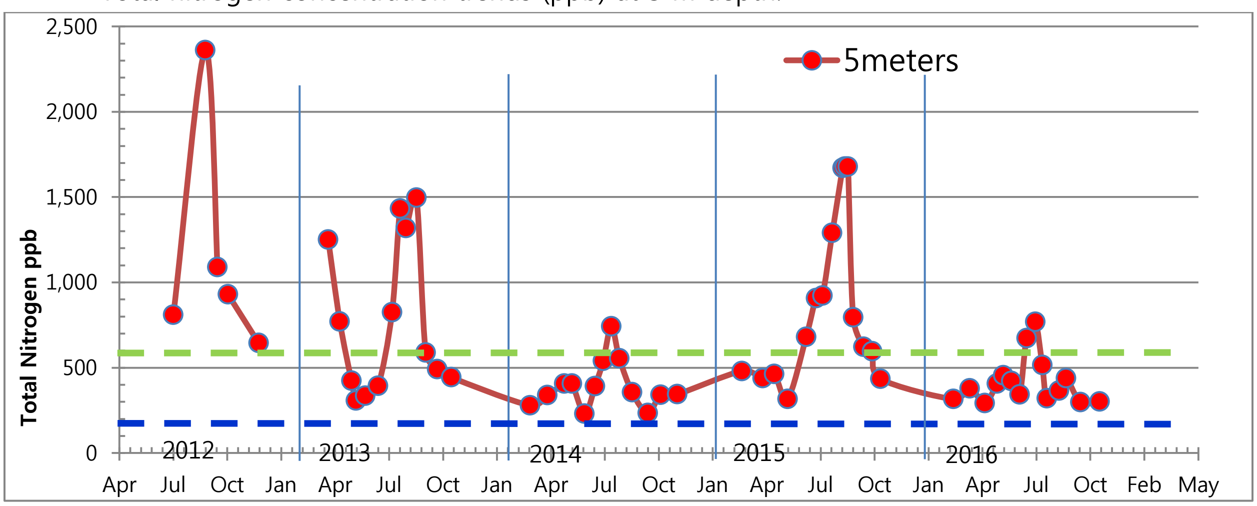
2 – Two episodes of 1,000ppb concentrations have occurred since 2012, once in early 2013, and next in late August 2015. Each associated with copper sulfate treatments to stop cyanobacteria blooms.

3 - Ammonium nitrogen at 5m is consistent with duration of coverage with anoxic water.

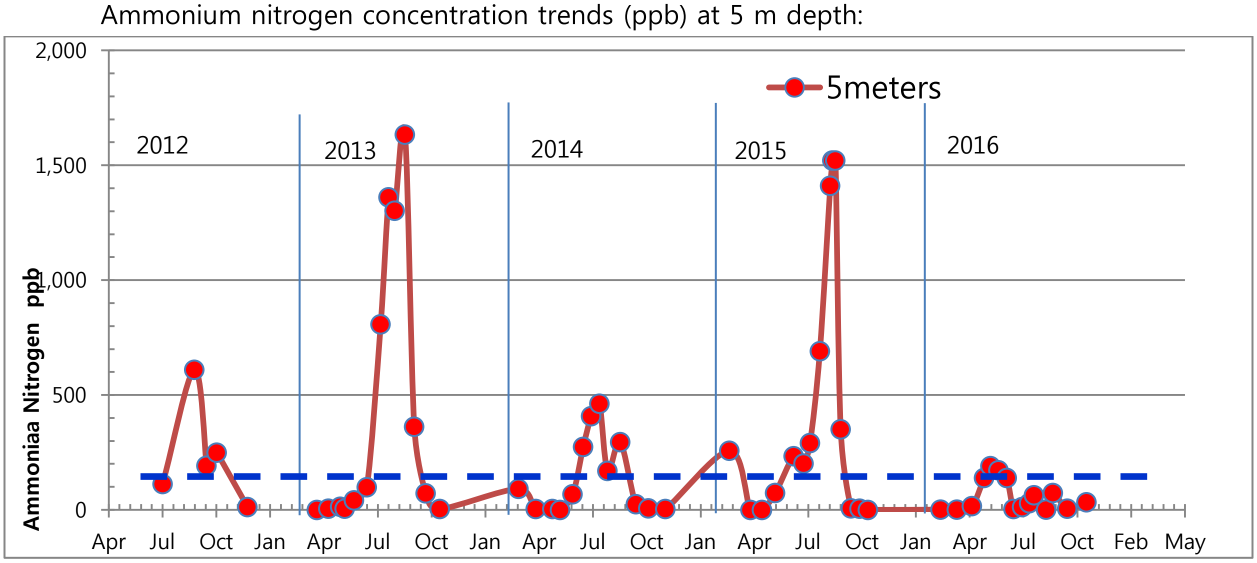
Total nitrogen concentration trends (ppb) at 1 m and 3 m depths:



Total nitrogen concentration trends (ppb) at 5 m depth:



Ammonium nitrogen concentration trends (ppb) at 5 m depth:



Total Iron

Goal for upper waters is Total Iron <50ppb.

Upper tolerable level is 150ppb.

Upper waters--------------------------------------

2011 =no samples,

2012 =no samples,

2013 =Average **396ppb**, max 446ppb,

No values <50ppb,

100% of samples >150ppb, (N=4)

2014 =Average **138ppb**, max 230ppb,

No values <50ppb,

36% of samples >150ppb, (N=11)

2015 =Average **208ppb**, max 426ppb,

No values of less than 50ppb,

70% of samples >150ppb, (N=23)

2016 =Average **186ppb**, max 1,030ppb,

No values <50ppb,

43% of samples >150ppb, (N=28),

Bottom waters-----------------------------

2011 =no samples

2012 =352_one sample

2013 =Avg. 10,383ppb, max 15,150ppb,

2014 =Avg. 1,371ppb, max 4,300ppb,

2015 =Avg. 2,109ppb, max 8,186ppb,

2016 =Avg. 1,801ppb, max 10,030ppb,

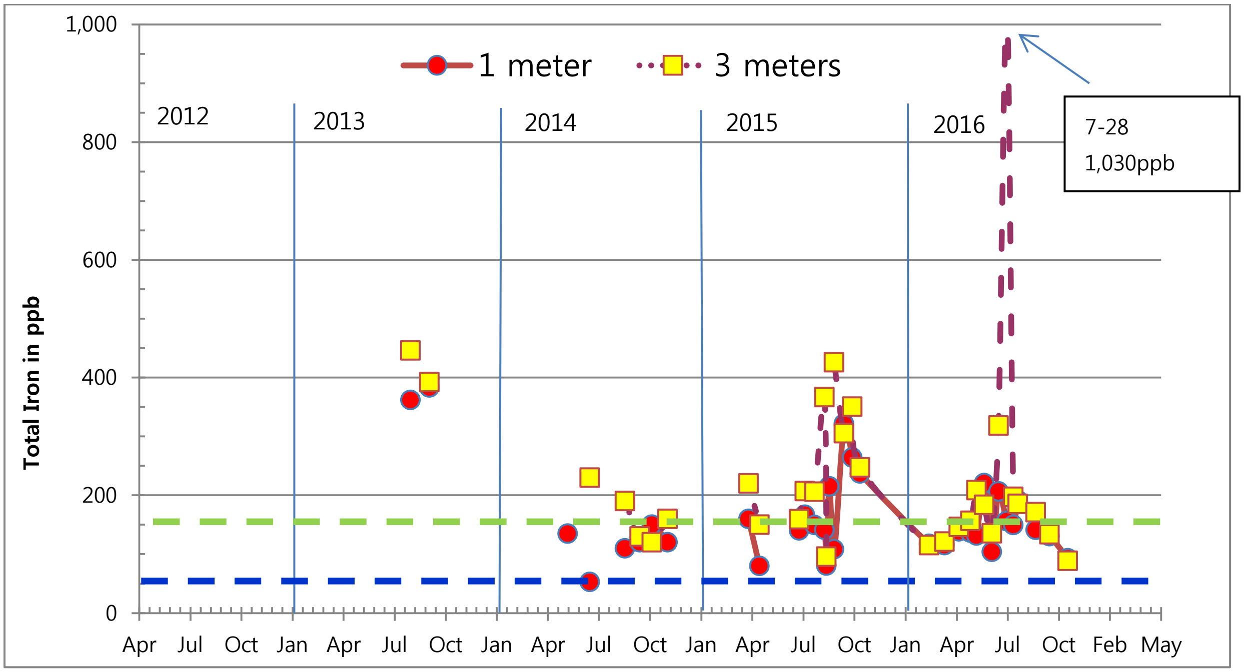
Total iron in oxygenated water should be low, while in anoxic water iron levels can be very high.

1- First measured in 2013, total iron was found to be considerably higher than background levels.

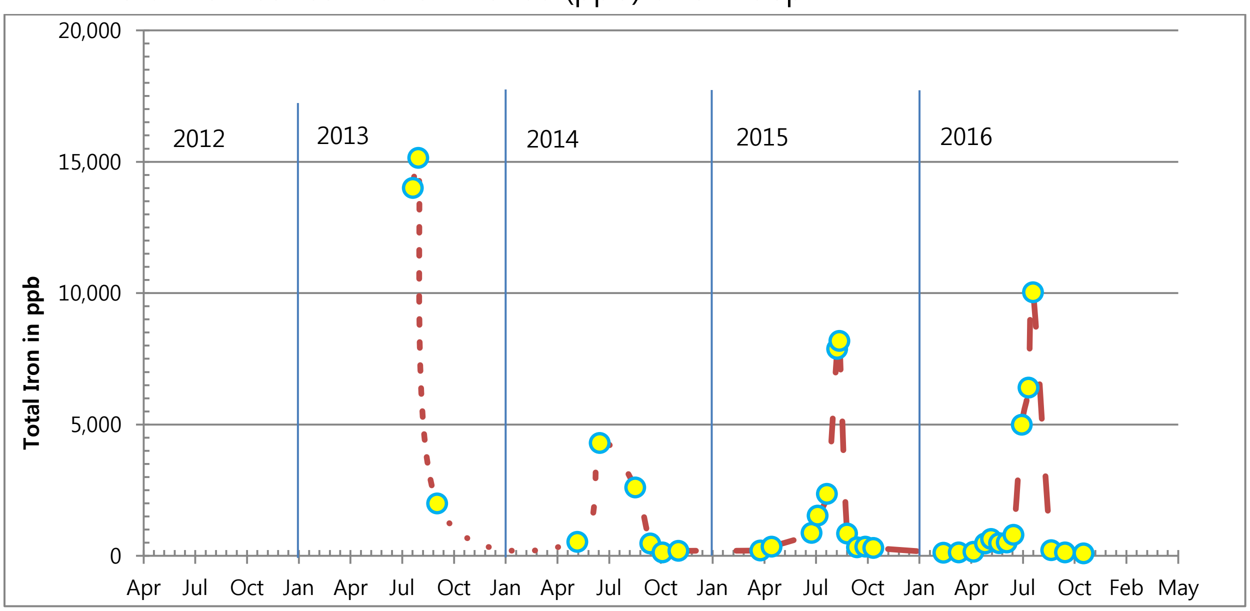
2 - Total iron concentration trends (ppb) at 1m and 3m depths trend with the increases occurring in bottom water during periods of anoxia.

3 – 2015 and 2016 saw lower total iron in upper waters although still present at higher than acceptable levels.

Total iron concentration trends (ppb) at 1m and 3m depths:



Total iron concentration trends (ppb) at 5m depth:



Primary and Secondary Impacts

Water clarity

Goal for water clarity is >3 meters.

Upper tolerable level is clarity 2m.

Upper waters--

2011 =3.7 meters _1 measurement,

2012 =Average 2.1 meters, max = 4.0m, min = 0.6 meters,

1 measurement >3m

50% of measurements <2m, (N=6)

2013 =Average 1.4m, max = 1.9m, min = 0.6m

No measurement >3m,

100% of measurements <2m, (N=13)

2014 =Average 2.1m, max = 3.1m (Winter under ice), min = 1.4m,

1 measurement >3m,

42% of measurements <2m, (N=14)

2015 =Average 1.7m, max = 3.1m (March), min = 0.7m,

1 measurement >3m,

60% of measurements <2m, (N=15)

2016 =Average 2.7m, max = 4.3m, min = 1.0m ,

4 measurements >3m,

33% of measurements <2m, (N=15),

The water clarity of Lower Bolton Lake between 2012 and 2015 is shown in chart below. Important aspects of the water clarity trend are:

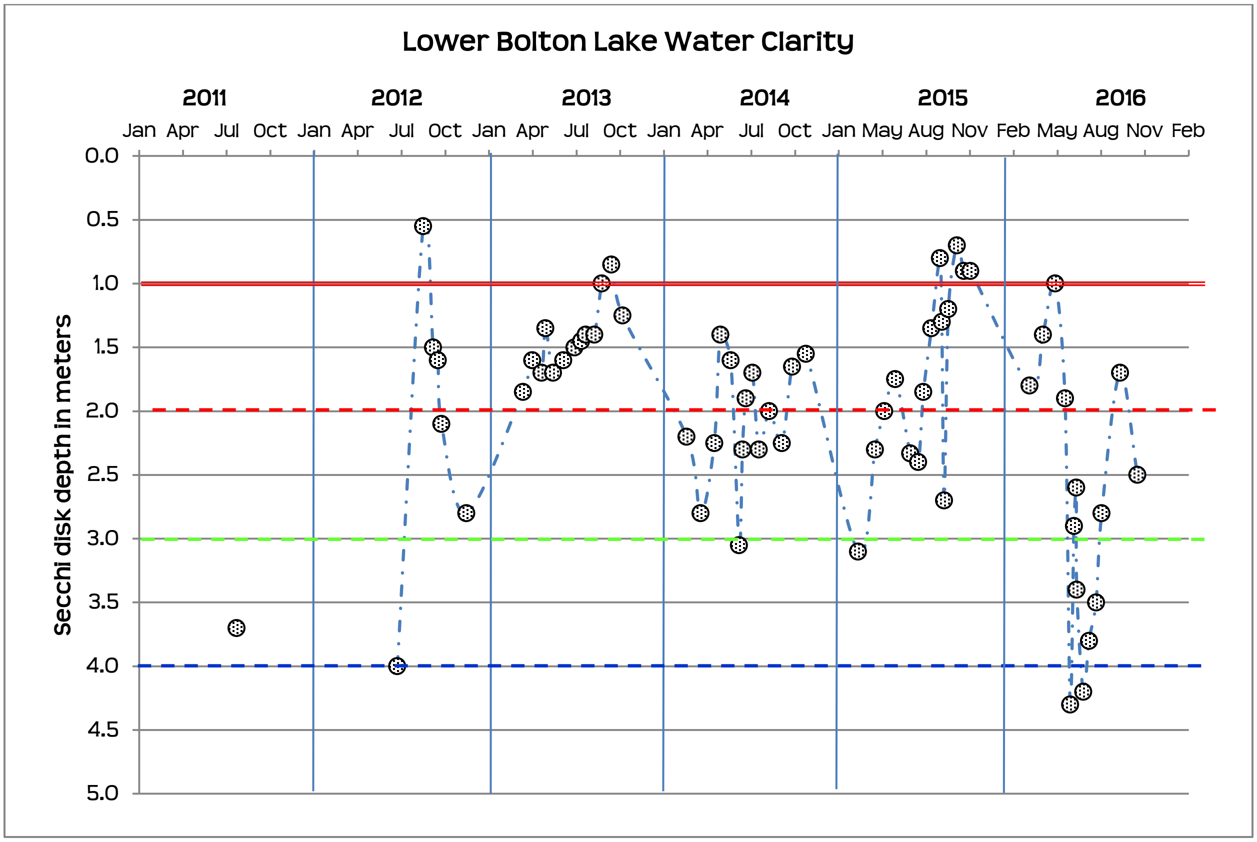
1 – Poorest clarity of 0.6 meters on August 27th, 2012 has not been repeated.

2 – Water clarity generally deteriorated through the seasons of 2013, 2014, and 2015 such that best clarity was in April and poorest seasonal clarity was in fall (often October).

3 – 2016 had clarity that was poorest in the April and showed steady improvement until best clarity of 4.2 meters on July 1.

4 – Although clarity declined after July 1 2016, the clarity didn't get bad as in prior years.

Water Clarity (Secchi disk depth) in Lower Bolton Lake during 2012-2016:



Cyanobacteria

Goal is cyanobacteria numbers <20,000 cells/mL.

Upper tolerable level is cyanobacteria of 75,000 cells/mL.

2011 =_1 measurement = retrieving archive to recount sample

2012 =max = 240,000 cells per mL

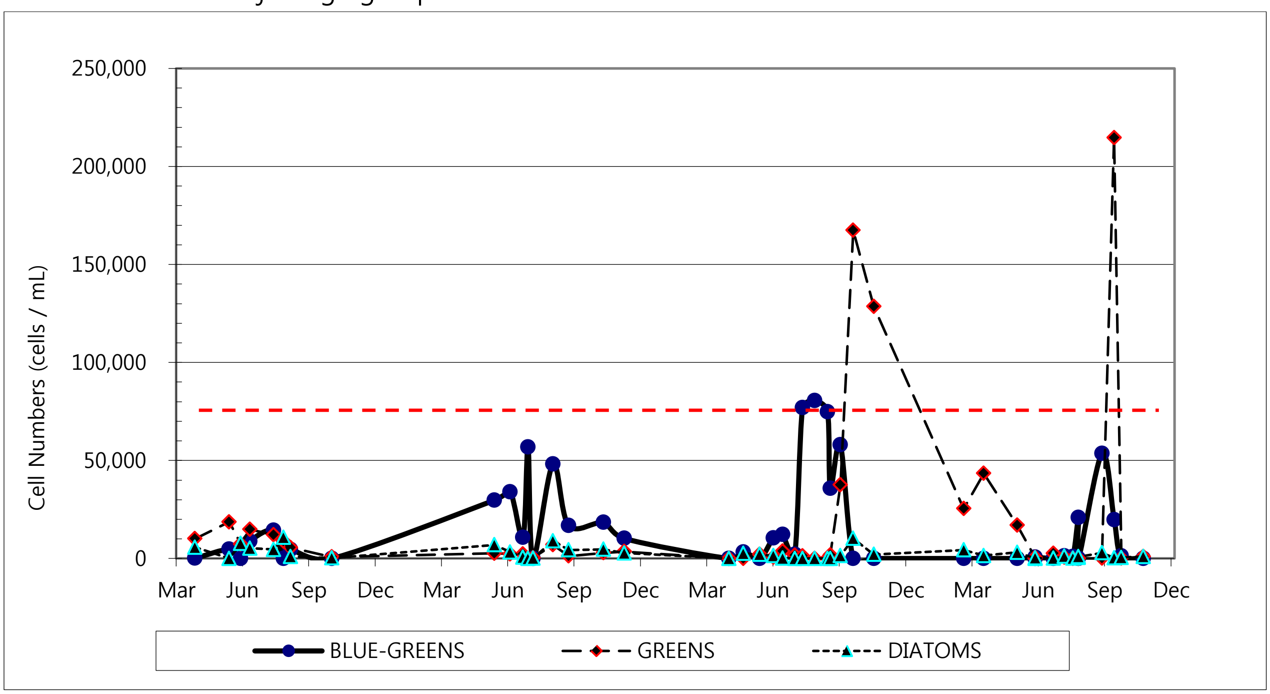
2013 =Average 4,063c/mL max = 14,286c/mL

2014 =Average 24,980c/mL max = 56,851c/mL

2015 =Average 27,232c/mL max= 80,544c/mL

2016 =Average 7,019c/mL max= 53,505c/mL

Trends in major alga groups in Lower Bolton Lake:



Dissolved Oxygen

Goal dissolved oxygen should be above 5ppm at all depths at all times.

Dissolved oxygen below 1ppm should not occur above 5meters (16ft).

2011 = 1 measurement Anoxic Boundary at 3.89m

5m =

2012 = AB max 3.79m

5m = 2 dates <1ppm

2013 = AB max 2.92m

5m = 6 dates <1ppm [June 21st – Sept. 11th]

2014 = AB max 3.18m

5m = 7 dates <1ppm [June 12th – Sept. 9th]

2015 = AB max 3.6m

5m = 9 dates <1ppm [May 28th – Sept. 18th]

2016 = AB max 4.5m

5m = 5 dates <1ppm [June 3rd - August 17th – not continuous]

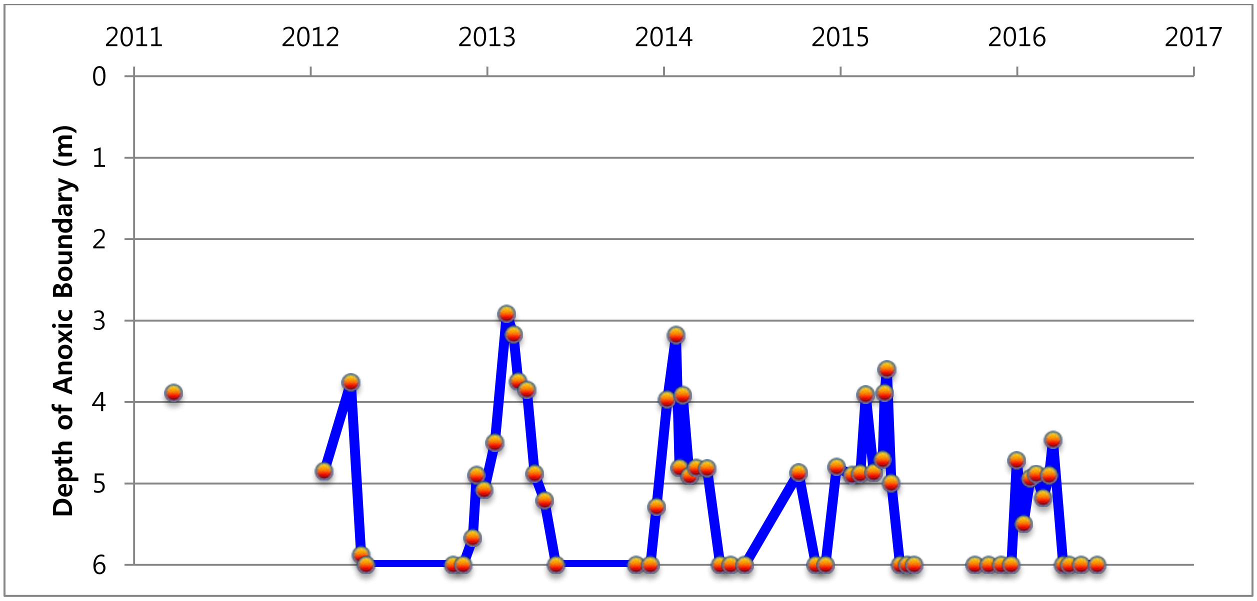
2013 - Dissolved oxygen demand and in deepest water was severe, with both significant amount of the water column without oxygen but also anoxic water covering almost half of the lake bottom sediments

2014 – Similar severe oxygen loss with duration of anoxia about the same as 2013 but not reaching the same extent of sediment coverage although still a large fraction 34% of the lake bottom was anoxic during the summer.

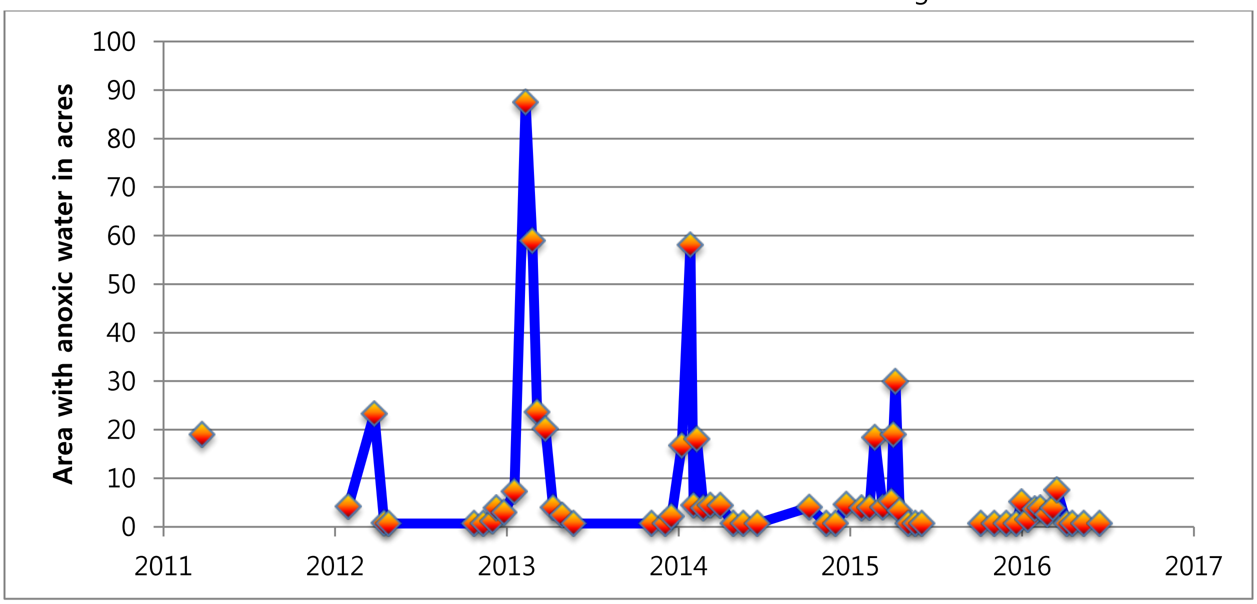
2015 – Severity and duration of oxygen loss in deep water about the same but large improvement in the height of the anoxic boundary and the area of the bottom sediments overlain by anoxic water 17%.

2016 – Severity and duration of oxygen loss further lessened over the last three years. Extent of anoxic water coverage much reduced to about 4% of the lake bottom area, meaning that anoxia was largely contained within the deep hole and that remaining lake bottom was fully oxygenated.

Dissolved oxygen concentrations in Lower Bolton Lake during 2012 – 2016:



Bottom area overlain with anoxic water in Lower Bolton Lake during 2012 – 2016



Monitoring Details: Invasive Aquatic Plants

Treatments

Between 2005 and 2011, Southern Water-Naiad (*Najas guadalupensis*), a rooted aquatic plant native to Connecticut, experienced explosive growth in Lower Bolton Lake. The herbicide: Fluridone was used in May 2013 to control naiad. Subsequent surveys showed naiad was reduced by >98% rendering the naiad control a success.

Lower Bolton Lake Treatment Summary

Date	Task
May 20, 2013	Initial Fluridone Herbicide (Sonar Genesis – liquid)
June 27, 2013	Booster Fluridone (Sonar Genesis – liquid)
June 27, 2013	Algaecide -planktonic cyanobacteria (Copper)
September 5, 2013	Fluridone treatment of small cove for fanwort (Sonar Q – granular)
2014	No treatments needed
September 2, 2015	Algaecide –planktonic cyanobacteria (Copper), Herbicide curly-leaf pondweed (Diquat)
June 21, 2016	Herbicide curly-leaf pondweed only (Diquat), no copper sulfate used
June 26, 2017	Herbicide curly-leaf pondweed only (Diquat), no copper sulfate used

Aquatic plant species list for Lower Bolton Lake before and after Fluridone

Species List	2013	2014	2015	2016	2017
Large-leaf pondweed *(Potamogeton amplifolius)*	Yes	Yes	Yes	Yes	Yes
Southern naiad *(Najas guadalupensis)*	Yes	Yes	Yes	Yes	No
Coontail *(Ceratophyllum demersum)*	Yes	No	No	No	No
Tape-grass *(Vallisneria americana)*	Yes	No	Yes	Yes	Yes
Snail-seed pondweed *(Potamogeton bicupulatus)*	No	Yes	No	No	No
Elodea *(Elodea nataliae)*	No	No	No	No	No
Floating bladderwort *(Utricularia radiata)*	No	No	No	No	No
Arrowhead *(Sagittaria graminea)*	No	No	Yes	Yes	No
Bushy pondweed *(Najas flexilis)*	No	Yes	No	No	Yes
Fanwort *(Cabomba caroliniana)*	**Yes**	**No**	**No**	**No**	**No**
Mudmat *(Glossostigma* sp.)	**No**	**Yes**	**Yes**	**Yes**	**Yes**
Quillwort *(Isoetes* sp.)	No	No	No	No	No
White waterlily *(Nymphaea odorata)*	No	No	No	No	No
Variable leaved milfoil *(Myriophyllum heterophyllum)*	**No**	**No**	**No**	**No**	**No**
Red-leaf pondweed *(Potamogeton epihydrus)*	No	No	No	No	No
Muskgrass *(Nitellla* sp.)	No	Yes	Yes	Yes	Yes
Stonewort *(Chara* sp.)	No	Yes	Yes	Yes	No
Hedgehyssop (Gratiola sp.)	No	Yes	No	No	No
^Curly-leaf pondweed (*Potamogeton crispus*)	No	No	**Yes**	**Yes**	**Yes**

RED = Invasive

^ new sighting fall 2014

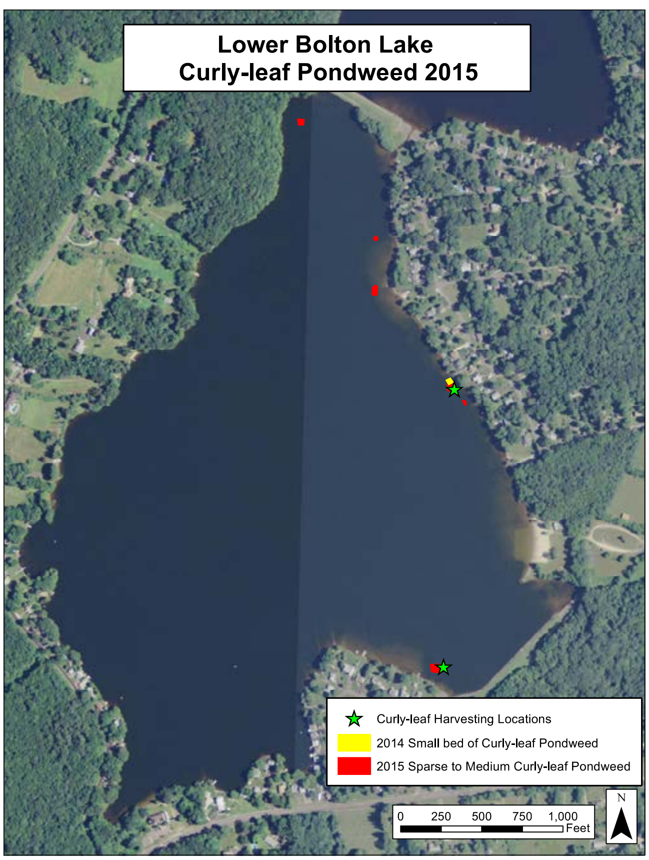
Curly-leaf pondweed (*Potamogeton crispus*) is an invasive species found in many lakes in Connecticut and the northeast. This species spreads via root runners and also produces turions, robust buds that can overwinter in the sediment and sprout new plants during subsequent seasons.

1 - Curly-leaf pondweed found in the lake near the boat ramp, along the eastern shore and along the northern shore below Middle Bolton Dam.

2 - Contrary to the plant's behavior in other lakes in Connecticut where it grows to greatest extent in May and early June and then exhibits a die off by July 1, curly-leaf in Lower Bolton Lake was found to be still growing vigorously in August and September.

3 - Diquat herbicide was used to target control of curly-leaf pondweed. The treatment was completed on September 2, 2015 (see below). During a post-treatment curly-leaf survey, no plants were found, but due to poor visibility and the ability of curly-leaf plants to grow from turions in the sediment, NEAR will be watching closely for regrowth of this invasive in coming seasons.

Curly-leaf pondweed distribution in Lower Bolton Lake 2014 and 2015



Curly-leaf pondweed treatment area in Lower Bolton Lake during 2016

Curly-leaf pondweed treatment area in Lower Bolton Lake during 2017