Lower Bolton Lake

2018 Status Up-Date

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Bolton, CT

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Purpose

This report is an update on three primary Threats to Lower Bolton Lake listed in the 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.
   (5) The 2017 season had few Cyanobacteria during the whole season. Counts of Green Alga were also low. No copper sulfate was added to the lake in 2017.
   (6) In 2018, Cyanobacteria were not in the water column until August. A bloom with maximum cell count of 204000c/mL occurred on September 4, 2018 prompting beach closure. Cell counts decreased quickly so closure was lifted in three weeks. No copper sulfate was added to the lake in 2018.

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, had developed a few established beds in the northeast sector of the lake and several isolated beds scattered around other parts of the lake. In 2016 and 2017, early season treatments attempted to kill the plant prior to its reaching maturity. In August 2018, curly-leaf was found growing in small patches scattered along the shoreline of the lake. No treatments were made in 2018

[1] Najas guadalupensis

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

Monitoring Details

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),

2017 =Average (1) **15ppb**, max 24ppb
2 values of less than 10ppb,
49% of samples 20ppb or higher, (N=37),

2018 =Average (1) **25ppb**, max 69ppb
2 values of less than 10ppb,
64% of samples 20ppb or higher, (N=28),

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,
2017 =Avg. 19ppb, max 34ppb,
2018 =Avg. 40ppb, max 69ppb,

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.

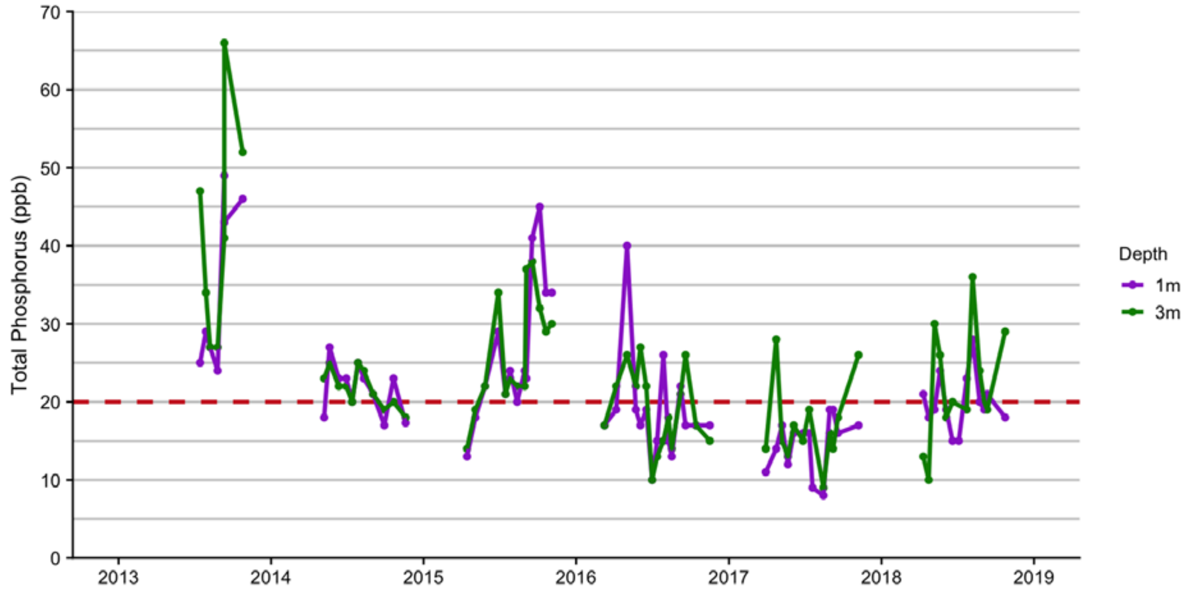
4 – Generally, 2016 phosphorus concentration at the 1 and 3 m depths were identical verifying that these depths represent the mixed layer of the lake. On two occasions 3m phosphorus exceeded 1m values due to increased concentrations at 5m.

5 – Bottom water phosphorus showed mid-summer increases each season.

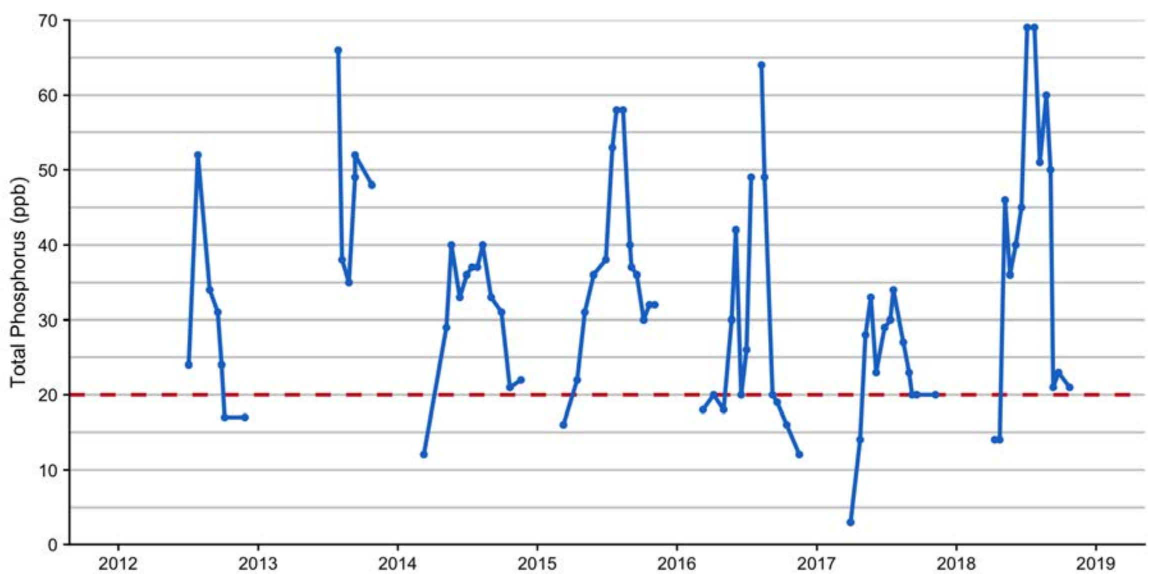
6 – Average phosphorus concentrations at all three sampling levels (top/middle and bottom) were lower in 2017 than in the previous years.

7 – In 2018, phosphorus concentrations were low in the spring, but at the height of the summer, phosphorus increased to the highest concentrations on record at all three sampling depths.

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,

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

2011 =934ppb _ one sample

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

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

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

2014 =Average **323ppb**, max 435ppb,
1 value less than 200ppb,
No 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,
No samples >600ppb, (N=30),

2017 =Average **318ppb**, max 400ppb
No values of less than 200ppb,
No samples >600ppb, (N=30),

2018 =Average **436ppb**, max 1081ppb
No values of less than 200ppb,
11% samples >600ppb, (N=28),

2014 =Avg. 401ppb, max 742ppb,

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

2016 =Avg. 420ppb, max 768ppb,

2017 =Avg. 361ppb, max 568ppb,

2018 =Avg. 757ppb, max 2.230ppb,

Total nitrogen trends in the mixed layer of Lower Bolton Lake from 2012 through 2018 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.

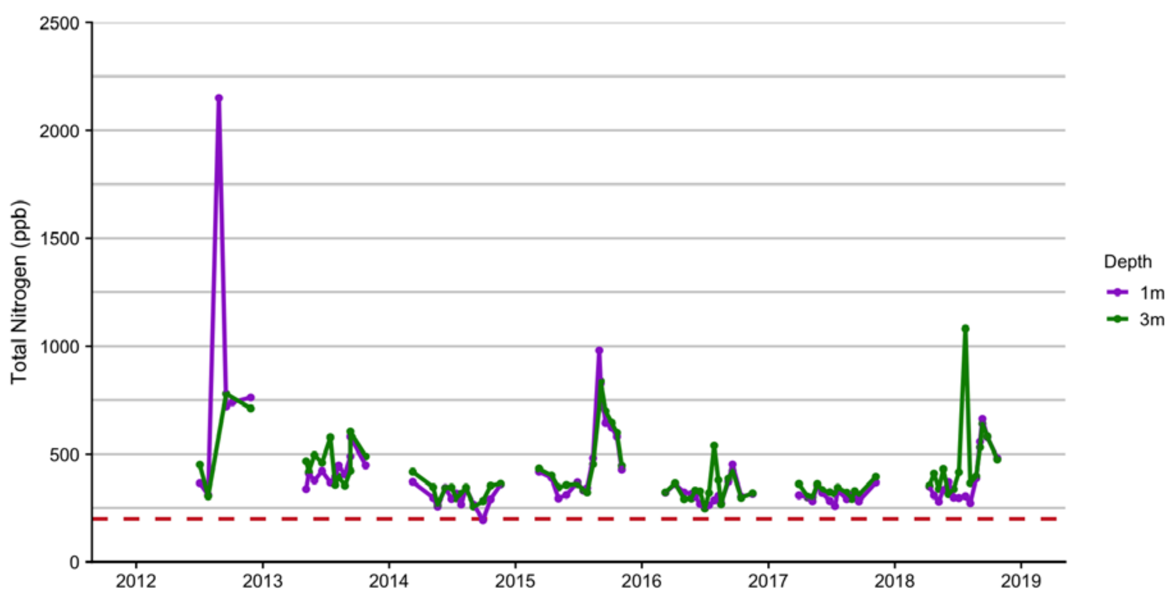
2 – Three episodes of 1,000ppb concentrations have occurred since 2012, once in early 2013, next in late August 2015, and again in August and September 2018. Copper sulfate treatments were administered to stop cyanobacteria blooms in 2012, 2013 and 2015. The 2018 bloom was not treated.

3 – Average TN concentrations at all three sampling levels (top/middle and bottom) were lower in 2017 than in the previous years.

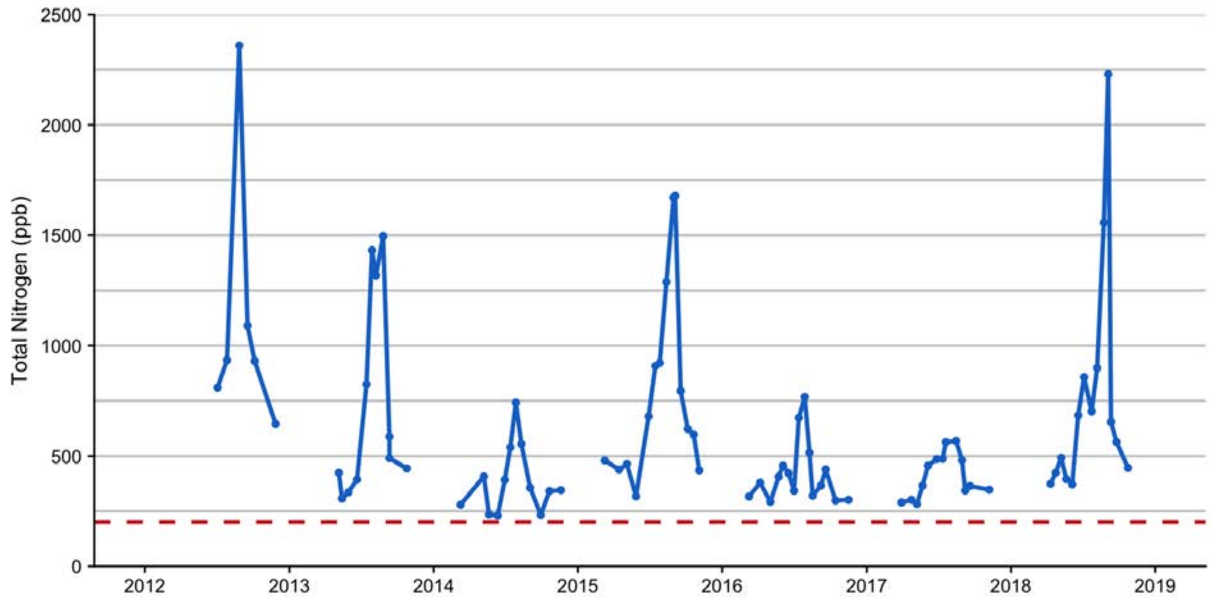
4 – In 2018, total nitrogen at the middle and bottom of the water column (3m and 5m) rose to the highest concentrations on record since the cyanobacteria bloom in 2012. Nitrogen at the top of the water column (1m) was also elevated in September.

5 – Ammonium nitrogen in 2018 rose to the highest concentrations on record at the middle of the water column in July and at the bottom of the water column in September. Ammonium nitrogen was also elevated at the top of the water column (1m) in September.

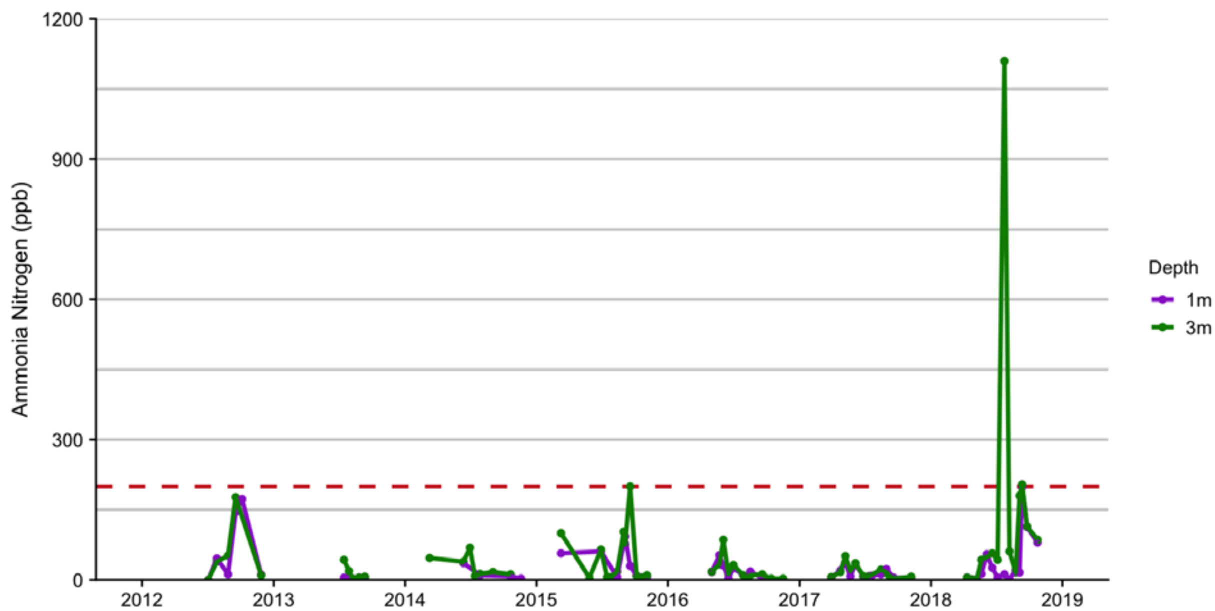
Total nitrogen concentration trends (ppb) at 1 m and 3 m depths:



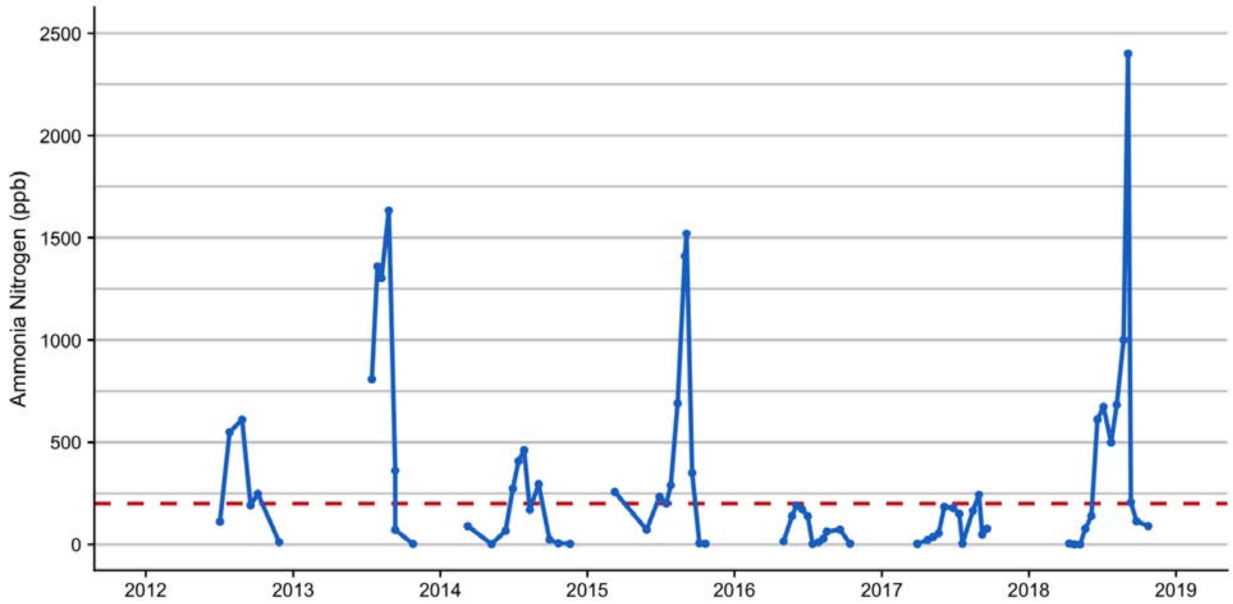
Total nitrogen concentration trends (ppb) at 5 m depth:



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



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



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),
2017 =Average **128ppb**, max 301ppb,
No values <50ppb,
12% of samples >150ppb, (N=33),
2018 =Average **442ppb**, max 5869ppb,
No values <50ppb,
65% of samples >150ppb, (N=26),

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,
2017 =Avg. 280ppb, max 907ppb,
2018 =Avg. 4417ppb, max 18,200ppb,

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

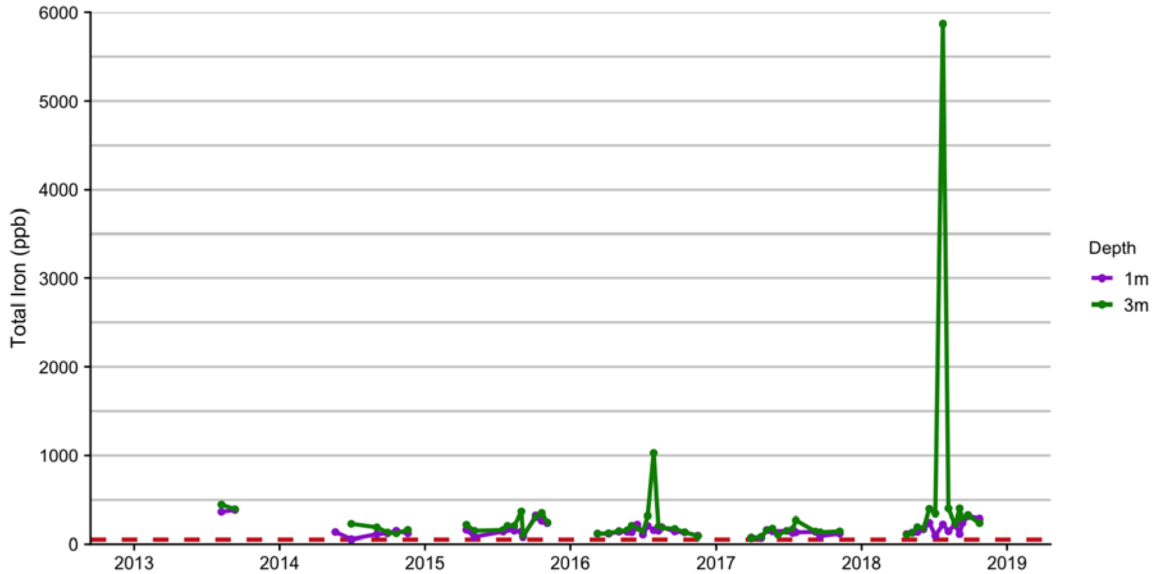
1- First measured in 2013, total iron was found to be considerably higher than background levels.

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

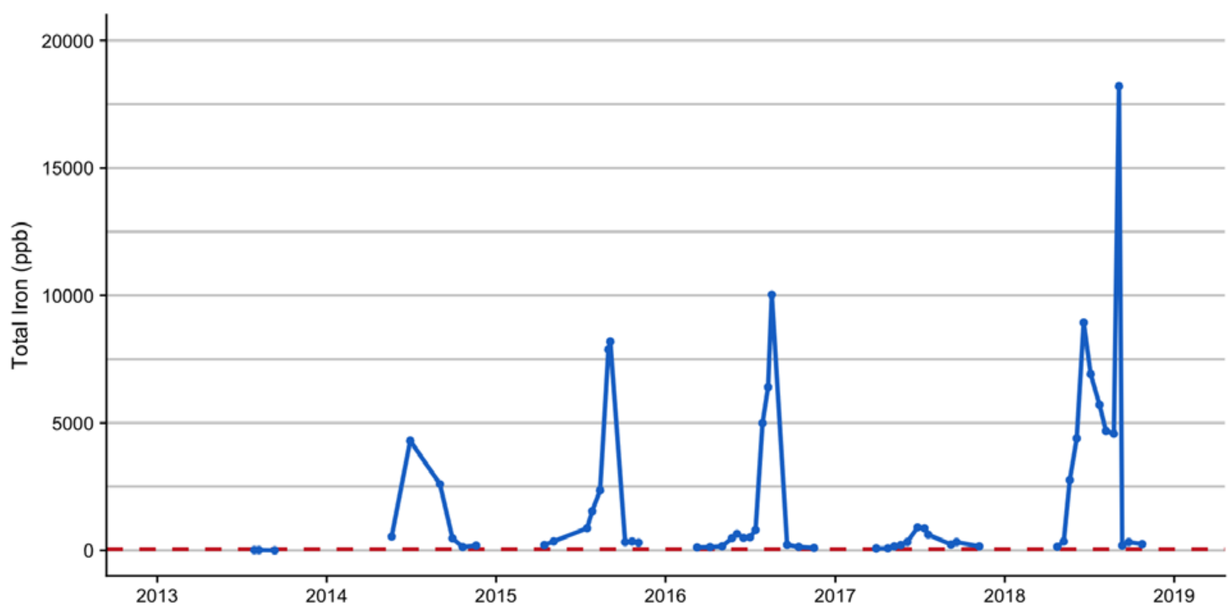
3 – 2015, 2016 and 2017 saw lower total iron in upper waters although still present at higher than acceptable levels.

4 – In 2018, total iron at the middle and bottom of the water column (3m and 5m) was exceptionally elevated, with maximum concentrations significantly higher than in any previous year.

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



Total iron concentration trends (ppb) at 5m depth: between 2014 and 2018



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),
2017 = Average 3m, max = 3.4m, min = 2.2m,
    7 measurements >3m,
    No measurements <2m, (N=11)
2018 = Average 2.2m, max = 3.5m, min = 1.1m,
    1 measurement >3m,
    4 measurements <2m, (N=14)

The water clarity of Lower Bolton Lake between 2012 and 2017 is shown in the 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).

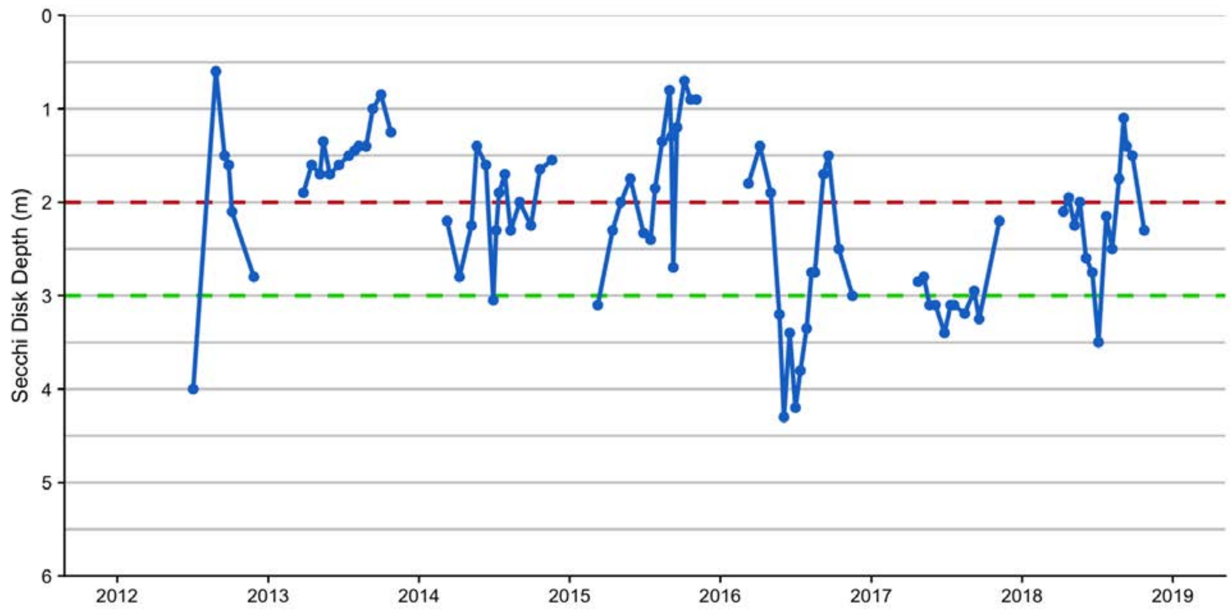
3 – 2016 had clarity that was poorest in April and showed steady improvement until the best recorded clarity of 4.2 meters on July 1.

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

5 – The average clarity was better in 2017 than in any previous year (2012-2016).

6 – Clarity worsened again in 2018. All but one of the clarity reading were above 3 meters and clarity was worse than 2 meters at Station 1 in August and September.

Water Clarity (Secchi disk depth) in Lower Bolton Lake, 2012-2018:



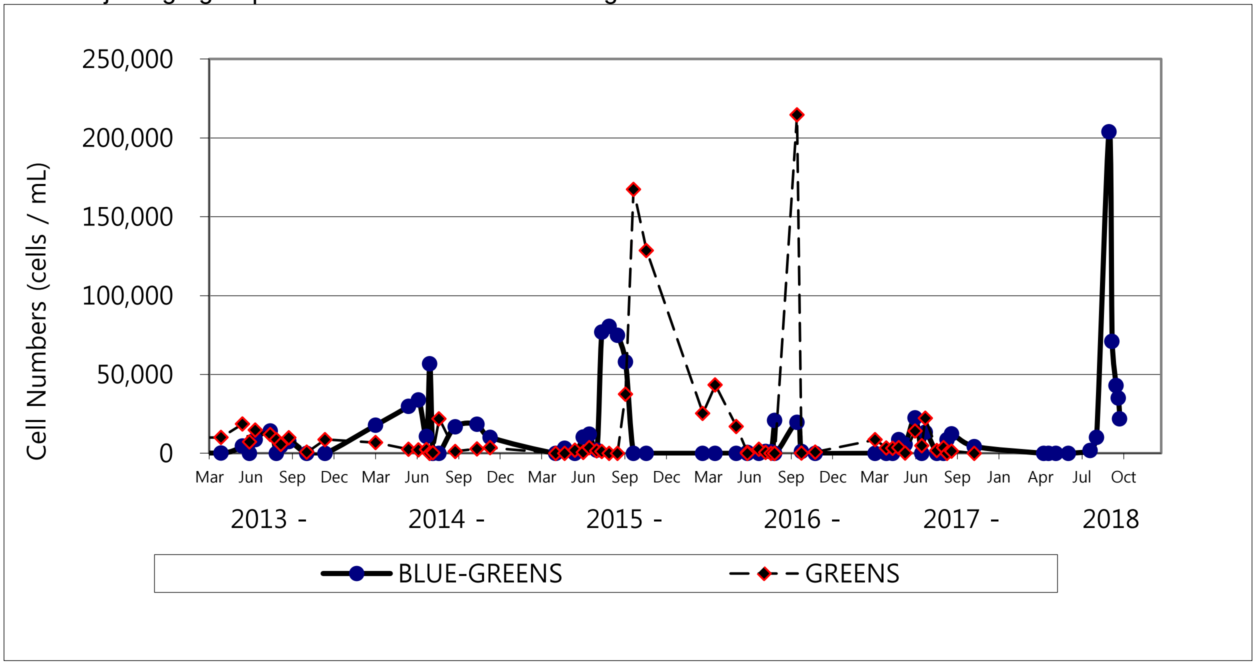
Cyanobacteria

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
2017 =Average 5,821c/mL	max= 22,585c/mL
2018 =Average 37,000c/mL	max= 204,000/mL

Trends in major alga groups in Lower Bolton Lake during 2013 -2018:



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]
2017 = AB max 4.75m
5m = 6 dates <1ppm [June 5th - September 19th – not continuous]
2018 = AB max 2.85m
5m = 9 dates <1ppm [May 21st - September 11th – not continuous]

2013 - Dissolved oxygen demand in the deepest water was severe, with both a significant amount of the water column devoid of oxygen, as well as 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.

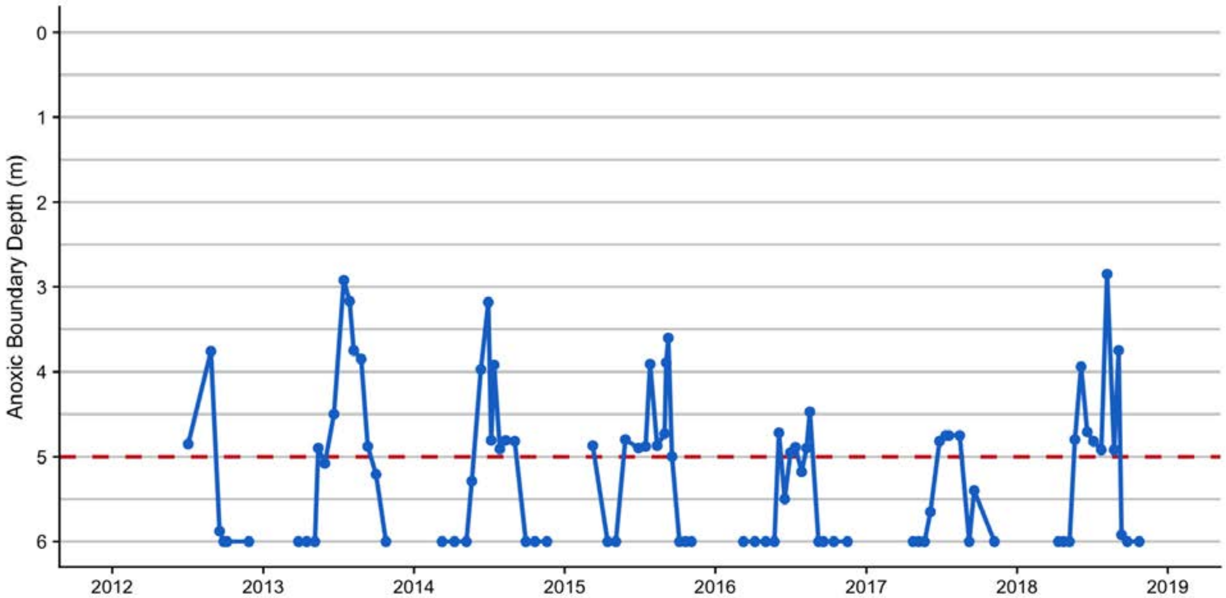
2015 – Severity and duration of oxygen loss in deep water about the same but large improvement in the height of the anoxic boundary and the area of the bottom sediments overlain by anoxic water 17%.

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.

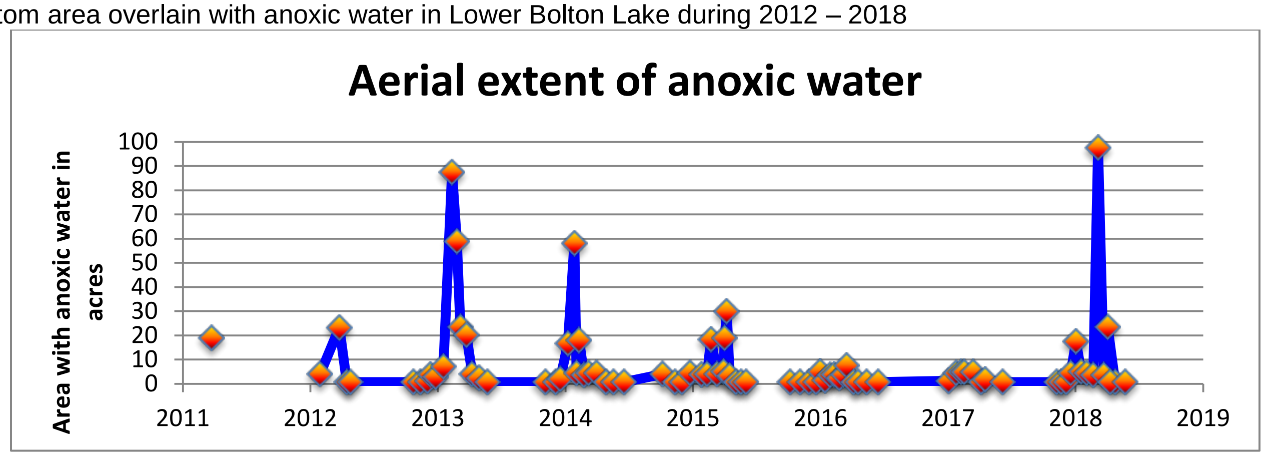
2017 – Oxygen remained low in the water column, similar to 2016 levels. However, the bottom water remained anoxic late into the season.

2018 – The extent of anoxic water was considerably elevated compared to 2016 and 2017, and the anoxic boundary reached higher in the water column than any record from the previous six years.

Dissolved oxygen concentrations in Lower Bolton Lake during 2012 – 2018:



Bottom area overlain with anoxic water in Lower Bolton Lake during 2012 – 2018



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.

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 control curly-leaf pondweed in 2015, 2016 and 2017. The herbicide treatments have prevented the population from rapidly expanding, but the ability of curly-leaf plants to grow from turions in the sediment has allowed the species to re-sprout each year.

Lower Bolton Lake Treatment Summary

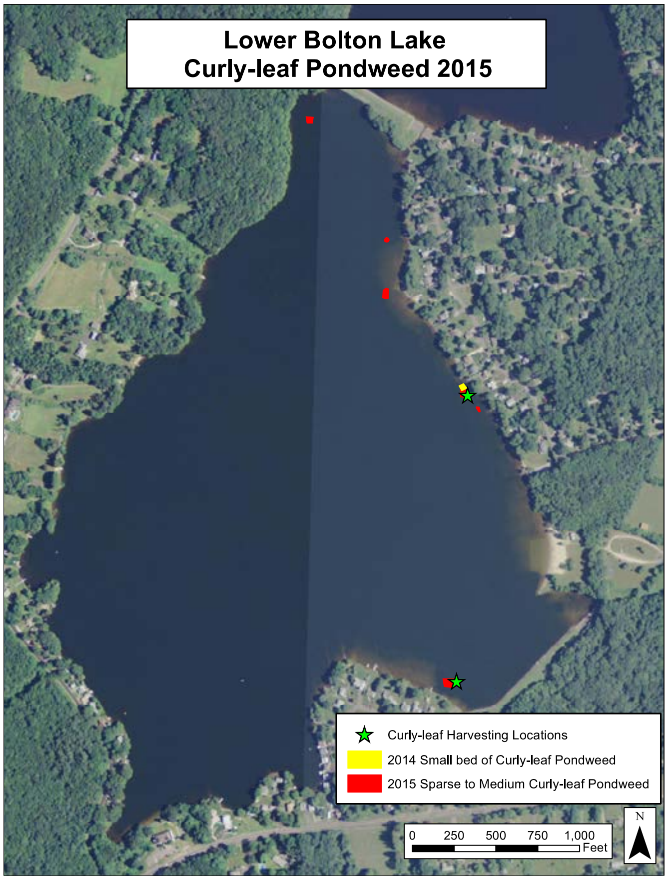
Date	Task
20-May-2013	Initial Fluridone Herbicide (Sonar Genesis – liquid)
27-Jun-2013	Booster Fluridone (Sonar Genesis – liquid)
27-Jun-2013	Algaecide -planktonic cyanobacteria (Copper)
5-Sep-2013	Fluridone treatment of small cove for fanwort (Sonar Q – granular)
2014	No treatments needed
2-Sep-2015	Algaecide –planktonic cyanobacteria (Copper), Herbicide curly-leaf pondweed (Diquat)
21-Jun-2016	Herbicide curly-leaf pondweed only (Diquat), no copper sulfate used
26-Jun-2017	Herbicide curly-leaf pondweed only (Diquat), no copper sulfate used
2018	No treatments conducted

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

Species List	2013	2014	2015	2016	2017	2018
Large-leaf pondweed *(Potamogeton amplifolius)*	Yes	Yes	Yes	Yes	Yes	Yes
Southern naiad *(Najas guadalupensis)*	Yes	Yes	Yes	Yes	No	Yes
Coontail *(Ceratophyllum demersum)*	Yes	No	No	No	No	No
Tape-grass *(Vallisneria americana)*	Yes	No	Yes	Yes	Yes	Yes
Snail-seed pondweed *(Potamogeton bicupulatus)*	No	Yes	No	No	No	Yes
Elodea *(Elodea nuttallii)*	No	No	No	No	No	No
Floating bladderwort *(Utricularia radiata)*	No	No	No	No	No	No
Arrowhead *(Sagittaria graminea)*	No	No	Yes	Yes	No	No
Bushy pondweed *(Najas flexilis)*	No	Yes	No	No	Yes	Yes
Fanwort *(Cabomba caroliniana)*	**Yes**	**No**	**No**	**No**	**No**	**No**
Mudmat *(Glossostigma* sp.)	**No**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Quillwort *(Isoetes sp.*)	No	No	No	No	No	No
White waterlily *(Nymphaea odorata)*	No	No	No	No	No	No
Variable leaved milfoil *(Myriophyllum heterophyllum)*	**No**	**No**	**No**	**No**	**No**	**No**
Red-leaf pondweed *(Potamogeton epihydrus)*	No	No	No	No	No	No
Muskgrass *(Nitellla* sp.)	No	Yes	Yes	Yes	Yes	Yes
Stonewort *(Chara* sp.)	No	Yes	Yes	Yes	No	Yes
Hedgehyssop *(Gratiola* sp.)	No	Yes	No	No	No	No
^Curly-leaf pondweed (*Potamogeton crispus*)	No	No	**Yes**	**Yes**	**Yes**	**Yes**

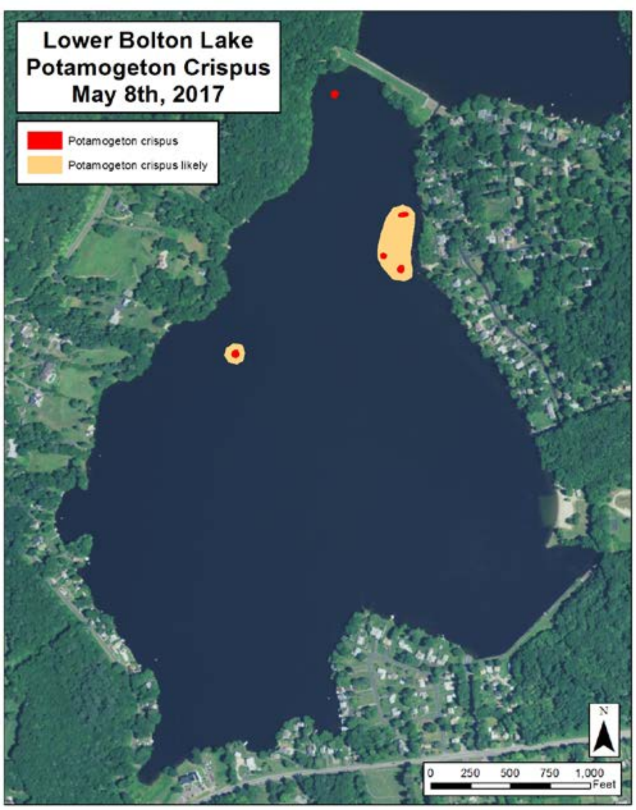
RED = Invasive
^ new sighting fall 2014

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



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

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



Curly-leaf pondweed locations, 2015-2018