# North and South Riga Lakes

# 2018 Monitoring Report

Salisbury, CT

Prepared For:

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# SYNOPSIS OF 2018 RESULTS

1. **Water clarity** at South Riga remained excellent in 2018, with the Secchi disk reaching the bottom of the deep spot in the lake through the entire sampling season. At North Riga, clarity was worse than previous years, suggesting that the water clarity may be deteriorating. North Riga has lost about 3 meters of clarity over the last 10 years.

2. **Total phosphorus (TP)** in South Riga was excellent in 2018, with concentrations remaining at or below 10 ppb throughout the water column for the duration of the monitoring season. TP in North Riga exhibited the highest concentrations on record at the middle and bottom of the water column, suggesting that the concentration of TP in the lake is increasing.

3. **Total nitrogen (TN)** at the middle and bottom of the water column in South Riga was excellent throughout the monitoring season, and was just slightly elevated at the top of the water column in October. In both August and October, the highest TN in the water column was recorded in the surface water, suggesting that nutrients are entering the lake from the watershed. In North Riga, TN remained low at the top and middle of the water column, but was elevated in the bottom water in July and August.

4. **Aquatic Plants** – 17 native aquatic plant species were found in South Riga in 2018 and of these, purple bladderwort (*Utricularia purpurea)* was the most abundant species and the only dominant species in the lake. 17 aquatic plant species were found in North Riga as well, although the assemblage of species differed between the two lakes. Purple bladderwort was the most abundant species in North Riga, although pipewort (*Eriocaulon sp.)* and low milfoil (*Myriophyllum humile)* were also dominant. No invasive aquatic plant species were found in either of the lakes in 2018.

# BACKGROUND

North Riga Lake (also known as Upper Riga) and South Riga Lake (also known as Lower Riga) are located at the top of Mount Riga in Salisbury. NEAR started lake monitoring in 2007 and began collecting water samples for nutrient analysis at this time, in addition to all other data collection. NEAR has monitored the two lakes every year since then, with the exception of 2009 and 2017. In 2018, volunteer monitors began conducting the lake monitoring and for the first time, monitoring was conducted one a month at each lake for the majority of the summer season.

NEAR first surveyed the aquatic plants in the two lakes in 2007. Since then, surveys have been conducted in 2011, 2012, 2013, 2014, 2015, 2016 and 2018. This year, NEAR surveyed the two lakes on October 5$^{th}$, to assess the extent and density of all aquatic plant species growing in each lake and to search for invasive species.

A watershed boundary defines the area of landscape that will capture water for the lake. All rain falling within the watershed boundary will be directed toward the lake. The watershed of North Riga, 1,557 acres, is a smaller sub-basin of South Riga with a watershed size of 2,204 acres (**Figure 1**). If we look at just landscape area and subtract the lake surface area the resulting drainage areas are 1,387 acres and 2,063 acres for North and South Riga, respectfully.

## NORTH RIGA LAKE

- North Riga Lake is 170 acres in size with a watershed boundary area of 1,557 acres, giving the lake a drainage basin of 1,387 acres (subtracting the lake area from the watershed area).
- North Riga Lake has a maximum depth of 34 feet and a mean depth of 9.4 feet (**Figure 2**).
- North Riga Lake contains approximately 1,598 acre-feet, or 526 million gallons of water.
- The theoretical residence time of water in North Riga Lake is 0.5 years, meaning that the lake completely flushes about twice a year.
- The lake lies at 1,749 feet above sea level.

## SOUTH RIGA LAKE

- South Riga Lake is a 141 acre lake with a watershed boundary area of 2,204 acres, giving the lake a drainage area of 2,063 acres (subtracting the lake area from the watershed area). North Riga Lake is within the drainage basin of South Riga Lake.
- South Riga Lake has a maximum depth of 20 feet with a mean depth of 9 feet (**Figure 3**).
- South Riga Lake contains approximately 1,294 acre-feet, or 426 million gallons of water.
- The theoretical residence time of South Riga Lake is 0.3 years, meaning that the lake completely flushes about once every 105 days.
- The lake lies at 1,716 feet above sea level.

**Figure 1 –** *Drainage Basin of Riga Lakes*

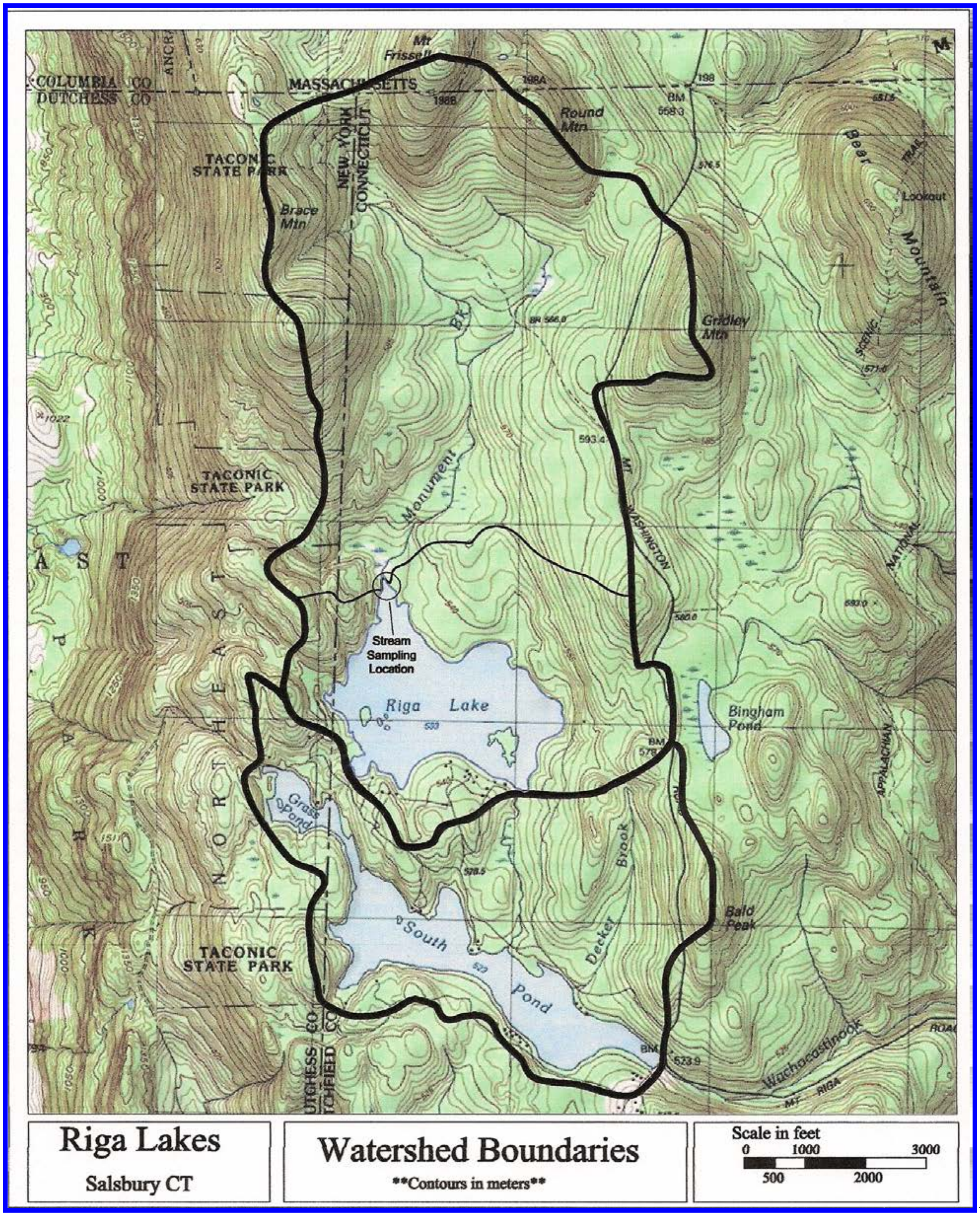


**Figure 2** – *Water depth contour map of North Riga Lake -contours in feet*

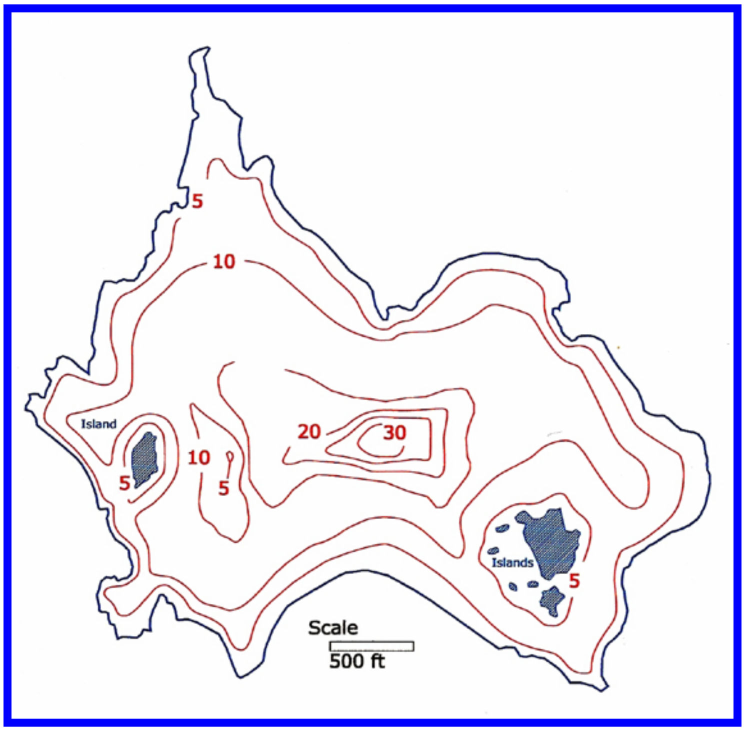
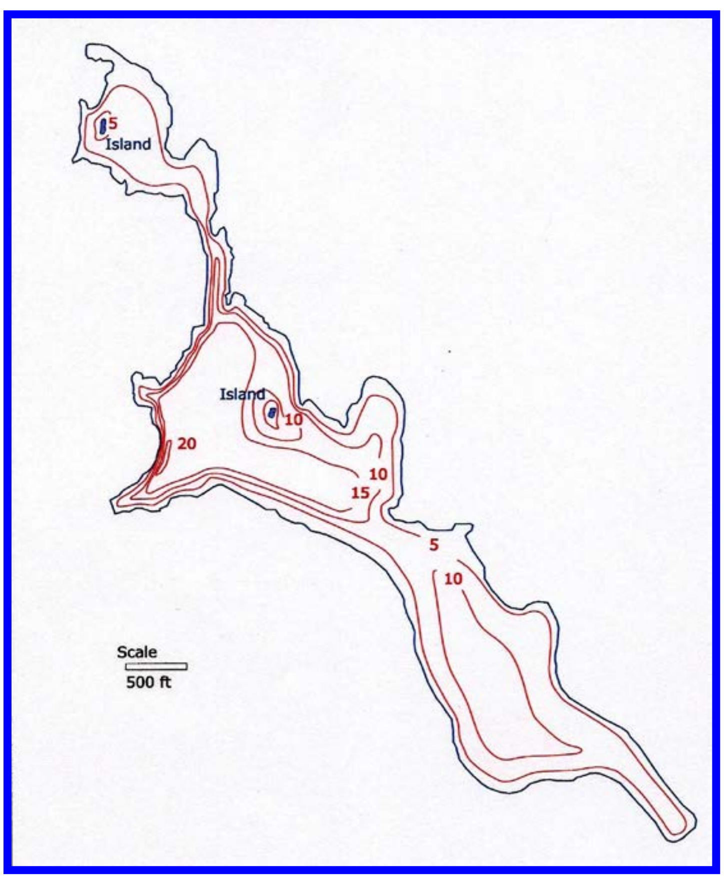



**Figure 3** – *Water depth contour map of South Riga Lake - contours in feet*



# MONITORING RESULTS

In 2018, water quality monitoring was conducted once per month from June through October at North Riga, and from July through October at South Riga.

The lake data is assessed based on the CT DEEP categorization of lakes based on the amount of nutrients in surface waters during summer conditions (**Table 1**). A trophic category is a way to define the degree of plant and algae growth that occurs in a lake, which is a way to track productivity and water quality decline. Very clear water with no weeds or algae results from very low nitrogen and phosphorus and is considered oligotrophic. Lakes with excessive amounts of weeds and very green water resulting from high nutrient concentrations are eutrophic. **Table 1** shows lake Trophic Status. South Riga is considered oligotrophic, which is the best possible category. North Riga is **considered oligo-mesotrophic, which is the second-best category. Target criteria are highlighted in green: TP <10ppb, TN <200ppb, and Secchi >6m**.

**Table 1** - *Lake trophic categories and ranges of indicator parameters*

| Category | T.P. (ppb) | T. Nitrogen (ppb) | Secchi Depth (m) | Chlorophyll *a* (ppb) |
|---|---|---|---|---|
| **Oligotrophic** | 0 – 10 | 0 – 200 | 6+ | 0 – 2 |
| **Oligo-** | 10 – 15 | 200- 300 | 4 – 6 | 2 – 5 |
| **Mesotrophic** | 15 – 25 | 300 - 500 | 3 – 4 | 5 – 10 |
| **Meso-eutrophic** | 25 – 30 | 500 - 600 | 2 – 3 | 10 – 15 |
| **Eutrophic** | 30 – 50 | 600 - 1000 | 1 – 2 | 15 – 30 |
| **Highly** | 50 + | 1000 + | 0 – 1 | 30 + |

**Source = CT DEP 1982*

**Chlorophyll-a not included in testing*

## Water Clarity / Secchi Disk Depth

South Riga Lake is approximately 6 meters deep at its deepest spot. The Secchi disk, which is used to measure water clarity, has always reached the bottom of the lake (**Table 2**). Typically there is some bladderwort on the bottom of the lake that can obscure the disk before it reaches the bottom. Should the Secchi disk not reach the bottom of the lake that will be a clear sign that the water quality of the lake is declining.

**Table 2 -** *Secchi disk depth record for South Riga Lake==Bottom is 5.5m-6m*

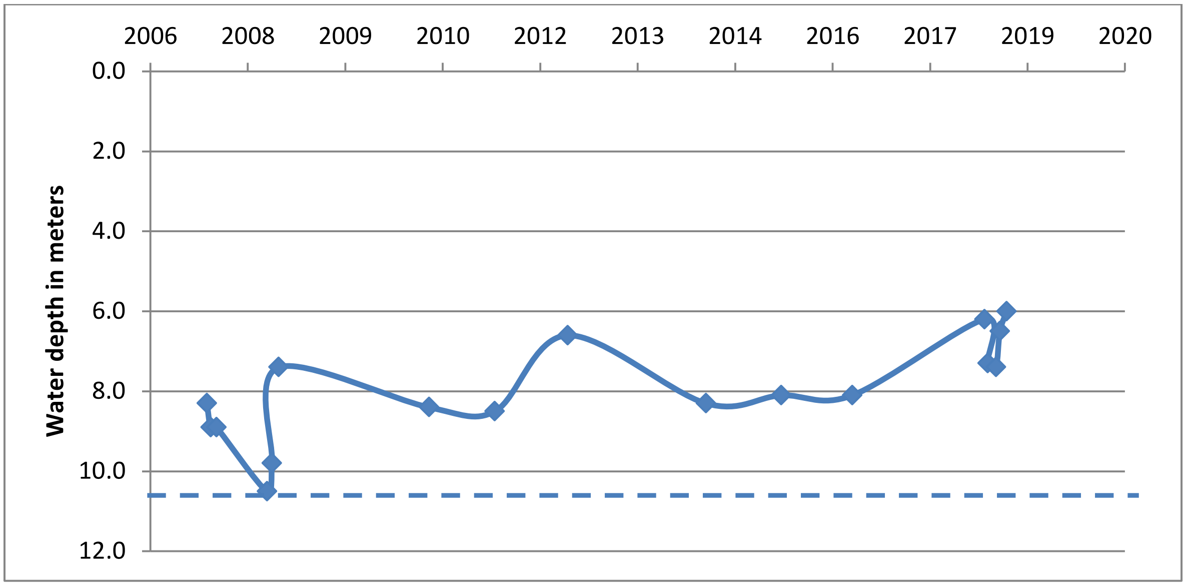
| | | | |
|---|---|---|---|
| **27-Jul-07** | Bottom | **10-Aug-13** | Bottom |
| **15-Aug-07** | Bottom | **15-Sep-15** | Bottom |
| **14-Sep-07** | Bottom | **26-Sep-16** | Bottom |
| **19-Oct-07** | Bottom | **17-Jul 18** | Bottom |
| **30-May-08** | Bottom | **12-Aug-18** | Bottom |
| **25-Jun-08** | Bottom | **16-Sep-18** | Bottom |
| **29-Jul-08** | Bottom | **14-Oct-18** | Bottom |
| **12-Jul-11** | Bottom | | |

North Riga is approximately 10 meters deep at its deepest spot. The Secchi disk reached the bottom of North Riga in 2008 but since then, clarity has never been recorded deeper than 8.5 meters. Over the course of the 2018 season, clarity ranged from 6.0 meters to 7.4 meters (**Table 3**). The 2018 Secchi measurements are a cause for concern, as the clarity is unmistakably deteriorating (**Figure 5**). 2018 exhibited the three poorest clarity readings of 6.2m, 6.5m, and 6.0m in June, September and October, respectively. The decline in clarity is alarming over the last 10 years losing about 4 meters of clarity. If the lake has indeed lost that much clarity seasonally there will be ramifications to the lakes thermal structure.

**Table 3** -- *Secchi disk depth record for North Riga*

| Date | Secchi meters | Date | Secchi meters | Date | Secchi meters |
|---|---|---|---|---|---|
| **27-Jul-07** | 8.3 | **8 Sep-10** | 8.4 | **28-Jun-18** | 6.2 |
| **15-Aug-07** | 8.9 | **12-Aug-11** | 8.5 | **14-Jul-18** | 7.3 |
| **14-Sep-07** | 8.9 | **20-Aug-12** | 6.6 | **26-Aug-18** | 7.4 |
| **30-May-08** | 10.5 | **30-Jul-14** | 8.3 | **15-Sep-18** | 6.5 |
| **25-Jun-08** | 9.8 | **20-Aug-15** | 8.1 | **20-Oct-18** | 6.0 |
| **29-Jul-08** | 7.4 | **19-Aug-16** | 8.1 | | |

**Figure 4** - *Secchi disk depths at North Riga. Dashed line indicates the lake bottom.*




## Dissolved Oxygen

Water beneath the anoxic boundary has less than 1 mg/L of dissolved oxygen. Water that is anoxic (devoid of oxygen) is not suitable for fish or other aerobic aquatic organisms. When the water at the bottom of a lake is anoxic, nutrients trapped in the mud are released into the water through the process of internal loading.

At North Riga in 2018, the water at the bottom of the deep spot was anoxic in July and August with an anoxic boundary (the depth in the water column where oxygen is lot-as measured down from the surface) reaching a maximum height of 8.6 meters (so that between 8.6 meters and the bottom at 10.5 meters there was no oxygen in the water) (**Figure 5**). By September, oxygen had returned to the bottom water and the water column was fully mixed. The occurrence of anoxic water at the bottom of North Riga Lake is cause for serious concern as it indicates that a number of factors have changed in the lake. Anoxia was first detected at the very bottom of the lake in 2011 (**Figure 6**), since that time anoxia has been detected in 2014, 2015, 2016 and 2018 (no sampling was conducted in 2017). Anoxia is caused by an imbalance between aerobic capacity and amount of material that needs to decompose. North Riga now has more material to decompose than oxygen supply so water become devoid of oxygen and $O_2$ debt builds up. The material is algae that grows in the lake during the summer and dies and sinks to the bottom which causes the decline in water clarity. The amount of algae is based on the phosphorus level which has increased over the last 10 years. Unfortunately, this process is a set of interconnected negative feedback loops. More algae causes decreased clarity which adds to loss of oxygen at the bottom which leads to more phosphorus originating from bottom sediments which causes more algae which causes further declines in water clarity and so on. So far the anoxic water has remained below 8 meters so the aerial extent of the anoxia is only about 2 acres, this will change if the loss of oxygen continues to increase.

South Riga did not become anoxic in 2018. The water column remained mixed (**Figure 5**). South Riga is a relatively shallow lake, so we do not expect it to go anoxic, and if it does, that would be a cause for concern, as it would signify increased aerobic activity in the lake, caused by increased nutrient availability. We have no record of South Riga ever going anoxic in previous years.

**Figure 5** - *Dissolved oxygen profiles at North Riga and South Riga in 2018*

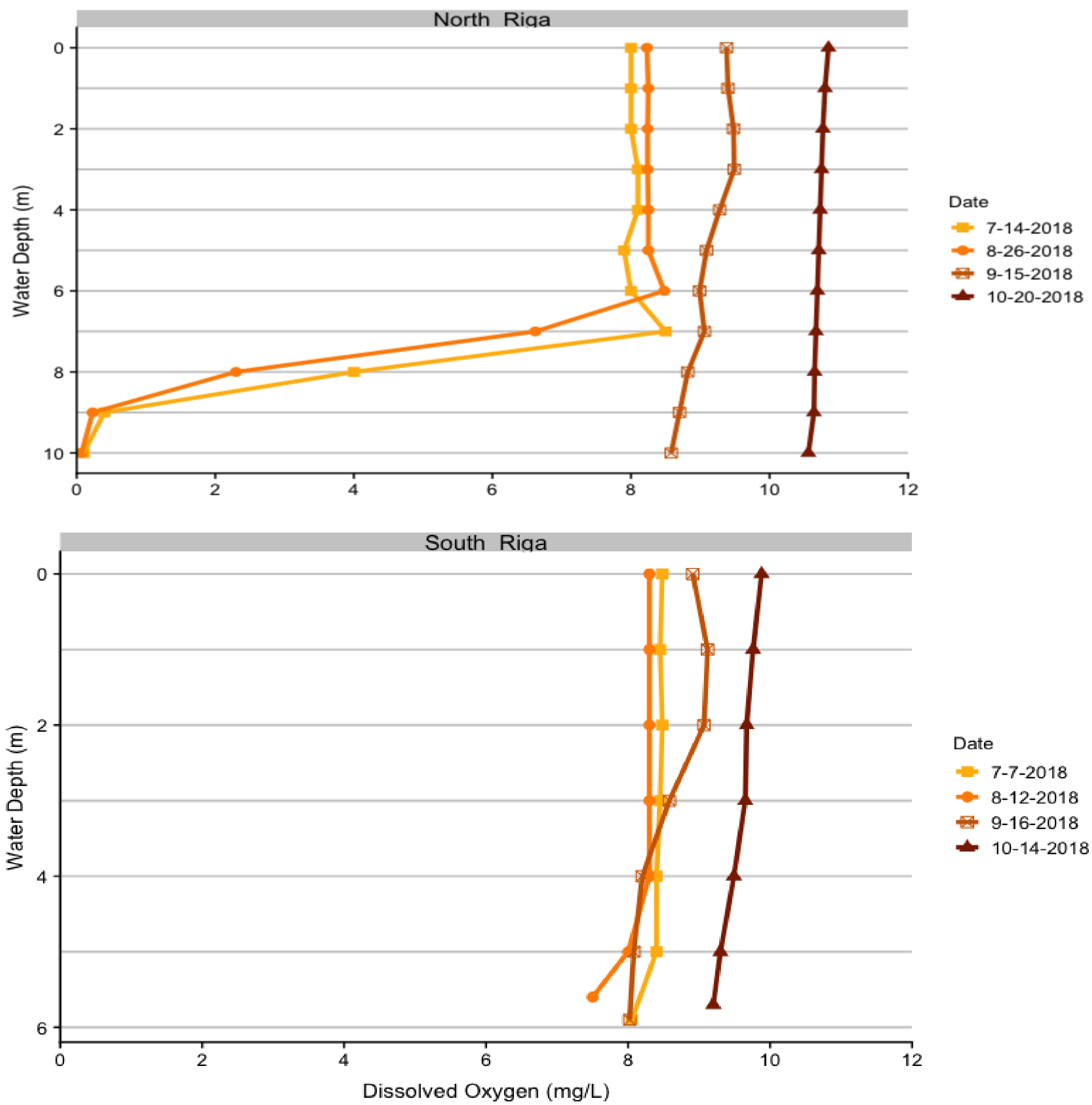
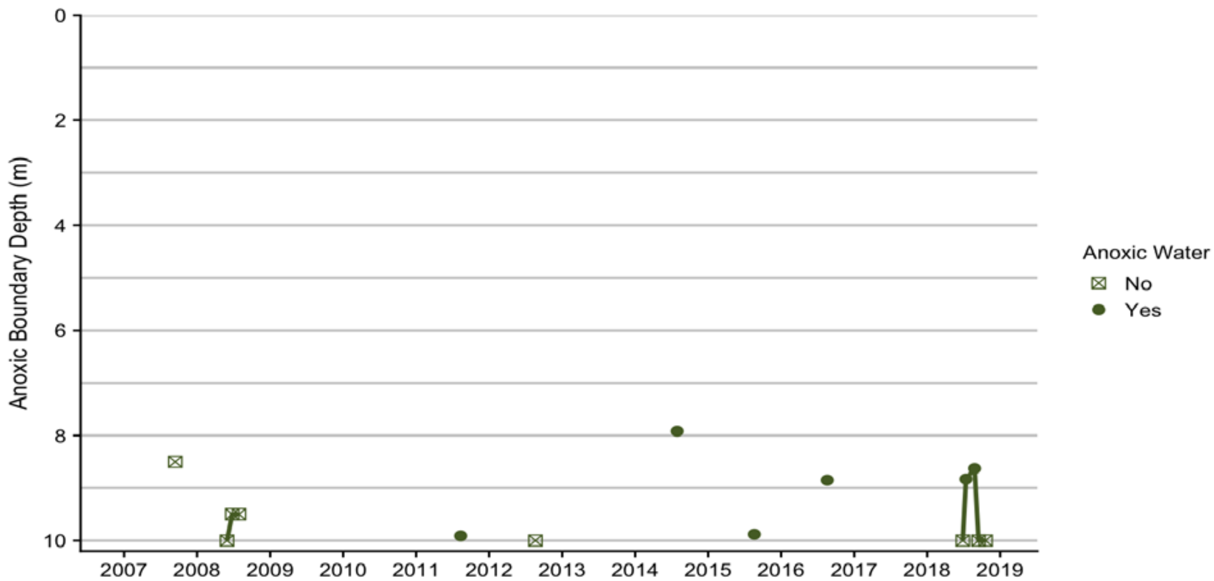


**Figure 6** – *Depths of anoxic boundaries in North Riga Lake*




## Total Phosphorus

2018 was the first year since 2007-2008 that water samples were collected monthly for the duration of the summer season. From 2008 through 2016 (monitoring was not conducted in 2017), water samples were collected either once each year, or once every other year. Water samples are collected from three depths because of the potential for a concentration gradient to exist between the bottom and top of the water column. As stated above, phosphorus can be liberated from bottom sediments when the water over the sediments becomes anoxic. Data from 2007-2008 showed no loss of oxygen at the bottom and subsequently no increased phosphorus at the bottom. 2011 was the first year that we found phosphorus accumulating in bottom waters (**Table 4**). Beginning in 2013, increased phosphorus in bottom water has occurred each year the lake has been sampled (**Figure 7**).

North Riga phosphorus at the top and middle depths has also shown an increase over the time we have been sampling the lake. In 2007-2008 phosphorus at top and middle depths ranged between 3ppb and 9ppb, with an average of 5.2ppb. In 2018, phosphorus in top and middle depths ranged between 7ppb and 19ppb with an average of 9.6ppb, a doubling of average phosphorus content in the lake. South Riga has not shown the same doubling of phosphorus concentration; rather levels have not changed appreciably since early sampling in 2007-2008. In South Riga, average phosphorus changed from 5.5ppb to 7.2ppb between 2008 and 2018.

**Figure 7** – *Phosphorus trends at North and South Riga Lakes*

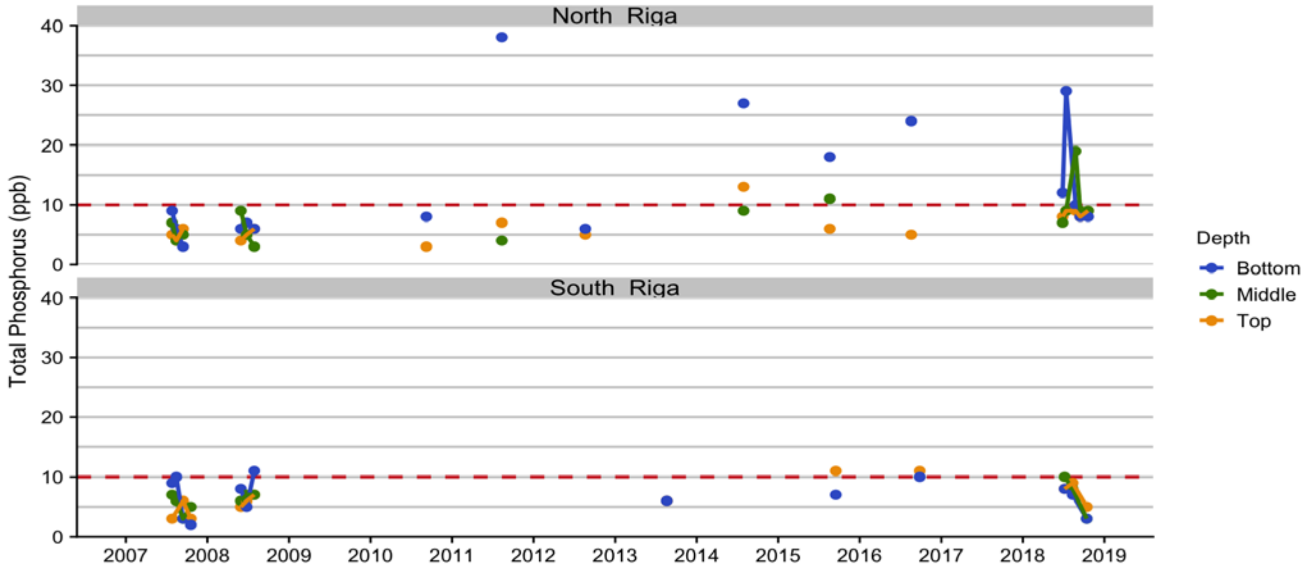



**Table 4** - *Total phosphorus results from North and South Riga*

| North Riga Total Phosphorus (ppb) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **6/28/18** | **7/14/18** | **8/25/18** | **9/15/18** | **10/20/18** | | | |
| **Top** | 8 | 9 | 9 | 8 | 9 | | | |
| **Middle** | 7 | 9 | 19 | 9 | 9 | | | |
| **Bottom** | 12 | 29 | 10 | 8 | 8 | | | |
| | **8/12/11** | **8-12-12** | **7/30/14** | **8/20/15** | **8/19/16** | | | |
| **Top** | 7 | 5 | 13 | 6 | 5 | | | |
| **Middle** | 4 | ~ | 9 | 11 | NA | | | |
| **Bottom** | 38 | 6 | 27 | 18 | 24 | | | |
| | **7/27/07** | **8/15/07** | **9/14/07** | **5/30/08** | **6/25/08** | **7/29/08** | | |
| **Top** | 5 | 4 | 6 | 4 | 5 | 6 | | |
| **Middle** | 7 | 4 | 5 | 9 | 5 | 3 | | |
| **Bottom** | 9 | 6 | 3 | 6 | 7 | 6 | | |

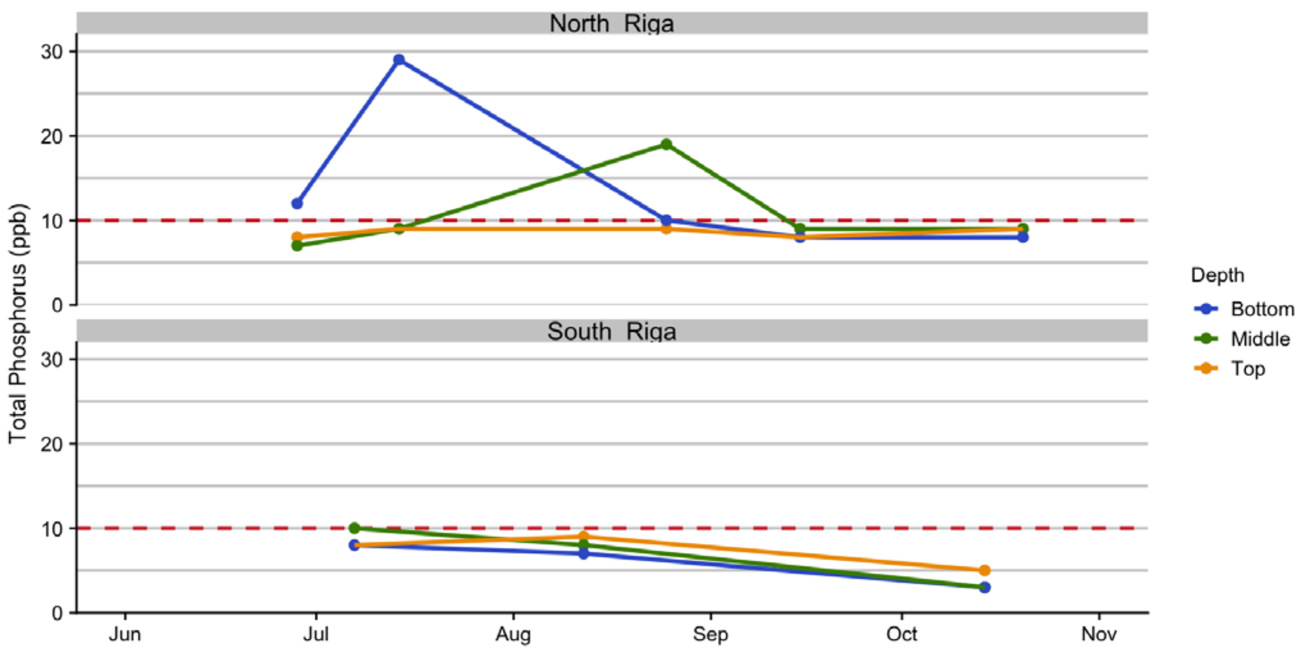
| South Riga Total Phosphorus (ppb) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **7/7/18** | **8/12/18** | **10/14/18** | | | | | |
| **Top** | 8 | 9 | 5 | | | | | |
| **Middle** | 10 | 8 | 3 | | | | | |
| **Bottom** | 8 | 7 | 3 | | | | | |
| | **8/20/13** | **9/16/15** | **9/26/16** | | | | | |
| **Top** | 6 | 11 | 11 | | | | | |
| **Middle** | NA | NA | | | | | | |
| **Bottom** | 6 | 7 | 10 | | | | | |
| | **7/27/07** | **8/15/07** | **9/14/07** | **10/19/07** | **5/30/08** | **6/25/08** | **7/29/08** | |
| **Top** | 3 | lost | 6 | 3 | 5 | 6 | 7 | |
| **Middle** | 7 | 6 | 3 | 5 | 6 | 7 | 7 | |
| **Bottom** | 9 | 10 | 3 | 2 | 8 | 5 | 11 | |

In 2018, total phosphorus (TP) in North Riga at the surface remained at slightly less than 10ppb all season. Bottom TP showed a large increase in July but decreased after that date. Mid-depth TP showed an increase in August that was not noted in either top or bottom samples suggesting subsurface source of TP (**Figure 8)**.

Total phosphorus at South Riga remained low in 2018, never rising above the 10ppb threshold, even in the bottom water. There was a distinct decrease in TP at all depths after August such that by October TP had decreased to <5ppb.

The TP threshold for both lakes is <10ppb.

**Figure 8** - *Total phosphorus results from North and South Riga in 2018*




## Total Nitrogen

Total nitrogen (TN) includes fractions of nitrate, ammonia, and organic components. Ideally, TN should remain below 200 ppb, to keep the lake in the 'oligotrophic' category (**Table 1**). At North Riga in 2018, TN remained low in top and middle samples (**Figure 9**). In the bottom water, TN was low in June but by mid-July it had spiked to 545 ppb concurrent with the bottom phosphorus increase. The 545ppb result is the highest concentration of TN on record for North Riga (**Table 5**). By August, TN had decreased, but was still somewhat elevated at 299 ppb. In September and October, TN had fallen back below the 200 ppb threshold.

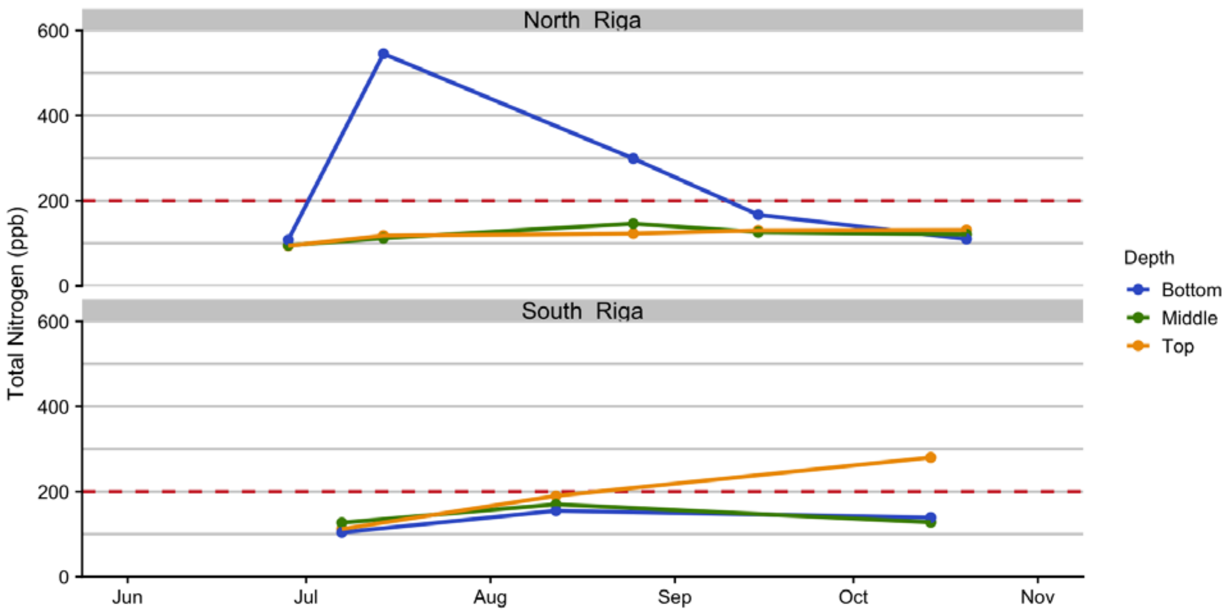
At South Riga, TN was low in July and August, remaining below 200 ppb. In October, TN was low at the middle and bottom of the water column, but reached 280 ppb in the surface water. In August, TN was also highest at the top of the water column. This suggests that nutrients are entering the lake from the watershed, by way of inlets and/or groundwater seeps. It would be beneficial to conduct an analysis of the watershed to determine the main sources of nutrients entering the lake.

**Table 5** -*Total nitrogen results from the top, middle and bottom of the water column at North Riga and South Riga.*

| North Riga Total Nitrogen (ppb) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **7/30/14** | **8/20/15** | **8/19/16** | **6/28/18** | **7/14/18** | **8/25/18** | **9/15/18** | **10/20/18** |
| **Top** | 26 | 129 | 130 | 94 | 118 | 123 | 130 | 131 |
| **Middle** | NA | 140 | NA | 95 | 112 | 146 | 126 | 121 |
| **Bottom** | 528 | 243 | 442 | 108 | 545 | 299 | 167 | 110 |
| | **27-Jul-07** | **15-Aug-07** | **14-Sep-07** | **30-May-08** | **25-Jun-08** | **29-Jul-08** | | |
| **Top** | 173 | 132 | 221 | 175 | 180 | 168 | | |
| **Middle** | 670 | 260 | 252 | 234 | 167 | 200 | | |
| **Bottom** | 68 | 175 | 196 | 110 | 248 | 220 | | |

| South Riga Total Nitrogen (ppb) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **8/20/13** | **9/16/15** | **9/26/16** | **7/7/18** | **8/12/18** | **10/14/18** | | |
| **Top** | 89 | 131 | 179 | 112 | 190 | 280 | | |
| **Middle** | NA | NA | NA | 127 | 170 | 128 | | |
| **Bottom** | 127 | 218 | 146 | 104 | 155 | 139 | | |
| | | | | | | | | |
| | **27-Jul-07** | **15-Aug-07** | **14-Sep-07** | **19-Oct-07** | **30-May-08** | **25-Jun-08** | **29-Jul-08** | |
| **Top** | 480 | 230 | 166 | 320 | 201 | 217 | 190 | |
| **Bottom** | 185 | 320 | 190 | 200 | 208 | 242 | 280 | |
| | | | | | | | | |

**Figure 9 -** *Total nitrogen results from the top, middle, and bottom depths at North Riga and South Riga, 2018*




## Aquatic Plants

The aquatic plants in North and South Riga lakes were surveyed on October 5th, 2018. During the North Riga survey, 17 aquatic plant species were found growing in the lake, all of which are native to Connecticut (**Table 6**). Purple bladderwort (*Utricularia purpurea*) was the most abundant species in the lake, present at approximately 40% frequency. Pipewort (*Eriocaulon sp*.), and low milfoil (*Myriophyllum humile*) and floating burred (*Sparganium fluctuans*) were also dominant in the lake.

Similar plant community exists in South Riga where we found 17 native aquatic plant species. Of these, purple bladderwort was the most abundant, present at 45% frequency. This was also the only dominant species in the lake, although floating burred and water lobelia were also fairly abundant, present at just below 20% frequency.

*Potamogeton confervoides* (Tuckerman's pondweed), which is a Connecticut State Listed Endangered Species, is present in both North Riga and South Riga at a low frequency. During the October 2018 survey, it was found in just one location in North Riga, on the eastern shoreline (**Figure 5**). In South Riga, it was found in three locations, all on the lake's northeast shoreline (**Figure 6**). No invasive species were found in either of the lakes during the 2018 surveys.

**Table 6 -** *Aquatic plants in North and South Riga lakes, October 2018.*

| North Riga | | |
|---|---|---|
| **Species** | **Frequency** | **Percent** |
| Utricularia purpurea | 40 | 42 |
| Eriocaulon | 37 | 38 |
| Myriophyllum humile | 37 | 46 |
| Sparganium fluctuans | 23 | 35 |
| Eleocharis acicularis | 19 | 26 |
| Emergent sparganium | 14 | 28 |
| Nuphar variegata | 9 | 7 |
| Lobelia | 7 | 6 |
| Nymphaea odorata | 5 | 25 |
| Eleocharis robbinsii | 5 | 40 |
| Fontinalis | 4 | 3 |
| Elatine | 4 | 5 |
| Isoetes sp. | 4 | 45 |
| Chara sp. | 4 | 3 |
| Utricularia minor | 4 | 6 |
| Potamogeton confervoides | 2 | 30 |
| Ludwigia | 2 | 1 |

| South Riga | | |
|---|---|---|
| **Species** | **Frequency** | **Percent** |
| Utricularia purpurea | 45 | 36 |
| Emergent sparganium | 19 | 14 |
| Lobelia | 19 | 24 |
| Eleocharis acicularis | 17 | 21 |
| Eleocharis robbinsii | 17 | 57 |
| Nuphar variegata | 12 | 11 |
| Nitella | 8 | 8 |
| Nymphaea odorata | 8 | 18 |
| Sparganium fluctuans | 7 | 11 |
| Elatine | 6 | 6 |
| Pipewort | 4 | 35 |
| Epihydrus | 3 | 29 |
| Fontinalis | 3 | 15 |
| Potamogeton confervoides | 3 | 9 |
| Isoetes | 3 | 38 |
| Myriophyllum humile | 3 | 10 |
| Potamogeton oakesianus | 3 | 40 |
| Filamentous algae | 1 | 33 |

Distribution of aquatic plants around both lakes appears to be increasing. Map of plant beds in 2007 shows generally sparse plant cover limited to the very shallow coves of each lake (**Figures 10** and **11**). In 2018, plants were found to cover considerably more of the lake as shown in **Figures 12** and **13**. The increase is mostly due to purple bladderwort and low milfoil in North Riga and purple bladderwort in South Riga, although, most of the common species were noted to have more extensive distributions in both lakes in 2018.

**Figure 10 –** *Distribution of aquatic plant beds in 2007 at North Riga*

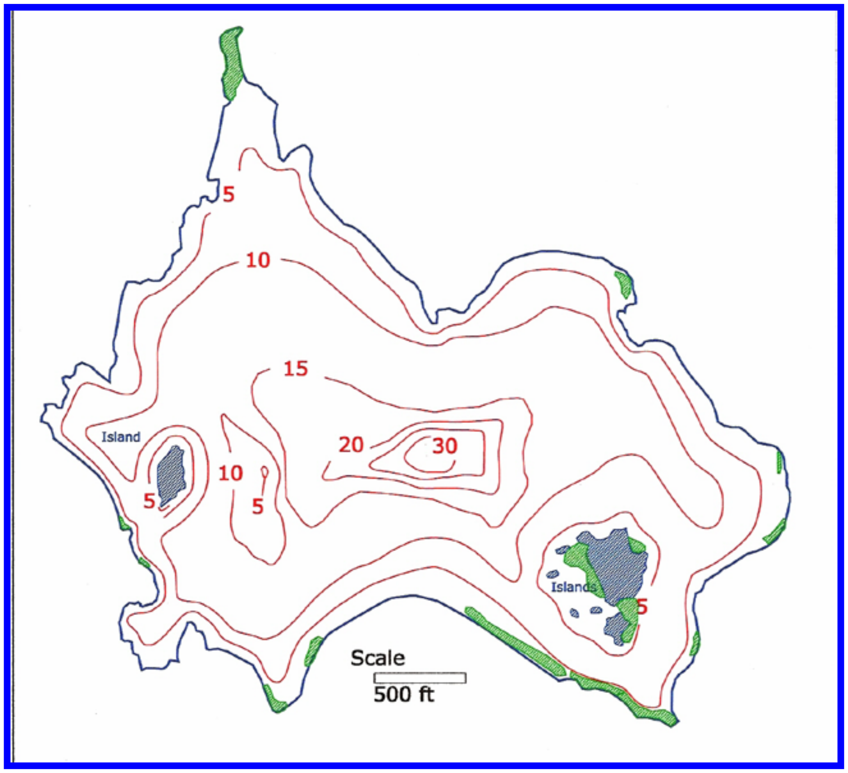



**Figure 11** - *Distribution of aquatic plants in North Riga Lake in 2007*

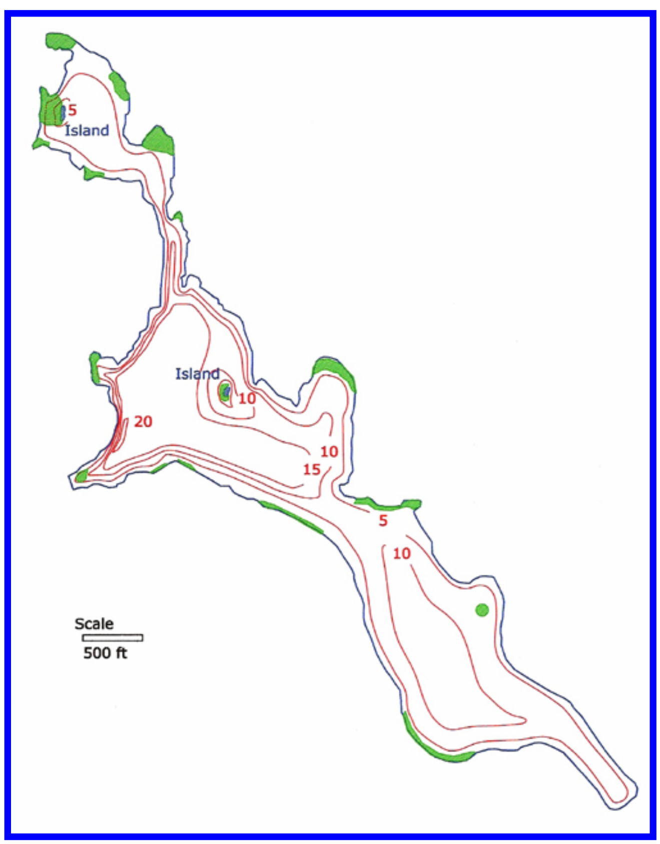


**Figure 12 -** *Aquatic plants of interest in North Riga Lake, October 5th, 2018*

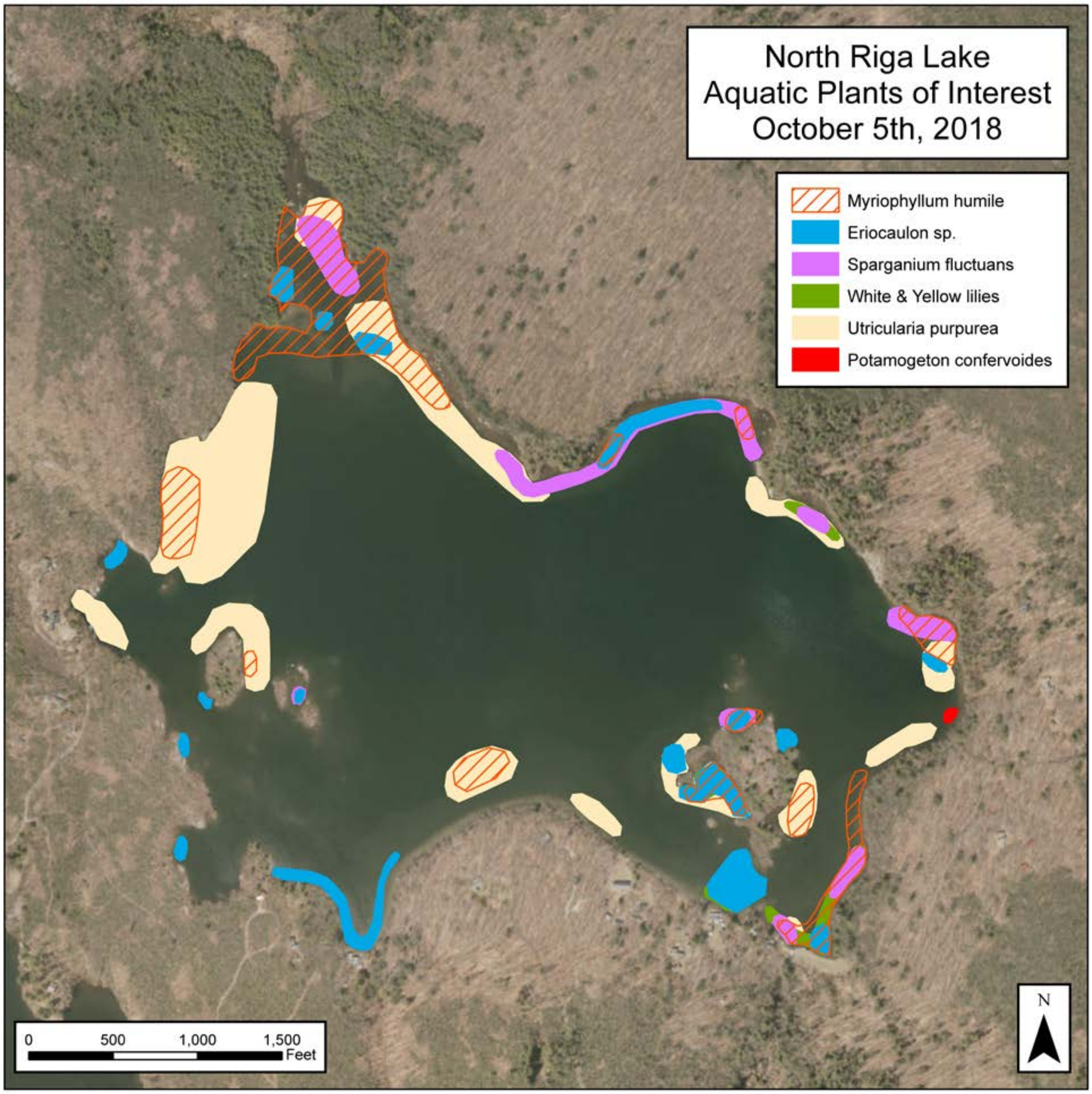
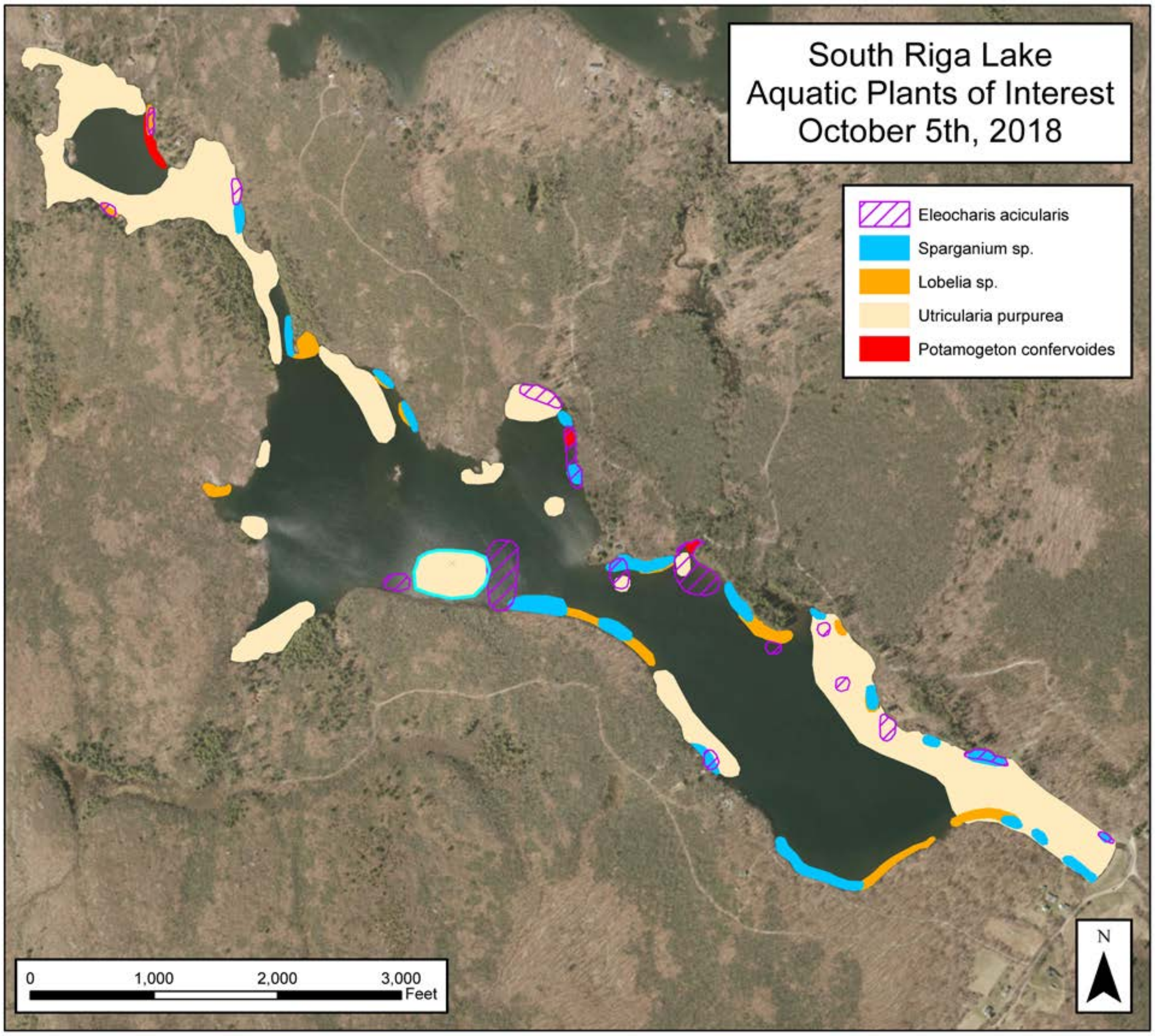



**Figure 13 -** *Aquatic plants of interest in South Riga Lake, October 5th, 2018*


South Riga Lake
Aquatic Plants of Interest
October 5th, 2018
Eleocharis acicularis
Sparganium sp.
Lobelia sp.
Utricularia purpurea
Potamogeton confervoides
0
1,000
2,000
3,000
Feet
N

# RECOMMENDATIONS

## Suggested 2019 Actions

1. Continue the in-lake water quality monitoring, ideally from April through October and maybe November at North Riga, to track the full extent of seasonal fluctuations, including peak extent of anoxic water, best and worst seasonal clarity, and peak nutrient concentrations.
2. Collect inlet samples from all flowing inlets in May and test the samples for total phosphorus, total nitrogen, and nitrate nitrogen.
3. Conduct a late-season full-lake aquatic plant survey to document the presence and abundance of aquatic plant species in the lake and to search for invasive species.