West Monponsett Pond

Halifax and Hanson, Massachusetts

2017 Year-End Alum Treatment Report

Prepared for:
Town of Halifax
499 Plymouth Street
Halifax, MA 02338

Prepared by:
SŌLitude Lake Management
590 Lake Street
Shrewsbury, MA 01545

Table of Contents

Appendices

Appendix A

'REVISED Habitat Management Plan for Phosphorus Inactivation in the Western Basin of Monponsett Pond' (SŌLitude Lake Management, 2017)

Appendix B

Treatment Monitoring Program at the West Basin of Monponsett Pond Raw Data (Table 1-4)

Appendix C

Mussel and Dragonfly Monitoring Report by Biodrawversity LLC, "*Effects of an Alum Treatment on Freshwater Mussels and Dragonflies in West Monponsett Pond: 2017 Monitoring*"

I. INTRODUCTION

Monponsett Pond located in the towns of Halifax and Hanson, Massachusetts, is a significant ecological, historical, and recreational resource as well as an important supplementary water supply for the nearby City of Brockton. The 528-acre pond is bisected by Route 58, which splits the water body into two basins - East and West - directly connected by a small culvert in the Southern portion of the pond. Both basins are highly developed with residential homes and receive inputs from a suburban watershed of approximately six square miles.

As a whole, Monponsett Pond has been heavily impacted by the use of its waters and watershed, and both basins have been listed as Category 5 “Impaired” waterbodies on the Massachusetts Integrated List of Waters (303(d) list). The East Basin was listed for nuisance aquatic plants and mercury in fish. A TMDL was approved by the EPA for mercury, thus removing the basin from the list of impaired waters. The Western basin appears on the 2014 303(d) list as a category 5 water body for nutrients, noxious aquatic plants, transparency, and exotic species. The West Basin was included in the mercury TMDL and a draft TMDL for phosphorus was released in November of 2016.

Both basins, especially the West Basin, have been subject to extensive nuisance algae blooms (specifically cyanobacteria – blue-green algae) for many years. During recent summers, these blooms prompted the frequent closure of the Western basin to swimming and boating. Algae testing has been carried out both by the Massachusetts Department of Public Health (MA DPH) and Massachusetts Department of Environmental Protection (MA DEP) throughout the summer months. MA DPH also conducted analysis of water quality, including total phosphorus. These results show a definite correlation between concentration of total phosphorus and total algal cell count in the Western basin throughout the summer. Previous testing and the TMDL have determined that internal loading of phosphorus is prominent in the West Basin, along with watershed loading.

Despite these water quality challenges, the Western basin has been identified as an area of priority habitat by the Massachusetts Division of Fisheries and Wildlife (DF&W) Natural Heritage and Endangered Species Program (NHESP). Three state-listed species of special concern have been confirmed in West Monponsett Pond: Tidewater Mucket (*Leptodea ochracea*), Eastern Pondmussel (*Ligumia nasuta*), and Umber Shadowdragon (*Neurocordulia obsoleta*).

Internal Phosphorus Management

Understanding the correlation between phosphorus levels and growth of potentially harmful cyanobacteria, the Town of Halifax, in cooperation with MA DEP, has investigated and implemented phosphorus management activities in West Monponsett Pond**.**

Various parties have been addressing watershed phosphorus loading including efforts by nearby cranberry bogs. Work focusing on internal phosphorous inactivation began in 2013, under Lycott Environmental, in accordance with the NHESP letter (09-27490) dated June 6, 2012, and the submitted Habitat Management Plan. In that year, a volumetric dose of 3.0 ppm Al was applied in one treatment for a total areal (sediment) dose of 7.1 g/m2. No treatment occurred in 2014, and in 2015 the dose and method were changed to a total of 2.1 ppm Al over three treatments (0.7 ppm each), resulting in an additional sediment dose of 4.9 g/m2 Al. The 2016 season saw one application of 1.4 ppm Al, depositing 3.2 g/m2 Al on the pond bottom. Prior to 2017, a total of 15.2 g/m2 of aluminum have been applied to the bottom of the Western basin.

Based on experience in similar lakes and the assessment of sediment phosphorus release, a sediment dose of up to 50 g/m^2 is likely to be needed in order to sufficiently reduce internal phosphorus recycling. The ongoing sediment release, in addition to annual watershed loading, has resulted in reduced efficacy of the current treatment plan on controlling nuisance bloom conditions.

Following award of a 319 Grant to the Town of Halifax and revision of the Habitat Management Plan with NHESP in 2017, the current plan involved an early season application of 17.0 g/m2 (~8 ppm Al). The plan aimed to inactivate a sufficient amount of available phosphorous in the pond sediment to provide desirably low growth of cyanobacteria. Past treatments have sequentially reduced phosphorus levels in the West Basin and it was estimated that the proposed treatment will meet WQ goals, at least for a period of time.

II. PERMITTING

U.S. Environmental Protection Agency National Pollution Discharge Elimination System Permit

Lycott Environmental filed an electronic Notice of Intent (eNOI) under the U.S. Environmental Protection Agency Pesticide General Permit (PGP) for the application of pesticides to the Monponsett Ponds on behalf of the Town of Halifax on May 9, 2012. This application was signed and submitted by the Town of Halifax on May 19, 2013, which then received an active status ten days following its submission. The NOI remains valid until May of 2018.

Massachusetts Endangered Species Act Project Review

A 'REVISED Habitat Management Plan for Phosphorus Inactivation in the Western Basin of Monponsett Pond' was submitted to the Massachusetts Division of Fisheries and Wildlife (DF&W) Natural Heritage and Endangered Species Review Program (NHESP) on March 27, 2017. The NHESP provided approval correspondence on May 4, 2017.

Order of Conditions

The Orders of Conditions (Halifax & Hanson) have been automatically extended by the Permit Extension Act and are therefore valid for an additional four years from the original date of expiration or until 2019. Revised alum treatment plans were presented to both Commissions in the spring of 2017.

Image 1: Treatment Vessel

Massachusetts Department of Environmental Protection License to Apply Chemicals

SLM prepared and filed for the required License to Apply Chemicals permit from MA DEP Office of Watershed Management; the approved license was issued on June 2, 2017 (#17266).

III. 2017 TREATMENT PROGRAM CHRONOLOGY

The tasks performed as part of the 2017 treatment program are outlined below.

➢ Received approved MA DEP License to Apply Chemicals	6/05/2017
➢ Received management plan approval from NHESP	5/04/2017
➢ Alum treatment	6/06 - 6/14/2017

IV. TREATMENT LOGISTICS

Over a nine (9) day period during the 2017 season, alum applications were administered throughout seven (7) days: June 6th through June 14th, excluding the weekend. The applications were conducted with a specially equipped treatment vessel (**Image 1**). The treatment vessel was equipped with 2 translucent polyethylene tanks, in addition to a fathometer, speedometer, in-line pressure gauges and flowmeters to measure and ensure appropriate chemical delivery. Two separate pumping systems were used to apply aluminum sulfate and sodium aluminate to areas greater than 4' in depth in the West Basin of Monponsett Pond, an area totaling 235 acres. The 235-acre treatment area was divided into three pre-determined treatment zones (**Image 2**) with similar depth characteristics in order to ensure accurate dosing and a more uniform application of the alum and sodium aluminate. An areal dose of 17 g/m^2 was applied to each treatment area. Over the course of the seven-day treatment, a total of 33,162 gallons of aluminum sulfate and 16,762 gallons of sodium aluminate were applied to West Monponsett Pond. A map of the treatment vessel tracks from the entire treatment event is provided in **Image 3**.

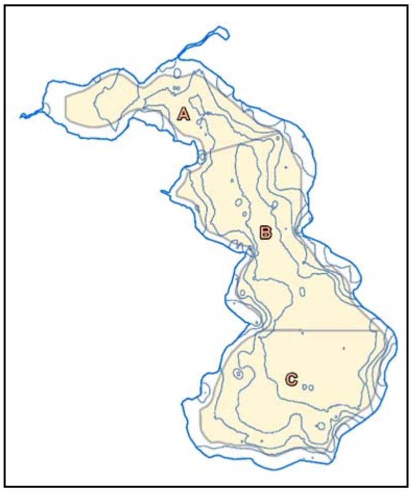


Image 2: Treatment Zones of the Western Basin of Monponsett Pond

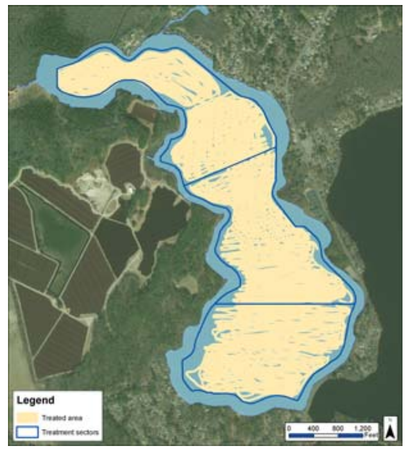


Image 3: 2017 Alum Treatment tracks

V. MONITORING PROGRAM

The following table outlines the major components of the monitoring program and their respective goals, as approved in the habitat management plan ('**Appendix A**').

Table 1. Monitoring program design

Monitoring component	Timing in relation to treatment	Location(s)	Goals
Water Quality	Before, during and after application	Established location within each treatment zone	Evaluate short and long-term effects on water quality
	Monthly		Monitor summer long water quality and algae conditions
Monitoring of state-listed species	Upon reaching suitable conditions (phosphorus levels <20 pbb and sustained cyanobacteria counts <50,000 cell/ml), one year following completion of alum treatments and 5-years after completion of alum treatments	5 paired plots	Evaluate short and long-term effects on these species identified by NHESP as potentially susceptible to the treatment

a. WATER QUALITY MONITORING

The water quality monitoring was comprised of sample collection for laboratory analysis and basic *in-situ* testing. Water quality samples were collected at predetermined locations within each treatment area immediately before and after the June treatment event, as well as, once a month for four months after the treatment. Each sample was analyzed for: water clarity, pH, turbidity, alkalinity, total phosphorus, and dissolved phosphorus ('**Appendix B, Table 1**'). The *in-situ* treatment testing was performed at the same predetermined locations before, during and after each treatment day. The testing included temp/dissolved oxygen, water clarity, pH, and alkalinity ('**Appendix B, Table 2**').

Total Phosphorus Monitoring

A total phosphorus measurement was collected before and after the June treatment event, and subsequently once a month until October (**Figure 1**). Total phosphorus levels decreased overall following the treatment event, but spiked in August before decreasing again in September and October. The results show a reduction in total phosphorus of roughly 50% (Avg. 28 ppb June – Avg. 12 ppb October) during the course of the season.

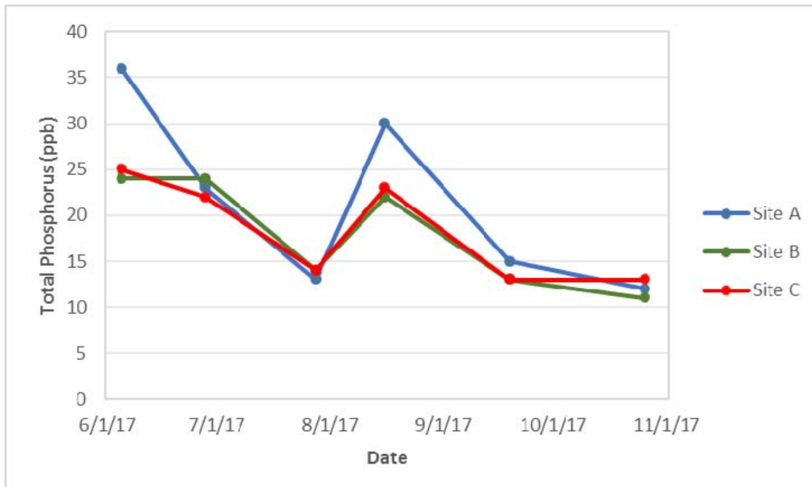


Figure 1: Comparison of total phosphorus (ppb) from June to October.

Dissolved Phosphorus Monitoring

A dissolved phosphorus measurement was collected before and after the June treatment event, and subsequently once a month until October (**Figure 2**). Dissolved phosphorus levels remained steady over the first month after the treatment event, with a slight increase. However, in the following months the dissolved phosphorus began to steadily drop until it reached levels that were too low to be detected by instruments, at less than 10 ppb (indicated by values at 10 ppb). Overall, the results show a significant reduction in dissolved phosphorus during the course of the season.

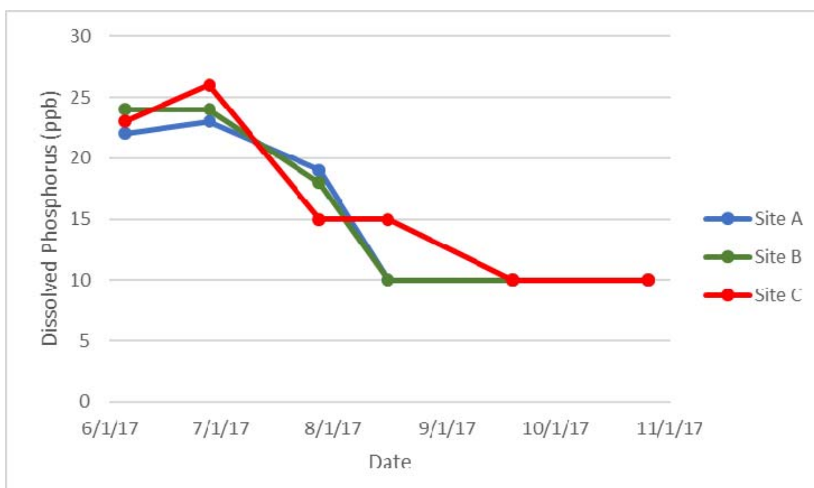


Figure 2: Comparison of dissolved phosphorus (ppb) from June to October.

Dissolved Oxygen Monitoring
A dissolved oxygen measurement was collected once a month from June to October (**Figure 3**). A slight increase in dissolved oxygen was observed following the June treatment event; however, levels later decreased, before increasing again at the final measurement. The dissolved oxygen measurements revealed that levels remained within a suitable range (> 5 mg/L) for wildlife populations throughout the duration of the program and were not substantially impacted by the buffered alum treatments.

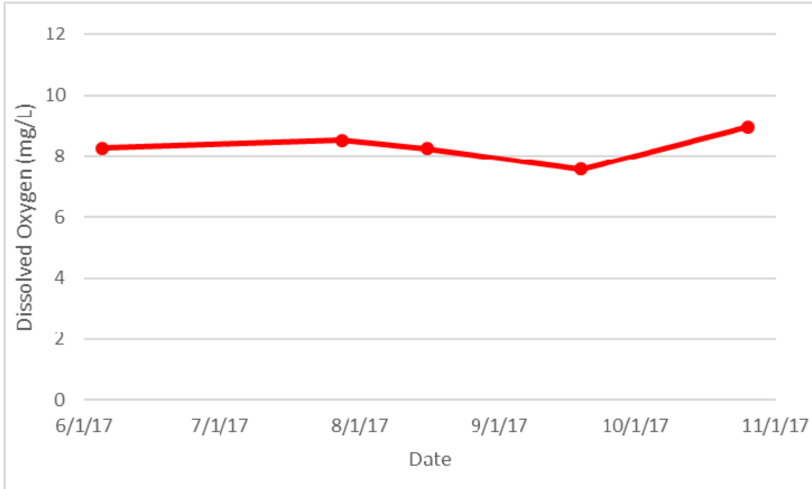


Figure 3: Average dissolved oxygen (mg/L) sampling results of all three treatment zones from June to October.

Water Clarity Monitoring (via Secchi Disk)
Water clarity was measured before, during and after each day of the June treatment event, and subsequently once per month until October (**Figure 4**). Throughout the seven days of the treatment event, the Secchi depth increased steadily, until July when it began to decrease. The depth continued to decrease until October, when it began to return to depths seen during the treatment event. The reduction in water clarity (Secchi depth) after June correlates with an increase in algal cell density.

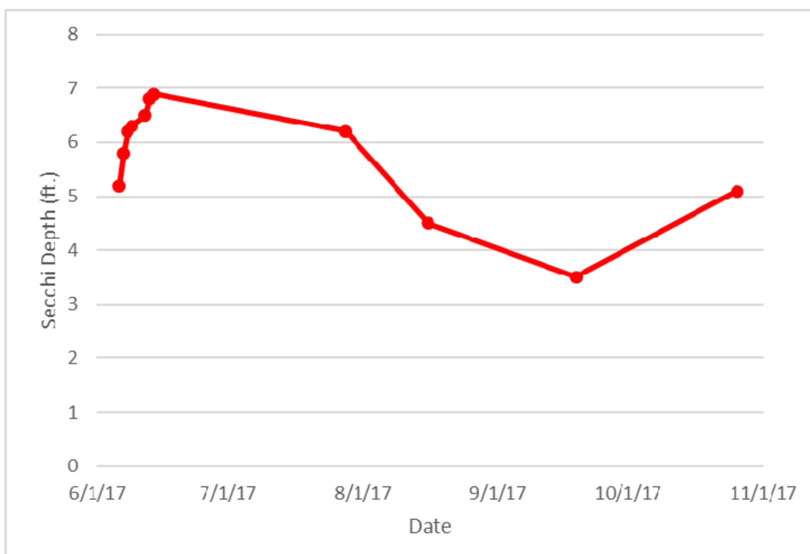


Figure 4: Average Secchi Disk depth (ft.) results of all three treatment zones throughout June treatment event and the following four months.

pH Monitoring

A pH measurement was collected before, during and after each day of the June treatment event (**Figure 5**). Overall, the results show relatively constant pH levels between 6 and 7 SU, with minimal fluctuation throughout the treatment event.

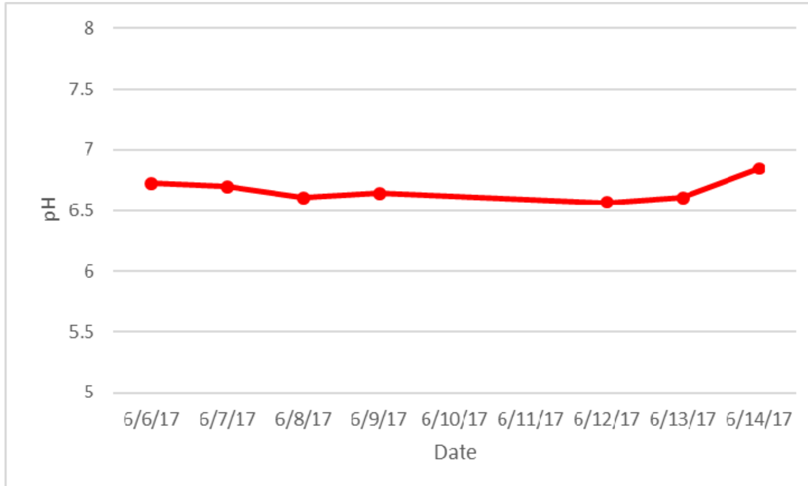


Figure 5: Average pH results of all three treatment zones throughout June treatment event.

Total Alkalinity Monitoring

Total alkalinity was measured before, during and after each day of the June treatment event, and subsequently once per month until October (**Figure 6**). The total alkalinity measurements remained between approximately 8 and 14 mg/L throughout the treatment event, with some fluctuation between each day. In the following months the total alkalinity steadily increased, before plateauing.

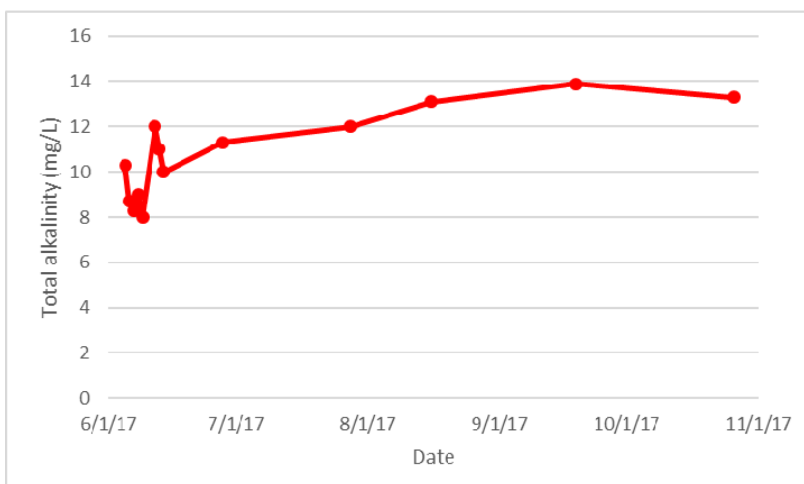


Figure 6: Average total alkalinity (mg/L) results of all three treatment zones throughout June treatment event and the following four months.

b. ALGAE SAMPLING

A single monthly sample (June-October) was collected from Area B within the West Basin for algae species identification and characterization of general species abundance/dominance. Based on the results of these samples the algae assemblage presented a fair amount of variance from month to month. See **Table 1** for a breakdown of the natural count/mL of each phylum of algae observed in the monthly samples.

Table 1:	Phylum of Algae (Natural Unit Count/mL)				
Date	**Diatomaceae**	**Rotifera**	**Chlorophyceae**	**Cyanophyceae**	**Protozoa**
6/5/17	314	30	135	12	64
6/28/17	106	-	53	597	14
7/28/17	-	-	202	220	190
8/16/17	144	-	19	73	-
9/19/17	139	-	87	129	139
10/26/17	12	-	110	118	144

The most abundant and frequently observed blue-green algae were *Anabaena* and *Psuedanabaena*. The unicellular, colonial blue-green *Microcystis* was prevalent in the October sample. Other common genus' were comprised of primarily diatoms (*Cyclotella* and *Synedra*) and green algae (*Ankistrodesmus*, *Closterium, Coelastrum*, and *Ulothrix*). The blue-green algae cell count fluctuated throughout the 2017 management season, with the lowest abundance occurring at the start of June and the greatest in the middle of September (**Figure 7**).

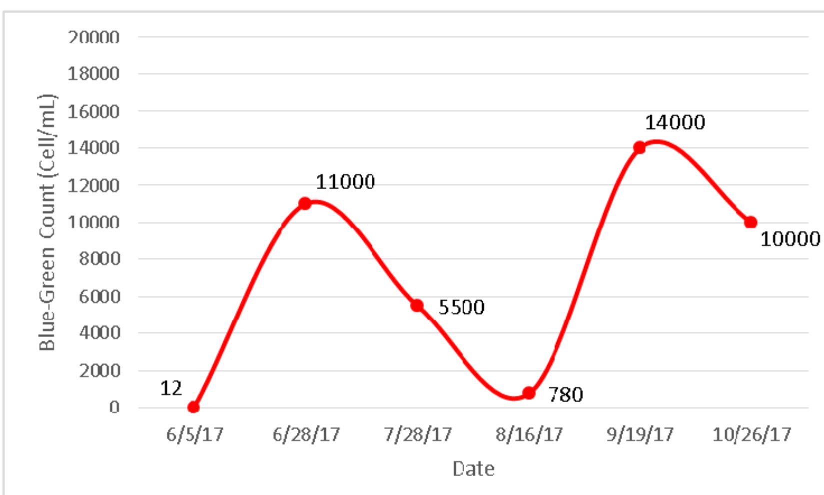


Figure 7: Blue-Green Cell Count/mL from June to October.

c. MUSSEL AND DRAGONFLY MONITORING

As a part of the Habitat Management Plan, an ongoing program initiated in 2013 to monitor mussel and dragonfly populations in West Monponsett was continued in 2017. Biodrawversity LLC was hired to complete the monitoring, providing their methodology and findings in the report titled "*Effects of an Alum Treatment on Freshwater Mussels and Dragonflies in West Monponsett Pond: 2017 Monitoring*" (**'Appendix C'**). During the 2017 post-treatment monitoring, five mussel species were present with a total of 2,536 individual mussels observed. *Elliptio complanata* was the dominant species at 76.5% of all observed mussels, with *Leptodea ochracea* the second most abundant at 14.3%. The state-listed species of special concern, *Leptodea ochracea* and *Ligumia nasuta*, had 363 and 46 individuals observed in 2017, respectively. Overall, the density of mussels was higher in 2017 in comparison to 2013 and 2014.

Throughout the monitoring program, thirteen dragonfly species have been found in West Monponsett pond. The state-listed species *Neurocordulia obsoleta* was observed in two locations in 2017, specifically within or close to the culvert between West and East Monponsett Pond. The study ultimately concluded, "data do not indicate that the alum treatment had any adverse effect on juveniles or adults of any mussel species". Additionally, the study found no apparent difference in the presence of listed dragonfly species as compared to the pre-treatment baseline in 2011. Listed species were present following the alum treatments in 2013 & 2017.

VI. DISCUSSION/CONCLUSION

Overall, the 2017 alum treatment at West Monponsett Pond was conducted successfully and with no adverse effects on water quality or non-target organisms. The treatment served to apply an additional 17 g/m^2 of aluminum to the sediment in order to further counteract internal phosphorus loading. Monthly water quality sampling showed overall improvements in phosphorus concentrations, water clarity and algae populations as compared to previous years.

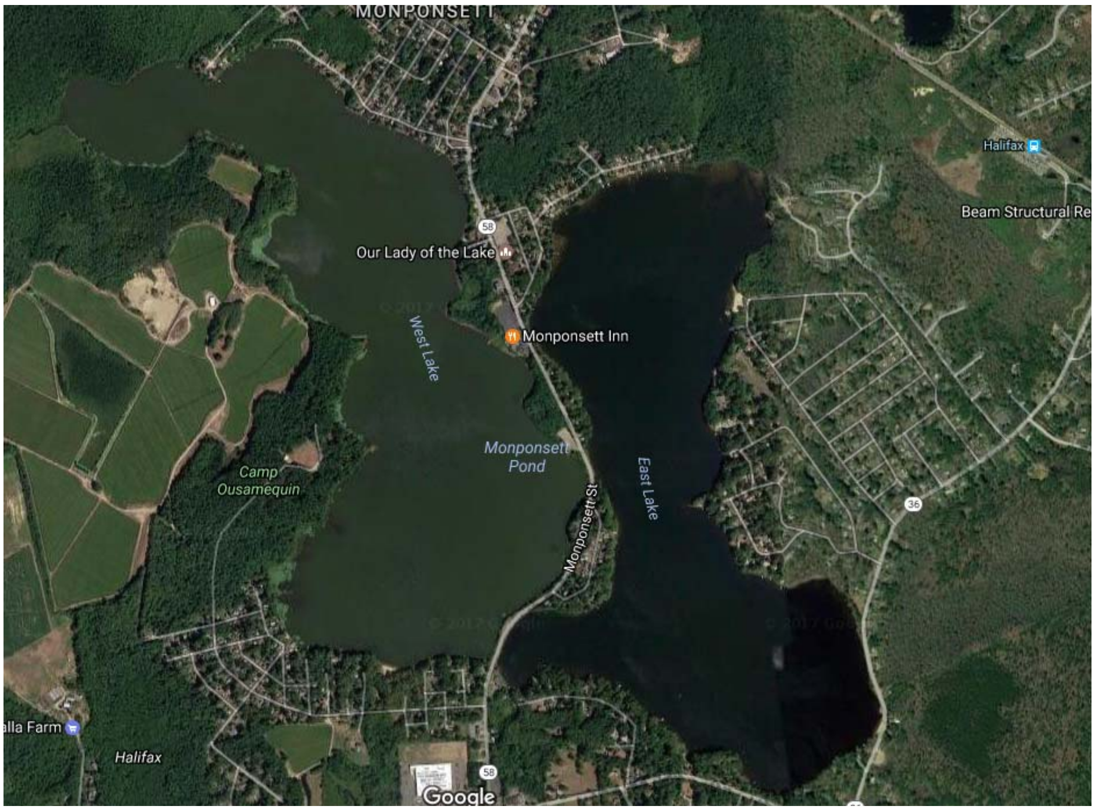
Unfortunately, based on MassDEP algae sampling of near shore areas, algae density did exceed the MA DPH threshold of 70,000 cells/ml at many points and the pond was closed to recreation for much of the summer. This was a wet year and watershed loading to the system was likely high, which may have counteracted the improvements made with the alum treatment. Regardless, the condition of the pond was much improved this year and the algae counts were much lower than seen in previous years. Hopefully, the pond will continue to improve in 2018 as a result of this treatment, especially if precipitation levels are more normal.

We understand that the Town is pursuing the design of an alum dosing system that can be used on an as needed basis to treat periodic watershed loading and continue to contribute to the inactivation of available sediment phosphorus. We are willing to contribute to any planning activities the Town may be conducting and discuss any additional in-lake treatments as necessary.

Appendix A

REVISED Habitat Management Plan for Phosphorus Inactivation in the Western Basin of Monponsett Pond

REVISED Habitat Management Plan for Phosphorus Inactivation in the Western Basin of Monponsett Pond (2017)



Applicant: Town of Halifax
499 Plymouth Street
Halifax, MA 02338

Representative: SOLitude Lake Management
590 Lake Street
Shrewsbury, MA 01545

TABLE OF CONTENTS

REVISED Habitat Management Plan for Phosphorus Inactivation in the West Basin of Monponsett Pond Halifax/Hanson, Massachusetts 2017

SITE DESCRIPTION & BACKGROUND

Monponsett Pond, located in the towns of Halifax and Hanson, Massachusetts, is a significant ecological, historical, and recreational resource as well as an important supplementary water supply for the nearby City of Brockton. The 528-acre pond is bisected by Route 58, which splits the water body into two basins - East and West - directly connected by a small culvert in the Southern portion of the pond. Both basins are highly developed with residential homes, and receive inputs from a suburban watershed of approximately 6 mi^2.

As a whole, Monponsett Pond has been heavily impacted by the use of its waters and watershed, and both basins have been placed on the Massachusetts Integrated List of Waters (303(d) list). Since 2010, the Eastern basin has been categorized as a 4c water body for presence of exotic species and a Total Maximum Daily Load (TMDL) was published in 2007 for high concentrations of mercury. The Western basin appears on the 2010 303(d) list as a category 5 water body for nutrients, noxious aquatic plants, turbidity, and exotic species. A draft TMDL for phosphorus was released in November of 2016. The presence of two exotic aquatic vegetation species; Fanwort (*Cabomba caroliniana*) and Variable Milfoil (*Myriophyllum heterophyllum*), have been recorded in the Eastern basin, while presence of Fanwort was noted in the Western basin.

Both basins have also been subject to extensive nuisance algae blooms (specifically cyanobacteria – blue-green algae) for many years. During recent summers, these blooms prompted the frequent closure of the Western basin to swimming and boating. Algae testing has been carried out both by the Massachusetts Department of Public Health (MA DPH) and Massachusetts Department of Environmental Protection (MA DEP) throughout the summer months. MA DPH also conducted analysis of water quality, including total phosphorus. These results show a definite correlation between concentration of total phosphorus and total cell count in the Western basin throughout the summer.

Despite these water quality challenges, the Western basin has been identified as an area of priority habitat by the Massachusetts Division of Fisheries and Wildlife (DF&W) Natural Heritage and Endangered Species Program (NHESP). T hree state-listed species of special concern has been confirmed in West Monponsett Pond: Tidewater Mucket (*Leptodea ochracea*), Eastern Pondmussel (*Ligumia nasuta*), and Umber Shadowdragon (*Neurocordulia obsoleta*).

PROPOSED PHOSPHORUS INACTIVATION PROGRAM

This phosphorous inactivation project began in 2013, under Lycott Environmental, in accordance with the NHESP letter (09-27490) dated June 6, 2012, and the submitted Habitat Management Plan. In that year, a volumetric dose of 3.0 ppm Al was applied in one treatment for a total areal (sediment) dose of 7.1 g/m^2. No treatment occurred in 2014, and in 2015 the dose and method was changed to a total of 2.1 ppm Al over three treatments (0.7 ppm each), resulting in an additional sediment dose of 4.9 g/m^2 Al. The 2016 season saw one application of 1.4 ppm Al, depositing 3.2 g/m^2 Al on the pond bottom. To date a total of 15.2 g/m^2 of aluminum has been applied onto the pond bottom.

Table 1-Historical Dosing Information

Treatment Year	Volumetric Dose	Areal Dose	Notes
2013	3.0 ppm	7.1 g/m^2	Single application
2015	2.1 ppm	4.9 g/m^2	Split over three applications
2013	1.4 ppm	3.2 g/m^2	Single application
Total Areal Dose Applied		**15.2 g/m^2**	

Based on experience in other similar lakes and assessments of the sediment phosphorus release, a sediment dose of up to 50 g/m^2 is likely to be needed in order to sufficiently reduce internal phosphorus recycling. This ongoing sediment release in addition to annual watershed loading has resulted in reduced efficacy of the current treatment plan on controlling nuisance bloom conditions. Based on recent discussion with Mark Mattson (MassDEP) modifications to the management plan are proposed. As a note, based on the recent phosphorus TMDL draft, alum treatment may be conducted in the East Basin of Monponsett Pond at a reduced dose, however no listed species have been identified in that basin.

Aluminum Dose Modification

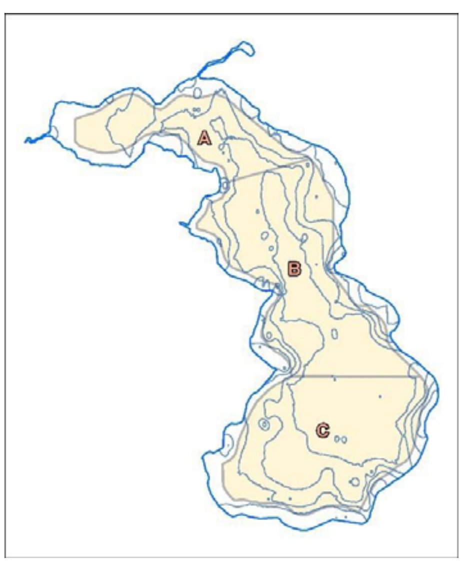
In 2017, the alum treatment plan will involve at least one large scale, early season application of 9.0 g/m^2 (~4 ppm Al) with the hope of inactivating a sufficient amount of available phosphorous in the pond sediments to provide desirably low growth of cyanobacteria. Past treatments have sequentially reduced phosphorus levels in the West Basin and it is estimated that the proposed treatment will meet WQ goals at least for a period of time. Depending on available resources, the dose may be increased up to 17.0 g/m^2 as a single or split-application treatment in 2017. Depending on how dramatically conditions improve in the lake, subsequent applications may not be necessary, however the remaining dose (up to the projected total dose of 50 g/m^2) may be applied in 2018 or plans and grants are also being pursued for an alum micro-floc injection system. The benefit of the injection system is that it will be in place to provide an option for addressing continued watershed phosphorus loading on an on-going basis. A summary of the 2017 treatment results and monitoring data will be supplied to NHESP in the fall, to facilitate their review of any proposed treatments in 2018.

Table 2-Proposed Alum Treatments for West Monponsett Pond

Treatment Year	Areal Dose	Notes
2017	9.0-17 g/m^2	Single or split application – any increase above 9 g/m^2 is pending funding and determination of need.
2018	Up to 17 g/m^2	Single or split application – only applied if needed after assessing results of 2017 treatments and pending funding. Also pending review by NHESP.

Treatment Area

No change to the overall extent of the treatment area is proposed. As with the 2013/2015-2016 treatment program, the aluminum sulfate and sodium aluminate will be applied to areas of the West Basin that are deeper than four (4) feet – a total treatment area of approximately 235 acres. We are proposing to divide the overall treatment area into three zones with relatively uniform depth characteristics (Zone A – 45 acres; Zone B – 98 acres; Zone C – 92 acres). This approach will enable accurate dosing and more uniform application without increasing the risk to rare species.



Application Methodology

Treatment will be conducted with our specially equipped treatment vessel. The treatment vessel will be equipped with a fathometer and speedometer. The use of the speedometer enables us to prepare calibration table for chemical delivery (gal/min) versus vessel speed (mph) which will insure even distribution of the alum and sodium aluminate. Suitable in-line pressure gauges and flowmeters to measure chemical delivery rates will also be used.

The treatment vessel will be equipped with 2 translucent polyethylene tanks with a combined capacity of up to 1,500 gallons. These tanks are also graduated on the outside, which allows our operators to visually monitor chemical delivery to insure the desired volumetric ratio is met.

Since the two chemicals cannot be tank-mixed prior to application, there are two separate pumping systems for each product including individual spray lines and drop-hoses. The chemical delivery spray boom will be mounted on the stern of the boat where the drop-hoses will emit the chemicals into the propwash of the outboard motor. Dispersing the chemicals into the propwash promotes flash mixing of the two products and ultimately excellent floc formation. Through our extensive prior alum/aluminate treatment experience, we have found that the use of this arrangement and application methodology provides the best results.

The treatment will be guided with an on-board GPS (CASE EX-Guide 250 guidance system). The guidance systems will show the pond and treatment area and treatment sector boundaries. The system logs the path of the treatment vessel. Each load of chemical will be logged and monitored.

The 9 g/m^2 treatment will entail the application of approximately 17,000 gallons of aluminum sulfate and 8,500 gallons of sodium aluminate. The treatment will require 3-4 days to complete.

MONITORING PROGRAM

The table below outlines the components of the monitoring program and the goals of each. Details are provided in the following sections.

Table 1: Monitoring Program Design

Monitoring Component	Timing in relation to treatment	Location(s)	Goal
Water quality	Before, during, and after each application	3 established locations within each treatment zone	Evaluate short and long-term effects on water quality
Monitoring of state-listed species	Upon reaching suitable conditions (phosphorus levels <20 pbb and sustained cyanobacteria counts <50,000 cell/ml), one year following completion of alum treatments and 5-years after completion of alum treatments	5 paired plots	Evaluate short and long-term effects on these species identified by NHESP as potentially susceptible to the treatment

Water Quality Monitoring

The water quality monitoring plan for West Monponsett Pond will include sampling at a single location within each of the three treatment zones. Sampling collection will occur immediately prior to each treatment and several days following each treatment. In addition to the sample collection, basic *in situ* testing will be performed throughout each alum application.

Each pre and post-treatment water quality sample will be analyzed for the following parameters.

- pH
- Alkalinity
- Total Phosphorus
- Dissolved Phosphorus

The *in situ* testing that will be performed during treatment will include the following.

- Secchi depth
- Dissolved oxygen
- pH
- Alkalinity

Monitoring of State-Listed Mussel Species

Long-term Mussel Monitoring Program

Since the submission of the original 'Habitat Management Plan' in May 2012, the pre-treatment and one year following the initial 2013 alum treatment long-term mussel monitoring event have been performed. Minor modifications to the proposed long-term mussel monitoring provided in the original 'Habitat Management Plan' were made by the NHESP-approved biologist performing these surveys. Monitoring was also conducted in 2015, but was abbreviated in extent due to poor and potentially toxic conditions. In order to maintain comparability with past mussel monitoring events, the modified survey methodology (below) will be implemented on 3 occasions, 1) upon reaching suitable conditions (phosphorus levels <20 pbb and sustained cyanobacteria counts <50,000 cells/ml), 2) one year following completion of alum treatments and 3) 5 years after completion of alum treatments. This methodology was provided to the NHESP by Biodrawversity in a report titled, "Monitoring the Effects of Low-Dose Alum Treatment on *Leptodea ochracea*, *L. nasuta*, and *Neurocordulia obsolete* in the Western Basin of Monponsett Pond (Halifax, Massachusetts)" and the relevant excerpt is copied below. Per conversations with the NHESP in 2015, additional revisions to this methodology is indicated below in **bold** text.

> *The basic sampling unit [will be] a 1 x 1 meter (1m^2) quadrat bounded by a frame, with two centerlines that [divide] the quadrat into four 0.5 x 0.5 meter sections. The centerlines facilitated more careful searching in the low-visibility environment. Quadrat locations [will be] marked with underwater markers and recorded with GPS to enable the precise area of each to be resurveyed. Five quadrats [will be] established at 10 sites (50 quadrats total); the 10 sites [will be] paired (one shallow, one deep) at five locations in the pond (Figure 1). The quadrats [will be] arranged in a consistent pattern at each site (Figure 2). For each quadrat, biologists [will] first [conduct] a visual and tactile search to count the number of mussels (all species) occurring at or near the surface. The biologists then [will excavate] and [sieve] sediment from within one-fourth (0.25m^2) of the quadrat area to find buried mussels. Surface counts and buried counts [will be] recorded for each species, and shell length* ***and shell condition*** *[will be] recorded for L. ochracea and L. nasuta. Once these two steps [are] completed, all mussels [will be] placed back within the confines of the each quadrat. The following habitat information [will be] recorded for each quadrat: water depth, spatial extent of each substrate type, and percent cover of macrophytes. During the two post-treatment surveys, biologists [will] also [count]* ***and note shell condition of*** *freshly dead shells in addition to the steps described above.*

Figure 1 & 2. Mussel and Dragonfly monitoring stations (**Figure 1**) and quadrat arrange (**Figure 2**) derived from Biodrawversity's 2014 report, "Monitoring the Effects of Low-Dose Alum Treatment *Leptodea ochracea*, *Ligumia nasuta*, and *Neurocordulia obsolete* in Monponsett Pond.

Figure 1. Locations of mussel monitoring sites (Sites 1-5, including shallow and deep plots at each site) and dragonfly survey sites (E-1, E-2, and W-1 to W-7) in West and East Monponsett Pond in Halifax, MA.

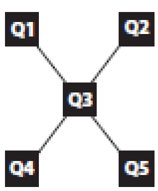


Figure 2. Spatial array of 5 1.0 m^2 quadrats (Q) at each site. Bricks were left on the lake bottom at Q1, Q2, Q4, and Q5; these were connected by strings and the intersection of the two strings marked the location of Q3. These were easily installed in 2013 and found again in 2014.

Monitoring of State-Listed Dragonfly Species

Long-term Dragonfly Monitoring Program

As stated above, since the submission of the original 'Habitat Management Plan' in May 2012, the pre- treatment and one year following the initial 2013 alum treatment long-term dragon-fly monitoring event have been performed. Minor modifications to the proposed long-term mussel monitoring were made by the NHESP-approved biologist performing these surveys. In order to maintain comparability with past events, the modified survey methodology will be implemented on 3 occasions, 1) upon reaching suitable conditions (phosphorus levels <20 pbb and sustained cyanobacteria counts <50,000 cells/ml), 2) one year following completion of alum treatments and 3) 5 years after completion of alum treatments.. This methodology was provided to the NHESP in a report titled, "Monitoring the Effects of Low-Dose Alum Treatment on *Leptodea ochracea*, *L. nasuta*, and *Neurocordulia obsolete* in the Western Basin of Monponsett Pond (Halifax, Massachusetts)" and the relevant excerpt is copied below. No additional revisions were requested during previous conversations with the NHESP.

> *Dragonfly surveys, focusing on N. obsoleta … [is scheduled to be completed in 2018]. Survey timing… [will]… accommodate weather conditions during the emergence period to ensure that surveys [are] conducted under the best possible conditions. Qualitative surveys of larvae, exuviae, and tenerals [will be conducted] using a combination of aquatic D-net sweeps in or near aquatic vegetation and other submerged structure,*

snorkeling in shallow water to hand-pick larvae, and walking along the shoreline to look for exuviae and tenerals on the lakeshore (especially rocks, bridge abutments, and trees). The causeway between the West and East basins [will be] surveyed most intensively, but several other locations in West and East Monponsett Pond [will] also [be] assessed and surveyed (Figure 1[see above]). Specimens [will be] collected, preserved in alcohol, and identified under a dissecting microscope.

Monitoring of Fish and Wildlife Response to Treatment

As in previous years, *in situ* in-water and shoreline monitoring will investigate any potential mortality of fish and other wildlife as a consequence of the buffered alum treatment. During the buffered alum treatment, *in situ* in-water and shoreline monitoring for fish and/or other wildlife mortalities will be conducted by the treatment/monitoring team. *In situ* in-water and shoreline monitoring will proceed as follows:

- **Treatment team**
  - Licensed applicator and assistant(s) will actively monitor the immediate treatment area for fish and/or wildlife mortality during application

- **Treatment/Monitoring Team**
  - Inspections of the treatment areas will be conducted in conjunction with *in situ* water testing
  - Twice daily (before and after daily treatment) visual inspection of pond's perimeter for fish and/or wildlife mortality will be performed.

Any deceased fish and/or wildlife encountered during *in situ* in-water monitoring will be documented. Documentation will include: written observations regarding the counts (by species), time observed, and photographs of each specimen. All information pertaining to a fish and/or wildlife kill event will be immediately provided to the Division of Fisheries and Wildlife—Southeast (DFW-SE).

REPORTING

During any year that treatment and/or monitoring is performed, the NHESP will be provided with a year-end report. The report will include documentation of any alum treatments performed (i.e., treatment dates and amounts of products applied) and associated monitoring (i.e., pre, in situ, and post-treatment water quality monitoring, and *in situ* monitoring of fish and wildlife in all years, as well as mussel monitoring. The year-end report will also discuss the treatment program's on-going efficacy any conclusion regarding effects of the treatment program to the state-listed species and their habitat.

Appendix B

Treatment Monitoring Program at the West Basin of Monponsett Pond Raw Data (Table 1-2)

Table 1. Monthly water quality sampling results

Date	Site ID	TP (ppb)	DP (ppb)	TAlk (mg/L)	Turbidity (NTU)	DO (mg/L)	Avg. Secchi (ft.)
6/5/17	A	36	22	10.2	2.4	8.5	5.0
	B	24	24	10.5	1.8	7.8	
	C	25	23	10.3	1.9	8.28	
6/28/17	A	36	22	10.2	2.4	X	X
	B	24	24	10.5	1.8	X	
	C	25	23	10.3	1.9	X	
7/28/17	A	13	19	11.9	1.7	8.46	6.2
	B	14	18	12.1	1.8	8.49	
	C	14	15	12.1	1.7	8.53	
8/16/17	A	30	ND	13.0	2.6	X	4.5
	B	22	ND	13.1	2.0	X	
	C	23	15	13.1	2.5	8.25	
9/19/17	A	15	ND	14.3	2.0	X	3.5
	B	13	ND	14.1	2.6	X	
	C	13	ND	13.4	2.5	7.58	
10/26/17	A	12	ND	12.8	1.2	8.43	5.1
	B	22	ND	12.3	2.0	8.93	
	C	12	ND	12.8	1.2	8.96	

X – No data collected

Table 2. *In-situ* water quality sampling results

Date	Site ID	pH (surface)	Avg. Alk (mg/L)	Avg. Secchi (ft)
6/6/17	A	6.73	8.7	5.2
	B	6.67		
	C	6.76		
6/7/17	A	6.52	8.3	5.8
	B	6.74		
	C	6.83		
6/8/17	A	6.6	9	6.2
	B	6.64		
	C	6.57		
6/9/17	A	6.5	8	6.3
	B	6.65		
	C	6.77		
6/12/17	A	6.51	12	6.5
	B	6.66		
	C	6.52		
6/13/17	A	6.57	11	6.8
	B	6.61		
	C	6.64		
6/14/17	A	6.8	10	6.89
	B	6.84		
	C	6.89		

Appendix C

Mussel and Dragonfly Monitoring Report by Biodrawversity LLC,
"*Effects of an Alum Treatment on Freshwater Mussels and Dragonflies in West Monponsett Pond: 2017 Monitoring*"

REPORT

Effects of an Alum Treatment on Freshwater Mussels and Dragonflies in West Monponsett Pond: 2017 Monitoring

prepared for

Solitude Lake Management
590 Lake Street, Shrewsbury, Massachusetts

prepared by

Biodrawversity LLC
206 Pratt Corner Road, Leverett, Massachusetts

January 2018

Shoreline of West Monponsett Pond in Halifax, Massachusetts.

INTRODUCTION

In 2013, a low-dose alum treatment was completed in the western basin of Monponsett Pond in Halifax, Massachusetts. At the request of the Massachusetts Natural Heritage and Endangered Species Program (NHESP), Lycott Environmental (now Solitude Lake Management) developed a Habitat Management Plan that included a plan to monitor the potential effects of the alum treatment on three state-listed aquatic species in the pond: *Leptodea ochracea* (Tidewater Mucket), *Ligumia nasuta* (Eastern Pondmussel), and *Neurocordulia obsoleta* (Umber Shadowdragon). Biodrawversity LLC was hired to complete the mussel and dragonfly monitoring, which included a pre-treatment study in 2013 and post-treatment monitoring in 2014.

The habitat management plan was revised in 2015 to allow for additional low-dose alum treatments. Three separate low-dose treatments were conducted in 2015, and one low-dose treatment was conducted in 2016, and Solitude staff completed basic mussel monitoring.

The Habitat Management Plan was revised again in 2017 to allow for a higher-dose treatment, which was completed in June of 2017. The revised plan specified that formal mussel monitoring (i.e., repeating the 2014 study) was to occur after treatment in 2017 (pending acceptable conditions), one-year post treatment (2018) and then again 5-years post treatment (2022). This report describes the pre-treatment surveys (2013) and post-treatment monitoring (2014 and 2017) completed to date. This report will be updated following completion of the post-treatment monitoring planned for 2018.

METHODS

I. Mussels

- The mussel survey was completed three times: (1) pre-treatment (May 23-24, 2013), (2) 1-year post-treatment (May 27-28, 2014), and 4-year post-treatment (June 28-29, 2017).
- The basic sampling unit was a 1 x 1 meter ($1m^2$) quadrat bounded by a frame, with two centerlines that divided the quadrat into four 0.5 x 0.5 meter sections. The centerlines facilitated more careful searching in the low-visibility environment. Quadrat locations were marked with underwater markers and recorded with GPS to enable the precise area of each to be resurveyed.
- Five quadrats were established at 10 sites (50

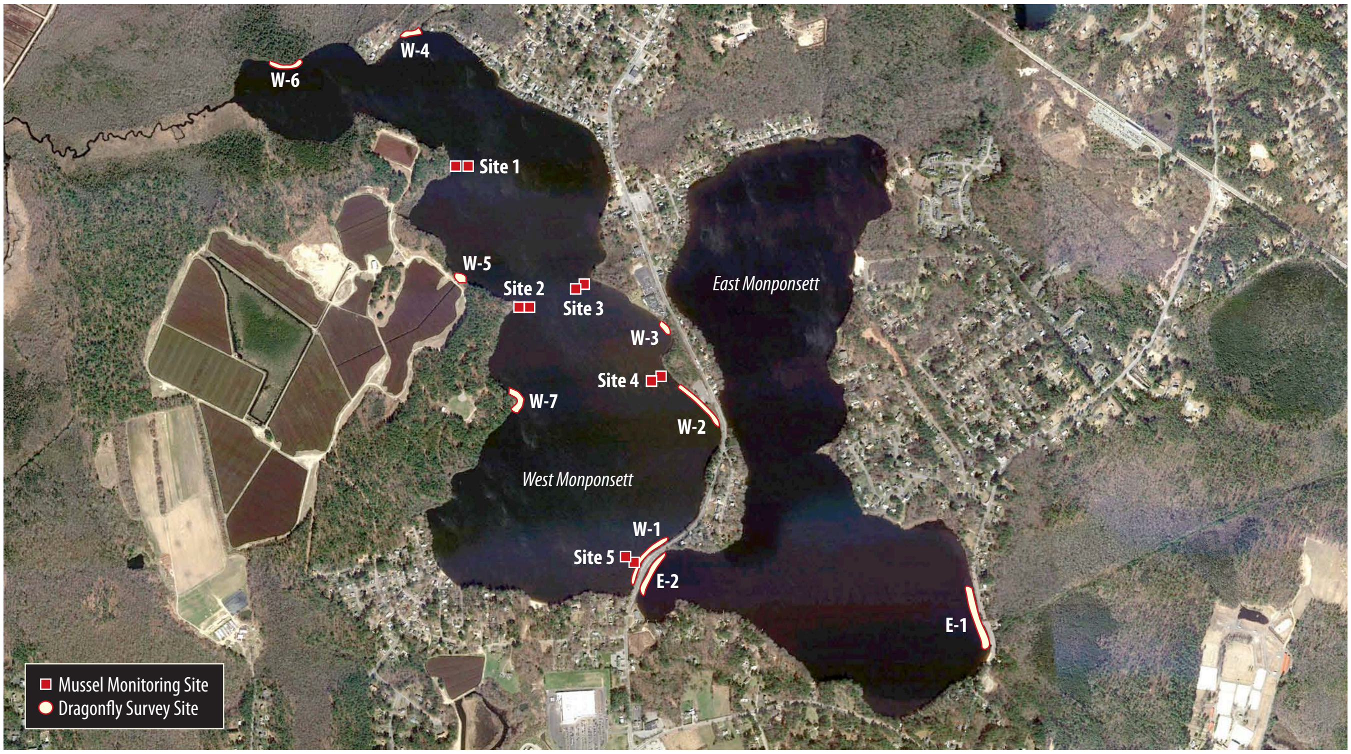


Figure 1. Locations of mussel monitoring sites (Sites 1-5, including shallow and deep plots at each site) and dragonfly survey sites (E-1, E-2, and W-1 to W-7) in West and East Monponsett Pond in Halifax, MA.

quadrats total); the 10 sites were paired (one shallow, one deep) at five locations in the pond (Figure 1, Table 1). The quadrats were arranged in a consistent pattern at each site (Figure 2).

- For each quadrat, biologists first conducted a visual and tactile search to count the number of mussels (all species) occurring at or near the surface. The biologists then excavated and sieved sediment from within one-fourth (0.25m^2) of the quadrat area to find buried mussels. Surface counts and buried counts were recorded for each species, and shell length was recorded for *L. ochracea* and *L. nasuta*. All mussels were placed back within the confines of the each quadrat.
- The following habitat information was recorded for each quadrat: water depth, spatial extent of each substrate type, and percent cover of macrophytes. During the two post-treatment surveys, biologists also counted freshly dead shells in addition to the steps described above.

Table 1. Locations and habitat parameters for each of the mussel monitoring sites in West Monponsett Pond. See Figure 1 for mapped locations. Water depth and substrate data are composite for the five quadrats at each location, since there very little variability in these parameters within each site from 2013 to 2017.

		Location*			Percent Cover					
Site	Plot Depth	Latitude	Longitude	Water Depth (ft)	Silt/Muck	Sand	Gravel	Cobble	Detritus	Vegetation
1	Shallow	42.01331	-70.85141	3.3	20	35	25	20	0	0
1	Deep	42.01334	-70.85120	5.7	25	25	40	10	30	0
2	Shallow	42.00918	-70.84885	3.3	15	65	20	1	1	1
2	Deep	42.00928	-70.84863	7.4	55	35	10	1	30	10
3	Shallow	42.00997	-70.84623	3.3	20	80	0	1	80	0
3	Deep	42.00997	-70.84641	7.4	20	80	1	0	50	0
4	Shallow	42.00738	-70.84306	3.3	60	30	5	5	10	0
4	Deep	42.00734	-70.84319	6.6	30	60	5	5	0	10
5	Shallow	42.00156	-70.84410	4.1	25	40	15	20	0	0
5	Deep	42.00157	-70.84415	6.6	25	55	15	5	15	1

*Coordinates are at centerpoint of the plot array.

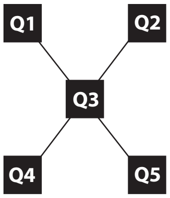


Figure 2. Spatial array of 5 1.0 m^2 quadrats (Q) at each site. Bricks were left on the lake bottom at Q1, Q2, Q4, and Q5; these were connected by strings and the intersection of the two strings marked the location of Q3. These were installed in 2013 and found again in 2014 and 2017.

II. Dragonflies

Dragonfly surveys, focusing on *N. obsoleta*, were completed just prior to or during peak emergence in late May to early July in 2013 and 2014, and in June 2017. Survey timing was intended to accommodate weather conditions to ensure that surveys were conducted under the best possible conditions. Notably, the spring of 2014 and 2017 was unusually cold and emergence was delayed 1-2 weeks.

Qualitative surveys of larvae, exuviae, and tenerals were conducted using a combination of aquatic D-net sweeps in or near aquatic vegetation and other submerged structure, snorkeling in shallow water to hand-pick larvae, and walking along the shoreline to look for exuviae and tenerals on the lakeshore (especially rocks, bridge abutments, and trees). The 2017 sampling focused primarily on exuviae and tenerals. The causeway between the West and East basins was surveyed most intensively, but other locations in West and East Monponsett Pond were also surveyed (Figure 1). Specimens were collected, preserved in alcohol, and identified under a dissecting microscope.

RESULTS

I. Mussels

Species Composition: Five mussel species were found during each of three surveys (Table 2). *E. complanata*, the dominant species, comprised 70.2, 80.9, and 76.5 percent of all individuals counted in 2013, 2014, and 2017, respectively. *L. ochracea*, the second-most common species, comprised 17.5,12.6, and 14.3 percent of all individuals counted in 2013, 2014, and 2017, respectively. The highest total count of *L. ochracea* was recorded in 2017, when 363 individuals were found. In all three years, *L. ochracea* was more numerous than *L. radiata*, *P. cataracta*, and *L. nasuta* combined. *L. nasuta* comprised 2.4, 1.1, and 1.8 percent of all individuals counted in 2013, 2014, and 2017 respectively. The highest count of *L. nasuta* was recorded in 2017, when 46 were found.

Table 2. Total counts and percent composition of the five mussel species found during the mussel monitoring in West Monponsett Pond in 2013, 2014, and 2017.

	2013		2014		2017	
Species	**Count**	**Percent**	**Count**	**Percent**	**Count**	**Percent**
Elliptio complanata [Eastern Elliptio] [ElCo]	973	70.2	888	80.9	1,941	76.5
Lampsilis radiata [Eastern Lampmussel] [LaRa]	88	6.3	37	3.4	160	6.3
Pyganodon cataracta [Eastern Floater] [PyCa]	50	3.6	22	2.0	26	1.0
Leptodea ochracea [Tidewater Mucket] [LeOc]	243	17.5	138	12.6	363	14.3
Ligumia nasuta [Eastern Pondmussel] [LiNa]	33	2.4	12	1.1	46	1.8
Total	1,387		1,097		2,536	

Species Density: Table 3 summarizes mussel density (mussels/m^2) for species, sites, and plot depths. Raw data are provided in Appendix 1. A total of 1,387 mussels were counted in 2013, 1,097 mussels were counted in 2014, and 2,536 mussels were counted in 2017. There was considerable among-site variation in mussel density; this was expected as different areas of a lake often have different mussel densities. There was also significant variation in mussel density due to water depth, despite only a 3-4 foot difference in water depth between "shallow" and "deep" plots. Shallow plots contained far higher density of mussels than deep plots (63.2 vs. 24.6 mussels/m^2 in 2013, 68.0 vs. 10.1 mussels/m^2 in 2014, and 117.2 vs. 24.8 mussels/m^2 in 2017), and this was consistent for all species and nearly all sites.

For all five species, densities were lower in 2014 than in 2013, and the overall density (all species) dropped slightly from 43.9 to 39.0 mussels/m^2. From 2013 to 2014, most of the observed decline was in deep plots, where mussel density dropped by 14.5 mussels/m^2 from 2013 to 2014, and the declining trend was consistent for all five species. In contrast, in shallow plots there was a modest increase of 4.8 mussels/m^2 from 2013 to 2014, and there was either an increase or no change for all species, except for *L. nasuta* that declined from 1.6 to 1.2 mussels/m^2.

Mussel densities were markedly higher in 2017 compared to 2013 or 2014, particularly for all species combined (71.0 mussels/m^2), but estimated density for all five species was also highest in 2017. The greatest change was for mussel density in the shallow plots, estimated at 117.2 mussels/m^2 in 2017 compared to 63.2 and 68.0 mussels/m^2 in 2013 and 2014, respectively. The density of mussels in the deep

Table 3. Average density of each mussel species, and for all species combined,from 2013 to 2017 at each monitoring site. The percent change (+ or -) is computed based on the departure from the 2013 density. See Appendix 1 and 2 for raw count and density data. Species abbreviated as in Table 2.

		E. complanata			*L. radiata*			*P. cataracta*			*L. ochracea*			*L. nasuta*			All Species			All Species, 2013-2017	
Site	**Plot Depth**	2013	2014	2017	2013	2014	2017	2013	2014	2017	2013	2014	2017	2013	2014	2017	2013	2014	2017	**Difference**	**% Change**
1	Shallow	60.6	78.8	99.0	3.0	5.2	5.4	3.4	1.6	0.4	4.4	6.6	5.2	2.4	1.2	1.6	73.8	93.4	111.6	37.8	51.2
1	Deep	17.0	4.0	5.2	3.8	1.2	1.2	1.4	0.0	0.0	0.4	3.2	2.6	0.0	0.0	1.2	22.6	8.4	10.2	-12.4	-54.9
2	Shallow	38.2	23.6	74.4	4.0	1.6	4.2	2.0	3.2	2.0	16.0	10.0	16.4	1.2	2.4	1.6	61.4	40.8	98.6	37.2	60.6
2	Deep	3.0	2.4	0.2	4.4	0.0	0.4	2.2	0.4	0.0	12.0	4.0	8.4	0.2	0.0	1.0	21.8	6.8	10.0	-11.8	-54.1
3	Shallow	78.8	107.4	141.4	4.6	5.4	9.6	1.0	1.6	2.8	6.8	14.2	19.6	1.0	1.8	0.6	92.2	130.4	174.0	81.8	88.7
3	Deep	42.4	6.0	27.2	3.0	0.2	1.2	0.2	0.6	1.2	7.8	5.8	12.4	1.0	0.2	1.2	54.4	12.8	43.2	-11.2	-20.6
4	Shallow	51.0	45.4	132.4	1.0	1.0	13.4	1.6	1.8	3.6	9.6	9.4	19.0	2.2	0.0	4.0	65.4	57.6	172.4	107.0	163.6
4	Deep	7.0	8.6	33.8	0.2	0.0	1.4	2.0	0.8	1.0	7.2	8.0	17.6	1.0	0.2	2.4	17.4	17.6	56.2	38.8	223.0
5	Shallow	18.8	13.8	22.2	0.4	2.2	3.0	1.0	0.8	2.0	1.4	0.0	2.2	1.4	0.8	0.2	23.0	17.6	29.6	6.6	28.7
5	Deep	3.2	1.6	1.8	0.4	0.2	0.6	1.2	0.8	0.0	1.6	2.4	1.6	0.4	0.0	0.2	6.8	5.0	4.2	-2.6	-38.2
Average Density		32.0	29.2	53.8	2.5	1.7	4.0	1.6	1.2	1.3	6.7	6.4	10.5	1.1	0.7	1.4	43.9	39.0	71.0	27.1	61.8
Average Density, Shallow		49.5	53.8	93.9	2.6	3.1	7.1	1.8	1.8	2.2	7.6	8.0	12.5	1.6	1.2	1.6	63.2	68.0	117.2	54.1	85.6
Average Density, Deep		14.5	4.5	13.6	2.4	0.3	1.0	1.4	0.5	0.4	5.8	4.7	8.5	0.5	0.1	1.2	24.6	10.1	24.8	0.2	0.7

Table 4. Average density (mussels/m^2) of each species at the sediment surface or buried (i.e., found by excavation) in 2013, 2014, and 2017; the ratio between surface (S) and buried (B) counts.

	Surface (S) Density			Buried (B) Density			S:B Ratio		
Species	**2013**	**2014**	**2017**	**2013**	**2014**	**2017**	**2013**	**2014**	**2017**
E. complanata	15.3	14.0	33.8	16.7	15.2	19.9	0.9	0.9	1.7
L. radiata	1.5	0.4	2.9	1.0	1.3	1.1	1.6	0.3	2.6
P. cataracta	0.8	0.2	0.3	0.8	1.0	1.0	1.0	0.2	0.3
L. ochracea	4.2	1.6	6.2	2.5	4.8	4.3	1.7	0.3	1.4
L. nasuta	0.5	0.1	0.8	0.6	0.6	0.6	0.9	0.2	1.2
All Species	22.4	16.2	44.0	21.5	22.8	27.0	1.0	0.7	1.6

Table 5. Shell length data for *L. ochracea* in 2013, 2014, and 2017.

	2013		2014		2017	
Length Class	**Count**	**%**	**Count**	**%**	**Count**	**%**
1 (<20.0 mm)	2	0.8	0	0.0	0	0.0
2 (20.0 - 29.9 mm)	3	1.2	11	7.9	8	2.2
3 (30.0 - 39.9 mm)	38	15.8	28	20.1	81	22.2
4 (40.0 - 49.9 mm)	162	67.2	68	48.9	147	40.3
5 (50.0 - 59.9 mm)	34	14.1	27	19.4	126	34.5
6 (60.0 - 69.9 mm)	2	0.8	5	3.6	3	0.8
7 (70.0 - 79.9 mm)	0	0.0	0	0.0	0	0.0
Length Statistics						
Total	241		139		365	
Mean Length (mm)	43.2		43.5		45.8	
Min Length (mm)	11.0		20.0		22.0	
Max Length (mm)	61.0		68.0		69.0	
Standard Deviation	6.12		9.16		7.86	

Table 6. Shell length data for *L. nasuta* in 2013, 2014, and 2017.

	2013		2014		2017	
Length Class	**Count**	**%**	**Count**	**%**	**Count**	**%**
1 (<20.0 mm)	0	0.0	0	0.0	0	0.0
2 (20.0 - 29.9 mm)	1	4.5	0	0.0	1	2.2
3 (30.0 - 39.9 mm)	2	9.1	4	33.3	11	23.9
4 (40.0 - 49.9 mm)	4	18.2	2	16.7	11	23.9
5 (50.0 - 59.9 mm)	11	50.0	5	41.7	16	34.8
6 (60.0 - 69.9 mm)	4	18.2	1	8.3	6	13.0
7 (70.0 - 79.9 mm)	0	0.0	0	0.0	1	2.2
Length Statistics						
Total	22		12		46	
Mean Length (mm)	51.5		46.4		47.7	
Min Length (mm)	24.0		30.0		20.0	
Max Length (mm)	64.0		64.0		75.0	
Standard Deviation	9.80		11.00		11.1	

plots was 24.8 mussels/m^2 in 2017, compared to 24.6 and 10.1 mussels/m^2 in 2013 and 2014, respectively.

Table 4 shows the mean density of each species at the surface or buried, and the ratio of surface animals to buried animals (S:B) for each species. For the ratio, values greater than one indicate a higher proportion of surface animals, values near one indicate similar proportions, and values below one indicate a higher proportion of buried animals. Generally, a higher proportion of mussels were found buried in 2014 compared to 2013 and 2017, especially for the four less common species. This was not true for *E. complanata* from 2013 to 2014, when the S:B ratio was nearly identical (0.9), but far higher numbers of *E. complanata* were found at the surface in 2017 (S:B ratio = 1.7).

The total count of excavated (buried) mussels was fairly consistent among years (269, 285, and 338 for 2013, 2014, and 2017, respectively), whereas counts for mussels at the surface dropped from 1,118 to 812 (27.4 percent decline) from 2013 to 2014, and then increased to 2,198 in 2017. Most of the decline in surface counts from 2013 to 2014 occurred in deep plots (351 to 149, a 57.5 percent decline), compared to shallow plots (767 to 663, a 13.6 percent decline). The far higher number of mussels in 2017 was mostly comprised of mussels at the surface within shallow plots, where 1,827 were counted in 2017 compared to 767 in 2013 and 663 in 2014.

L. ochracea: A total of 243 *L. ochracea* were counted in 2013, 138 were counted in 2014, and 363 were counted in 2017. The ratio of surface to buried *L. ochracea* was 1.7 in 2013, 0.3 in 2014, and 1.4 in 2017. Overall density changed only slightly (6.7 to 6.4 mussels/m^2) from 2013 to 2014, but jumped to 10.5 mussels/m^2 in 2017. Table 5 provides shell length data for *L. ochracea* for all three years.

L. nasuta: A total of 33 *L. nasuta* were counted in 2013, 12 were counted in 2014, and 46 were counted in 2017. The ratio of surface to buried *L. nasuta* was 0.9 in 2013, 0.2 in 2014, and 1.2 in 2017. Overall density changed only slightly (1.1 to 0.7 mussels/m^2) from 2013 to 2014, and increased slightly to 1.4 mussels/m^2 in 2017. Table 6 provides shell length data for *L. nasuta* for all three years.

II. Dragonflies

Thirteen dragonfly species were documented during the study (Tables 7, 8). *Epitheca princeps* was the most common species encountered; other relatively common species (based on number of occurrences)

Table 7. Dragonfly species documented in West and East Monponsett Pond during surveys from 2013 to 2017.

Species	Common Name	Abbreviation
Basiaeschna janata	Springtime Darner	BaJa
Dromogomphus spinosus	Black-shouldered Spinyleg	DrSp
Epitheca princeps	Prince Baskettail	EpPr
Erythemis simplicicollis	Eastern Pondhawk	ErSi
Gomphus sp.		GoSp.
Ladona julia	Chalk-fronted Corporal	LaJu
Libellula sp.		LiSp.
Macromia illinoiensis	Swift River Cruiser	MaIl
Neurocordulia obsoleta	Umber Shadowdragon	NeOb
Pachydiplax longipennis	Blue Dasher	PaLo
Perithemis tenera	Eastern Amberwng	PeTe
Progomphus obscurus	Common Sanddragon	PrOb
Tetragoneuria cynosura	Common Baskettail	TeCy

The box culvert that separates East and West Monponsett Pond.

included *Tetragoneuria cynosura*, *Perithemis tenera*, and *Macromia illinoiensis*. *N. obsoleta* was found in only two locations: within or near the box culvert separating West Monponsett from East Monponsett (found here in 2013, 2014, and 2017), and on riprap and a concrete retaining wall on the eastern side of East Monponsett Pond (2013 only).

DISCUSSION

Mussels: There was considerable variation in mussel density estimates for all species among and within sites, with increases and decreases of similar magnitude from 2013 to 2014, and generally higher mussel density in 2017 compared to both 2013 and 2014 for all species except *P. cataracta*. The largest difference in mussel density from 2013 to 2014 was observed at Sites 1, 2 and 3, where there was an apparent large decline in mussel density in deep plots, though this was strongly influenced by counts of just one species, *E. complanata*. Similarly, there were some large increases in mussel density from 2013 to 2014 (e.g., Site 3-S with a 41.4 percent increase), and especially from 2014 to 2017, that are more difficult to explain.

Very few dead/dying mussels or recently dead shells were observed in 2014; therefore, the lower density of live mussels in some of the deep plots from 2013 to 2014 may not necessarily indicate mortality. Mussel densities were markedly higher in 2017 compared to 2014, and we are not certain whether this is due to actual population increases, or sampling bias. Factors that might contribute to variation in density estimates include movement, seasonal differences in detectability of each species (e.g., lower detectability of buried mussels), or insufficient samples sizes. Although the 2013 and 2014 studies were completed on similar dates, 2014 was a cooler spring and mussels may have been less active than they were at the same

Table 8. Dragonfly species found at each survey location and date in East and West Monponsett Pond, 2013 to 2017.

						Species**												
Pond	**Site**	**Location**	**Date**	**Method**	**Stage***	**BaJa**	**DrSp**	**EpPr**	**ErSi**	**GoSp.**	**LaJu**	**LiSp.**	**MaIl**	**NeOb**	**PaLo**	**PeTe**	**PrOb**	**TeCy**
East Monponsett	E-1	Riprap, East Side	6/19/13	Shoreline/Wading	E		X	X		X	X			X				X
East Monponsett	E-1	Riprap, East Side	6/21/17	Shoreline	E		X	X					X			X		X
East Monponsett	E-1	Riprap, East Side	6/28/17	Shoreline	E		X	X								X		X
East Monponsett	E-2	Causeway	6/17/13	Snorkeling/D-Net	L			X								X		
East Monponsett	E-2	Causeway	7/9/13	Shoreline/Wading	E		X	X			X					X		
East Monponsett	E-2	Causeway	5/27/14	Shoreline/Wading	E	X	X	X					X					X
East Monponsett	E-2	Causeway	6/30/14	Shoreline/Wading	E		X	X		X	X				X	X		X
East Monponsett	E-2	Causeway	6/20/17	Shoreline	E		X	X					X			X	X	X
East Monponsett	E-2	Causeway	6/28/17	Shoreline	E		X	X			X		X			X		X
West Monponsett	W-1	Causeway + Culvert	6/17/13	Snorkeling/D-Net	L			X					X		X	X		
West Monponsett	W-1	Causeway + Culvert	6/18/13	Shoreline/Wading	E			X					X	X				X
West Monponsett	W-1	Causeway + Culvert	7/9/13	Shoreline/Wading	E		X	X					X			X		
West Monponsett	W-1	Causeway + Culvert	5/27/14	Shoreline/Wading	E	X		X		X								X
West Monponsett	W-1	Causeway + Culvert	6/30/14	Shoreline/Wading	E, L		X	X					X	X	X	X		X
West Monponsett	W-1	Causeway + Culvert	6/20/17	Shoreline	E	X	X	X					X	X		X		X
West Monponsett	W-1	Causeway	6/28/17	Shoreline	E		X	X					X	X		X		X
West Monponsett	W-1	Culvert	6/28/17	Shoreline	E		X	X			X		X	X		X		X
West Monponsett	W-2	Boat Ramp	5/27/14	Shoreline/Wading	E								X					X
West Monponsett	W-2	Boat Ramp	6/30/14	Shoreline/Wading	E			X		X								
West Monponsett	W-2	Boat Ramp	6/21/17	Shoreline	E		X	X					X			X		X
West Monponsett	W-3	Eastern Shoreline	6/18/13	Shoreline/Wading	E			X										X
West Monponsett	W-4	Northern Shoreline	6/18/13	Shoreline/Wading	E			X					X					X
West Monponsett	W-5	Cranberry Outlet	6/30/14	Shoreline/Wading	E	X		X							X			X
West Monponsett	W-5	Cranberry Outlet	6/21/17	Shoreline	E	X	X	X	X				X		X	X		X
West Monponsett	W-6	Northwest Shoreline	6/30/14	Shoreline/Wading	E			X					X			X		
West Monponsett	W-7	Western Shoreline	6/30/14	Shoreline/Wading	E		X	X		X			X			X		X
West Monponsett	W-7	Western Shoreline	6/21/17	Shoreline	E			X					X			X		X

*E = Exuvia, L = Larva. **Species abbreviated as in Table 7.

time in 2013. Sampling was conducted one month later in 2017, and water clarity in West Monponsett Pond was the best we have ever observed, which may have contributed to higher mussel counts in 2017.

Overall, it is difficult to discern any adverse effects of the alum treatment on mussel density. There were some notable increases and decreases in mussel density from 2013 to 2014, and for the most part higher mussel densities in 2017 compared to 2013 and 2014. Video monitoring during treatment (2013) did not detect stress responses, such as gaping or movement. There were very few shells observed in 2014 that might explain some of the larger decreases in species counts from 2013 to 2014. Juvenile mussels are considered more sensitive to stressors than adults, but very few juveniles were ever detected in the quantitative sampling. In summary, data do not indicate that the alum treatment had any adverse effect on juveniles or adults of any mussel species. Perhaps more importantly, the 2017 data suggest that the mussel community in West Monponsett Pond is doing as well, or better, than it has in the last four years despite periodic challenging environmental conditions.

Dragonflies: Results were consistent with the 2011 baseline report that found only four *N. obsoleta* exuviae within the box culvert between West and East Monponsett, and no *N. obsoleta* larvae or adults elsewhere in the pond. This report also documents *N. obsoleta* on the far eastern side of East Monponsett Pond, in habitat similar to the causeway and box culvert. Due to low densities and limited habitat availability for *N. obsoleta* in West Monponsett Pond, this was a qualitative presence/absence study to determine if *N. obsoleta* could be detected emerging after the alum treatment. Both the 2013 and 2014 dragonfly surveys were conducted after the 2013 alum treatment, and *N. obsoleta* and other species were detected within or near the box culvert on both years, and also in 2017.

REPORTS CITED

GZA GeoEnvironmental, Inc. 2011. Mussel & Dragonfly Baseline Survey, West Basin Monponsett Pond. Reported submitted to Lycott Environmental Inc. and the Town of Halifax, MA. Report prepared in partial response to requirements of NHESP Tracking No 09-27490.

Appendix 1: Raw Mussel Count Data

Site = site number (1-5); Plot: S = shallow plot, D = deep plot; Quad = quadrat number (5 per plot); Position: Surf = surface count, Exc = excavated count; mussel species abbreviated as in Table 2.

				2013					2014					2017				
Site	**Plot**	**Quad**	**Position**	**ElCo**	**LaRa**	**PyCa**	**LeOc**	**LiNa**	**ElCo**	**LaRa**	**PyCa**	**LeOc**	**LiNa**	**ElCo**	**LaRa**	**PyCa**	**LeOc**	**LiNa**
1	S	1	Surf	10	2	0	0	0	34	1	0	0	0	84	5	0	7	1
1	S	1	Exc	9	0	0	2	0	10	1	0	2	0	6	0	0	1	0
1	S	2	Surf	10	2	0	0	0	24	1	0	1	0	65	1	0	2	0
1	S	2	Exc	14	2	1	3	0	7	0	0	1	0	4	0	0	0	0
1	S	3	Surf	14	2	0	1	12	31	0	0	0	2	88	6	2	1	0
1	S	3	Exc	14	0	2	0	0	11	0	1	0	0	0	0	0	0	1
1	S	4	Surf	22	0	1	0	0	39	3	0	0	0	95	6	0	1	2
1	S	4	Exc	13	0	0	0	0	16	2	0	3	0	3	0	0	1	0
1	S	5	Surf	7	1	0	1	0	46	1	0	0	0	79	1	0	3	1
1	S	5	Exc	10	0	1	0	0	11	2	1	2	1	8	2	0	1	0
1	D	1	Surf	4	0	0	0	0	4	1	0	0	0	7	0	0	3	1
1	D	1	Exc	3	1	0	0	0	0	0	0	3	0	0	0	0	0	0
1	D	2	Surf	2	2	1	0	0	2	0	0	2	0	6	0	0	1	1
1	D	2	Exc	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0
1	D	3	Surf	15	5	0	1	0	2	3	0	2	0	6	3	0	0	1
1	D	3	Exc	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	D	4	Surf	3	0	2	1	0	4	2	0	0	0	3	1	0	4	0
1	D	4	Exc	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0
1	D	5	Surf	5	0	0	0	0	4	0	0	0	0	4	2	0	5	3
1	D	5	Exc	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	S	1	Surf	16	1	0	2	0	3	0	0	1	0	62	2	0	9	0
2	S	1	Exc	4	1	0	4	0	3	0	0	0	3	9	0	0	4	1
2	S	2	Surf	7	1	0	1	0	14	0	0	2	0	66	4	1	8	1
2	S	2	Exc	11	1	0	5	0	4	2	0	2	0	6	0	0	3	0
2	S	3	Surf	23	0	1	6	0	7	0	0	1	0	49	2	0	0	1
2	S	3	Exc	4	1	0	3	0	4	0	2	1	0	5	0	0	1	0
2	S	4	Surf	12	2	0	3	2	3	0	0	1	0	54	3	1	7	0
2	S	4	Exc	4	0	2	2	0	5	0	0	4	0	0	1	0	2	0
2	S	5	Surf	13	4	1	12	0	7	0	0	1	0	49	6	0	6	2
2	S	5	Exc	7	0	0	0	1	5	0	2	4	0	3	0	2	3	0
2	D	1	Surf	1	2	3	6	1	0	0	0	0	0	0	0	0	16	0
2	D	1	Exc	2	2	1	3	0	0	0	0	0	0	0	0	0	0	0
2	D	2	Surf	1	2	1	10	0	0	0	1	0	0	0	0	0	4	0
2	D	2	Exc	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0
2	D	3	Surf	0	2	1	6	0	0	0	1	0	0	1	0	0	9	2
2	D	3	Exc	0	1	0	1	0	0	0	0	3	0	0	0	0	0	0
2	D	4	Surf	1	2	0	7	0	0	0	0	0	0	0	0	0	4	1
2	D	4	Exc	0	0	0	2	0	2	0	0	2	0	0	0	0	0	0
2	D	5	Surf	0	2	2	7	0	0	0	0	0	0	0	2	0	5	2
2	D	5	Exc	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
3	S	1	Surf	68	3	0	8	0	62	0	0	0	0	63	8	0	2	0
3	S	1	Exc	3	1	0	1	0	11	2	1	4	1	10	1	2	1	0
3	S	2	Surf	46	5	2	4	0	45	0	0	0	1	79	4	1	5	0
3	S	2	Exc	3	0	0	1	0	6	1	1	2	0	26	2	1	5	0
3	S	3	Surf	44	2	1	5	1	61	1	0	1	0	58	6	0	4	1
3	S	3	Exc	2	0	0	0	0	7	0	0	4	1	12	0	0	4	0
3	S	4	Surf	58	5	0	5	0	69	0	0	0	0	63	7	1	5	1
3	S	4	Exc	5	0	0	0	0	23	2	0	4	0	18	0	0	4	0
3	S	5	Surf	74	4	2	4	0	72	2	0	2	0	96	11	0	6	1
3	S	5	Exc	13	0	0	0	1	10	1	0	3	0	21	0	0	5	0
3	D	1	Surf	7	0	0	4	0	5	0	2	3	0	16	2	1	12	2
3	D	1	Exc	4	0	0	0	1	0	0	0	0	0	2	0	0	0	0
3	D	2	Surf	5	0	0	5	0	3	0	0	8	1	14	1	1	10	2
3	D	2	Exc	3	0	0	0	0	0	0	0	0	0	13	0	1	3	0
3	D	3	Surf	17	2	0	7	0	3	1	0	3	0	8	0	0	5	0

Appendix 1 (continued)

				2013					2014					2017				
Site	Plot	Quad	Position	ElCo	LaRa	PyCa	LeOc	LiNa	ElCo	LaRa	PyCa	LeOc	LiNa	ElCo	LaRa	PyCa	LeOc	LiNa
3	D	3	Exc	5	0	0	0	0	1	0	0	0	0	1	0	0	0	0
3	D	4	Surf	76	10	1	17	0	2	0	0	5	0	12	1	0	12	2
3	D	4	Exc	8	0	0	0	0	1	0	0	0	0	2	0	0	0	0
3	D	5	Surf	15	3	0	6	1	5	0	1	10	0	6	2	0	11	0
3	D	5	Exc	3	0	0	0	0	1	0	0	0	0	2	0	0	0	0
4	S	1	Surf	15	1	3	5	1	15	0	0	1	0	83	5	0	9	1
4	S	1	Exc	9	0	1	1	1	10	1	0	4	0	8	0	1	2	0
4	S	2	Surf	22	0	0	8	2	12	0	0	0	0	46	6	0	6	0
4	S	2	Exc	6	0	0	2	0	5	0	0	1	0	14	2	1	2	0
4	S	3	Surf	19	2	0	4	0	14	0	0	1	0	104	8	0	5	2
4	S	3	Exc	4	0	0	0	0	4	0	0	4	0	11	3	2	1	1
4	S	4	Surf	27	1	1	7	0	29	1	1	0	0	78	16	1	16	0
4	S	4	Exc	9	0	0	0	1	7	0	2	2	0	16	1	0	1	2
4	S	5	Surf	36	1	0	12	0	21	0	0	1	0	119	8	1	19	1
4	S	5	Exc	6	0	0	0	0	8	0	0	0	0	9	0	0	4	1
4	D	1	Surf	1	0	1	9	0	12	0	2	12	0	7	0	0	13	1
4	D	1	Exc	0	0	0	0	0	2	0	0	2	0	0	0	1	0	0
4	D	2	Surf	1	0	0	5	0	4	0	2	2	0	25	2	1	18	0
4	D	2	Exc	0	0	0	0	0	1	0	0	0	0	13	0	0	1	1
4	D	3	Surf	3	0	3	5	0	0	0	0	4	0	5	0	0	11	2
4	D	3	Exc	3	0	0	0	0	0	0	0	0	0	1	0	0	0	0
4	D	4	Surf	1	0	3	10	0	4	0	0	8	1	12	3	0	13	1
4	D	4	Exc	1	0	0	0	1	1	0	0	0	0	7	0	0	2	0
4	D	5	Surf	1	1	3	7	1	3	0	0	6	0	8	2	0	13	0
4	D	5	Exc	3	0	0	0	0	1	0	0	0	0	7	0	0	2	1
5	S	1	Surf	17	0	1	1	2	4	1	0	0	0	16	0	1	1	1
5	S	1	Exc	3	0	0	0	0	2	0	0	0	0	2	1	1	0	0
5	S	2	Surf	10	0	4	2	1	4	0	0	0	0	20	2	0	6	0
5	S	2	Exc	1	0	0	0	0	2	1	1	0	1	2	0	0	0	0
5	S	3	Surf	11	2	0	0	0	5	1	0	0	0	8	3	0	3	0
5	S	3	Exc	1	0	0	0	1	2	0	0	0	0	3	0	0	0	0
5	S	4	Surf	12	0	0	0	0	5	0	0	0	0	12	1	0	1	0
5	S	4	Exc	2	0	0	0	0	2	0	0	0	0	3	0	0	0	0
5	S	5	Surf	4	0	0	0	0	7	1	0	0	0	11	1	1	0	0
5	S	5	Exc	3	0	0	1	0	3	1	0	0	0	1	1	1	0	0
5	D	1	Surf	2	1	1	2	1	2	0	0	0	0	2	0	0	0	0
5	D	1	Exc	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
5	D	2	Surf	2	0	0	1	0	0	0	0	0	0	0	1	0	3	1
5	D	2	Exc	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
5	D	3	Surf	1	1	1	1	0	0	0	0	0	0	2	1	0	3	0
5	D	3	Exc	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
5	D	4	Surf	1	0	0	1	0	2	0	0	0	0	0	0	0	1	0
5	D	4	Exc	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	D	5	Surf	2	0	0	3	1	4	1	0	0	0	1	1	0	1	0
5	D	5	Exc	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0
				973	88	50	243	33	888	37	22	138	12	1941	160	26	363	46