REPORT

Freshwater Mussel Surveys in Mystic Lake and Middle Pond: 2007-2017 (Barnstable, Massachusetts)

prepared for

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Northern shoreline of Mystic Lake in Barnstable, Massachusetts.

INTRODUCTION

Biodrawversity LLC conducted a freshwater mussel survey in Mystic Lake and Middle Pond in Barnstable, MA, as a six-year follow-up to quantitative surveys that were conducted in both ponds in June 2011 (and previously in 2007 and 2010). The survey updated the presence, distribution, density, and evidence of recruitment in freshwater mussel populations, and assessed changes in population parameters during the period from 2007 to 2017.

Mystic Lake: Between 2007 and 2011, Biodrawversity conducted three lake-wide freshwater mussel surveys in Mystic Lake. The first survey determined the distribution, density, and habitat of three state-listed species: tidewater mucket (*Leptodea ochracea*), eastern pondmussel (*Ligumia nasuta*), and triangle floater (*Alasmidonta undulata*) (Biodrawversity 2007). Compared with similar surveys conducted in other coastal ponds from 2007-2009 (Biodrawversity 2008, 2009, 2010a), results suggested that Mystic Lake supported one of the three best tidewater mucket populations in Massachusetts, as well as one of the best lake populations of triangle floater.

In the summer of 2009, there was an exceptionally large mussel die-off that began in early August and quickly escalated, reaching a peak by mid-month. In 2010, Biodrawversity was contracted by the Natural Heritage and Endangered Species Program (NHESP) to repeat the 2007 mussel survey, determine the magnitude of the mussel die-off, and provide a status report for state-listed mussel populations in Mystic

Tidewater Mucket (*Leptodea ochracea*) from Mystic Lake.

Figure 1. Mussel sampling sites in Middle Pond and Mystic Lake, 2007 to 2017. Not all sites were surveyed each year; see Table 1 for details on locations and year(s) sampled.

Lake (Biodrawversity 2010b). The 2010 survey (conducted in June) also established a new baseline prior to a lake-wide alum treatment that occurred in September 2010. A second mussel die-off occurred in August-September of 2010, after the baseline study was completed but before the alum treatment began. Prior to, during, and after the alum treatment, Biodrawversity biologists monitored mortality and behavior of freshwater mussels that had been placed in enclosures within both treatment areas and control areas (Biodrawversity 2011a); this study did not detect significant short-term responses of mussels to the treatment. NHESP required a one-year follow-up survey to check for response(s) of the mussel community to the alum treatment. This was completed in 2011 (Biodrawversity 2011b), and generally used the same methods and survey sites as the 2007 and 2010 lake-wide surveys.

Table 1. Quantitative mussel survey sites in Mystic Lake and Middle Pond, for the period from 2007 to 2017.

					Year(s) Sampled				
Lake	**Site**	**Plot**	**Latitude**	**Longitude**	**2007**	**2010**	**2011**	**2017**	**Previous Site Name**
Mystic Lake	1	Shallow	41.67841	-70.41183			X	X	East Cove
	1	Deep	41.67843	-70.41200					
	2	Shallow	41.67647	-70.41485		X	X	X	East Shore
	2	Deep	41.67656	-70.41508					
	3	Shallow	41.67435	-70.41909	X	X	X	X	South Beach
	3	Deep	41.67459	-70.41874					
	4	Shallow	41.67724	-70.41900	X	X	X	X	West Shore
	4	Deep	41.67721	-70.41880					
	5	Shallow	41.68303	-70.41682	X	X	X	X	NW Corner
	5	Deep	41.68226	-70.41606					
	6	Shallow	41.68418	-70.41408	X	X	X	X	North Beach (Pair 1)
	6	Deep	41.68410	-70.41416					
	7	Shallow	41.68426	-70.41454	X	X	X	X	North Beach (Pair 2)
	7	Deep	41.68418	-70.41459					
	8	Shallow	41.68155	-70.41315	X	X	X	X	Island-North
	8	Deep	41.68171	-70.41312					
	9	Shallow	41.68130	-70.41379	X	X	X	X	Island-West
	9	Deep	41.68130	-70.41390					
	10	Shallow	41.67922	-70.41159	X			X	Sauerbrey Dock
	10	Deep	41.67926	-70.41186					
Middle Pond	1	Shallow	41.67810	-70.40738	X		X	X	MP1
	1	Deep	41.67810	-70.40738					MP2
	2	Shallow	41.67706	-70.41036			X	X	-
	2	Deep	41.67699	-70.41028					-
	3	Shallow	41.67481	-70.41095	X		X	X	MP3
	3	Deep	41.67481	-70.41095					MP4
	4	Shallow	41.67392	-70.41562	X		X	X	MP7
	4	Deep	41.67389	-70.41562					MP8
	5	Shallow	41.67238	-70.41842			X	X	-
	5	Deep	41.67238	-70.41832					-
	6	Shallow	41.66920	-70.41782	X		X	X	MP9
	6	Deep	41.66932	-70.41754					MP10
	7	Shallow	41.67030	-70.41373			X	X	-
	7	Deep	41.67029	-70.41348					-
	8	Shallow	41.67237	-70.41326	X		X	X	MP5
	8	Deep	41.67254	-70.41343					MP6
	9	Shallow	41.67309	-70.41000			X	X	-
	9	Deep	41.67317	-70.41003					-
	10	Shallow	41.67485	-70.40868			X	X	-
	10	Deep	41.67492	-70.40901					-

Middle Pond: Biodrawversity first completed a lake-wide mussel survey in Middle Pond in 2007 (Biodrawversity 2008); the summary report concluded that Middle Pond "…may be the single best pond in Massachusetts and the entire Northern Atlantic Slope in terms of freshwater mussel diversity and abundance." There were reports of mussel die-offs in Middle Pond from 2009 to 2010. In 2011, a freshwater mussel survey was conducted in Middle Pond at the request of the Indian Ponds Association. The objective was to assess species occurrence, population density, age demographics (inferred from size distribution), and shell condition of state-listed mussel species, and to compare these data to the 2007 study (Biodrawversity 2011c).

METHODS

Quantitative sampling was conducted in early July 2017 in Middle Pond and Mystic Lake at the same sites that were surveyed quantitatively in 2011 (Figure 1, Table 1). This included paired sites (deep and

shallow) at 10 locations around each lake. We used different plot sizes than had been used previously. In 2007, 2010, and 2011, a single 25.0m^2 (5x5 meter) plot was used in both shallow (0.5 to 1.5 meters) and deep (2.5 to 5.5 meters) water at the survey sites. In 2017, 2-4 4.0m^2 (2x2 meter) quadrats per site were sampled in the shallow and deep areas (typically 4 quadrats in shallow water and 2 quadrats in deep water, with some exceptions). Substrate was excavated and sieved within 1/8 of each quadrat to detect buried mussels. This resulted in a sample size of 68 4.0m^2 quadrats in Middle Pond and 61 4.0 m^2 quadrats in Mystic Lake. This modification of quadrat sizes allowed for more precise mussel counts of all species, increased sample sizes, and allowed for better characterization of variability.

Within each quadrat, biologists recorded counts for all mussel species, shell lengths and shell conditions of all uncommon species and of a subset of common species, and habitat (water depth, substrate, presence and percent cover of aquatic vegetation). Shell condition refers to degree of shell erosion, which is given one of five numeric ranks for each individual mussel: 0 = little/no shell erosion, 0.25 = light shell erosion, 0.50 = moderate shell erosion, 0.75 = moderate/heavy shell erosion, 1.0 = heavy shell erosion. These individual scores are then averaged for all individuals in a sample to produce a Shell Condition Index that ranges from 0 to 1, with lower values indicating better shell condition.

In Mystic Lake, the 2017 study followed the 2011 study by counting all species, whereas only state-listed species were counted in 2007 and 2010 (with coarse density estimates for common species). Likewise, for Middle Pond, all mussel species were counted in 2011 and 2017, but only state-listed species were counted in 2007. To compare population trends from 2007 to 2017, mussel counts were converted to densities (mussels/m^2).

2017 RESULTS

Species Counts and Densities

Mystic Lake: A total of five species and 2,126 mussels were counted in 2017, including 1,460 eastern elliptio (68.7%), 390 eastern floater (18.3%), 147 tidewater mucket (6.9%), 127 eastern lampmussel (6.0%), and 2 triangle floater (Table 2). Eastern pondmussel was not detected in Mystic Lake for the third consecutive lake-wide survey since they were first observed in 2007. Eastern elliptio had the highest average density (9.07 mussels/m^2), followed by eastern floater (2.60 mussels/m^2), eastern lampmussel and tidewater mucket (1.40 mussels/m^2 each), and triangle floater (0.008 mussels/m^2). Lake-wide, average mussel density was 14.48 mussels/m^2, but this varied widely across sites and water depths (Table 4). Overall, mussels were far more dense in deeper water (average = 30.28 mussels/m^2) than shallow water (average = 5.56 mussels/m^2), and this was consistent for nearly all species that were found. Tidewater mucket was an exception; average density in shallow water was comparable to that in deep water (1.41 vs. 1.39 mussels/m^2) (Table 3).

Middle Pond: A total of six species and 1,945 mussels were counted in 2017, including 1,731 eastern elliptio (89.0%), 81 tidewater mucket (4.2%), 69 eastern floater (3.5%), 59 eastern lampmussel (3.0%), and only 3 triangle floater and 2 eastern pondmussel (Table 3). Eastern elliptio had the highest average density (7.55 mussels/m^2), followed by tidewater mucket (0.86 mussels/m^2), eastern floater (0.61 mussels/m^2), eastern lampmussel (0.29 mussels/m^2), and distantly by triangle floater (0.037 mussels/m^2) and eastern pondmussel (0.007 mussels/m^2). Lakewide, average mussel density was 9.36 mussels/m^2, but this varied widely across sites and water depths (Table 5). Mussels were far more dense in deeper water (average = 17.22 mussels/m^2) than shallow water (average = 3.86 mussels/m^2), and this was consistent for nearly all species that were found. Tidewater mucket was an exception; average density in shallow water was higher than in deep water (1.01 vs. 0.66 mussels/m^2) (Table 5).

Shell Lengths and Conditions

Mystic Lake: Table 6 summarizes length class distributions for the four numerous species in Mystic Lake, and Table 7 summarizes shell length and shell condition parameters for 2017 and for previous years for which these data were collected. Considering sample sizes and methods, which typically tend to under-sample juvenile mussels, there was fairly strong evidence of recruitment within the last few years for these four mussel species. Length classes were shifted toward younger populations, and shell condition indices suggest mussels were mostly in fair to excellent condition, especially in contrast to the 2010 results. Too few eastern pondmussel and triangle floater were found to analyze shell length and condition.

- Tidewater mucket: 31% of the mussels were

Table 2. Species counts and average densities at survey sites in Mystic Lake for the period from 2007 to 2017. *Plot: S = Shallow, D = Deep. "-" means site not sampled. Non-listed species were not precisely counted (coarse estimates only) in 2007 and 2010.

		L. ochracea				*A. undulata*				*L. nasuta*				*E. complanata*		*L. radiata*		*P. cataracta*		All Species			
Site	Plot*	2007	2010	2011	2017	2007	2010	2011	2017	2007	2010	2011	2017	2011	2017	2011	2017	2011	2017	2007	2010	2011	2017
1	S	35	-	0	14	1	-	0	1	0	-	0	0	4	17	0	1	0	13	>200	-	4	46
1	D	-	-	0	3	-	-	0	0	0	-	0	0	2	37	0	0	0	33	-	-	2	73
2	S	-	11	0	28	-	4	0	0	-	0	0	0	1	36	1	1	0	22	-	30-50	2	87
2	D	-	0	0	11	-	0	0	0	-	0	0	0	10	240	1	21	1	29	-	>500	12	301
3	S	88	2	0	18	1	2	0	0	0	0	0	0	2	5	0	0	0	4	>200	<10	2	27
3	D	23	0	0	2	0	0	0	1	3	0	0	0	10	126	0	36	3	17	>200	20-30	13	182
4	S	12	1	0	17	0	0	0	0	1	0	0	0	0	23	0	6	0	4	>200	<10	0	50
4	D	34	0	0	10	1	0	0	0	0	0	0	0	5	180	0	22	5	8	>200	>200	10	220
5	S	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	1	9	13	3	1	13
5	D	42	0	0	0	0	0	0	0	1	0	0	0	1	31	0	0	0	42	>500	<100	1	73
6	S	42	0	0	0	0	0	0	0	0	0	0	0	1	5	0	2	0	2	>200	<10	1	9
6	D	27	0	0	0	0	0	0	0	2	0	0	0	2	28	0	15	1	14	>500	100-150	3	57
7	S	47	0	0	2	0	1	0	0	0	0	0	0	1	6	0	0	0	1	>200	20-30	1	9
7	D	8	1	0	2	0	0	0	0	0	0	0	0	6	139	1	15	1	17	>200	150-200	8	173
8	S	38	10	1	9	0	0	0	0	0	0	0	0	6	118	0	1	0	39	>200	<100	7	167
8	D	18	0	0	0	1	0	0	0	0	0	0	0	16	147	0	2	1	38	>500	<100	17	187
9	S	4	4	0	1	0	0	0	0	0	0	0	0	0	5	0	0	0	33	~100	20-30	0	39
9	D	38	2	0	1	0	0	0	0	0	0	0	0	7	113	0	5	0	27	>500	>500	7	146
10	S	27	-	-	26	5	-	-	0	0	-	-	0	-	109	-	0	-	20	>200	-	-	155
10	D	46	-	-	3	1	-	-	0	2	-	-	0	-	91	-	0	-	18	>200	-	-	112
Total Count		529	31	1	147	10	7	0	2	9	0	0	0	74	1460	3	127	13	390	1000s	-	91	2126
Density (#/m^2)		1.245	0.078	0.002	1.402	0.024	0.018	0.000	0.008	0.020	0.000	0.000	0.000	0.164	9.075	0.007	1.396	0.029	2.599	~15-20	~5	0.202	14.480

Table 3. Species counts and average densities at survey sites in Middle Pond for the period from 2007 to 2017. *Plot: S = Shallow, D = Deep. "-" means site not sampled.

		L. ochracea			*A. undulata*			*L. nasuta*			*E. complanata*		*L. radiata*		*P. cataracta*		State-Listed			All Species	
Site	Plot	2007	2011	2017	2007	2011	2017	2007	2011	2017	2011	2017	2011	2017	2011	2017	2007	2011	2017	2011	2017
1	S	25	1	5	0	0	1	1	0	0	7	55	2	0	0	1	26	1	6	10	62
1	D	-	1	3	-	0	0	-	0	0	25	150	1	1	1	0	-	1	3	28	154
2	S	-	1	5	-	0	0	-	0	1	31	94	2	5	0	0	-	1	6	34	105
2	D	-	6	3	-	0	0	-	0	0	67	121	8	5	0	2	-	6	3	81	131
3	S	31	0	7	0	0	1	0	0	0	41	19	1	0	0	3	31	0	8	42	30
3	D	192	13	4	2	0	0	6	0	0	40	2	2	0	0	7	200	13	4	55	13
4	S	26	0	1	0	0	0	2	0	0	12	32	1	1	0	1	28	0	1	13	35
4	D	252	9	5	0	0	0	22	0	0	157	257	9	8	1	22	274	9	5	176	292
5	S	-	0	4	-	0	0	-	0	0	3	40	7	1	0	5	-	0	4	10	50
5	D	-	0	1	-	0	1	-	0	0	25	353	4	3	0	4	-	0	2	29	362
6	S	70	1	5	3	0	0	4	0	0	3	24	0	2	0	2	77	1	5	4	33
6	D	90	5	10	0	0	0	4	0	0	59	226	4	3	2	5	94	5	10	70	244
7	S	-	0	3	-	0	0	-	0	0	8	8	0	0	0	0	-	0	3	8	11
7	D	-	0	0	-	0	0	-	0	0	0	2	0	0	0	0	-	0	0	0	2
8	S	13	34	5	0	1	0	0	0	0	152	11	11	2	0	4	13	35	5	198	22
8	D	130	11	4	0	0	0	2	0	0	16	71	6	2	0	5	132	11	4	33	82
9	S	-	9	7	-	0	0	-	0	0	71	21	10	10	1	0	-	9	7	91	38
9	D	-	24	0	-	1	0	-	0	1	10	49	6	6	1	5	-	25	1	42	61
10	S	-	10	7	-	0	0	-	0	0	14	39	7	3	1	1	-	10	7	32	50
10	D	-	10	2	-	1	0	-	0	0	195	157	2	7	0	2	-	11	2	208	168
Total Count		829	135	81	5	3	3	41	0	2	936	1731	83	59	7	69	875	138	86	1164	1945
Density (#/m^2)		3.684	0.270	0.864	0.022	0.006	0.037	0.182	0.000	0.007	1.872	7.548	0.166	0.294	0.014	0.614	3.889	0.276	0.908	2.328	9.364

Table 4. Calculated species densities in Mystic Lake in 2017, by site, plot (S = Shallow, D = Deep), and for all sites combined.

Pond	Site	Plot	*L. ochracea*	*P. cataracta*	*L. radiata*	*E. complanata*	*L. nasuta*	*A. undulata*	ALL
Mystic	1	S	1.75	1.08	0.08	1.42	0.00	0.08	4.42
Mystic	1	D	2.13	7.63	0.00	6.38	0.00	0.00	16.13
Mystic	2	S	1.75	1.38	0.06	2.69	0.00	0.00	5.88
Mystic	2	D	2.14	5.26	4.82	36.78	0.00	0.00	49.00
Mystic	3	S	2.44	0.69	0.00	0.31	0.00	0.00	3.44
Mystic	3	D	2.00	8.25	14.13	40.25	0.00	0.13	64.75
Mystic	4	S	1.06	0.25	0.38	1.88	0.00	0.00	3.56
Mystic	4	D	6.50	4.50	9.75	57.50	0.00	0.00	78.25
Mystic	5	S	0.00	1.88	0.00	0.25	0.00	0.00	2.13
Mystic	5	D	0.00	6.13	0.00	3.88	0.00	0.00	10.00
Mystic	6	S	0.00	0.13	1.00	0.75	0.00	0.00	1.88
Mystic	6	D	0.00	2.63	7.13	6.13	0.00	0.00	15.88
Mystic	7	S	1.00	0.50	0.00	1.25	0.00	0.00	2.75
Mystic	7	D	0.56	2.38	1.38	16.13	0.00	0.00	20.44
Mystic	8	S	1.44	4.63	0.06	7.81	0.00	0.00	13.94
Mystic	8	D	0.00	4.75	0.25	19.25	0.00	0.00	24.25
Mystic	9	S	0.06	2.06	0.00	0.31	0.00	0.00	2.44
Mystic	9	D	0.13	3.38	0.63	14.13	0.00	0.00	18.25
Mystic	10	S	4.69	2.13	0.00	8.13	0.00	0.00	14.94
Mystic	10	D	1.25	3.13	0.00	11.38	0.00	0.00	15.75
Mystic	1	S+D	1.90	3.70	0.05	3.40	0.00	0.05	9.10
Mystic	2	S+D	1.88	2.67	1.65	14.05	0.00	0.00	20.25
Mystic	3	S+D	2.29	3.21	4.71	13.63	0.00	0.04	23.88
Mystic	4	S+D	2.88	1.67	3.50	20.42	0.00	0.00	28.46
Mystic	5	S+D	0.00	3.29	0.00	1.46	0.00	0.00	4.75
Mystic	6	S+D	0.00	0.96	3.04	2.54	0.00	0.00	6.54
Mystic	7	S+D	0.78	1.44	0.69	8.69	0.00	0.00	11.59
Mystic	8	S+D	0.96	4.67	0.13	11.63	0.00	0.00	17.38
Mystic	9	S+D	0.08	2.50	0.21	4.92	0.00	0.00	7.71
Mystic	10	S+D	3.54	2.46	0.00	9.21	0.00	0.00	15.21
Mystic	All	S	1.41	1.48	0.16	2.51	0.00	0.01	5.56
Mystic	All	D	1.39	4.58	3.59	20.72	0.00	0.01	30.28
Mystic	All	S+D	1.40	2.60	1.40	9.07	0.00	0.01	14.48

Table 5. Calculated species densities in Middle Pond in 2017, by site, plot (S = Shallow, D = Deep), and for all sites combined.

Pond	Site	Plot	*L. ochracea*	*P. cataracta*	*L. radiata*	*E. complanata*	*L. nasuta*	*A. undulata*	ALL
Middle	1	S	0.75	0.06	0.00	3.88	0.00	0.06	4.75
Middle	1	D	1.25	0.00	0.13	18.75	0.00	0.00	20.13
Middle	2	S	1.63	0.00	0.31	6.75	0.06	0.00	8.75
Middle	2	D	1.06	0.56	1.19	7.56	0.00	0.00	10.38
Middle	3	S	1.75	0.19	0.00	1.19	0.00	0.06	3.19
Middle	3	D	1.38	1.75	0.00	1.13	0.00	0.00	4.25
Middle	4	S	0.06	0.50	0.06	2.00	0.00	0.00	2.63
Middle	4	D	0.75	3.56	0.50	17.81	0.00	0.00	22.63
Middle	5	S	1.56	0.75	0.06	2.94	0.00	0.00	5.31
Middle	5	D	0.06	0.69	0.19	33.44	0.00	0.50	34.88
Middle	6	S	0.31	1.00	0.56	1.50	0.00	0.00	3.38
Middle	6	D	0.63	0.75	0.19	18.50	0.00	0.00	20.06
Middle	7	S	1.06	0.00	0.00	0.50	0.00	0.00	1.56
Middle	7	D	0.00	0.00	0.00	0.25	0.00	0.00	0.25
Middle	8	S	0.75	0.25	0.13	1.13	0.00	0.00	2.25
Middle	8	D	1.38	1.50	0.25	8.88	0.00	0.00	12.00
Middle	9	S	0.88	0.00	0.63	1.31	0.00	0.00	2.81
Middle	9	D	0.00	0.63	0.75	6.13	0.13	0.00	7.63
Middle	10	S	1.31	0.06	0.19	2.44	0.00	0.00	4.00
Middle	10	D	0.25	0.25	0.88	19.63	0.00	0.00	21.00
Middle	1	S+D	0.92	0.04	0.04	8.83	0.00	0.04	9.88
Middle	2	S+D	1.34	0.28	0.75	7.16	0.03	0.00	9.56
Middle	3	S+D	1.63	0.71	0.00	1.17	0.00	0.04	3.54
Middle	4	S+D	0.41	2.03	0.28	9.91	0.00	0.00	12.63
Middle	5	S+D	0.81	0.72	0.13	18.19	0.00	0.25	20.09
Middle	6	S+D	0.47	0.88	0.38	10.00	0.00	0.00	11.72
Middle	7	S+D	0.71	0.00	0.00	0.42	0.00	0.00	1.13
Middle	8	S+D	0.96	0.67	0.17	3.71	0.00	0.00	5.50
Middle	9	S+D	0.58	0.21	0.67	2.92	0.04	0.00	4.42
Middle	10	S+D	0.96	0.13	0.42	8.17	0.00	0.00	9.67
Middle	All	S	1.01	0.28	0.19	2.36	0.01	0.01	3.86
Middle	All	D	0.66	1.09	0.44	14.96	0.01	0.07	17.22
Middle	All	S+D	0.86	0.61	0.29	7.55	0.01	0.04	9.36

Table 6. Length class distributions for four mussel species found in Mystic Lake and Middle Pond in 2017. Too few triangle floater and eastern pondmussel were found/measured for this analysis.

	Mystic Lake		Middle Pond	
Length Class	**Count**	**Percent**	**Count**	**Percent**
L. ochracea				
< 20.0 mm	4	2.8	1	1.2
20.0 - 29.9 mm	4	2.8	2	2.3
30.0 - 39.9 mm	36	25.4	12	14.0
40.0 - 49.9 mm	52	36.6	14	16.3
50.0 - 59.9 mm	25	17.6	19	22.1
60.0 - 69.9 mm	12	8.5	26	30.2
70.0 - 79.9 mm	7	4.9	11	12.8
80.0 - 89.9 mm	2	1.4	1	1.2
90.0 - 99.9 mm	0	0.0	0	0.0
> 100.0 mm	0	0.0	0	0.0
Total Measured	142		86	
E. complanata				
< 20.0 mm	3	0.9	0	0.0
20.0 - 29.9 mm	8	2.3	3	0.6
30.0 - 39.9 mm	19	5.5	2	0.4
40.0 - 49.9 mm	21	6.1	11	2.1
50.0 - 59.9 mm	63	18.3	49	9.4
60.0 - 69.9 mm	95	27.5	160	30.5
70.0 - 79.9 mm	95	27.5	207	39.5
80.0 - 89.9 mm	28	8.1	83	15.8
90.0 - 99.9 mm	11	3.2	8	1.5
> 100.0 mm	2	0.6	1	0.2
Total Measured	345		524	

	Mystic Lake		Middle Pond	
Length Class	**Count**	**Percent**	**Count**	**Percent**
L. radiata				
< 20.0 mm	3	3.6	0	0.0
20.0 - 29.9 mm	17	20.2	2	3.1
30.0 - 39.9 mm	5	6.0	0	0.0
40.0 - 49.9 mm	2	2.4	1	1.6
50.0 - 59.9 mm	21	25.0	1	1.6
60.0 - 69.9 mm	7	8.3	13	20.3
70.0 - 79.9 mm	21	25.0	37	57.8
80.0 - 89.9 mm	7	8.3	9	14.1
90.0 - 99.9 mm	1	1.2	1	1.6
> 100.0 mm	0	0.0	0	0.0
Total Measured	84		64	
P. cataracta				
< 20.0 mm	0	0.0	0	0.0
20.0 - 29.9 mm	1	0.4	0	0.0
30.0 - 39.9 mm	14	5.2	2	2.9
40.0 - 49.9 mm	21	7.8	7	10.0
50.0 - 59.9 mm	19	7.0	1	1.4
60.0 - 69.9 mm	32	11.9	27	38.6
70.0 - 79.9 mm	35	13.0	14	20.0
80.0 - 89.9 mm	50	18.5	10	14.3
90.0 - 99.9 mm	52	19.3	6	8.6
> 100.0 mm	46	17.0	3	4.3
Total Measured	270		70	

smaller than 40.0 mm in length, and juveniles as small as 14.0 mm were detected. Average shell length was 46.2 mm, 13.0 mm smaller than the 2010 average and 21.3 mm smaller than the 2007 average. The shell condition index of 0.28 was the lowest among the three years of data, down from an index of 0.72 in 2010.

- Eastern lampmussel: 29.8% of the mussels were smaller than 40.0 mm in length, and juveniles as small as 16.0 mm were detected. Average shell length was 54.3 mm, 8.9 mm smaller than the 2010 average. The shell condition index was 0.02, down from 0.62 in 2010.
- Eastern elliptio: Only 8.7% of the mussels were smaller than 40.0 mm, and the length classes were still dominated by larger adult mussels (60.0 to 80.0 mm), suggesting that recruitment is occurring for this species but that the population is more mature than the tidewater mucket or eastern lampmussel populations. Average shell length was 64.0 mm, 11.7 mm smaller than the 2010 average. The shell condition index was 0.12, down from 0.41 in 2010.
- Eastern floater: Although few small juveniles were found, there was a fairly even distribution among the length classes from 30.0 to >100.0 mm. Average shell length was 78.9 mm and ranged from 22.0 to 120.0 mm, and the shell condition index was 0.16. This species was not measured previously in Mystic Lake, so there is no basis for comparison, but these parameters, combined with 2017 densities, suggest that this species is faring very well in Mystic Lake.

Middle Pond: Table 6 summarizes length class distributions for the four numerous species in Middle Pond, and Table 8 summarizes shell length and shell condition parameters for 2017 and for previous years for which these data were collected. Although there was some evidence of recruitment for the four most common mussel species, length classes were shifted toward "middle-aged" or older populations, especially compared to Mystic Lake where there was far more evidence of recruitment among most species. Shell condition indices suggest mussels were mostly in moderate to fair condition, generally better than in 2011, but not as good as the Middle Pond mussels in 2007 or the Mystic Lake mussels in 2017. Too few eastern pondmussel and triangle floater were found to meaningfully analyze shell length and condition.

- Tidewater mucket: Average shell length was 55.1 mm (range: 13.0 to 85.0 mm), similar to 2007 and

Table 7. Shell length parameters and shell condition indices for mussel species found/measured in Mystic Lake, 2007 to 2017.

	L. ochracea			*L. nasuta*			*A. undulata*			*L. radiata*		*E. complanata*		*P. cataracta*
Mystic Lake	**2007**	**2010**	**2017**	**2007**	**2010**	**2017**	**2007**	**2010**	**2017**	**2010**	**2017**	**2010**	**2017**	**2017**
Sample Size	529	77	142	9	0	0	10	0	2	71	84	117	345	270
Average Shell Length (mm)	67.5	59.3	46.2	68.2	-	-	49.8	-	46.0	63.2	54.3	75.7	64.0	78.9
Min Shell Length (mm)	25.0	38.0	14.0	30.0	-	-	42.0	-	46.0	10.0	16.0	56.0	13.0	22.0
Max Shell Length (mm)	92.0	89.0	80.0	88.0	-	-	65.0	-	46.0	90.0	90.0	101.0	103.0	120.0
Shell Condition Index	0.40	0.72	0.28	0.10	-	-	0.17	-	0.00	0.62	0.02	0.41	0.12	0.16

Table 8. Shell length parameters and shell condition indices for mussel species found/measured in Middle Pond, 2007 to 2017.

	L. ochracea			*L. nasuta*			*A. undulata*			*L. radiata*		*P. cataracta*		*E. complanata*
Middle Pond	**2007**	**2011**	**2017**	**2007**	**2011**	**2017**	**2007**	**2011**	**2017**	**2011**	**2017**	**2011**	**2017**	**2017**
Sample Size	348	135	86	48	0	2	4	3	3	83	64	7	70	524
Average Shell Length (mm)	53.0	53.3	55.1	60.4	-	77.0	37.0	47.3	47.7	60.0	72.0	83.9	70.5	70.3
Min Shell Length (mm)	29.0	38.0	13.0	41.0	-	77.0	34.0	45.0	37.0	44.0	23.0	58.0	36.0	23.0
Max Shell Length (mm)	80.0	73.0	85.0	75.0	-	77.0	41.0	50.0	65.0	73.0	92.0	109.0	101.0	100.0
Shell Condition Index	0.22	0.77	0.51	0.19	-	0.63	0.00	0.17	0.00	0.47	0.40	0.39	0.20	0.40

2011. The shell condition index of 0.51 was down from an index of 0.77 in 2011, but up from an index of 0.22 in 2007.

- Eastern lampmussel: Average shell length was 72.0 mm (range: 23.0 to 92.0 mm), 12.0 mm higher than the 2011 average. The population was dominated by the 70.0 – 79.9 mm length class (57.8%), and very few mussels found (4) were smaller than 60.0 mm. The shell condition index of 0.40 was similar to the 2011 index of 0.47. Eastern lampmussels were not measured in 2007, so we lack data from before the mussel die-offs.
- Eastern elliptio: Average shell length was 70.3 mm, and mussels ranged in length from 23.0 to 100.0 mm. No small juveniles, and only five mussels smaller than 40.0 mm were found. The population was dominated by mussels in the 60.0 to 90.0 mm size range. The shell condition index was 0.40. This species was not measured previously in Middle Pond.
- Eastern floater: Average shell length was 70.5 mm, down from the 2011 average of 83.9 mm. Shell lengths ranged from 36.0 to 101.0 mm; no small juveniles were found, and the population was dominated by mussels in the 60.0 to 80.0 mm size range. The shell condition index was 0.20, down from 0.39 in 2011. Only a small subset (7 mussels) were measured in 2011, so it is hard to compare the 2011 and 2017 parameters for this species.

Juvenile tidewater mucket from Mystic Lake.

DISCUSSION

Mystic Lake: In 2007, a total of 529 live tidewater mucket, 10 triangle floater, and 9 eastern pondmussel were counted within 17 plots (each plot was 5x5 meters, or 25m^2). Although common mussel species were not counted in 2007, observations suggest that eastern elliptio and eastern lampmussel were the two most abundant species. In 2010, the first lake-wide survey after the 2009 die-off, only 31 live tidewater mucket and 9 live triangle floater were counted within 16 plots. Shell (dead animal) counts within plots totaled 491 tidewater mucket, 11 triangle floater, and 10 eastern pondmussel. Eastern elliptio were still common in some areas of the lake. In 2011, counts were extremely low for all mussel species. Only one tidewater mucket was found in 18 plots; no live triangle floater or eastern pondmussel were observed. Eastern elliptio was the most common mussel species (84 observed), and only four live eastern lampmussel were found.

There was an estimated a 94.1 percent reduction in Mystic Lake's tidewater mucket population from 2007 to 2010, and a 99.8 percent reduction from 2007 to 2011. No area of the lake, nor any depth, seemed to have been spared from heavy mortality for this species. In both 2010 and 2011, some plots were carefully excavated to determine if juvenile mussels persisted through the die-off, but few juveniles (or any live mussels) were found. In 2010, most of the buried mussels found were dead (they had clearly died in place because they were in an otherwise natural position and black rotting tissues were often still contained within the shells). The shallow plot along the south beach, where 88 live tidewater mucket were found in 2007, yielded only two live tidewater mucket (and 133 dead animals) in 2010, and none were found here in 2011. Live triangle floater were not observed in 2011, and live eastern pondmussel were not observed in 2010 or 2011. Observations suggested that all other mussel species may have experienced similar levels of mortality, although a comparatively larger number of eastern elliptio, eastern lampmussel, and eastern floater populations still remained in Mystic Lake.

The 2017 study used a smaller sampling unit (2 x 2 quadrat, or 4.0 m^2) than had been used in prior studies in Mystic Lake, thus we anticipated lower counts for all species in 2017 yet perhaps more precise density estimates. Five species and 2,126 live mussels were counted within quadrats in 2017, compared to only four species and 91 live mussels in 2011. Four species experienced exceptional increases in density from 2011 to 2017 (Table 2). Lake-wide, average mussel density (all species) increased from 0.202 mussels/m^2 in 2011 to 14.48 mussels/m^2 in 2017. We consider this a dramatic recovery for a mussel assemblage that appeared to be devastated from the 2009 and 2010 die-offs.

It should be reiterated that the lake-wide mussel die-off occurred prior to the alum treatment of September 2010. Biodrawversity conducted a mussel study immediately prior to, during, and after the alum treatment to determine if mussels responded (i.e., behavioral (stress) or mortality) to the treatment (Biodrawversity 2011a). The study did not detect any mussel stress or mortality from the alum treatment.

Although triangle floater and eastern lampmussel appear to continue to be rare in Mystic Lake, the other species are again relatively common in some areas of the lake. The shell length and condition data corroborate the recovery; there was strong evidence of juvenile recruitment and populations with a large proportion of younger animals in excellent condition, particularly for tidewater mucket and eastern lampmussel. The lack of counts for common species in 2007 makes it difficult to compare mussel densities between 2007 and 2017. In qualitative terms, it appears that eastern elliptio and eastern lampmussel populations are still quite a bit lower then they were in 2007, but tidewater mucket may have fully recovered, especially in certain areas of the lake (i.e., areas along the eastern shoreline). We anticipate that this recovery will continue for all species throughout the lake.

Middle Pond: In Middle Pond, mussel diversity and density declined steeply within almost all quadrats between 2007 and 2011. Species richness of live mussels dropped from seven to five, and average species richness per quadrat dropped from 5.6 to 2.9. For tidewater mucket, a total of 829 were counted or estimated in nine quadrats in 2007, compared to only 135 individuals in 20 quadrats in 2011, a decline in density of nearly 93 percent. A total of 63 live eastern pondmussel were found in 2007, including 41 within quadrats and 22 in an unconfined search at Site 1. None were found in the 20 quadrats surveyed in 2011.

For these and other mussel species, studies documented a significant change (decline) in shell condition from 2007 to 2011. The 2007 survey was focused only on state-listed mussels (tidewater mucket, eastern pondmussel, and triangle floater) and some of the other species were considered too numerous to count. Therefore, the magnitude of the decline in density of the four species that were not precisely counted in 2007 could not be estimated. Generally, the 2011 report concluded that eastern floater, eastern lampmussel, and eastern elliptio populations may have experienced 85–95 percent mortality based on the relative abundances that were estimated in 2007.

As with Mystic Lake, the 2017 study in Middle Pond used a smaller sampling unit (2 x 2 quadrat, or 4.0 m^2) than had been used in prior studies, and thus we anticipated lower counts for all species in 2017 yet perhaps more precise density estimates. Six species and 1,945 live mussels were counted within quadrats in 2017, compared to five species and 1,164 live mussels in 2011. Density estimates were higher for all six species in 2017 than in 2011 (Table 2), though the magnitude of change was not nearly as great as it was in Mystic Lake. Lake-wide, average mussel density (all

species) increased from 2.33 mussels/m^2 in 2011 to 9.36 mussels/m^2 in 2017. The tidewater mucket population in Middle Pond still appears to be significantly smaller than it was in 2007; estimated density was 3.68 mussels/m^2 in 2007 compared to 0.864 mussels/m^2 in 2017. Similarly, eastern pondmussel density was 0.182 mussels/m^2 in 2007 compared to 0.007 mussels/m^2 in 2017. Common species were not counted in 2007, but in qualitative terms, we think all species had considerably higher densities in 2007 than in 2017.

Although there was some evidence of recruitment for the four most common mussel species in Middle Pond, length classes are shifted toward "middle-aged" or older populations, especially compared to Mystic Lake where there was far more evidence of recruitment among most species. Shell condition indices suggest mussels were mostly in moderate to fair condition, generally better than in 2011, but not as good as the Middle Pond mussels in 2007 or the Mystic Lake mussels in 2017. Overall, we think that the mussel die-offs in Middle Pond were smaller in magnitude than the die-offs in Mystic Lake, and recovery is occurring more slowly. Nevertheless, the 2017 study provides good evidence that the mussel community is faring better now than in 2011, and there is no reason to doubt that this trend will continue.

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Biodrawversity. 2011c. Freshwater Mussel Survey in Middle Pond and Hamblin Pond (Barnstable, Massachusetts). Report prepared for the Indian Ponds Association.

Appendix 1. Surface counts, buried counts, and combined densities for sites, plots (S = Shallow, D = deep), and quadrats in Middle Pond and Mystic Lake (2017).

				Surface Counts							Buried Counts						Combined Density (mussels/m²)						
POND	SITE	PLOT	QUAD	LeOc	PyCa	LaRa	ElCo	LiNa	AlUn	ALL	LeOc	PyCa	LaRa	ElCo	AlUn	ALL	LeOc	PyCa	LaRa	ElCo	LiNa	AlUn	ALL
Middle	1	D	1	1	0	0	68	0	0	69	1	0	0	0	0	1	2.25	0.00	0.00	17.00	0.00	0.00	19.25
Middle	1	D	2	1	0	1	82	0	0	84	0	0	0	0	0	0	0.25	0.00	0.25	20.50	0.00	0.00	21.00
Middle	1	S	1	0	0	0	9	0	0	9	0	0	0	0	0	0	0.00	0.00	0.00	2.25	0.00	0.00	2.25
Middle	1	S	2	0	0	0	7	0	0	7	0	0	0	0	0	0	0.00	0.00	0.00	1.75	0.00	0.00	1.75
Middle	1	S	3	1	0	0	9	0	0	10	1	0	0	1	0	2	2.25	0.00	0.00	4.25	0.00	0.00	6.50
Middle	1	S	4	3	1	0	29	0	1	34	0	0	0	0	0	0	0.75	0.25	0.00	7.25	0.00	0.25	8.50
Middle	2	D	1	0	0	1	32	0	0	33	0	0	0	0	0	0	0.00	0.00	0.25	8.00	0.00	0.00	8.25
Middle	2	D	2	0	1	0	22	0	0	23	0	0	0	0	0	0	0.00	0.25	0.00	5.50	0.00	0.00	5.75
Middle	2	D	3	0	0	1	37	0	0	38	1	1	1	0	0	3	2.00	2.00	2.25	9.25	0.00	0.00	15.50
Middle	2	D	4	1	0	1	30	0	0	32	1	0	1	0	0	2	2.25	0.00	2.25	7.50	0.00	0.00	12.00
Middle	2	S	1	1	0	0	39	0	0	40	0	0	0	0	0	0	0.25	0.00	0.00	9.75	0.00	0.00	10.00
Middle	2	S	2	0	0	0	13	0	0	13	1	0	0	2	0	3	2.00	0.00	0.00	7.25	0.00	0.00	9.25
Middle	2	S	3	0	0	3	19	1	0	23	1	0	0	0	0	1	2.00	0.00	0.75	4.75	0.25	0.00	7.75
Middle	2	S	4	1	0	2	21	0	0	24	1	0	0	0	0	1	2.25	0.00	0.50	5.25	0.00	0.00	8.00
Middle	3	D	1	2	1	0	1	0	0	4	0	0	0	0	0	0	0.50	0.25	0.00	0.25	0.00	0.00	1.00
Middle	3	D	2	1	5	0	0	0	0	6	1	1	0	1	0	3	2.25	3.25	0.00	2.00	0.00	0.00	7.50
Middle	3	S	1	0	0	0	0	0	1	1	1	0	0	0	0	1	2.00	0.00	0.00	0.00	0.00	0.25	2.25
Middle	3	S	2	1	2	0	7	0	0	10	0	0	0	0	0	0	0.25	0.50	0.00	1.75	0.00	0.00	2.50
Middle	3	S	3	3	1	0	7	0	0	11	1	0	0	0	0	1	2.75	0.25	0.00	1.75	0.00	0.00	4.75
Middle	3	S	4	0	0	0	5	0	0	5	1	0	0	0	0	1	2.00	0.00	0.00	1.25	0.00	0.00	3.25
Middle	4	D	1	1	4	3	104	0	0	112	0	3	0	0	0	3	0.25	7.00	0.75	26.00	0.00	0.00	34.00
Middle	4	D	2	0	5	1	42	0	0	48	0	0	0	0	0	0	0.00	1.25	0.25	10.50	0.00	0.00	12.00
Middle	4	D	3	3	4	2	68	0	0	77	0	0	0	2	0	2	0.75	1.00	0.50	21.00	0.00	0.00	23.25
Middle	4	D	4	0	4	2	39	0	0	45	1	2	0	2	0	5	2.00	5.00	0.50	13.75	0.00	0.00	21.25
Middle	4	S	1	1	0	0	7	0	0	8	0	0	0	0	0	0	0.25	0.00	0.00	1.75	0.00	0.00	2.00
Middle	4	S	2	0	0	0	6	0	0	6	0	1	0	0	0	1	0.00	2.00	0.00	1.50	0.00	0.00	3.50
Middle	4	S	3	0	0	1	6	0	0	7	0	0	0	0	0	0	0.00	0.00	0.25	1.50	0.00	0.00	1.75
Middle	4	S	4	0	0	0	13	0	0	13	0	0	0	0	0	0	0.00	0.00	0.00	3.25	0.00	0.00	3.25
Middle	5	D	1	1	2	1	131	0	0	135	0	1	0	10	1	12	0.25	2.50	0.25	52.75	0.00	2.00	57.75
Middle	5	D	2	0	0	1	78	0	0	79	0	0	0	13	0	13	0.00	0.00	0.25	45.50	0.00	0.00	45.75
Middle	5	D	3	0	0	0	62	0	0	62	0	0	0	1	0	1	0.00	0.00	0.00	17.50	0.00	0.00	17.50
Middle	5	D	4	0	1	1	56	0	0	58	0	0	0	2	0	2	0.00	0.25	0.25	18.00	0.00	0.00	18.50
Middle	5	S	1	0	1	1	17	0	0	19	1	0	0	1	0	2	2.00	0.25	0.25	6.25	0.00	0.00	8.75
Middle	5	S	2	0	1	0	8	0	0	9	0	0	0	0	0	0	0.00	0.25	0.00	2.00	0.00	0.00	2.25
Middle	5	S	3	0	1	0	8	0	0	9	0	0	0	0	0	0	0.00	0.25	0.00	2.00	0.00	0.00	2.25
Middle	5	S	4	1	1	0	6	0	0	8	2	1	0	0	0	3	4.25	2.25	0.00	1.50	0.00	0.00	8.00
Middle	6	D	1	1	1	1	53	0	0	56	0	1	0	6	0	7	0.25	2.25	0.25	25.25	0.00	0.00	28.00
Middle	6	D	2	6	2	0	47	0	0	55	0	0	0	0	0	0	1.50	0.50	0.00	11.75	0.00	0.00	13.75
Middle	6	D	3	0	0	1	49	0	0	50	0	0	0	0	0	0	0.00	0.00	0.25	12.25	0.00	0.00	12.50
Middle	6	D	4	3	1	1	67	0	0	72	0	0	0	4	0	4	0.75	0.25	0.25	24.75	0.00	0.00	26.00
Middle	6	S	1	0	0	0	6	0	0	6	0	0	0	0	0	0	0.00	0.00	0.00	1.50	0.00	0.00	1.50
Middle	6	S	2	0	0	0	8	0	0	8	0	0	0	0	0	0	0.00	0.00	0.00	2.00	0.00	0.00	2.00
Middle	6	S	3	2	0	0	7	0	0	9	0	2	1	0	0	3	0.50	4.00	2.00	1.75	0.00	0.00	8.25
Middle	6	S	4	3	0	1	3	0	0	7	0	0	0	0	0	0	0.75	0.00	0.25	0.75	0.00	0.00	1.75
Middle	7	D	1	0	0	0	1	0	0	1	0	0	0	0	0	0	0.00	0.00	0.00	0.25	0.00	0.00	0.25

*Species abbreviations: LeOc = *L. ochracea*, PyCa = *P. cataracta*, LaRa = *L. radiata*, ElCo = *E. complanata*, LiNa = *L. nasuta*, AlUn = *A. undulata*

Appendix 1. Surface counts, buried counts, and combined densities for sites, plots (S = Shallow, D = deep), and quadrats in Middle Pond and Mystic Lake (2017).

				Surface Counts							Buried Counts						Combined Density (mussels/m²)						
POND	SITE	PLOT	QUAD	LeOc	PyCa	LaRa	ElCo	LiNa	AlUn	ALL	LeOc	PyCa	LaRa	ElCo	AlUn	ALL	LeOc	PyCa	LaRa	ElCo	LiNa	AlUn	ALL
Middle	7	D	2	0	0	0	1	0	0	1	0	0	0	0	0	0	0.00	0.00	0.00	0.25	0.00	0.00	0.25
Middle	7	S	1	1	0	0	6	0	0	7	0	0	0	0	0	0	0.25	0.00	0.00	1.50	0.00	0.00	1.75
Middle	7	S	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Middle	7	S	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Middle	7	S	4	0	0	0	2	0	0	2	2	0	0	0	0	2	4.00	0.00	0.00	0.50	0.00	0.00	4.50
Middle	8	D	1	2	1	2	39	0	0	44	0	1	0	0	0	1	0.50	2.25	0.50	9.75	0.00	0.00	13.00
Middle	8	D	2	1	3	0	32	0	0	36	1	0	0	0	0	1	2.25	0.75	0.00	8.00	0.00	0.00	11.00
Middle	8	S	1	1	2	0	4	0	0	7	0	0	0	0	0	0	0.25	0.50	0.00	1.00	0.00	0.00	1.75
Middle	8	S	2	1	1	1	2	0	0	5	0	0	0	0	0	0	0.25	0.25	0.25	0.50	0.00	0.00	1.25
Middle	8	S	3	0	1	1	2	0	0	4	1	0	0	1	0	2	2.00	0.25	0.25	2.50	0.00	0.00	5.00
Middle	8	S	4	2	0	0	2	0	0	4	0	0	0	0	0	0	0.50	0.00	0.00	0.50	0.00	0.00	1.00
Middle	9	D	1	0	4	4	26	0	0	34	0	0	0	0	0	0	0.00	1.00	1.00	6.50	0.00	0.00	8.50
Middle	9	D	2	0	1	2	23	1	0	27	0	0	0	0	0	0	0.00	0.25	0.50	5.75	0.25	0.00	6.75
Middle	9	S	1	1	0	3	4	0	0	8	0	0	0	0	0	0	0.25	0.00	0.75	1.00	0.00	0.00	2.00
Middle	9	S	2	2	0	5	12	0	0	19	0	0	0	0	0	0	0.50	0.00	1.25	3.00	0.00	0.00	4.75
Middle	9	S	3	1	0	0	1	0	0	2	0	0	0	0	0	0	0.25	0.00	0.00	0.25	0.00	0.00	0.50
Middle	9	S	4	2	0	2	4	0	0	8	1	0	0	0	0	1	2.50	0.00	0.50	1.00	0.00	0.00	4.00
Middle	10	D	1	2	1	4	67	0	0	74	0	0	0	0	0	0	0.50	0.25	1.00	16.75	0.00	0.00	18.50
Middle	10	D	2	0	1	3	90	0	0	94	0	0	0	0	0	0	0.00	0.25	0.75	22.50	0.00	0.00	23.50
Middle	10	S	1	0	1	2	1	0	0	4	0	0	0	0	0	0	0.00	0.25	0.50	0.25	0.00	0.00	1.00
Middle	10	S	2	3	0	0	4	0	0	7	0	0	0	0	0	0	0.75	0.00	0.00	1.00	0.00	0.00	1.75
Middle	10	S	3	2	0	0	12	0	0	14	1	0	0	0	0	1	2.50	0.00	0.00	3.00	0.00	0.00	5.50
Middle	10	S	4	0	0	1	22	0	0	23	1	0	0	0	0	1	2.00	0.00	0.25	5.50	0.00	0.00	7.75
Mystic	1	D	1	0	13	0	18	0	0	31	1	2	0	1	0	4	2.00	7.25	0.00	6.50	0.00	0.00	15.75
Mystic	1	D	2	1	16	0	17	0	0	34	1	2	0	1	0	4	2.25	8.00	0.00	6.25	0.00	0.00	16.50
Mystic	1	S	1	7	0	0	4	0	0	11	0	0	0	0	0	0	1.75	0.00	0.00	1.00	0.00	0.00	2.75
Mystic	1	S	2	4	4	0	1	0	1	10	1	0	0	0	0	1	3.00	1.00	0.00	0.25	0.00	0.25	4.50
Mystic	1	S	3	2	9	1	12	0	0	24	0	0	0	0	0	0	0.50	2.25	0.25	3.00	0.00	0.00	6.00
Mystic	2	D	1	6	18	10	115	0	0	149	0.4	0.9	1.2	3.9	0	6.5	2.39	6.39	4.94	36.53	0.00	0.00	50.25
Mystic	2	D	2	4	9	9	117	0	0	139	0.4	0.9	1.2	3.9	0	6.5	1.89	4.14	4.69	37.03	0.00	0.00	47.75
Mystic	2	S	1	4	0	0	6	0	0	10	0	0	0	0	0	0	1.00	0.00	0.00	1.50	0.00	0.00	2.50
Mystic	2	S	2	10	11	1	16	0	0	38	0	0	0	0	0	0	2.50	2.75	0.25	4.00	0.00	0.00	9.50
Mystic	2	S	3	8	7	0	11	0	0	26	0	0	0	0	0	0	2.00	1.75	0.00	2.75	0.00	0.00	6.50
Mystic	2	S	4	6	4	0	2	0	0	12	0	0	0	1	0	1	1.50	1.00	0.00	2.50	0.00	0.00	5.00
Mystic	3	D	1	0	5	12	50	0	1	68	1	5	6	15	0	27	2.00	11.25	15.00	42.50	0.00	0.25	71.00
Mystic	3	D	2	0	5	13	48	0	0	66	1	2	5	13	0	21	2.00	5.25	13.25	38.00	0.00	0.00	58.50
Mystic	3	S	1	4	0	0	1	0	0	5	0	0	0	0	0	0	1.00	0.00	0.00	0.25	0.00	0.00	1.25
Mystic	3	S	2	1	0	0	0	0	0	1	0	0	0	0	0	0	0.25	0.00	0.00	0.00	0.00	0.00	0.25
Mystic	3	S	3	6	0	0	1	0	0	7	2	1	0	0	0	3	5.50	2.00	0.00	0.25	0.00	0.00	7.75
Mystic	3	S	4	4	3	0	3	0	0	10	1	0	0	0	0	1	3.00	0.75	0.00	0.75	0.00	0.00	4.50
Mystic	4	D	1	0	3	1	66	0	0	70	3	2	4	20	0	29	6.00	4.75	8.25	56.50	0.00	0.00	75.50
Mystic	4	D	2	4	1	13	74	0	0	92	3	2	4	20	0	29	7.00	4.25	11.25	58.50	0.00	0.00	81.00
Mystic	4	S	1	1	0	2	7	0	0	10	0	0	0	0	0	0	0.25	0.00	0.50	1.75	0.00	0.00	2.50
Mystic	4	S	2	4	0	0	3	0	0	7	0	0	0	0	0	0	1.00	0.00	0.00	0.75	0.00	0.00	1.75
Mystic	4	S	3	5	2	3	6	0	0	16	0	0	0	1	0	1	1.25	0.50	0.75	3.50	0.00	0.00	6.00

Appendix 1. Surface counts, buried counts, and combined densities for sites, plots (S = Shallow, D = deep), and quadrats in Middle Pond and Mystic Lake (2017).

				Surface Counts							Buried Counts						Combined Density (mussels/m²)						
POND	SITE	PLOT	QUAD	LeOc	PyCa	LaRa	ElCo	LiNa	AlUn	ALL	LeOc	PyCa	LaRa	ElCo	AlUn	ALL	LeOc	PyCa	LaRa	ElCo	LiNa	AlUn	ALL
Mystic	4	S	4	7	2	1	6	0	0	16	0	0	0	0	0	0	1.75	0.50	0.25	1.50	0.00	0.00	4.00
Mystic	5	D	1	0	18	0	9	0	0	27	0	0	0	0	0	0	0.00	4.50	0.00	2.25	0.00	0.00	6.75
Mystic	5	D	2	0	23	0	22	0	0	45	0	1	0	0	0	1	0.00	7.75	0.00	5.50	0.00	0.00	13.25
Mystic	5	S	1	0	1	0	0	0	0	1	0	2	0	0	0	2	0.00	4.25	0.00	0.00	0.00	0.00	4.25
Mystic	5	S	2	0	2	0	0	0	0	2	0	1	0	0	0	1	0.00	2.50	0.00	0.00	0.00	0.00	2.50
Mystic	5	S	3	0	1	0	2	0	0	3	0	0	0	0	0	0	0.00	0.25	0.00	0.50	0.00	0.00	0.75
Mystic	5	S	4	0	2	0	2	0	0	4	0	0	0	0	0	0	0.00	0.50	0.00	0.50	0.00	0.00	1.00
Mystic	6	D	1	0	8	4	11	0	0	23	0	1	3	1	0	5	0.00	4.00	7.00	4.75	0.00	0.00	15.75
Mystic	6	D	2	0	5	5	14	0	0	24	0	0	3	2	0	5	0.00	1.25	7.25	7.50	0.00	0.00	16.00
Mystic	6	S	1	0	0	0	1	0	0	1	0	0	0	0	0	0	0.00	0.00	0.00	0.25	0.00	0.00	0.25
Mystic	6	S	2	0	0	0	3	0	0	3	0	0	1	1	0	2	0.00	0.00	2.00	2.75	0.00	0.00	4.75
Mystic	6	S	3	0	1	0	0	0	0	1	0	0	0	0	0	0	0.00	0.25	0.00	0.00	0.00	0.00	0.25
Mystic	6	S	4	0	1	0	0	0	0	1	0	0	1	0	0	1	0.00	0.25	2.00	0.00	0.00	0.00	2.25
Mystic	7	D	1	0	6	4	42	0	0	52	0	0	0	8	0	8	0.00	1.50	1.00	26.50	0.00	0.00	29.00
Mystic	7	D	2	0	4	3	34	0	0	41	1	0	0	3	0	4	2.00	1.00	0.75	14.50	0.00	0.00	18.25
Mystic	7	D	3	1	3	2	24	0	0	30	0	2	0	4	0	6	0.25	4.75	0.50	14.00	0.00	0.00	19.50
Mystic	7	D	4	0	1	5	22	0	0	28	0	1	1	2	0	4	0.00	2.25	3.25	9.50	0.00	0.00	15.00
Mystic	7	S	1	0	0	0	1	0	0	1	0	0	0	0	0	0	0.00	0.00	0.00	0.25	0.00	0.00	0.25
Mystic	7	S	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mystic	7	S	3	0	0	0	2	0	0	2	0	1	0	0	0	1	0.00	2.00	0.00	0.50	0.00	0.00	2.50
Mystic	7	S	4	0	0	0	1	0	0	1	2	0	0	2	0	4	4.00	0.00	0.00	4.25	0.00	0.00	8.25
Mystic	8	D	1	0	10	1	81	0	0	92	0	0	0	1	0	1	0.00	2.50	0.25	22.25	0.00	0.00	25.00
Mystic	8	D	2	0	28	1	65	0	0	94	0	0	0	0	0	0	0.00	7.00	0.25	16.25	0.00	0.00	23.50
Mystic	8	S	1	4	1	0	13	0	0	18	1	1	0	0	0	2	3.00	2.25	0.00	3.25	0.00	0.00	8.50
Mystic	8	S	2	1	16	0	35	0	0	52	0	3	0	0	0	3	0.25	10.00	0.00	8.75	0.00	0.00	19.00
Mystic	8	S	3	1	16	1	56	0	0	74	1	0	0	1	0	2	2.25	4.00	0.25	16.00	0.00	0.00	22.50
Mystic	8	S	4	1	1	0	13	0	0	15	0	1	0	0	0	1	0.25	2.25	0.00	3.25	0.00	0.00	5.75
Mystic	9	D	1	1	11	2	60	0	0	74	0	0	0	0	0	0	0.25	2.75	0.50	15.00	0.00	0.00	18.50
Mystic	9	D	2	0	16	3	53	0	0	72	0	0	0	0	0	0	0.00	4.00	0.75	13.25	0.00	0.00	18.00
Mystic	9	S	1	0	3	0	0	0	0	3	0	0	0	0	0	0	0.00	0.75	0.00	0.00	0.00	0.00	0.75
Mystic	9	S	2	0	9	0	1	0	0	10	0	0	0	0	0	0	0.00	2.25	0.00	0.25	0.00	0.00	2.50
Mystic	9	S	3	1	13	0	3	0	0	17	0	0	0	0	0	0	0.25	3.25	0.00	0.75	0.00	0.00	4.25
Mystic	9	S	4	0	8	0	1	0	0	9	0	0	0	0	0	0	0.00	2.00	0.00	0.25	0.00	0.00	2.25
Mystic	10	D	1	0	8	0	42	0	0	50	1	0	0	0	0	1	2.00	2.00	0.00	10.50	0.00	0.00	14.50
Mystic	10	D	2	2	9	0	49	0	0	60	0	1	0	0	0	1	0.50	4.25	0.00	12.25	0.00	0.00	17.00
Mystic	10	S	1	3	4	0	25	0	0	32	1	1	0	1	0	3	2.75	3.00	0.00	8.25	0.00	0.00	14.00
Mystic	10	S	2	5	7	0	35	0	0	47	2	0	0	0	0	2	5.25	1.75	0.00	8.75	0.00	0.00	15.75
Mystic	10	S	3	9	5	0	27	0	0	41	4	1	0	0	0	5	10.25	3.25	0.00	6.75	0.00	0.00	20.25
Mystic	10	S	4	2	2	0	19	0	0	23	0	0	0	2	0	2	0.50	0.50	0.00	8.75	0.00	0.00	9.75