Brook Floater (*Alasmidonta varicosa*) in the West River in Vermont

prepared for

Vermont Fish and Wildlife
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prepared by

Biodrawversity LLC
206 Pratt Corner Road, Leverett, Massachusetts

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The West River in Newfane, Vermont, at quantitative monitoring site 2 (Q-2).

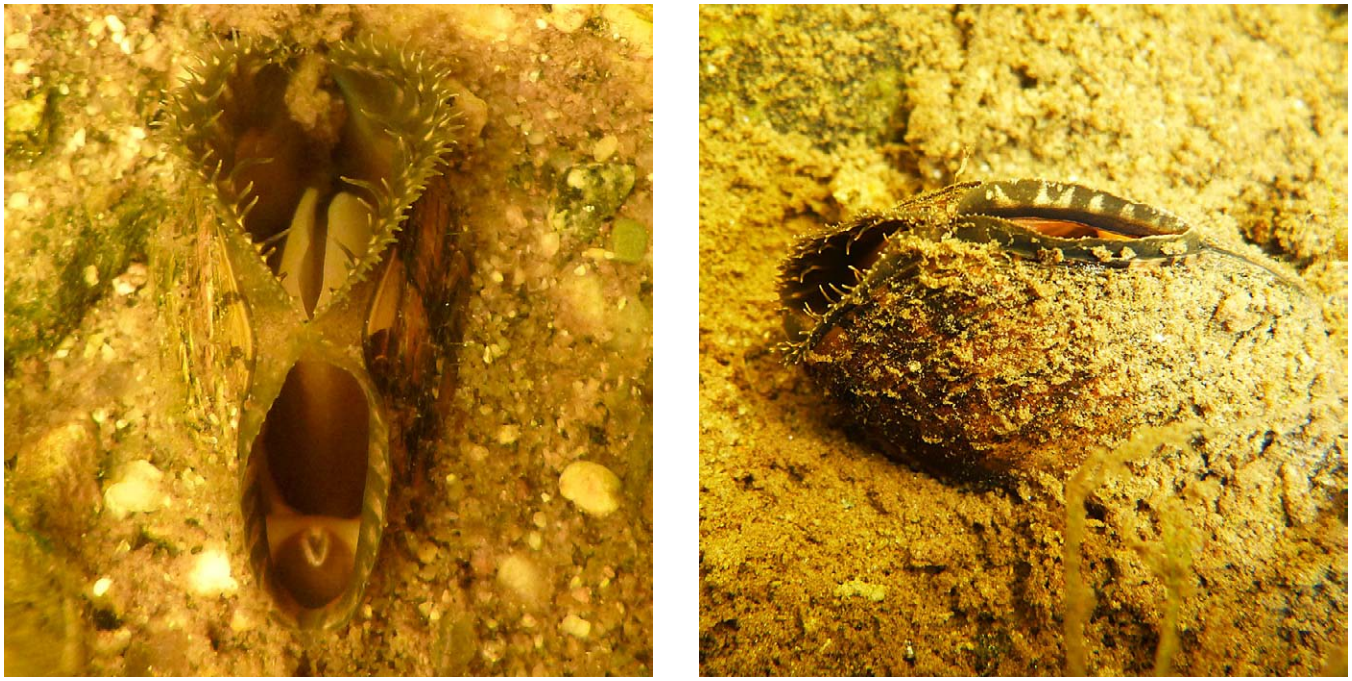
INTRODUCTION

The Brook Floater (*Alasmidonta varicosa*) is one of the most imperiled freshwater animals in northeastern North America. It is listed as Endangered in Massachusetts, New Hampshire, and Connecticut; Threatened in Vermont and Maine; and extirpated in Rhode Island (Nedeau 2008). The West River in southeastern Vermont holds Vermont's only Brook Floater population (Fichtel and Smith 1995, Biodrawversity 2008). The species was discovered in the West River in 1979-1980, and has since been found sporadically from Jamaica to Brattleboro, usually at low population densities. High-density populations were documented downstream of the Townshend Dam, a flood control dam operated by the U.S. Army Corps of Engineers, especially in the towns of Townshend and Newfane.

Qualitative and quantitative surveys of mussel beds at the Scotts Covered Bridge (Townshend) and the Green Bridge Pool (Newfane) were conducted in 1991, 1992, 1993, and 2002 (Fichtel 1992, Fichtel 1993, Ferguson 2002), with more cursory surveys in intervening years. Early surveys generally documented a large Brook Floater population—larger than any other known population in the Connecticut River watershed. However, early reports also described high mortality from predators and possibly sedimentation, and investigators questioned if the Brook Floater population could withstand such high mortality. The 2002 survey documented startlingly low numbers of Brook Floater (alive or dead) compared to the early 1990s (Ferguson 2002).

In 2008, Ethan Nedeau conducted qualitative and quantitative freshwater mussel surveys in the West River in Townshend and Newfane (Biodrawversity 2008). The main objectives were to assess the status of the Brook Floater at the Green Bridge Pool and Scotts Covered Bridge, compare results to prior surveys, and present a clearer picture of the viability of the Brook Floater population. Six species were encountered during the survey,

Brook Floater (*Alasmidonta varicosa*).



Close-up views of Brook Floater in its natural position, including one found in the Pleasant River, Maine (left) and in the West River (right).

including (in order of abundance) the Eastern Elliptio (*Elliptio complanata*), Eastern Lampmussel (*Lampsilis radiata*), Brook Floater, Triangle Floater (*Alasmidonta undulata*), Eastern Pearlshell (*Margaritifera margaritifera*), and Creeper (*Strophitus undulatus*). From 1993 to 2008, transect data indicated an 86 and 84 percent decrease in Brook Floater densities at Scotts Covered Bridge and Green Bridge Pool, respectively. For the same period, transect data indicated a 957 and 3,052 percent increase in Eastern Elliptio densities at Scotts Covered Bridge and Green Bridge Pool, respectively. Qualitative surveys, including both snorkel surveys and analysis of shell middens, provided further evidence of a Brook Floater decline and Eastern Elliptio increase. The 2008 survey posited that environmental conditions, such as water temperature, may have shifted enough to decrease the recruitment and survival of Brook Floater, and increase the recruitment and survival of Eastern Elliptio.

The current study was initiated due to the results of the 2008 study at the two long-term monitoring sites, and a need to assess populations of Brook Floater and co-occurring mussel species in the entire West River from Ball Mountain Dam to the Connecticut River, a distance of approximately 25 miles. The objectives of the study were as follows:

1. Conduct semi-quantitative surveys along a nearly 25-mile reach of the West River to characterize the density, demographics, shell condition, and habitat of Brook Floater and co-occurring mussel species.
2. Collect quantitative data on population density, demographics, shell condition, and habitat in two areas of highest Brook Floater population density to establish new baseline data at these sites.
3. Provide an updated assessment (based on 2011 and 2012 fieldwork, compared to prior surveys) of the mussel fauna of the West River.

METHODS

Semi-quantitative Survey: In 2011, two biologists spent nine days conducting semi-quantitative (i.e., timed searches) surveys at 103 locations from Jamaica State Park in Jamaica to the I-91 Bridge in Brattleboro (**Figure 1, Appendices 1 and 2**). Jeffrey Cole led the semi-quantitative surveys and was assisted by one technician. Surveys were mostly non-continuous in the reach upstream from the Townshend Flood Control Project (Sites 1-15, called "Reach 1" in this report), surveys were nearly continuous in the reach from the Townshend Dam downstream to the Rock River confluence (Sites 16-93, called "Reach 2"), and surveys were non-continuous in the lowermost river (Sites 94-103, called "Reach 3"). Overall, surveys were conducted along approximately 11.5 miles of the river.

All surveys were completed by snorkeling. Biologists recorded counts for all species; and shell length, shell condition, and substrate for uncommon species. Shell condition refers to the degree of shell erosion; for each animal, this was recorded as one of five numeric categories (0 = Light, 0.25 = Light/Medium, 0.5 = Medium, 0.75 = Medium/Heavy, and 1.0 = Heavy). A shell condition index ranging from 0 to 1 was then calculated as the

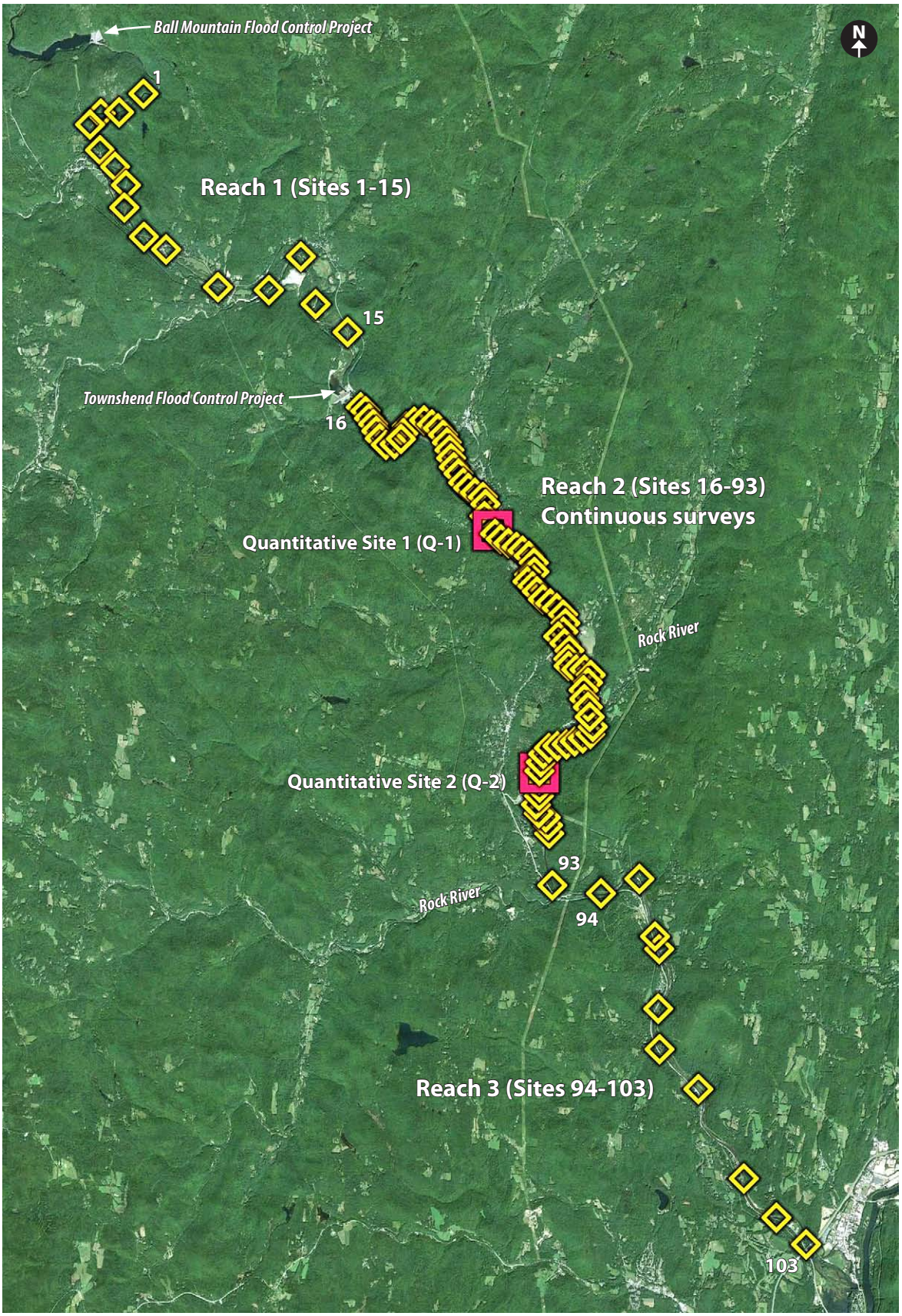


Figure 1. Distribution of survey sites in the West River from below Ball Mountain Dam in Jamaica (Site 1) to the I-91 Bridge in Brattleboro (Site 103). Sites are numbered sequentially from upstream to downstream. Only the centerpoint of each survey site is labelled; GPS coordinates for starting and ending points are provided in Appendix 1, and a .kmz file (Google Earth) is also provided with this report.

Biologist collecting mussel data along a transect at quantitative monitoring site 1 (Q-1).

average of these shell condition values. General habitat conditions were either recorded or inferred from aerial imagery for each survey site. For each site, catch-per-unit-effort (CPUE) was computed by dividing the counts for each species by total survey duration, with results reported as mussels/hr. CPUE by reach and river was calculated by averaging the site CPUE values.

Quantitative Survey: Transect and quadrat surveys were conducted at two locations where the semi-quantitative survey had detected high densities of Brook Floater. Quantitative Site Q-1, surveyed on July 31, 2012, was located 500 meters upstream from the Route 30 Bridge in Townshend, corresponding with semi-quantitative survey sites 42 and 43. At this site, biologists established 12 50-meter transects and sampled within 10 0.25m^2 quadrats spaced 5 meters apart along each transect, for a total of 120 0.25m^2 quadrats. All quadrats were excavated to a maximum depth of 10 cm to detect buried mussels. At each quadrat, biologists recorded counts of all species (surface and buried), water depth, and percent cover of each substrate type. Shell length and shell condition were recorded for each Brook Floater.

Quantitative Site Q-2, surveyed on August 1, 2012, was located along River Road in Newfane, corresponding with semi-quantitative survey sites 83 and 84. At this site, biologists established three 150-meter strip transects (1.0 meters wide) and obtained two types of quantitative data: (1) counts of uncommon mussel species along the entire transect, and (2) counts of all species within 30 0.25m^2 quadrats along each transect (90 quadrats total). Water depth and percent cover of each substrate type were recorded at each quadrat location along each transect. Shell length and shell condition were recorded for each Brook Floater.

RESULTS

1. Semi-quantitative Survey

Species Composition and Relative Abundance: Six mussel species were found during the semi-quantitative survey; a summary of counts, occurrences, and CPUE are provided in **Table 1**. Eastern Elliptio was the most common species; 4,718 individuals (88.5 percent of the total) were counted, and it was found at 74.8 percent of the survey sites. Eastern Elliptio was not found upstream from the Townshend Dam. Brook Floater was the second most common species overall; 287 individuals (5.4 percent of the total) were counted, and it was found at 50.5 percent of the survey sites. Eastern Pearlshell was the third most common species overall; 168 individuals (3.2 percent of the total) were counted, and it was found at 54.4 percent of the survey sites. Creeper was the least common species; only 17 live Creeper were found among 11 survey sites. Mussels were not found at 16 of the survey sites; six of these were in Reach 1 and three were in Reach 3 (i.e., mussels were not found at 40 percent of the sites in Reach 1, and 30 percent of sites in Reach 3, compared to only 9 percent of sites in Reach 2).

Table 1. Summary of occurrence, count, and CPUE data for each mussel species found during the semi-quantitative surveys in the West River.

Statistic	Triangle Floater	Eastern Elliptio	Eastern Lampmussel	Creeper	Eastern Pearlshell	Brook Floater	All
Number of Occurrences							
Reach 1	0	0	0	1	9	3	9
Reach 2	23	71	11	10	43	46	71
Reach 3	1	6	1	0	4	3	7
All Reaches	24	77	12	11	56	52	87
Occurrence Frequency (Percent of Sites)							
Reach 1	0.0	0.0	0.0	6.7	60.0	20.0	60.0
Reach 2	29.5	91.0	14.1	12.8	55.1	59.0	91.0
Reach 3	10.0	60.0	10.0	0.0	40.0	30.0	70.0
All Reaches	23.3	74.8	11.7	10.7	54.4	50.5	84.5
Total Mussel Count							
Reach 1	0	0	0	2	57	8	67
Reach 2	105	4,620	34	15	107	268	5,149
Reach 3	1	98	1	0	4	11	115
All Reaches	106	4,718	35	17	168	287	5,331
Relative Abundance (Percent of Total Mussels)							
Reach 1	0.0	0.0	0.0	3.0	85.1	11.9	-
Reach 2	2.0	89.7	0.7	0.3	2.1	5.2	-
Reach 3	0.9	85.2	0.9	0.0	3.5	9.6	-
All Reaches	2.0	88.5	0.7	0.3	3.2	5.4	-
Average CPUE							
Reach 1	0.0	0.0	0.0	0.3	6.6	0.7	7.5
Reach 2	1.3	63.8	0.4	0.2	1.6	3.5	70.8
Reach 3	0.1	11.8	0.1	0.0	1.0	1.4	14.4
All Reaches	1.0	49.5	0.3	0.2	2.3	2.9	56.1

Mean species richness (i.e., number of species) among all sites was 2.3; species richness was distinctly higher in Reach 2 (6 species, average = 2.6 species/site) compared to Reach 1 (3 species, average = 0.9 species/site) (**Table 2**). Reach 1 was inhabited primarily by Eastern Pearlshell and Brook Floater (85.1 and 11.9 percent of all mussels encountered, respectively). Three species—Eastern Elliptio, Eastern Lampmussel, and Triangle Floater—were found only downstream from the Townshend Dam (Reach 2 and Reach 3). Eastern Elliptio comprised 89.7 and 85.2 percent of mussels counted in Reach 2 and 3.

For all species, average CPUE was 56.1 mussels/hour and there was high variation among sites (range: 0 to 383 mussels/hour) (**Figure 2**). Average CPUE was 7.5 mussels/hour in Reach 1, 70.8 mussels/hour in Reach 2, and 14.4 mussels/hour in Reach 3. Patterns of mussel species richness and mussel density among reaches are summarized as follows. Here, density refers to the number of mussels per unit area [mussels/m^2]; for semi-quantitative surveys, this is inferrred from CPUE [mussels/hour].

- Reach 1: Low species richness, low density, dominated by Eastern Pearlshell.
- Reach 2: High species richness, high density, dominated by Eastern Elliptio.
- Reach 3: High species richness, low density, dominated by Eastern Elliptio.

Table 2. Summary of species richness data from the semi-quantitative surveys in the West River.

Richness Statistic	Reach 1	Reach 2	Reach 3	All
Total Species Present	3	6	5	6
Mean Species Richness (species/site)	0.9	2.6	1.5	2.3
Max Species Richness	3	6	4	6

Brook Floater Density, Demographics, and Habitat: A total of 287 Brook Floater were found. Counts ranged from 0 to 25 per site (average = 2.8), and CPUE ranged from 0.0 to 18.8 mussels/hour (average = 2.9 mussels/hour) (**Table 1, Figure 3**). Brook Floater comprised only 5.4 percent of all mussels found; this proportion of the community was 11.9, 5.2, and 9.6 percent in Reaches 1-3, respectively.

Average shell length was 51.7 mm and ranged from 31.0 to 69.0 mm (**Table 3**). Most mussels (152, or 53.1 percent) were in the 50.0–59.9 mm size range and 40 (14.0 percent) were larger than 60.0 mm. Brook Floater in Reach 1 were slightly larger than those in Reach 2 and 3 (averaging 56.9 versus 51.6 and 50.6 mm for Reaches 1-3, respectively), though low sample sizes in Reach 1 and 3 bias this analysis. The overall shell condition index

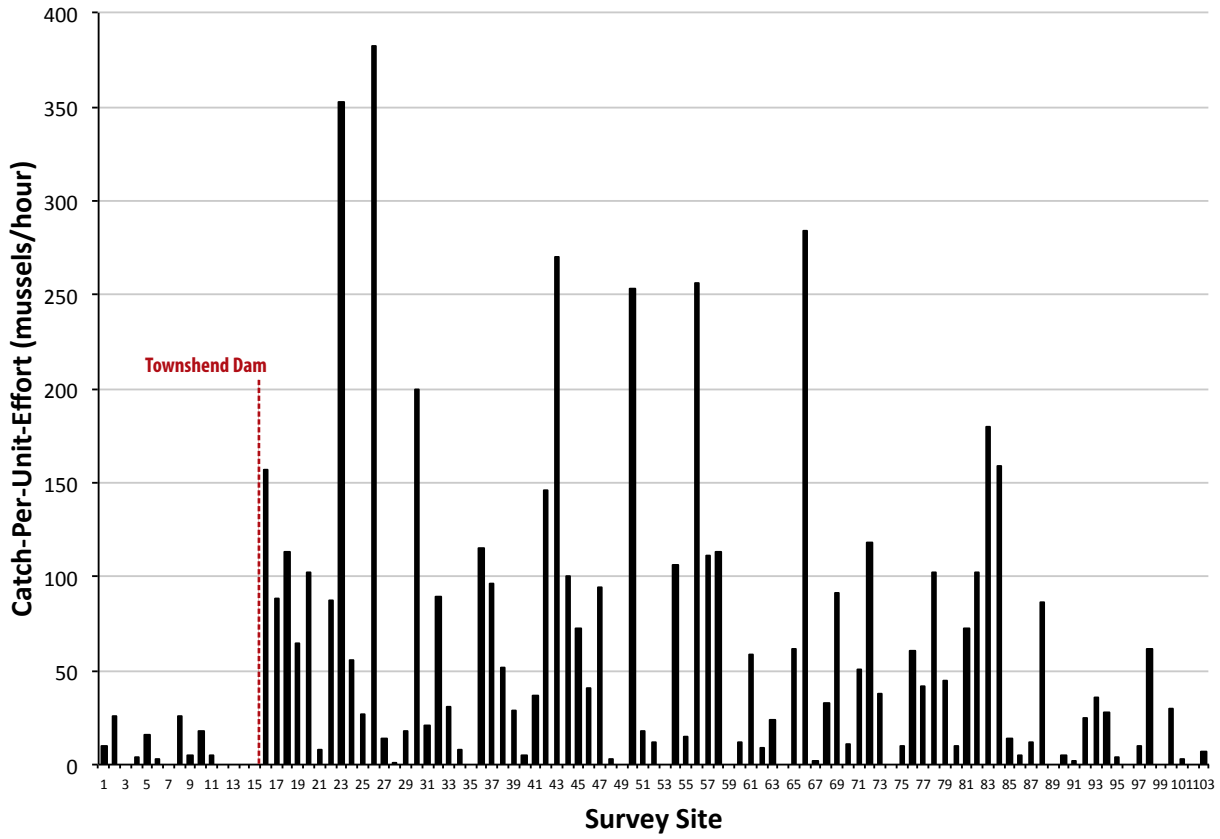


Figure 2. CPUE (all mussel species combined) from the semi-quantitative surveys in the West River. See Appendices 1 and 2 for site-by-site data.

Table 3. Summary of shell length and condition data for five uncommon mussel species found during the semi-quantitative surveys in the West River.

		Brook Floater		E. Pearlshell		Triangle Floater		Creeper		E. Lampmussel	
Class	Length Range (mm)	Total	%	Total	%	Total	%	Total	%	Total	%
1	<10	0	0.0	0	0.0	1	0.9	0	0.0	0	0.0
2	10.0 - 19.9	0	0.0	1	0.6	0	0.0	0	0.0	0	0.0
3	20.0 - 29.9	0	0.0	0	0.0	7	6.6	1	6.3	0	0.0
4	30.0 - 39.9	18	6.3	2	1.2	20	18.9	1	6.3	0	0.0
5	40.0 - 49.9	76	26.6	5	3.0	35	33.0	6	37.5	4	12.1
6	50.0 - 59.9	152	53.1	5	3.0	31	29.2	5	31.3	2	6.1
7	60.0 - 69.9	40	14.0	5	3.0	11	10.4	3	18.8	0	0.0
8	70.0 - 79.9	0	0.0	8	4.9	1	0.9	0	0.0	7	21.2
9	80.0 - 89.9	0	0.0	23	14.0	0	0.0	0	0.0	4	12.1
10	90.0 - 99.9	0	0.0	23	14.0	0	0.0	0	0.0	6	18.2
11	100.0 - 109.9	0	0.0	15	9.1	0	0.0	0	0.0	3	9.1
12	110.0 - 119.9	0	0.0	29	17.7	0	0.0	0	0.0	5	15.2
13	120.0 - 129.9	0	0.0	22	13.4	0	0.0	0	0.0	2	6.1
14	130.0 - 139.9	0	0.0	17	10.4	0	0.0	0	0.0	0	0.0
15	140.0 - 149.9	0	0.0	5	3.0	0	0.0	0	0.0	0	0.0
16	>150	0	0.0	4	2.4	0	0.0	0	0.0	0	0.0
Total		286		164		106		16		33	
Average Shell Length (mm)		51.7		102.5		45.9		50.1		85.9	
Min Length (mm)		31.0		11.0		5.0		28.0		40.0	
Max Length (mm)		69.0		152.0		71.0		66.0		121.0	
Standard Deviation		31.9		7.4		28.5		6.7		0.2	
Shell Condition Index		0.28		0.16		0.33		0.18		0.23	

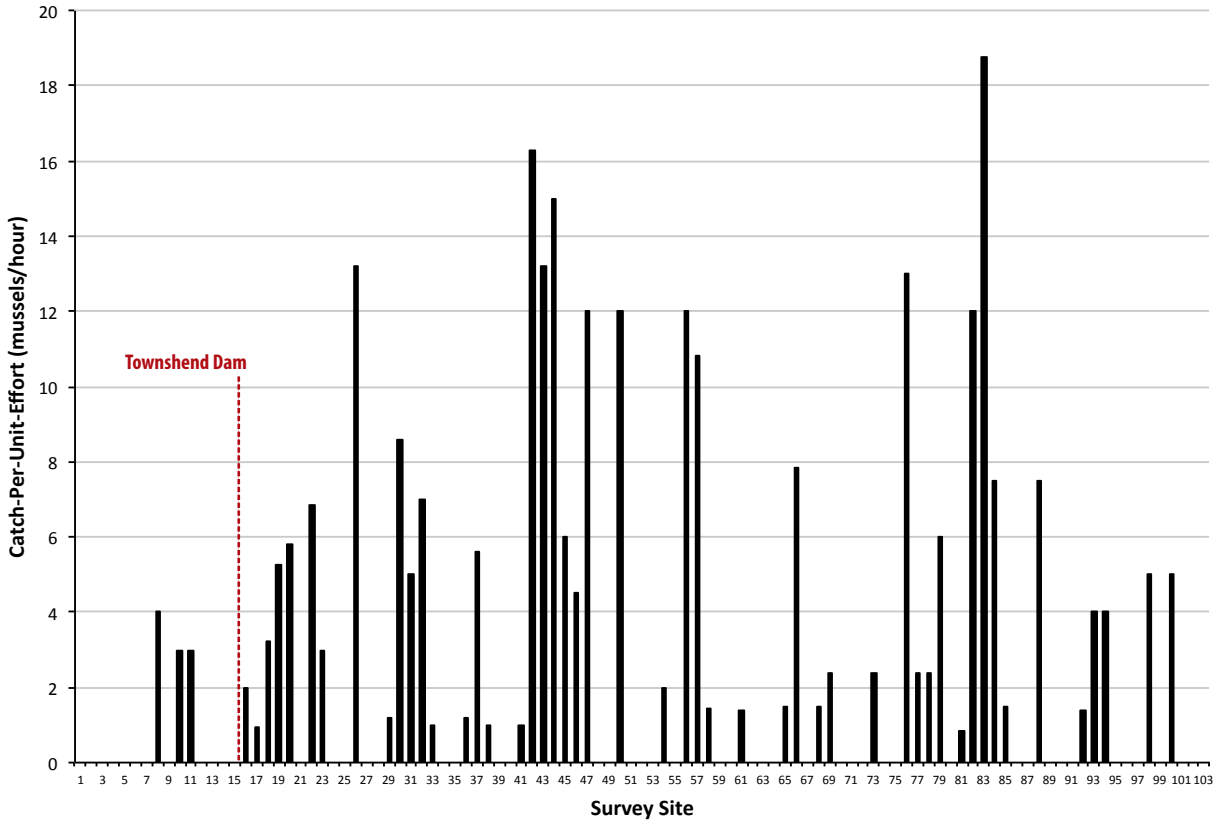


Figure 3. Brook Floater CPUE from the semi-quantitative surveys in the West River. See Appendices 1 and 2 for site-by-site data.

was 0.28, which corresponds to light to moderate levels of shell erosion. The overall shell condition index is similar to what had been reported for Brook Floater in the West River in 2008 (Biodrawversity 2008), and suggest that these individuals are in relatively good condition. Shell condition indices in the range of 0.5 to 0.9 have been reported in more acidic waterbodies, or where erosive forces are more prevalent, or where populations are dominated by older individuals (Biodrawversity 2010).

Brook Floater were found at three sites in Reach 1, 46 sites in Reach 2, and three sites in Reach 3. It exhibited a distinctly discontinuous distribution along the river, with isolated high-density patches often separated by 0.5 to >2.0 miles within which few or none were found (**Figure 3**). The best habitats appeared to be broad and shallow pools, runs, and glides, whereas few were found in deeper scour pools, riffles, or rapids. Most Brook Floater were found in sand and gravel substrates, often among or near cobble and boulder.

Eastern Pearlshell Density, Demographics, and Habitat: A total of 168 Eastern Pearlshell were found. Counts ranged from 0 to 15 per site (average = 1.6 mussels/site), and CPUE ranged from 0.0 to 26.0 mussels/hour (average = 2.3 mussels/hour) (**Table 1**, **Figure 4**). Eastern Pearlshell comprised only 3.2 percent of all mussels found; this proportion of the community was 85.1, 2.1, and 3.5 percent in Reaches 1-3, respectively. Average CPUE was 6.6 mussels/hour in Reach 1, compared to 1.6 and 1.0 mussels/hour in Reach 2 and 3, respectively. The five highest CPUE values for Eastern Pearlshell were all from Reach 1.

Average shell length was 102.5 mm and ranged from 11.0 to 152.0 mm (**Table 3**). Eastern Pearlshell in Reach 1 were smaller than those in Reach 2 and 3 (93.7 versus 107.1 and 108.6 mm for Reaches 1-3, respectively), although evidence of recruitment was found in all three reaches. The shell condition index was 0.16, corresponding to light levels of shell erosion, which is typical for this species due to its unusually thick and strong periostracum that is resistant to damage.

Eastern Pearlshell were found at nine sites in Reach 1, 43 sites in Reach 2, and four sites in Reach 3. Like other species, it exhibited a distinctly discontinuous distribution along the river, with isolated higher-density patches often separated by 0.5 to >2.0 miles within which few or none were found (**Figure 4**). The best habitats appeared to be shallow riffles, runs, and glides, whereas few were found in deeper scour pools or rapids. Most Eastern

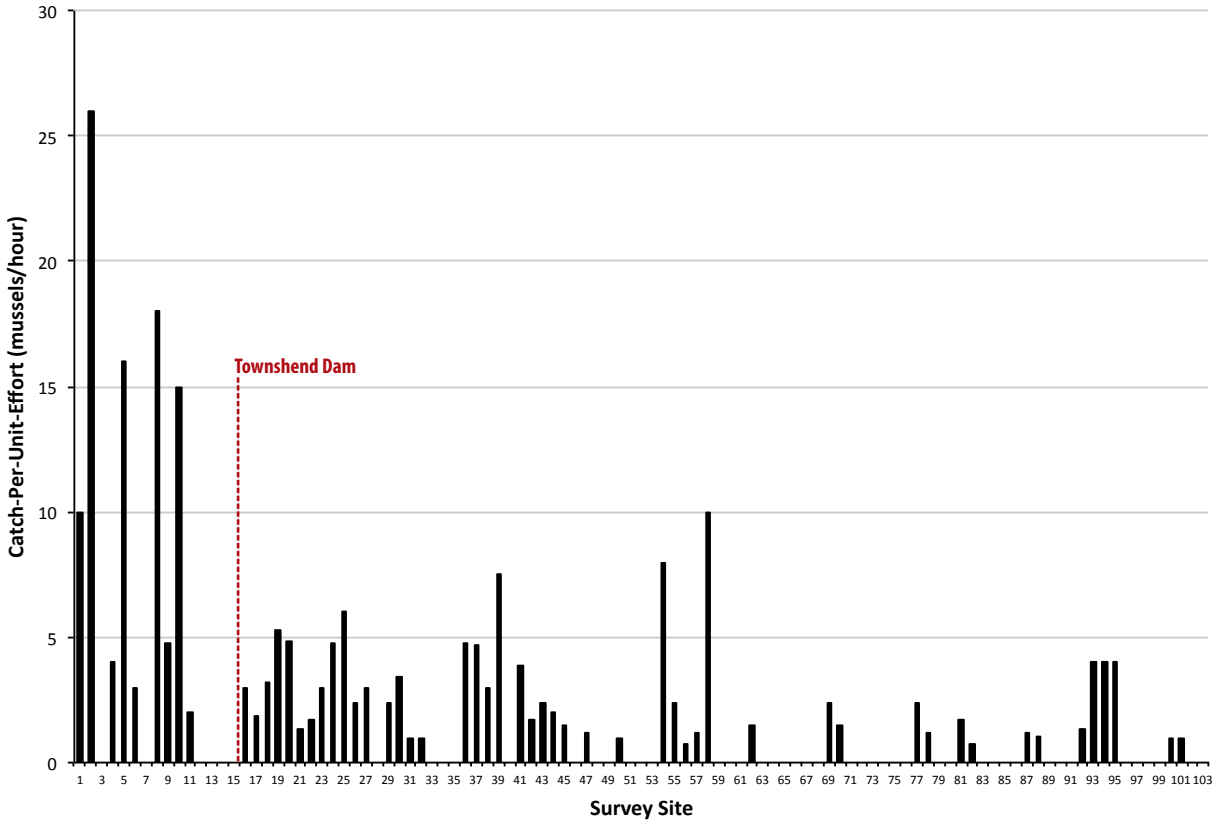


Figure 4. Eastern Pearlshell CPUE from the semi-quantitative surveys in the West River. See Appendices 1 and 2 for site-by-site data.

Pearlshell were found in sand and gravel substrates, often among or near cobble and boulder.

Other Uncommon Species: Three mussel species were uncommon in the West River, collectively comprising only 3.0 percent of all mussels found. They either exhibited highly restricted distributions (e.g., Triangle Floater and Eastern Lampmussel), or occurred over a broad area but at very low densities (e.g., Creeper).

A total of 106 Triangle Floater were found, and these occurred at 23 locations in Reach 2. None were found in Reach 1 or Reach 3. They were usually found in areas where densities of other species were also higher, especially in the section of river from sites 16-20 where 53, or 50 percent of all Triangle Floater, were found; and also at Sites 23, 26, 30, and 56. Average shell length was 45.9 mm and ranged from 5.0 to 71.0 mm.

A total of 35 Eastern Lampmussel were found, and these occurred at 12 locations scattered throughout Reach 2 and 3. None were found in Reach 1. They were usually found in areas where densities of other species were also higher, especially at sites 23, 50, 56, and 83 where 23 Eastern Lampmussel (65.7 percent of all) were found. Average shell length was 85.9 mm and ranged from 40.0 to 121.0 mm.

A total of 17 Creeper were found scattered among 11 sites in Reach 1 (1 site) and Reach 2 (10 sites). None were found in Reach 3. The highest CPUE was 4.0 mussels/hour (2 mussels at Site 8), and the highest count among all sites was three (Site 56). Average shell length was 50.1 mm and ranged from 28.0 to 66.0 mm.

2. Quantitative Survey

Site Q-1: The quadrat survey at Site Q-1, which sampled an area of 30.0 m^2 (120 0.25m^2 quadrats, all excavated), yielded only three species and 88 live mussels, including 75 Eastern Elliptio, 11 Brook Floater, and two Triangle Floater (**Table 4, Appendix 3**). Densities were 2.50, 0.37, and 0.07 mussels/m^2 for these three species, respectively. No Brook Floater or Triangle Floater were found by excavating sediment. Measured habitat parameters (water depth and substrate) were fairly homogenous throughout the sampled reach, as was water velocity (although water velocity was not specifically measured). Average shell length of Brook Floater at Site Q-1 was 55.0 mm, and ranged from 45.0 to 61.0 mm.

Site Q-2: Quantitative sampling at Site Q-2 yielded 48 Brook Floater, which included 45 in transects and three in quadrats (**Table 5, Appendix 4**). Brook Floater density was 0.10 mussel/m^2 based on transects and 0.13 mussel/

Table 4. Count and density data for each species found during the quantitative survey at Site Q-1. See Appendix 3 for full data.

Transect	Sample Area (m^2)*	Brook Floater	Triangle Floater	Eastern Elliptio	Total
Species Count					
1	2.5	0	0	2	2
2	2.5	1	0	3	4
3	2.5	2	0	12	14
4	2.5	0	0	6	6
5	2.5	2	0	9	11
6	2.5	0	0	5	5
7	2.5	2	0	12	14
8	2.5	0	0	7	7
9	2.5	1	1	4	6
10	2.5	3	1	7	11
11	2.5	0	0	5	5
12	2.5	0	0	3	3
Total	30	11	2	75	88
Species Density (mussels/m^2)					
1	2.5	0.00	0.00	0.80	0.80
2	2.5	0.40	0.00	1.20	1.60
3	2.5	0.80	0.00	4.80	5.60
4	2.5	0.00	0.00	2.40	2.40
5	2.5	0.80	0.00	3.60	4.40
6	2.5	0.00	0.00	2.00	2.00
7	2.5	0.80	0.00	4.80	5.60
8	2.5	0.00	0.00	2.80	2.80
9	2.5	0.40	0.40	1.60	2.40
10	2.5	1.20	0.40	2.80	4.40
11	2.5	0.00	0.00	2.00	2.00
12	2.5	0.00	0.00	1.20	1.20
Total	30	0.37	0.07	2.50	2.93

*10 0.25m^2 quadrats per transect

Table 5. Count and density data for each species found during the quantitative survey at Site Q-2. See Appendix 4 for additional data.

		Species				
Transect	Sample Area (m^2)	Brook Floater	Triangle Floater	E. Pearlshell	Creeper	E. Elliptio
TRANSECT DATA*						
Count						
1	150	12	1	0	1	-
2	150	15	6	1	1	-
3	150	18	8	2	3	-
Total	450	45	15	3	5	-
Density (mussels/m^2)						
1	150	0.08	0.01	0.00	0.01	-
2	150	0.10	0.04	0.01	0.01	-
3	150	0.12	0.05	0.01	0.02	-
Total	450	0.10	0.03	0.01	0.01	-
QUADRAT DATA**						
Count						
1	7.5	0	0	0	3	28
2	7.5	2	0	0	0	13
3	7.5	1	2	0	0	15
Total	22.5	3	2	0	3	56
Density (mussels/m^2)						
1	7.5	0.00	0.00	0.00	0.40	3.73
2	7.5	0.27	0.00	0.00	0.00	1.73
3	7.5	0.13	0.27	0.00	0.00	2.00
Total	22.5	0.13	0.09	0.00	0.13	2.49

*3 transects, 1 x 150 meters each

**30 0.25m^2 quadrats per transect

m^2 based on quadrats. Three other uncommon species were counted along transects (Triangle Floater, Creeper, and Eastern Pearlshell) and were far less common than Brook Floater. Creeper and Triangle Floater were also detected in quadrats, at similar (low) densities as Brook Floater. Average density of Eastern Elliptio was 2.5 mussels/m^2 based on quadrat data, almost 20X higher than other species. Measured habitat parameters (water depth and substrate) were homogenous throughout the sampled reach, as was water velocity (although water velocity was not specifically measured). Average shell length of Brook Floater at Site Q-2 was 50.0 mm, and ranged from 40.0 to 59.0 mm.

DISCUSSION

Although prior (2008 and earlier) surveys were not as comprehensive in their coverage as the 2011-2012 surveys, all available data suggests a dramatic change in the mussel assemblage in the West River. The most significant changes include the decrease in the density and relative abundance (i.e., proportion of all mussels, expressed as percent) of Brook Floater and Creeper, and the large increase in the density and relative abundance of Eastern Elliptio. Consider these examples:

Scotts Covered Bridge

- In 1992, biologists examined 1,084 shells in middens, of which 919 (84.8 percent) were Brook Floater, 138 (12.7 percent) were Creeper, and only one was Eastern Elliptio.
- In 2008, Eastern Elliptio comprised more than 80 percent of the live mussels found during semi-quantitative surveys, compared to 5.4 percent Brook Floater and 0.7 percent Creeper.
- Transect data collected four times (1992, 1993, 2002, and 2008) documented a 957 percent increase in Eastern Elliptio density over that period, and an 86 percent decrease in Brook Floater. Eastern Elliptio comprised 81.7 percent of live mussels found in transects in 2008.
- In 2011, semi-quantitative surveys near Scotts Covered Bridge (Sites 17 and 18) found a total of 200 mussels, including 167 (83.5 percent) Eastern Elliptio, four (2.0 percent) Brook Floater, and one (0.5 percent) Creeper.

Green Bridge Pool

- Transect data collected in 1992, 1993, 2002, and 2008 documented a 3,052 percent increase in Elliptio density over that period (from 0.21 to 6.62/m^2), and an 84 percent decrease in Brook Floater.
- The relative abundance of Brook Floater dropped from 78.1 to 2.9 percent of the mussel community from 1992 to 2008, while the relative abundance of Eastern Elliptio increased from 18.2 to 94.7 percent.
- In 2011, semi-quantitative surveys near the Green Bridge Pool (Sites 67 and 68) found a total of 23 mussels, including 22 (95.7 percent) Eastern Elliptio, and one (4.3 percent) Brook Floater.
- The Green Bridge Pool had been monitored repeatedly from 1992 to 2008 because it was an area where Brook Floater were considered numerous, but Brook Floater CPUE in this area in 2011 was considerably lower than at many other survey sites and below the average CPUE for all sites combined.

There is little historic data on the mussel community upstream from the Townshend Dam (Reach 1). The 2011-2012 data indicate a community dominated by Eastern Pearlshell, with low density of Brook Floater and even lower density of Creeper. Eastern Elliptio, Triangle Floater, and Eastern Lampmussel were not found in Reach 1.

There was a striking change in the mussel community below Townshend Dam (Reach 2), to a community characterized by high species richness, high density, and dominance by Eastern Elliptio. This type of mussel community is not uncommon in tributaries of the Connecticut River; in fact, this is probably the most common type of mussel assemblage in rivers of comparable size and gradient (Nedeau 2008). The most remarkable aspect of the mussel community downstream from Townshend Dam is the extent to which it has changed in the last 20 years, from one dominated by Brook Floater to one dominated by Eastern Elliptio. Only 20 years ago, Brook Floater may have been as dominant in the West River as Eastern Elliptio are today. Also, the 138 Creeper shells found in middens at Scotts Covered Bridge (the second most common species) in 1992 provides important insight on the assemblage shift, as only 17 live Creeper were found during semi-quantitative surveys in the entire West River in 2011, and none were found near Scotts Covered Bridge. Based on available data, there appears to be a greater than 90 percent decrease in Brook Floater and Creeper population in the West River. Eastern Elliptio became far more abundant, and Eastern Lampmussel and Triangle Floater may have also increased in Reach 2.

Eastern Pearlshell had not been documented at Scotts Covered Bridge or Green Bridge Pool in 1992, 1993, or 2003. It was found at Scotts Covered Bridge in 2008 and 2011, and overall, appears to be more widespread in Reach 2 and Reach 3 than historic surveys had suggested. This may be due to undersampling in past surveys, or possibly a population increase. Although one of its key fish hosts may be extirpated (Atlantic Salmon), populations of other key hosts (Brook Trout, Brown Trout, and Rainbow Trout) are maintained through natural reproduction or stocking.

Possible Causes

In light of the status and apparent trajectory of the Brook Floater population in the West River, it is important to consider possible causes and interventions. To date, all mussel studies in the West River have described status and trends, and there have not been adequate studies of potential causes. Many factors may influence mussel populations, but the most important factors in the West River may be those that have species-specific, positive or negative effects (i.e., harm some species, help others), as they are more likely to cause a community shift. A good example is thermal alteration, which may affect mussels both directly (thermal stress, metabolism, growth, breeding, spawning) and indirectly (through changes in the availability and abundance of host fish). Warming might cause a shift from a coldwater fish and mussel assemblage to a warmwater fish and mussel assemblage, and these effects could occur rapidly.

Factors that may affect all species in similar ways, such as sedimentation, acidification, pollution, and certain aspects of hydrology and geomorphology, may also be important throughout the West River, but are probably not responsible for the community shift. High levels of sedimentation may favor habitat generalists, such as Eastern Elliptio, but that level of sedimentation is not apparent in the reaches where Eastern Elliptio has become so abundant. Nevertheless, sedimentation should be part of a river-wide geomorphic study. A threat assessment is complicated because different reaches of the river, and mussel species, seem to be influenced by different factors. These are summarized as follows:

1. Upstream of Ball Mountain Dam
- Community: low-density, species-poor (1?) mussel community (Eastern Pearlshell).
- Trends: No long-term data; trends unknown.
- Major Threats: This reach was not observed in 2008, 2011, or 2012, so threats have not been identified. Likely threats include hydrologic alteration and altered/and unstable channel geomorphology.

2. Ball Mountain Dam to Townshend Dam (Reach 1)
- Community: low-density, species-poor (3) mussel community dominated by coldwater species (Eastern Pearlshell), few Brook Floater, and possibly nonviable Creeper population.
- Trends: No long-term data; trends unknown.
- Major Threats: Bank erosion, channel geomorphology, loss of riparian buffers, hydrologic alteration, tributary influence.

3. Below Townshend Dam (Reach 2)
- Community: high-density, species-rich (6) mussel community dominated by warmwater species (Eastern Elliptio). Richness and density may be unnaturally high below Townshend Dam due to hydrologic and geomorphic stability caused by flood control.
- Trends: Two long-term monitoring sites suggest large increase in Eastern Elliptio, large decrease in Brook Floater and Creeper. Large magnitude and fast rate of change.
- Major Threats: Thermal alteration, hydrologic alteration, changes in fish assemblage are likely reach-wide threats, and may be responsible for the shift to an Elliptio-dominated community and decline of Brook Floater. There are also more localized issues that may threaten all species, such as bank erosion, loss of riparian buffers, channel geomorphology, and tributary influence. Geomorphic effects seem more evident with increasing distance from Townshend Dam, especially below larger tributaries.

4. Below Rock River (Reach 3)
- Community: low-density and patchy mussel community dominated by warmwater species (Eastern Elliptio), with low species richness at most sites yet high species richness (5) for entire reach.
- Trends: No long-term data; trends unknown.
- Major Threats: Similar threats as Reach 2, but with greater prevalence of hydrologic and geomorphic effects, especially below tributaries and near where riparian areas and floodplains were altered by land use and roadways.

Research Questions/Priorities

- Has the thermal regime of the West River changed in the last 50 years? Are long-term temperature datasets available? It would be prudent to establish a stream temperature monitoring program in the entire reach from Ball Mountain Dam to the Connecticut River to understand this potential phenomenon. Data on other water chemistry parameters (e.g., pH, conductivity, dissolved oxygen, nutrients) should also be collected and synthesized, if available.
- To what extent has the fish assemblage of the West River and its principal tributaries changed in the last 50 years? For example, Atlantic Salmon, the once-dominant salmonid in the West River, are all but extirpated. Salmonid (Brook Trout, Brown Trout, and Rainbow Trout) numbers in the West River are now enhanced by stocking, and non-native Smallmouth Bass is now the top fish predator. What are the implications of a fish community shift on the mussel community?
- Most of the mussel data collected for this report were collected in 2011, before Tropical Storm Irene. Although Ball Mountain Dam and Townshend Dam

did capture and dissipate much of the energy associated with Irene, several tributaries were profoundly affected and transported tremendous amounts of sediment into the West River. A re-assessment of some of the 2011 survey sites is justified.

- A comprehensive geomorphic study of the West River from Ball Mountain Dam to the Connecticut River is necessary.
- It would be worthwhile to convene a meeting to discuss results from this study and to develop a long-term mussel and habitat monitoring program for the West River, and to coordinate these with any past or ongoing fish studies.

REPORTS CITED

Biodrawversity. 2008. Status and Conservation of the Brook Floater (*Alasmidonta varicosa*) in the West River in Vermont. Vermont Fish and Wildlife Department, Waterbury, Vermont.

Biodrawversity. 2010. Brook Floater (*Alasmidonta varicosa*) Population Assessments in Nine Maine Rivers. Reported prepared for the Maine Department of Inland Fisheries and Wildlife, Bangor, Maine.

Ferguson, M. 2002. Quantitative survey of the brook floater (*Alasmidonta varicosa*) at sites on the West River. 2002 Performance Report. Vermont Fish and Wildlife Department, Waterbury, Vermont.

Fichtel, C. 1992. Status survey of the brook floater (*Alasmidonta varicosa*) in Vermont. 1992 Performance Report. Vermont Fish and Wildlife Department, Waterbury, Vermont.

Fichtel, C. 1993. Status of the brook floater (*Alasmidonta varicosa*) in Vermont. 1993 Performance Report. Vermont Fish and Wildlife Department, Waterbury, Vermont.

Fichtel, C., and D.G. Smith. 1995. *The Freshwater Mussels of Vermont*. Vermont Fish and Wildlife Department Technical Report 18. Leahy Press, Montpelier, VT. 54 p.

Nedeau, E.J. 2008. *Freshwater Mussels and the Connecticut River Watershed*. Connecticut River Watershed Council, Greenfield, MA.

Appendix 1
Location information for semi-quantitative survey sites.

	Start (Upstream)		End (Downstream)			
Site	Latitude	Longitude	Latitude	Longitude	Survey Date	Section Length (m)
1	43.115555	-72.760052	43.115381	-72.760682	5/26/11	70
2	43.111745	-72.767097	43.111623	-72.767549	5/26/11	50
3	43.111421	-72.772279	43.111452	-72.772872	5/26/11	50
4	43.109718	-72.775640	43.108840	-72.775499	5/26/11	100
5	43.104399	-72.773146	43.103287	-72.772869	5/26/11	125
6	43.100953	-72.768631	43.100104	-72.767774	7/19/11	100
7	43.097079	-72.765234	43.095981	-72.765596	7/19/11	100
8	43.092390	-72.765863	43.091360	-72.765808	7/19/11	100
9	43.085899	-72.760818	43.085568	-72.759624	7/19/11	100
10	43.083715	-72.754344	43.082666	-72.753185	7/19/11	150
11	43.075463	-72.739882	43.075033	-72.738263	5/26/11	150
12	43.074431	-72.725089	43.074882	-72.723941	5/26/11	100
13	43.082106	-72.716102	43.080852	-72.714951	7/19/11	100
14	43.072290	-72.710808	43.071157	-72.711348	7/19/11	100
15	43.066320	-72.702705	43.064963	-72.701958	7/19/11	100
16	43.050491	-72.699071	43.049780	-72.697500	7/19/11	150
17	43.049780	-72.697500	43.048812	-72.696403	8/2/11	150
18	43.048812	-72.696403	43.047096	-72.695228	8/2/11	200
19	43.047096	-72.695228	43.046104	-72.694051	8/2/11	150
20	43.046104	-72.694051	43.044576	-72.693209	8/2/11	180
21	43.044576	-72.693209	43.042709	-72.692158	8/2/11	220
22	43.042709	-72.692158	43.042058	-72.689703	8/2/11	200
23	43.042058	-72.689703	43.042920	-72.687581	8/2/11	200
24	43.042920	-72.687581	43.043926	-72.685669	8/2/11	200
25	43.043926	-72.685669	43.045399	-72.686067	8/2/11	150
26	43.045399	-72.686067	43.046763	-72.684220	8/2/11	200
27	43.046763	-72.684220	43.047611	-72.681609	8/2/11	225
28	43.047611	-72.681609	43.046914	-72.678973	8/2/11	240
29	43.046914	-72.678973	43.046158	-72.677053	8/3/11	200
30	43.046158	-72.677053	43.045124	-72.675291	8/3/11	200
31	43.045124	-72.675291	43.043678	-72.673892	8/3/11	200
32	43.043678	-72.673892	43.041957	-72.673020	8/3/11	200
33	43.041957	-72.673020	43.040423	-72.672631	8/3/11	175
34	43.040423	-72.672631	43.038514	-72.672080	8/3/11	215
35	43.038514	-72.672080	43.036904	-72.671022	8/3/11	200
36	43.036904	-72.671022	43.035353	-72.669612	8/3/11	200
37	43.035353	-72.669612	43.033778	-72.668296	8/3/11	200
38	43.033778	-72.668296	43.032636	-72.666763	8/3/11	180
39	43.032636	-72.666763	43.031928	-72.664407	8/3/11	210
40	43.031928	-72.664407	43.030738	-72.662422	8/3/11	210
41	43.030738	-72.662422	43.029034	-72.663404	8/3/11	210
42	43.029034	-72.663404	43.026093	-72.661733	8/3/11	350
43	43.026093	-72.661733	43.024382	-72.660564	8/4/11	210
44	43.024382	-72.660564	43.023122	-72.658979	8/4/11	190
45	43.023122	-72.658979	43.022289	-72.657256	8/4/11	170
46	43.022289	-72.657256	43.021242	-72.655039	8/4/11	210
47	43.021242	-72.655039	43.020785	-72.652754	8/4/11	200
48	43.020785	-72.652754	43.019639	-72.651163	8/4/11	180
49	43.019639	-72.651163	43.018492	-72.649224	8/4/11	200
50	43.018492	-72.649224	43.016807	-72.648792	8/4/11	200
51	43.016807	-72.648792	43.015139	-72.648959	8/4/11	200
52	43.015139	-72.648959	43.014481	-72.651156	8/4/11	225
53	43.014481	-72.651156	43.013117	-72.649698	8/4/11	200
54	43.013117	-72.649698	43.012351	-72.648775	8/9/11	200
55	43.012351	-72.648775	43.010812	-72.647368	8/9/11	200

Appendix 1
Location information for semi-quantitative survey sites (continued).

	Start (Upstream)		End (Downstream)			
Site	Latitude	Longitude	Latitude	Longitude	Survey Date	Section Length (m)
56	43.010812	-72.647368	43.009591	-72.645064	8/9/11	180
57	43.009591	-72.645064	43.008758	-72.642982	8/9/11	200
58	43.008758	-72.642982	43.007746	-72.641003	8/9/11	200
59	43.007746	-72.641003	43.006080	-72.640065	8/9/11	200
60	43.006080	-72.640065	43.004089	-72.639062	8/9/11	220
61	43.004089	-72.639062	43.003209	-72.641666	8/9/11	200
62	43.003209	-72.641666	43.001470	-72.640700	8/9/11	200
63	43.001470	-72.640700	43.000104	-72.639188	8/9/11	200
64	43.000104	-72.639188	42.998363	-72.638353	8/9/11	200
65	42.998363	-72.638353	42.996726	-72.639445	8/9/11	200
66	42.996726	-72.639445	42.995651	-72.637930	8/9/11	200
67	42.995651	-72.637930	42.995245	-72.635563	8/9/11	200
68	42.995245	-72.635563	42.995203	-72.633276	8/10/11	200
69	42.995203	-72.633276	42.993366	-72.632668	8/10/11	200
70	42.993366	-72.632668	42.991705	-72.633793	8/10/11	200
71	42.991705	-72.633793	42.990078	-72.634789	8/10/11	200
72	42.990078	-72.634789	42.988430	-72.633634	8/10/11	200
73	42.988430	-72.633634	42.986536	-72.633159	8/10/11	250
74	42.986536	-72.633159	42.984408	-72.632347	8/10/11	200
75	42.984408	-72.632347	42.982556	-72.631729	8/10/11	200
76	42.982556	-72.631729	42.981347	-72.633638	8/10/11	200
77	42.981347	-72.633638	42.980589	-72.635993	8/10/11	200
78	42.980589	-72.635993	42.979904	-72.638341	8/10/11	200
79	42.979904	-72.638341	42.979538	-72.640842	8/10/11	200
80	42.979538	-72.640842	42.979303	-72.643240	8/10/11	200
81	42.979303	-72.643240	42.978424	-72.645507	8/11/11	200
82	42.978424	-72.645507	42.976823	-72.646538	8/11/11	200
83	42.976823	-72.646538	42.975122	-72.647210	8/11/11	200
84	42.975122	-72.647210	42.973343	-72.647053	8/11/11	200
85	42.973343	-72.647053	42.971642	-72.647029	8/11/11	200
86	42.971642	-72.647029	42.969847	-72.647070	8/11/11	200
87	42.969847	-72.647070	42.968137	-72.647681	8/11/11	200
88	42.968137	-72.647681	42.966132	-72.648204	8/11/11	200
89	42.966132	-72.648204	42.964972	-72.646418	8/11/11	200
90	42.964972	-72.646418	42.963648	-72.644817	8/11/11	200
91	42.963648	-72.644817	42.962008	-72.644450	8/11/11	200
92	42.962008	-72.644450	42.960214	-72.644434	8/11/11	200
93	42.951210	-72.643970	42.949586	-72.643245	8/11/11	200
94	42.948585	-72.630462	42.948420	-72.629159	5/26/11	100
95	42.951974	-72.619118	42.951377	-72.618244	5/26/11	100
96	42.940062	-72.614433	42.939366	-72.613785	5/26/11	100
97	42.937387	-72.613343	42.936499	-72.613202	5/31/11	100
98	42.925261	-72.612726	42.923808	-72.614028	5/31/11	200
99	42.916287	-72.613338	42.915655	-72.612559	5/31/11	100
100	42.908267	-72.602875	42.907094	-72.601171	5/31/11	200
101	42.889994	-72.589136	42.888134	-72.588808	5/31/11	200
102	42.880852	-72.580996	42.880713	-72.578507	5/31/11	200
103	42.875684	-72.571374	42.874669	-72.571191	5/31/11	100

Appendix 2
Species count and CPUE data for semi-quantitative survey sites.

		Species Counts						Species CPUE								
Reach	Site	AlUn	ElCo	LaRa	StUn	MaMa	AlVa	AlUn	ElCo	LaRa	StUn	MaMa	AlVa	All Count	All CPUE	#Taxa
1	1	0	0	0	0	5	0	0.0	0.0	0.0	0.0	10.0	0.0	5	10.0	1
1	2	0	0	0	0	13	0	0.0	0.0	0.0	0.0	26.0	0.0	13	26.0	1
1	3	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0
1	4	0	0	0	0	2	0	0.0	0.0	0.0	0.0	4.0	0.0	2	4.0	1
1	5	0	0	0	0	8	0	0.0	0.0	0.0	0.0	16.0	0.0	8	16.0	1
1	6	0	0	0	0	1	0	0.0	0.0	0.0	0.0	3.0	0.0	1	3.0	1
1	7	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0
1	8	0	0	0	2	9	2	0.0	0.0	0.0	4.0	18.0	4.0	13	26.0	3
1	9	0	0	0	0	2	0	0.0	0.0	0.0	0.0	4.8	0.0	2	4.8	1
1	10	0	0	0	0	15	3	0.0	0.0	0.0	0.0	15.0	3.0	18	18.0	2
1	11	0	0	0	0	2	3	0.0	0.0	0.0	0.0	2.0	3.0	5	5.0	2
1	12	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0
1	13	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0
1	14	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0
1	15	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0
2	16	9	142	0	1	3	2	9.0	142.0	0.0	1.0	3.0	2.0	157	157.0	5
2	17	11	78	2	0	2	1	10.3	73.1	1.9	0.0	1.9	0.9	94	88.1	5
2	18	10	89	0	1	3	3	10.7	95.4	0.0	1.1	3.2	3.2	106	113.6	5
2	19	9	61	1	1	7	7	6.8	45.8	0.8	0.8	5.3	5.3	86	64.5	6
2	20	14	78	1	2	5	6	13.5	75.5	1.0	1.9	4.8	5.8	106	102.6	6
2	21	0	5	0	0	1	0	0.0	6.8	0.0	0.0	1.4	0.0	6	8.2	2
2	22	1	91	0	0	2	8	0.9	78.0	0.0	0.0	1.7	6.9	102	87.4	4
2	23	5	332	8	2	3	3	5.0	332.0	8.0	2.0	3.0	3.0	353	353.0	6
2	24	0	42	0	0	4	0	0.0	50.4	0.0	0.0	4.8	0.0	46	55.2	2
2	25	0	14	0	0	4	0	0.0	21.0	0.0	0.0	6.0	0.0	18	27.0	2
2	26	6	297	1	2	2	11	7.2	356.4	1.2	2.4	2.4	13.2	319	382.8	6
2	27	0	11	0	0	3	0	0.0	11.0	0.0	0.0	3.0	0.0	14	14.0	2
2	28	0	1	0	0	0	0	0.0	1.2	0.0	0.0	0.0	0.0	1	1.2	1
2	29	0	12	0	0	2	1	0.0	14.4	0.0	0.0	2.4	1.2	15	18.0	3
2	30	9	210	0	0	4	10	7.7	180.0	0.0	0.0	3.4	8.6	233	199.7	4
2	31	3	12	0	0	1	5	3.0	12.0	0.0	0.0	1.0	5.0	21	21.0	4
2	32	0	81	0	0	1	7	0.0	81.0	0.0	0.0	1.0	7.0	89	89.0	3
2	33	0	31	0	0	0	1	0.0	30.0	0.0	0.0	0.0	1.0	32	31.0	2
2	34	0	5	0	0	0	0	0.0	7.5	0.0	0.0	0.0	0.0	5	7.5	1
2	35	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0
2	36	0	91	0	0	4	1	0.0	109.2	0.0	0.0	4.8	1.2	96	115.2	3
2	37	0	92	0	0	5	6	0.0	86.3	0.0	0.0	4.7	5.6	103	96.6	3
2	38	0	48	0	0	3	1	0.0	48.0	0.0	0.0	3.0	1.0	52	52.0	3
2	39	0	14	0	0	5	0	0.0	21.0	0.0	0.0	7.5	0.0	19	28.5	2
2	40	0	3	0	0	0	0	0.0	4.5	0.0	0.0	0.0	0.0	3	4.5	1
2	41	0	31	2	0	4	1	0.0	30.0	1.9	0.0	3.9	1.0	38	36.8	4
2	42	3	145	0	1	2	19	2.6	124.3	0.0	0.9	1.7	16.3	170	145.7	5
2	43	2	210	0	0	2	11	2.4	252.0	0.0	0.0	2.4	13.2	225	270.0	4
2	44	2	78	2	1	2	15	2.0	78.0	2.0	1.0	2.0	15.0	100	100.0	6
2	45	1	42	0	0	1	4	1.5	63.0	0.0	0.0	1.5	6.0	48	72.0	4
2	46	0	24	0	0	0	3	0.0	36.0	0.0	0.0	0.0	4.5	27	40.5	2
2	47	0	68	0	0	1	10	0.0	81.6	0.0	0.0	1.2	12.0	79	94.8	3
2	48	0	2	0	0	0	0	0.0	3.0	0.0	0.0	0.0	0.0	2	3.0	1
2	49	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0
2	50	1	232	6	1	1	12	1.0	232.0	6.0	1.0	1.0	12.0	253	253.0	6
2	51	0	12	0	0	0	0	0.0	18.0	0.0	0.0	0.0	0.0	12	18.0	1
2	52	0	8	0	0	0	0	0.0	12.0	0.0	0.0	0.0	0.0	8	12.0	1
2	53	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0
2	54	0	48	0	0	4	1	0.0	96.0	0.0	0.0	8.0	2.0	53	106.0	3
2	55	0	10	0	0	2	0	0.0	12.0	0.0	0.0	2.4	0.0	12	14.4	2
2	56	6	310	5	3	1	16	4.5	232.5	3.8	2.3	0.8	12.0	341	255.8	6
2	57	1	82	0	0	1	9	1.2	98.4	0.0	0.0	1.2	10.8	93	111.6	4
2	58	0	71	0	0	7	1	0.0	101.4	0.0	0.0	10.0	1.4	79	112.9	3
2	59	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0

Appendix 2
Species count and CPUE data for semi-quantitative survey sites (continued).

		Species Counts						Species CPUE								
Reach	Site	AlUn	ElCo	LaRa	StUn	MaMa	AlVa	AlUn	ElCo	LaRa	StUn	MaMa	AlVa	All Count	All CPUE	#Taxa
2	60	0	8	0	0	0	0	0.0	12.0	0.0	0.0	0.0	0.0	8	12.0	1
2	61	0	42	0	0	0	1	0.0	57.3	0.0	0.0	0.0	1.4	43	58.6	2
2	62	0	5	0	0	1	0	0.0	7.5	0.0	0.0	1.5	0.0	6	9.0	2
2	63	0	16	0	0	0	0	0.0	24.0	0.0	0.0	0.0	0.0	16	24.0	1
2	64	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0
2	65	1	39	0	0	0	1	1.5	58.5	0.0	0.0	0.0	1.5	41	61.5	3
2	66	0	210	2	0	0	6	0.0	273.9	2.6	0.0	0.0	7.8	218	284.3	3
2	67	0	1	0	0	0	0	0.0	2.0	0.0	0.0	0.0	0.0	1	2.0	1
2	68	0	21	0	0	0	1	0.0	31.5	0.0	0.0	0.0	1.5	22	33.0	2
2	69	0	72	0	0	2	2	0.0	86.4	0.0	0.0	2.4	2.4	76	91.2	3
2	70	0	6	0	0	1	0	0.0	9.0	0.0	0.0	1.5	0.0	7	10.5	2
2	71	0	42	0	0	0	0	0.0	50.4	0.0	0.0	0.0	0.0	42	50.4	1
2	72	1	78	0	0	0	0	1.5	117.0	0.0	0.0	0.0	0.0	79	118.5	2
2	73	0	29	0	0	0	2	0.0	34.8	0.0	0.0	0.0	2.4	31	37.2	2
2	74	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0
2	75	0	8	0	0	0	0	0.0	9.6	0.0	0.0	0.0	0.0	8	9.6	1
2	76	0	48	0	0	0	13	0.0	48.0	0.0	0.0	0.0	13.0	61	61.0	2
2	77	0	31	0	0	2	2	0.0	37.2	0.0	0.0	2.4	2.4	35	42.0	3
2	78	0	82	0	0	1	2	0.0	98.4	0.0	0.0	1.2	2.4	85	102.0	3
2	79	0	32	0	0	0	5	0.0	38.4	0.0	0.0	0.0	6.0	37	44.4	2
2	80	0	8	0	0	0	0	0.0	9.6	0.0	0.0	0.0	0.0	8	9.6	1
2	81	0	81	0	0	2	1	0.0	69.4	0.0	0.0	1.7	0.9	84	72.0	3
2	82	5	114	0	0	1	16	3.8	85.5	0.0	0.0	0.8	12.0	136	102.0	4
2	83	1	210	4	0	0	25	0.8	157.5	3.0	0.0	0.0	18.8	240	180.0	4
2	84	3	98	0	0	0	5	4.5	147.0	0.0	0.0	0.0	7.5	106	159.0	3
2	85	0	8	0	0	0	1	0.0	12.0	0.0	0.0	0.0	1.5	9	13.5	2
2	86	0	3	0	0	0	0	0.0	4.5	0.0	0.0	0.0	0.0	3	4.5	1
2	87	0	9	0	0	1	0	0.0	10.4	0.0	0.0	1.2	0.0	10	11.5	2
2	88	1	72	0	0	1	7	1.1	77.1	0.0	0.0	1.1	7.5	81	86.8	4
2	89	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0
2	90	0	3	0	0	0	0	0.0	4.5	0.0	0.0	0.0	0.0	3	4.5	1
2	91	0	1	0	0	0	0	0.0	1.5	0.0	0.0	0.0	0.0	1	1.5	1
2	92	0	16	0	0	1	1	0.0	21.8	0.0	0.0	1.4	1.4	18	24.5	3
2	93	0	14	0	0	2	2	0.0	28.0	0.0	0.0	4.0	4.0	18	36.0	3
3	94	0	5	0	0	1	1	0.0	20.0	0.0	0.0	4.0	4.0	7	28.0	3
3	95	0	0	0	0	1	0	0.0	0.0	0.0	0.0	4.0	0.0	1	4.0	1
3	96	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0
3	97	0	5	0	0	0	0	0.0	10.0	0.0	0.0	0.0	0.0	5	10.0	1
3	98	1	55	1	0	0	5	1.0	55.0	1.0	0.0	0.0	5.0	62	62.0	4
3	99	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0
3	100	0	24	0	0	1	5	0.0	24.0	0.0	0.0	1.0	5.0	30	30.0	3
3	101	0	2	0	0	1	0	0.0	2.0	0.0	0.0	1.0	0.0	3	3.0	2
3	102	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0
3	103	0	7	0	0	0	0	0.0	7.0	0.0	0.0	0.0	0.0	7	7.0	1

Species abbreviations: AlUn = *Alasmidonta undulata*, ElCo = *Elliptio complanata*, LaRa = *Lampsilis radiata*, StUn = *Strophitus undulatus*, MaMa = *Margaritifera margaritifera*, AlVa = *Alasmidonta varicosa*

Appendix 3
Raw data for the quantitative survey at Site Q-1.

								Percent Substrate				
ROW	QUAD	ID	AlVa	AlUn	ElCo	TOTAL	DEPTH (CM)	SILT	SAND	GRAV	COBB	BLDR
1	1	1-1	0	0	0	0	16	5	5	10	80	0
1	2	1-2	0	0	0	0	15	10	30	40	20	0
1	3	1-3	0	0	0	0	17	15	10	30	40	5
1	4	1-4	0	0	0	0	22	15	10	25	30	20
1	5	1-5	0	0	0	0	27	15	5	10	70	0
1	6	1-6	0	0	0	0	13	5	10	55	30	0
1	7	1-7	0	0	2	2	33	40	15	15	30	0
1	8	1-8	0	0	0	0	44	60	10	30	0	0
1	9	1-9	0	0	0	0	40	60	10	30	0	0
1	10	1-10	0	0	0	0	26	50	0	10	40	0
2	1	2-1	0	0	0	0	26	0	40	10	50	0
2	2	2-2	0	0	0	0	25	0	50	10	40	0
2	3	2-3	0	0	0	0	27	0	0	80	20	0
2	4	2-4	0	0	0	0	33	0	50	15	35	0
2	5	2-5	0	0	0	0	27	0	30	20	50	0
2	6	2-6	0	0	1	1	30	0	20	10	70	0
2	7	2-7	1	0	0	1	36	0	40	40	20	0
2	8	2-8	0	0	0	0	53	20	20	20	40	0
2	9	2-9	0	0	1	1	51	10	0	10	30	50
2	10	2-10	0	0	1	1	45	10	30	20	40	0
3	1	3-1	1	0	0	1	41	10	10	20	60	0
3	2	3-2	0	0	2	2	42	10	20	30	40	0
3	3	3-3	0	0	0	0	33	0	15	15	60	10
3	4	3-4	0	0	1	1	48	0	10	10	80	0
3	5	3-5	0	0	3	3	45	5	10	15	70	0
3	6	3-6	0	0	1	1	53	10	10	10	70	0
3	7	3-7	1	0	4	5	57	10	10	20	60	0
3	8	3-8	0	0	1	1	53	10	15	25	50	0
3	9	3-9	0	0	0	0	48	20	10	10	60	0
3	10	3-10	0	0	0	0	33	20	10	10	60	0
4	1	4-1	0	0	0	0	45	0	30	20	40	10
4	2	4-2	0	0	1	1	45	0	20	20	60	0
4	3	4-3	0	0	0	0	50	0	40	20	40	0
4	4	4-4	0	0	2	2	58	5	30	0	40	25
4	5	4-5	0	0	1	1	65	40	0	20	40	0
4	6	4-6	0	0	0	0	50	0	10	10	30	50
4	7	4-7	0	0	0	0	60	0	40	30	30	0
4	8	4-8	0	0	1	1	60	0	40	40	20	0
4	9	4-9	0	0	1	1	55	0	20	40	40	0
4	10	4-10	0	0	0	0	40	0	30	30	40	0
5	1	5-1	0	0	1	1	58	30	20	10	40	0
5	2	5-2	0	0	1	1	47	5	15	30	50	0
5	3	5-3	1	0	1	2	53	0	20	20	60	0
5	4	5-4	0	0	1	1	66	10	20	10	50	10
5	5	5-5	0	0	1	1	67	0	20	20	60	0
5	6	5-6	0	0	0	0	68	0	40	20	40	0
5	7	5-7	1	0	1	2	63	0	20	20	30	30
5	8	5-8	0	0	0	0	58	0	40	20	20	20
5	9	5-9	0	0	2	2	53	0	20	30	50	0
5	10	5-10	0	0	1	1	49	0	20	20	60	0
6	1	6-1	0	0	1	1	55	0	40	10	30	20
6	2	6-2	0	0	0	0	68	0	30	30	40	0
6	3	6-3	0	0	0	0	65	0	20	40	10	30
6	4	6-4	0	0	0	0	100	0	60	0	40	0
6	5	6-5	0	0	2	2	70	0	60	10	30	0
6	6	6-6	0	0	0	0	74	10	50	0	40	0
6	7	6-7	0	0	1	1	67	0	40	20	40	0
6	8	6-8	0	0	0	0	60	0	40	10	0	60
6	9	6-9	0	0	0	0	55	0	20	10	30	40
6	10	6-10	0	0	1	1	40	0	40	20	40	0
7	1	7-1	0	0	0	0	55	0	20	30	50	0
7	2	7-2	0	0	0	0	20	0	0	0	0	100

	Start Point (downstream)	
Row	Latitude	Longitude
1	43.025260	-72.661512
2	43.025269	-72.661521
3	43.025261	-72.661519
4	43.025346	-72.661385
5	43.025389	-72.661516
6	43.025388	-72.661544
7	43.025375	-72.661518
8	43.025223	-72.661355
9	43.025200	-72.661313
10	43.025253	-72.661482
11	43.025259	-72.661469
12	43.025263	-72.661457

Appendix 3
Raw data for the quantitative survey at Site Q-1 (continued).

									Percent Substrate			
ROW	QUAD	ID	AlVa	AlUn	ElCo	TOTAL	DEPTH (CM)	SILT	SAND	GRAV	COBB	BLDR
7	3	7-3	0	0	3	3	62	0	20	25	40	15
7	4	7-4	1	0	1	2	74	0	10	20	50	20
7	5	7-5	0	0	2	2	86	0	30	40	30	0
7	6	7-6	0	0	0	0	81	0	40	40	20	0
7	7	7-7	0	0	0	0	70	0	35	15	50	0
7	8	7-8	0	0	2	2	67	0	50	30	20	0
7	9	7-9	0	0	3	3	62	0	10	30	40	20
7	10	7-10	1	0	1	2	54	0	15	15	70	0
8	1	8-1	0	0	0	0	65	0	25	25	50	0
8	2	8-2	0	0	0	0	71	0	30	20	50	0
8	3	8-3	0	0	2	2	70	0	60	20	20	0
8	4	8-4	0	0	0	0	95	0	30	25	45	0
8	5	8-5	0	0	3	3	80	0	40	30	30	0
8	6	8-6	0	0	2	2	90	0	40	10	50	0
8	7	8-7	0	0	0	0	75	0	20	30	50	10
8	8	8-8	0	0	0	0	60	30	30	20	20	0
8	9	8-9	0	0	0	0	65	0	30	20	50	0
8	10	8-10	0	0	0	0	20	0	10	0	0	90
9	1	9-1	0	0	0	0	75	0	10	20	70	0
9	2	9-2	0	0	0	0	77	0	20	40	40	0
9	3	9-3	0	0	0	0	82	0	30	40	30	0
9	4	9-4	0	0	0	0	79	0	20	50	30	0
9	5	9-5	0	0	1	1	84	0	10	30	60	0
9	6	9-6	0	1	0	1	74	0	20	30	50	0
9	7	9-7	0	0	2	2	65	0	30	40	30	0
9	8	9-8	1	0	1	2	57	0	30	40	30	0
9	9	9-9	0	0	0	0	52	0	25	35	40	0
9	10	9-10	0	0	0	0	65	0	10	20	70	0
10	1	10-1	0	0	0	0	75	0	10	30	50	10
10	2	10-2	1	0	0	1	81	0	10	20	70	0
10	3	10-3	0	0	1	1	72	0	30	60	10	0
10	4	10-4	0	0	2	2	73	0	20	70	10	0
10	5	10-5	0	0	0	0	75	0	20	70	10	0
10	6	10-6	0	0	1	1	70	0	20	60	20	0
10	7	10-7	2	0	0	2	67	0	20	60	20	0
10	8	10-8	0	0	1	1	58	0	10	60	30	0
10	9	10-9	0	0	0	0	56	0	25	35	40	0
10	10	10-10	0	1	2	3	63	0	25	25	50	0
11	1	11-1	0	0	0	0	75	0	40	45	15	0
11	2	11-2	0	0	0	0	70	0	30	70	0	0
11	3	11-3	0	0	0	0	77	0	70	5	25	0
11	4	11-4	0	0	2	2	65	0	30	40	30	0
11	5	11-5	0	0	1	1	64	0	40	40	20	0
11	6	11-6	0	0	0	0	67	0	50	50	0	0
11	7	11-7	0	0	0	0	55	0	50	50	0	0
11	8	11-8	0	0	1	1	50	0	60	30	10	0
11	9	11-9	0	0	1	1	42	0	20	70	10	0
11	10	11-10	0	0	0	0	53	0	40	50	10	0
12	1	12-1	0	0	0	0	65	0	40	50	10	0
12	2	12-2	0	0	0	0	70	0	40	50	10	0
12	3	12-3	0	0	1	1	65	0	50	40	10	0
12	4	12-4	0	0	0	0	69	0	50	50	0	0
12	5	12-5	0	0	0	0	53	0	40	30	30	0
12	6	12-6	0	0	0	0	50	0	30	30	40	0
12	7	12-7	0	0	1	1	45	0	30	40	30	0
12	8	12-8	0	0	0	0	40	0	40	40	20	0
12	9	12-9	0	0	1	1	40	0	40	40	20	0
12	10	12-10	0	0	0	0	45	0	30	15	55	0

Species abbreviations: AlUn = *Alasmidonta undulata*, ElCo = *Elliptio complanata*, LaRa = *Lampsilis radiata*, StUn = *Strophitus undulatus*, MaMa = *Margaritifera margaritifera*, AlVa = *Alasmidonta varicosa*

Appendix 4

Raw data for the quantitative survey at Site Q-2: mussel count and habitat data for the quadrats along each transect.

	Start		End	
Transect	Latitude	Longitude	Latitude	Longitude
1	42.973083	-72.647462	42.974486	-72.647363
2	42.973169	-72.647150	42.974618	-72.647073
3	42.973197	-72.647260	42.974646	-72.647201

Thirty .5 x .5 m quads every 10 m along each of three 150 m long strip transects

	Species								Percent Substrate				
ID*	AlVa	AlUn	StUn	MaMa	ElCo	LaRa	Total	Depth (cm)	SILT	SAND	GRAV	COBB	BLDR
1-1	0	0	0	0	0	0	0	25	25	0	50	25	0
1-2	0	0	0	0	0	0	0	23	33	0	33	33	0
1-3	0	0	0	0	1	0	1	32	20	10	20	50	0
1-4	0	0	1	0	0	0	1	30	30	10	40	20	0
1-5	0	0	0	0	0	0	0	31	30	0	20	50	0
1-6	0	0	0	0	0	0	0	34	30	20	10	40	0
1-7	0	0	0	0	0	0	0	36	40	20	10	30	0
1-8	0	0	0	0	0	0	0	41	0	40	20	40	0
1-9	0	0	0	0	0	0	0	35	50	0	30	20	0
1-10	0	0	0	0	1	0	1	37	40	0	40	20	0
1-11	0	0	0	0	0	0	0	27	30	15	30	25	0
1-12	0	0	0	0	1	0	1	36	60	0	10	30	0
1-13	0	0	0	0	2	0	2	41	50	0	10	40	0
1-14	0	0	0	0	1	0	1	50	20	0	0	40	40
1-15	0	0	1	0	1	0	2	50	70	0	0	30	0
1-16	0	0	0	0	0	0	0	55	70	0	0	30	0
1-17	0	0	0	0	0	0	0	55	70	0	0	30	0
1-18	0	0	0	0	0	0	0	55	40	15	0	45	0
1-19	0	0	0	0	0	0	0	55	30	20	20	30	0
1-20	0	0	1	0	1	0	2	55	30	60	0	10	0
1-21	0	0	0	0	2	0	2	55	0	60	10	30	0
1-22	0	0	0	0	1	0	1	51	20	40	15	25	0
1-23	0	0	0	0	2	0	2	67	20	50	20	10	0
1-24	0	0	0	0	1	0	1	65	40	30	5	25	0
1-25	0	0	0	0	2	0	2	65	30	10	10	50	0
1-26	0	0	0	0	3	0	3	75	70	5	5	20	0
1-27	0	0	0	0	3	0	3	73	50	5	5	40	0
1-28	0	0	0	0	0	0	0	72	50	10	10	30	0
1-29	0	0	0	0	4	0	4	71	70	5	5	20	0
1-30	0	0	0	0	2	0	2	85	80	5	5	10	0
2-1	0	0	0	0	0	0	0	65	0	95	5	0	0
2-2	0	0	0	0	0	0	0	68	0	95	5	0	0
2-3	0	0	0	0	0	0	0	70	0	70	5	15	0
2-4	0	0	0	0	1	0	1	75	0	75	10	15	0
2-5	0	0	0	0	0	0	0	65	0	85	15	0	0
2-6	0	0	0	0	0	0	0	70	0	95	5	0	0
2-7	0	0	0	0	2	0	2	73	0	95	5	0	0
2-8	1	0	0	0	1	0	2	74	0	90	5	5	0
2-9	0	0	0	0	0	0	0	75	0	95	5	0	0
2-10	0	0	0	0	0	0	0	55	0	80	5	15	0
2-11	0	0	0	0	0	0	0	70	0	90	10	0	0
2-12	0	0	0	0	2	0	2	75	0	70	30	0	0
2-13	0	0	0	0	0	0	0	83	0	94	1	5	0
2-14	0	0	0	0	2	0	2	85	0	100	0	0	0
2-15	0	0	0	0	0	0	0	90	0	100	0	0	0
2-16	0	0	0	0	0	0	0	65	0	95	5	0	0
2-17	0	0	0	0	0	0	0	58	70	30	0	0	0
2-18	0	0	0	0	0	0	0	5	0	20	80	0	0
2-19	0	0	0	0	0	0	0	5	0	20	80	0	0
2-20	0	0	0	0	0	0	0	13	0	30	70	0	0
2-21	1	0	0	0	3	0	4	45	0	85	15	0	0

*ID = transect (1-3) - quadrat (1-30)

Appendix 4

Raw data for the quantitative survey at Site Q-2: mussel count and habitat data for the quadrats along each transect (continued).

	Species								Percent Substrate				
ID*	AlVa	AlUn	StUn	MaMa	ElCo	LaRa	Total	Depth (cm)	SILT	SAND	GRAV	COBB	BLDR
2-22	0	0	0	0	0	0	0	45	0	90	10	0	0
2-23	0	0	0	0	2	0	2	50	0	85	15	0	0
2-24	0	0	0	0	0	0	0	46	0	75	20	5	0
2-25	0	0	0	0	0	0	0	55	0	75	20	5	0
2-26	0	0	0	0	0	0	0	60	0	85	10	5	0
2-27	0	0	0	0	0	0	0	90	0	80	10	10	0
2-28	0	0	0	0	0	0	0	120	0	95	5	0	0
2-29	0	0	0	0	0	0	0	100	0	95	5	0	0
2-30	0	0	0	0	0	0	0	100	0	95	5	0	0
3-1	0	0	0	0	1	0	1	53	0	70	30	0	0
3-2	0	0	0	0	1	0	1	51	0	55	15	30	0
3-3	0	0	0	0	0	0	0	60	0	30	5	65	0
3-4	0	0	0	0	1	0	1	55	0	70	5	25	0
3-5	0	0	0	0	0	0	0	65	0	70	5	25	0
3-6	0	0	0	0	1	0	1	60	0	70	5	25	0
3-7	0	1	0	0	0	0	1	65	0	90	10	0	0
3-8	0	0	0	0	1	0	1	63	0	60	10	30	0
3-9	0	0	0	0	0	0	0	70	0	80	15	5	0
3-10	1	0	0	0	1	0	2	65	0	88	10	2	0
3-11	0	0	0	0	0	0	0	65	0	75	10	15	0
3-12	0	0	0	0	0	0	0	70	0	75	10	5	0
3-13	0	0	0	0	0	0	0	80	0	65	10	25	0
3-14	0	0	0	0	0	0	0	100	0	90	10	0	0
3-15	0	0	0	0	0	0	0	72	0	75	15	10	0
3-16	0	0	0	0	0	0	0	65	0	85	10	5	0
3-17	0	0	0	0	2	0	2	65	0	80	15	5	0
3-18	0	0	0	0	0	0	0	68	0	85	10	5	0
3-19	0	1	0	0	0	0	1	62	0	80	10	10	0
3-20	0	0	0	0	0	0	0	80	0	70	25	5	0
3-21	0	0	0	0	0	0	0	60	0	80	10	10	0
3-22	0	0	0	0	3	0	3	60	20	55	25	0	0
3-23	0	0	0	0	1	0	1	55	20	30	40	10	0
3-24	0	0	0	0	0	0	0	55	0	25	50	25	0
3-25	0	0	0	0	0	0	0	50	0	40	50	10	0
3-26	0	0	0	0	0	0	0	60	0	70	5	25	0
3-27	0	0	0	0	2	0	2	70	0	60	20	20	0
3-28	0	0	0	0	0	0	0	65	0	70	25	5	0
3-29	0	0	0	0	0	0	0	75	0	65	10	25	0
3-30	0	0	0	0	1	0	1	78	0	50	10	30	0

Species abbreviations: AlUn = *Alasmidonta undulata*, ElCo = *Elliptio complanata*, LaRa = *Lampsilis radiata*, StUn = *Strophitus undulatus*, MaMa = *Margaritifera margaritifera*, AlVa = *Alasmidonta varicosa*