TRANSCANADA HYDRO NORTHEAST INC.

ILP Study 24
Dwarf Wedgemussel and Co-Occurring Mussel Study, Phase 1 Report

In support of Federal Energy Regulatory Commission Relicensing of:

Wilder Hydroelectric Project (FERC Project No. 1892-026)
Bellows Falls Hydroelectric Project (FERC Project No. 1855-045)
Vernon Hydroelectric Project (FERC Project No. 1904-073)

Prepared by:

Biodrawversity, LLC.
The Louis Berger Group, Inc.
and
Normandeau Associates, Inc.

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EXECUTIVE SUMMARY

In 2011 and 2013, Biodrawversity LLC conducted freshwater mussel surveys in the Connecticut River and tributaries within the boundary of the Wilder, Bellows Falls, and Vernon Hydroelectric Projects (projects), and in the 17-mile free-flowing reach between the Wilder and Bellows Falls projects ("free-flowing reach"). There were three primary objectives of the fieldwork: (1) assess the distribution, abundance, demographics, and habitat of dwarf wedgemussel (*Alasmidonta heterodon*), a federally endangered species known to occur in the Connecticut River, (2) gather similar information on co-occurring mussel species and, (3) record incidental observations of tessellated darter (*Etheostoma olmstedi*) (2013 only). These data were necessary to plan later phases of a comprehensive mussel study, including possible quantitative sampling, *in situ* observations of dwarf wedgemussel behavior, and an analysis of the effects of flow regime on dwarf wedgemussel populations and their habitat.

The 2011 field research provided information for pre-application documents (PADs) for the relicensing of each hydroelectric project, and the 2013 field research accomplished the first phase of a multi-phase relicensing mussel study that had been approved by stakeholders in 2013 (TransCanada ILP Study 24 – Dwarf Wedgemussel and Co-occurring Mussel Study). This report is a comprehensive summary of the 2011 and 2013 field data.

Mussel surveys were conducted at 210 sites, including 72 in the Wilder project, 39 in the free-flowing reach downstream of Wilder dam, 69 in the Bellows Falls project, and 30 in the Vernon project. A total of 147 sites were in impoundments and 24 were located immediately downstream from dams (eight sites below each dam). Surveys were carried out between May and October, and included semi-quantitative mussel sampling (i.e., timed searches) and documentation of habitat conditions. Surveys were typically conducted by SCUBA diving in deep (>5 feet) water and snorkeling in shallow areas.

A total of 69 dwarf wedgemussel were counted in the Wilder and Bellows Falls impoundments; none were found in the Vernon project or in the free-flowing reach. In the Wilder impoundment, 45 dwarf wedgemussel were found among 17 survey sites, for an average of 0.7 mussels/site and a maximum catch-per-unit-effort (CPUE) of 8.0 mussels/hour. These 45 mussels were found between Sites W-29 and W–62, located between 27 and 41 miles upstream from the Wilder dam. In the Bellows Falls impoundment, 24 dwarf wedgemussel were found among 14 survey sites, for an average of 0.4 mussels/site and a maximum CPUE of 3.0 mussels/hour. These 24 mussels were found sporadically between Sites BF-14 and BF–62, which were located in the upper 17 miles of the impoundment. Dwarf wedgemussel in the Bellows Falls impoundment were found slightly more frequently near Wethersfield Bow, in the Connecticut River near the Black River confluence, and in the project-affected portion of the Black River. Dwarf wedgemussel were not found in the tailwaters of any of the three dams. Shell length data for dwarf wedgemussel indicated some evidence of recruitment, small average shell length

compared to other known populations in the watershed, and scarcity of older mature mussels. The tessellated darter, which is the primary host for dwarf wedgemussel, was found at only 17.9 percent of sites in the free-flowing reach and always at low densities. Tessellated darters were found somewhat more frequently (22.4%) in the Wilder and Bellows Falls impoundments, especially near shorelines where habitat heterogeneity was higher than it was toward the center of the river channel.

Six other species of freshwater mussels were found during the surveys: eastern elliptio (*Elliptio complanata*), eastern lampmussel (*Lampsilis radiata*), alewife floater (*Anodonta implicata*), triangle floater (*Alasmidonta undulata*), creeper (*Strophitus undulatus*), and eastern floater (*Pyganodon cataracta*). The mussel communities were dominated by eastern elliptio and eastern lampmussel, which were found at 95.2 and 87.6 percent of survey sites, respectively. Together, these two species comprised more than 99 percent of the mussels observed at most survey sites. Alewife floater was the third most common species overall, occurring at 12.6 percent of all survey sites, and at 66.7 percent of all survey sites located downstream from the Bellows Falls dam. A total of 460 alewife floater were counted, including only two upstream from the Bellows Falls dam, 217 below the Bellows Falls dam, 166 in the Vernon impoundment, and 75 below the Vernon dam.

The other three species were far less common. Creeper was found at 22 survey sites (10.5 percent) and was usually only present at very low numbers. It was found at two sites (two animals) in the Wilder impoundment, two sites (two animals) in the free-flowing reach, 14 sites (44 animals) in the Bellows Falls impoundment (mostly in the Black River), and four sites (six animals) in the Vernon impoundment. None were found immediately downstream from any of the three dams. Triangle floater was found at 31 survey sites (14.8 percent) and usually at very low numbers, including at ten sites (19 animals) in the Wilder impoundment, and four sites (six animals) in the free-flowing reach, nine sites (18 animals) in the Bellows Falls impoundment, and two sites (two animals) in the Vernon impoundment. Triangle floater was also found downstream from the Wilder dam (three live animals) and Bellows Falls dam (five live animals). Eastern floater occurred primarily in two locations: in the lower Black River in the Bellows Falls impoundment and within the downstream half of the Vernon impoundment.

The three fluvial mussel species—dwarf wedgemussel, triangle floater, and creeper—were rare and patchily distributed. Dwarf wedgemussel were not found in the free-flowing reach where the species was historically known to occur (e.g., Sumner Falls or Cornish Covered Bridge), and densities of other fluvial species (triangle floater and creeper) were also very low in the free-flowing reach. The free-flowing reach contained the lowest species richness and mussel density (all species) among the areas surveyed, and had the poorest quality mussel habitat. Important areas for the rare fluvial species in the Wilder impoundment were primarily confined to a 14-mile reach in the upper third of the impoundment. Important areas for the three fluvial species in the Bellows Falls impoundment appear to include Wethersfield Bow, the Connecticut River near the Black River confluence, and the lower Black River. Eastern elliptio and eastern lampmussel are the only two species

with robust populations throughout all study areas, although alewife floater populations may also be stable in areas of the Connecticut River downstream from the Bellows Falls dam.

The FERC-approved freshwater mussel study plan (FERC Study Plan Determination, February 21, 2014) for the relicensing of the Wilder, Bellows Falls, and Vernon Hydroelectric Projects specifies quantitative sampling of dwarf wedgemussel and co-occurring mussel species, *in situ* monitoring of dwarf wedgemussel, and an evaluation of the effects of flow regime on dwarf wedgemussel populations and habitat. The absence or scarcity of dwarf wedgemussel in the free-flowing reach and other areas that experience the most change (e.g., water depth or water velocity) during daily or sub-daily project-related flow fluctuations will greatly constrain the types of sampling, monitoring, and analyses that would be effective. Though less direct than studying dwarf wedgemussel populations, an approach that focuses on mussel communities (i.e., all species), important habitat parameters, and host fish might shed more insight than population-level research and monitoring.

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1. INTRODUCTION

The Connecticut River in the upper Bellows Falls impoundment, looking across to Mt. Ascutney.

An approximate 120-mile reach of the Connecticut River from North Haverhill, New Hampshire, to downstream of Vernon dam, is influenced by the presence and operations of three major hydroelectric facilities: Wilder, Bellows Falls, and Vernon (Figure 1-1). TransCanada owns and operates these hydroelectric facilities, and the current Federal Energy Regulatory Commission (FERC) license for these will expire in 2018. The impoundments of these three facilities are approximately 45, 26, and 26 miles long, respectively, and they include the mouths of numerous tributaries. The operations of the hydroelectric facilities influence both upstream and downstream areas with daily or sub-daily flow fluctuations. An important area subjected to sub-daily flow fluctuations is the 17-mile free-flowing reach between Wilder dam and the upper end of the Bellows Falls project, referred to as the "free-flowing reach" throughout this report.

In 2011, TransCanada completed a freshwater mussel survey in the three project areas to provide information for the projects' Pre-Application Documents (PADs). The primary objectives of the 2011 survey were to assess the distribution, abundance, demographics, and habitat of dwarf wedgemussel in the impoundments and areas a short distance downstream from Wilder and Bellows Falls dams. The survey also provided information on the diversity, abundance, and habitat of the entire freshwater mussel community in these locations. The free-flowing reach was not surveyed in 2011.

Dwarf wedgemussel from the Wilder impoundment.

In 2013, relicensing stakeholders requested a study of the potential effects of the Wilder and Bellows Falls hydroelectric operations on dwarf wedgemussel populations. Five objectives were stated in each study request: three were related to baseline population studies and long-term monitoring, and two were focused specifically on the potential effects of flow regime/water level fluctuations on mussel behavior or habitat. The study

plan approved by stakeholders and FERC outlined an adaptive, two-phase plan that would benefit from collaboration with stakeholders throughout the design and implementation of the study. Specifically, mussel surveys were planned for 2013, and these results would help refine study plans for 2014 fieldwork and analyses. Primary among the tasks were to conduct a mussel survey in the 17-mile free-flowing reach using the same methods as the 2011 survey, and to integrate the 2011 and 2013 data into a comprehensive report. The 2013 field research also evaluated potential sites for quantitative mussel sampling, and evaluated the feasibility of observing behavior of dwarf wedgemussel in situ during varying flow conditions.

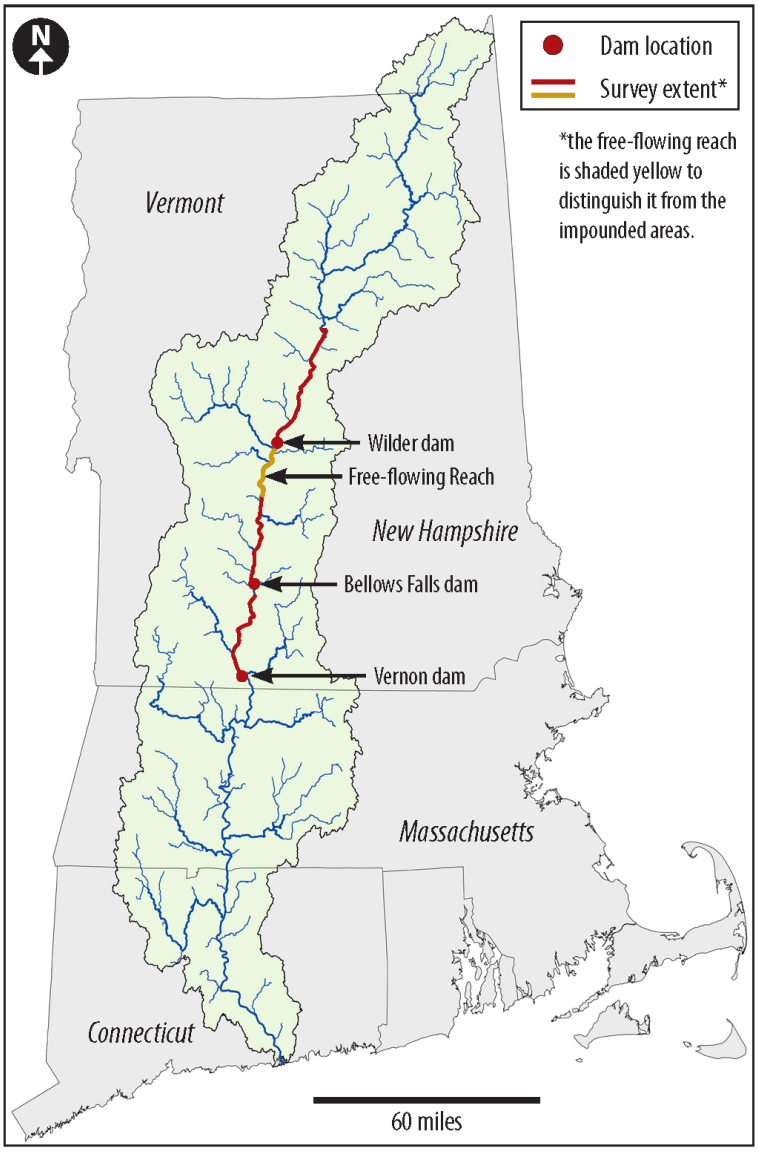


Figure 1-1: Locations of the Wilder, Bellows Falls, and Vernon hydroelectric projects in the Connecticut River watershed, and the linear extent of the 2011 and 2013 mussel surveys.

2. STUDY AREA DESCRIPTION

2.1 Wilder Project

The Wilder impoundment is approximately 45 miles long and includes 105 total miles of shoreline. Several tributaries are influenced by the impoundment, including the Ompompanoosuc and Waits Rivers from the west, as well as smaller and higher-gradient tributaries from the east. The land along the river corridor is mostly comprised of mixed farmland, residential areas, and forests, although substantially more development occurs near Fairlee, Bradford, and Hanover. In 2006, dwarf wedgemussel were documented along a 16-mile reach of the impoundment between Haverhill and Orford, New Hampshire (Nedeau 2006, 2008b).

The Wilder impoundment near the old Bedell Bridge (Haverhill, NH).

2.2 Free-flowing Reach

The "free-flowing reach" is the 17-mile-long reach between the Wilder dam and the upstream extent of the Bellows Falls impoundment, which is considered the downstream tip of Chase Island (Cornish, NH). The Connecticut River drops almost 55 feet in elevation over this distance, and contains many miles of fast-flowing runs, riffles, and rapids. The predominant substrates are gravel and cobble, though sand is transient in fast-flowing areas and accumulates in depositional areas, and there are areas where boulders and bedrock are the defining features of the stream channel. There are numerous islands and high-energy gravel and cobble bars, many of which are only evident during low-flow periods. One of the most interesting geologic features in this reach is Sumner Falls, formed by a north-south oriented bedrock outcrop. Numerous tributaries enter this reach from the east and west, the largest including the White River and Ottaquechee River from the west and the Mascoma River from the east. The land along the river is mostly comprised of urban/industrial near White River Junction and Lebanon, and mixed farmland, forests, and residential lands farther downstream. Historically, dwarf wedgemussel were documented in the pool downstream from Sumner Falls and near the Cornish Covered Bridge (Gabriel 1995).

2.3 Bellows Falls Project

The Bellows Falls impoundment is approximately 26 miles long and its upper reach ends 17 miles downstream from the Wilder dam. Land use along the river corridor is primarily mixed agriculture, forests, and residential. Several mid-sized tributaries flow into the impoundment, including Mill Brook, Sugar River, Black River, and

Williams River. Dwarf wedgemussel were already known to occur in the impoundment of the Bellows Falls dam and in the project-affected section of the lower Black River (Ferguson 1999, Nedeau 2008a-b).

2.4 Vernon Project

The Vernon impoundment is approximately 26 miles long. The upper reach of this impoundment extends to less than six miles below the dam at the Bellows Falls project. Its upper reach is located in a relatively wide and open section of the Connecticut River valley, with agricultural and residential land uses prevalent along the river corridor. Further downstream, the valley narrows and the landscape becomes more mountainous and heavily forested. Vermont's West River is the most significant tributary in this reach, although many small streams enter from both the east and west. There are historical records of dwarf wedgemussel in the Connecticut River in the lower Vernon impoundment, near Brattleboro. However, dwarf wedgemussel have not been found within this impoundment or its tributaries in at least 30 years (Nedeau 2005).

The ledges of Sumner Falls in the free-flowing reach (Hartland, VT).

Typical gravel-cobble substrate and shallow water in the free-flowing reach.

3. METHODS

3.1 Site Selection

Sites were selected to provide adequate spatial coverage of each study area, and to target habitats suitable for dwarf wedgemussel. Table 3-1 provides statistics for the number and frequency of survey sites in each study area. Site locations for each study area are shown in Appendix A.

Table 3-1: Level of survey effort allocated to the Wilder, Bellows Falls, and Vernon study areas, and to the free-flowing reach.

	Study Area				
Statistic	**Free-Flowing**	**Wilder**	**Bellows Falls**	**Vernon**	**Total**
# Sites Just Below Dam	-	8	8	8	24
# Sites in Impoundment [a]	-	64 (15)	61 (16)	22	147 (31)
Total Sites [a]	(39)	72 (15)	69 (16)	30	210 (70)
Mean Distance Between Sites [b]	0.4	0.7	0.4	1.3	0.6
Max Distance Between Sites	1.6	1.8	1.3	1.8	1.8
Total Search-Hours	42.5	68.5	71.8	25.5	208.3
Mean Search-hours Per Site	1.09	0.95	1.04	0.85	0.99

[a] Numbers in parentheses indicate 2013 sampling sites.

[b] Excluding the tight cluster of 8 sites downstream from each of the three dams.

In 2011, biologists systematically surveyed sites along the entire length of each impoundment and below each dam. More fieldwork was allocated to the Wilder and Bellows Falls impoundments because dwarf wedgemussel were known to occur in these impoundments (Nedeau 2008). The Vernon impoundment was surveyed less intensively because the likelihood of finding dwarf wedgemussel was considered low based on prior experiences (Nedeau 2008). In the Wilder and Vernon impoundments, all survey sites were confined to the Connecticut River. In the Bellows Falls impoundment, the lower reaches of the Sugar River, Black River, and Williams River were surveyed. In 2013, the 17-mile free-flowing reach was

surveyed in the same manner as the 2011 surveys. Additional surveys were also conducted in the Wilder and Bellows Falls impoundments near where dwarf wedgemussel were found in 2011. These areas included a 14-mile reach in the Wilder project (from 27 to 41 miles upstream from the Wilder dam), and a 17-mile reach in the Bellows Falls project from Chase Island downstream to just below the Black River confluence. One key objective for the 2013 surveys was to determine where quantitative sampling methods and *in situ* monitoring might be most effective based on the following factors:

- Spatial extent of the dwarf wedgemussel population
- Density of dwarf wedgemussel and other species
- Habitat use by dwarf wedgemussel
- Habitat suitability for dwarf wedgemussel
- Environmental conditions (e.g., sampling constraints)
- Accessibility (e.g., potential property rights issues)
- Other factors that may influence whether a site could be used for further study.

Mussels like this one with near-complete loss of periostracum are assigned a shell condition value of 1.0.

3.2 Field Surveys

Field surveys were conducted during the period from May to September of 2011, and during September and early October of 2013. Survey methods varied according to specific habitat conditions at each site, but typically biologists used SCUBA in water deeper than five feet, and snorkeled in shallower areas. Most survey sites were accessed using a motorboat or kayaks, and a few were accessed from convenient entry points on public land (e.g., bridges, boat launches, and fishing areas). Biologists usually spent approximately one person-hour at each site searching for mussels, sometimes less if habitat was poor and few mussels were observed, and sometimes more if habitat was suitable and dwarf wedgemussel were found. Surveys typically involved two biologists each conducting a 30-minute timed search. The following information was recorded:

- Precise counts of dwarf wedgemussel, triangle floater, creeper, alewife floater, and eastern floater
- Qualitative abundance estimates (Table 3-2) for eastern elliptio and eastern lampmussel
- Shell length and shell condition for every dwarf wedgemussel, triangle floater, and creeper, and more cursory observations of the length range

and shell conditions for other species. Shell condition refers to the degree of shell erosion (i.e., loss of periostracum and other damage). This was recorded as one of five numeric scores: 0 (light), 0.25 (light-medium), 0.5 (medium), 0.75 (medium-heavy), and 1 (heavy). These scores were averaged for all mussels in a sample to produce an overall shell condition index that ranged from 0 to 1.

- In 2013, biologists noted whether tessellated darter were observed at survey sites
- General descriptions of bank condition, surrounding land use, other noteworthy observations
- Representative photographs of habitats and species
- Notes on instream habitat such as water depth, substrate, flow conditions, submerged aquatic vegetation, and woody debris at each survey site. Water velocity was not specifically measured but was subjectively recorded as light (typically less than 0.1 m/s), moderate (0.1 to 0.3 m/s), or strong (>0.3 m/s).
- GPS coordinates of the survey sites

Table 3-2: Abundance categories for eastern lampmussel and eastern elliptio.

Score	Descriptor	General Range*
0	None	0
1	Very Low	1-20
2	Low	21-50
3	Medium	51-100
4	Medium-High	101-200
5	High	201-400
6	Very High	401-800
7	Extreme	>800

3.3 Data Analysis

Data collected during field surveys were entered into a Microsoft Excel spreadsheet and GPS coordinates were imported into ArcGIS to generate maps. Catch-per-unit-effort (CPUE, expressed as mussels/hour) statistics were computed for the five

species that were precisely counted. Shell length data collected for rare species (dwarf wedgemussel, triangle floater, and creeper) were used to develop length-frequency histograms (a surrogate for age-frequency; reviewed in Nedeau 2008a). Counts and descriptive statistics were tabulated, graphed, and mapped. Raw data is provided in Appendix B (privileged data).

4. RESULTS

4.1 Species Richness

Wilder Project: Mussels were encountered at every survey site in the Wilder project (Table 4-1, Figure 4-1). Three species were found downstream from the Wilder dam: eastern elliptio, eastern lampmussel, and triangle floater. Five species were found in the Wilder impoundment; these were the same species from below the dam plus dwarf wedgemussel and creeper. Downstream from the dam, average species richness (i.e., number of species) was 1.75 (range = 0–3) among the eight survey locations that comprised the single composite site. In the impoundment, average species richness was 2.39 (range = 1–4) among the 64 sites, and species richness was highest in areas between Sites W-29 and W-62 where dwarf wedgemussel were found (see Figure 4-5).

Free-flowing Reach: Mussels were encountered at 32 of 39 sites (82 percent) in the free-flowing reach (Table 4-1, Figure 4-2). Four species were found: eastern elliptio, eastern lampmussel, triangle floater, and creeper. Average species richness was 1.59, which was the lowest among all of the survey areas. Highest species richness among the 39 survey sites was four, at Site FF-32, where two of the species (triangle floater and creeper) were found only in the mouth of the Ottaquechee River. In addition to having low species richness, the free-flowing reach contained lower densities of mussels than almost anywhere else surveyed for this report. Most survey sites contained low to moderate numbers of eastern elliptio and even fewer numbers of eastern lampmussel. In addition, tessellated darters were observed at only seven (17.9 percent) of survey sites, always at very low densities (fewer than five fish per site) (Appendix B).

Bellows Falls Project: Mussels were encountered at all but two survey sites in the Bellows Falls project (Table 4-1, Figure 4-3). Five species were found downstream from the Bellows Falls dam: eastern elliptio, eastern lampmussel, alewife floater, eastern floater, and triangle floater. Seven species were found in the Bellows Falls impoundment; these were the same species from below the dam plus dwarf wedgemussel and creeper. Downstream from the dam, average species richness was 3.50 (range = 2–4) among the eight survey locations that comprised the single composite site. In the impoundment, average species richness was 2.61 (range = 0–6) among the 61 sites. Species richness was generally highest in areas between Sites BF-14 and BF-32 and Sites BF-39 and BF–54 (Figure 4-4). Three of the four highest species richness values were from survey sites in the Black River (Sites BF-26, BF-27, and BF–28). The only two locations where mussels were not found were in the lower Sugar River and Williams River.

Vernon Project: Mussels were encountered at every survey site in the Vernon project (Table 4-1, Figure 4-4). Four species were found downstream from the Vernon dam: eastern elliptio, eastern lampmussel, alewife floater, and eastern floater. Six species were found in the Vernon impoundment; these were the same species from below the dam plus triangle floater and creeper. Downstream from the dam, average species richness was 2.88 (range = 1–4) among the eight survey

sites that comprised the single composite site. In the impoundment, average species richness was 3.05 (range = 2–5) among the 22 sites, and there was no apparent pattern to the species richness (Figure 4-5). Dwarf wedgemussel were not found within the Vernon project.

Table 4-1: Species richness, mean CPUE or abundance estimates, and number of occurrences for mussel species found in the Wilder, Bellows Falls, and Vernon study areas, and in the free-flowing reach.

	Study Area						
	Wilder Impoundment	**Below Wilder Dam**	**Free-Flowing Reach**	**Bellows Falls Impoundment**	**Below Bellows Falls Dam**	**Vernon Impoundment**	**Below Vernon Dam**
Richness Descriptor							
Total Richness	5	3	4	7	5	6	4
Mean Richness/Site	2.39	1.75	1.59	2.61	3.50	3.05	2.88
Min Richness	1	0	0	0	2	2	1
Max Richness	4	3	4	6	4	5	4
Mean CPUE or Abundance Estimate							
AlHe (CPUE)	0.68	0.00	0.00	0.30	0.00	0.00	0.00
AlUn (CPUE)	0.31	0.75	0.17	0.29	0.63	0.09	0.00
AnIm (CPUE)	0.00	0.00	0.00	0.04	29.75	7.62	18.75
PyCa (CPUE)	0.00	0.00	0.00	0.13	0.13	0.27	5.00
StUn (CPUE)	0.03	0.00	0.04	0.73	0.00	0.27	0.00
ElCo (Estimate) a	5.25	2.38	2.10	4.98	5.38	4.27	4.50

	Study Area						
	Wilder Impoundment	**Below Wilder Dam**	**Free-Flowing Reach**	**Bellows Falls Impoundment**	**Below Bellows Falls Dam**	**Vernon Impoundment**	**Below Vernon Dam**
LaRa (Estimate)[a]	2.50	1.50	1.50	3.38	2.63	2.18	1.75
# Sites Where Found							
AlHe	17	0	0	14	0	0	0
AlUn	10	2	4	9	4	2	0
AnIm	0	0	0	2	7	14	3
PyCa	0	0	0	2	1	4	5
StUn	2	0	2	14	0	4	0
ElCo	64	7	32	59	8	22	8
LaRa	60	5	24	59	8	21	7

[a] See Table 3-2 for abundance categories for ElCo and LaRa.

Species Abbreviations
AlHe = *Alasmidonta heterodon* (dwarf wedgemussel); AlUn = *Alasmidonta undulata* (triangle floater); AnIm = *Anodonta implicata* (alewife floater); PyCa = *Pyganodon cataracta* (eastern floater); StUn = *Strophitus undulatus* (creeper); ElCo = *Elliptio complanata* (eastern elliptio); LaRa = *Lampsilis radiata* (eastern lampmussel)

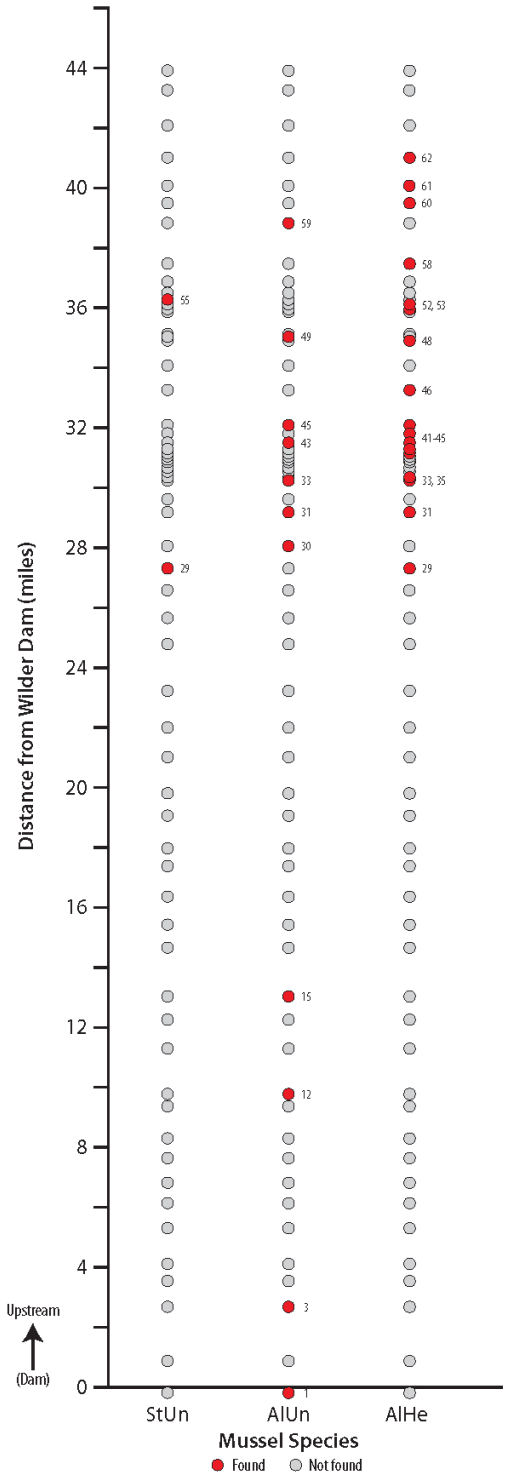


Figure 4-1. Sites where the three fluvial mussel species were encountered in the Wilder project. Sites are ordered by distance from the Wilder dam; Site 1 is downstream from the dam. Site numbers are provided only for sites where a species was found.

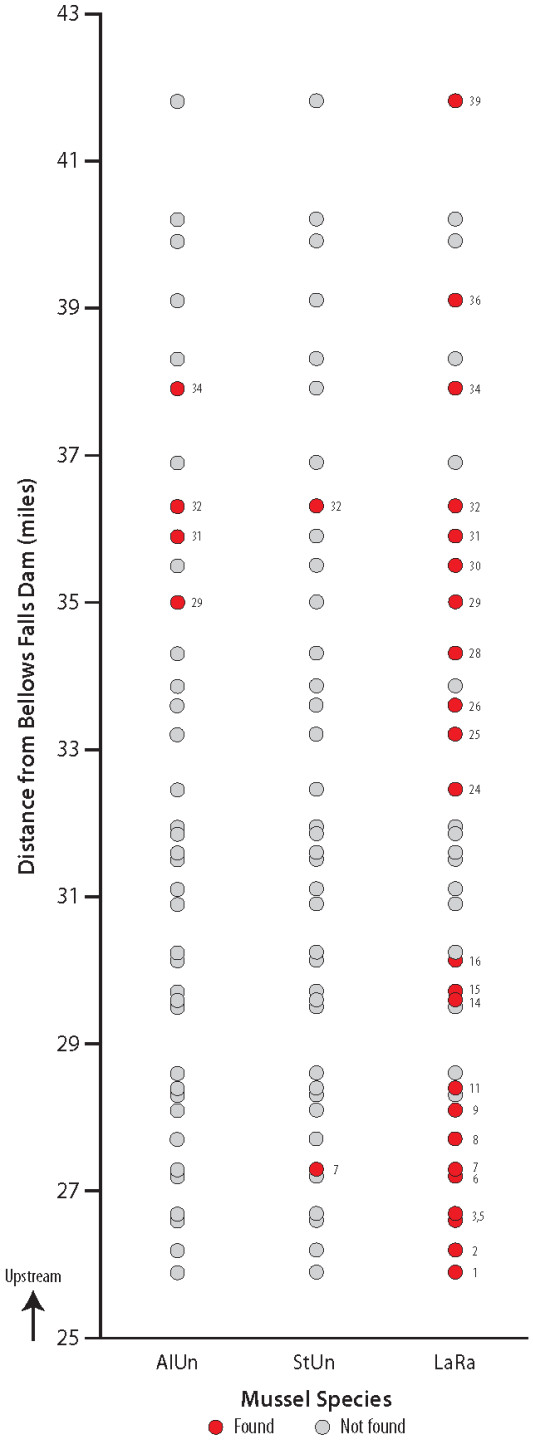


Figure 4-2. Sites where two fluvial mussel species and the eastern lampmussel were encountered in the free-flowing reach. Dwarf wedgemussel were not found in this reach. Sites are ordered by distance from the Bellows Falls dam. Site numbers are provided only for sites where a species was found.

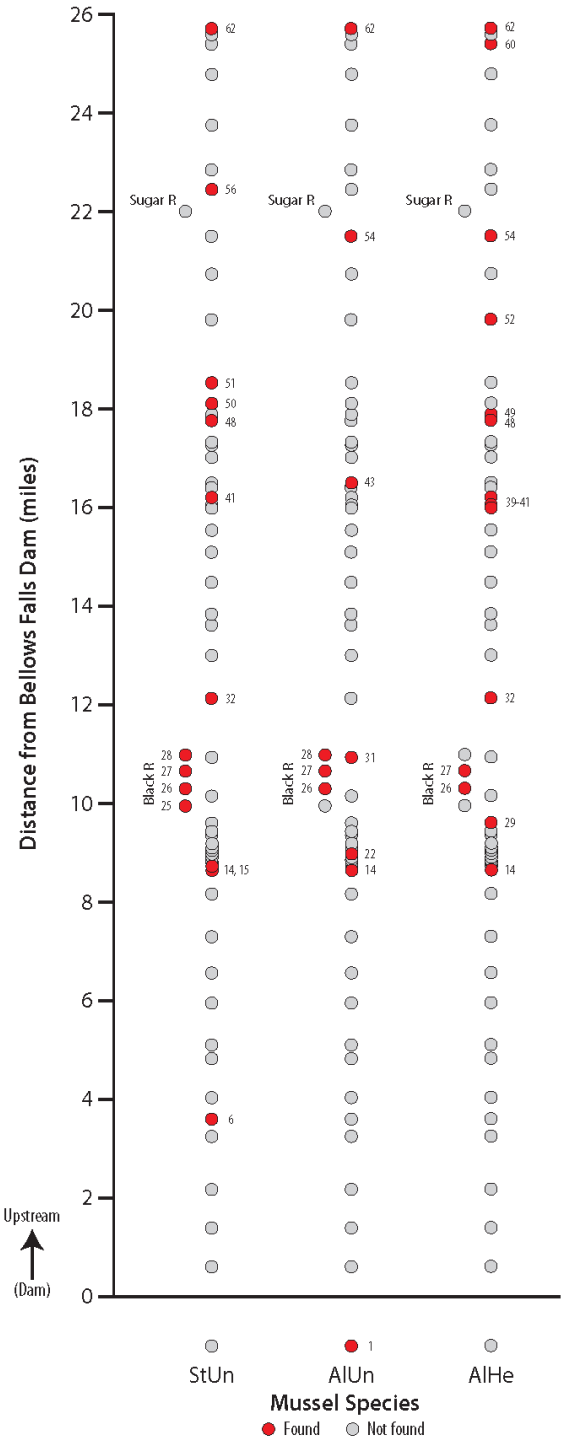


Figure 4-3. Survey sites where the three fluvial mussel species were encountered in the Bellows Falls project. Sites are ordered by distance from the Bellows Falls dam; Site 1 is downstream from the dam. Site numbers are provided only for sites where a species was found.

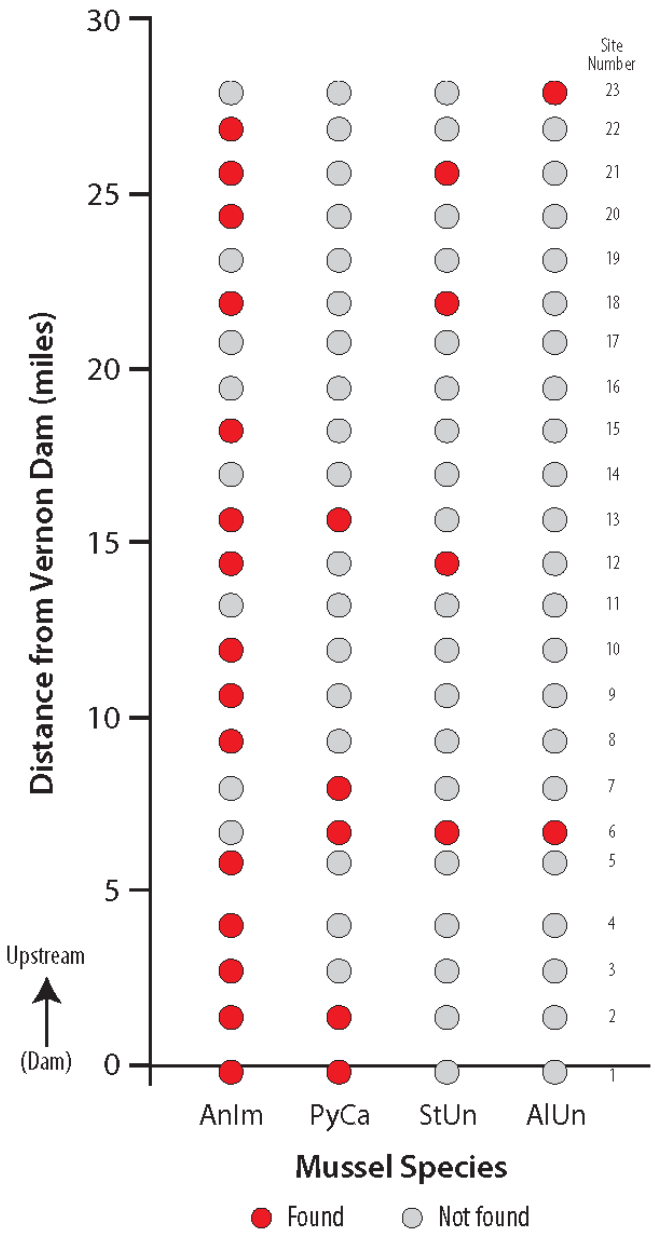


Figure 4-4. Survey sites where each mussel species were encountered in the Vernon project. Sites are ordered by distance from the Vernon dam; Site 1 is downstream from the dam.

4.2 Dwarf Wedgemussel

Distribution: Dwarf wedgemussel were only found in the Wilder and Bellows Falls impoundments (Table 4-2). In the Wilder impoundment, they were found at 17 survey sites (26.6 percent) between Sites W-29 and W-62, located 27–41 miles upstream from the Wilder dam (Figures 4-1, 4-6). In the Bellows Falls impoundment, they were found at 14 sites (23.0 percent), including two sites in the lower Black River and 12 sites in the Connecticut River between Sites BF-14 and BF-62, located in the upper 17 miles of the impoundment (Figures 4-3, 4-7). In addition, dwarf wedgemussel shells were found at three sites within this same reach. Dwarf wedgemussel in the Bellows Falls impoundment were found slightly more frequently near Wethersfield Bow, the Black River confluence, and in the Black River. Tessellated darters were usually observed where dwarf wedgemussel were found (Appendix B).

Abundance: A total of 69 dwarf wedgemussel were found (Table 4-2). A total of 45 dwarf wedgemussel were found in the Wilder impoundment, for an average of 0.70 mussels/site and an average CPUE of 0.68 mussels/hour. The highest CPUE recorded in the Wilder impoundment was 8.0 mussels/hour at Site W-58 (eight animals) (Figure 4-8). Twenty-four dwarf wedgemussel were found in the Bellows Falls impoundment, for an average of 0.39 mussels/site and an average CPUE of 0.30 mussels/hour. The highest CPUE recorded in the Bellows Falls impoundment was 3.0 mussels/hour at Site BF-26 in the Black River (three animals). Usually only one dwarf wedgemussel was found per site in the Bellows Falls impoundment. None were found in the Vernon impoundment or in the free-flowing reach.

Representative dwarf wedgemussel.

The lower Black River where dwarf wedgemussel were found.

The upper end of the Bellows Falls impoundment, looking toward the downstream tip of Chase Island, where one dwarf wedgemussel was found.

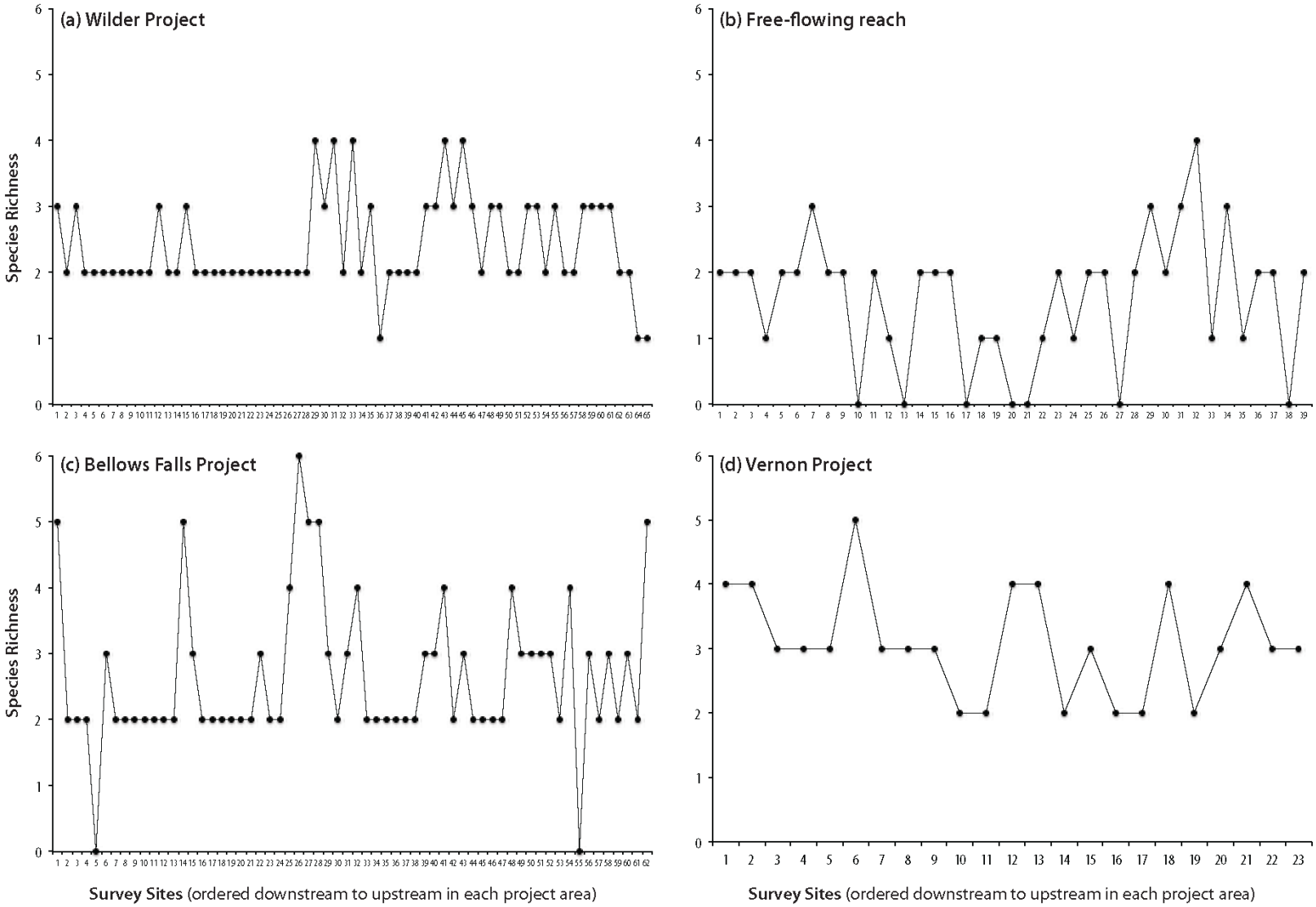


Figure 4-5. Mussel species richness at survey sites in the Wilder project (a), free-flowing reach (b), Bellows Falls project (c), and Vernon project (d). Sites are ordered downstream to upstream in each project.

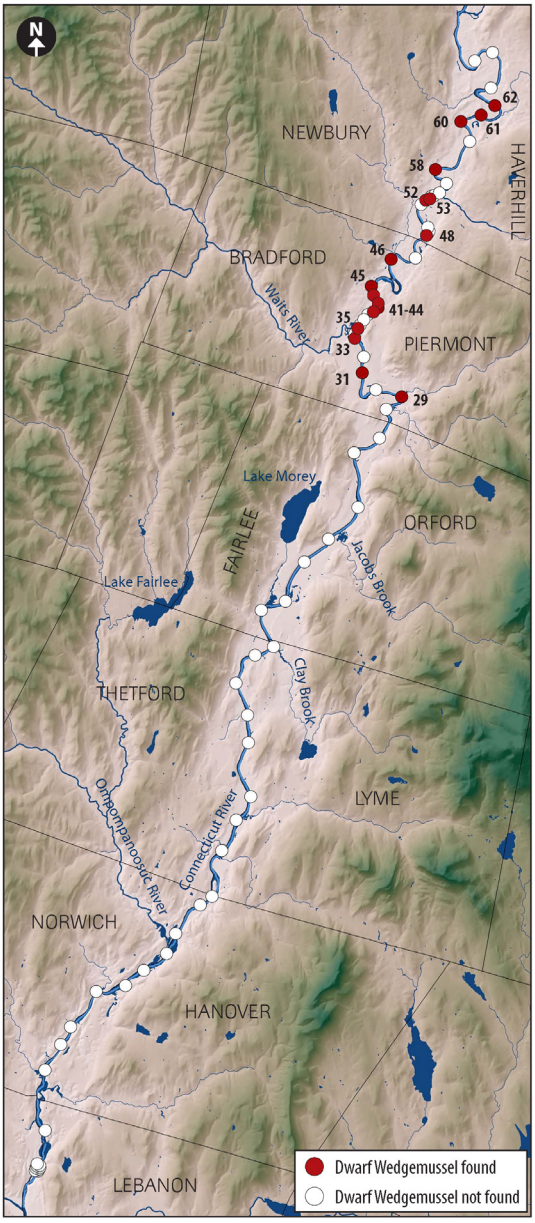


Figure 4-6. Survey sites where dwarf wedgemussel were found in the Wilder impoundment. See Appendix A for a fully labeled map.

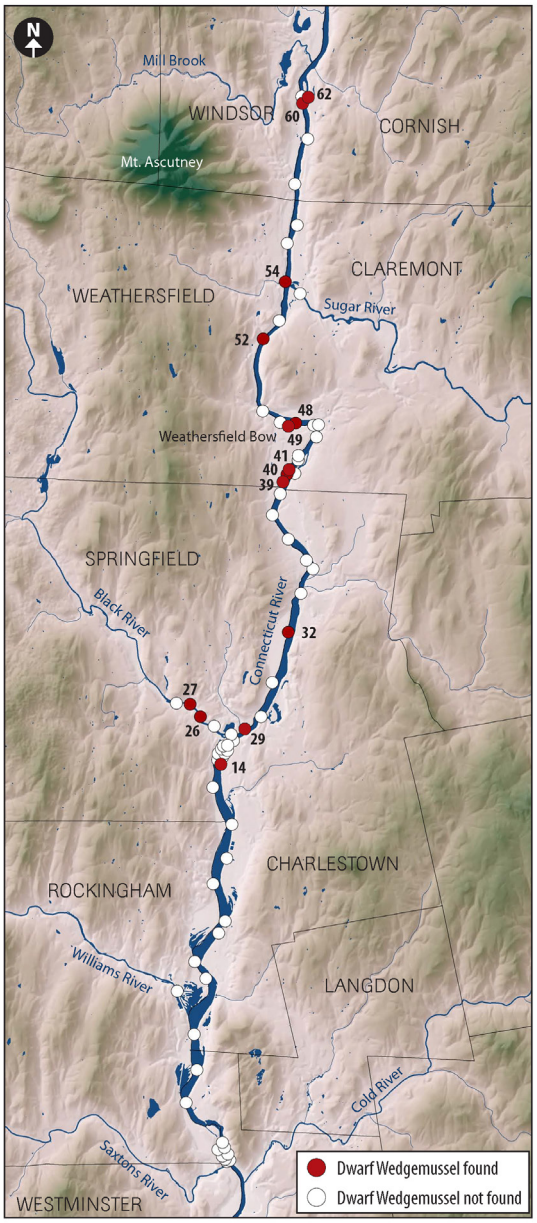


Figure 4-7. Survey sites where dwarf wedgemussel were found in the Bellows Falls impoundment. See Appendix A for a fully labeled map.

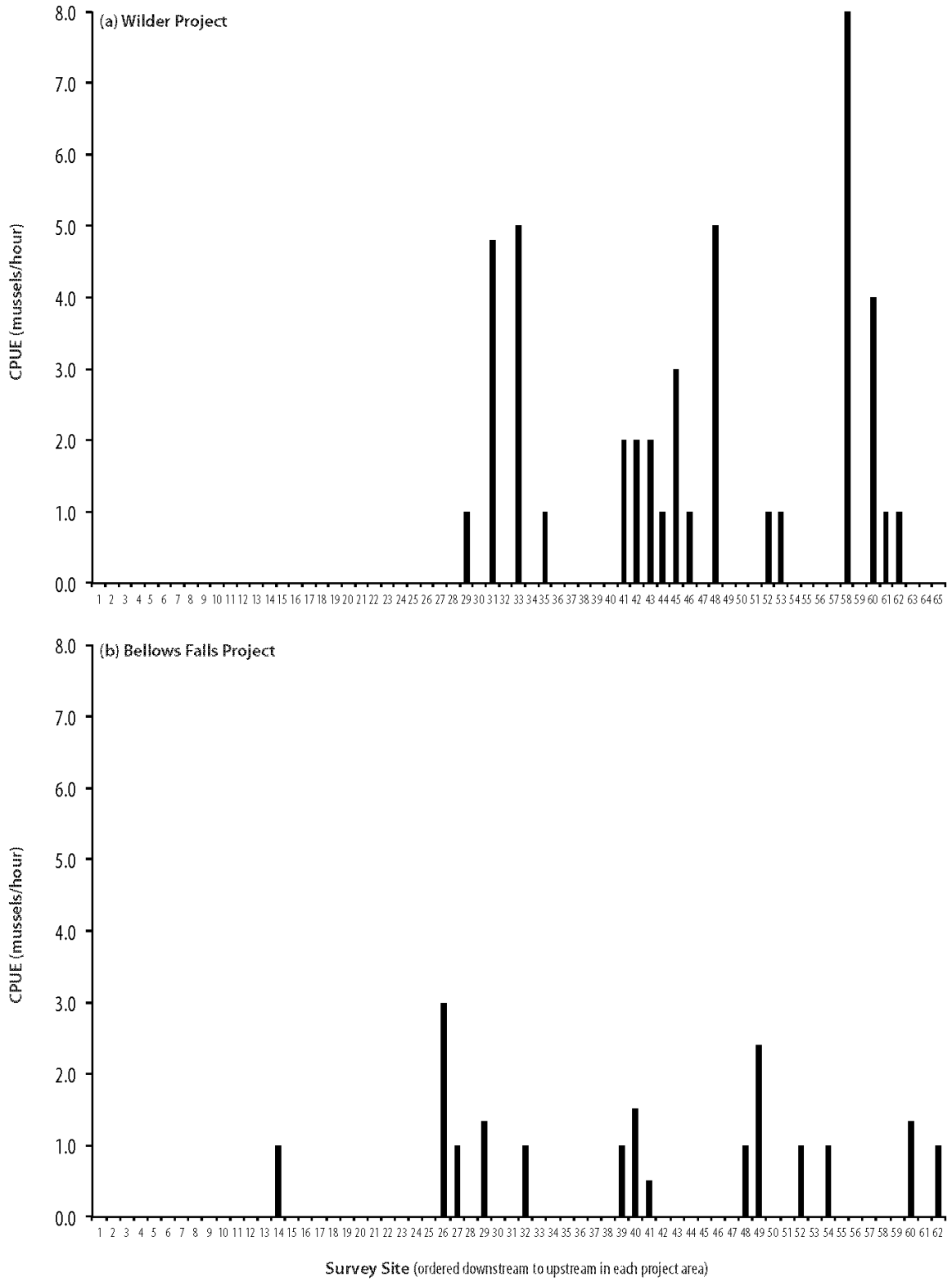


Figure 4-8. Dwarf wedgemussel CPUE for each survey site in the (a) Wilder impoundment and (b) Bellows Falls impoundment.

Table 4-2: Summary statistics for dwarf wedgemussel in areas where they were found.

Parameter	Wilder Impoundment	Bellows Falls Impoundment
Catch Statistics		
# Survey Sites	64	61
# of Sites Where Found	17	14
% of Sites Where Found	26.6	23.0
Total Count	45	24
Mean Count/Site	0.70	0.39
Max Count/Site	8	3
Mean CPUE (mussels/hr)	0.68	0.30
Max CPUE (mussels/hr)	8.00	3.00
Demographics and Condition Statistics		
Shell Condition	0.48	0.48
Average Length (mm)	26.77	31.50
Min Length (mm)	18.0	10.0
Max Length (mm)	37.0	44.5
Length Classes (mm)		
<20	2	1
20 - 24.9	14	0
25 - 29.9	14	6
30 - 34.9	14	9
35 - 39.9	1	4
40 - 44.9	0	2
45 - 49.9	0	0

Demographics and Shell Condition: Average shell length for all dwarf wedgemussel encountered was 28.4 mm, and individuals ranged from 10.0–44.5 mm (Table 4-2). There was evidence of recruitment in both impoundments. The shell condition index indicated moderate levels of shell erosion (0.48).

Habitat: Nearly all dwarf wedgemussel were found by SCUBA diving in water depths of 6-20 feet. They were found in a variety of substrate types, often with some combination of clay, silt, sand, and gravel. Some were found in pockets of these fine substrates in areas dominated by cobble, boulder, or bedrock. Most dwarf wedgemussel were found in areas with light to moderate flow velocities. They tended to be associated with two other uncommon mussel species—creeper and triangle floater.

4.3 Creeper

Distribution: Creeper were found in the Wilder, Bellows Falls, and Vernon impoundments, and in the free-flowing reach (Table 4-3); none were found immediately downstream from the three dams. In the Wilder impoundment, they were found at just two sites: W-29 and W-55, which were 27.3 and 36.3 miles upstream from the dam, respectively (see Figure 4-1). In the Bellows Falls impoundment, they were found at 14 survey sites (22.9 percent), including at all four sites in the lower Black River and ten sites in the Connecticut River widely spaced throughout much of the impoundment (see Figure 4-3). In the Vernon impoundment, they were found at four survey sites (18.2 percent) at least four miles apart (see Figure 4-4). Creeper were found at only two sites in the free-flowing reach, including at Site FF-7 and in the lower Ottaquechee River at Site FF-32 (see Figure 4-2).

Abundance: A total of 54 creeper were found (Table 4-3). Only two creeper were found in the Wilder impoundment, for an average CPUE of 0.03 mussels/hour. Forty-four creeper were found in the Bellows Falls impoundment, for an average of 0.72 mussels/site and an average CPUE of 0.73 mussels/hour. The highest CPUE recorded in the Bellows Falls impoundment was 18.0 mussels/hour at Site BF-26 in the Black River (18 animals). In fact, 75 percent (33 of 44) of the creeper found in the Bellows Falls impoundment were found in the Black River. Four creeper were found in the Vernon impoundment, for an average of only 0.27 mussels/site and an average CPUE of 0.27 mussels/hour. The highest CPUE recorded in the Vernon impoundment was 3.0 mussels/hour at Site V-21 (three animals). Only two creeper were found in the free-flowing reach, for an average CPUE of 0.04 mussels/hour. Figure 4-9 shows creeper CPUE by site.

Creeper from the Bellows Falls impoundment.

Table 4-3: Summary statistics for creeper in areas where they were found.

Parameter	Wilder Impoundment	Free-flowing Reach	Bellows Falls Impoundment	Vernon Impoundment
Catch Statistics				
# Survey Sites	64	39	61	22
# of Sites Where Found	2	2	14	4
% of Sites Where Found	3.1	5.1	23.0	18.2
Total Count	2	2	44	6
Mean Count/Site	0.03	0.05	0.72	0.27
Max Count/Site	1	1	18	3
Mean CPUE (mussels/hr)	0.03	0.04	0.73	0.27
Max CPUE (mussels/hr)	1.00	1.00	18.00	3.00
Demographics and Condition Statistics				
Shell Condition	0.00	0.25	0.27	0.29
Average Length (mm)	37.9	61.9	55.2	54.7
Min Length (mm)	31.0	60.0	31.0	47.0
Max Length (mm)	44.8	63.9	78.0	62.0
Length Classes (mm)				
<20	0	0	0	0
20 - 24.9	0	0	0	0
25 - 29.9	0	0	0	0
30 - 34.9	1	0	2	0
35 - 39.9	0	0	0	0
40 - 44.9	1	0	4	0
45 - 49.9	0	0	7	1
50 - 54.9	0	0	11	1
55 - 59.9	0	0	5	3
60 - 64.9	0	2	5	1
65 - 69.9	0	0	4	0
70 - 74.9	0	0	4	0
75 - 79.9	0	0	2	0

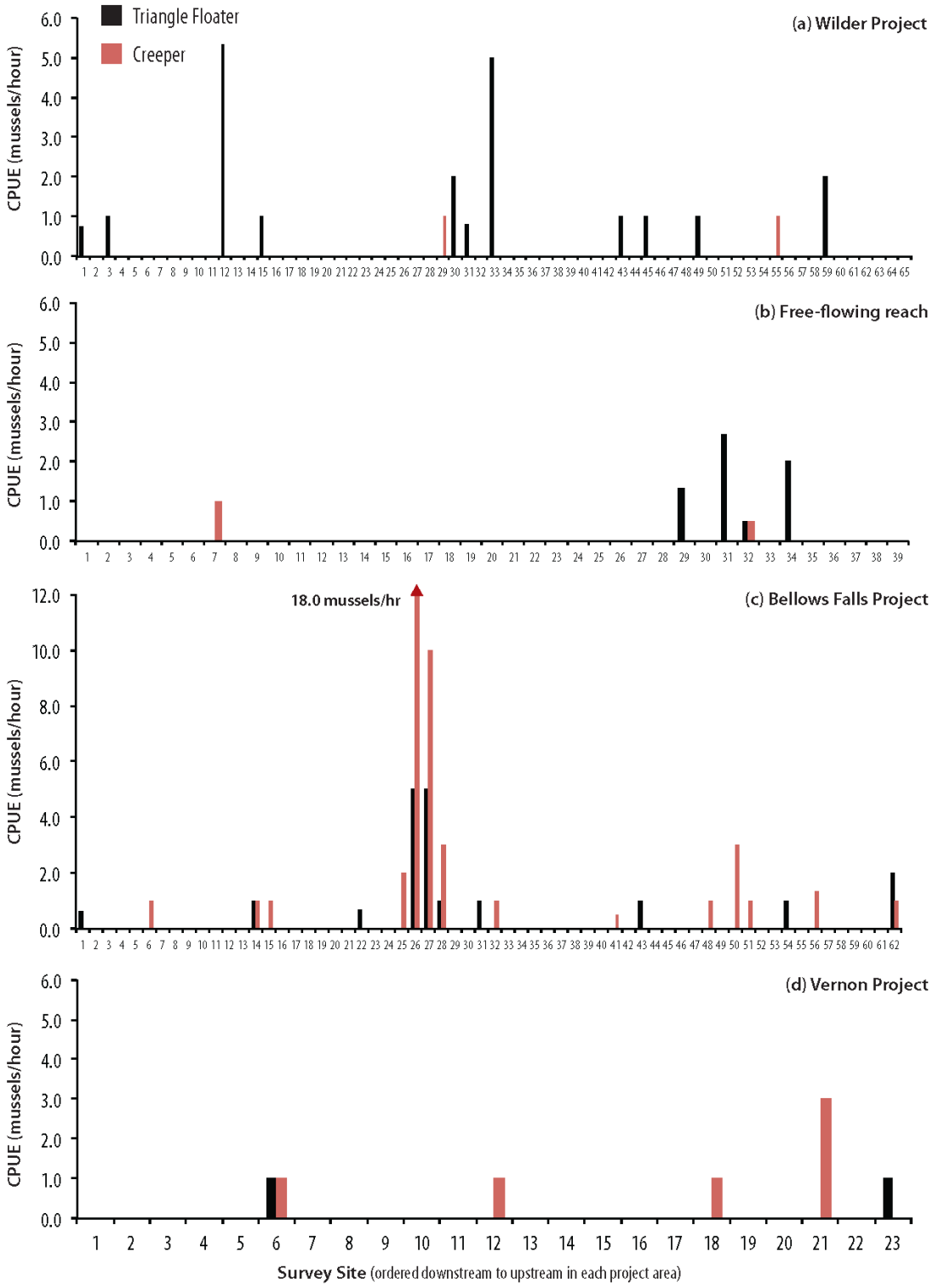


Figure 4-9. Triangle floater and creeper CPUE for each survey site in the Wilder project (a), free-flowing reach (b), Bellows Falls project (c), and Vernon project (d).

Demographics and Shell Condition: Average shell length for all creeper encountered was 54.8 mm (range = 31.0–78.0 mm) (Table 4-3). Average shell length was nearly identical in the Vernon and Bellows Falls impoundments, although there was a greater size range in the Bellows Falls impoundment (31.0–78.0 mm vs. 47.0–62.0 mm). The shell condition index was similar in both project areas (0.29 and 0.27), suggesting light-moderate levels of shell erosion. Low sample sizes precluded more robust demographic and shell condition analyses.

Habitat: Nearly all creeper were found in water depths between 3–15 feet. They were found in a variety of substrate types, often with some combination of clay, silt, sand, and gravel. Some were found in pockets of these fine substrates in areas dominated by cobble, boulder, or bedrock. All were found in areas with light to moderate flow velocities. They tended to co-occur with dwarf wedgemussel and triangle floater.

4.4 Triangle Floater

Distribution: Triangle floater were found in all three impoundments, in the free-flowing reach, and below both the Wilder and Bellows Falls dams (Table 4-4). Triangle floater were found at 11 survey sites (17.2 percent) widely spaced throughout the Wilder impoundment (see Figure 4-1). In the Bellows Falls impoundment, they were found at nine survey sites (14.8 percent), including at all three sites in the lower Black River and six sites in the Connecticut River between Site BF-14 and the upper end of the impoundment (see Figure 4-3). In the Vernon impoundment, they were found at two survey sites nearly 20 miles apart (see Figure 4-4). They were found at just four sites (10.2 percent) in the free-flowing reach between sites FF-29 and FF-34, including in the mouth of the Ottaquechee River (Site FF-32) (see Figure 4-2).

Abundance: A total of 53 triangle floater were found (Table 4-4). Nineteen triangle floater were found in the Wilder impoundment, for an average of 0.30 mussels/site and an average CPUE of 0.31 mussels/hour. The highest CPUE recorded in the Wilder impoundment was 5.3 mussels/hour (4 mussels) at Site W-12 in the lower impoundment. Eighteen triangle floater were found in the Bellows Falls impoundment, for an average of 0.30 mussels/site and an average CPUE of 0.29 mussels/hour. The highest CPUE recorded in the Bellows Falls impoundment was 5.0 mussels/hour at Sites BF-26 and BF-27, both of which were in the Black River. In fact, 61.1 percent (11 of 18) of the triangle floater found in the Bellows Falls impoundment were found in the Black River. Two triangle floater were found in the Vernon impoundment, for an average of only 0.09 mussels/site and an average CPUE of 0.09 mussels/hour. Six live triangle floater were found in the free-flowing reach, with an average CPUE of 0.17 mussels/hour. Triangle floater were also found downstream from the Wilder dam (3 mussels, average CPUE = 0.75 mussels/hour) and Bellows Falls dam (5 mussels, average CPUE = 0.63 mussels/hour). Figure 4-9 shows triangle floater CPUE by site.

Table 4-4: Summary statistics for triangle floaters in areas where they were found.

Parameter	Wilder Impoundment	Below Wilder Dam	Free-flowing Reach	Bellows Falls Impound-ment	Below Bellows Falls Dam	Vernon Impound-ment
Catch Statistics						
# Survey Sites	64	8	39	61	8	22
# of Sites Where Found	10	2	4	9	4	2
% of Sites Where Found	15.6	25.0	10.3	14.8	50.0	9.1
Total Count	19	3	3	18	5	2
Mean Count/Site	0.30	0.38	0.08	0.30	0.63	0.09
Max Count/Site	5	2	2	5	2	1
Mean CPUE (mussels/hr)	0.31	0.75	0.17	0.29	0.63	0.09
Max CPUE (mussels/hr)	5.33	4.00	2.00	5.00	2.00	1.00
Demographics and Condition Statistics						
Shell Condition	0.24	0.17	0.00	0.29	0.55	0.38
Average Length (mm)	36.07	51.00	32.42	39.67	55.00	32.00
Min Length (mm)	22.4	46.0	23.0	25.0	43.0	28.0
Max Length (mm)	47.0	58.0	41.8	51.0	65.0	36.0
Length Classes (mm)						
<20	0	0	0	0	0	0
20 - 24.9	2	0	1	0	0	0
25 - 29.9	2	0	0	3	0	1
30 - 34.9	5	0	0	3	0	0
35 - 39.9	4	0	0	2	0	1
40 - 44.9	2	0	1	4	1	0
45 - 49.9	3	2	0	4	1	0
50 - 54.9	1	0	0	2	0	0
55 - 59.9	0	1	0	0	1	0
60 - 64.9	0	0	0	0	1	0
65 - 69.9	0	0	0	0	1	0

Demographics and Shell Condition: Average shell length for all triangle floater encountered was 39.9 mm (range = 22.4–65.0 mm) (Table 4-4). The overall shell condition index was 0.30, indicating light-moderate levels of shell erosion. Low sample sizes precluded more robust demographic and shell condition analyses.

Habitat: Nearly all triangle floater were found in water depths ranging 3–15 feet. They were found in a variety of substrate types, often with some combination of

clay, silt, sand, gravel, and small cobble. Most were found in areas with light to moderate flow velocities, though the animals found at the upstream end of the Wilder and Vernon impoundments, and below the Wilder and Bellows Falls dams, were in areas with stronger flows. They tended to co-occur with dwarf wedgemussel and creeper.

4.5 Alewife Floater

Distribution: Alewife floater was the third most common species overall. Alewife floater were found in the Bellows Falls and Vernon Project areas, both upstream and downstream from the dams (Table 4-5). In the Bellows Falls impoundment, they were found at only two survey sites, including at one site in the lower Black River (Site BF-26) and one site toward the upper end of the impoundment (Site BF-58). In the Vernon impoundment, they were found at 14 survey sites (63.6 percent) (see Figure 4-1). None were found at survey sites within the Wilder project boundary, or in the free-flowing reach.

Live alewife floater in its natural position, observed downstream from the Bellows Falls dam.

Abundance: A total of 460 alewife floater were found (Table 4-5). Only two alewife floater were found in the Bellows Falls impoundment, for an average of 0.04 mussels/site and an average CPUE of 0.05 mussels/hour; while 166 were found in the Vernon impoundment, for an average of 7.55 mussels/site and an average CPUE of 8.44 mussels/hour. Alewife floater were numerous downstream from the Bellows Falls dam (217 mussels, average CPUE = 29.7 mussels/hour) and Vernon dam (75 mussels, average CPUE = 18.7 mussels/hour). Figure 4-10 shows alewife floater CPUE by site in the Vernon project.

Alewife floater

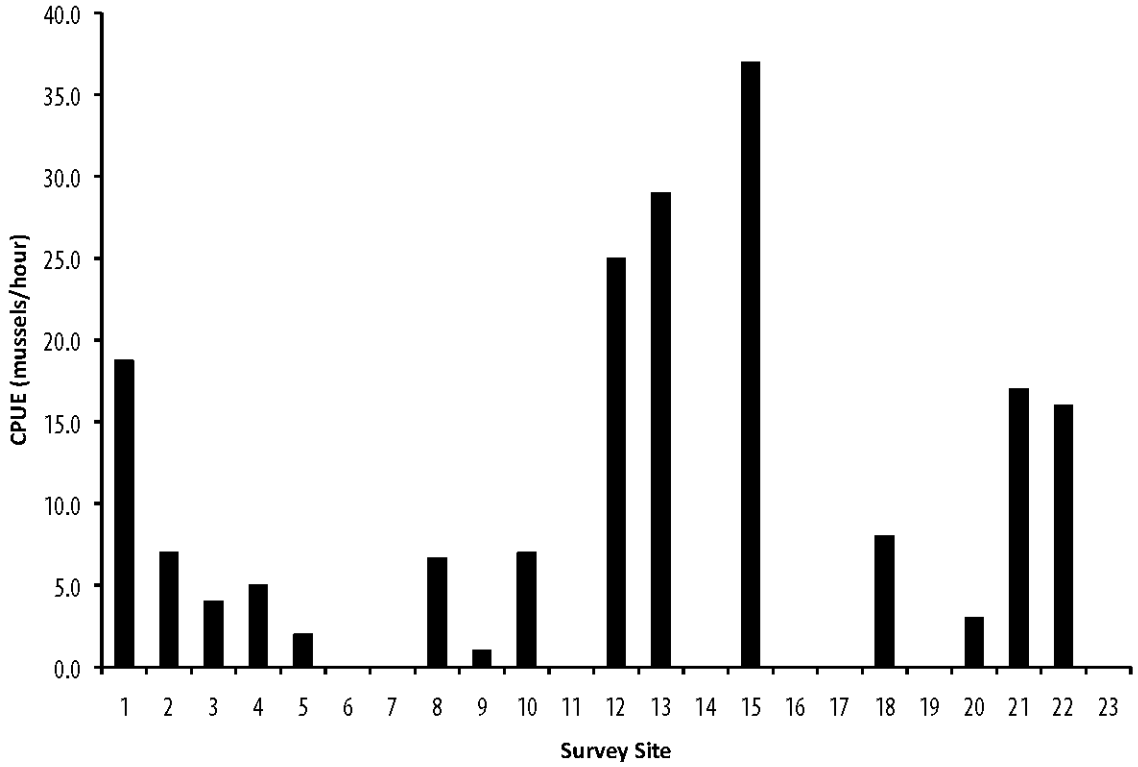


Figure 4-10. Alewife floater CPUE for each survey site in the Vernon project.

Table 4-5: Summary statistics for eastern elliptio, eastern lampmussel, eastern floater, and alewife floater in areas where they were found.

Catch Statistic	Wilder Impound-ment	Below Wilder Dam	Free-Flowing Reach	Bellows Falls Impound-ment	Below Bellows Falls Dam	Vernon Impound-ment	Below Vernon Dam
Eastern Elliptio							
# of Sites Where Found	64	7	32	59	8	22	8
% of Sites Where Found	100.0	87.5	82.1	96.7	100.0	100.0	100.0
Mean Abundance[a]	5.25	2.38	2.10	4.98	5.38	4.27	4.50
Eastern Lampmussel							
# of Sites Where Found	60	5	24	59	8	21	7
% of Sites Where Found	93.8	62.5	61.5	96.7	100.0	95.5	87.5
Mean Abundance[a]	2.50	1.50	0.90	3.38	2.63	2.18	1.75
Eastern Floater							
# of Sites Where Found	0	0	0	2	1	4	5
% of Sites Where Found	0.0	0.0	0.0	3.3	12.5	18.2	62.5
Total Count	0	0	0	8	1	6	20
Mean Count Per Site	0.00	0.00	0.00	0.13	0.13	0.27	2.50
Max Count	0	0	0	7	1	3	8
Mean CPUE (mussels/ hr)	0.00	0.00	0.00	0.13	0.13	0.27	5.00

Catch Statistic	Wilder Impound-ment	Below Wilder Dam	Free-Flowing Reach	Bellows Falls Impound-ment	Below Bellows Falls Dam	Vernon Impound-ment	Below Vernon Dam
Max CPUE (mussels/ hr)	0.00	0.00	0.00	7.00	1.00	3.00	16.00
Alewife Floater							
# of Sites Where Found	0	0	0	2	7	14	3
% of Sites Where Found	0.0	0.0	0.0	3.3	87.5	63.6	37.5
Total Count	0	0	0	2	217	166	75
Mean Count Per Site	0.00	0.00	0.00	0.03	27.13	7.55	9.38
Max Count	0	0	0	1	50	37	41
Mean CPUE (mussels/ hr)	0.00	0.00	0.00	0.04	29.75	7.62	18.75
Max CPUE (mussels/ hr)	0.00	0.00	0.00	1.33	50.00	37.00	82.00

[a] See Table 3-2 for abundance categories for eastern elliptio and eastern lampmussel.

Demographics and Shell Condition: Neither shell length nor shell condition were recorded for all alewife floater. Generally, both young animals (30-50 mm) and older animals (>120 mm) were observed downstream from both the Bellows Falls and Vernon dams, and in the Vernon impoundment. The alewife floater found toward the upstream end of the Bellows Falls impoundment was 71.0 mm in length; based on annular rings it was probably 7–10 years old. Alewife floater inhabiting silt and sand substrates toward the downstream end of the Vernon impoundment exhibited light shell erosion, whereas those animals living in gravel and cobble substrates and areas with higher flow velocities exhibited moderate to heavy shell erosion.

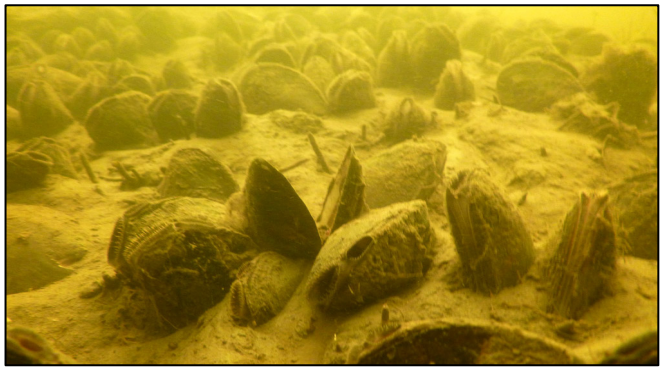
Habitat: Alewife floater were found in water depths between 3–20 feet. They were found in a variety of substrate types, often with some combination of clay, silt, sand, gravel, and small cobble. Most were found in a broad range of flow velocities, including in strong flows downstream from the Bellows Falls and Vernon dams.

4.6 Eastern Elliptio

Eastern elliptio was the most widespread and abundant mussel species (Table 4-5). It was found at 95.2 percent of all survey sites and comprised 65–95 percent of the mussels observed. Eastern elliptio were found at only two sites in impoundments, the project-affected mouths of the Sugar River and Williams River. They were least common in the free-flowing reach, where they were found at 32 of 39 sites (82 percent).

Abundance was considered High to Extremely High (abundance indices of 5, 6, or 7) at 48 sites (75 percent) in the Wilder impoundment (Figure 4-11), 41 sites (67.2 percent) in the Bellows Falls impoundment, and at eight sites (36.3 percent) in the Vernon impoundment. Elliptio were also very common downstream from the Bellows Falls and Vernon dams, but far less common downstream from the Wilder dam. Though highly variable, elliptio abundance was generally lowest toward the upper end of each impoundment. There was strong evidence of recruitment (small animals less than 30 mm in length) throughout all three impoundments and mussels typically exhibited light to moderate levels of shell erosion.

Eastern elliptio in its natural position, observed downstream from the Bellows Falls dam.



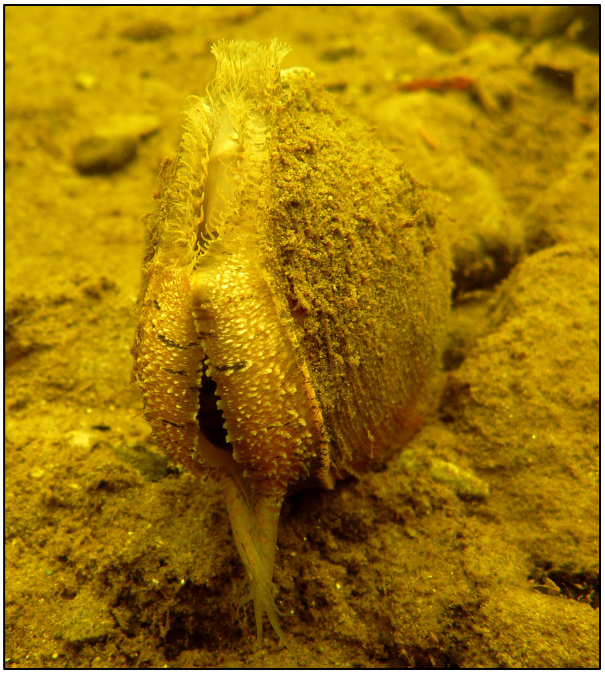
Mussel bed comprised almost entirely of eastern elliptio

Eastern elliptio were less common in the free-flowing reach; the mean abundance index of 2.10 was less than half of that recorded for the Wilder, Bellows Falls, and Vernon projects. except immediately below the Wilder dam (where the mean index was 2.38). In the free-flowing reach, there was notably higher elliptio density just below Sumner Falls (Site FF-26) and at the mouth of the Ottaquechee River (Site FF-32). Elliptio found in the free-flowing reach tended to be larger, and exhibited moderate to high levels of shell erosion. Elliptio occupied a broad range of habitats, from near riverbanks in only 3–4 feet of water, to the middle of the channel in water depths greater than 25 feet.

4.7 Eastern Lampmussel

Eastern lampmussel was the second-most widespread and abundant mussel species (Table 4-5). They were found at 87.6 percent of the survey sites, including at all but four, two, and one survey sites in the Wilder, Bellows Falls and Vernon impoundments, respectively. They were found downstream from each of the dams, but usually at lower abundances than in impoundments. In the free-flowing reach, they were found at only 61.5 percent of the sites (24 of 39).

Abundance was considered High to Very High (abundance indices of 5 or 6) at five sites (7.8 percent) in the Wilder impoundment (Figure 4-11) and at 11 sites (18.0 percent) in the Bellows Falls impoundment. Abundance was considered Very Low to Low, or Absent (abundance indices of 0, 1, or 2) at 29 sites (45.3 percent) in the Wilder project, 16 sites (26.2 percent) in the Bellows Falls project, and 15 sites (65.2 percent) in the Vernon project. In the free-flowing reach, eastern lampmussel were not found at 15 sites, had very low abundance (index = 1) at 18 sites, had low abundance (index = 2) at three sites, and the overall average abundance index was 0.91, which was substantially lower than any of the other study areas. The only location in the free-flowing reach where eastern lampmussel were numerous (index = 4) was at Site FF-26, below Sumner Falls.



Female eastern lampmussel displaying mantle lures.

Though highly variable, eastern lampmussel were most abundant in the downstream third of the Wilder and Vernon impoundments, and also in the middle third of the Bellows Falls impoundment. Abundance generally diminished toward the upper end of all three impoundments. There was evidence of recruitment (small animals less than 50 mm in length), and large numbers of gravid females were observed luring fish and discharging glochidia. Although eastern lampmussel occupied a broad range of habitats, they seemed to be more prevalent in nearshore areas at depths of 3–10 feet, in clay, silt, sand, and gravel substrates.

Eastern lampmussel.

4.8 Eastern Floater

Eastern floater were found downstream from the Bellows Falls and Vernon dams, at two locations in the Bellows Falls impoundment and at four locations in the Vernon impoundment (Table 4-5). A total of 35 animals were found, including eight in the lower Black River in the Bellows Falls impoundment, one downstream of the Bellows Falls dam, six in the lower half of the Vernon impoundment, and 20 downstream of the Vernon dam. Some of the animals identified above or below the Vernon dam may have been alewife floater, as young animals of these two species are difficult to distinguish without sacrificing (i.e., killing) them.

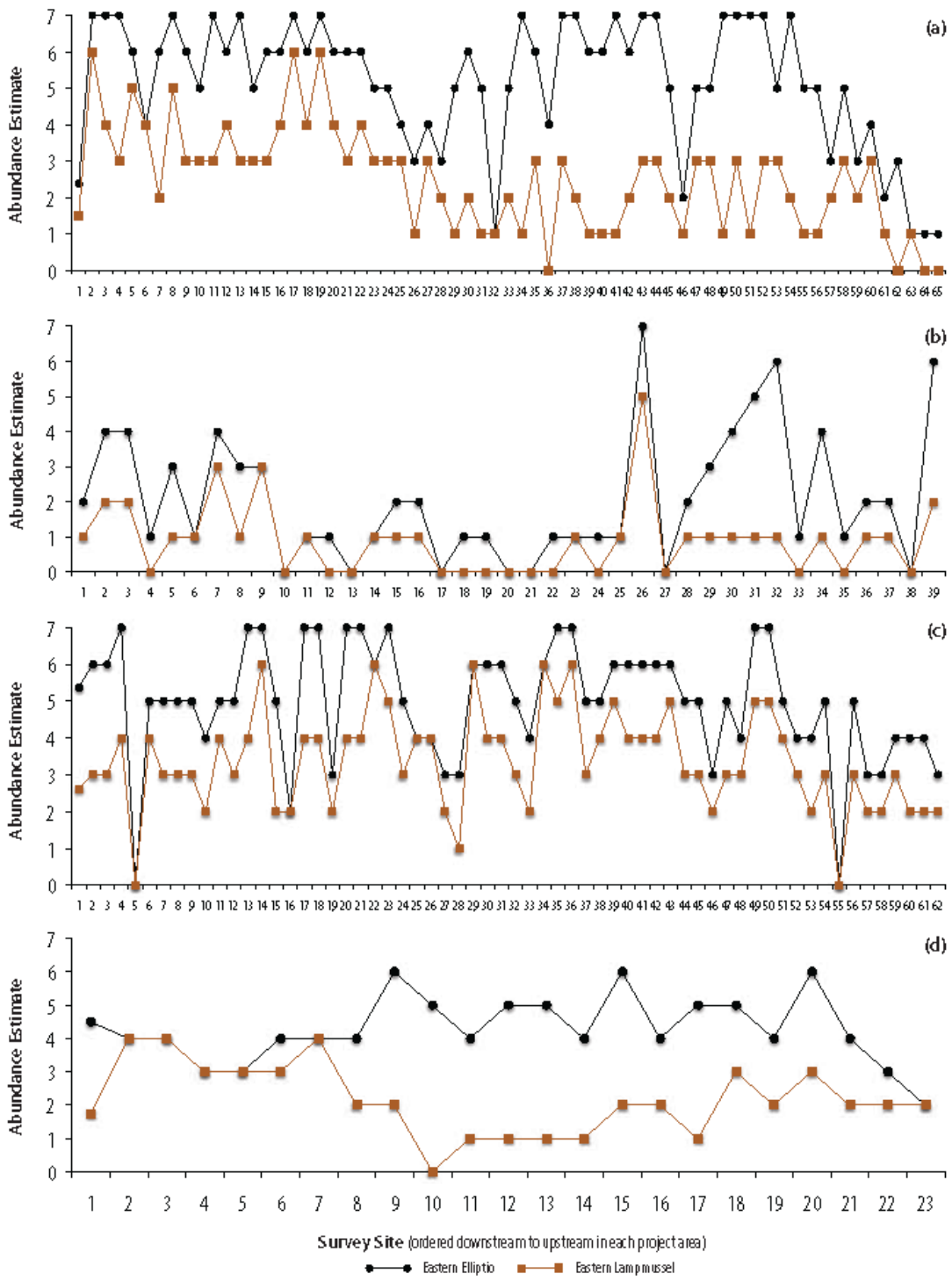


Figure 4-11. Abundance estimates for eastern elliptio and eastern lampmussel in the Wilder project (a), free-flowing reach (b), Bellows Falls project (c), and Vernon project (d). See Table 3-2 for definition of the abundance categories.

5. DISCUSSION

5.1 Wilder Project

The Wilder impoundment had the lowest species richness (5) of the three impoundments, lacking eastern floater and alewife floater, and nearly lacking creeper (just two animals were found). However, mussels were abundant in the impoundment—eastern elliptio was abundant throughout most of the impoundment and eastern lampmussel was numerous in its lower half. Triangle floater were found infrequently and at fairly low abundance throughout the impoundment.

Dwarf wedgemussel were found consistently along a 14-mile reach of the Wilder impoundment, from 27 to 41 miles upstream from the dam. This range generally corresponds to the 16-mile range documented in 2006 (Nedeau 2006), the main difference being that animals were found slightly further downstream in 2006 than in 2011 or 2013. Most of the 2011 and 2013 survey sites were in slightly different locations than the 2006 survey sites, confirming an assertion in the 2006 report that dwarf wedgemussel could be found almost anywhere within the core range with careful SCUBA surveys.

The average CPUE for dwarf wedgemussel in the Wilder impoundment was more than two times higher than it was in the Bellows Falls impoundment. Dwarf wedgemussel were usually found at water depths from 8 to 20 feet, often near the toe of the steep-sloped banks or toward the center of the river channel. Areas of the river where dwarf wedgemussel were found typically had light to moderate flow velocities, or at least featured zones of hydraulic refuge near shore, even where the flows in the middle of the channel were quite strong. All dwarf wedgemussel were found by SCUBA diving; snorkeling along the shallow shorelines proved to be ineffective for finding them. Tessellated darters were observed at most of the survey sites in the Wilder impoundment in 2013 (Appendix B), and they were typically found closer to shorelines where habitat was more complex (e.g., among or near beds of submergent vegetation, woody debris, or rocky slopes with interstitial spaces).

The mussel community immediately downstream from the Wilder dam exhibited low species richness (3) and low abundance compared to the other survey areas. Strong flows, rocky substrates, and high shear stress may limit mussel densities downstream from the dam.

5.2 Free-flowing Reach

The mussel community in the free-flowing reach exhibited low species richness and low abundance compared to the other survey areas. Dwarf wedgemussel were not found, even within two areas that historically contained them (in the pool downstream from Sumner Falls and near the Cornish Covered Bridge) (Gabriel 1995). Only one live creeper was found in the mainstem Connecticut River (at Site FF-7) and one was also found in the mouth of the Ottaquechee River (Site FF-32).

Six live triangle floater were found, mostly downstream from, or within, the mouth of the Ottaquechee River.

Eastern elliptio were absent at seven sites in the free-flowing reach and had a mean abundance index (2.10) less than half of all other study areas except immediately below Wilder dam (2.38). There was notably higher elliptio density just below Sumner Falls (Site FF-26), within and downstream from the mouth of the Ottaquechee River (Sites FF-30, FF-31, and FF-32), and at Site FF-39 at the upper end of the reach. Elliptio tended to be large, and exhibited moderate to high levels of shell erosion. Eastern lampmussel, another species common elsewhere in the Connecticut River, was absent from 15 sites in the free-flowing reach and, where found, occurred at very low densities. The area just below Sumner Falls (Site FF-26) was the only location in the free-flowing reach where eastern lampmussel were numerous. In addition, tessellated darters were observed at only seven (17.9 percent) survey sites and always at very low densities (fewer than five fish per site) (Appendix B. They were typically found closer to shorelines where habitat was more complex (e.g., among or near beds of submergent vegetation, woody debris, or rocky slopes with interstitial spaces).

The distribution of mussels in the free-flowing reach may be influenced by challenging habitat conditions, especially strong water velocities, rocky substrates, shallow water, high shear stress, and possibly ice scour during the winter. In deeper areas of the river, where fine materials (e.g., silt, sand, and fine gravel) accumulate, eastern elliptio and eastern lampmussel densities tended to be higher. This was particularly true below Sumner Falls and near the mouth of the Ottaquechee River. The reach between the Cornish Covered Bridge and Chase Island was geomorphically and hydraulically complex, and contained small patches of high-quality mussel habitat where eastern elliptio were numerous but where few other species were found.

5.3 Bellows Falls Project

Species richness in the Bellows Falls impoundment (7) was higher than it was in the other impoundments or project tailwaters, yet the density and distribution of rare species suggests that these populations may not be large. Although dwarf wedgemussel were found over a 17-mile distance, very few (24) animals were observed and the distances between them were great. The same was generally true for triangle floater and creeper, two species that have similar habitat preferences and usually co-occur with dwarf wedgemussel. Eastern elliptio and eastern lampmussel are only two species with robust populations in the Bellows Falls impoundment. The Bellows Falls impoundment contains a tributary population of dwarf wedgemussel, in the lower Black River. This population was first documented in 1999 (Ferguson 1999). Likewise, the highest concentration of creeper and triangle floater in the Bellows Falls impoundment were found in the lower Black River.

Tessellated darters were observed at most of the survey sites in the Bellows Falls impoundment in 2013 (Appendix B), and they were typically found closer to

shorelines where habitat was more complex (e.g., among or near beds of submergent vegetation, woody debris, or rocky slopes with interstitial spaces).

The geography of the impoundment features two physically distinct reaches. Downstream of Wethersfield Bow, the river is wider, flow velocities are slower, the channel is deeper, and the substrate is generally finer (silt, sand, and fine gravel). Upstream of Wethersfield Bow, the dam's influence is less obvious and the river is slightly narrower, flow velocities are stronger, the channel is shallower, and there is a higher proportion of gravel, cobble, and boulder substrates.

The mussel community downstream from the Bellows Falls dam contained five of the same species that occurred throughout the Vernon impoundment, and among the highest densities of eastern elliptio and alewife floater encountered during the entire survey. This was expected, as the Bellows Falls dam is only about six miles upstream from the upper end of the Vernon impoundment, and because American shad, the primary host fish for alewife floater, reach their upstream limit in the Connecticut River in the tailwaters of Bellows Falls dam. Two alewife floater were also found in the Bellows Falls impoundment, though these were likely either the result of overland transport of American shad (carrying alewife floater glochidia) above the Bellows Falls dam by New Hampshire Fish & Game, or a small number of shad that may have ascended fishways designed for only adult Atlantic salmon.

5.4 Vernon Project

The mussel community at the Vernon project area, both in the impoundment and downstream from the dam, was dominated by eastern elliptio. This species was found at every survey location and outnumbered other species by at least 10:1, except in the lowermost part of the impoundment (Sites V-2 through V-7) near the dam, where eastern lampmussel were nearly as abundant.

Of the three impoundments surveyed, Vernon was the only one with a significant population of the alewife floater, a species that relies on American shad and alewife as hosts and whose presence in the Vernon impoundment can be attributed to anadromous fish passage at three facilities downstream: Vernon dam, Turners Falls dam, and Holyoke dam (Smith 1985, Nedeau 2008a).

The very low numbers of triangle floater and creeper in the Vernon impoundment were surprising; both of these species are often numerous in the types of habitats present in the Vernon impoundment, especially in the more free-flowing middle and upper reaches. The survey also failed to detect dwarf wedgemussel, which corroborates results of the few recent surveys conducted in the impoundment (Nedeau 2005). However, dwarf wedgemussel were found in the impoundment near Brattleboro 30 years ago (Vermont Fish and Wildlife, unpublished).

The four species found at the sites downstream from the Vernon dam were the same four species found consistently in the reach of the Connecticut River between the Vernon dam and the Turners Falls dam about 19 miles downstream (Biodrawversity 2012).

5.5 Challenges for Research and Monitoring

Background: Six stakeholders submitted similar study requests for the dwarf wedgemussel, all relating to the effects of Wilder and Bellows Falls project operations on the species. Five objectives were stated in each study request: three were related to baseline population studies, and two were focused specifically on the potential effects of flow regime/water level fluctuations on mussel behavior or habitat. The final FERC-approved study plan outlined an adaptive, two-phase plan that met the objectives of the study requests and would benefit from collaboration with resource agencies throughout the design and implementation of the study. The primary reason for a two-phase approach was that additional surveys were needed to determine if, and where, dwarf wedgemussel populations were large enough to permit quantitative sampling, behavioral studies, or certain types of flow-related analyses, especially in areas of the river where flow fluctuations are greatest. The 2011 survey did not detect any "populations" large enough to permit certain types of quantitative sampling, monitoring, or analyses. Thus, the most important task for 2013 was to identify concentrations of dwarf wedgemussel (if present) and/or high-quality habitat, to help inform the development of an effective and realistic Phase 2 study. Phase 2 (2014) might include quantitative mussel sampling, behavioral studies using underwater video (if considered feasible based on Phase 1 results), and an overall assessment of the effects of flow regime/project operations on dwarf wedgemussel, co-occurring species, and their habitat.

Sampling and Monitoring: Based on the 2011 and 2013 mussel surveys at 210 sites, and the existing mussel data from 1990-2010, dwarf wedgemussel populations are not large enough to permit certain types of quantitative sampling, monitoring, or analysis. In the free-flowing reach, no live or dead dwarf wedgemussel were found at the 39 survey sites, the fluvial mussel species commonly associated with dwarf wedgemussel (triangle floater and creeper) were also extremely rare, and very few tessellated darters were observed. Even eastern elliptio and eastern lampmussel, which are typically widespread and abundant in the Connecticut River, exhibit patchy distribution and low-density populations in the free-flowing reach. Based on the mussel survey results and documentation of habitat conditions, we do not recommend quantitative sampling or *in situ* monitoring of dwarf wedgemussel in the free-flowing reach simply because they may not even occur there, or are at such low densities that it is impractical to study them using quantitative methods. Likewise, it is impractical to plan *in situ* video monitoring of dwarf wedgemussel in the free-flowing reach because of the challenges of finding even one live animal to observe, and the challenges of adequately replicating behavioral observations while controlling for confounded variables.

The 2011 and 2013 field studies detected dwarf wedgemussel in the upper Wilder and Bellows Falls impoundments, but almost always at very low densities. They were found at only about one-fourth of the sites in both impoundments, and where they were found, a typical survey lasting 1-2 person-hours typically detected fewer than two or three animals. In contrast, at one location in the Connecticut River in the Northern Macrosite near Lunenberg (Vermont), several miles upstream from the

Moore Reservoir and well upstream of the Wilder project, biologists found more dwarf wedgemussel in one hour than were found throughout the entire Wilder and Bellows Falls projects (Nedeau 2002). Co-occurring fluvial species (i.e., triangle floater and creeper) were also rare in both impoundments, except in the lower Black River. Such low population densities precludes the use of certain types of quantitative monitoring; this same challenge was recognized in the mid-1990s when Gabriel (1995) recommended a CPUE monitoring protocol using timed searches within transects to provide comparable indices of dwarf wedgemussel population density and size class distribution. More robust quantitative sampling was discussed but not recommended due to low population densities. Almost 20 years later, we concur with this same conclusion.

Aside from a dwarf wedgemussel population that appears to be patchy and at very low density, dwarf wedgemussel appear to occur only in surveyed areas of the Connecticut River where water level fluctuations are minimal or non-existent. The shallowest depth at which dwarf wedgemussel were found was approximately 6 feet, though mussels were more typically found at depths of 10 to 20 feet. These mussels are not at risk of being dewatered during licensed operating range in either the Wilder or Bellows Falls projects, much less the normal operating range (Wilder: elevation 382.0 to 384.5 feet MSL, Bellows Falls: elevation 289.6 to 291.4 feet MSL). The channel morphometry in areas where dwarf wedgemussel were found includes steep banks, and mussels (all species) were always found at highest densities near the toe of the slope or in the flatter areas toward the deeper parts of the channel, and were never common in shallow areas. Overall, almost all dwarf wedgemussel detected in 2011 and 2013 were found in locations that may experience minimal or no changes associated with daily water level fluctuations, at least from a mussel's perspective. Therefore, *in situ* monitoring is not a promising line of inquiry, nor will certain types of sampling or analysis provide much insight into effects of project operations on dwarf wedgemussel.

Recommendations: Details of Phase 2 mussel studies should be discussed in light of the 2011 and 2013 survey results. From the FERC-approved freshwater mussel study plan, there were three objectives/tasks that were considered for Phase 2 (2014). These are as follows:

Task 3 (Phase 2): "*Collect statistically sound and repeatable data, using quantitative methods, to determine density, age-class distribution, and habitat for dwarf wedgemussel and co-occurring mussel species*." Based on low population densities, we do not recommend quadrat sampling or other rigorous quantitative methods. Instead, we recommend establishing a series of linear transects in several areas and conducting semi-quantitative (timed) searches along each transect, as described in Gabriel (1995). It is possible that dwarf wedgemussel will not be detected during this sampling; thus, the searches should also count and characterize all co-occurring mussel species to determine their density, age-class distribution, and habitat. Biologists should also conduct qualitative surveys in areas near the transects to increase chances of detecting dwarf wedgemussel.

Any dwarf wedgemussel encountered should be tagged, and data on shell length, shell condition, gravidity, habitat, and location should be recorded for each. *Potential* transect locations, based on the presence of dwarf wedgemussel and/or suitable habitat, are as follows:

Wilder Project

- Near Bedell Bridge State Park (2 transects)
- Near Waits River confluence (2 transects)

Free-flowing reach

- Sumner Falls (2 transects)
- Cornish Covered Bridge to Chase Island (4 transects)

Bellows Falls Project

- Upper Bellows Falls impoundment below Chase Island (2 transects)
- Wilgus State Park (2 transects)
- Wethersfield Bow (4 transects)
- Lower Black River (2 transects)

Task 4 (Phase 2): "*Observe and record behavior of dwarf wedgemussel and co-occurring mussel species in situ during varying flow conditions."* We do not recommend *in situ* monitoring of dwarf wedgemussel, but video monitoring of co-occurring mussel species may be appropriate in some instances. It may be more appropriate to use photo or video technology to document changes in wetted area and other key habitat parameters, rather than behavior of individual mussels, during daily flow fluctuations. This could be part of a comprehensive study of the effect of water level fluctuations on instream habitat and the mussel community (see next task).

Task 5 (Phase 2): "*Assess the potential effects of flow regime on dwarf wedgemussel, co-occurring species, and their habitat.*" TransCanada proposes to use data from Phase 1 studies (this report) and Tasks 3 and 4 from Phase 2 (2014; described above), in combination with the data collection and analysis for Studies 4 (Hydraulic Modeling), 5 (Operations Modeling), 7 (Aquatic Habitat Mapping), and 9 (Instream Flow Study) to assess the effects of flow regime on dwarf wedgemussel and their habitat. Supporting information on dwarf wedgemussel habitat preference will come from other studies conducted in the Connecticut River watershed (Nedeau 2008 and references therein) and elsewhere in their range. The data collection and analysis for the other studies (4, 5, 7, and 9) may focus specifically on those areas where these mussel data are collected to allow better integration of both physical and biological data in the resulting models. Due to the complex and multidisciplinary nature of this task, TransCanada feels it is premature to plan this specific task until stakeholders have reviewed Phase 1 results. As described in the FERC-approved study plan, this is an open collaborative approach that will ensure that resource agency goals and objectives are addressed, time is used efficiently, and studies serve their intended purpose.

6. LITERATURE CITED

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Appendix A

Survey Sites

Figure A-1
Survey Sites in the Wilder Project

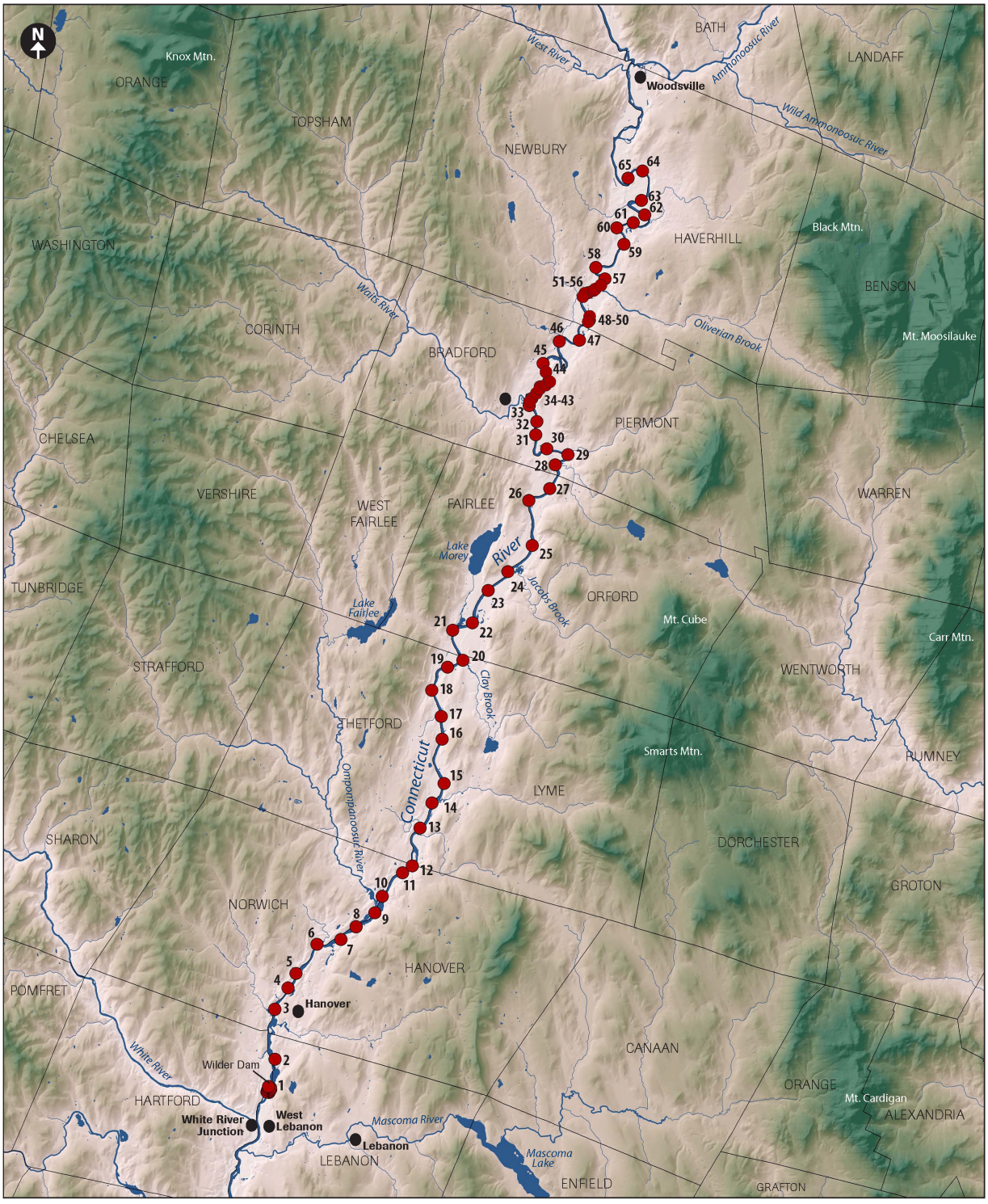


Figure A-2
Survey Sites in the Free-flowing Reach

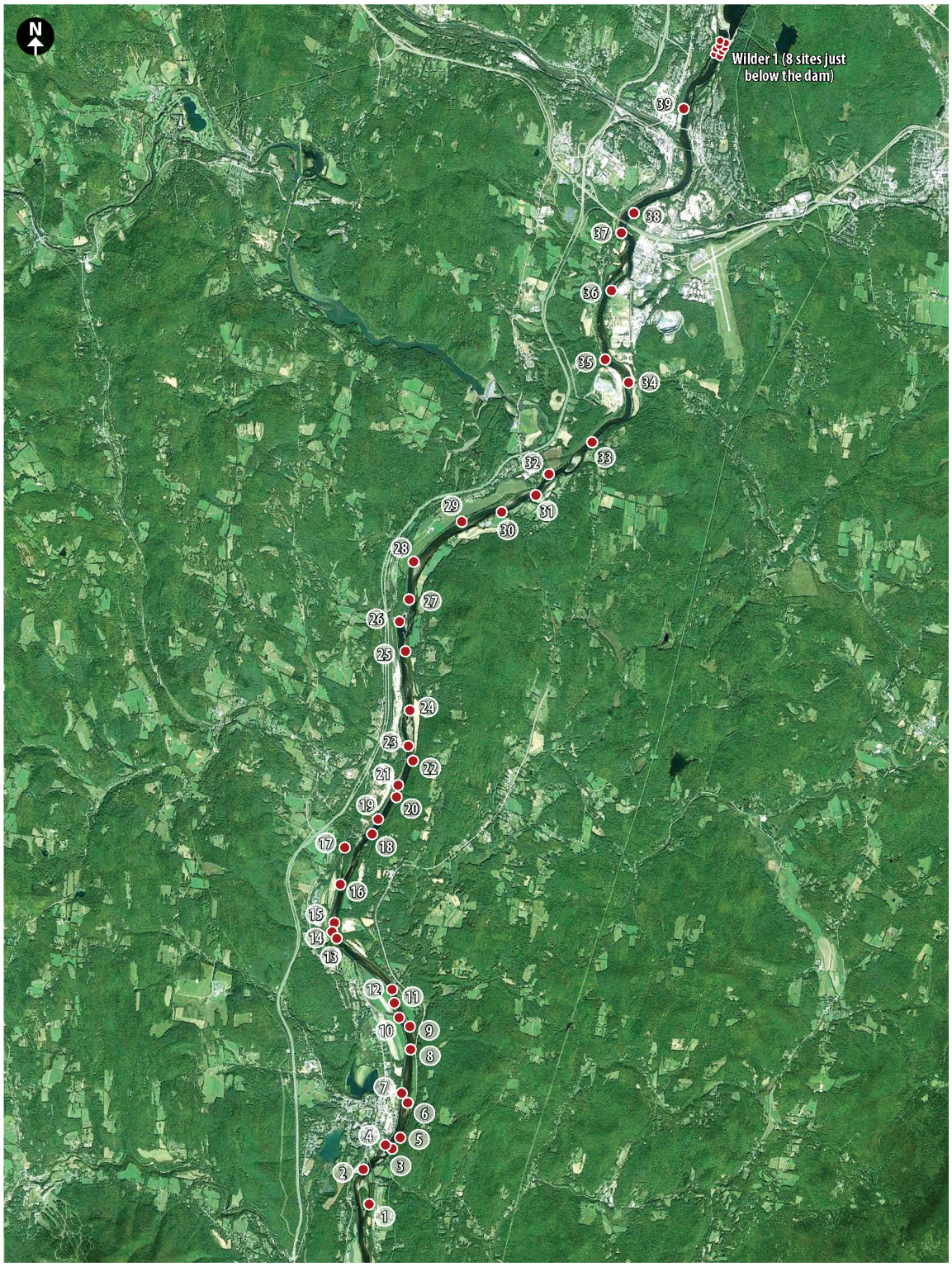


Figure A-3
Survey Sites in the Bellows Falls Project

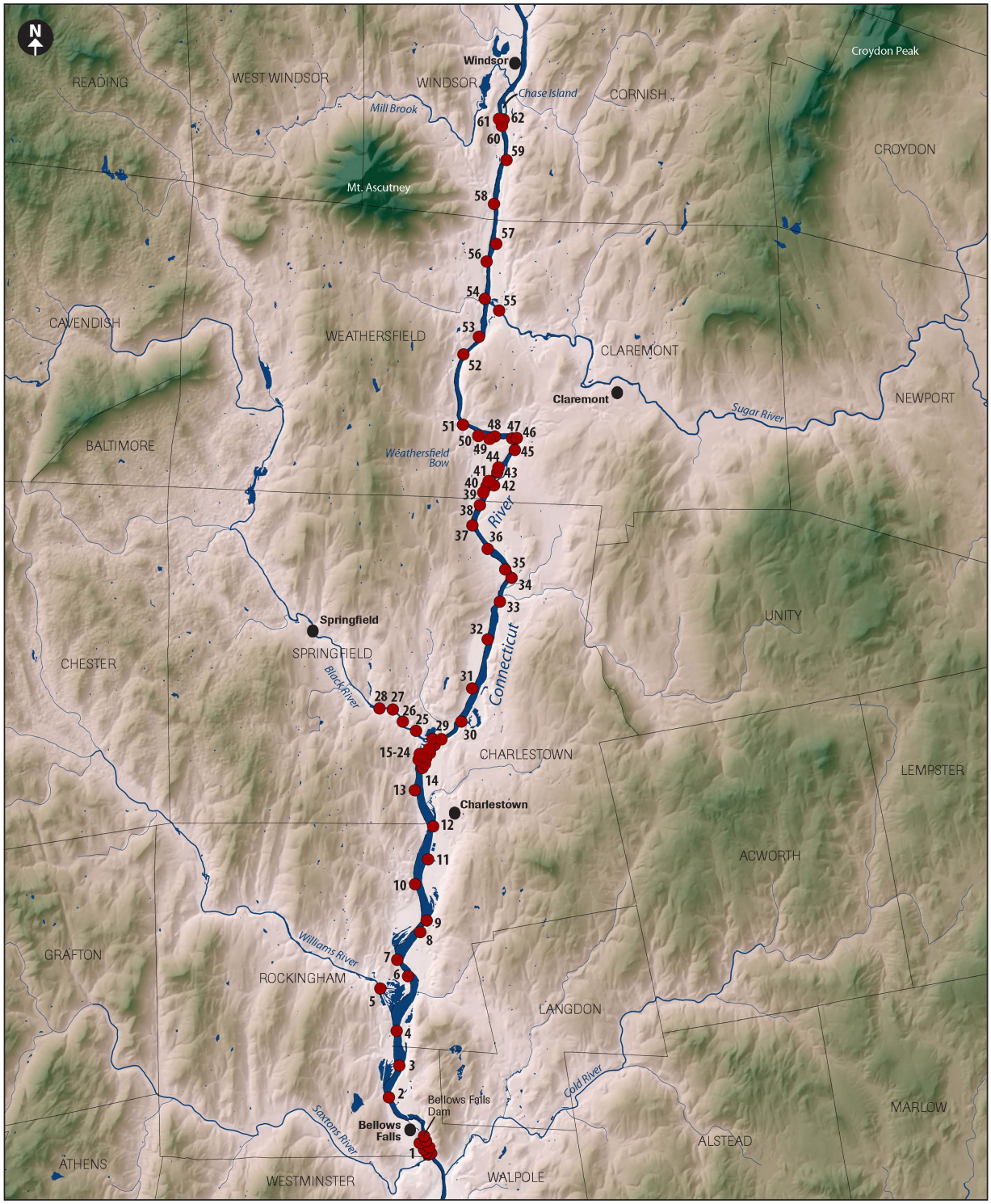
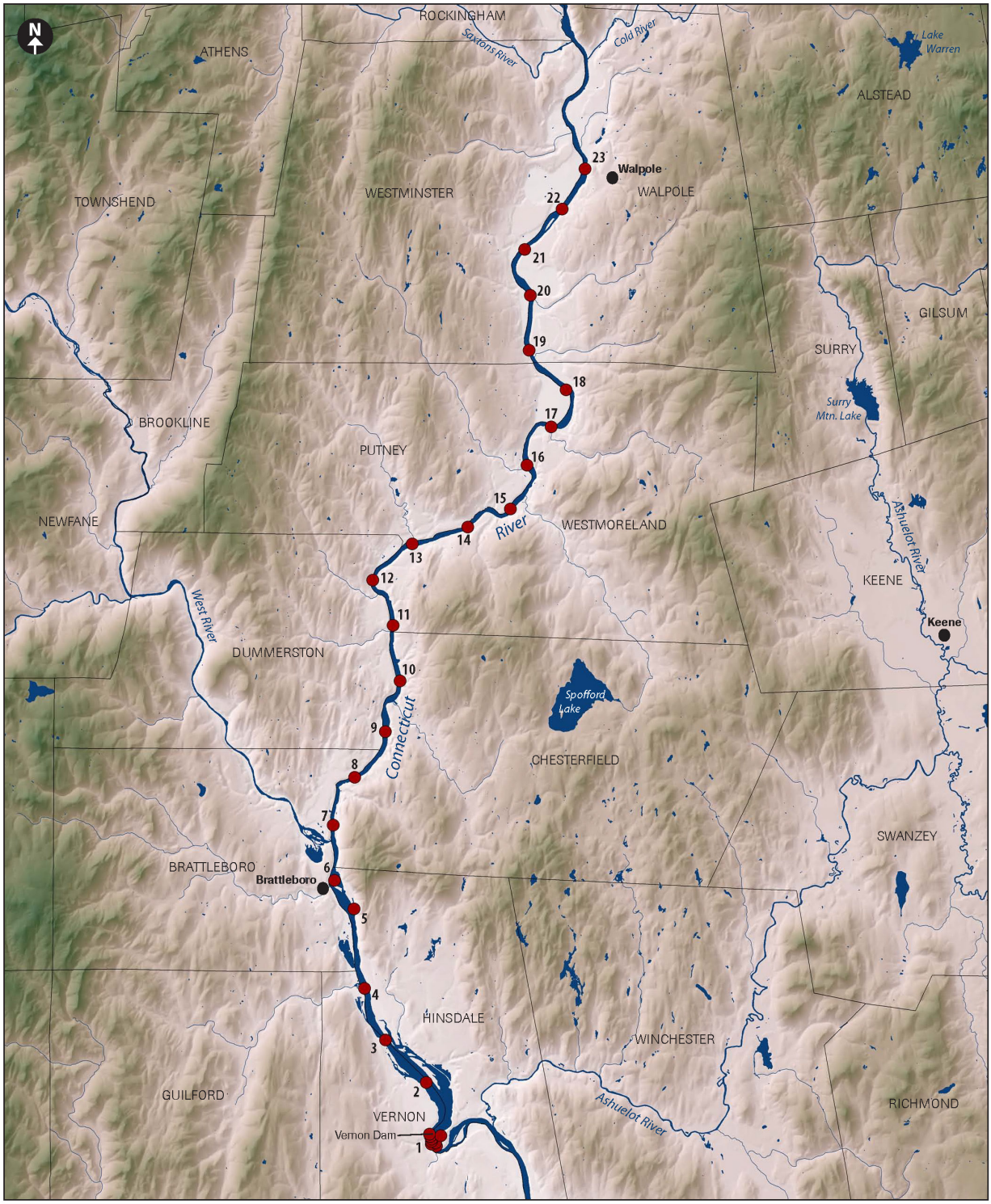


Figure A-4
Survey Sites in the Vernon Project



Appendix B

Mussel Survey Data

PRIVILEGED DATA IS CONTAINED IN

THE

TRANSCANADA INITIAL STUDY REPORT

VOLUME V AND VOLUME VII (SUPPLEMENTAL GEO DATABASE)

FILED SEPTEMBER 15, 2014