The Mussels of Muddy Creek on Erie National Wildlife Refuge

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Abstract - A qualitative mussel survey was performed on Muddy Creek, a tributary to French Creek in Crawford County, PA, within the boundaries of the Erie National Wildlife Refuge. Riffle-run-pool sequences were sampled at 20 locations in the study area using visual and tactile timed-search techniques. Live specimens represented by 22 species were encountered at a rate of 54 individuals per person-hour and included the federally-endangered *Pleurobema clava* (clubshell) and *Epioblasma torulosa rangiana* (northern riffleshell) as well as four Pennsylvania state-imperiled species. Evidence of recruitment in the clubshell population was found in excavated quadrats and by hand-collecting. Brillouin diversity indices ranged from 0.35–2.88 over the study area, with a mean (SD) of 1.67 (0.59). The three most abundant species were *Actinonaias ligamentina, Amblema plicata*, and *Lasmigona costata*, while the three most rare were *Anodontoides ferussacianus*, *E. torulosa rangiana*, and *Villosa fabalis*. The high diversity of mussels along with the presence of federally listed and state-imperiled species warrants a pro-active approach to future protection of the aquatic resources of Muddy Creek.

Introduction

It is widely recognized that freshwater mussels in North America are an important component of many aquatic ecosystems. Mussels are sessile filter-feeders, which makes them useful indicators of the health of aquatic environments, and they have regional commercial importance as seed pearl material for the cultured pearl industry (Cummings and Mayer 1992, Strayer and Smith 2003, Williams et al. 1993). In North America, they are of biological interest due to their diversity, which is characterized by nearly 300 species in the United States and Canada. Being sessile organisms associated with stream-bottom habitats, mussels have developed unique reproductive strategies that require larval metamorphosis on a host fish, with some species employing a "lure" to attract potential hosts. Mussels are an important food supply for many animals including muskrat, mink, otter, fish, and some birds (Cummings and Mayer 1992). Unfortunately, about 72% of the North American mussel taxa are considered endangered, threatened, or of special concern due primarily to habitat destruction and degradation associated with anthropogenic activities (Williams et al. 1993).

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In consideration of the above, it is important to perform baseline surveys of freshwater mussel populations, to document species richness and reproductive success. One area that supports a highly diverse aquatic community is French Creek (Western Pennsylvania Conservancy and French Creek Project 2002), a tributary to the Allegheny River located in northwestern Pennsylvania. French Creek is part of the Ohio River drainage and has ten major tributaries, including Muddy Creek, which flows through the Erie National Wildlife Refuge (Erie NWR) for the last 18 river kilometers of its journey. Tributary streams such as Muddy Creek support species of special concern and are critical to the maintenance of habitat and water quality in the French Creek basin (Crisswell 2001). Previous mussel studies on Muddy Creek were limited to localized surveys by Dennis (1971), who collected six species at the confluence with French Creek, and Bogan (1995), who documented the presence of four species during a survey required for a bridge-replacement project. To establish more complete baseline information, we performed a qualitative mussel survey on the portion of Muddy Creek that flows through the Seneca Division of Erie NWR in Crawford County, PA (Fig. 1). Results are presented as the most complete data thus far on species richness, abundance, diversity, and documentation of recruitment in the mussel populations of Muddy Creek.

Study Area

The study area consisted of an 18-km portion of Muddy Creek that flows through the heart of the Seneca Division of Erie NWR and drains into French Creek at the refuge boundary (Fig. 1). The Seneca Division of the refuge contains 3544 acres that were timbered for their hardwood resources in the early 19th century, with some of the land cleared and drained for farming. Land in the Muddy Creek watershed is used for agriculture as well as gravel mining and extraction of natural gas, but the portion of the watershed within refuge boundaries lies in a relatively undisturbed condition. The topography and hydrology of the area is heavily influenced by past Pleistocene glaciation, with much of the Muddy Creek riparian area comprised of shrub-scrub and forested wetlands with tracts of hardwood timber. Muddy Creek is incised into the topography as much as 3 m in some areas and meanders extensively through the study area. Stream gradient in the study area was estimated at < 2 m/km. Log jams, which form through natural storm events, were numerous and caused survey crews to portage around or over obstructions frequently in order to travel down the stream corridor via canoe. Stream width was typically 6–10 m at the time of field surveys. Substrate was sand and gravel, easily penetrated by hand to a depth of 15 cm or more. Large cobbles were mostly absent. Seams of clay were found near cut banks, and woody debris was commonly imbedded into the substrate. Areas of submerged aquatic vegetation were also frequently encountered and were often rich with mussels.

The first and upper portion of the Muddy Creek survey took place during August 19–22, 2003, and covered the area beginning about 2 km stream

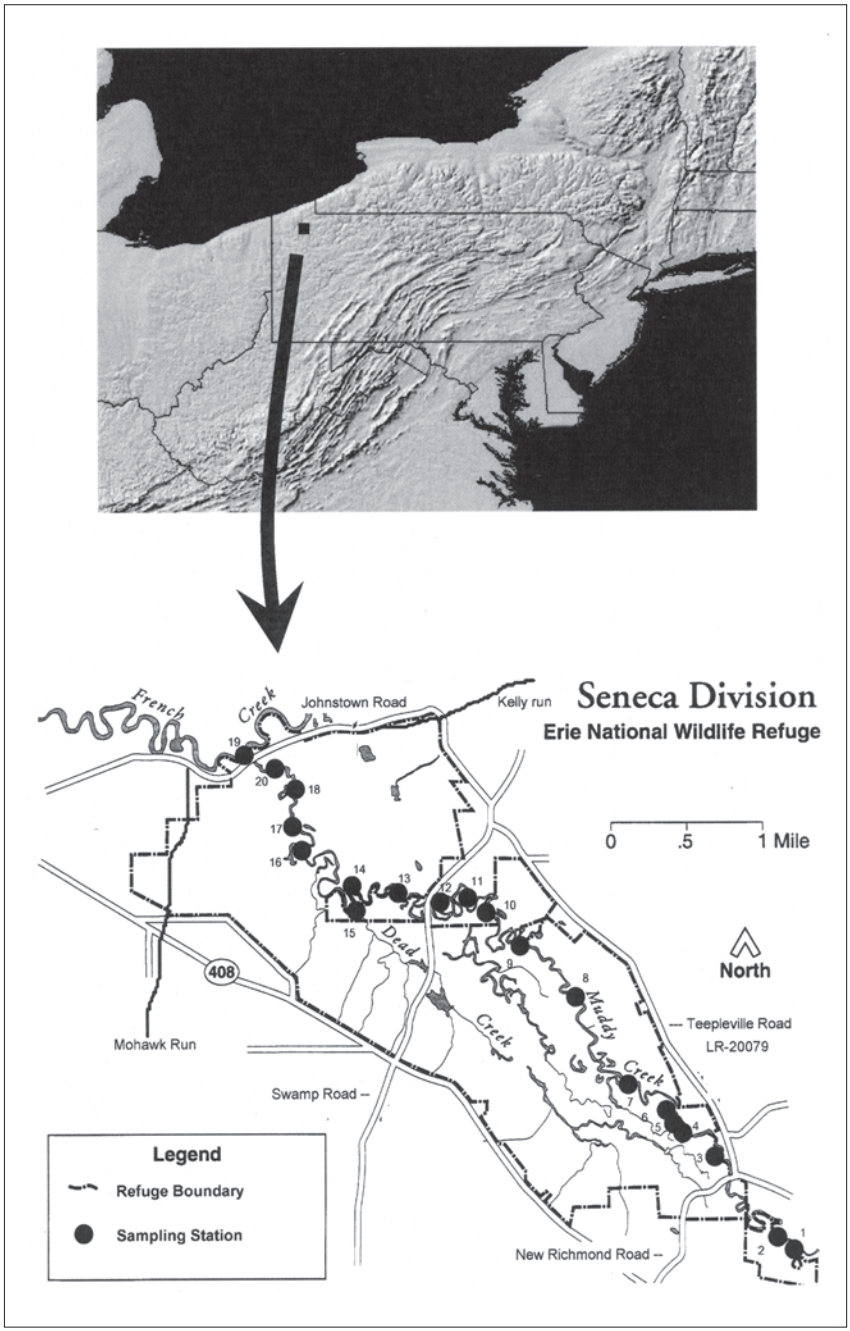

Figure 1. Location map of the Muddy Creek study area surveyed for mussels in 2003.

distance above the New Richmond Road bridge and ending at Swamp Road, for a stream distance of about 11 km. The second and lower portion of the survey took place during September 10–12, 2003, and covered the area from Swamp Road downstream to the confluence with French Creek, for a stream distance of about 7 km (Fig. 1).

Methods

A preliminary field survey of the study area was performed in June 2003 via canoe to determine stream navigability and to identify areas that showed evidence of mussel habitation through presence of muskrat middens and visual observation of mussel beds. Subsequently, a survey design was formulated with the objectives of determining species richness and relative abundance, and of documenting reproduction of mussels in the study area in the summer of 2003. Since objectives were primarily qualitative, field sampling consisted of timed searches in riffle-run-pool sequences throughout the study area, including mussel-bed areas identified in the preliminary survey. A total of 20 stations were subjectively chosen during the preliminary field view, and each consisted of a riffle-run-pool complex (Fig. 1). Stream length and stream track, as well as beginning and end of all sampling locations, were documented using a hand-held global positioning system (GPS) unit with field accuracy routinely observed at 3–4 meters. Sampling-station lengths varied, but were less than 100 m with stream widths of 6–10 m. Four sampling stations were arbitrarily selected for measurement of pH, dissolved oxygen, and temperature using hand-held meters.

The method of sampling at each station consisted of 2–4 individuals equipped with wet suits, masks, and snorkels and spaced evenly across the stream. One additional individual searched stream edges using a viewing bucket and collected mussels using superficial visual techniques. Searchers equipped with snorkels used both visual and tactile methods by raking their fingers through the substrate, with search times limited to a maximum of 75 min per person at each station. SCUBA gear and weight belts were not used; therefore, pool habitats with water depths greater than 1.5 meters were not examined. Muskrat middens found at sampling stations were also examined for additional species, but relative abundance of mussels found in middens was not documented. When the search was completed at each station, mussels were identified and counted. Species and numbers of individuals collected were recorded, and mussels were individually inserted back into the substrate before moving to the next sample station. Additional sampling was performed at station 6 to determine recruitment via excavation and screening of the substrate at ten 0.25-m^2 quadrats that were arbitrarily selected by tossing a 0.25-m^2 weighted plastic frame within the run habitat of the riffle-run-pool complex at the station. Station 6 was chosen for quadrat excavation based solely upon the judgment on the investigators that

it appeared to be typical of a sampling station selected during the preliminary field survey. Within this station, the run habitat was selected because water depth and laminar flow yielded conditions conducive to a good view of the substrate and hence, efficient quadrat excavation. All mussels found in the quadrat excavations were measured for length, with individuals less than 30 mm long considered as juveniles except for *Villosa fabalis* (Lea) (rayed bean), which has a length of only 25–38 mm at maturity (Cummings and Mayer 1992).

Field data from each sampling station were used to compute the Brillouin diversity index (Zar 1984) with natural logarithms in the formula:

$$\text{Brillouin diversity index } H = (\log n! - \sum \log f_i!)/n$$

where n = the number of live and fresh dead individuals collected within the stream and f = the number of observations in the species i. Equitability of numbers of individuals between species is reported at each station as "evenness" with the maximum possible value of 1, which would reflect collecting equal numbers of individuals of each species (Zar 1984).

Species were ranked according to the quantity of each collected to demonstrate relative abundance. The encounter rate was calculated for each sampling station by dividing the number of live animals collected by search time in person-hours (p-h).

Results

The linear distance sampled from upstream (station 1) to the most distant station downstream at the confluence with French Creek (station 19) was 7.9 km. However, the high degree of stream meander was reflected by our measured stream track of 18.3 km. During field work, water clarity was good, with relatively low stream flows. Average values for water temperature, dissolved oxygen, and pH during the survey were: 18.8 ºC, 7.6 mg/l, and 6.9, respectively.

Overall, a total of 2965 live mussels were collected using 54.6 hours of search time, which reflects a recovery rate of 54.3 live animals/p-h. Encounter rates at individual sampling stations ranged from 0–144 animals/p-h (Fig. 2). Average encounter rates were greater for stations downstream of Swamp Road at 63.3 animals/p-h vs. upstream at 30.1 animals/p-h. Twenty-two mussel taxa were found including *Pleurobema clava* (Lamarck) (clubshell) and *Epioblasma torulosa rangiana* (Rafinesque) (northern riffleshell), both of which are currently on the federal list of endangered species. In addition, four species were also found which are currently on the Pennsylvania state list of critically imperiled species: *Epioblasma triquetra* (Rafinesque) (snuffbox), *Fusconaia subrotunda* (Lea) (long solid), *Quadrula cylindrica* (Say) (rabbitsfoot), and *V. fabalis*. Also, *V. fabalis* is currently on the federal list of candidate threatened and endangered species (US Fish and Wildlife Service 1991).

The most abundant species encountered was *Actinonaias ligamentina* (Lamarck) (mucket), representing 29.8% of all individuals collected,

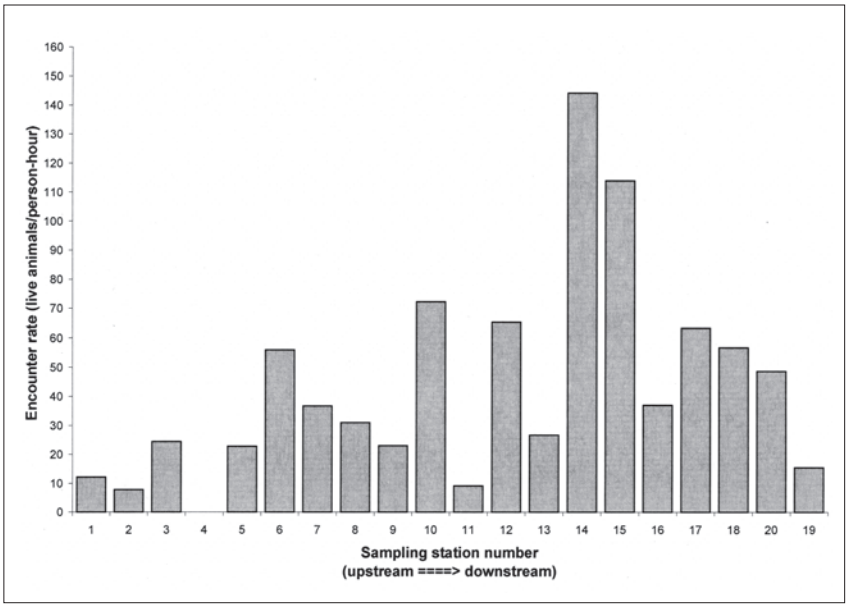

Figure 2. Encounter rate in person-hours of live animals collected at Muddy Creek sampling stations in 2003.

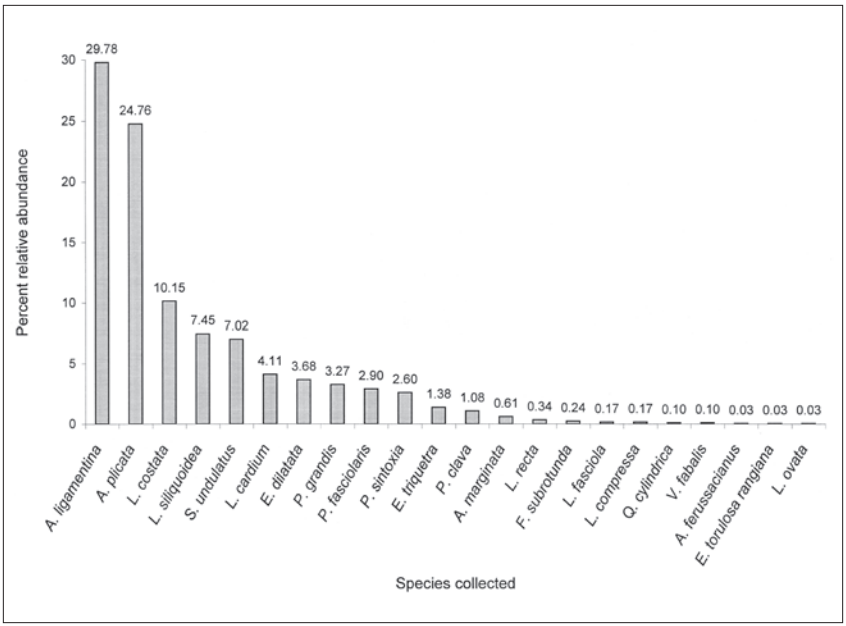

Figure 3. Percent relative abundance of mussel species collected in Muddy Creek in 2003.

followed by *Amblema plicata* (Say) (three-ridge) at 24.7%. The three most rare species, with only one live individual collected each, were: *Lampsilis ovata* (Say) (pocketbook mussel), *Anodontoides ferussacianus* (Lea) (cylindrical papershell), and *Epioblasma torulosa rangiana* (northern riffleshell) (Fig. 3). Brillouin diversity indices (natural log values) ranged from a low of 0.35 at station 4 to a high of 2.88 at station 10 with an overall mean (SD) of 1.67 (0.59) for all 20 sampling stations (Fig. 4). Quadrat excavation at station 6 showed that eight of the twenty live individuals (47%) collected were juveniles less than 30 mm in length, including a 17 mm specimen of *P. clava*. Mean live mussel density (SD) was 6.8 (6.6) individuals per m^2 with a density of juvenile mussels (SD) at 3.2 (4.1) individuals per m^2. Juveniles of ten species were collected over the course of the survey (Table 1). Two gastropod species were also collected: *Campeloma decisum* (Say) and *Elimia livescens* (Menke). Though many fresh-dead mussels were encountered along the banks at our sampling stations, only one concentrated midden, located on the right bank of station 20, was found. This midden yielded 2 fresh-dead *E. t. rangiana* and 4 fresh-dead *V. fabalis*. Voucher specimens of all species collected except for gastropods are deposited in the

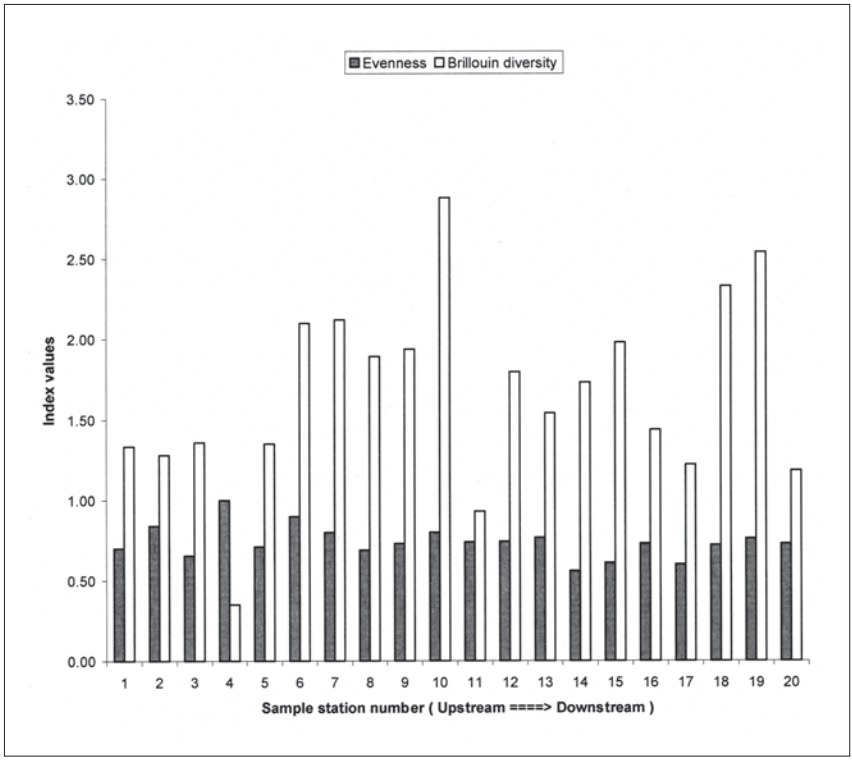

Figure 4. Brillouin diversity indices and evenness values for live and fresh dead mussels collected at Muddy Creek sampling stations in 2003.

Carnegie Museum of Natural History. No live animals were sacrificed as vouchers for this collection.

Discussion

We found that Muddy Creek supports a diverse mussel community with at least 22 extant species. In comparison, 27 mussel species reportedly have surviving populations in the French Creek watershed, with 26 of those species still surviving in the main stem of adjacent French Creek (Western Pennsylvania Conservancy and French Creek Project 2002). The species list from French Creek watershed includes all the current species we found in Muddy Creek. The five species reported as currently present in the French Creek watershed but not found in our survey were: *Lasmigona complanata* (Barnes) (white heelsplitter), *Ligumia nasuta* (Say) (eastern pondmussel), *Simpsonaias ambigua* (Say) (salamander mussel), *Utterbackia imbecillis* (Say) (paper pondshell), and *Villosa iris* (Lea) (rainbow mussel). Of these species, both *U. imbecillis* and *L. complanata* prefer pools and sluggish streams (Cummings and Mayer 1992). Therefore, the possibility exists that these two species are also present in Muddy Creek, but were not encountered

Table 1. Current federal status (US Fish and Wildlife Service 1991, Williams et al. 1993) and Pennsylvania state status (Western Pennsylvania Conservancy and French Creek Project 2002) of mussel species collected from Muddy Creek in 2003 along with species of juvenile mussels found.

Species collected	Live juveniles found (x)	Pennsylvania state status	Federal status
Actinonaias ligamentina	x	Apparently secure	Currently stable
Amblema plicata	x	Imperiled	Currently stable
Alasmidonta marginata		Apparently secure	Currently stable
Anodontoides ferussacianus		Imperiled/vulnerable	Currently stable
Elliptio dilatata		Apparently secure	Currently stable
Epioblasma torulosa rangiana		Imperiled	Endangered
Epioblasma triquetra	x	Critically imperiled	Under review
Fusconaia subrotunda		Critically imperiled	Currently stable
Lampsilis cardium	x	Apparently secure	Currently stable
Lampsilis fasciola		Apparently secure	Currently stable
Lampsilis ovata		Vulnerable/apparently secure	Currently stable
Lampsilis siliquoidea	x	Apparently secure	Currently stable
Lasmigona costata	x	Apparently secure	Currently stable
Lasmigona compressa		Imperiled/vulnerable	Currently stable
Ligumai recta		Vulnerable/apparently secure	Currently stable
Pleurobema clava	x	Critically imperiled /imperiled	Endangered
Pleurobema sintoxia	x	Imperiled	Currently stable
Ptychobranchus fasciolaris	x	Apparently secure	Currently stable
Pyganodon grandis		Apparently secure	Currently stable
Quadrula cylindrica		Critically imperiled	Under review
Strophitus undulatus	x	Apparently secure/secure	Currently stable
Villosa fabalis		Critically imperiled /imperiled	Candidate endangered

in our survey since we did not utilize weight belts to facilitate examining pools with water depths over 1.5 m. It is less likely that *S. ambigua* and *L. nasuta* occur in the study area since the latter is thought to be an introduced species to the French Creek drainage and the preferred habitat of the former is under large stones or slabs (Cummings and Mayer 1992), which were few, if at all present, in the survey area. The preferred coarse sand and gravel habitat of *V. iris* was abundant in Muddy Creek, but if present, this species is likely rare.

In order to discover all species present at a single survey site, Metcalfe-Smith et al. (2000) showed that even an effort of 4.5 p-h of search time may not be sufficient for wadeable stream reaches having mean widths of 20 m and lengths of 100–300 m in length. They also stated that most rare species were found using at least 3.0–4.5 p-h. In the current study, our average search time per site was 173 min or 2.9 p-h, which is less than the previous recommendation, but our stream reach widths and lengths were smaller at 6–10 m and < 100 m, respectively. Nonetheless, we still found rare species such as *E. torulosa rangiana*. We consider this species to be rare in the study area since the survey including midden searches yielded only 1 live and 3 fresh-dead individuals. This species as well as many others were collected via tactile searching in the sediment; tactile searching included manual disturbance of the substrate and observation of the immediate area after suspended sediments had cleared. This technique, along with quadrat excavation at station 6, uncovered relatively small species as well as juveniles during the survey. The only live specimen of *E. torulosa rangiana* was found just inches from a specimen of *P. clava* (Fig. 5) at station 18. These individuals were found in relatively swift, ankle-deep water buried approximately 3–6 cm deep in clean gravel adjacent to a piece of woody debris that was imbedded into the substrate, but this particular habitat type did not appear to be unique relative to other stations surveyed.

None of our survey stations corresponded to those reported by Bogan (1995), who surveyed a site upstream from our study area. However, Dennis (1971) sampled French Creek at the confluence with Muddy Creek, but it is unlikely that that site corresponds to our station 19 since the limits of our station were confined within Muddy Creek. Dennis (1971) reported 6 species present at that site: *Actinonaias carinata* = *A. ligamentina* (Bogan 1993), *L. siliquoidea*, *Amblema costata* = *A. plicata* (Bogan 1993), *P. clava*, *Pleurobema cordatum* (Rafinesque), and *Q. cylindrica*. Of these 6 species, three were found in the current study at station 19: *A. ligamentina*, *L. siliquoidea*, and *A. plicata*. We found the substrate at station 19 to be mostly deposits of fine sediment and accumulated organic material with little clean gravel exposed; therefore, it is not surprising we did not encounter *P. clava* here. As listed above, Dennis (1971) reported *P. cordatum* at this site, but the report stated that within this species, *P. coccineum* = *sintoxia* was also included.

Relative abundance of all species collected at sampling stations (Appendix 1) along with locations of sampling stations (Fig. 1) document where species in our study were found. These locations are only meant to be approximations since Muddy Creek exhibits very dynamic fluvial processes as evidenced by numerous log jams, extensive meandering, meander scars, and by comparison of our recorded stream track with an ortho-photo of Muddy Creek produced about a decade prior. As such, future studies can only rely on Figure 1 for general rather than specific stream locations if the intent is to return to a certain site to find a particular species or assemblage reported. No conclusive explanation is given for greater average encounter rates at sampling stations located downstream of Swamp Road (Fig. 2). However, it was observed that more woody debris log jams that required portage of canoes and equipment were present in the downstream section. Perhaps these log jams create in-stream substrate and flow conditions favorable to mussel populations.

Even though the mussel community in the immediate portion of Muddy Creek we sampled is afforded some level of protection due to its location in the Erie NWR, there are still threats to the integrity of the aquatic

Figure 5. Specimens of *P. clava* (top) and *E. torulosa rangiana* (bottom) were found inches from each other at station 18.

community from regional land development, commerce, and other influences (Mohler 2003). As such, the Brillouin diversity index values we report for this section of Muddy Creek (Fig. 4) may become important for comparison with future surveys on Muddy Creek as an indicator of change over time. Caution should be exercised when using data presented from the current study for assessment of temporal changes to mussel populations in Muddy Creek since timed searches are not believed to be reliable for assessing density or relative abundance. According to Strayer and Smith (2003), there are serious, unresolved issues underlying the assumption that timed-search catch rates are related to actual mussel population densities. Furthermore, this relationship appears to have a high variance and thus, low power to detect temporal change.

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Appendix 1. Percent relative abundance of live mussel species found at each sampling station in Muddy Creek in 2003.

	Sampling station									
Species	1	2	3	4	5	6	7	8	9	10
Unionid bivalves										
Actinonaias ligamentina (Lamarck)	4.5		6.1		5.0	13.1	10.1	23.4	3.5	34.9
Alasmidonta marginata (Say)	4.5						1.3	2.4		1.7
Amblema plicata (Say 1817)			2.0		25.0	8.9	16.8	35.5	33.7	22.8
Anodontoides ferussacianus (Lea)	4.5	6.7					0.7			
Elliptio dilatata (Rafinesque)	31.8	26.7	12.2		2.5	12.5	10.1	2.4	1.2	3.5
Epioblasma torulosa rangiana (Rafinesque)										
Epioblasma triquetra (Rafinesque)							1.3	1.6	1.2	1.4
Fusconaia subrotunda (Lea)						0.6				
Lampsilis cardium (Rafinesque)	4.5		10.2		10.0	15.5	4.0	1.6	3.5	4.5
Lampsilis fasciola (Rafinesque)						1.2	0.7	0.8		0.3
Lampsilis ovata (Say)										
Lampsilis siliquoidea (Barnes)	4.5	33.3	6.1		42.5	15.5	24.8	5.6	15.1	8.3
Lasmigona compressa (Lea)										
Lasmigona costata (Rafinesque)			6.1		10.0	8.3	6.7	3.2	5.8	5.5
Ligumia recta (Lamarck)						3.0			1.2	0.3
Pleurobema clava (Lamarck)						2.4	6.0	4.8	7.0	0.3
Pleurobema sintoxia (Rafinesque)	4.5	6.7	2.0			14.3	2.7	2.4	7.0	3.8
Ptychobranchus fasciolaris (Rafinesque)	4.5	6.7	2.0				4.7	3.2	2.3	5.5
Pyganodon grandis (Say)		6.7					0.7	2.4	5.8	1.4
Quadrula cylindrica (Say)							0.7	0.8	1.2	
Strophitus undulatus (Say)	36.4	13.3	53.1		5.0	4.8	8.7	8.1	10.5	5.5
Villosa fabalis (Lea)								1.6	1.2	
Gastropods										
Campeloma decisum (Say)						X				
Elimia livescens (Menke)						X				

Species	Sampling station									
	11	12	13	14	15	16	17	18	19	20
Unionid bivalves										
Actinonaias ligamentina (Lamarck)		13.9	3.1	44.4	43.2	10.8	4.7	38.3	19.2	26.4
Alasmidonta marginata (Say)		2.8		0.1	0.2			0.4		
Amblema plicata (Say)	18.2	24.3	21.9	24.5	27.2	37.8	60.0	17.6	50.0	28.7
Anodontoides ferussacianus (Lea)										
Elliptio dilatata (Rafinesque)		2.1		1.0	1.8	8.1	2.4	3.5		3.9
Epioblasma torulosa rangiana (Rafinesque)								0.4		
Epioblasma triquetra (Rafinesque)		0.7		0.4	1.1	2.7	1.2	1.3		7.0
Fusconaia subrotunda (Lea)					0.9	2.7				0.4
Lampsilis cardium (Rafinesque)		5.6	3.1	1.4	1.3			4.8	7.7	8.9
Lampsilis fasciola (Rafinesque)										
Lampsilis ovata (Say)				0.1						0.4
Lampsilis siliquoidea (Barnes)		3.5	14.1	3.9	2.4		8.2	5.7		5.8
Lasmigona compressa (Lea)		1.4	1.6					0.4		0.4
Lasmigona costata (Rafinesque)	27.3	11.1	4.7	14.8	9.2		2.4	18.9	3.8	10.9
Ligumia recta (Lamarck)			1.6	0.1				0.4		
Pleurobema clava (Lamarck)					0.4			0.4		1.2
Pleurobema sintoxia (Rafinesque)		0.7		1.1	3.3			0.4		0.8
Ptychobranchus fasciolaris (Rafinesque)		1.4		2.5	3.9	2.7		2.6		3.9
Pyganodon grandis (Say)	9.1	1.4	37.5	3.5	2.9	10.8	7.1	3.1	7.7	0.4
Quadrula cylindrica (Say)										
Strophitus undulatus (Say)	45.5	31.3	12.5	2.1	2.2	24.3	14.1	1.3	11.5	1.6
Villosa fabalis (Lea)										