Freshwater Mussels
and the
Connecticut River Watershed

Chapter 5: Species Profiles

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CHAPTER 5

Species Profiles

Citizens often have more questions about why they should care about mussels than how many species there are or what each species looks like. Therefore, the first half of this book was a departure from a traditional field guide; it was intended to promote a stronger interest in freshwater mussels and aquatic ecosystems, especially in the Connecticut River watershed. It is also essential to be able to recognize all the species that occur in the watershed and to have a basic understanding of their habitat, biology, and status. This chapter helps people identify freshwater mussels and to become more familiar with each species.

I. ABOUT SPECIES PROFILES

Profiles for each species contain the following information:

1. **Description**: Describes the major features of the shell, anatomy, or other traits that are used to distinguish each species. Jargon is used sparingly and many of the technical terms are illustrated in this chapter or in figures 1 and 2 (page 2). Photographs of the shell, including the external lateral view of the left shell and the internal lateral view of the right shell, are provided for each species. Hinge teeth morphology is illustrated for several of the species. Species that a novice is likely to confuse with other species are listed; people should compare photographs and descriptions when trying to identify animals.
2. **Habitat**: Describes the types of habitats where a species is likely to occur, and environmental conditions that influence its distribution and abundance. The amount of detail provided varies because of the disparity in what is published or known for each species. The focus is the Connecticut River watershed but the text provides relevant observations or publications from other parts of a species range.
3. **Biology**: Provides details on reproductive periods, host fish relationships, behavior, growth, longevity, and other items of interest. The amount of detail provided varies because of the disparity in what is published or known for each species. Since few biological studies have been conducted within the Connecticut River watershed, this section cites studies that have been conducted elsewhere.

Photo: The Westfield River in Russell, Massachusetts. This rocky and high-gradient portion of the Westfield supports few freshwater mussels but its excellent water quality helps sustain diverse mussel populations further downstream. Ethan Nedeau

4. **Range and Range Map**: Describes the geographic range of a species in North America and in the Connecticut River watershed. The map shows the major watersheds, and in some cases minor watersheds and specific tributaries, where a species occurs. Freshwater mussel surveys continue to be performed, and there are undoubtedly many populations that await discovery, so the ranges described here (and in Chapter 2) should be considered current as of April 2008. Location-specific details are not provided. People interested in this information should contact the appropriate state or federal natural resource agency (Appendix 2).
5. **Status:** Provides details on the status of a species within the watershed and throughout its entire range. Relevant threats and research needs are listed, if known.

GEOGRAPHIC SCOPE OF THIS BOOK

This book covers 12 species that occur in the Connecticut River watershed and that are part of the Northern Atlantic Slope faunal group. Johnson (1970) described the Northern Atlantic Slope as the Atlantic coastal region extending from the York River in Virginia to the Saint Lawrence River in Canada, including Labrador and Newfoundland. The Northern Atlantic Slope fauna is comprised of 17 species, four that are confined to watersheds south of New England and one that is confined to northern areas. This book covers all or most of the species that would likely be found in the Canadian Maritime provinces, New England (except for the Champlain Valley in Vermont), and Atlantic coastal watersheds of New York, New Jersey, Delaware, Maryland, and Pennsylvania. Fichtel and Smith (1995), Strayer and Jirka (1997) and Nedeau *et al.* (2000) cover the species from these areas that are not covered in this publication.

Readers are encouraged to explore the literature that is cited for each species—abstracts of scholarly research journals can be found online and entire journal articles can be purchased online or photocopied from a university library. Journal articles have a reference section that reveals a world of information that is virtually unknown to the general public. These published works provide the foundation of knowledge that conservation and management is built on.

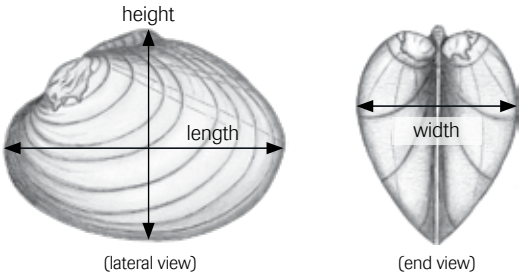
A Note About Identification

The color, shape, and appearance of mussel shells can be highly variable. Many people have trouble recognizing subtle differences between species even using specimens with typical features. Variability (i.e., atypical features) makes the challenge all that much more difficult. Few specimens are picture-perfect: individuals usually have some degree of shell erosion, a stained periostracum, or other damage that makes them appear different from published descriptions. It is often not possible to identify small juveniles that have not yet developed characteristic adult features. Internal shell morphology provides many diagnostic features for a species—especially hinge teeth and color of the nacre. These features are only available with dead animals and it is not okay to kill an animal just to identify it. For all of these reasons, identifying freshwater mussels, especially live animals, is a challenge and should be done with expert guidance, especially when there is potential of finding protected species. Once people become familiar with the species in the watershed, it will be easier for them to correctly identify species despite atypical features. The best way to learn to identify freshwater mussels is to weigh several pieces of evidence (including habitat and location) and to keep an open mind! It is always best to take photographs, return an animal to its original location without harming it, record information about the site, and submit the information to your state wildlife agency (Appendix 2).

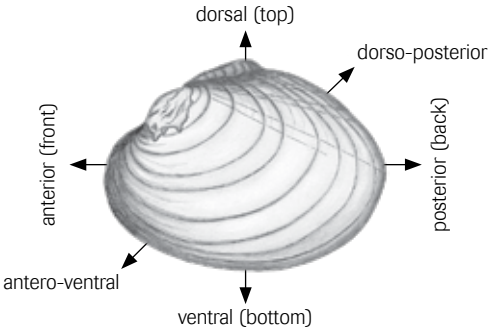
II. TERMS TO KNOW

It can be daunting to learn all of the words used to describe the shape and appearance of mussels. Species identification is a visual process, and this book tries to minimize the technical words and illustrate the ones that are used. In addition to the terms below, features of shells and soft anatomy shown in figures 1 and 2 (page 2) must be learned. Other helpful publications include Strayer and Jirka (1997), Nedeau *et al.* (2000), and Nedeau and Victoria (2003).

I. DIMENSIONS

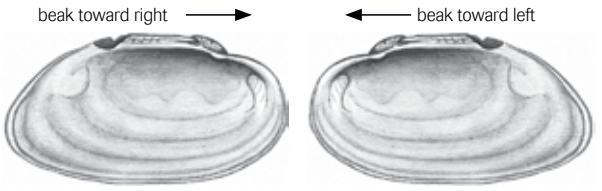


II. DIRECTIONS

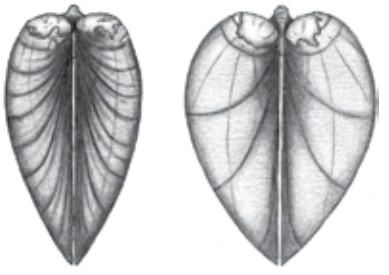


III. LEFT VS. RIGHT

Place the shell in your palm with the nacre toward you and the beak up. If the beak is toward the right, it is the left valve. If the beak is toward the left, it is the right valve.

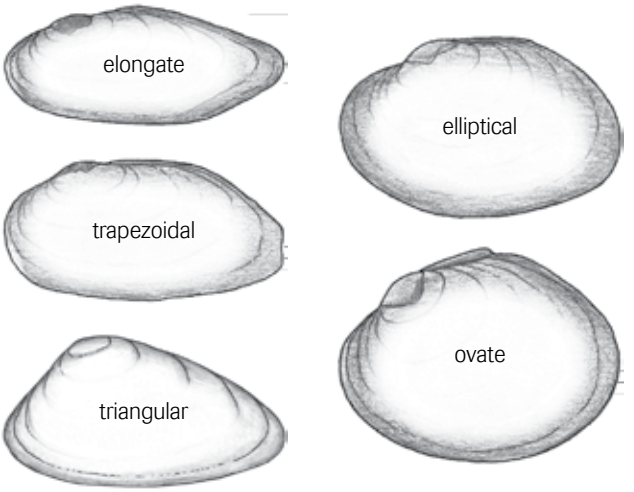


IV. SHELL WIDTH



V. SHELL SHAPE

Many terms are used to describe the general shape of shells, some of which require people to consult advanced geometry textbooks. This book uses just five terms and these are illustrated here. Species are variable and individual animals will either resemble these shapes or be intermediate between two (for example, some are described as either trapezoidal or elliptical). Its better to become familiar with the shapes and variability than to become too focused on precise terminology.



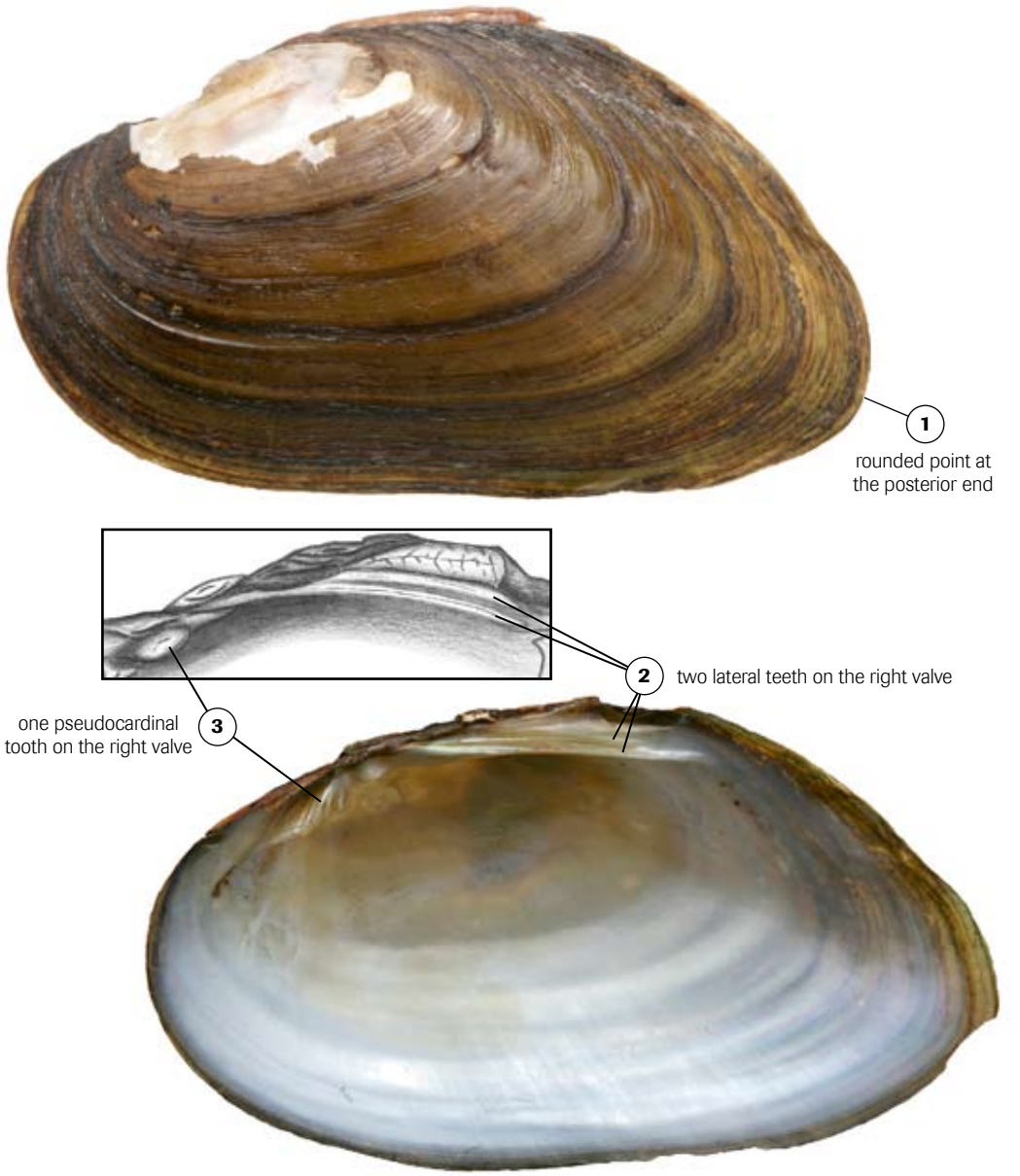
Deep and slow-flowing portions of the upper Connecticut River near Lancaster, New Hampshire, support the best dwarf wedgemussel population in the world. Ethan Nedeau

Dwarf Wedgemussel

Alasmidonta heterodon (Lea, 1830)

Description: The dwarf wedgemussel is a small species that rarely exceeds 1.75 inches (45 mm) in length; the largest known specimens came from a New Hampshire river and were 2.2 inches (56 mm) long. The shell is triangular or trapezoidal. The posterior end of the shell tapers to a rounded point **[1]** and has been described as "wedge-shaped," although this distinctive shape varies with the size and gender of an individual. There is a prominent rounded ridge along the dorso-posterior slope. The valves are usually laterally compressed to slightly inflated; mature females tend to be more inflated than males. The shell is smooth and may be yellowish-brown, olive-brown, or brownish-black in color. Faint greenish rays are evident on the shells of juveniles and light-colored adults. Hinge teeth are present but delicate. This is the only species in North America that has two lateral teeth on the right valve **[2]** and one lateral tooth on the left valve (all other species with lateral teeth have the opposite configuration). The dwarf wedgemussel also has pseudocardinal teeth—two in the left valve and one in the right valve **[3]**. The color of the nacre is bluish-white and often iridescent along the posterior margin. The foot is often a pale beige or slightly orange color.
Often confused with the creeper, triangle floater, and brook floater.

Habitat: The dwarf wedgemussel is a generalist in terms of its preference for stream size, substrate, and flow conditions (Strayer and Ralley 1993, Michaelson and Neves 1995, McLain and Ross 2005, Nedeau 2006d). It inhabits small streams less than five meters wide to large rivers more than 100 meters wide. It is found in a variety of substrate types including clay, sand, grav-



Dwarf Wedgemussel. External view of the left valve (top) and internal view of the right valve (bottom). Inset illustration shows hinge teeth detail. Numbers correspond to features in the description. Ethan Nedeau

el, and pebble, and often in areas of rivers with large amounts of silt (e.g., depositional areas and near banks). The dwarf wedgemussel inhabits very shallow water along streambanks and can move laterally or horizontally in the substrate as water levels fluctuate (Nedeau 2006a), but they have also been found at depths of 25 feet in the Connecticut River (Nedeau 2006d). The dwarf wedgemussel does not inhabit lakes or reservoirs but may occur in small impoundments created by run-of-river lowhead dams, beaver dams, or by natural landforms that create deep and stable stream reaches. They occur in impounded portions of the upper Connecticut River but only where some flow is present (Nedeau 2005d, 2006d). An increasing number of pub-

A handful of dwarf wedgemussel shells from the Connecticut River near Hartland, Vermont. Ethan Nedeau

lished studies and field observations suggest that stable flow and substrate are critical for this species (Strayer and Ralley 1993, Strayer 1999, Baldigo *et al.* 2004). In New England, the dwarf wedgemussel shares habitat with the eastern elliptio, creeper, triangle floater, and eastern lampmussel. It is usually absent in streams where the eastern pearlshell is the dominant species, but the Fort River in Massachusetts is a notable exception (Nedeau 2008). Dwarf wedgemussels are often patchily distributed in rivers, especially those with highly variable physical habitat and fragmenting features such as dams and culverts. Identifying and protecting these patches are critical for conserving the species (McLain and Ross (2005).
Primary habitat types (see page 16): SSLR, LNR.

Biology: Fertilization occurs in late summer and glochidia are released between March and May of the following spring. The tessellated darter is considered the primary host in the watershed and its range is most congruent with that of the dwarf wedgemussel, but several other fish have been identified as potential hosts (Table 1, page 5). The dwarf wedgemussel may undulate its mantle margins to attract its host fish (Wicklow 2004), and it releases its glochidia individually into the water column. It has a lower fecundity than most other species (Michaelson and Neves 1995, McLain and Ross 2005). Tessellated darters do not move very far—usually less than 100 meters during their short lives—thus the dispersal ability of dwarf wedgemussels is low and the rate at which they might recolonize former habitat is slow (McLain and Ross 2005). The life span of a dwarf wedgemussel is considered less than 12 years (Michaelson and Neves 1995), which is young compared with many other freshwater mussel species in the Northeast. Short life spans, low fecundity, high degree of host specificity, limited dispersal ability of its host species (except for the Atlantic salmon and striped bass), and low population densities likely all contribute to the endangered status of the dwarf wedgemussel.

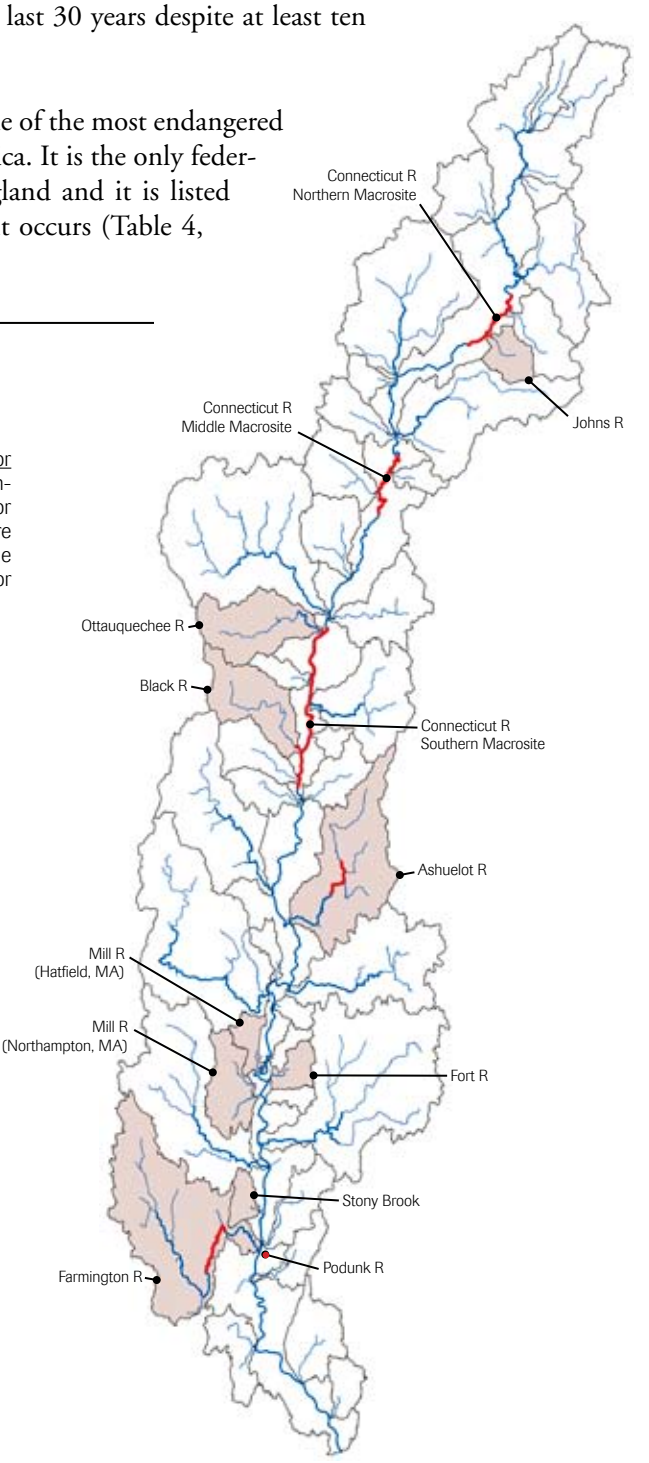
Range: The historic range of the dwarf wedgemussel included 70 locations in 15 major Atlantic coastal watersheds from North Carolina to eastern New Brunswick. By the early 1990s, its range was thought to have shrunk to approximately 20 locations in eight watersheds (USFWS 1993). In the last 15-18 years, biologists have rediscovered populations that were considered extirpated and discovered entirely new populations (Strayer *et al.* 1996, Nedeau 2006g). It is currently known from at least 70 locations in 15 major watersheds, with the largest populations in the Connecticut River watershed. It occurs in nine major watersheds in the Connecticut River watershed and the Connecticut River mainstem in New Hampshire and Vermont. The upper Connecticut River mainstem supports the three largest populations remaining in the world (Nedeau 2005d, 2006d). Large hydropower dams fragment what was likely once a single continuous population. It is known to occur in only one minor tributary (the Podunk River in Connecticut). In Massachusetts, it is believed extirpated from the Merrimack River, Canoe River (Bristol County), Agawam River (Bristol County), Scantic River (Hampden

County), and the mainstem Connecticut River (USFWS 1993). Of the three rivers that still support the dwarf wedgemussel in Connecticut, only the Farmington River is thought to support a stable population (Nedeau 2005b, 2006h). It is presumed extirpated from the Quinnipiac River system in Connecticut, the mainstem Connecticut River, and may be irreversibly endangered in the Stony Brook watershed. Only one animal (in 2005) has been found in the Stony Brook watershed in the last 30 years despite at least ten different surveys (Nedeau 2006i).

Status: The dwarf wedgemussel is one of the most endangered mussels in northeastern North America. It is the only federally endangered mussel in New England and it is listed as endangered by every state where it occurs (Table 4, page 30).

Dwarf Wedgemussel Range in the Connecticut River Watershed

Shading indicates presence in a major tributary or widespread distribution along the mainstem Connecticut River (which may include several minor tributaries along that reach). **Bold red lines** are used to indicate restricted occurrences along the mainstem Connecticut River and within large major tributaries.



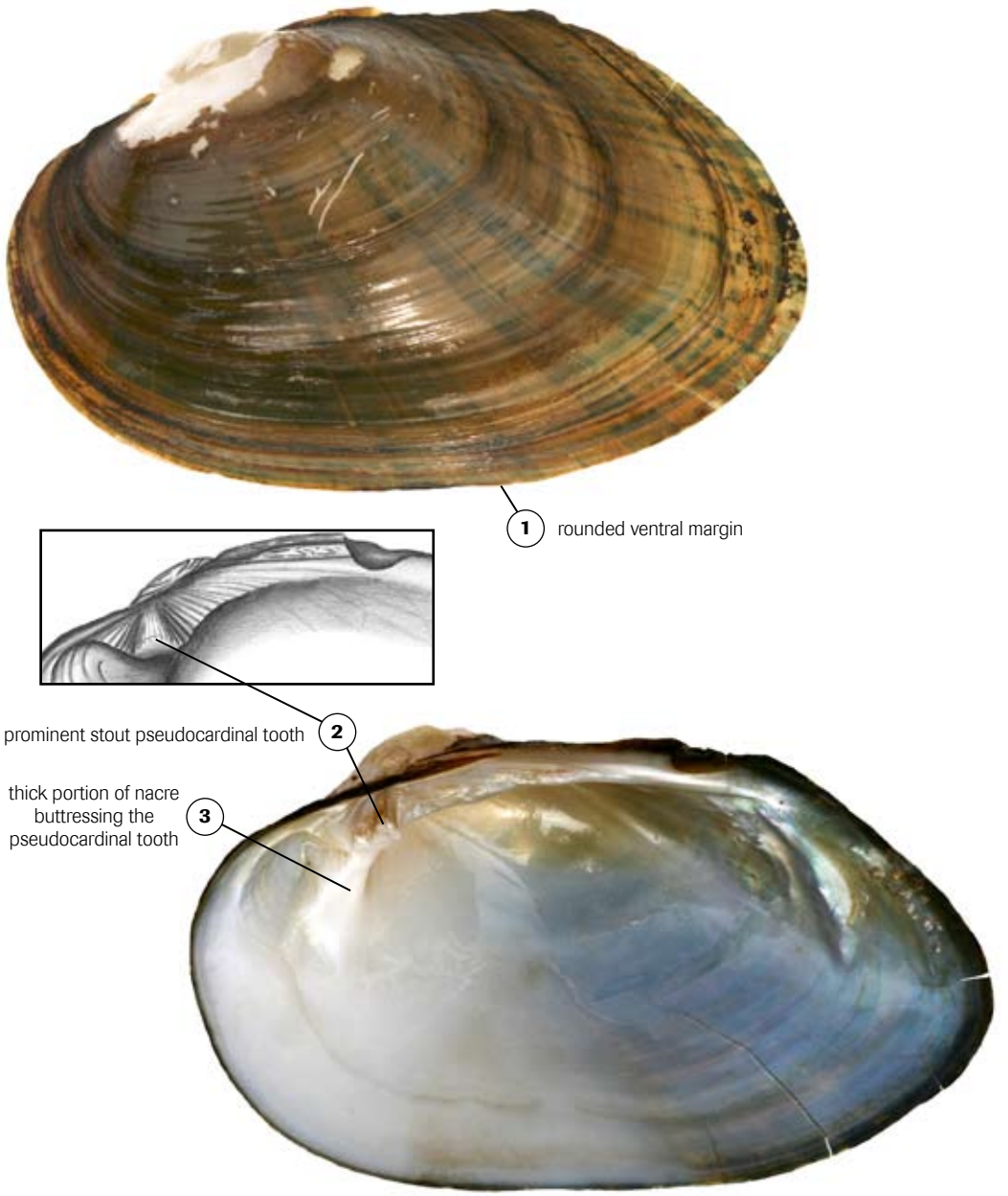
The triangle floater persists in many smaller tributaries of the Connecticut River such as Stony Brook in Suffield, Connecticut. Ethan Nedeau

Triangle Floater

Alasmidonta undulata (Say, 1817)

Description: The triangle floater is a small mussel that rarely exceeds three inches (75 mm) in length. Shell shape is variable and may appear triangular, elliptical, or ovate. Valves are moderately inflated. The ventral margin is rounded **[1]**, so that the shell rocks evenly when placed on a flat surface. Beaks are prominent and raised above the hinge line. Sculpturing on the beak is uneven and coarse, although this feature is more readily observed in young animals with little shell erosion. The periostracum is smooth and shiny, and ranges in color from yellowish-green to nearly black. The periostracum has green shell rays that are prominent on all but very old, stained, or eroded animals. Pseudocardinal teeth are a triangular shape and very prominent **[2]**; the pseudocardinal teeth are buttressed by a thick portion of the nacre **[3]**. Lateral teeth are absent. The nacre is distinctively bicolored: the posterior half of the shell is thin and an iridescent bluish-pink color, and the anterior half of the shell is substantially thicker and a white or pinkish color. The foot is usually white.
Often confused with the creeper, dwarf wedgemussel, and brook floater.

Habitat: The triangle floater inhabits small to large rivers and lakes. It is most common in flowing water, where it occupies a wide range of substrate and flow conditions. Preferred habitats include low-gradient river reaches with sand and gravel substrates and with low to moderate water velocities. It inhabits streams smaller than five meters wide and rivers wider than 100 meters. The triangle floater is the only species in the genus *Alasmidonta* that inhabits lakes; it occurs in both natural lakes and reservoirs in New England, although at lower population



Triangle Floater. External view of the left valve (top) and internal view of the right valve (bottom). Inset illustration shows hinge teeth detail. Numbers correspond to features in the description. Ethan Nedeau

densities than in rivers. Its ability to tolerate standing water makes this species less sensitive to effects of dams than other species, such as the brook floater. In fact, it is often as abundant in small impoundments of run-of-river dams as it is in free-flowing portions of those rivers. Because they are widespread in the watershed and inhabit a wide range of habitats, they share habitat with almost every other mussel species. However, they are most abundant in rivers that support eastern elliptio, eastern lampmussel, creeper, brook floater, and dwarf wedgemussel. *Primary habitat types* (see page 16): SSLR, SUR, LNR, lakes.

Five healthy triangle floaters from a coastal pond in Massachusetts. Ethan Nedeau

Biology: Fertilization occurs in the summer and glochidia are released the following spring. Studies have identified several hosts that are common in coldwater and warmwater environments in the Connecticut River watershed (Table 1, page 5). The triangle floater uses a broader variety of host fish than the closely related dwarf wedgemussel and brook floater. Longevity is unknown, but given their size and the longevity of closely related species (dwarf wedgemussel and brook floater), the triangle floater likely lives as long as 20 years in New England.

Range: The North American range of the triangle floater extends from North Carolina to Nova Scotia and New Brunswick. It occurs in most Atlantic coastal drainages throughout that range, and in tributaries of the lower St. Lawrence River in Quebec. It occurs in 20 major tributaries of the Connecticut River, the entire Connecticut River mainstem (though far more common in the north), and in 23 of 28 (82 percent) of all major watersheds or mainstem segments that support three or more species. It is also commonly found in minor tributaries of the Connecticut River and in many small streams within larger subwatersheds.

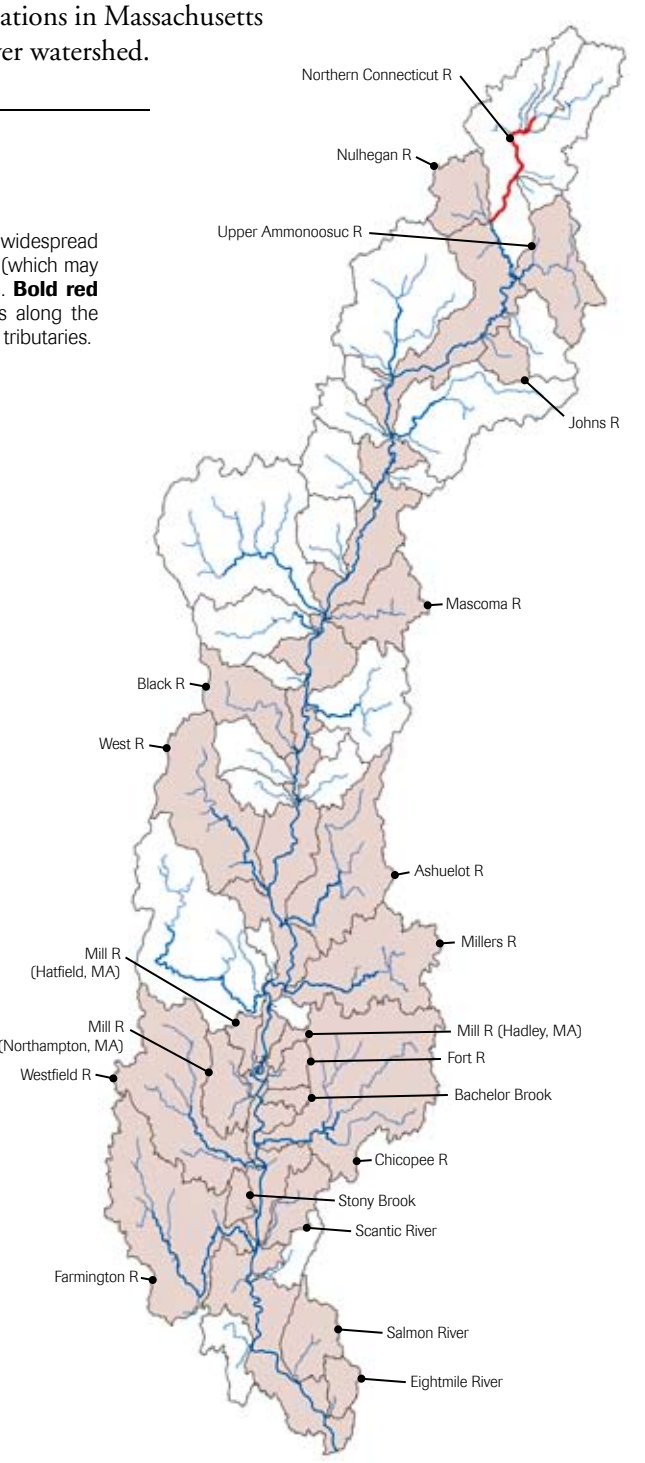
An undisturbed triangle floater with its valves open and inhalent and exhalent apertures exposed. Andre Martel, reproduced with permission of the Canadian Museum of Nature, Ottawa, Canada.

Status: The triangle floater is listed as special concern in Massachusetts due

to its low abundance within its known range. No other state in the watershed or New England considers the triangle floater a species of concern. Maine removed it from their list of special concern species in 2006 after a careful status review. The triangle floater is one of three species in Rhode Island, along with eastern elliptio and eastern floater, considered widespread (Raithel and Hartenstine 2006). A careful status review is needed to assess the long-term viability of triangle floater populations in Massachusetts and elsewhere in the Connecticut River watershed.

Triangle Floater Range in the Connecticut River Watershed

Shading indicates presence in a major tributary or widespread distribution along the mainstem Connecticut River (which may include several minor tributaries along that reach). **Bold red lines** are used to indicate restricted occurrences along the mainstem Connecticut River and within large major tributaries.



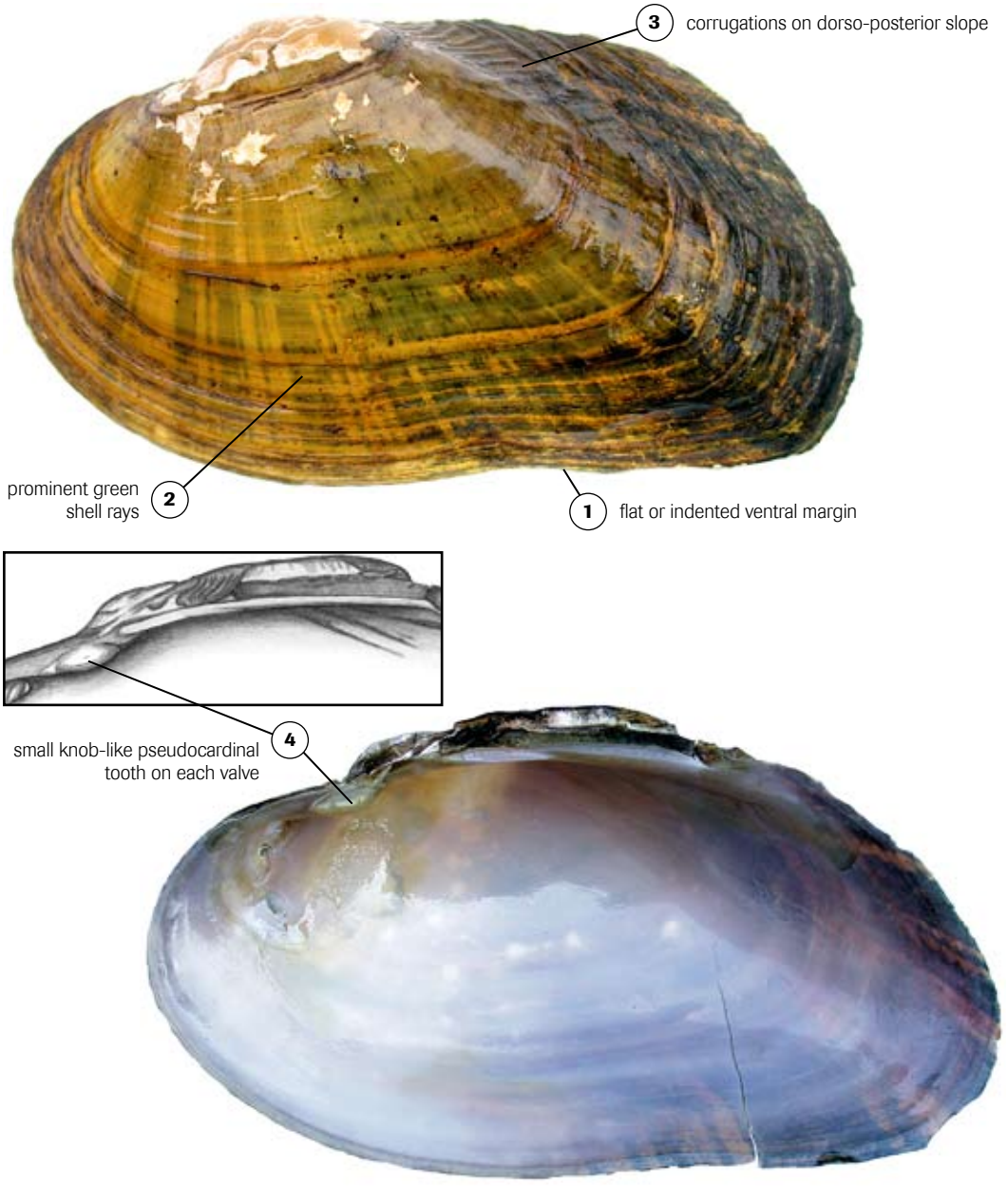
The West River is Vermont's best Connecticut River tributary in terms of its freshwater mussel community. The West River supports Vermont's only brook floater population.

Brook Floater

Alasmidonta varicosa (Lamarck, 1819)

Description: The brook floater is a small mussel that rarely exceeds three inches (75mm) in length. The shape is trapezoidal to almost elliptical, and it has a prominent posterior ridge that gives it a "roman nose" lateral profile. The ventral margin is usually flat or slightly indented **[1]**. The valves are moderately inflated, giving it a swollen appearance in cross section. The periostracum is yellowish-green in young animals to brownish-black in mature specimens and usually has prominent green rays **[2]**. Rays are often obscure in heavily eroded or stained shells. The diagnostic feature is a series of corrugations along the dorso-posterior slope, perpendicular to the growth lines **[3]**; these corrugations are difficult to discern on shells that are young, eroded, stained, or covered with algae. Pseudocardinal teeth are poorly developed, consisting of one small knob-like tooth on each valve **[4]**. Lateral teeth are absent. The color of the nacre is variable, ranging from bluish-white to pinkish-white to a pale orange. The foot is usually the striking color of cantaloupe but the intensity of that color is variable. The brook floater has a unique habit of "gaping" (relaxing its adductor muscles and opening its valves) when removed from the water, exposing its cantaloupe-colored foot and mantle cavity.
Sometimes confused with the triangle floater, creeper, and dwarf wedgemussel.

Habitat: The brook floater inhabits streams and rivers of varying sizes, but that usually have low to moderate flow velocities and stable substrates. In fast water, they often will be found clustered in protected areas such as behind boulders and near banks. The brook floater never occurs in lakes or reservoirs but may inhabit the upstream end of small impoundments cre-



Brook floater. External view of the left valve (top) and internal view of the right valve (bottom). Inset illustration shows hinge teeth detail. Numbers correspond to features in the description. Ethan Nedeau

ated by run-of-river dams. Like most other mussel species, the brook floater is sparse or absent in headwater streams and high-gradient river reaches that are prone to scour. It is frequently found in streams that have low calcium levels, low nutrients, and good water quality. Five of the six populations in the Connecticut River watershed are restricted to relatively undisturbed stream reaches in upper portions of large watersheds with relatively intact upland forests (e.g., Jeremy River, West Branch Farmington River, Ware River, West River, and North Branch Sugar River). This suggests that they may be intolerant of the many stressors present in down-

Brook floater with foot extended. Ethan Nedeau

Brook floater with darker shell. Ethan Nedeau

stream portions of these watersheds, especially related to dams, urban areas, and other land uses that affect the quality of water and habitat. They usually occur with the triangle floater, eastern pearlshell, creeper, and eastern elliptio.
Primary habitat types (see page 16): SSLR, SUR.

Biology: Fertilization occurs in the summer and glochidia are released the following spring. Females release glochidia in loose masses that drift downstream, encounter suitable host species, and become encysted in fins or gills. Several fish hosts have been reported under laboratory conditions (see Table 1, page 5) but no studies have confirmed how well laboratory results relate to the availability of hosts or parasitism under natural conditions. Given its large number of widely distributed host fish, its rarity is likely due to aspects of their biology and ecology that are unrelated to host availability, such as sensitivity to water quality or habitat conditions. The brook floater has a unique, and rather unfortunate, tendency to gape (relax its adductor muscles and open its valves) when removed from the sediment, making it vulnerable to predators, tissue damage, and desiccation. It is not known how this trait might contribute to its sensitivity and rarity in the Connecticut River watershed.

Range: The North American range of the brook floater includes Atlantic coastal rivers from South Carolina to Nova Scotia and New Brunswick. In the Connecticut River watershed, the brook floater occurs in only one river in Vermont (West River), one river in New Hampshire (North Branch Sugar River), three rivers in Massachusetts (Ware River, Bachelor Brook, and West Branch Farmington River), and possibly two rivers in Connecticut (Jeremy River and Eightmile River). Larger populations exist in the neighboring Merrimack River watershed and in Maine.

Status: The brook floater is one of the most endangered mussels in northeastern North America. It is listed as endangered in Massachusetts, Connecticut, and New Hampshire, and threatened in Vermont (Table 4, page 30). Populations within each of the seven rivers in the Connecticut River watershed are isolated and fragmented, and the rivers themselves are geographically isolated from each other. Few areas with what could be considered "source populations" have been found anywhere in the watershed and there is growing concern that some populations have dwindled to the point where reproduction is unlikely. Recent surveys have generally yielded small numbers of old animals that are in poor condition, and often little or no evidence

of recent reproductive success. They may have been recently (within 25 years) extirpated from Stony Brook and the Eightmile River in Connecticut but intensive surveys are needed. The best known brook floater site in Massachusetts, located in the West Branch Farmington River, was assessed in 2007 and was found to be comprised entirely of old animals with a high to severe degree of shell erosion (Nedeau and Low 2008a). Nearly 92 percent (22 of 24) of the animals were within five percent (or larger) than the typical maximum size for the species, and there was no evidence that the population had produced new offspring in the last 8-10 years. This population may not persist longer than the life span of the remaining individuals. Identifying source populations, identifying environmental factors that are hindering known populations, and developing protection and restoration strategies are urgent priorities.

Brook Floater Range in the Connecticut River Watershed

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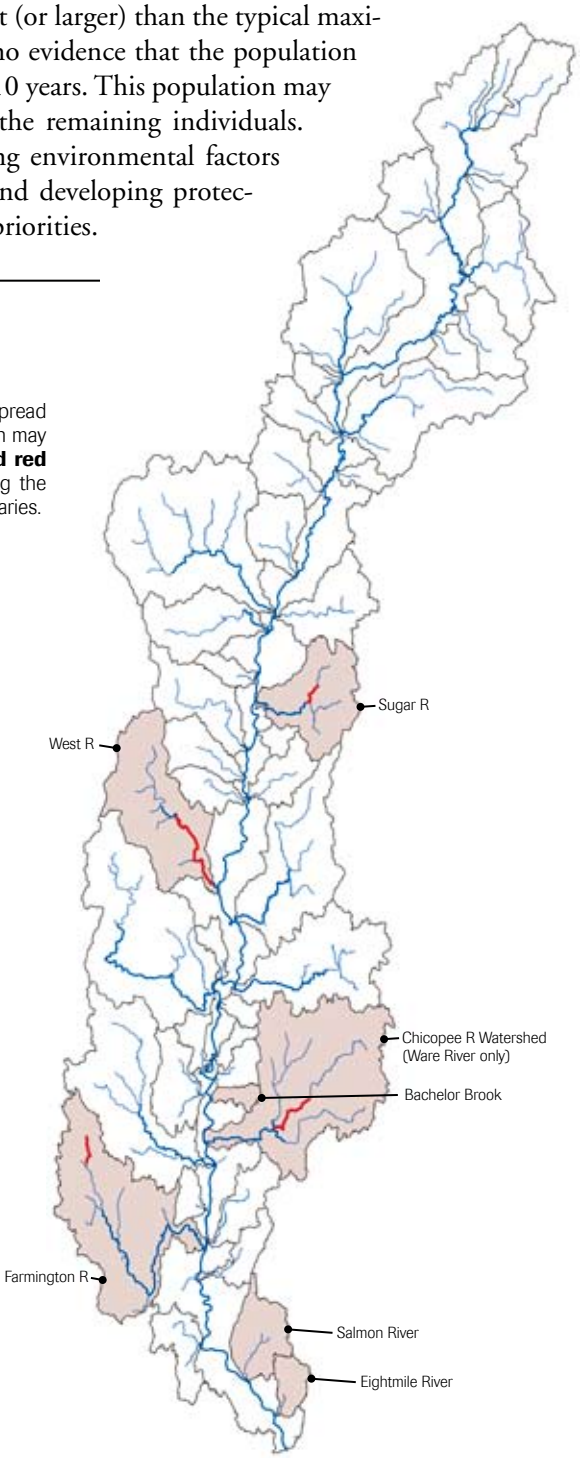


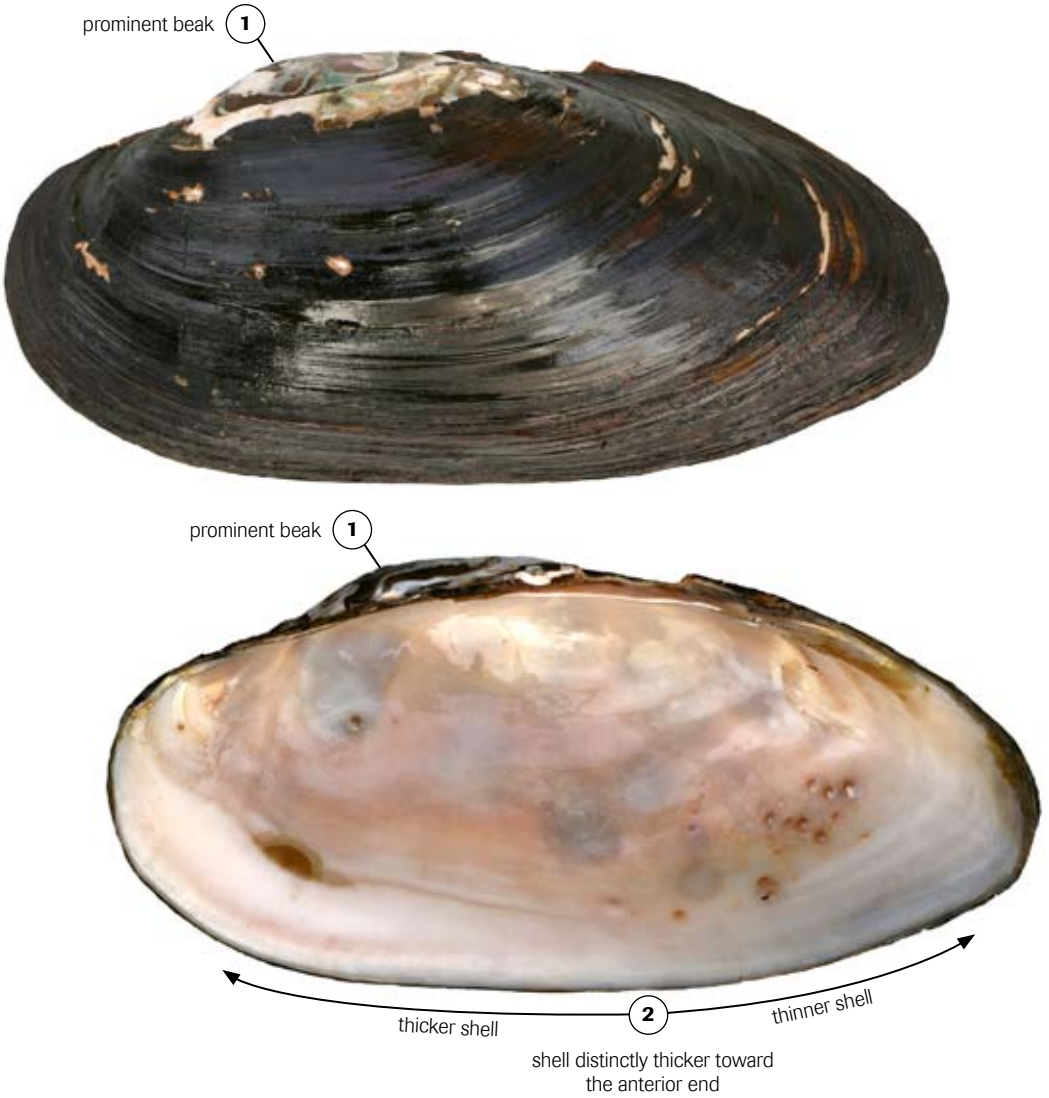
Thanks to fish passage at the Holyoke Dam, Turners Falls Dam, and Vernon Dam, shad can now reach portions of the Connecticut River up to Bellows Falls Dam. Alewife floater are once again found in these waters. Ethan Nedeau

Alewife Floater

Anodonta implicata Say, 1829

Description: The alewife floater is a medium-sized to large mussel that may exceed six inches (150 mm) in length. The shape is usually ovate or elliptical and somewhat elongate. Shells are laterally inflated. Beaks are usually prominent and raised above the hinge line **[1]**, and the long hinge is straight or slightly curved. Shells are relatively thin, especially in smaller animals. Internally, the nacre along the ventral margin is thicker at the anterior end than it is at the posterior end **[2]**; this can be discerned visually and by feeling the thickness of the shell along the ventral margin. Hinge teeth are entirely absent. The shell is smooth and color is variable, including green, straw yellow, brown, or black. Growth lines are usually prominent on the periostracum, and young specimens sometimes have shell rays. The nacre is pale copper, pinkish, or white. Because of the lack of hinge teeth and fairly thin shells, application of moderate pressure on the dorsal and ventral surfaces will cause the shells to gape; this may not work well for large animals that have strong shells.
Often confused with the eastern floater and creeper.

Habitat: The alewife floater inhabits streams, rivers, and lakes. High densities are found in coastal ponds with a direct unimpeded connection to rivers that support yearly runs of alewife. However, it also exists in small streams and large rivers, without clear preference for substrate, depth, or flow conditions. Davenport and Warmuth (1965) stated, "*In our experience, the animals present in streams are larger and handsomer than pond specimens; clearly the former are in the optimal environment.*" Its habitat use and population density seems to be more strongly tied



Alewife Floater. External view of the left valve (top) and internal view of the right valve (bottom). Numbers correspond to features in the description. Ethan Nedeau

to where its host fish are likely to spawn or congregate. In coastal ponds of southeastern Massachusetts with strong alewife runs, it was usually one of the most abundant species and was exceptionally abundant near outlet streams where adult alewife were abundant in the spring and where juvenile alewife would congregate in the fall before migrating back to the ocean. In these lakes, they were found in shallow areas with high wave intensity (<1 foot) and in deep areas (>30 feet) below the thermocline (Nedeau and Low 2008b). It may be more tolerant of mud and silt than many other species, and is abundant in tidal-depositional environments where aquatic plant growth is high, such as Salmon Cove, lower Eightmile River, and other coves and backwaters of the lower Connecticut River. It also occurs in gravel and cobble substrates in small rivers with fairly strong flows.

Primary habitat types (see page 16): LTR, LSR, SSLR, lakes.

A younger and lighter-colored alewife floater than what is pictured on page 81. Ethan Nedeau

Biology: Fertilization occurs in late summer or early fall and glochidia are released the following spring. The timing of glochidia release is thought to coincide with the spawning migration of its three fish hosts: alewife, blueback herring, and American shad (Table 1, page 5). Kneeland and Rhymer (2008) also found two striped bass infested with alewife floater glochidia. Subsiding streamflows and a rise in water temperature from late April to early June are thought to be the spawning cues. Glochidia are relatively large at 0.014 inches (0.345 mm), triangular shaped, and have strong hooks and protuberances that help ensure a strong latch on the gills or fins of its host fish (Rand and Wiles 1982). Fecundity is not known but is probably low because glochidia are on the larger end of the size spectrum for freshwater mussels, and there is usually a tradeoff between offspring size and fecundity (Bauer 1994). Glochidia may remain attached for three to four weeks, during which time the fish might travel more than 100 miles up the Connecticut River or into tributaries, allowing the mussel an excellent opportunity to disperse within the range of its fish hosts.

Range: The alewife floater occurs in Atlantic coastal drainages from the Potomac River system in Maryland to Nova Scotia and New Brunswick. It has been found in 13 major tributaries of the Connecticut River, all in Massachusetts or Connecticut, except for the Ashuelot River in New Hampshire where the species was inadvertently introduced via the stocking of adult shad taken from the Connecticut River in Massachusetts (Nedeau and Werle 2003). It occurs in the mainstem Connecticut River as far upstream as the Bellows Falls Dam and becomes increasingly uncommon upstream of each of the major hydropower dams at Holyoke, Turners Falls, and Vernon. It was historically eliminated from these areas due to dams that blocked fish passage, but installation of fishways at the three dams restored the species in much of its historic habitat (Smith 1985). The persistence of the alewife floater toward

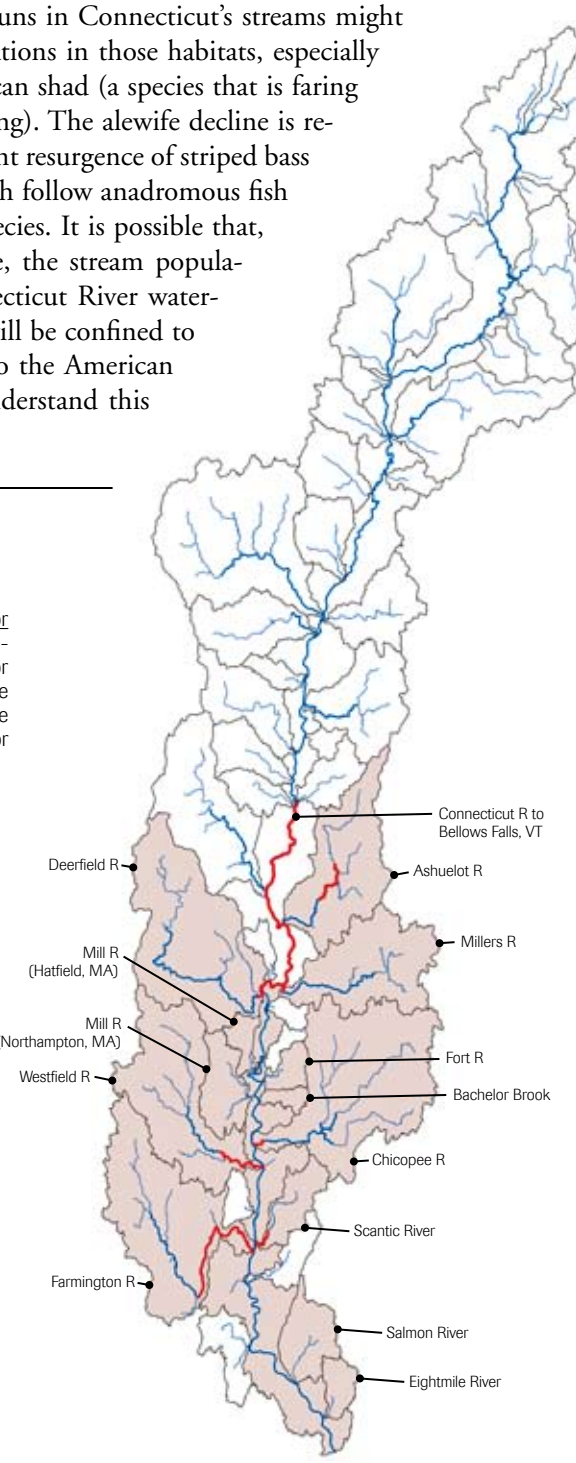
Recent declines of alewife and blueback herring in small rivers in Connecticut and Massachusetts may also be affecting the viability of the alewife floater in these rivers. Ethan Nedeau

the upstream end of its range in the Connecticut River probably relies on continual dispersal of juveniles from high-density populations to the south, carried upriver by American shad or blueback herring (alewife do not swim much beyond the Massachusetts border).

Status: The alewife floater is not a species of concern anywhere in its range. Nevertheless, the decline and loss of alewife runs in Connecticut's streams might also jeopardize alewife floater populations in those habitats, especially streams that are too small for American shad (a species that is faring better than alewife or blueback herring). The alewife decline is related to dams, habitat loss, and a recent resurgence of striped bass in the lower Connecticut River, which follow anadromous fish upriver and prey heavily on these species. It is possible that, due to the loss or decline of alewife, the stream populations of alewife floater in the Connecticut River watershed will disappear and the species will be confined to those large-river habitats accessible to the American shad. More research is needed to understand this possible scenario.

Alewife Floater Range in the Connecticut River Watershed

Shading indicates presence in a major tributary or widespread distribution along the mainstem Connecticut River (which may include several minor tributaries along that reach). **Bold red lines** are used to indicate restricted occurrences along the mainstem Connecticut River and within large major tributaries.



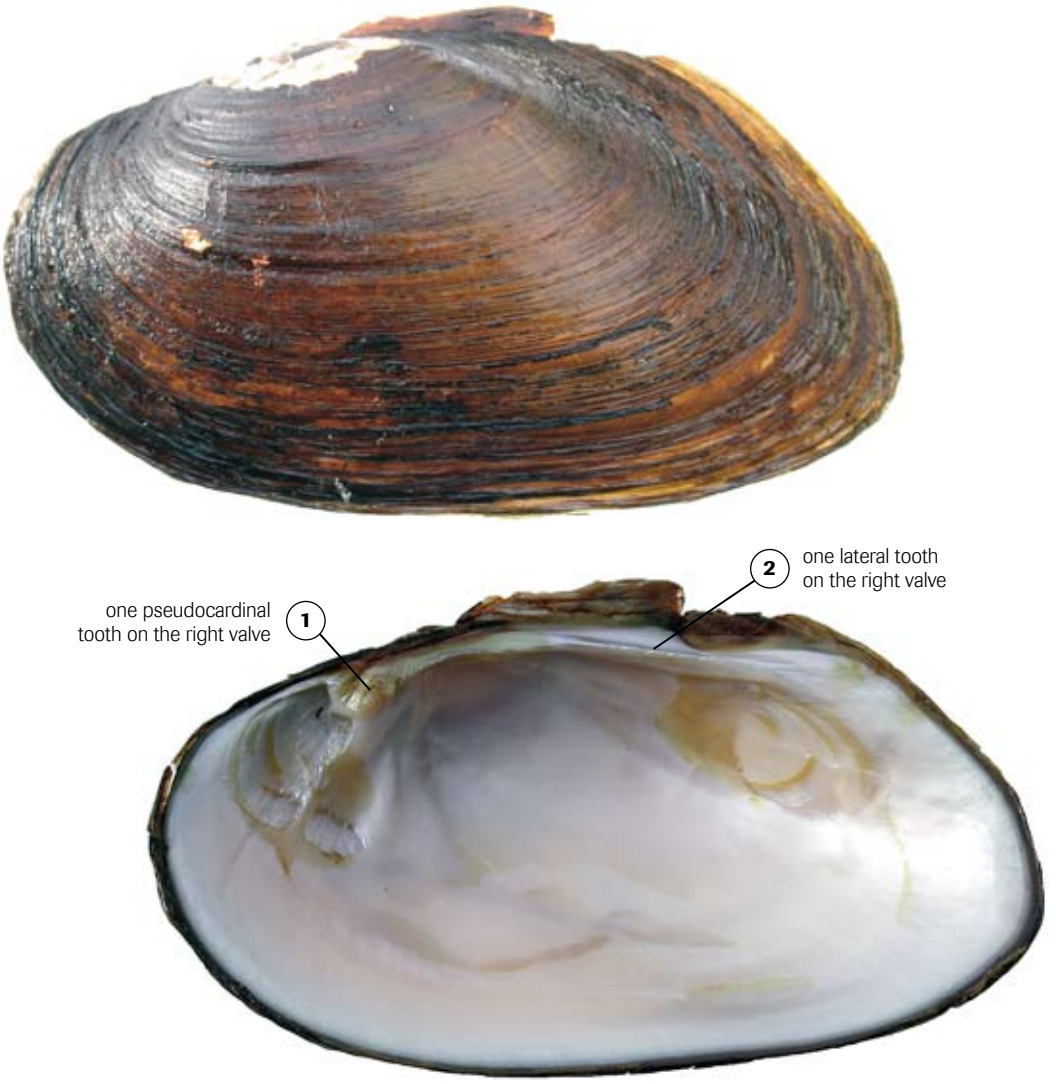
Although the eastern elliptio will occur almost anywhere, low-gradient rivers in the southern half of the watershed, such as the Fort River in Massachusetts, support highest densities. Ethan Nedeau

Eastern Elliptio

Elliptio complanata (Lightfoot, 1786)

Description: The eastern floater is a medium-sized mussel that is usually less than five inches (127 mm) in length. The shape is highly variable but most often elliptical or trapezoidal. Shells are laterally compressed and very strong. Beaks are not very prominent and not raised above the hinge line. Pseudocardinal teeth are well developed—the left valve has two and the right valve has one **[1]**. Lateral teeth are also well developed—the left valve has two and the right valve has one **[2]**. The periostracum is usually tan or brownish in younger individuals to dark brown or black in adults, and there are usually rays on the periostracum. The nacre is purplish, rose-colored, or white in fresh specimens to chalky white in older shells. The mantle margin is gray, white, or reddish, without any distinct patterns. The foot is white.
Often confused with the eastern lampmussel, creeper, and eastern pearlshell.

Habitat: The eastern elliptio inhabits a remarkable variety of habitats, from small coldwater streams to large tidal rivers, and from small ponds to large lakes. It usually outnumbers all other mussel species by at least 10:1 (and sometimes more than 100:1) in these habitats, especially in rivers, except in some coldwater rivers where eastern pearlshell are dominant. In watersheds where eastern elliptio and eastern pearlshell co-occur, the proportional abundance of these two species can indicate large-scale patterns of coldwater habitats (dominated by eastern pearlshell) versus warmwater habitats (dominated by eastern elliptio). The two species can be co-dominant in some portions of rivers, such as the Fort River in Massachusetts, but this situation is far less common than complete dominance by one. In species-rich coastal ponds



Eastern Elliptio. External view of the left valve (top) and internal view of the right valve (bottom). Numbers correspond to features in the description. Ethan Nedeau

of southeastern Massachusetts, eastern elliptio was often co-dominant with, or at least did not vastly outnumber, eastern lampmussel, eastern floater, alewife floater, and tidewater mucket (Nedeau and Low 2008b). The eastern elliptio has no clear preference for substrate: it is found in clay, mud, sand, gravel, and cobble bottoms. Like most species, it is less common in the silty substrates of deep lakes and areas of rivers where substrate is largely boulder and bedrock. Eastern elliptio is one of the few species that may thrive in areas where habitat has been greatly modified or where pollution is moderate to severe, suggesting that the species is tolerant to many of the stressors that limit the distribution and abundance of other species. It also seems to also have an extraordinary ability to quickly colonize new or former habitats if nearby source populations exist.

Primary habitat types (see page 16): LTR, LSR, LNR, SSLR, SUR, lakes.

Biology: Fertilization takes place in early spring and glochidia are released later the same summer. Glochidia are released in long strands of a mucous-like material that drifts in the water or settles to the bottom and ensnares its host fish (Matteson 1948). Individual fecundity is unknown but Haag and Staton (2003) reported average annual fecundity of 136,227 for the closely related *Elliptio arca* from the southern United States. If an elliptio bed that was 100 meters long and 25 meters wide had an average density of 250 mussels per square meter (which is not unusual for some locations in the Connecticut River), and 25 percent of those animals were spawning females, then more than 21 billion glochidia could be released from that mussel bed during a single season! Few studies have attempted to determine the fish hosts for eastern elliptio, but several of its known hosts are native to the Connecticut River watershed, including the American eel, yellow perch, and brook trout (Table 1, page 5). Given the wide range of the eastern elliptio in a variety of habitats, it must use a number of hosts and has therefore been called a generalist. Kneeland and Rhymer (2008) found eastern elliptio on 13 species of fish in central Maine, nine of which were not previously known as hosts. William Lellis and his associates at the U.S. Geological Survey in Pennsylvania conducted host-fish studies for eastern elliptio in the Susquehanna River watershed and found that most fish in the watershed were not suitable hosts. Trials with yellow perch and largemouth bass—two species reported to be hosts for eastern elliptio in other studies—failed to produce juveniles. Several papers describe the life history, behavior, and habitat of eastern elliptio: Matteson 1948, Kesler and Bailey 1993, Balfour and Smock 1995, Kesler and Downing 1997, Amyot and Downing 1997, 1998.

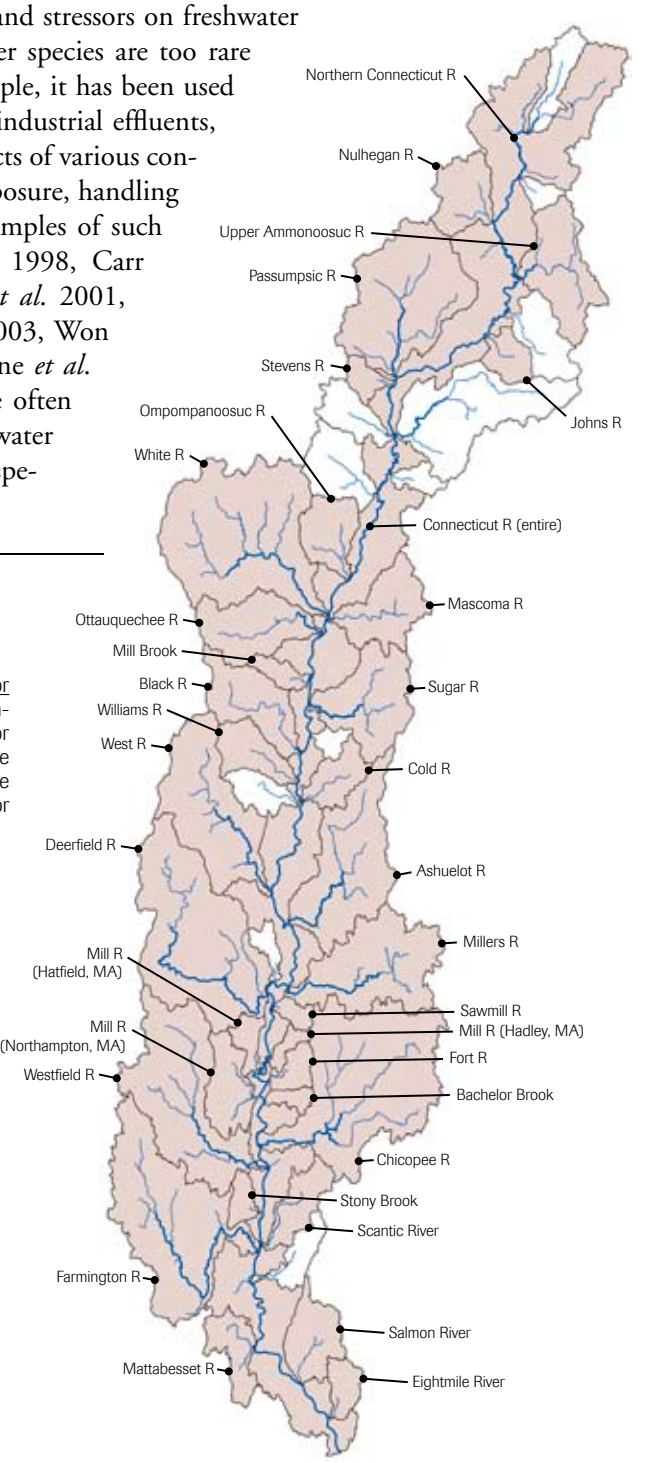
Range: The eastern elliptio occurs along the Atlantic coast from Nova Scotia to Florida. It is also found in the St. Lawrence drainage, some of the Great Lakes (Lake Superior, upper Lake Huron, and Lake Ontario), and the southern James Bay drainages. It is found in nearly every water body that is capable of supporting mussels. It is currently known from 31 major tributaries of the Connecticut River and the entire Connecticut River mainstem (Table 3, page 19). It occurs in all 33 major tributaries or mainstem segments that support two or more species. The only major tributaries where it has not been found are cold-water, high-gradient watersheds in Vermont and New Hampshire that contain only SUR habitat and support no mussels at all. The Israel River is the only major tributary where mussels have been found but eastern elliptio were not found. It probably occurs in watersheds where it has not yet been discovered, especially in lakes or ponds, but surveys have not been completed yet.

High variation in the shape and coloration of eastern elliptio, such as seen here, are thought to be due to local environmental conditions and perhaps naturally high genetic variation within and among "populations." Over the years, people have proposed different races, variants, subspecies, and species within the genus *Elliptio* in eastern North America. Whether the remarkable variation occurs within a single species, or whether different species or subspecies exist, will likely be resolved with genetic and molecular studies. Ethan Nedeau

Status: The eastern elliptio is the most common mussel species in northeastern North America. No state or province considers it a species of concern. It may be the most ecologically valuable benthic animal in the watershed because it is a staple food for other animals, it has a tremendous ability to filter and clean water, and it has a profound effect on nutrient cycling and other ecosystem processes. It serves a valuable role in ecological research and in assessing effects of contaminants and stressors on freshwater mussels, particularly since most other species are too rare for some types of research. For example, it has been used to study lethal or chronic effects of industrial effluents, uptake of metals and toxins, and effects of various conditions such as low oxygen, aerial exposure, handling stress, and thermal stress. A few examples of such studies include Sparks and Strayer 1998, Carr and Mierzykowski 2001, Chittick *et al.* 2001, Gewurtz *et al.* 2002, Martel *et al.* 2003, Won *et al.* 2005, Gagne *et al.* 2006, Gagne *et al.* 2007. Results from these studies are often used to assess risk to the entire freshwater mussel community, particularly rare species.

Eastern Elliptio Range in the Connecticut River Watershed

Shading indicates presence in a major tributary or widespread distribution along the mainstem Connecticut River (which may include several minor tributaries along that reach). **Bold red lines** are used to indicate restricted occurrences along the mainstem Connecticut River and within large major tributaries.



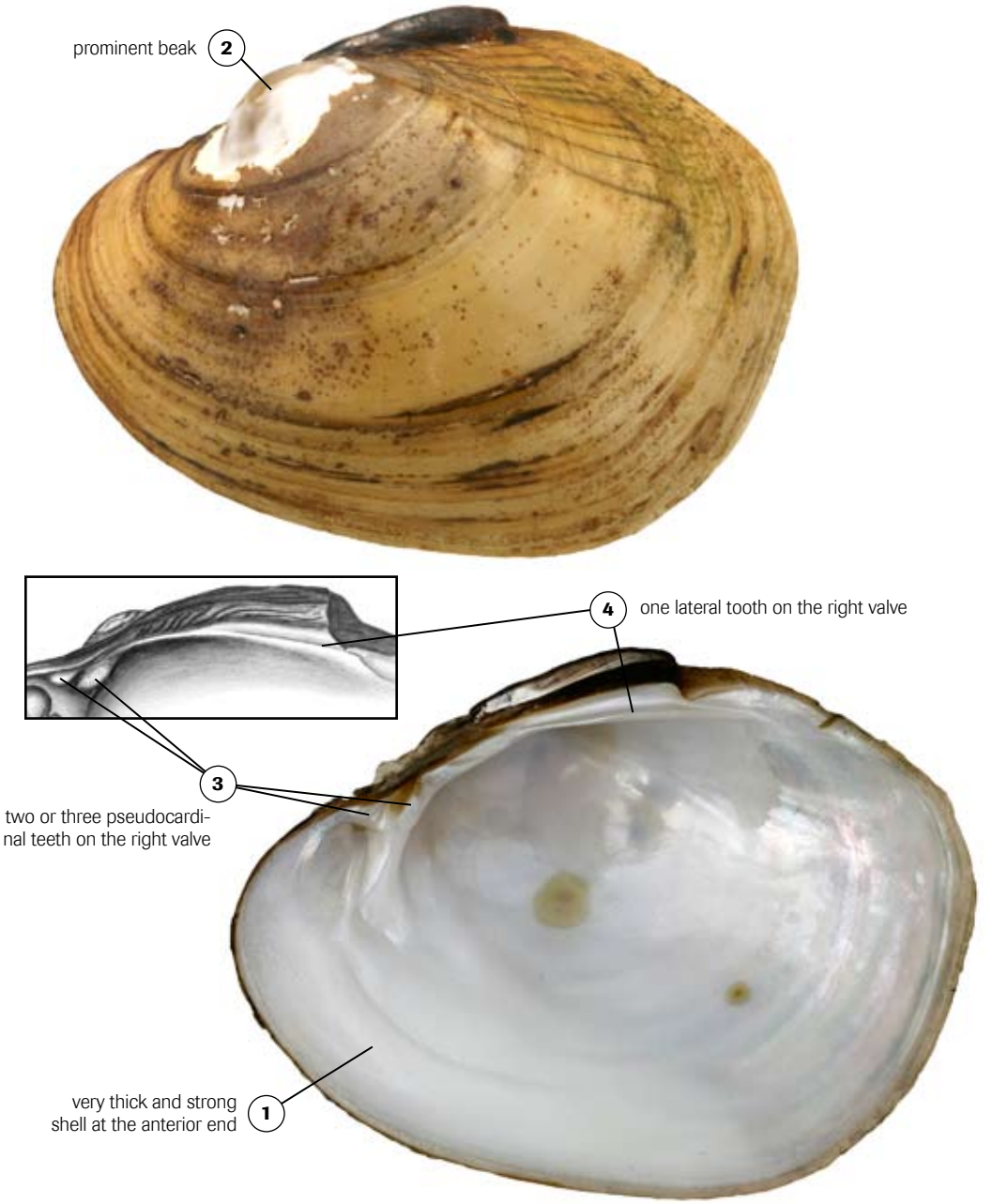
Once thought extirpated in Connecticut and nearly so in Massachusetts, the yellow lampmussel occurs in the Connecticut River in both states, with largest known populations upstream of the Holyoke Dam. Ethan Nedeau

Yellow Lampmussel

Lampsilis cariosa (Say, 1817)

Description: The yellow lampmussel is a medium-sized to large mussel that is usually less than 5.25 inches (134 mm) in length. The shape is ovate and the shells are laterally inflated. Shells of sexually mature females are usually more rounded toward the posterior ventral margin, and thus more distinctly oval-shaped, than males or adolescent females. The shells are thick and very strong, particularly toward the anterior end **[1]**. Beaks are prominent and raised above the hinge line **[2]**. Pseudocardinal teeth are well developed—the left valve has two and the right valve has two or three **[3]**. Pseudocardinal teeth are usually stout, with distinct striations on the surface, and are located nearly directly under the beak. Lateral teeth are also well developed—the left valve has two and the right valve has one **[4]**. The periostracum of young healthy specimens is often a bright shiny yellow, but may lose its luster and become darker with age. Most individuals (particularly young ones) have faint green rays on the periostracum, especially toward the dorsal-posterior portion of the shell. The nacre is usually white or bluish-white.
Often confused with the tidewater mucket (especially young animals) and eastern lampmussel (especially stained or damaged shells).

Habitat: Within the limited range of the yellow lampmussel in the Connecticut River, it has been found in shallow water and areas more than 30 feet deep, usually in slow to moderate flow conditions. Nedeau (2005a) found that within its core range in Massachusetts, it exhibited a distinct preference for sand and fine gravel substrates, and it was proportionately more abun-



Yellow Lampmussel. External view of the left valve (top) and internal view of the right valve (bottom). Inset illustration shows hinge teeth detail. Numbers correspond to features in the description. Ethan Nedeau

dant in shallow sandbars than it was in nearby areas that were deeper and had a rocky or muddy substrate. In contrast, the other two species consistently found with it—the eastern elliptio and alewife floater—were more common in nearby deeper rockier habitats and in muddy areas near banks. All specimens found in Connecticut were also found in a shallow sandbar (Nedeau 2006i) and shared habitat with tidewater muckets, eastern elliptio, alewife floater, and triangle floater (as well as the non-native Asian clam). Outside of the Connecticut River watershed, the

yellow lampmussel has been found in medium to large rivers and lakes, including free-flowing rivers with rocky substrates and a mussel fauna more characteristic of SSLR or SUR habitats (Strayer and Fetterman 1999, Nedeau *et al.* 2000). For example, it was found alongside the eastern pearlshell, brook floater, creeper, and triangle floater in several rivers in Maine (Nedeau *et al.* 2000). Thus, the limited range of habitats that the yellow lampmussel occupies in the Connecticut River watershed is uncharacteristic for the species and may be the result of historic pollution, loss of habitat, or perhaps natural limiting factors.
Primary habitat types (see page 16): LTR, LSR

Biology: Eggs are fertilized in the late summer and glochidia are released the following spring. Spawning females have a mantle margin with bright pigmentation, a swollen appearance, and fleshy lobes that are used to lure host fish toward them. A dark "eyespot" near the inhalent aperture makes the display look even more fish-like (see photo on page 6). Species that have a mantle modified to attract host fish are thought to be less reliant on the overall density of fish than species without such adaptations (Haag and Warren 1998), but they do rely on being seen by these fish. This might help explain why yellow lampmussels seem to prefer shallow sandy areas of the river where they are very conspicuous, especially since few other species are there to crowd them out (especially eastern elliptio). Wick (2003) found that females displayed their mantle lure more actively at night and postulated that this was an adaptation to take advantage of piscivorous fish that move into shallow areas to feed at night. Their reliance on the visual acuity of their fish hosts also indicates the potential importance of turbidity in interfering with reproduction. The white perch and yellow perch may be the primary hosts but recent studies in Maine have identified several other possible hosts (Table 1, page 5). The striped bass is closely related to the white perch (in the genus *Morone*) and has made a recent resurgence in the Connecticut River. If the striped bass is a host, it is possible that the recent range expansion of the yellow lampmussel in the Connecticut River, particularly the discovery of young yellow lampmussels in Connecticut, is related to the resurgence of the striped bass. Wick (2003) found that longevity could exceed 20 years, and based on the large size and slow growth of relic yellow lampmussel shells from the Connecticut River, life spans exceeding 30 years are not unlikely.

Range: The yellow lampmussel is distributed throughout the Atlantic coastal watersheds from Georgia to Nova Scotia and Cape Breton Island. Its range in New England is confined to only four major watersheds: the Connecticut River, Kennebec River, Saint George River, and Penobscot River, with the latter three all in Maine. In the Connecticut River watershed, the yellow lampmussel is confined to a 50-mile segment of the mainstem Connecticut River from Windsor, CT to Turners Falls, MA. It also occurs in the Holyoke Power Canals in Holyoke, Massachusetts.

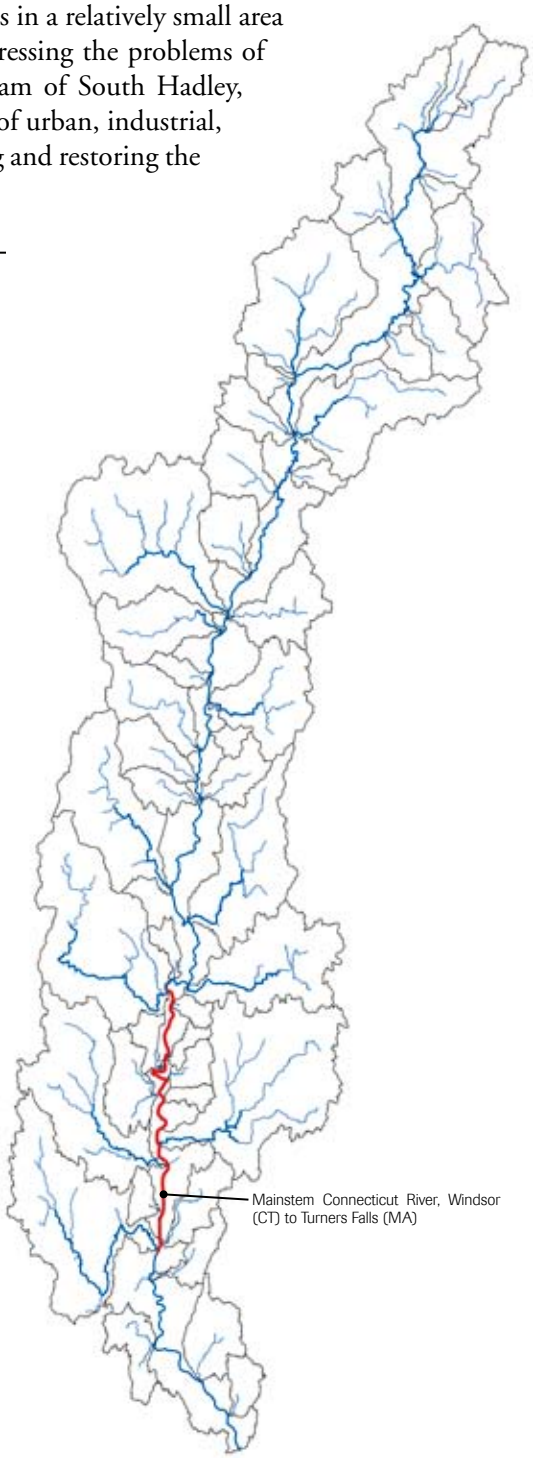
Three young and healthy-looking yellow lampmussels from the Connecticut River in Hadley, Massachusetts. Ethan Nedeau

Status: The yellow lampmussel is listed as endangered in Massachusetts. Until 2006, it was thought to be extirpated

in Connecticut and it was therefore listed as special concern, but its rediscovery in 2006 meant that its status could be switched to endangered. Only three live animals have been seen in Connecticut. Much larger populations exist in Massachusetts, upstream of the Holyoke Dam, and it is hoped that this large population will remain healthy and produce new recruits that will recolonize more areas of the river. Until then, the yellow lampmussel population will remain critically imperiled because it exists in a relatively small area and is vulnerable to catastrophic events. Addressing the problems of combined sewer overflows in areas downstream of South Hadley, Massachusetts, and dealing with other effects of urban, industrial, and agricultural runoff is critical for protecting and restoring the yellow lampmussel.

Yellow Lampmussel Range in the Connecticut River Watershed

Shading indicates presence in a major tributary or widespread distribution along the mainstem Connecticut River (which may include several minor tributaries along that reach). **Bold red lines** are used to indicate restricted occurrences along the mainstem Connecticut River and within large major tributaries.



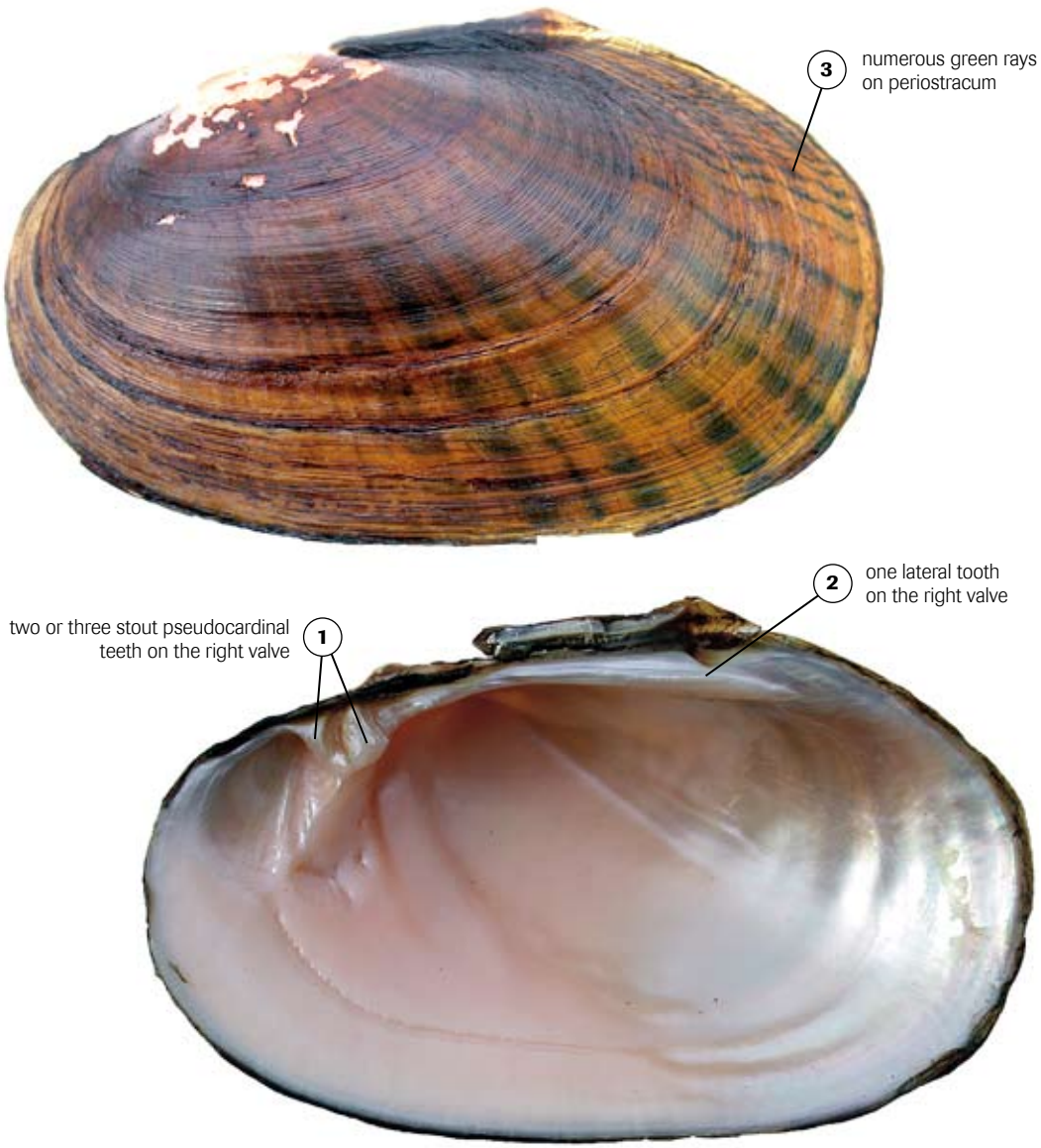
At this site in the Ashuelot River (New Hampshire), the eastern lampmussel shares habitat with the creeper, triangle floater, eastern floater, alewife floater, eastern elliptio, and dwarf wedgemussel. Ethan Nedeau

Eastern Lampmussel

Lampsilis radiata radiata (Gmelin, 1791)

Description: The eastern lampmussel is a medium-sized mussel that is usually less than five inches (127 mm) in length. The shape is ovate or elliptical, and the shells are moderately inflated. Shells of sexually mature females are usually more rounded toward the posterior ventral margin than the shells of males or adolescent females. The shells are thick (especially in larger animals) and very strong. Beaks are not very prominent and barely raised above the hinge line. Hinge teeth are well developed; the left valve has two pseudocardinal teeth and two lateral teeth, and the right valve has two or three pseudocardinal teeth **[1]** and one lateral tooth **[2]**. The shell is yellowish-green in younger individuals to brownish-green or black in older individuals. There are usually numerous green rays covering the periostracum **[3]**, though these are sometimes obscured in stained or heavily eroded shells. The nacre is usually white, pink, or bluish-white. Spawning females have a mantle margin with striking pigmentation, a swollen appearance, and fleshy extensions that are unmistakable from all other species except the yellow lampmussel.
Often confused with the eastern elliptio, tidewater mucket, or yellow lampmussel.

Habitat: The eastern lampmussel inhabits a variety of aquatic habitats, including streams, large rivers, and lakes. It is as common in lakes as it is in rivers in southeastern New Hampshire, eastern Massachusetts and Maine, but its distribution in lakes in the Connecticut River watershed is not well documented. In coastal ponds of southeastern Massachusetts, it was often co-dominant with eastern elliptio and occurred at depths of one to more than 30 feet in a variety of



Eastern Lampmussel. External view of the left valve (top) and internal view of the right valve (bottom). Numbers correspond to features in the description. Ethan Nedeau

substrates (Nedeau and Low 2008b). It is often found in deeper and more stable areas of large rivers, usually in sand and gravel. It is rarely found in small coldwater streams that may support species such as eastern pearlshell. Because of its broad distribution, preference for rivers and lakes (and impoundments), and its abundance in warmwater environments, it is regarded as tolerant of some parameters that often pose challenges for other more sensitive species, such as warm water and low dissolved oxygen. Nevertheless, the best known populations occur in high-quality areas of the Connecticut River watershed and the species is conspicuously scarce in some areas, suggesting it may be sensitive to conditions that have not been identified.
Primary habitat types (see page 16): LTR, LSR, LNR, SSLR, lakes.

Biology: Eggs are fertilized in summer or early fall and glochidia are released the following year. Spawning females have a mantle margin with striking pigmentation, a swollen appearance, and fleshy lobes. A pair of long fleshy lobes protrudes away from the shell and females undulate, or "wiggle" these lobes to lure fish toward them. Spawning females also tend to migrate toward the surface of the sediment and "stand on their tippy toes" to make themselves more visible to fish, whereas males and non-breeding females tend to be more buried. These behaviors and morphological adaptations increase the chances that glochidia will encounter their hosts. Spawning females have been observed from June to October in the Connecticut River watershed. Glochidia are released in conglutinates that resemble orzo. This species has been reported to parasitize a number of warmwater species, especially perch, bass, and sunfish (Table 1, page 5). No experimental studies of host fish suitability have been conducted in New England, but the range and habitat of eastern lampmussels correlates well with the range of habitat of its suspected hosts. The large size, strong shell, and relatively slow growth of these animals suggests that longevity is high; perhaps more than 30-40 years.

Top: Close-up of the inhalent and exhalent aperture of a male or non-gravid female. Bottom: Close-up of the swollen and showy mantle of a gravid female; an arrow points to a pair of flaps that the female wiggles to lure fish closer to her.

Photos by Andre Martel, reproduced with permission of the Canadian Musem of Nature, Ottawa, Canada.

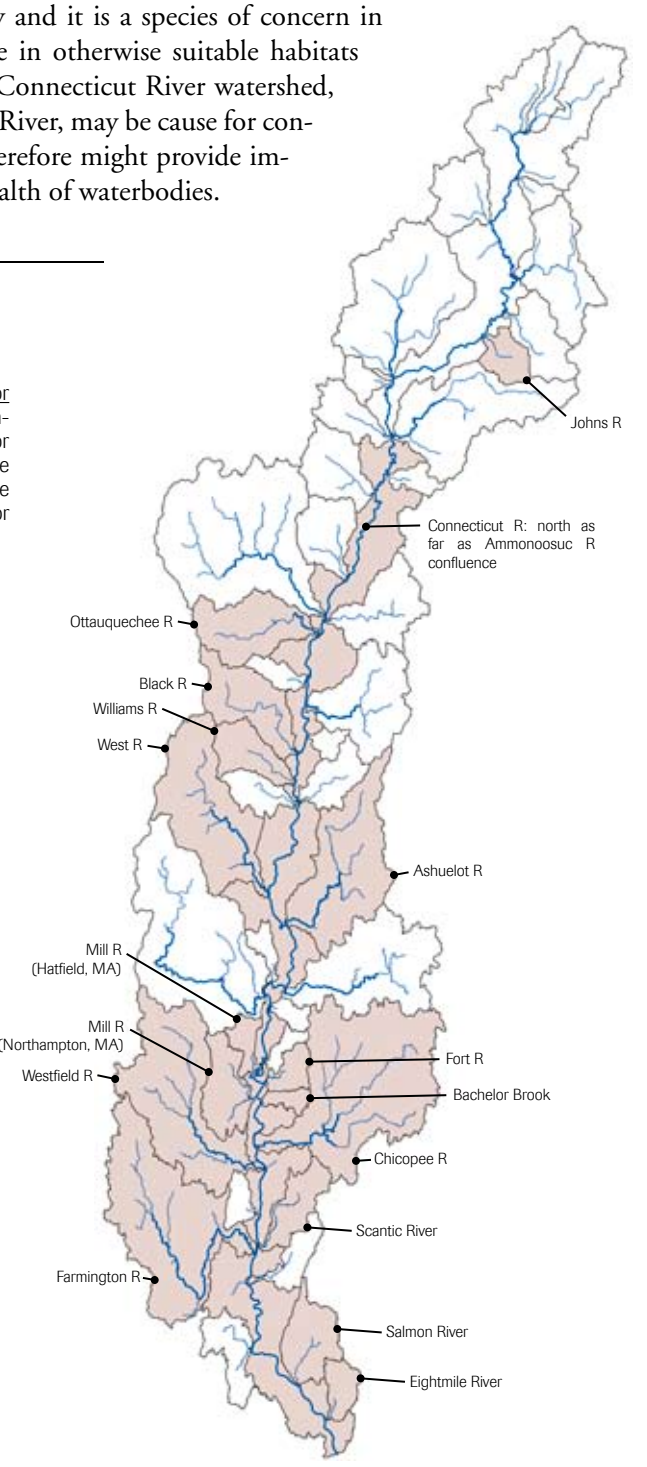
Range: The eastern lampmussel is widely distributed in Atlantic coastal drainages from South Carolina to Nova Scotia, as well as the lower St. Lawrence River drainage. It is found in 16 major tributaries of the Connecticut River and in the entire mainstem south of Barnet, Vermont. None have been found in the mainstem upstream of the Moore Reservoir but were found in the lower Johns River. They are conspicuously scarce in the Massachusetts portion of the mainstem Connecticut River, although very old relic shells have been found in some locales suggesting that they were once more common there (Nedeau 2005a). They occur in all major tributaries or mainstem segments that support six or more species, and

in only two of 28 (seven percent) major tributaries that support five or fewer species. It occurs in several minor tributaries of the Connecticut River, mainly in the southern half of the watershed, and in many smaller rivers within major watersheds.

Status: This species is common and widespread throughout most of its range. It is listed as Threatened in New Jersey and it is a species of concern in Rhode Island. Its scarcity or absence in otherwise suitable habitats in the Massachusetts portion of the Connecticut River watershed, especially the mainstem Connecticut River, may be cause for concern. It is a long-lived species and therefore might provide important insight into the long-term health of waterbodies.

Eastern Lampmussel Range in the Connecticut River Watershed

Shading indicates presence in a major tributary or widespread distribution along the mainstem Connecticut River (which may include several minor tributaries along that reach). **Bold red lines** are used to indicate restricted occurrences along the mainstem Connecticut River and within large major tributaries.



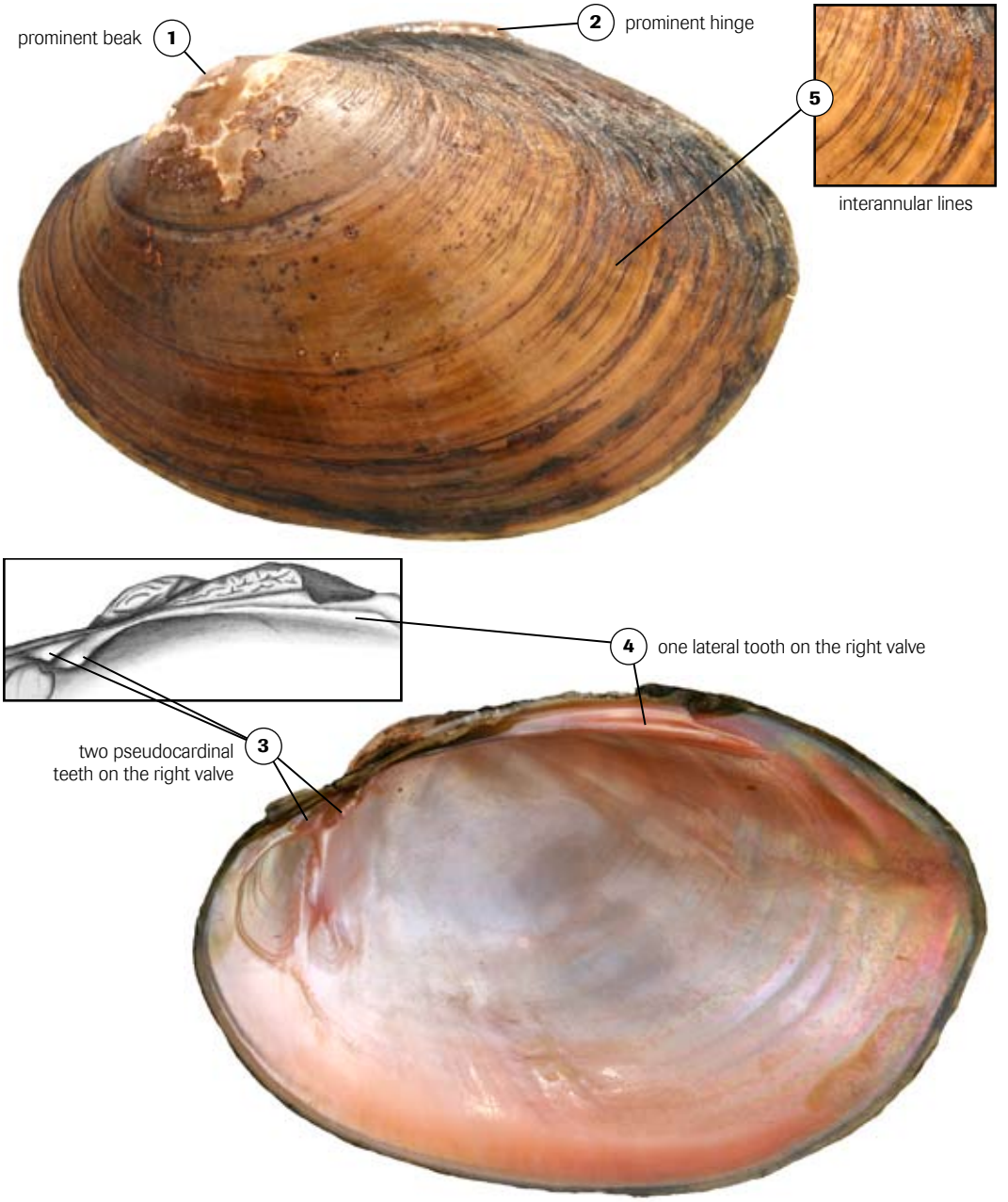
Salmon Cove, near where the Salmon River joins the Connecticut River in Connecticut, is perhaps the best tidewater mucket habitat in the Connecticut River watershed. Ethan Nedeau

Tidewater Mucket

Leptodea ochracea (Say, 1817)

Description: The tidewater mucket is a medium-sized mussel that rarely exceeds four inches (100 mm) in length. The shape is ovate and the shells are laterally inflated. Shells of sexually mature females are usually more rounded toward the posterior ventral margin, and thus more oval-shaped than males or adolescent females. Shells are uniformly thin but quite strong. The beaks are prominent and raised above the hinge line **[1]**, and the hinge itself is also quite prominent **[2]**. Hinge teeth are thin and delicate. The left valve has two pseudocardinal teeth and two lateral teeth, and the right valve has two pseudocardinal teeth **[3]** and one lateral tooth **[4]**. Pseudocardinal teeth are rather thin and elongate (compared to the stout triangular teeth of some other species), and are located anterior of the beak. The periostracum is usually yellowish or greenish-brown, sometimes with a bronze or reddish hue. Juveniles tend to be more yellowish but their shells darken with age. Fine green rays are usually evident on the shell, especially in younger specimens. Dark interannular lines may also be evident on clean shells **[5]**. The nacre is usually pinkish or salmon-colored.
Often confused with the yellow lampmussel (especially young animals) and the eastern lampmussel (especially stained or damaged shells).

Habitat: The tidewater mucket, as its name suggests, inhabits coastal freshwater environments despite that none of its confirmed fish hosts are anadromous. It occurs in small to large rivers, ponds, and lakes that have, or historically had, direct unimpeded connections with coastal waters. In the Connecticut River watershed, it inhabits muddy, sandy, and gravelly substrates in



Tidewater Mucket. External view of the left valve (top) and internal view of the right valve (bottom). Inset illustration shows hinge teeth detail. Numbers correspond to features in the description. Ethan Nedeau

the Connecticut River downstream of the Holyoke Dam and in comparable habitats near the mouths of major tributaries. The tidewater mucket may infrequently be encountered in small low-gradient streams near the Connecticut River in Connecticut, such as the Podunk River in East Windsor or Pattaconk Brook in Chester. They have been found in water depths of one to more than 25 feet, and in a variety of flow conditions, but seem to prefer depositional areas with slow currents. Highest densities have been found in Salmon Cove, a freshwater tidal en-

vironment near the mouth of the Salmon River in Connecticut, and healthy populations also exist in sandbar habitats near islands in the mainstem Connecticut River. Coastal plain ponds of southeastern Massachusetts with springtime alewife runs may provide the best habitat for this species; densities exceeding 10-15 animals per square meter have been found in the sandy bottoms of these ponds (Nedeau and Low 2008b). No lake or pond populations are currently known in the Connecticut River watershed. Lake populations are prevalent throughout central Maine (Nedeau *et al*. 2000).
Primary habitat types (see page 16): LTR, LSR (lakes elsewhere in its range)

Biology: Eggs are fertilized in late summer and glochidia are released the following spring. Wick (2003) studied the reproductive biology of tidewater muckets in Maine and found that females did not have specialized mantle displays to attract fish hosts, nor did they release glochidia in a conglutinate. The unhooked glochidia attach to gill filaments of their host fish. Wick (2003) found that white perch was a suitable host for the tidewater mucket. The suitability of alewife as a host for tidewater muckets was also tested but all fish perished before results were apparent. Kneeland and Rhymer (2008) found that the banded killifish was a potential host for tidewater muckets in Maine, based on the observation of one fish that was heavily infested with 21 glochidia. The white perch and banded killifish are each tolerant of brackish conditions and prefer the same types of habitats as tidewater muckets in the Connecticut River watershed. The potential role of alewife as a host fish for the tidewater mucket should be further investigated. Also, the striped bass is closely related to the white perch (in the genus *Morone*) and its recent resurgence in the lower Connecticut River might be related to a recent perceived recovery of tidewater muckets in this same area. Based on the relatively small size and thin shells of tidewater muckets, and aging studies done in Maine (Wick 2003), longevity is probably less than 15 years for this species. However, the extremely large size of tidewater muckets from Salmon Cove, including a 4.25-inch (108 mm) animal that is the largest tidewater mucket ever observed, suggests that size and perhaps longevity could be greater in stable and highly productive habitats.

Range: The tidewater mucket is found in Atlantic coastal drainages from Georgia to Nova Scotia. It has been found in only two major tributaries of the Connecticut River in Connecticut, including the lower Farmington River (within one mile of its confluence with the Connecticut River) and Salmon River (Salmon Cove to Leesville Dam). In the mainstem, it has been found near the mouths of other rivers and in coves and backwater areas. In Massachusetts, it has only been found in a small area downstream of the Holyoke Dam, although most of the mainstem between the Holyoke Dam and the Connecticut border has been poorly surveyed.

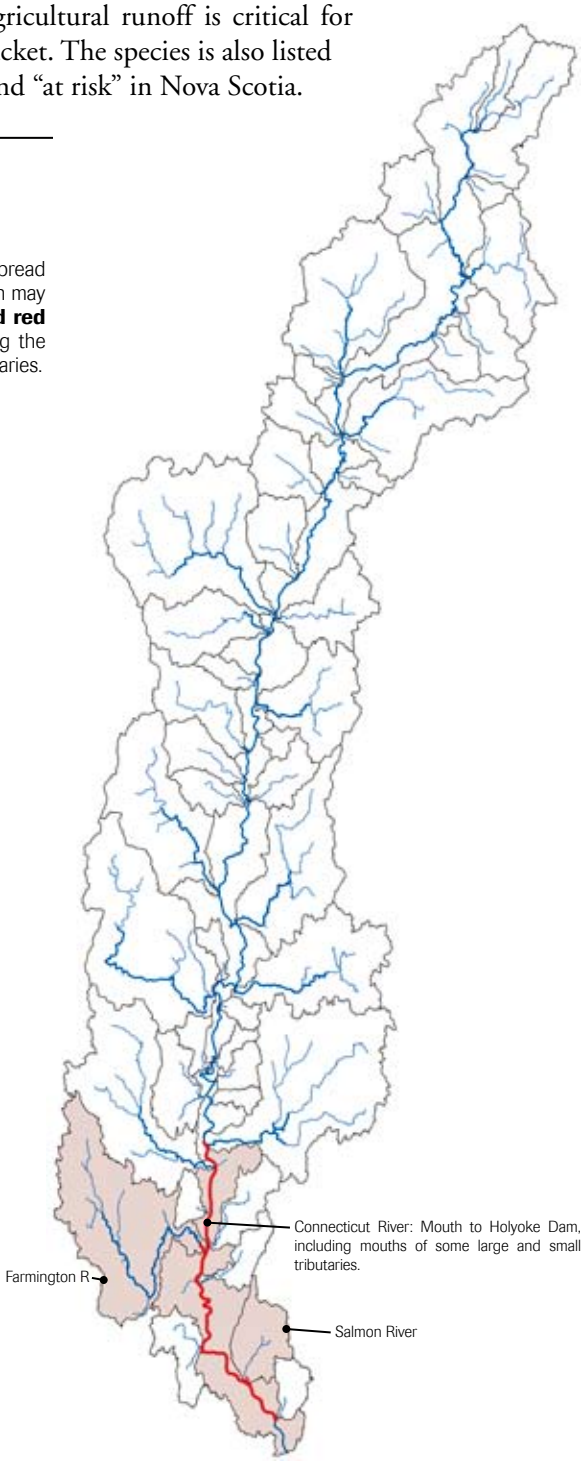
A young tidewater mucket with a more yellow shell. These can sometimes be difficult to distinguish from yellow lampmussels.
Ethan Nedeau

Status: The tidewater mucket is listed as special concern in Massachusetts. This listing is based largely upon relatively healthy and stable populations

in southeastern Massachusetts, whereas the population in the Connecticut River watershed is considerably more rare and imperiled. As of April 2008, the tidewater mucket was listed as threatened in Connecticut but it has been found at an increasing number of locations and its status may be changed to special concern. Addressing the problems of combined sewer overflows in areas downstream of South Hadley, Massachusetts, and dealing with other effects of urban, industrial, and agricultural runoff is critical for protecting and restoring the tidewater mucket. The species is also listed as threatened in New Jersey and Maine, and "at risk" in Nova Scotia.

Tidewater Mucket Range in the Connecticut River Watershed

Shading indicates presence in a major tributary or widespread distribution along the mainstem Connecticut River (which may include several minor tributaries along that reach). **Bold red lines** are used to indicate restricted occurrences along the mainstem Connecticut River and within large major tributaries.



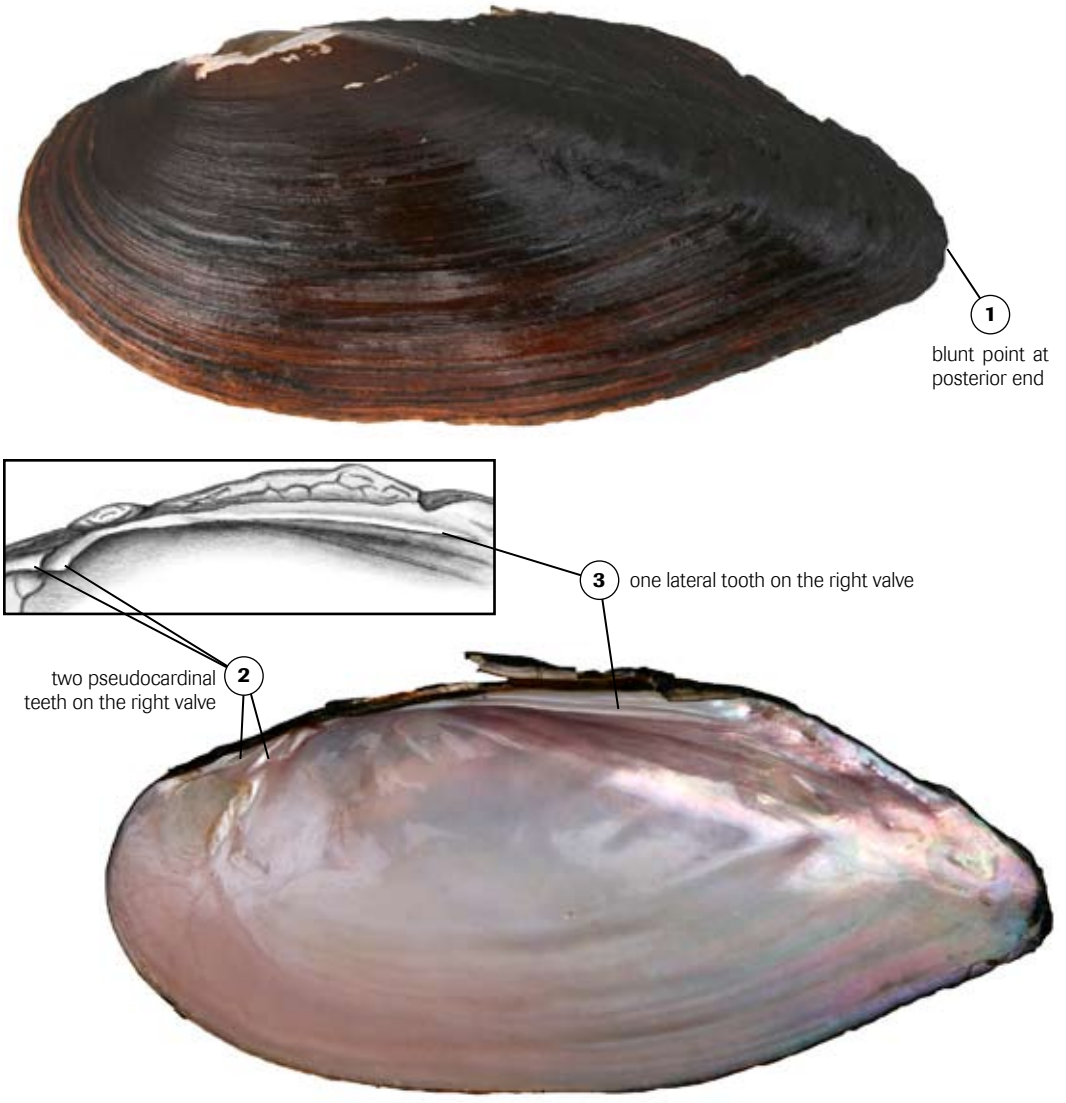
The eastern pondmussel exists in the southern third of the watershed, in places like the lower tidal portion of the Eightmile River. Eightmile River Coordinating Committee

Eastern Pondmussel

Ligumia nasuta (Say, 1817)

Description: The eastern pondmussel is a medium-sized to large mussel that may exceed six inches (150 mm) in length. The shape is distinctly elongate or elliptical and the posterior end tapers to a blunt point **[1]**. Shells of sexually mature females may be slightly more rounded toward the posterior ventral margin than males or adolescent females. Shells are laterally compressed, and despite being thin, they are quite strong. Beaks are low and barely extend beyond the line of the hinge. Hinge teeth are well developed but delicate—the left valve has two pseudocardinal teeth and two lateral teeth, and the right valve has two pseudocardinal teeth **[2]** and one lateral tooth **[3]**. The periostracum is yellowish or greenish-black in young individuals, but usually dark brown or black in older specimens. Shell rays are sometimes evident on those individuals with a light-colored periostracum. The nacre is usually purple, pink, or silvery-white.

Habitat: The eastern pondmussel inhabits a wide variety of habitats in the southern part of the watershed, including small to large rivers and lakes. It exhibits no distinct preference for substrate, depth, or flow conditions. It has been found at relatively high densities at depths of 15-25 feet in coastal ponds where the substrate was primarily mud (Nedeau and Low 2008b), and in shallow rivers with relatively strong currents and a substrate of gravel and cobble. It is more commonly found in deeper areas of low-gradient tidal and non-tidal rivers than in small shallow streams; best examples are the lower Farmington River, lower Salmon River, and near islands and coves of the lower Connecticut River. It is known to occur in only three ponds in the watershed, all in Connecticut, yet it occurs in many ponds in eastern Massachusetts.



Eastern Pondmussel. External view of the left valve (top) and internal view of the right valve (bottom). Inset illustration shows hinge teeth detail. Numbers correspond to features in the description. Ethan Nedeau

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Primary habitat types (see page 16): LTR, LSR, SSLR, lakes.

Biology: Fertilization occurs in late summer and glochidia are released the following spring. Females use papillae along their mantle margins to lure potential host fish; this behavior was described by Corey *et al.* (2006). Displaying females tend to migrate toward the surface of the sediment, and may even lie fully on the surface of the sediment (unburied) to increase their visibility to fish. They will also part their valves widely, exposing more of the mantle edge. Quoting from Corey *et al.* (2006), "*The mantle edges separated and papillae along each margin fluttered in synchrony up and down the mantle margin. As the mantle edges parted, the light-colored interior was exposed and contrasted sharply with the darkly pigmented mantle edges. This light-colored patch appeared to move along the mantle margin as well, giving the illusion of a*

A lighter-colored specimen than what is shown on page 101. Green shell rays are evident on this shell, especially toward the posterior half. Ethan Nedeau

A displaying female eastern pondmussel. The white dot described by Corey et al. (2006) is marked with an arrow. Catherine Corey

moving white dot. This spot moving along the mantle margin resembled a small swimming invertebrate, such as an amphipod…Fish attempted to attack the moving white spot…All three of these mussels released a burst of free glochidia when attacked. Attacking fish retreated quickly with their gill covers flared." This display behavior occurred primarily during daylight and paused at night and when turbidity was raised in the tanks. In addition to the free (unbound) glochidia mentioned above, they also observed females releasing elongate, light-colored conglutinates when no fish were present. The host fish have not yet been determined, though the mussel's range suggests that its hosts have some affinity for coastal areas. Closely related species have been reported to parasitize centrarchids (sunfishes and bass) as well as the banded killifish. Many of these species also occur throughout the eastern pondmussel's range in the Connecticut River watershed and elsewhere in southern New England. Little else is known about the biology of the eastern pondmussel. The largest known specimen, at 6.25 inches (159 mm), was found in Salmon Cove in East Haddam, Connecticut (Nedeau 2005c).

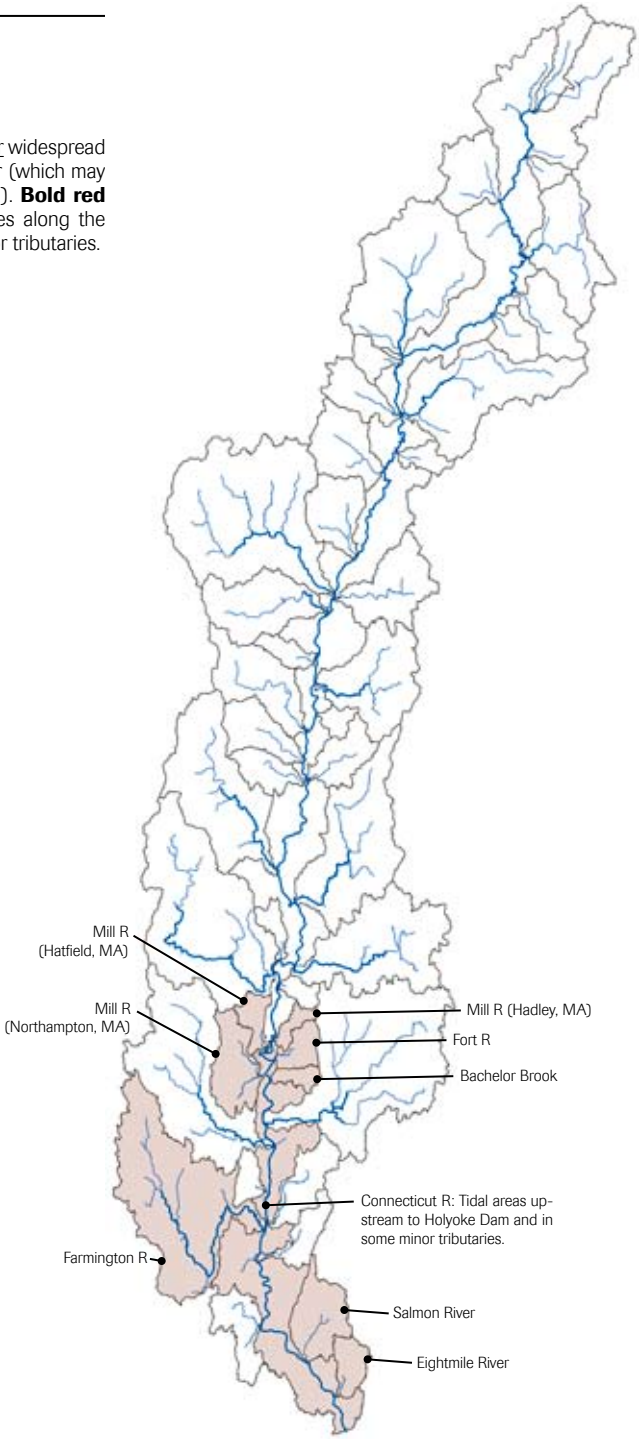
Range: The eastern pondmussel is distributed throughout Atlantic coastal drainages from Virginia to New Hampshire and in the eastern Great Lakes region. It is most abundant in southeastern Massachusetts, particularly large coastal plain ponds and rivers in the mainland and on Cape Cod. There is a dubious historic record from the Ashuelot River in New Hampshire, and it also occurs in a few locations in southeastern New Hampshire. It is currently known to occur in eight major tributaries of the Connecticut River in Massachusetts and Connecticut (Table 3, page 19), several minor tributaries, and the mainstem Connecticut River in Connecticut.

Status: This species is listed as Special Concern in Massachusetts, Connecticut, and New Hampshire. It is quite rare in the Connecticut River watershed in Massachusetts and would likely warrant greater protection were it not for large populations in southeastern Massachusetts. Thus, special considerations may be required for watershed-level protection of this spe-

cies. Though it is faring better in Connecticut, there are only three areas that seem to support relatively large populations that exhibit signs of recruitment, including the Farmington River, lower Salmon River, and portions of the lower tidal Connecticut River. Additional surveys are needed to determine the distribution, abundance, and viability of this species in the Connecticut River watershed.

Eastern Pondmussel Range in the Connecticut River Watershed

Shading indicates presence in a major tributary or widespread distribution along the mainstem Connecticut River (which may include several minor tributaries along that reach). **Bold red lines** are used to indicate restricted occurrences along the mainstem Connecticut River and within large major tributaries.



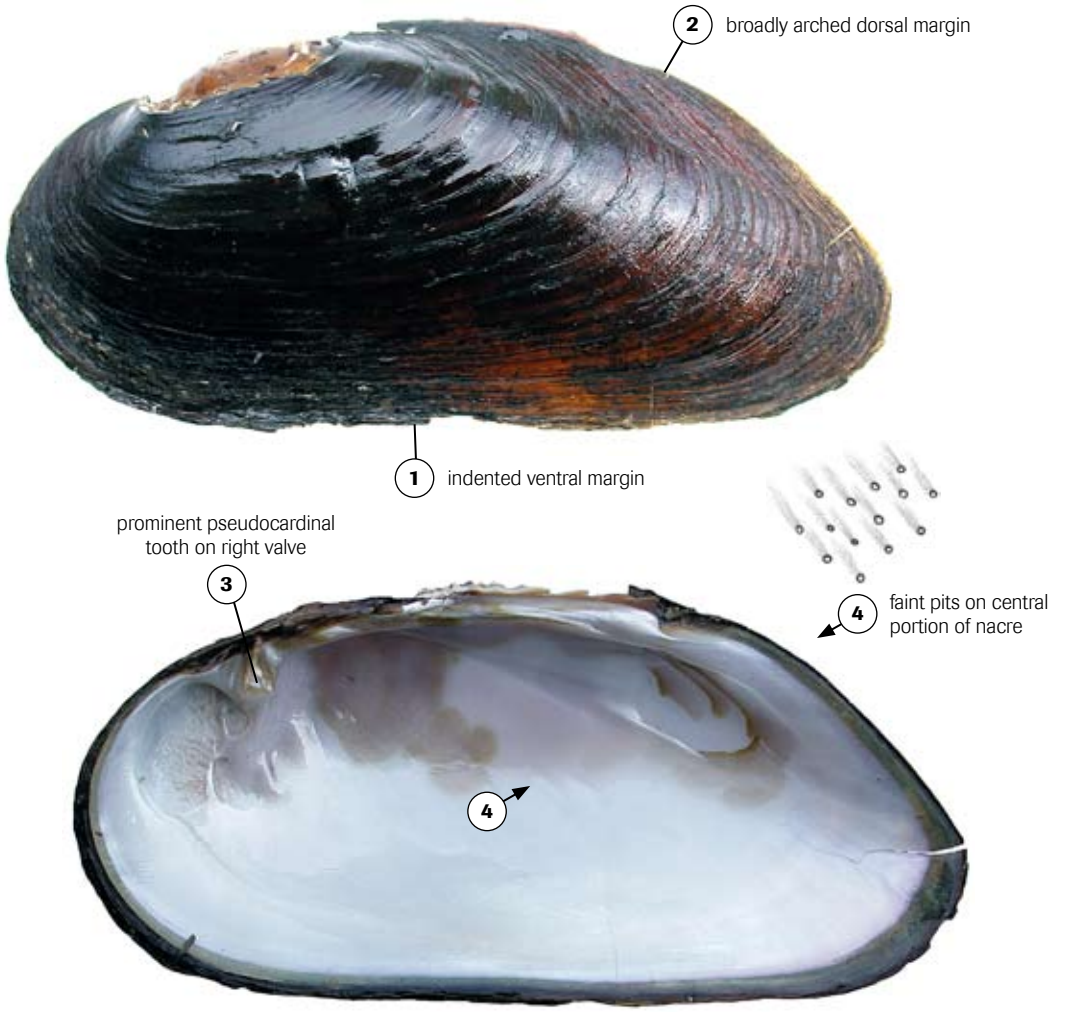
Sandy Brook, a tributary of the West Branch Farmington River in Connecticut, supports a healthy population of the eastern pearlshell. Ethan Nedeau

Eastern Pearlshell

Margaritifera margaritifera (Linnaeus, 1758)

Description: The eastern pearlshell is a medium-sized to large mussel that rarely exceeds 5.5 inches (140 mm) in length. The shape is trapezoidal or elongate. Older individuals often have a slightly or obviously indented ventral margin **[1]** that, together with a broadly arched dorsal margin **[2]**, makes their shape resemble that of a banana. Shells are laterally compressed, and beaks are low and barely extend above the hinge line. Juvenile shells are smooth and brown to golden-brown, whereas adult shells are rougher and nearly black. The periostracum is thick and durable; unlike all other mussels in this region, there is often excess periostracum material along the shell margins that can actually appear "shaggy". Pseudocardinal teeth are well developed—the left valve has two and the right valve has one **[3]**. Lateral teeth are absent. The nacre is usually white or sometimes bluish-white. The central portion of the nacre has distinctive pits, each with a faint tail that points toward the beak cavity **[4]**, though this feature is sometimes difficult to discern. Key distinguishing features in live undisturbed animals are the lack of separation between the inhalent and exhalent apertures, and dark mantle margins that can be reddish-gray to nearly black. The eastern pearlshell has an interesting habit of "sputtering and wheezing" soon after being removed from the water—this trait is unique and may be used to distinguish this species from eastern elliptio that might be similar in appearance.
Rarely confused with the eastern elliptio.

Habitat: The eastern pearlshell is found in streams and small rivers that have cool water temperatures and support populations of trout and salmon. It never occurs in lakes, ponds, or



Eastern Pearlshell. External view of the left valve (top) and internal view of the right valve (bottom). Numbers correspond to features in the description. Ethan Nedeau

warm-water streams—although relict populations may exist in warm and degraded portions of streams whose thermal regime and upland landscape have been altered by humans. Best habitats are fairly small streams that are heavily shaded by a riparian canopy, possess clean cold water with high dissolved oxygen, and have stable channels with substrates of coarse sand, gravel, and cobble (Nedeau *et al.* 2000, Morales *et al.* 2004, Geist and Auerswald 2007). Large rivers rarely provide habitat for this species because of their warm water temperatures, lack of a forest canopy, unsuitable substrates, and lack of quality trout habitat. Given its preference for small coldwater rivers, one might expect it to be widespread and abundant in the Connecticut River watershed. Yet, it is absent or extremely rare in most coldwater rivers in Vermont and New Hampshire, and it is also rare in some of the largest watersheds in Connecticut and Massachusetts that collectively provide thousands of miles of what seems like suitable habitat.

Factors that are widely believed to limit this species are eutrophication, pH (acidity), sedimentation, and water temperature. Bauer (1988) demonstrated that the adult mortality rate increased as stream nitrate concentrations increased. He also found that juvenile recruitment

declined as phosphate, calcium, and biological oxygen demand increased. Larvae and juveniles are considered far more sensitive than adults. Dolmen and Kleiven (2004) suggested that eutrophication and acidification were responsible for the extinction of 94 percent of eastern pearlshell populations in southern Norway. They suggest that when pH was near or below 5.0-5.5 for extended durations, the eastern pearlshell population would perish. In Norway's lowland rivers that did not experience acidification, eutrophication was considered the primary threat to the eastern pearlshell population. For populations in Germany, Geist and Auerswald (2007) found that habitat quality depended strongly on the texture of the substrate, especially as it relates to the exchange water between the surface and subsurface sediments. Deposition of sand and mud, and compaction of the streambed, reduced surface-subsurface exchange and had a pronounced negative effect on habitat quality and juvenile recruitment. Finally, warmer stream temperatures due to combined effects of land use, dams, altered flow regimes, and climate change may have contributed to the loss of coldwater fisheries and eastern pearlshell populations in some watersheds.

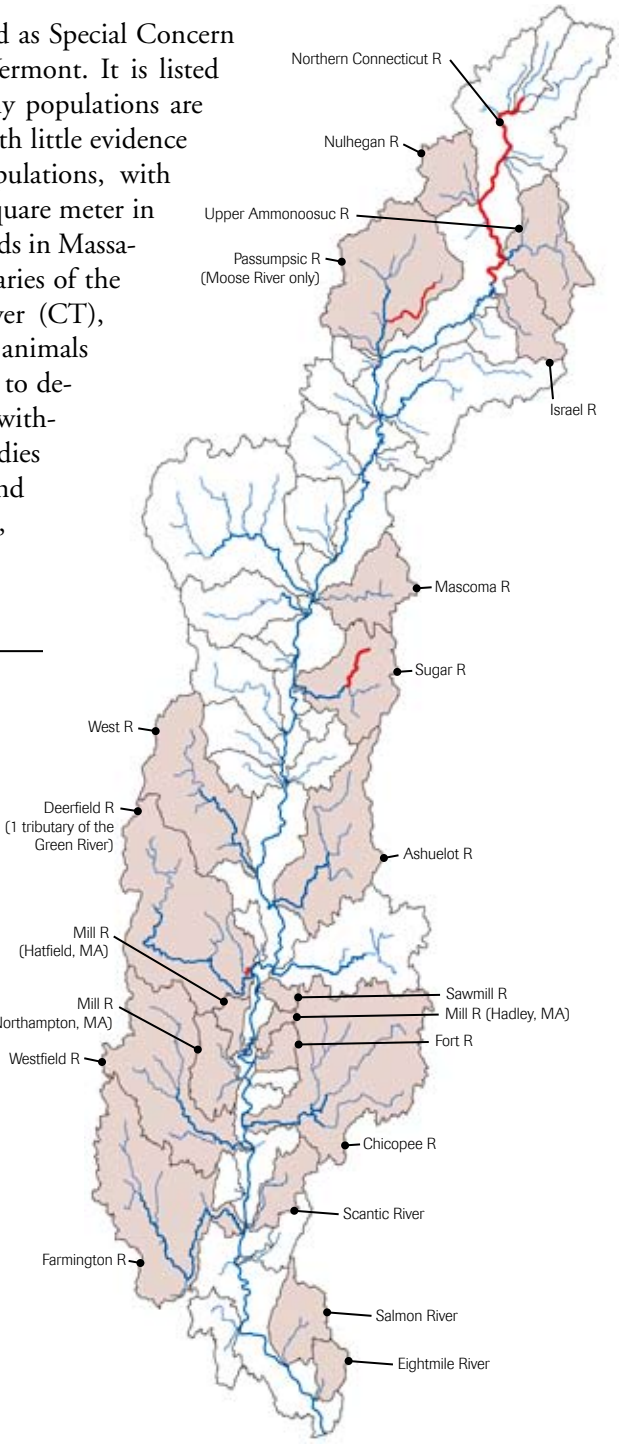
These studies may help explain the general patterns of habitat use and distribution of eastern pearlshell in the Connecticut River watershed. Many small upland rivers might be too acidic to allow the eastern pearlshell to flourish, and these rivers have also historically been subjected to the effects of forest cutting, land clearing, and dams. Many lowland rivers in the southern half of the watershed, where landscape alterations and urbanization have been particularly acute, have suffered from nutrient enrichment, sedimentation, and altered thermal regimes that may have eliminated the eastern pearlshell from much of its native range.
Primary habitat types (see page 16): SSLR, SUR

Biology: Bauer (1987) wrote, "*If the geographical range, abundance, and age of a species are measures of its fitness, then the freshwater pearl mussel must be considered one of the most successful animal species*." The eastern pearlshell has the highest fecundity reported for any freshwater mussel: a single female may produce as many as 17 million glochidia annually, although four to eight million is more typical (Bauer 1987, 1994). They become sexually mature somewhere between 12 and 20 years of age (Young and Williams 1984, Bauer 1987) and their fecundity does not diminish with age. Bauer (1987) reported a life expectancy of 93 years for 17 populations in Germany. This means that a 20-year old female may have more than 75 reproductive years ahead of her, and in that time, she may produce hundreds of millions of glochidia. The eastern pearlshell is one of the longest-lived animals on Earth; Bauer (1992) reported a maximum life span of 132 years and Ziuganov (1994) reported a theoretical maximum age of 167 years! Growth is remarkably slow, especially in the latter two-thirds of their lives (Hastie *et al*. 2000). Females are gravid from late summer to late October, and the release of glochidia seems to depend on temperature (Smith 1976, Hastie and Young 2003). Host fish include native and non-native trout and Atlantic salmon (Table 1, page 5). Metamorphosis may take several weeks to more than ten months depending on water temperature (Ziuganov *et al*. 1998); meaning that they likely overwinter on the gills of fish and excyst in the spring. This species has a remarkable ability to become hermaphroditic (capable of self-fertilization) when population densities become very low (Bauer 1987). There is not enough space in this book to write about the fascinating biology of the eastern pearlshell and readers are encouraged to explore the cited literature and references therein.

Range: The eastern pearlshell is primarily a northern species. In North America it is found as far south and west as Pennsylvania and New York. It is widespread in New England and the

Canadian Maritime Provinces. Its range also extends across the Atlantic Ocean to Scandinavia and northern Europe. It is North America's only native freshwater mussel whose range extends beyond the continent. It occurs in 19 major tributaries of the Connecticut River and also occurs sporadically in the mainstem Connecticut River north of Guildhall, Vermont. It occurs in several minor tributaries, and in small streams within major watersheds.

Status: The eastern pearlshell is listed as Special Concern in Connecticut and Threatened in Vermont. It is listed as Endangered in Rhode Island. Many populations are comprised of a few old individuals, with little evidence of recent recruitment. The best populations, with densities exceeding 200 animals per square meter in some areas, exist in just a few watersheds in Massachusetts and Connecticut (e.g., tributaries of the Farmington River (CT), Salmon River (CT), and Swift River (MA)). Because these animals are so long-lived, it would be difficult to detect trends in population abundance without long-term monitoring. Careful studies are needed to understand the status and trends of populations in the watershed, and protecting high-quality habitats should be a priority.



Eastern Pearlshell Range in the Connecticut River Watershed

Shading indicates presence in a major tributary or widespread distribution along the mainstem Connecticut River (which may include several minor tributaries along that reach). **Bold red lines** are used to indicate restricted occurrences along the mainstem Connecticut River and within large major tributaries.

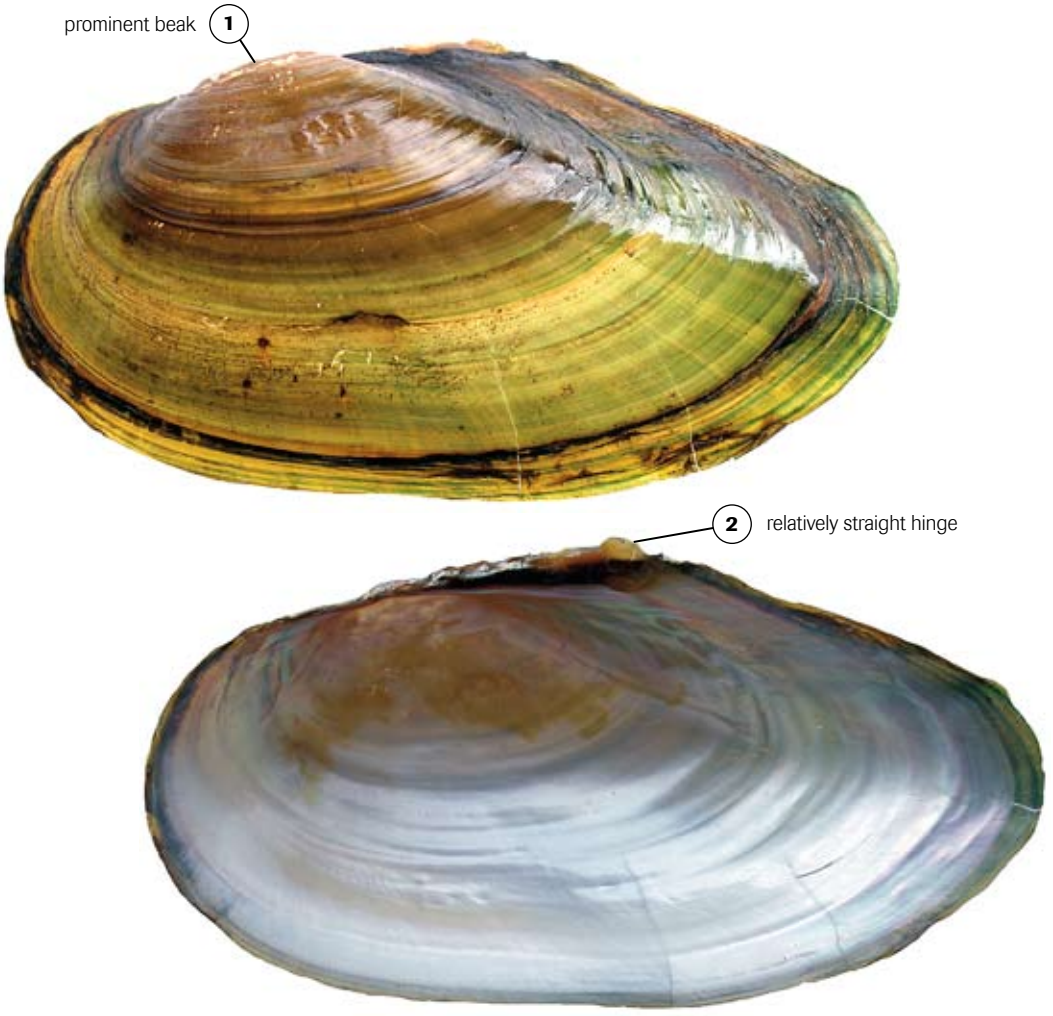
Slow-flowing and weedy portions of rivers are more likely to support the eastern floater than most other stream habitats; this is the upper West Branch Farmington River in Massachusetts. Ethan Nedeau

Eastern Floater

Pyganodon cataracta (Say, 1817)

Description: The eastern floater is a medium-sized to large mussel that may exceed six inches (150 mm) in length. Some specimens larger than eight to nine inches in length have been found in small nutrient-rich ponds. Shells are ovate or elliptical and somewhat elongate. Shells are laterally inflated and extremely thin and fragile. Beaks are prominent and raised above the hinge line **[1]**. The hinge is either straight or has a slight upward curve **[2]**. Hinge teeth are entirely absent. Shells are smooth with prominent growth annuli and may have faint rays. The periostracum is yellowish, greenish, or brownish-black. The nacre is usually silvery white or a metallic blue, sometimes with a yellowish tinge. Because of the lack of hinge teeth and fairly thin shells, application of light pressure on the dorsal and ventral surfaces will cause the shells to gape (more so than any other species).
Often confused with the alewife floater and creeper.

Habitat: The eastern floater is found in a wide variety of habitats, including small streams, rivers, ponds, and lakes. It is much more common and abundant in lakes and ponds than it is in rivers, where its densities may rival or exceed all other species. In several coastal ponds in Massachusetts, the eastern floater became increasingly dominant (compared to other species) in deep water and was the only species that seemed to thrive in soft mucky substrates (called gyttja) located in the deepest areas of the lakes (25-40 feet) (Nedeau and Low 2008b). Its ability to thrive in silt and mud—substrates that most other mussel species seem to avoid—has been attributed to its extremely thin and light shell and inflated shape. In addition to its toler-



Eastern Floater. External view of the left valve (top) and internal view of the right valve (bottom). Numbers correspond to features in the description. Ethan Nedeau

ance for muddy substrates, it is tolerant of other parameters that typically pose challenges for mussels, such as warm water temperatures, low dissolved oxygen, and eutrophic conditions. It is one of the only species that can be stocked in small eutrophic manmade ponds. In streams and rivers, it is usually confined to depositional areas with finer substrates and in natural or manmade impoundments.
Primary habitat types (see page 16): LTR, LSR, LNR, SSLR, lakes.

Biology: Eggs are fertilized in the summer or early fall and glochidia are released the following spring. Host fish are not entirely known but a few related species (in the genera *Anodonta* or *Pyganodon*) are considered host generalists. Given the broad geographic range of the eastern floater, and the range of natural and manmade habitats that it will thrive in, it probably uses a variety of hosts. Two of its hosts—pumpkinseed sunfish and bluegill—are very common in waterbodies throughout the Connecticut River watershed. Glochidia are relatively large at 0.015 inches (0.382 mm); these are among the largest known glochidia (Bauer 1994). Similar

Variation in the color and shape of the eastern floater. Ethan Nedeau

to the alewife floater, glochidia are triangular-shaped and have strong hooks and protuberances that help ensure a strong latch on the gills or fins of its host fish (Rand and Wiles 1982). Fecundity is not known but may be low because the glochidia are so large. Growth, inferred from the distance between growth lines and age-size relationships, can be quite high in productive waterbodies. Due to its thin and fragile shells, and relatively high rate of growth, the eastern floater is thought to have a short life span. In eutrophic waterbodies, they are susceptible to heavy mortality during periods of low oxygen, especially in the summer, and will often float to the surface of the water due to the buildup of gases inside the mantle cavity after the animal dies and begins to decompose. Eastern floaters are also a favorite prey of predators such as muskrat or otter that can easily break their thin shells.

Range: The eastern floater is found in Atlantic coastal drainages from Georgia to Nova Scotia, though it is less common in the southern parts of its range. It is also found in the lower St. Lawrence River drainage, and its range extends westward to the Great Lakes. It is found in 29 major tributaries of the Connecticut River and the entire mainstem Connecticut River. It is likely to occur in the 14 major tributaries where it has not yet been documented, especially in lakes or ponds that have been poorly surveyed. It also occurs in many minor tributaries of the Connecticut River. It is the second-most common species in the entire watershed, and with no concern about its populations, surveys targeting this species are rarely performed.

Status: This species is common and widespread throughout most of its range, and no state considers it a species of concern. Because it is so common and widely available, it is an important species for ecological research and teaching, and it might provide insight into the health and productivity of waterbodies.

Eastern Floater Range in the Connecticut River Watershed

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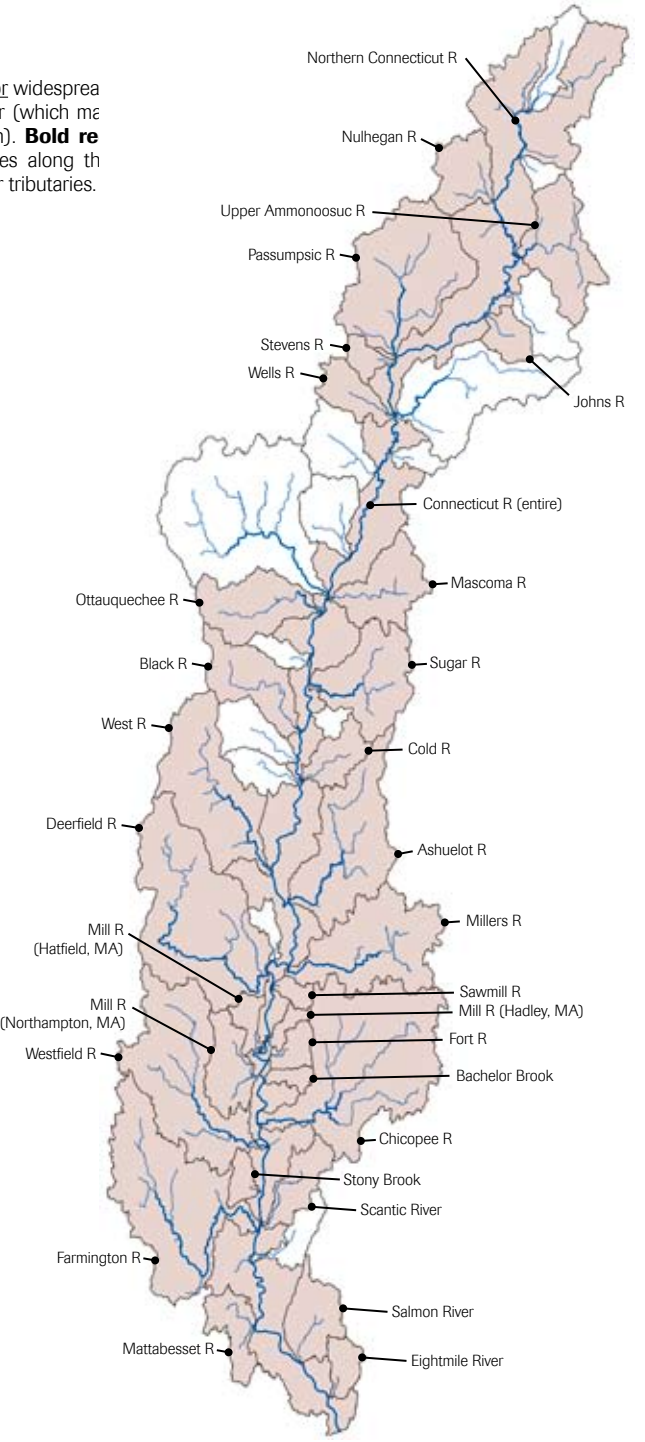


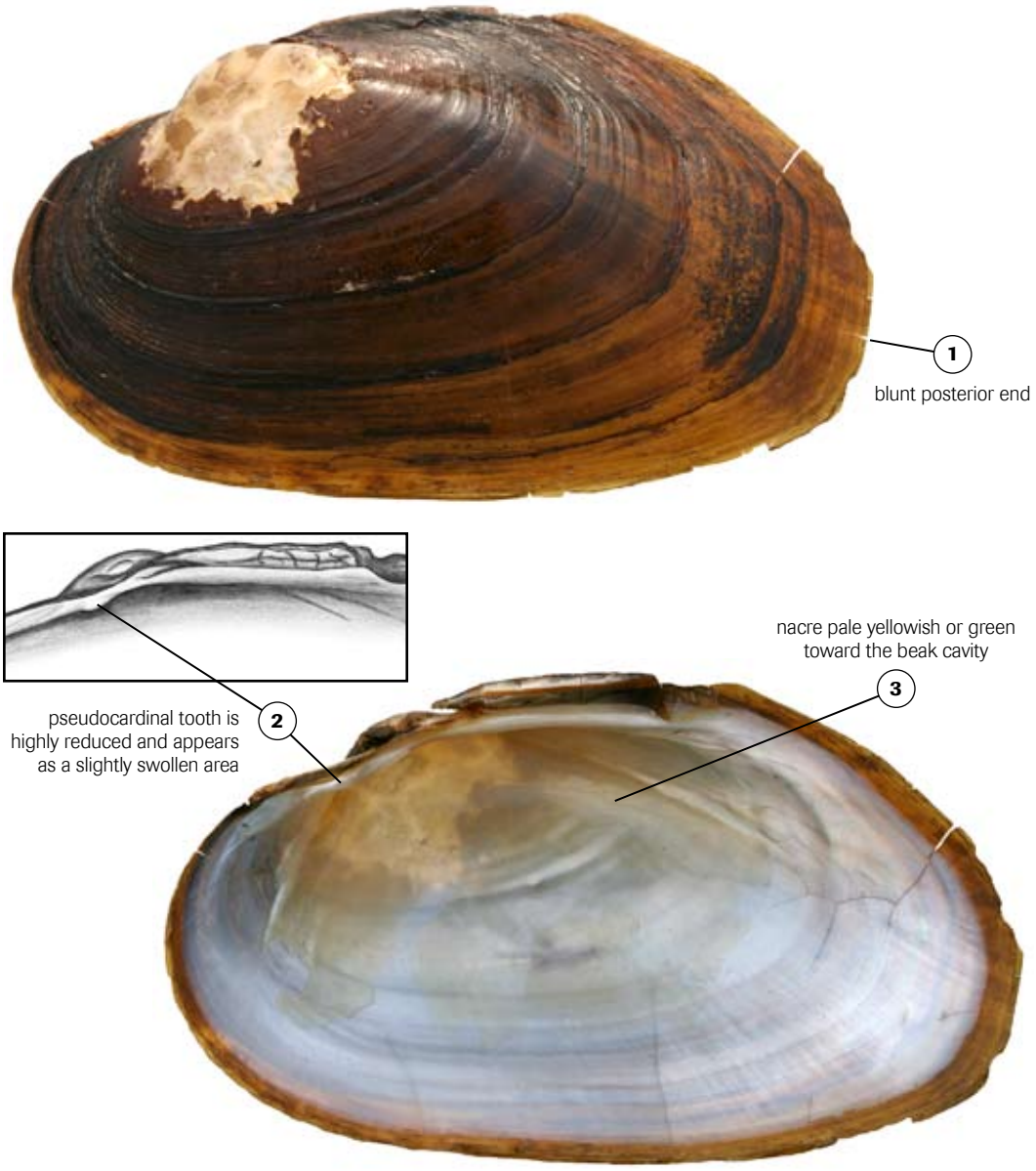
The creeper can be found in the Passumpsic River in St. Johnsbury, Vermont.

Creeper

Strophitus undulatus (Say, 1817)

Description: The creeper is a small mussel that rarely exceeds three inches (75 mm) in length. The shape is variable and may appear ovate, elliptical, or trapezoidal. The shell usually has a blunt posterior end **[1]**. The shells are slightly inflated, thin, and fragile. Beaks are barely elevated above the hinge line. The surface of the shell is often rough due to prominent growth lines. Hinge teeth are almost entirely absent—pseudocardinal teeth appear as an indistinct swollen area of the nacre below the beak **[2]**. Lateral teeth are absent. The periostracum may be yellow or greenish-brown in young animals, and brown or black in older animals. Fine green shell rays may be evident toward the posterior slope, particularly in young animals or light-colored adults. The nacre is white or bluish-white, and often dull-yellow or greenish toward the beak cavity **[3]**. Feet may be a very pale orange color but this trait is variable. Because of their thin shell and lack of hinge teeth, creepers can be forced to gape at the posterior end by applying moderate pressure on the dorsal and ventral surfaces.
Often confused with several other species, including eastern elliptio, brook floater, dwarf wedgemussel, triangle floater, alewife floater, and young eastern floater.

Habitat: The creeper is found in small to large rivers. Preferred habitats include low-gradient river reaches with sand and gravel substrates and with low to moderate water velocities, although they can occur within a broader range of habitat conditions (Nedeau *et al.* 2000). Although the creeper has never been found in lakes in the Northeast, they often occur in small impoundments of run-of-river dams that retain some amount of flow. Streams and rivers that



Creeper. External view of the left valve (top) and internal view (bottom). Inset illustration shows hinge teeth detail. Numbers correspond to features in the description. Ethan Nedeau

are productive, cool to warm-water environments with diverse fish assemblages are most likely to support the species. Creepers are generally sparse or absent in headwater streams and high-gradient portions of rivers. They occur most frequently with eastern elliptio, triangle floater, dwarf wedgemussel, and brook floater but have a far broader distribution than the latter two species. In one location in the Passumpsic River in Barnet, Vermont, Nedeau (2006c) snorkeled for nearly 1.25 hours and found more than 100 creepers and no other species! It is highly unusual to find that many creepers in one place and to not find at least two other species with it.
Primary habitat types (see page 16): LNR, SSLR, SUR

Biology: Fertilization occurs in the summer and glochidia are released the following spring. When released, glochidia are tethered to small packets called conglutinates that are light-colored and resemble grains of rice. Conglutinates are adhesive and usually stick to the substrate near the female mussel; one can see these conglutinates if they conduct creeper surveys during the spawning season. The large hooked glochidia number as many as 15 per conglutinate, and these will snap onto the fins of host fish. Even if only one of the glochidia initially snaps onto a fish, it will remain strongly tethered to the conglutinate and will pull along the other glochidia and increase the chances that they too will attach to the fish. Studies have identified many vertebrate hosts that are common in cool to warm-water streams in the Connecticut River watershed (Table 1, page 5). Gray *et al.* (2002) found a low degree of host specificity for the creeper—its glochidia successfully metamorphosed into juveniles on 15 of the 22 species examined. The creeper is the only northeastern species known to parasitize amphibians, including two-lined salamanders and red-spotted newts. Because the creeper will parasitize such a broad range of native and nonnative species, its viability may be less reliant on specific fish than species such as the dwarf wedgemussel that is host-specific. Lefevre and Curtis (1911) found that glochidia of the creeper could transform into juveniles without a fish host. Their ability to do this has never been confirmed. Longevity is unknown, but given its small size and thin shell, it probably does not live much longer than 15-20 years.

Conglutinates (light-colored rice-like pieces) and glochidia of the creeper.

Chris Barnhart, http://unionid.missouristate.edu

Range: The creeper is widely distributed in eastern North America. It occurs in most Atlantic coastal drainages from Florida to Newfoundland and occurs west of the Appalachian Mountains to Texas and Saskatchewan (including the St. Lawrence River, Great Lakes basin, and the Ohio and Mississippi River systems). It occurs in 21 major tributaries of the Connecticut River but is currently only known from the upper portion of the Connecticut River mainstem in New Hampshire in Vermont. It occurs in 23 of 28 (82 percent) of all major watersheds or mainstem segments that support three or more species. In addition, it occurs in many minor tributaries of the Connecticut River and in many small streams within major watersheds.

Status: The creeper is listed as special concern in Massachusetts due to its low abundance within its known range. No other state in the watershed considers the creeper a species of concern (Table 4, page 30). Maine lists the creeper as a species of special concern for similar reasons as Massachusetts (Nedeau *et al.* 2000), and there is concern for the species in Rhode

Island even though it receives no formal protection (Raithel and Hartenstine 2006). Many surveys in the last two decades have focused on species that are more endangered, such as the dwarf wedgemussel and brook floater, and have inadequately characterized the distribution, abundance, and habitat of the creeper. Recent surveys have indicated that the creeper might be more rare than previously thought and therefore may deserve special protection; for example, intensive surveys in the Farmington River watershed in Massachusetts and Connecticut from 2005-2007 yielded fewer than 20 live animals. Since the Farmington supports the highest diversity of mussels in the watershed, and is Connecticut's largest watershed within the Connecticut River basin, the rarity of creepers in the Farmington be indicative of its status elsewhere in its range. Very few high-density populations have been found in the watershed.

Creeper Range in the Connecticut River Watershed

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