The Freshwater Mussels of West Virginia

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Abbreviations

FMCS – Freshwater Mollusk Conservation Society
HUC -- hydrologic unit code
MU – Marshall University
NRDA – Natural Resources Damage Assessment
ORINWR – Ohio River Islands National Wildlife Refuge
OSU – Ohio State University
PIT -- passive integrated transponder
TTU – Tennessee Technological University
USCOE – U.S. Army Corp of Engineers
USFWS – U.S. Fish and Wildlife Service
WSSNFH – White Sulfur Springs National Fish Hatchery
WVDNR – West Virginia Division of Natural Resources

Introduction

This handbook was designed to introduce freshwater mussels to the general public and for biologists interested in learning more about WV's pearly treasures. Mussel identification, ecology, life history, importance, and threats will be covered.

When talking about freshwater mussels, I am referring to freshwater bivalves (two opposing valves attached by a hinge ligament) that live in WV. These bivalves are in the order Unionoida that includes the families Unionidae and Margaritiferidae. There are three other families of bivalves in WV which all belong to the order Veneroida. These include two families of true clams, Sphaeridae (fingernail clams) and Cyrenidae (Asian clams), and one family of true mussels, Dreissenidae (zebra mussels) (Figures 1 to 3). The terms clam and mussel are typically associated with marine bivalves. Clams are considered burrowing bivalves whereas mussels are considered bivalves that attach to substrate or objects with multiple protein fibers known as byssal threads.

Figure 1. Fingernail clams, left three, and young unionids, *Potamilus fragilis* (Fragile Papershell), right two.

Figure 2. *Corbicula fluminea* (Asian Clam), invasive true clam found throughout WV since 1963.

Fingernail clams are the only native true clams that are found in WV. As their common name implies, they grow to about the size of a human's little fingernail and are typically found burrowed into the substrate. The Asian clam is

Figure 3. *Dreissena polymorpha* (Zebra Mussel) attached to a live *Cyprogenia stegaria* (Fanshell).

native to southern Asia south into Africa where it is known as a good food resource. It is thought to have been introduced into the US by way of Washington state in the 1920s for that purpose (Counts 1981). It rapidly spread throughout the US including WV, where it was first recorded in 1963 in the Kanawha River (https://nas.er.usgs.gov/queries/FactSheet. aspx?speciesID=92; accessed 10/20/2020). It is thought to have negative impacts to native mussels however the reasons behind the recent impacts are speculative (Sousa *et al*. 2008 and references therein). Haag (2019) identified the Asian Clam as one of two possible causes to broadly explain enigmatic mussel declines of recent years. The non-native zebra mussel is the only true mussel found in WV and was first reported in the Racine Pool of the Ohio River in 1994 (ESI 2002) and the Belleville Pool of the Ohio River in 1995 (USFWS 1999). It is believed to have been introduced from Europe into Lake St. Clair (Great Lakes System) via ship ballast water exchange around 1985. Being a true mussel, it attaches itself to hard structures, including unionids, with multiple byssal threads. In comparison native freshwater mussels as juveniles may possess a single byssal thread. Zebra mussels quickly spread throughout the Mississippi River System as adults hitchhiking on commercial barges through the Chicago Sanitary Shipping Canal which is a man-made canal connecting the Great Lakes System to the Mississippi River System (http://www.seagrant.umn.edu/ais/zebramussels_threaten; accessed 11/3/2020). The Quagga Mussel (*Dreissena bugensis*), another dressenid true mussel, has invaded the US but so far it has not been found in WV (https://nas.er.usgs.gov/queries/FactSheet.aspx?speciesID=95: assessed 02/22/2021). It has however been found in PA. For clarification, future use of the word mussel or freshwater mussel refers to those native bivalves of the family Unionidae and Margaritiferidae which are neither clams nor mussels.

Adult freshwater mussels in WV range in size from 1 ¾ inches (*Toxolasma parvum*, Lilliput) to 10 inches (*Megalonaias nervosa*, Washboard). They may live as few as 3-4 years (*Lasmigona subviridis*, Green Floater) to over 70 years (*Cumberlandia monodonta*, Spectaclecase and *Elliptio crassidens*, Elephantear). As well as size, there is great variation in shell shape. See Figures 4 and 5 for shell morphology and terminology. Shell shape varies from small bean or triangular-shaped to large and round or rectangular. Freshwater mussels have two valves that are connected by a flexible hinge and held together by two adductor mussels, one anterior and one posterior (Figure 6). There is great variation on how flat or inflated (swollen) the shell is.

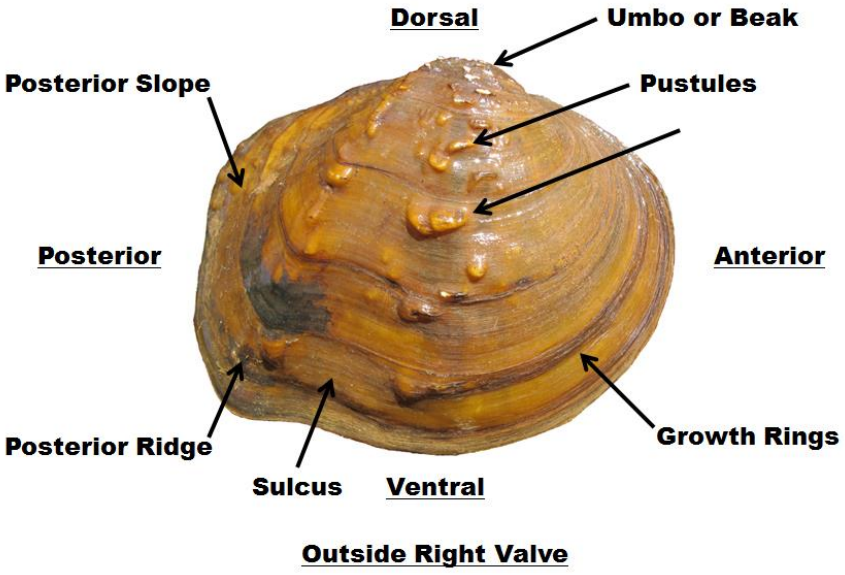


Figure 4. External shell characters of *Quadrula quadrula* (Mapleleaf).

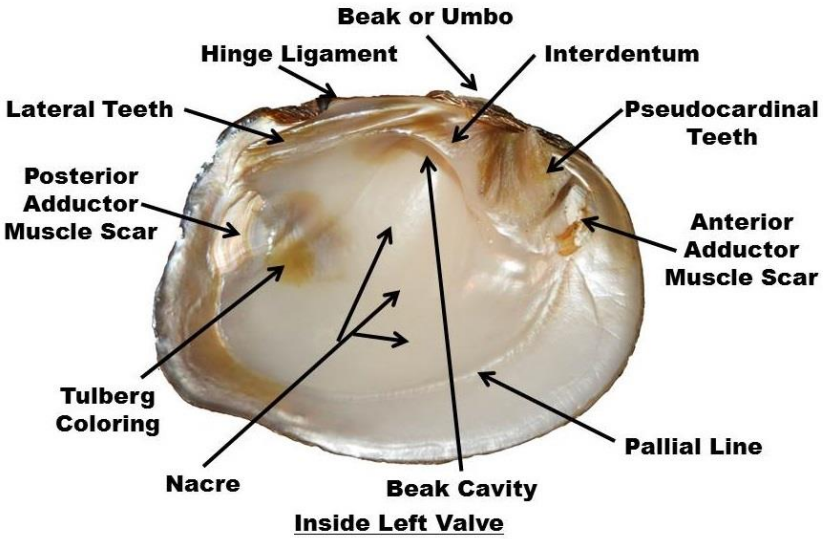


Figure 5. Internal shell characters of *Quadrula quadrula* (Mapleleaf).

Figure 6. Posterior (left) and anterior (right) adductor mussels of *Potamilus alatus* (Pink Heelsplitter). Note also the purple nacre and the teeth along the dorsal margin.

(White Heelsplitter) in Figure 7, to very inflated like the female *Epioblasma triquetra* (Snuffbox) in Figure 8. The inside of the shell is made up of calcium carbonate, otherwise known as "mother of pearl" or nacre. The nacre may be white or other colors such as pink, purple, and orange. Note the purple nacre of *Potamilus alatus* (Pink Heelsplitter) in Figure 6. Although there may be a range of nacre colors within a single species such as *Eurynia dilatata* (Spike) which ranges from purple or salmon to white, nacre color is typically diagnostic. The epidermis or periostracum is the outer layer of the shell and made up of an acid-resistant conchiolin protein layer. Between these two layers, lies the prismatic layer which also consists of calcium carbonate although the crystals are in a different orientation than the nacre. Lining the interior of the shell is a thin layer of soft tissue called the mantle which is responsible for nacre formation. It is attached to the valves at the pallial line. The periostracum and prismatic layers are responsible for growth at the shell margin. The periostracum color ranges from yellow to black, may have a secondary color pattern, and may also have rays. Shells of many species also have interlocking hinge teeth while in others, teeth may be weak or lacking.

Figure 7. Oblique view of *Lasmigona complanata* (White Heelsplitter) showing the compressed shell shape.

Figure 8. Ventral view of *Epioblasma triquetra* (Snuffbox) showing the extreme shell inflation.

There are three basic types of sculpturing found on the outside of freshwater mussel shells. The most common, but not necessarily the most evident, is beak or umbo sculpture that is found on or near the point of the umbo (Figure 9). It is formed during the first year of life. Especially in WV's poorly buffered streams, beak sculpture is most evident in very young individuals or those individuals in which the umbo has not been worn away. More often, beak sculpture is eroded away in older mussels. Once the periostracum is worn away, poorly buffered streams begin to erode away the calcium carbonate shell. Sculpture over the valve face is found in only 11 of WV's 64 extant species. This sculpture can consist of pustules, knobs, ridges, or a combination thereof. More common is sculpture on the posterior slope (Figure 10), which typically consists of fine wavy ridges or crenulations, series of ridges, or small pustules.

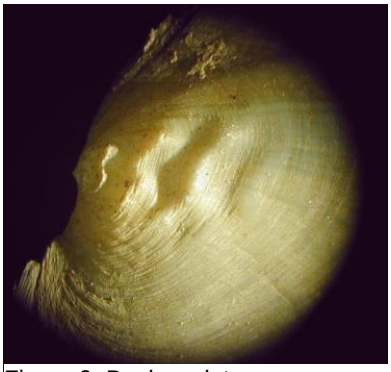


Figure 9. Beak sculpture on a very young *Lasmigona complanata* (White Heelsplitter).

Figure 10. Posterior slope sculpture on an *Alasmidonta varicosa* (Brook Floater).

Shell shape, amount of inflation, and valve sculpturing can vary greatly within and between species. Shell thickness varies more among and between species than within species. Shells of some species are extremely thin while others are very thick and robust. The within-species variation is speculated to be an adaptation to various habitat types. As a general rule, the thinner the shell is, the softer the substrates it is found in. *Pyganodon grandis* (Giant Floater) in lakes and ponds can be nearly circular and highly inflated which most likely helps the individuals maintain position in very soft substrates. In creeks and rivers, it is more compressed and the shell is a little thicker which most likely helps the individuals to accommodate flowing river conditions and sediment movement. *Obliquaria reflexa* (Threehorn Wartyback) typically has three very large protruding knobs that may help it to maintain position in very sandy mobile substrates of large rivers. Between watersheds of similar size, *Amblema plicata* (Threeridge) can have major differences in the amount of sculpturing. Some individuals lack nearly all sculpturing while those in a different watershed are extremely ornate. Ortmann (1920) came up with the "law of stream position". As the stream size or order increases, shell inflation increases. In WV this is most notable in *Fusconaia flava* (Wabash Pigtoe) (Page 49) and *Pleurobema sintoxia* (Round Pigtoe) (Page 76). Individuals from the extremes are typically not recognizable as being the same species. Haag (2012) does a very nice job in covering various speculations suggested by many authors about the cause and effect of shell variation. Habitat features can have a direct effect on shell shape. If a mussel is unlucky enough to grow up in a bad location, the shell growth may conform to the habitat as seen in this mussel that grew around a rock (Figure 11).

Figure 11. Deformed mussel found growing around a rock.

Mussels live a fairly sedentary life, typically buried in the stream bottom. The anterior end with its large muscular foot (Figure 12) is buried in the substrate and the posterior end with its two apertures (inhalant and exhalant) visible at the substrate surface (Figure 13). The inhalant aperture can be quite ornate with its coloration and various sizes of papillae (see page 95). Depending on species, season, etc, some mussels may be completely buried out of sight and others much more visible.

Figure 12. Large muscular foot of *Ligumia recta* (Black Sandshell) which is used for locomotion and holding position within the substrate.

Figure 13. *Elliptio complanata* (Eastern Elliptio) in life position. The inhalant aperture (left) and exhalant aperture (right) are visible.

Mussels typically do not move much horizontally within the stream except maybe to avoid adverse conditions such as dewatering. They may, however, move significantly vertically within the substrate. This movement can vary by species. Some move up to lie on the surface during reproductive periods and may be completely buried the rest of the year. Juvenile mussels are typically completely buried in the substrate. In contrast to zebra mussels which have multiple byssal threads, juvenile mussels produce a single byssal thread that attaches to the substrate to help hold them in place (Figure 14). They produce these primarily during their first year of life but small species like *Paetulunio fabalis* (Rayed Bean) may use them throughout their entire life.

Figure 14. Young *Epioblasma triquetra* (Snuffbox) with attached single byssal thread used to hold its position within the substrate.

It is extremely important that live mussels pulled from the substrate are returned appropriately. Put them back into the spot where you collected them and in the same orientation (Figure 13). Placing the mussel in an improper orientation, such as burying the apertures down, can be fatal. Proper orientation requires that the anterior end be in the substrate. It is typically best to avoid handling live mussels.

Which is anterior and which is posterior one may ask? First hold the mussel with both valves together with the hinge at the top and parallel to the ground. Looking at the face of the valve, place an imaginary line perpendicular to the hinge, going down through the umbo. The shorter side of the mussel from the line is anterior and the long end is posterior (Figure 15). If the mussel is held with the short end (anterior) forward and the posterior end to the rear, the valve on the right is the right valve, and the one on the left is the left valve.

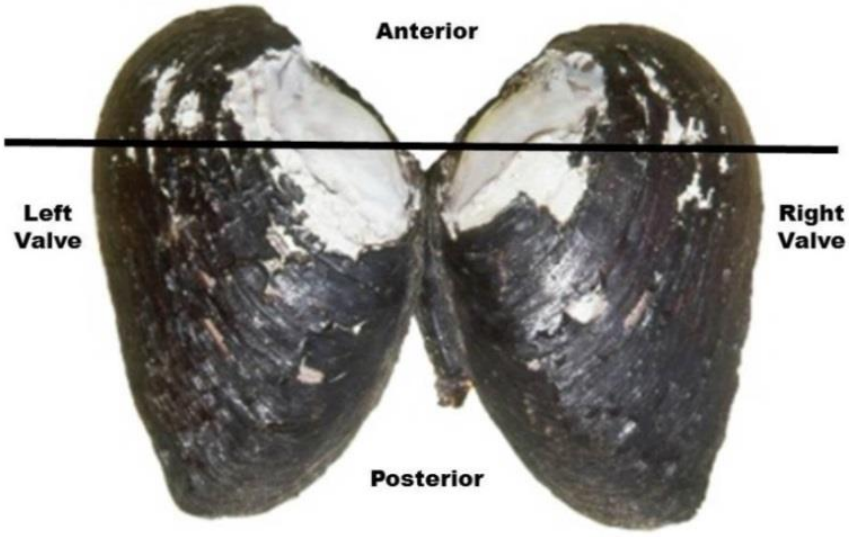


Figure 15. *Elliptio crassidens* (Elephantear) showing anterior vs. posterior and left vs. right valve descriptors.

Mussels breathe and filter feed by bringing oxygenated water and food in through the inhalant aperture. While juveniles have long been known to sweep food items into the shell gap using their foot, otherwise known as pedal feeding (Yeager *et al*. 1994), recent studies have also shown that adult mussels may feed by bringing in food through the shell gap and moved by cilia on the foot to the mouth in addition to filter-feeding (Strayer 2008, Vaughn *et al*. 2008, Nichols *et al*. 2005). Food items can range in a wide variety of sizes though thought to be generally less than 20 micrometers in size and consist of phytoplankton, zooplankton, bacteria, fungi, and fine organic matter (Strayer 2008). Most excrement is expelled via the exhalant aperture. However when excess or unwanted particles, like sediment, are taken in they can be accumulated in a mucous mass and expelled as pseudofeces back through the inhalant aperture (McMahon and Bogan 2001) or out through the shell gap (Nichols *et al*. 2005). Strayer (2008) noted that freshwater mussels may be food limited if environmental conditions make it difficult for animals to obtain food, such as an increase in stream flows and high sediment loads. He further notes that this has not been studied in freshwater mussels but has been documented by several authors to occur in zebra mussels. The WVDNR and USFWS have noticed that high flows with high sediment loads also appear to affect reproductive potential based on the inability to find gravid individuals during high-flow years on the Ohio River.

The gills consist of two parts (demibranchs) on each side of the foot. There is an inner demibranch and an outer demibranch. They, like the foot, are covered in cilia. The gills are multipurpose in that they are used for obtaining food and oxygen as water passes through the water tubes and for brooding their young within the same water tubes. Water is brought in through the inhalant aperture, passes across and through the gills where food, oxygen, and sperm are collected and any unwanted material is bound into pseudofeces and expelled. Feces are eliminated from the anus and expelled through the exhalant aperture. Figure 16 shows the internal anatomy of *Reginia ebenus* (Ebonyshell).

Life History

Although a few mussel species are hermaphroditic [example *Utterbackia imbecillis* (Paper Pondshell) (Hoeh, 1991)], in most, sexes are separate. The lifecycle of a freshwater mussel is depicted in Figure 17. In general, the male releases the sperm into the water column, the female

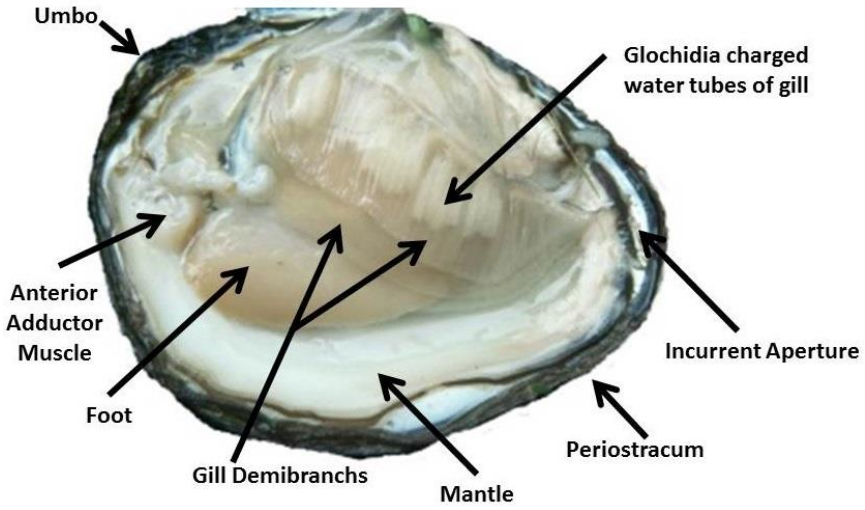


Figure 16. Internal anatomy of freshwater mussel *Reginia ebenus* (Ebonyshell).

draws it in through the inhalant aperture and fertilizes the eggs which she has placed within the water tubes of her gills. Once fertilized she continues to brood the embryos in her gills until they become mature larvae (glochidia). Freshwater mussel species are typically placed into two categories, short-term and long-term brooders. Short-term brooders spawn (eggs fertilized) in spring or early summer and brood for a short time, typically a few weeks, before release. Long-term brooders typically spawn in late summer or early fall. The larvae are brooded over winter and typically released spring or early summer.

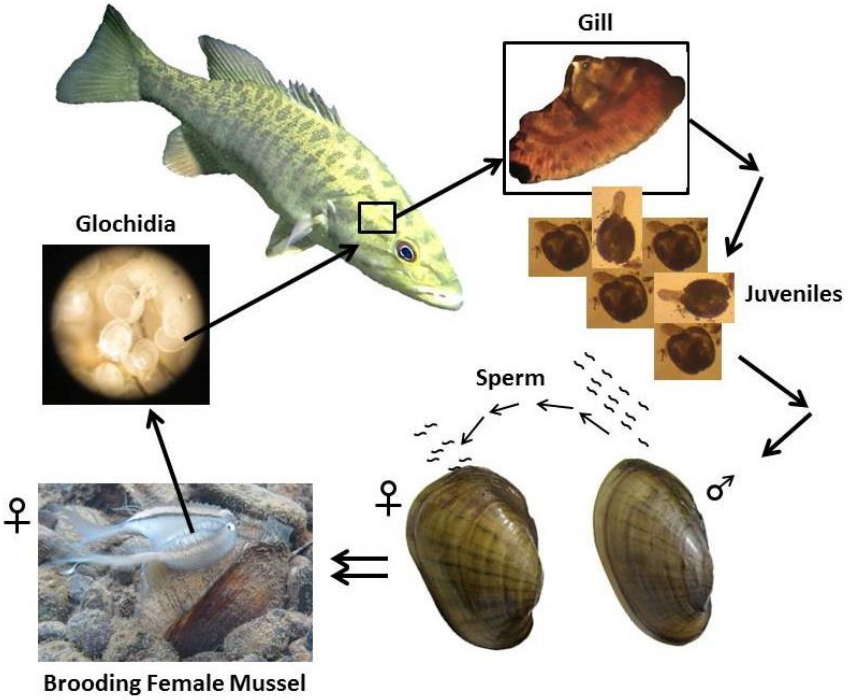


Figure 17. General lifecycle of a freshwater mussel.

Once mature, the object is to get the glochidia onto a host. In all but one known instance, the host is a fish. One species, *Simpsonaias ambigua* (Salamander Mussel) uses the mudpuppy (*Necturus maculosus*) as a host. Mussel species may only use one species of fish as a host or

they may be a host generalist where they can use numerous species within one fish family or even many species of several fish families. The glochidia remain on the host for a week or two, but may be longer, going through a metamorphosis at which time they fall off as juveniles. If they fall into suitable habitat, they will continue to grow and the cycle repeats. At least two species are known to at least partially autotransform or have direct development without a host, *Lasmigona subviridis* (Green Floater) (Lellis and King 1998) and *Utterbackia imbecillis* (Paper Pondshell) (Dickinson and Sietman 2008). For these species, the fish host stage may be bypassed and the glochidia metamorphose within the mussels' gills before dispersal as juveniles.

The parasitic glochidia phase lasts from several days to several months. This attachment to a mobile host provides the main mechanism for species dispersal. The juvenile mussel falls to the substrate when transformation is complete, hopefully into suitable habitat. Unless otherwise noted, fish hosts provided in the species accounts were obtained from the Mussel Host Database found at https://mollusk.inhs.illinois.edu/57-2/.

There are five primary methods to get the glochidia onto a host. The most unusual is where the mantle is modified into a lure that may resemble a fish [*Lampsilis* spp. (Kraemer 1970)] as seen in Figure 17 or other food organism such as a crayfish (*Cambarunio iris*, Rainbow) (see Page 96). A modification of the lure methodology is typical in the *Epioblasma* spp. where the lure is small and the host fish is captured between the mussel's valves. The mantle is used to form a seal around the fish while the mussel fills the cavity with glochidia which then attach around the snout and gills of the fish host (see *Epioblasma triquetra*, Page 47). Another group of species release packets of glochidia called conglutinates. These conglutinates typically resemble food organisms that their preferred host may eat such as larval fish or aquatic insects. *Megalonaias nervosa* (Washboard) has been observed casting a glochidia-filled net (Page 97) over the stream bottom which could be snagged onto a fish swimming by and thus infesting it. The last method is simply the dispersal of glochidia into the water column in hopes that they come in contact with and attach to the appropriate host(s).

Importance of Freshwater Mussels

Mussels provide great ecosystem services and functions (Vaughn 2018). There is much ongoing research to place a value on ecosystem services pertaining to human's benefits. They continuously filter water to obtain oxygen, food, and gametes. In the process of doing so, they filter out pollutants from their environment and assimilate them into their bodies and shells. Thus they help provide us with cleaner water. Their large muscular foot helps to hold substrate in place. Based on personal observation, it appears that the loss of the mussel population at the head of Blennerhassett Island on the Ohio River destabilized the gravel substrate which is retarding mussel recolonization. Likewise, it appears the loss of the mussel population from Dunkard Creek resulted in increased bedload movement within that stream. In addition to helping stabilize substrate, mussels also help to loosen compacted substrates. Juvenile mussels are often found right next to large buried mussels where the substrate has been loosened.

Freshwater mussels provide food for wildlife. Muskrat, raccoons, river otters, and several species of fish are known to eat freshwater mussels. A pile of mussels along the river's edge is typically the result of a muskrat's feast. They use feeding stations such as a large rock or tree stump. They swim out and get a mussel, bring it back to their feeding station, eat, and repeat. The result is a midden pile of shells (Figure 18). Freshwater drum and river redhorse suckers have frequently been observed cruising the streambed looking for mussels that divers kicked up

while conducting mussel surveys. This blue catfish stomach (Figure 19) shows that even large mussels are consumed, shell and all.

Figure 18. Muskrat feeding station (midden pile) on Little Kanawha River.

Kathy Higgs

Figure 19. Blue catfish guts containing freshwater mussels from Lake Marion, NC.

Freshwater mussels were important to Native Americans for food, tools, decorations, and pearls. It was the rediscovery of pearls by European settlers in the mid-1800s that emphasized their economic importance throughout the Mississippi Watershed and worldwide. All freshwater mussels like the marine, non-Unionidae, Japanese pearl oysters have the ability to create pearls. When a piece of foreign matter gets stuck between the shell and the mantle in a mussel, it gets covered with shell material to reduce the irritation. The result is a pearl, most often resembling the nacre color of the mussel in which it was formed. As not all freshwater mussels contain pearls, pearl hunting gave little return for the effort and thus a lot of dead mussels for the number of pearls that were found. However, with the high value placed on the pearls, this activity led to declines in mussel populations.

It was however, the harvest for the pearl button industry later in that century that was even more economically valuable. See Claasen (1994) for a history of human uses of freshwater mussels. The pearl button industry was started by the German button maker, John Boepple, when he happened upon a bed of freshwater mussels. Prior to that he made many of his buttons from marine shells and just about anything he could find. The heart of the industry was located in Muscatine, IA along the Mississippi River but as new shell beds were located further away and new entrepreneurs started factories, factories soon were found throughout the eastern United States (https://muscatine history.org/ accessed 10/29/2010). From 1910 to 1928 there was a factory in St. Marys, Pleasants County, WV (Efaw 1995). It was reported to have had 65 to 100 employees and benefited the locals who could easily collect mussels from the then shallow, clear, Ohio River. The shell remnants (Figure 20) were crushed and fed to chickens or used to pave the roads of St. Marys. The factory's demise was reported to have resulted from river dredging, damming (circa 1920), and poor water quality resulting from release of acid mine

drainage into the upper river. The entire industry only lasted about 75 years (1890s to 1940s) due to foreign competition, changing fashion, development of plastics, overfishing of mussel beds and damming of rivers (https://muscatinehistory.org/ accessed 10/29/2010).

Figure 20. Shell remnant after button blanks were cut. Species appears to be *Tritogonia verrucosa* (Pistolgrip).

In the late 1800s, Kokichi Mikimoto of Japan created the first cultured pearl. For years he worked to perfect the technique and experimented with many types of material to use as nuclei (the seed to start the pearl). He ultimately chose to use freshwater mussels from North America. Introducing nuclei of varying sizes can cut the culture time drastically. Instead of 15 to 20 years to form a full pearl naturally, cultured pearls can be grown in a matter of months. The collection of freshwater mussels for pearl nuclei was at its height in the early 1990s (attributed to the rise in price) but so was the decline in freshwater mussel shells from overharvest. Shell collectors were on the hunt for new resources and came to the upper Ohio River in WV and were caught poaching, arrested, and fined. Not too long after, prices dropped as a virus decimated the Japanese oysters. There are still a few states that permit commercial harvest of freshwater mussels but the industry has not returned to pre-virus levels. West Virginia had a commercial musseling law that was most likely instituted for the pearl button industry. The law was terminated in 1989 as a result of the 1988 Ashland Oil spill on the Ohio River.

Threats

North America is home to the most diverse freshwater mussel fauna in the world. However, freshwater mussels are one of the most, if not the most, endangered group of animals in North America. Populations, and entire species, have been lost due to water pollution, dams, sedimentation, invasive species and other habitat losses or modifications. The long life span of mussels has provided a chance for species to survive some of the human-induced impacts, while short-lived species may have disappeared. While overharvest for the pearl and shell button industries mentioned above depleted many mussel beds, water quality impacts and damming of mussel streams are probably the main two stressors for defining where mussel populations still occur. As harvesting of the state's resources such as timber, coal, and gas, increased and brought about water quality impacts, the benefit of altering the stream's course to improve movement of these materials downstream increased, impacting miles of mussel habitat. The logging industry probably had the most widespread impact historically as it occurred throughout most of WV's watersheds. Beginning in the late 1800s, land was cleared, increasing sediment runoff; first was the removal of gravel bars and tree snags from streams and then they were blasted and cleared to make way for logs floating downstream. Additional impacts included the installation of log booms consisting of rock piles or timber cribbing, and impoundments were built for milling (https://wvforestry.com/wvdof-history/; accessed 9/24/2021). Remnants of many of these log booms are still evident like those on the Greenbrier River near Ronceverte, Greenbrier County (Figure 21). Many miles of streams were blasted with dynamite, dredged, and channelized first to provide clear paths for moving of logs and then later to provide better access to boats hauling coal and other commodities (Johnson 1979).

Figure 21. Remnants of the historic timber cribbing found within the Greenbrier River near Ronceverte, Greenbrier County, WV.

A benefit of mussels filtering water is that they serve as good indicators of water quality and stream health. Because they filter pollutants, this also makes them susceptible to pollution. Even as far back as the mid-1800s, naturalists were noticing the decline of freshwater mussels from acid mine drainage. Mussel populations in the upper Ohio River and elsewhere were severely reduced prior to the implementation of the Clean Water Act in 1972 and were further impacted by the construction of the lock and dam system. By the late 1800's the Monongahela Watershed was severely impacted historically by acid mine drainage and effects from impoundments. The streams of the southwestern part of the State such as the Tug Fork River were also impacted from mine drainage, which though not acidic, was high in dissolved metals, etc. Today, these same issues continue to threaten freshwater mussel populations. One of the beneficial uses of Summersville Dam on the Gauley River and Sutton Dam on the Elk River was to provide dilution flows if water quality standards were not being met in the Kanawha River at Charleston. Such augmented flows are still required today though not as often.

Water quality impacts most likely pre-date impoundment impacts however; the two are intimately tied together through the industrialization era. Dams affect habitat by changing the stream from lotic (flowing water such as found in creeks and rivers) to lentic (slow water such as found in lakes and ponds). This allows sediment to build up over the previously clean substrate that many mussel species prefer. The impounded lakes tend to stratify in temperature, dissolved oxygen, and other nutrients. Stratification leads to cold, oxygen poor water on the bottom of the lake. Most of the old dams were designed to release water from the lower levels of the lake and thus the dams affected downstream water quality by reducing oxygen levels and changing the natural temperature regime, among other issues. In many cases the once warmwater stream became a coldwater stream after it was dammed. Today new dams are typically required to have a discharge where temperatures mimic the natural state.

The change in temperature resulting from these lake bottom discharges can affect the ability of freshwater mussels to reproduce as temperature is one of the ques triggering reproduction. Dams also restrict the movement of host fish. This is evidenced in the upper Ohio River and the Monongahela River where mussel populations were lost due to historical water quality degradation. Even though water quality has improved, host fish carrying glochidia are unable to pass over the dams. In many cases the impact was so wide-ranging that there is no nearby broodstock. In order for an area to be re-colonized or for a species to expand its range, the fish host must move into an uncolonized area while infested with glochidia. If there are no mussels nearby to provide glochidia, then recolonization can take many decades or more, if possible at all. It is difficult to get an accurate count of the number of dams in WV, but at least hundreds of dams exist. The only river in WV that remains unaffected by damming today is the Greenbrier River, although the subject of building one has arisen many times over the past 40 years, to protect the town of Marlinton, Pocahontas County, which is located within the river's floodplain.

A total of 11 rivers in WV have had locks and dams constructed on them at some point in history to aid in commercial navigation (Table 1). The Kanawha River is reported to be the first river in the nation to be entirely made into a series of impoundments by wicket dams (Figure 22).

Wicket dams work by raising the wickets during low flow periods which backs water upstream creating a pool and thus lockages were required. During high flows the wickets were lowered, allowing boats to avoid the locks and go right over the lowered wickets. Ten low-lift wicket dams with single-lock chambers were built on the river by the federal government between 1875 and 1898 (https://www.wvencyclopedia.org/print/Article/1428; accessed 10/27/2020). The upper 5 miles of the Kanawha River from the town of Glen Ferris downstream to the community of Deepwater is currently the only un-impounded section of this big river.

Figure 22. Dam No. 6 on the Ohio River showing wickets and props (Thomas and Watt 1903). The wickets were raised and lowered as needed to adjust upstream water levels.

Table 1. Navigation lock and dam history in West Virginia.

River: Navigable Portion	Construction Year	Locks & Dams	Year Removed, Abandoned, or Modified	Current Lock & Dams
Ohio River	1910+	21	1956+	7
Kanawha River	1875+	10	1930s	3
Elk River	1848	1	1881	0
Coal River	1855+	5	1881	0
Little Coal River	1855+	1	1881	0
Guyandotte River	1849-1853	7	1861	0
Big Sandy River, Tug Fork	1874-1952	4	1925	1*
Monongahela River (WV Portion)	1895-1904	8	1950-1967	3
West Fork River	?	6[1]	1824	0
Little Kanawha River	1867-1891	5	1930s	1*
*Abandoned and still in place [1] Most likely mill dams with sluices or chutes for downstream navigation.				

The Monongahela River (WV portion) had eight wicket dams at one time and in the 1950s and 1960s, they were replaced by three high-lift dams (Morgantown, Hildebrand, and Opekiska). These three dams have a significant impact on the river habitat. The slowing of river flow allows sediment to settle to the stream bottom. The riverbed is heavily sediment-laden except for 1-2 miles immediately below the dams. The WVDNR conducted mussel surveys in 2002 and found soft sediments so deep that divers reaching into them could not touch hard bottom. Low dissolved oxygen is regularly recorded downstream of Opekiska Dam. Proposed hydroelectric facilities have the potential to reduce oxygen levels even further. Hildebrand and Opekiska are obsolete as no commercial river facilities remain upstream of Hildebrand. Only minimal lockages are being conducted for recreational boaters and sediment is accumulating within the lock chambers. Opekiska Dam does provide pooling for water withdrawals for the city of Fairmont. However if both Hildebrand and Opekiska were removed, Tygart Dam (1938) at Grafton, Taylor

County could be regulated to provide enough water for Fairmont's need though intake structures may need to be modified.

Prior to the construction of the navigation dams, as early as 1824 the US Congress authorized the removal of snags and construction of deflectors to aid in navigation. The first complete lock and dam project built by the USCOE on the Ohio River was at Davis Island, a few miles downstream of Pittsburgh, PA (Robinson 1983 and https://www.lrl.usace.army.mil/Missions/Civil-Works/Navigation/History; accessed 10/27/2020). This lock and dam opened to traffic in 1885. The project proved greatly beneficial to navigation, and in 1910 Congress passed the Rivers and Harbors Act. This Act authorized construction of a system of locks and dams the length of the river which would provide a nine-foot navigation depth. Previous management maintained only a three-foot depth which was later raised to six-feet. The first wicket dam in WV was established in 1910 (Lock 18) in what is now the Belleville Pool near Parkersburg, WV (http://www.eastliverpoolhistoricalsociety.org/wicketdams.htm; accessed 10/27/2020). When completed in 1929 (Pittsburgh, PA to Cairo, IL), the project consisted of 51 movable dams with wooden wickets and a lock chamber, 21 of which were in WV. In the 1950s modernization began and a series of 18 high-lift concrete and steel dams replaced the wicket dams. The sole purpose of the dams was for navigation. The first high-lift dam in WV at New Cumberland provided navigation by 1956. Modernization continued to as recently as 1993 at R.C. Byrd Lock and Dam which replaced Gallipolis Lock and Dam. The Ohio River currently has seven locks and dams located in WV and the most downstream reach is impounded by an eighth dam located in Greenup, KY.

The Little Kanawha River is one of the best remaining mussel streams in WV. For the most part, the mussel population was able to survive the extensive petroleum industry and historical damming. At one time there were five navigation dams in place on the river for around 60 years and the petroleum industry was quite extensive within the watershed. Burning Springs was the destination of thousands of fortune seekers during the 1860s following the discovery of oil. In August of 1860 the "town" had fewer than 20 permanent residents, swelling to over 6,000 opportunists in six months. Hundreds of thousands of barrels of crude oil were produced there between 1860 and 1870. Gas produced was used to light the community and marked the beginning of gas exploration in the state. In 1863, during the Civil War, Confederate cavalrymen burned the town to the ground, along with all the oil in the town's storage tanks. One hundred thousand barrels of oil were ignited, and the light from the fire was visible at night as far away as Parkersburg, 42 miles away; oil was reported to have burned on the river (http://www.littlekanawha.com/wirthistory.htm and https://www.wvencyclopedia.org/articles/ 1422; accessed 10/27/2020).

Gas and salt brine are often associated. Oil and gas production in WV actually began as an outgrowth of the salt industry in the 1800s. During the salt production era, petroleum by-products where dumped into nearby streams. Then during the petroleum era the reverse was true where the brine was considered an unwanted by-product and dumped into the nearby streams. Chlorides (salt) are known to be highly toxic to freshwater mussels, especially juveniles (Patnode *et al.* 2015). Brine may also have been the downfall of other streams in the state such as the Pocatalico River.

The oil industry in WV grew to reach its peak production of 16 million barrels in 1900. As the oil industry started a decline, natural gas production was growing. From 1906 to 1917, WV was the leader in gas production in the United States. From 1917 to 1934, the State's output declined markedly, and then increased again until about 1970 (Eggleston 1996). Not only were oil and brine released into mussel streams but many times transmission pipes were laid in and along

the streams and numerous stream crossings were made. Frequently abandoned pipes were left in place and continue to leak pollutants even to this day (Figure 23). What is worse, destroy the stream habitat to remove the pipes or leave them in place to leak?

Figure 23. Leaky abandoned oil pipe in bank of Meathouse Fork of Middle Island Creek, Doddridge County.

The Marcellus gas industry with its associated hydraulic fracturing (fracking) and horizontal drilling technology overtook conventional gas exploration in 2011. In order to conduct the fracturing, massive amounts of water are needed. The industry removes water from streams for this purpose. In 2010 the impact of this removal became evident and many mussel beds in Middle Island Creek were left high and dry (Figure 24). Chlorides and other proprietary chemicals are added to the water to assist in the fracking process. Accidental spills and disposal of fluids have the potential to impact water quality. Over 4,000 miles of interstate and intrastate natural gas pipelines cross the state (https://www. energywv.org/wv-energy-profile/natural-gas-marcellus-shale; accessed 11/13/2020). These pipelines and the many miles of

Figure 24. WVDNR Biologist Mike Everhart pointing at a stranded mussel in 2010 in dewatered Middle Island Creek.

Figure 25. Sediment load coming from Arnold Creek into Middle Island Creek as a result of gas exploration activities in the watershed.

access roads cut into the landscape and increase the sediment load significantly (Figure 25). Direct loss of habitat also occurs as the pipelines and roads crisscross many WV streams.

Invasive species throughout history have caused impacts to native species. The black carp (*Mylopharyngodon piceus*) escaped from aquaculture ponds in the deep south and are making their way throughout the Mississippi Watershed. They are known molluscivores and could further impact mussel populations as their numbers and range expands. Release of aquarium fish such as predatory snakeheads (Channidae) could affect mussel host fish populations. While they have been found within the Potomac Watershed, they have not yet been found in WV. As previously noted, zebra mussels harm native mussels by interfering with their feeding, growth, movement, respiration, and reproduction (https://www.fws.gov/midwest/endangered/clams/zebra.html and http://www.seagrant.umn. edu/ais/zebramussels_threaten: accessed

11/3/2020). Only six years after appearing in WV they were responsible for the loss of nearly 25% of the mussel population in the Belleville Pool of the Ohio River in 2000. They currently are found in all streams that support commercial navigation. This is most likely a result of the transport of adult zebra mussels attached to tow boats and barges. Because zebra mussels have free-swimming larvae (veligers) that do not require a host, infested watercraft are constantly seeding those rivers. In other states zebra mussels have spread into lakes and impoundments via adult attachment to recreational boats and veligers being transported in live wells and bait buckets. Although zebra mussels have been observed in some smaller streams in WV such as the Buckhannon River, they are not known to persist. They typically do not form large populations in small streams except just downstream of lakes or reservoirs. It is thought that there may not be enough dissolved calcium to support them in WV's lakes. Zebra mussels also require slow-moving water in order to attach via their byssal threads. As long as streams remain free-flowing, stream colonization is not likely and therefore biologists are hopeful they will not reach harmful levels such as they did in the Ohio River.

Other pests may be native (or not) though their numbers may be exacerbated by adverse environmental conditions. Trematodes can castrate mussels by feeding on gonadal tissue (Taskinen and Valtonen 1995). Extensive trematode infestations were noted within New River mussels (Julie Devers – USFWS, personal communication). While collecting *Cyclonaias pustulosa* (Wartyback) from the Ohio River for use in propagation activities, a large number were noted to have been infested with a *Beucephalus* trematode (Figure 26). Whether parasitic or opportunistic, water mites and dragonfly larvae also may affect reproduction (Strayer 2008). Water mites were also observed within mussel gills in the Belleville Pool (Figure 27). Nationwide there are unexplained mussel die-offs that may likely be caused by introduced diseases and pathogens. More and more today the exact cause of mussel declines are not known. Patterson Creek, Mineral County, had a diverse abundant mussel population as recently as the 1990s. Although mussels still occur, they are much less abundant. The cause of the decline is not known. Water quality itself may not be the total answer. Increased nutrients could be leading to cyanobacteria (blue-green algae) blooms which can be toxic to mussels. Cyanobacteria did appear to cause a small mussel kill in 2018 in South Mill Creek Lake, Grant County. Poor water quality in Dunkard Creek, Monongalia County, in 2009 lead to a golden algae (*Prymnesium parvum*, a brackish/saltwater alga) bloom that was toxic to 100% of the resident freshwater mussels.

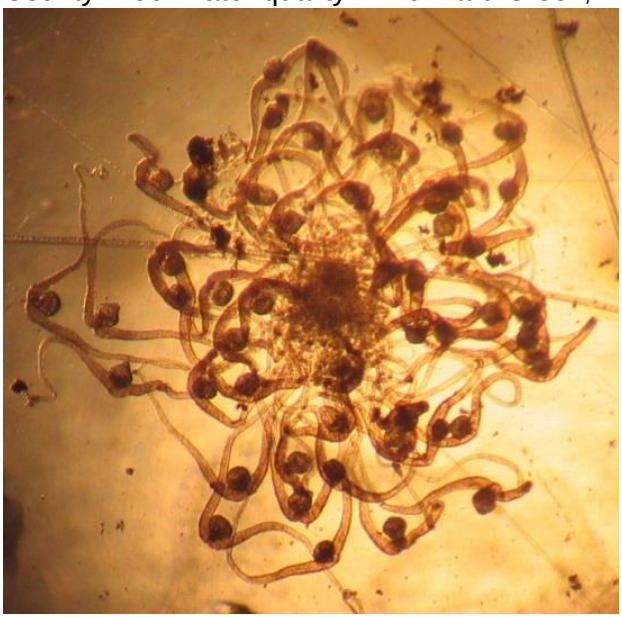


Figure 26. *Beaucephalus* trematodes extracted from the gills of *Cyclonaias pustulosa* collected within the Belleville Pool of the Ohio River, Wood County.

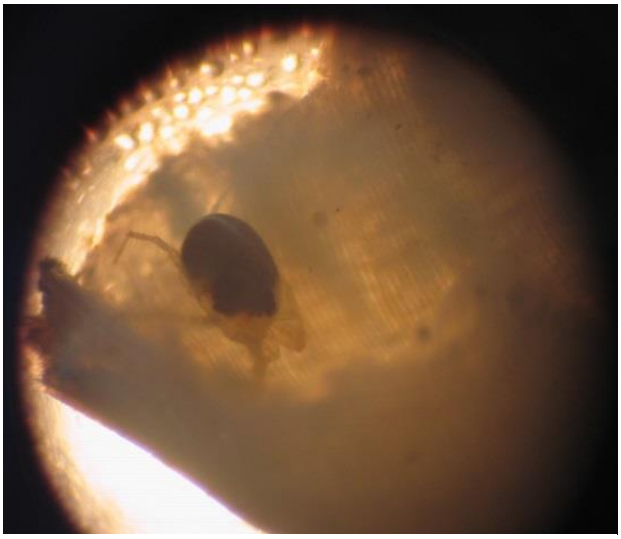


Figure 27. Water mite observed in mussel gill within the Belleville Pool of the Ohio River, Wood County.

Mussel silos (Figures 28 to 31) can be used to assess effects of stream condition on freshwater mussels. The silos contain a small screened cup (screened on both ends) in the center containing propagated juvenile mussels. The domed shape causes the water flowing over them to also pull water up through the screens. They are typically left in the stream throughout the summer. Upon retrieval, the survival and growth of the juveniles are assessed. These silos can also be placed upstream and downstream of a suspected impact. Comparing the growth and survival between the two sites can indicate if the discharge is having an effect on the downstream mussel population.

Figure 28. Silo used to hold juvenile mussels to assess stream conditions

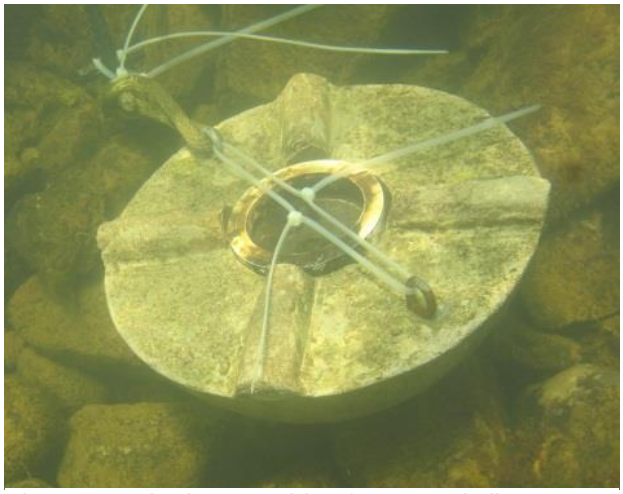


Figure 29. The bottom side of a mussel silo showing the installation of the screened cup which holds the juvenile mussels.

Figure 30. Cup used to hold juvenile mussels within silo. Cup is screened on both ends to allow flow through and splits apart to allow insert or removal of mussels.

Figure 31. Silo cup opened showing juvenile *Ligumia recta* (Black Sandshell) to be tested in the Elk River, Braxton County, WV.

The first assessed mussel kill during recent times was an extremely large event that originated in the Belleville Pool of the Ohio River. It resulted from a discharge along the Ohio shoreline. Due to the low flows the kill (100% mortality at this point) was confined within the northern half (Ohio side)

of the river until reaching Blennerhassett Island where the river makes a bend to the north and the toxicant began to spread the width of the river. It is believed that the affects from this discharge impacted mussels within the Ohio River for over 20 miles. The assessment of five mussel beds known to occur within the kill zone estimated nearly 1,000,000 mussels of 26 species died in those five beds alone as a result of this discharge. Many other mussel beds were not assessed. Even more devastating was the mussel kill in Dunkard Creek which occurred in 2009 as a result of a toxic algal bloom resulting from poor water quality. Even though the estimated number of mussels killed was far less than the kill in the Ohio River, 100% mortality of freshwater mussels occurred in the stream, losing the last significant mussel population in the entire Monongahela Watershed. The lack of nearby broodstock will make natural recovery of this population nearly impossible. A list of some of the known freshwater mussel mortality events in recent history in WV is provided in Table 2.

Table 2. Some freshwater mussel mortality events documented in recent history throughout West Virginia.

Stream	Year	Cause	Responsible Party	Impact
Ohio River	1999	Water Quality Violations: Hexavalent Chromium	Allegedly Eramet/Elkem Metals	20+ rivermiles
Ohio River	2000	Bellville Pool mortality due to invasive species, downstream pools also impacted	Zebra Mussels	Approximately 25% of mussel population lost
Ohio River	2005	Loss of habitat when barges blocked dam and pool level dropped 16ft below normal pool during freezing conditions	B&H Towing	Estimated 84,000+ individuals of 18 species, 25 rivermiles
Ohio River	2008	Heavy oil spill coated stream bottom	Degussa	100% mortality estimated at 4028 mussels of 5 species
Tug Fork River	2000	Coal Slurry Spill	Martin County Coal	100% all individuals, nearly 30 rivermiles
North Fork Hughes River	2003	Dam construction, loss of habitat, reduced oxygen levels	Natural Resources Conservation Service	Impact downstream not assessed but 5+ rivermiles were impounded
Elk River	2005+	Mussels near Sutton are not reproducing	Unknown	All species affected but at least 35% mortality of *Amblema plicata* from 2013 to 2014.
Dunkard Creek	2009	High Conductivity, high TDS water discharge resulting in Golden Algae (*Prymnesium parvum*) bloom	Consolidated Coal	100% entire stream, WV and PA; WV's 15 rivermiles, conservative estimate was 25,000 mussels of 14 species
Middle Island Creek	2010	Mussels stranded	Withdrawals for Marcellus Gas industry	Unknown

Mussels and the Law

The State owns all wildlife in WV (§ 20-2-3), and may classify, by regulation, species into categories necessary for the purposes of control and protection [§ 20-1-7 (4)], and may prescribe the locality, manner and method by which various species of wildlife may be taken (§ 20-1-7(5), § 20-2-5[26], § 20-2-27]). All mussels are protected in the State of West Virginia pursuant to WV §20-2-4 and CSR 58-60-5.11. In addition, ten federally endangered and two threatened freshwater mussel species are known to occur in the state. These species are protected by the Endangered Species Act (87 Stat. 884, as amended; 16 U.S.C. 1531 et seq.). Impacts to state and federally protected mussels and their habitats should be avoided and minimized to the maximum extent practicable.

A commercial fish and mussel permit is included in state law (§ 20-2-51). It is unlikely that any mussel permits were issued following the demise of the shell button industry; however, commercial fishing occurred on the Ohio River until the Ashland Oil Spill in 1989. At that time, commercial fishing and musseling were closed. As previously mentioned, mussel poaching occurred in the early 1990s. In attempt to avoid prosecution their claim was that they were collecting fishing bait (several thousand pounds worth). At the time it was legal to collect 50 aquatic organisms per day for bait; mussels were included as aquatic life with a possession limit of 100. So in effect they were still in violation. Their further downfall was that they then crossed state lines making it a federal Lacey Act violation. As a result of this event, in 1992 mussels were no longer permissible to use for bait and the fishing regulations now state: "…may not possess mussels or any parts thereof…".

If you do not have a permit to handle live mussels, please leave them in place and just enjoy them in their natural setting. If you do have a permit or you see a mussel that someone has removed and not replaced into the substrate, please only return it back into the substrate if you know how to do so appropriately. If placed upside down, its fate may be sealed. It is better to leave it lying on the surface and let it rebury itself than to place it incorrectly upside down.

Restoration

Due to the watershed-wide impacts that have affected the mussel resources of the state, active restoration needs to be conducted to reach full recovery as they are unable to recover on their own. If even possible, it would take many decades. Before restoration can occur, the stream needs to have adequate water quality, habitat, and host fish available. As noted previously, habitat is continually being lost due to stream dredging, pipeline construction, etc. On a bright note, habitat is also being restored. The Clarksburg Water Board had built a series of dams years ago on the West Fork River to ensure enough water for public use. With the construction of Stonewall Jackson Dam, most of these became obsolete and were a liability. In 2016, the USFWS was successful in removing three of these dams, once again opening up at least 40 miles of free flowing river which would promote freshwater mussel recovery (Figures 32 and 33).

Figure 32. Removal of West Milford Dam, Harrison County, on the West Fork River in March 2016.

As noted previously, the lifecycle of a mussel is complex. While natural recovery can occur if broodstock and fish hosts are still available nearby, it would most likely take decades. Other restoration efforts can be done by propagating in a hatchery, cage culture, or relocation. The first propagation attempts were made by Coker and others in the early 1900s in response to mussel declines from the pearl button industry (Coker *et al*. 1921). In recent years great progress has been made in the production of mussels. Taking the step from research (identifying fish hosts) to production of a large number of taggable-sized mussels was difficult, and over the last 10 years great success has been achieved. However, many of the species reared have been long-term brooders as it is much easier to obtain gravid females. Propagation efforts for the Ohio River NRDA restoration project helped develop methodologies for collection of gravid short-term brooders. For some species the host fish have yet to be identified.

Figure 33. West Milford Dam site, Harrison County, on the West Fork River in April 2016 following dam removal.

As WVDNR does not have a mussel hatchery, the primary methodology for restoration has been relocating adult mussels from one location to another (translocation) or relying on propagation by cooperating agencies to provide juveniles for stocking. Several restoration projects have been occurring throughout WV since 2007. The most involved restoration project undertaken thus far has been for the Ohio River NRDA resulting from the 1999 kill event which affected over 20 miles of the river. Although only two states (WV and OH) and the ORINWR were affected, many states, universities, and USFWS hatcheries and offices assisted in the recovery efforts. This was a 10 year project in which 54,772 mussels of 34 species were added through translocation and propagation to the Belleville Pool of the Ohio River or moved from areas within the pool to the kill/recovery zone. While 24,513 adults were translocated from other areas in WV, PA, and KY, this was not the preferred method as this does not provide any net gain to the resource. It only moves mussels from one area to another and does not replace those numbers lost. Translocating provides broodstock to the area and provides adult mussels for stabilizing habitat prior to the introduction of small juveniles. Many of the translocated individuals were moved to avoid impacts from where they were collected. Translocations were also undertaken as part of restoration work on Dunkard Creek and the Monongahela River tailwaters at Opekiska and Hildebrand dams as well as many of the federally endangered species restoration projects. The KY Center for Mollusk Conservation provided adult *Cyprogenia stegaria* (Fanshell) from the Licking River which were stocked at two locations on the Ohio River and one on the Kanawha River. Adult *Epioblasma rangiana* (Riffleshell) and *Pleurobema clava* (Clubshell) were provided from the Allegheny River with cooperation from the PA Fish and Boat Commission. It should be noted that federally endangered species restoration is being conducted in streams that already have endangered species so that no additional regulatory burden is incurred.

One method to propagate mussels without a hatchery is cage culturing. In this method, mussel broodstock is collected, glochidia extracted and used to inoculate the appropriate fish host. The fish are then placed into cages with solid bottoms covered with sand. In time, the juveniles fall off the fish to the bottom of the cage. The fish are then released. The juvenile mussels continue to grow until they reach a taggable size and are then stocked. Early attempts by the WVDNR

using cages were for the Ohio River NRDA. Propagation cages were placed under the dock at the Stonewall Jackson Lake Marina. Limited success was obtained (Figure 34 and 35) due to water quality issues and conflicts with motorboats. In more recent years, work with WSSNFH and USCOE at Burnsville and Sutton lakes has been more successful. For the Ohio River NRDA, cooperators had more luck with cage culture and hatchery propagation to provide thousands of juveniles for stocking including the federally listed *Lampsilis abrupta* (Pink Mucket).

Figure 34. WVDNR biologist, Mike Everhart, getting ready to install a mussel propagation cage underneath the dock at Stonewall Jackson Lake Marina, Lewis County. Glochidia-infested fish are being placed into the cage where they remained

Hatchery propagation is similar to cage culture; gravid female mussels are collected, glochidia extracted and host fish infested. The fish are then held in the hatchery and the transformed juveniles collected as they drop off the host. The juveniles are then moved to grow-out containers and fed either an artificial diet or naturally produced algae. Once large enough to not be threatened by natural predators such as flatworms, they may be moved to larger containers with substrate for continued grow-out or moved to cages or other containers in ponds or raceways where they feed on a natural diet. As of 2022 the WVDNR had a design competed for a state mussel hatchery but has yet been constructed. It is being funded through mitigation funds received for impacts to the resource throughout the state.

Figure 35. Juvenile *Lampsilis siliquoidea* (Fat Mucket) propagated by WVDNR in cages at Stonewall Jackson Lake, Lewis County. They were later stocked into the kill zone of the Belleville Pool of the Ohio River, Wood County.

One other method of propagation eliminates the need for the host. *In-vitro* culture has the ability to produce large numbers of juveniles and though expensive to setup, can reduce costs overall. *In-vitro* places the glochidia in a sterile medium which provides the nutrition needed to grow and transform into juveniles. This is all done in extreme sterile conditions to avoid bacterial and fungal contamination. *In-vitro* is an ideal method for producing juveniles for species requiring fish hosts that are difficult to hold in a hatchery setting such as freshwater drum and skipjack herring, or for those species in which hosts are unknown. The KY Center for Mollusk Conservation used this technique to produce the federally endangered *Epioblasma obliquata* (Catspaw) that were re-introduced into the Ohio River in 2017 and 2019 (Figure 36). This species is critically endangered with only one natural population remaining in a small tributary in OH.

For streams that have completely lost their mussel population, silos are being used to assess the stream for restoration potential. Silos are placed in the stream in the spring and retrieved in the fall. If survival and growth are good then restoration potential is good. One such study was undertaken on Opequon Creek, Berkeley County. Based on shell material found over the years, this stream once had an abundant, diverse mussel population. It is unclear what caused the demise of this population historically. Silo studies conducted in 2017 and 2019 indicated that water quality has not improved enough to conduct restoration activities.

Figure 36. ORINWR biologist-retired, Patricia Morrison, holding the six *Epioblasma obliquata* (Catspaw) recovered during 2018 monitoring. Individuals were stocked into the Ohio River, Belleville Pool, Wood County in 2017.

Taxonomy

Although there are around 300 species known from throughout North America, most of these are known from east of the Rocky Mountains in the US. West Virginia has at least 64 extant species of freshwater mussels, 10 of which are listed by the USFWS as endangered and two threatened. An additional two species were proposed in 2023, one threated and one endangered. There is no state endangered species list but all mussels are protected as described previously. West Virginia does maintain a ranking list based on their level of occurrence and potential threats within the state. This ranking is based on NatureServe (https://www.natureserve. org) criteria. NatureServe also maintains a global rank. Table 3 provides a list of WV freshwater mussel species (current and historical) and their federal, state, and global rank. The state rank was last assessed in 2014. At least six species are believed to be extirpated from the state which brings the total of known (live and dead) WV mussel species to 70. Although *Pleurobema rubrum* (Pyramid Pigtoe) was reported to have been found in the Ohio River historically, this occurrence has recently been brought into question and review of historical shell material indicates that it was most likely misidentified specimens of *Pleurobema cordatum* (Ohio Pigtoe) or *Pleurobema sintoxia* (Round Pigtoe) (Andrew Henderson, personal communication 10/22/2020).

The identification of freshwater mussels can be confusing. Some shells are similar in appearance and even the experts argue over some identifications. The difficulty is due to the fact that most identifications are based on shell characteristics when the basic taxonomy was established using the internal or soft part anatomy and more recently using genetic analysis. A very good summary on the history of mussel taxonomy and classification can be found in Parmalee and Bogan (1998). The study of North American bivalves began as early as the 1600s (Lister 1685). While early classifications were primarily based on shell shape and sculpturing, von Ihering (1883) was the first to classify freshwater bivalves belonging to the family Unionidae as having developing glochidia with bivalve shells. Simpson (1900) was responsible for classification based on sexual characters such as the size, shape, and number of gill demibranchs used as marsupium. It was Ortmann (1918); however, who further refined classification based on soft part anatomy which set the framework for the classification system

used today. Ortmann was also responsible for the separation of Unionidae and Margaritiferidae based on gill morphology (the two families known to occur in WV).

The era of molecular studies such as DNA sequencing took off in the mid-1990s. These studies have helped further the identification of species and their relationships. While some species have been eliminated due to unsupported molecular analysis, others thought of as a single species have been split into multiple species. Haag (2012) speculates that there could be as many as 24% more species than currently recognized.

The American Fisheries Society published an approved list of common and scientific mollusk names (Turgeon *et al.* 1988 and 1998). It was again updated in 2017 (Williams *et al.* 2017). The use of genetics to clarify species has greatly increased the need to update the list more frequently. Leading up to 2019, the Names Committee of the Freshwater Mollusk Conservation Society (FMCS) began developing a plan to continue with updating this list more frequently. The FMCS is dedicated to the conservation and advocacy of freshwater mollusks and it has become an international organization. As stated on their website (http://www.molluskconservation.org) "The FMCS now maintains lists of common and scientific names of freshwater gastropods and bivalves". Both lists cover native species of the United States and Canada. The lists maintained by FMCS serve as a consensus of accepted names and are a resource for conservation practitioners, hobbyists, scientists, and the public. The reason for maintaining names lists is simple: science moves fast and new species are described almost every month. Taxonomic changes to described species are also common. In contrast, these lists are semi-stable. These lists serve to support stability and promote effective communication about freshwater mollusks. These lists are periodically published by FMCS, and the next printing is anticipated in 2025. Every two years, coinciding with the FMCS biannual symposium, the FMCS names subcommittees meet to update the lists. The names subcommittees consist of experts on mollusks and taxonomy. At each meeting, petitions to change the list are reviewed and voted on by subcommittee members. In 2019, 2021, and 2023 the lists were updated based on decisions made about petitions submitted prior to the meeting." The currently accepted nomenclature can be found at https://molluskconservation.org/MServices_Names.html. The names used in this document are based on the 2023 posting.

Species Accounts

This section covers a description of each currently extant species. The first species, *Cumberlandia monodonta* (Spectaclecase), is the only species belonging to the family Margaritiferidae. All other species belong to the family Unionidae. The species range maps consist of data accessioned to the WVDNR mussel database through 2021. The data include those obtained through literature searches, museum collections (Academy of Natural Sciences, Carnegie Museum of Natural History, Harvard Museum of Comparative Zoology, Ohio State University Museum of Biological Diversity, Smithsonian Museum of Natural History, and University of Michigan Museum of Zoology), Marshall University records, WVDNR and USFWS surveys, and data provided through scientific collecting permits. **Red dots are those records prior to 1990. Black dots are those live and fresh dead data collected from 1990 to 2021. Collection of weathered dead shell only since 1990 are also depicted as red dots.**

Specimens used for photos were either taken of live individuals, collected by the author throughout her 30+ year career as State Malacologist and part of a teaching collection or accessioned to the State collection which in part was initially established by Marshall University. Some specimen photographs were also taken at the Ohio State Museum of Biological Diversity.

The specimens of *Epioblasma obliquata* (Catspaw) were on loan from the KY Mollusk Conservation Center.

There are three primary drainages in WV. The largest is the Ohio Basin which drains WV from the western slope of the Appalachian Mountains. The other two drain the Atlantic Slope with the Potomac River Basin to the north and the James River Basin to the south. The drainages depicted are HUC 8 (Figure 37). Within the following species accounts, unless otherwise noted, all species are presumed to be found within the Ohio Basin.

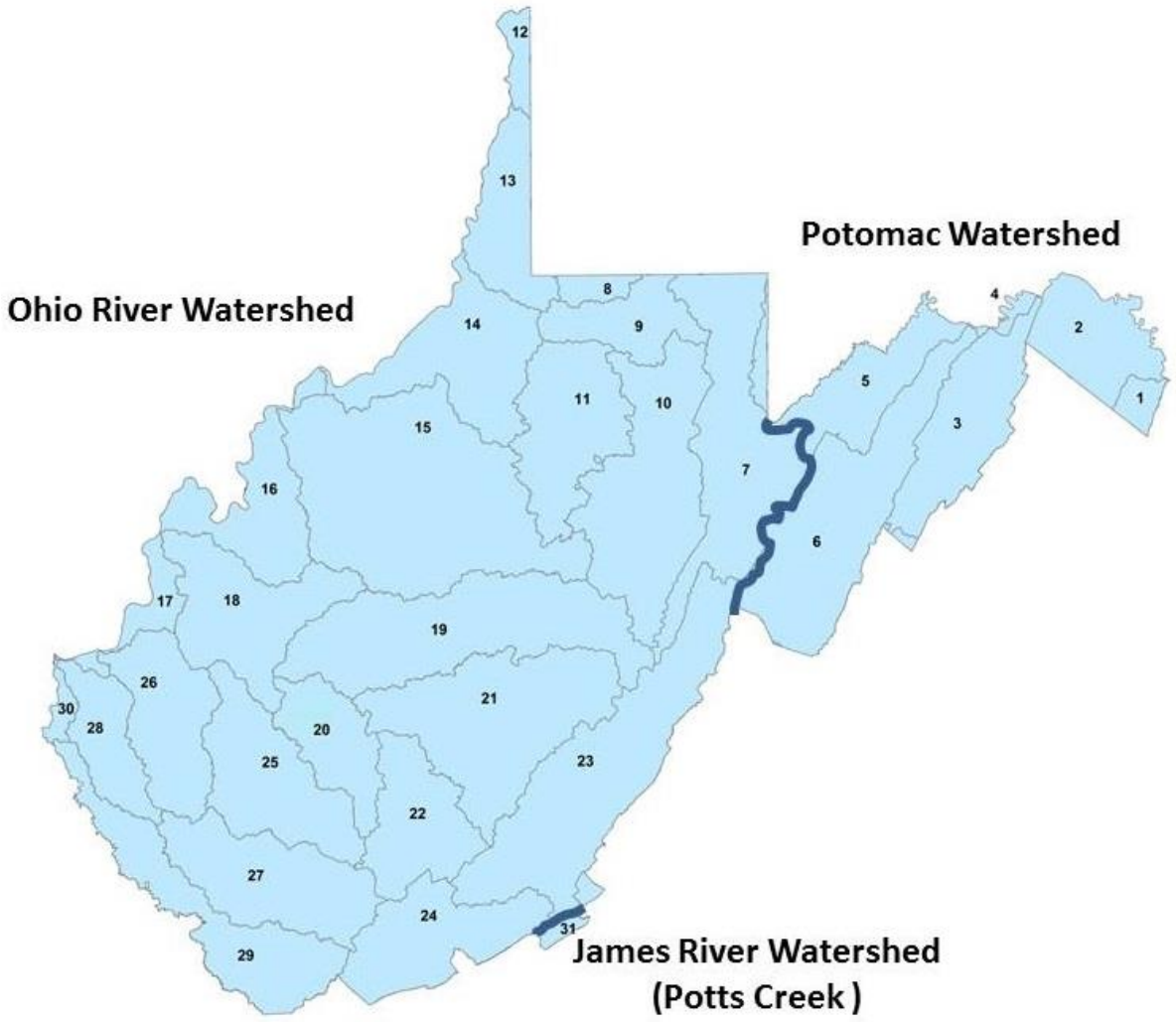


Figure 37. HUC 8 watershed within WV's three primary watersheds. 1 – Shenandoah River, 2 – Potomac River, 3 – Cacapon River, 4 – Potomac River , 5 – North Branch Potomac River, 6 – South Branch Potomac River, 7 – Cheat River, 8 – Dunkard Creek, 9 – Monongahela River, 10 – Tygart Valley River, 11 – West Fork River, 12 – Upper Ohio River 1, 13 – Upper Ohio River 2, 14 – Middle Ohio River 1/Middle Island Creek, 15 – Little Kanwaha River, 16 – Middle Ohio River 2, 17 – Lower Ohio River, 18 – Lower Kanawha, 19 – Elk River, 20 – Upper Kanawha River, 21 – Gauley River, 22 – Lower New River, 23 – Greenbrier River, 24 – Upper New River, 25 – Coal River, 26 – Lower Guyandotte River, 27 – Upper Guyandotte River, 28- Twelvepole Creek, 29 – Tug Fork River, 30 – Big Sandy River, 31 - Potts Creek

Table 3. List of West Virginia freshwater mussel species and their federal and state status, the higher the number the more common. Page number refers to page where each species is referenced in this document. The bold page number corresponds to the species description. (Federal Status: E = Endangered, TH = Threatened, PT = Proposed TH, PE = Proposed E; year of listing)

Taxa[1]	Common Name[1]	Federal Status[2]	Global Status[3]	State Status[3]	Page Numbers
Family Margaritiferidae					
Cumberlandia monodonta	Spectaclecase	E 2012	G3	S1	4,24,29
Family Unionidae					
Actinonaias ligamentina	Mucket		G5	S3	30
Alasmidonta marginata	Elktoe		G4	S2	31
Alasmidonta undulata	Triangle Floater		G4	S1	32
Alasmidonta varicosa	Brook Floater		G3	S1S2	6,33
Amblema plicata	Threeridge		G5	S3	6,34
Anodontoides ferussacianus	Cylindrical Papershell		G5	S2	35
Cambarunio iris	Rainbow		G5	S2	10,36
Cyclonaias nodulata	Wartyback		G4	S1	37
Cyclonaias pustulosa	Pimpleback		G5	S3	17,38
Cyclonaias tuberculata	Purple Wartyback		G5	S2	39
Cyprogenia stegaria	Fanshell	E 1990	G1	S1	3,21,40
Ellipsaria lineolata	Butterfly		G4	S2	41
Elliptio complanata	Eastern Elliptio		G5	S2	7,42
Elliptio crassidens	Elephantear		G5	S2	4,8,43
Elliptio fisheriana	Northern Lance		G4	S2	44
Epioblasma obliquata	Catspaw	E 1990	G1	S1	22,23,25,45
Epioblasma rangiana	Northern Riffleshell	E 1993	G1	S1	21,46
Epioblasma torulosa	Tubercled Blossom	E 1976, EX	GX	SX	
Epioblasma triquetra	Snuffbox	E 2012	G3	S2	5,7,10,47
Eurynia dilatata	Spike		G5	S3	5,48
Fusconaia flava	Wabash Pigtoe		G5	S3	6,49
Fusconaia subrotunda	Longsolid	TH 2023	G3	S3	50
Hemistena lata	Cracking Pearly Mussel	E 1989	G1	SX	
Lampsilis abrupta	Pink Mucket	E 1976	G1	S1	22,51
Lampsilis cardium	Plain Pocketbook		G5	S3	52,53
Lampsilis cariosa	Yellow Lampmussel		G3	S2	54,55
Lampsilis fasciola	Wavyrayed Lampmussel		G5	S3	56
Lampsilis ovata	Pocketbook		G5	S3	57
Lampsilis radiata	Eastern Lampmussel		G5	S1	58
Lampsilis siliquoidea	Fatmucket		G5	S4	22,59
Lampsilis teres	Yellow Sandshell		G5	S1	60

Table 3. Continued

Taxa[1]	Common Name[1]	Federal Status[2]	Global Status[3]	State Status[3]	Page Numbers
Lasmigona complanata	White Heelsplitter		G5	S3	5,6,61
Lasmigona compressa	Creek Heelsplitter		G5	S1	62
Lasmigona costata	Flutedshell		G5	S3	63
Lasmigona subviridis	Green Floater	PT 2023	G3	S2	4,10,64
Leaunio lienosus	Little Spectaclecase		G5	S1	65
Ligumia recta	Black Sandshell		G5	S3	7,23,66
Megalonaias nervosa	Washboard		G5	S2	4,10,67
Obliquaria reflexa	Threehorn Wartyback		G5	S3	6,68
Obovaria olivaria	Hickorynut		G4	S1	69
Obovaria retusa	Ring Pink	E 1989	G1	SX	
Obovaria subrotunda	Round Hickorynut	TH 2023	G4	S3	70
Paetulunio fabalis	Rayed Bean	E 2012	G2	S1	7,71
Parvaspina collina	James Spinymussel	E 1988	G1	S1	72
Plethobasus cicatricosus	White Wartyback	E 1976	G1	SX	
Plethobasus cooperianus	Orangefoot Pimpleback	E 1976	G1	SX	
Plethobasus cyphyus	Sheepnose	E 2012	G3	S2	73
Pleurobema clava	Clubshell	E 1993	G1	S1	21,74
Pleurobema cordatum	Ohio Pigtoe		G4	S2	23,75
Pleurobema sintoxia	Round Pigtoe		G4	S2	6,23,76
Potamilus alatus	Pink Heelsplitter		G5	S4	5,77
Potamilus fragilis	Fragile Papershell		G5	S3	78
Potamilus ohiensis	Pink Papershell		G5	S2	79
Ptychobranchus fasciolaris	Kidneyshell		G4	S3	80
Pyganodon cataracta	Eastern Floater		G5	S2	81
Pyganodon grandis	Giant Floater		G5	S3	6,82
Quadrula quadrula	Mapleleaf		G5	S3	4,5,83
Reginaia ebenus	Ebonyshell		G4	S1	8,9,84
Simpsonaias ambigua	Salamander Mussel	PE 2023	G3	S2	9,85
Strophitus undulatus	Creeper		G5	S3	86
Theliderma cylindricum	Rabbitsfoot	TH 2013	G3	SX	
Theliderma metanevra	Monkeyface		G4	S2	87
Toxolasma parvum	Lilliput		G5	S2	4,88
Tritogonia verrucosa	Pistolgrip		G4	S3	12,89
Truncilla donaciformis	Fawnsfoot		G5	S1	90
Truncilla truncata	Deertoe		G5	S2	91
Uniomerus tetralasmus	Pondhorn		G5	S1	92
Utterbackia imbecillis	Paper Pondshell		G5	S2	8,10,93
Utterbackiana suborbiculata	Flat Floater		G5	S2	94

[1]Scientific and Common Names Approved list from Williams *et al*. 2017 as updated by the Freshwater Mollusk Conservation Society 2023 (https://molluskconservation.org/MServices_Names.html)

[2]Federal Status and year listed. EX presumed extinct. E endangered. TH threatened. P proposed for listing.
[3]Global Status and State Status as of 2014 based on NatureServe criteria, SX presumed extirpated.

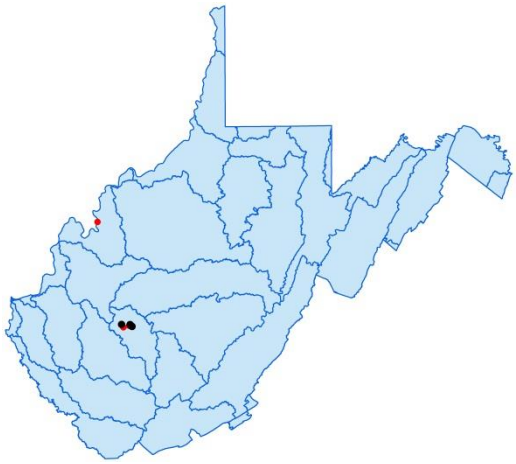
G1 - Critically Imperiled - Critically imperiled globally because of extreme rarity or because of some factor(s) making it especially vulnerable to extinction. Typically five or fewer occurrences or very few remaining individuals (<1,000) or acres (<2,000) or linear miles (<10).
G2 - Imperiled - Imperiled globally because of rarity or because of some factor(s) making it very vulnerable to extinction or elimination. Typically 6 to 20 occurrences or few remaining individuals (1,000 to 3,000) or acres (2,000 to 10,000) or linear miles (10 to 50)
G3 - Vulnerable - Vulnerable globally either because very rare and local throughout its range, found only in a restricted range (even if abundant at some locations), or because of other factors making it vulnerable to extinction or elimination. Typically 21 to 100 occurrences or between 3,000 and 10,000 individuals.
G4 - Apparently Secure - Uncommon but not rare (although it may be rare in parts of its range, particularly on the periphery), and usually widespread. Apparently not vulnerable in most of its range, but possibly cause for long-term concern. Typically more than 100 occurrences and more than 10,000 individuals.
G5 - Secure - Common, widespread, and abundant (although it may be rare in parts of its range, particularly on the periphery). Not vulnerable in most of its range. Typically with considerably more than 100 occurrences and more than 10,000 individuals.
S1 - Critically Imperiled - Critically imperiled in the state because of extreme rarity or because of some factor(s) making it especially vulnerable to extirpation from the state. Typically five or fewer occurrences or very few remaining individuals (<1,000).
S2 - Imperiled - Imperiled in the state because of rarity or because of some factor(s) making it very vulnerable to extirpation from the state. Typically 6 to 20 occurrences or few remaining individuals (1,000 to 3,000).
S3 - Vulnerable - Vulnerable in the state either because rare and uncommon, or found only in a restricted range (even if abundant at some locations), or because of other factors making it vulnerable to extirpation. Typically 21 to 100 occurrences or between 3,000 and 10,000 individuals.
S4 - Apparently Secure - Uncommon but not rare, and usually widespread in the state. Possible cause of long-term concern. Usually more than 100 occurrences and more than 10,000 individuals.
SX – presumed extirpated

Family Margaritiferidae
***Cumberlandia monodonta* (Spectaclecase)**

Description: The shell is elongate and compressed with anterior end rounded, and posterior end bluntly pointed becoming rounded with age. The ventral margin may be arched in older individuals. The umbo may be slightly elevated above the hinge line and forms a moderately shallow beak cavity. The beak sculpture, if present, consists of 3 - 4 straight heavy ridges. The lateral teeth are typically evident in young but fade into a thickened area with age. Pseudocardinal teeth also fade with age and become one tooth in the right valve. It is from this feature that the species name is derived with "*mono*" meaning one and "*donta*" meaning tooth. Very large anterior and posterior muscle scars are present. The periostracum is yellow in very young, and become brown darkening to black with age. Nacre is white and may be iridescent posteriorly. Length to 8 inches.

Habitat and Distribution: This species prefers medium to large rivers where it can be found buried in patches of mud and sand under large boulders, or slab rock. Watters *et al*. (2009) indicated that Ortmann observed this species at Buffington Island on the Ohio River in 1912. Watters more recently observed a weathered shell at the mouth of the Muskingum River in OH. More recently it was found live within the Marmet Pool of the Kanawha River where it was first collected in 2002 by Enviroscience Inc. and subsequently collected by WVDNR and USFWS biologists and Lewis Environmental.

Life History: This species does not fit into the typical long-term, short-term brooder groups. It has been reported to have two brood periods (Howard 1915, Gordon and Smith 1990). It was also reported to possibly be hermaphroditic (van der Schalie 1966). It is known to have flat, branched conglutinates (Knudsen and Hove 1997). Goldeye and Mooneye have been shown to transform larvae.



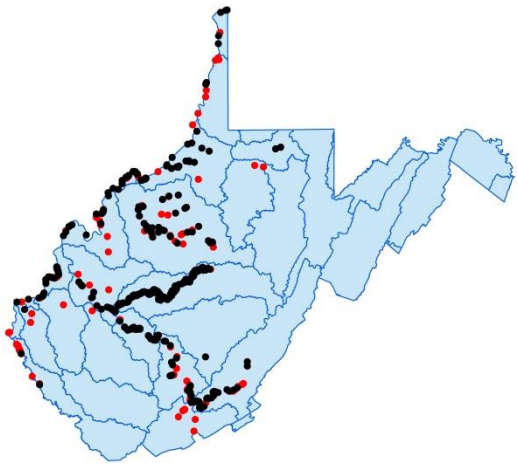
Similar Species: *C. monodonta* (juveniles only), *Simpsonaias ambigua* (Salamander Mussel)

Family Unionidae
***Actinonaias ligamentina* (Mucket)**

Description: The shell is ovate and generally compressed when young, becoming heavy and more inflated with age. The anterior end is rounded and the posterior end is broadly rounded to bluntly pointed at or just below the midline. The umbo rises slightly above the hinge line though it is typically worn flat. The umbo is about one-third distance from the anterior end and projects forward. It is only slightly inflated forming a moderately deep to open beak cavity. The beak sculpture is generally only evident in very young individuals, but consists of a few delicate distinct double-looped bars. The teeth are well-developed, and the interdentum is moderate in length and width. The periostracum of young shells appears yellow to brown with broad green rays. As individuals become older, the green rays become obscure and the shell appears much darker. Nacre is generally white. Length to 7 inches.

Habitat and Distribution: This species is found within large to medium-sized rivers throughout the Ohio Basin and where found is typically one of the most common species.

Life History: Long-term brooder. This species produces white leaf-shaped conglutinates (Watters 2008). It is a host generalist, having transformed larvae on numerous members of sunfish, minnow, darter, and sculpin families, American Eel, and others.

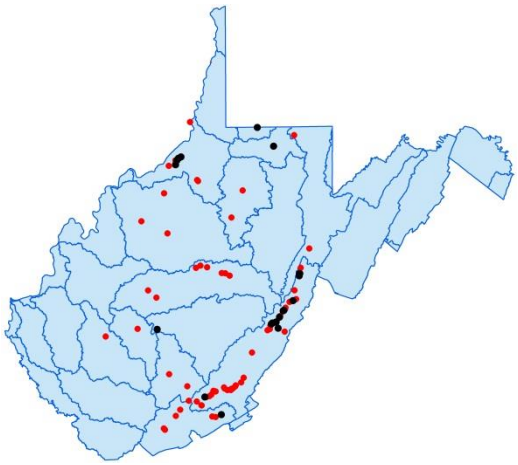


Similar Species: male *Lampsilis siliquoidea* (Fat Mucket), male *Lampsilis abrupta* (Pink Mucket) see Pages 101 and 102

***Alasmidonta marginata* (Elktoe)**

Description: The shell is elongate, triangular, thin, and inflated with a fairly sharp posterior ridge. Maximum inflation is at the posterior ridge. The posterior slope has fine costations and is moderately steep. The anterior end is rounded, and the posterior end is bluntly pointed below the midline. The umbo is positioned centrally and rises slightly above the hinge line forming a moderately deep beak cavity. The beak sculpture consists of heavy thick bars which may appear as double-looped. Lateral teeth may appear as slight swellings or may be absent. The pseudocardinal teeth are thin and elongated. The periostracum is yellowish brown with broad green rays and is speckled with dark green dots. The posterior slope tends to be lighter in color. Nacre is bluish white and may be washed with salmon. This species possesses an orange foot. Length to 4 inches.

Habitat and Distribution: This species is wide ranging throughout the Ohio Basin in small to large rivers but is never common. It is more abundant in cool-water streams such as the Greenbrier River. In New York and Pennsylvania it has been found to cross the continental divide and a subspecies is now found within the Atlantic Watershed there.



Life History: Long-term brooder. This species appears to be a host generalist with shiners, dace, sculpins, and others transforming larvae.

Similar species: male *Epioblasma triquetra* (Snuffbox)

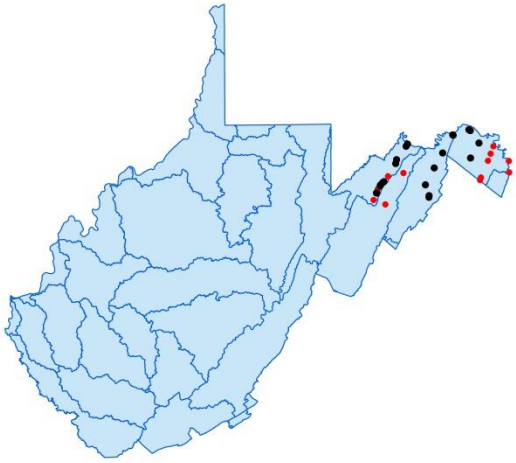
***Alasmidonta undulata* (Triangle Floater)**

Description: The shell is variable in shape appearing broadly triangular to almost quadrate when young and becoming more club-shaped in older individuals. The posterior slope is somewhat compressed while the umbo is generally inflated being slightly elevated above the hinge line. The umbo is positioned in the anterior one-third and points forward forming a deep beak cavity. The beak sculpture consists of heavy bars and may be variable. The shell is generally thicker, especially the anterior end, than other *Alasmidonta* species. No lateral teeth are evident though the area may be thickened. Pseudocardinal teeth are strong though rudimentary. Periostracum in younger individuals is yellowish green to yellowish brown with extensive rays while older individuals appear almost black. Nacre is most commonly pink or salmon but may be white and may be iridescent. The foot in this species varies in color from pale white to orange brown. Length to 3 inches.

Habitat and Distribution: In WV this species is restricted to the Potomac Watershed where it is widespread though not abundant. In some areas it is being impacted by livestock access to streams. This species has been observed “crawling across the streambed” in mid-winter (Bogan personal communication). In Maine, this species has also been found in lakes and ponds.

Life History: Long-term brooder. Species appears to be a host generalist with fallfish, largemouth bass, darters, dace, shiners, sculpins, and others all transforming juveniles.

Similar Species:
Strophitus undulatus Creeper), *Alasmidonta varicosa* (Brook Floater)



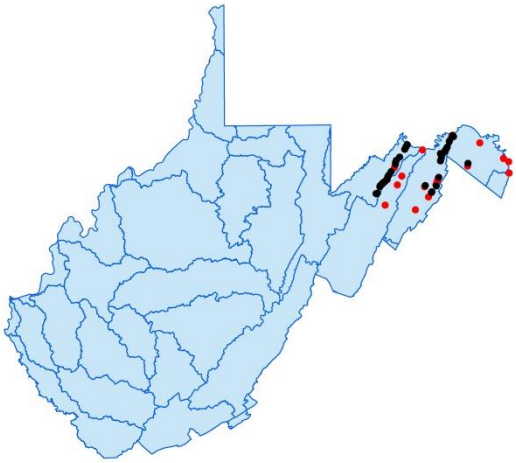
***Alasmidonta varicosa* (Brook Floater)**

Description: The shell is thin, somewhat rectangular, and inflated with the maximum inflation at the posterior ridge which is pronounced. Posterior slope has small wavy ridges. The umbo rises slightly above the hinge line forming a moderately shallow beak cavity. Beak sculpture consists of several bars and may appear double-looped (bottom photo). A small rudimentary pseudocardinal tooth is present in each valve and no lateral teeth are present. The periostracum is yellowish to greenish brown and generally heavily rayed such that the shell may appear green. Nacre is iridescent bluish white to pink. This species has an orange foot. Length to 3 inches.

Habitat and Distribution: In WV this species is found within the Potomac River system and is fairly well distributed in several tributary streams. It is generally found in smaller streams with stable gravel and good flow. Though references list this as a riffle species, the WVDNR has not commonly found it directly in the riffles. It is more commonly found along the stream margins and in low gradient riffles and runs. In the mid-1990s it was found to be locally common in a few areas but has shown dramatic decline since.

Life History: Long-term brooder. Although limited host testing has been conducted, this species appears to be a host generalist as slimy sculpin, pumpkinseed sunfish, and blacknose dace have all transformed juveniles.

Similar species: *Strophitus undulatus* (Creeper), *Alasmidonta undulata* (Triangle Floater)

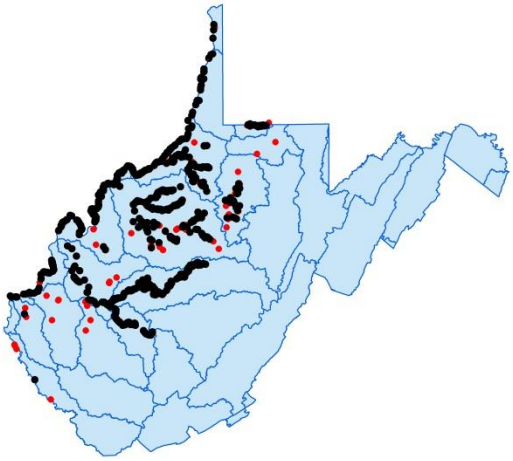


***Amblema plicata* (Threeridge)**

Description: The shell is typically quadrate with a rounded anterior end. It is fairly heavy and is moderately inflated at the umbo. The shell tapers to a compressed posterior end with the dorsal margin appearing somewhat alate or winged. The posterior two-thirds of the shell generally has large folds or undulations. Individuals vary from specimens without any sculpture to very ornate. All sculpturing is posterior of the umbo. The umbo is positioned far forward and rises slightly above the hinge line though it may be almost flush in large river forms. The beak cavity is very deep, and the beak sculpture if evident consists of heavy concentric bars (bottom left photo). The teeth are well-developed with a short, wide interdentum. In juvenile *A. plicata*, the periostracum is light brown to yellowish green and may have washes of green. Folds may not be evident. Older individuals become yellowish brown to dark brown. Nacre is white. Length to 7 inches.

Habitat and Distribution: This species is generally found in small to large rivers. It can be found in a wide range of substrate types (preferring gravel) and a wide range of flow types (pools to riffles).

Life History: Short-term brooder. This species releases glochidia in mucous strands (Page 97). Utterback (1915) reported leaf-like conglutinates that quickly disassociate into free larvae (Watters *et al*. 2009). Numerous fish hosts have been identified.



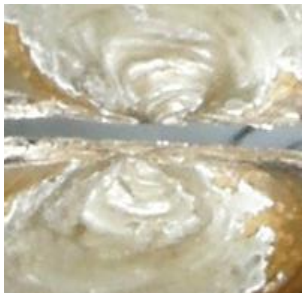
Similar Species: *Megalonaias nervosa* (Washboard) (See Page 100)

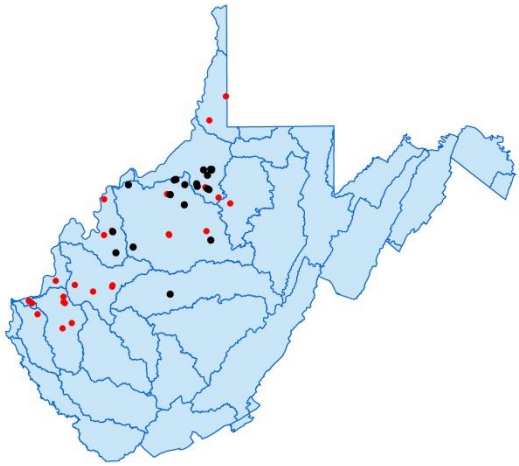
***Anodontoides ferussacianus* (Cylindrical Papershell)**

Description: The shell is thin and somewhat ovate, and the dorsal posterior margin is straight to slightly curved. The umbo rises slightly above the hinge line producing a shallow beak cavity. The umbo is located within the anterior third of the shell. Beak sculpture consists of 3-4 very fine concentric ridges. This species lacks teeth though it may have an irregular swelling (small knob) on the hinge line beneath the umbo in the left valve. Periostracum is yellowish green to brown and may have fine green rays. Nacre is bluish white and may be iridescent. Length to 3 inches.

Habitat and Distribution: This species is uncommon in WV though numbers and distribution may be under-represented due to confusion with *Pyganodon grandis* and *Strophitus undulatus*. It is generally found in calmer habitats in small streams.

Life history: Long-term brooder. Known to release glochidia in mucus strands that entangle hosts. Species appears to be a host generalist with members of the sunfish, darter, minnow, and other families having transformed juveniles.





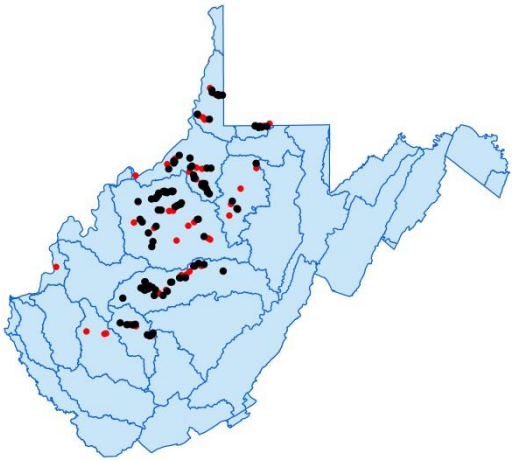
Similar Species: *Pyganodon grandis* (Giant Floater), *Strophitus undulatus* (Creeper) (See Page 99)

***Cambarunio iris* (Rainbow)**

Description: This species is sexually dimorphic. The shell is fairly small, thin, and elongate. The anterior end is rounded while the posterior end is bluntly pointed ventral of the midline in males and rounded at the midline in females. Males also tend to be relatively compressed compared to the somewhat inflated females. The posterior ridge is low and rounded. The umbo is slightly elevated above the hinge line and positioned well anterior of the midline. The beak cavity is shallow and beak sculpture consists of 4-6 distinct double-looped bars. The teeth are well-developed though they appear thin and delicate. No interdentum is evident. The periostracum is yellow to greenish yellow with dark green rays which are often interrupted. Nacre is silvery white and iridescent. Some individuals may have a deep pink beak cavity region fading out to tan and silvery white at the margins. Length to 3 inches.

Habitat and Distribution: This species is often found under flat rocks in creeks to midsized rivers. Typically associated with clean-swept substrates.

Life History: Long-term brooder. This species has a lure that consists of tan and black appendages. The lure can resemble a hellgrammite at rest or a crayfish when actively moving (Page 96). Members of the sunfish, darter, and minnow families as well as Mottled Sculpin have transformed larvae.



Similar Species: *Eurynia dilatata* (Spike)

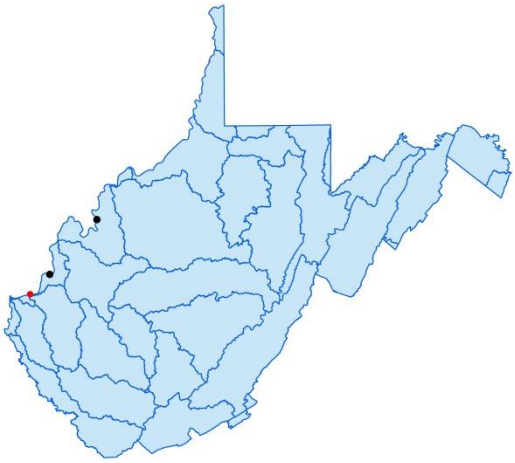
***Cyclonaias nodulata* (Wartyback)**

Description: The shell is nearly circular with the posterior end somewhat square. Shell length is roughly equal to shell height. It is highly inflated with the umbo rising above the hinge line and projects forward. Beak sculpture consists of 1-2 coarse bars or ridges. A few large pustules or small knobs may be found along the posterior ridge and within the median face of the valve forming two rows. The area between the two rows does not form a sulcus. Fine pustules may be present on the posterior slope. The umbo is very inflated forming a fairly deep beak cavity. The teeth are well-developed with a very short, wide interdentum. The periostracum is light brown to yellowish brown and rarely may have light green rays. Nacre is white. Length less than 3 inches.

Habitat and Distribution: Found in mud to fine gravel in large rivers. Rare in WV only being known from the Ohio River where it appears to be on the northern edge of its range.

Life History: Short-term brooder. Various species of catfish have been shown to transform larvae.

Similar species: *Quadrula quadrula* (Mapleleaf), *Cyclonaias pustulosa* (Pimpleback), *Cyclonaias tuberculata* (Purple Wartyback)



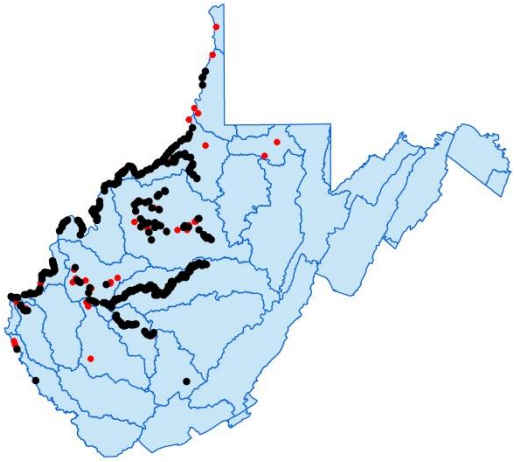
***Cyclonaias pustulosa* (Pimpleback)**

Description: The shell is rounded to triangular and moderately inflated. The posterior ridge protrudes to form a small “corner” on otherwise rounded shell. The posterior two-thirds of the shell is generally covered with small pustules and the posterior slope is slightly compressed. Some specimens lack all pustules, especially juveniles. The umbo barely extends above the hinge line and is positioned very anterior. The umbo can be strongly projected forward and inward facing opposing umbo to more depressed and less projecting forming a fairly deep beak cavity. The beak sculpture consists of 2-3 indistinct concentric ridges. The teeth are well-developed with a very wide short interdentum. The periostracum is yellowish brown trending to dark brown with age and may contain broad broken green rays most evident at the umbo. Nacre is white. Length to 4 inches.

Habitat and Distribution: The species is found in large creeks to large rivers in most substrates as well as in variable flow conditions. Kanawha Falls was thought to be a natural barrier to its distribution though it appears to have recently been introduced upstream into the New River.

Life History: Short-term brooder. Gravid individuals have been observed in early June in the Ohio River. Juvenile transformations have been observed on several catfish species.

Similar Species: *Cyclonaias tuberculata* (Purple Wartyback), *Cyclonaias nodulata* (Wartyback)

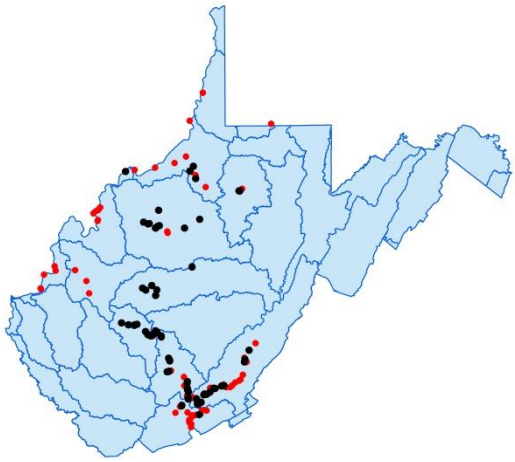


***Cyclonaias tuberculata* (Purple Wartyback)**

Description: The shell is rather thick and somewhat compressed with adults appearing quadrate. The anterior end is broadly rounded and the posterior end appears slightly squared off to bluntly pointed. The posterior slope is compressed giving the appearance of a slight wing. The umbo may rise slightly above the nearly straight hinge line and is positioned far anteriorly forming a deep beak cavity. The beak sculpture, typically only evident in juveniles, consists of fine concentric wavy lines. The posterior two-thirds of shell is generally covered with pustules which extend onto the umbos. In young specimens, these pustules appear in two rows giving the appearance of a sulcus; however, there is no indentation on the ventral margin to indicate the presence of a sulcus. The teeth are well-developed with a long wide interdentum. The periostracum is yellowish to greenish brown becoming darker brown with age. Faint green rays may be evident in juveniles. Nacre is purple. Length to 5 inches.

Habitat and Distribution: This species is not common in WV except in the upper Kanawha River system. In 1919, Ortmann described this species as “nowhere abundant”. Thought to have been extirpated from the Monongahela Watershed, it was rediscovered in the West Fork River in 2019.

Life History: Short-term brooder. Reportedly releases white, oblong conglutinates (Watters 2008). A fleshy lure has been observed at Kanawha Falls (Page 96). Several species of catfish are known to have transformed larvae.



Similar species: *Quadrula quadrula* (Mapleleaf) (as young), *Cyclonaias pustulosa* (Pimpleback)

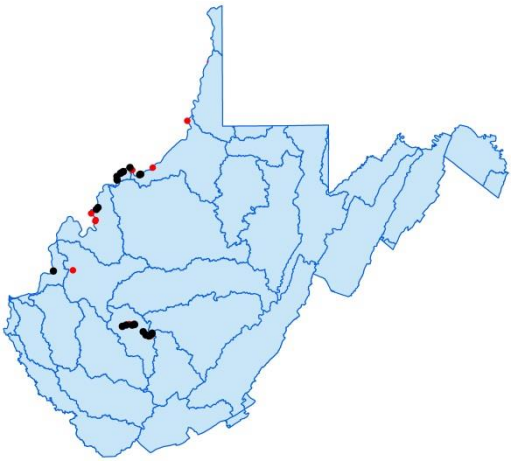
***Cyprogenia stegaria* (Fanshell)**

Description: The shell is somewhat rounded to triangular and inflated. A median sulcus is evident in young individuals becoming more obscure with age, appearing as a gap in the pustules. Growth lines are prominent and slightly raised. Pustules generally cover the face of the shell though typically concentrated anterior of the posterior ridge. The pustules appear to "droop". The umbo is inflated rising slightly above the hinge line and projecting inward toward opposing umbo. The beak cavity is moderate and the beak sculpture, when evident, consists of a few weak double-loops. The teeth are well-developed with a wide interdentum. The periostracum is yellow to yellowish brown with broken darker green rays and may have blotches of green areas. Rays and blotches may be so prevalent the shell appears green. Nacre is white and may be iridescent posteriorly. Length to 3 inches.

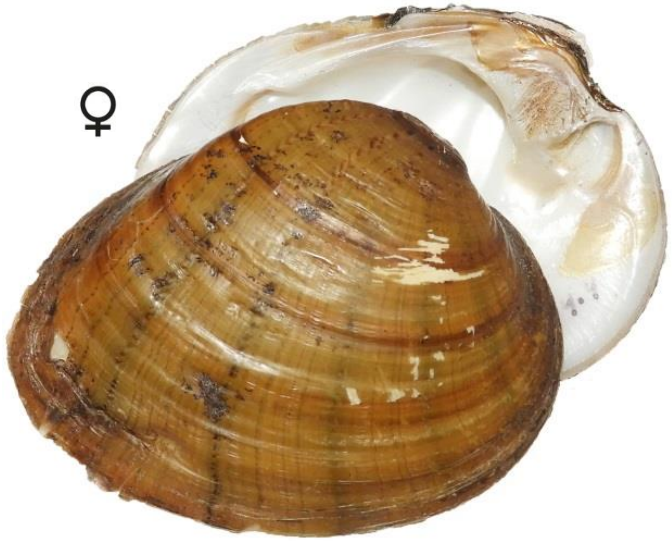
Habitat and Distribution: This species is known from the Ohio and upper Kanawha rivers in WV although also found in medium-sized rivers in other states. Found in a variety of substrates ranging from sand to cobble. It is also found in a variety of flow regimes and is able to withstand dammed large rivers such as the Ohio River.

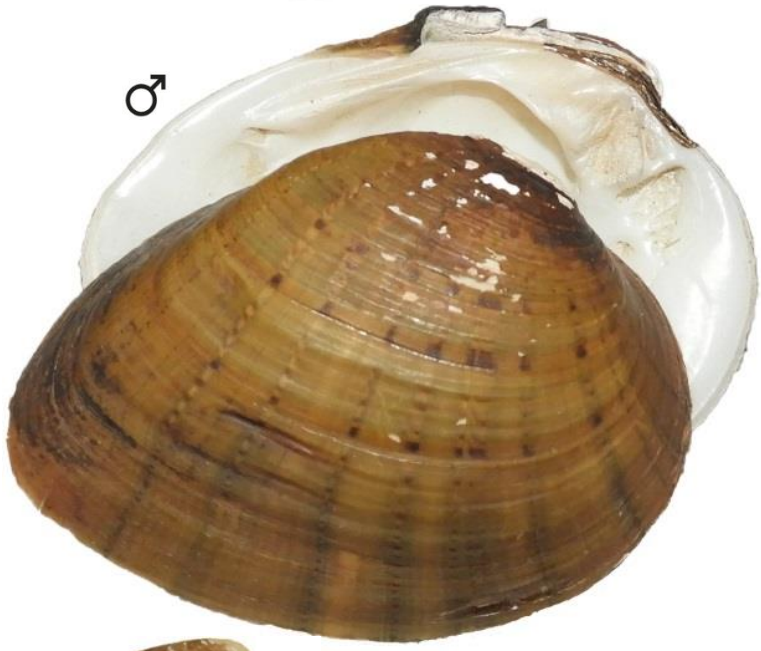
Life history: Long-term brooder. It forms a worm-like conglutinate that stays attached to the mussel. On the tip of the conglutinate is a small club-shaped head and the entire lure can be either white or pink. Sculpin and darters have successfully transformed larvae.

Similar Species:
Cyclonaias pustulosa (Pimpleback)



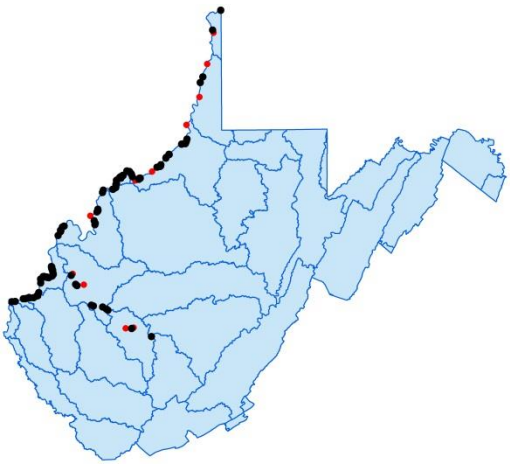
***Ellipsaria lineolata* (Butterfly)**





Description: This species is sexually dimorphic (female top, male bottom). The shell is triangular with the umbo positioned very anteriorly, pointing anteriorly, and not rising above hinge line. The shell is heavy and generally compressed though more inflated in females. The anterior end is broadly rounded tapering to a bluntly pointed posterior end in the female and more sharply pointed in the male. The posterior ridge is distinct nearing 90 degrees although it may be somewhat rounded in the female. The posterior slope is very narrow and truncate. The beak cavity is moderate, and beak sculpture is obscure consisting of fine double-looped ridges. The teeth are well-developed with a short moderate interdentum. The periostracum is generally light yellowish brown to brown and contains several broken brown rays. Nacre is white. Length to 4 inches.

Habitat and Distribution: This is a large-river species found only within the Ohio and Kanawha rivers of WV. It is much less abundant in the Kanawha River. The lower Kanawha River appears to be recovering from past water quality issues, and likewise the *E. lineolata* populations are beginning to rebound. The northern panhandle populations are slow to recover due to the dams restricting fish host movement.



Life History: Long-term brooder. Individuals can be located easily during the spring season when females are found near or on the substrate surface to release mature larvae. They tend to bury deeper when not brooding young. Freshwater Drum are the only fish known to have successfully transformed larvae.

Similar Species: *Truncilla truncata* (Elktoe)

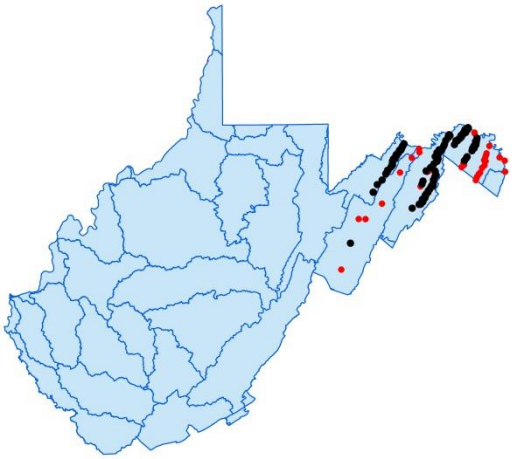
***Elliptio complanata* (Eastern Elliptio)**

Description: The shell is rectangular to trapezoidal and rather compressed. The anterior end is rounded and the posterior end is slightly rounded to bluntly pointed. The posterior ridge is low and rounded and the umbos are not inflated, barely rising above the hinge line. Beak sculpture consists of 5-6 ridges. The beak cavity is shallow and the teeth are well-developed with a very narrow interdentum. The periostracum is reddish brown to brown and faint green rays may be evident. Juveniles are typically light yellowish to greenish brown and highly rayed. Nacre may be purple, pink, salmon, or white iridescent in color. Length to 3.5 inches.

Habitat and Distribution: This species is found in creeks to large rivers in a wide range of habitats and is the most common species within the Atlantic Slope of WV.

Life History: Short-term brooder. Conglutinates (picture below) were observed being released in mid-June in the Cacapon River. A host generalist, as members of the sunfish family, Yellow Perch, American Eel, sculpins, and trout have all transformed juveniles.

Similar Species: *Elliptio fisheriana* (Northern Lance), *Eurynia dilatata* (Spike) Ohio Basin

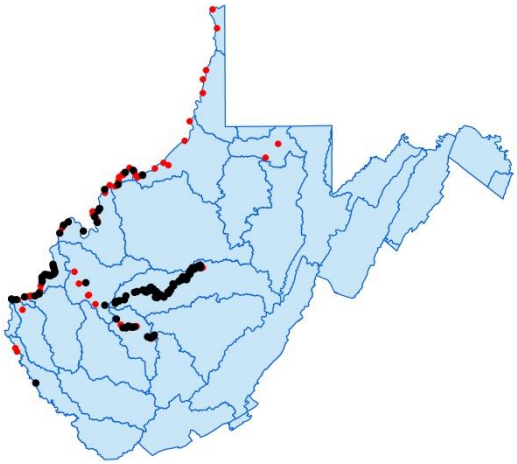


***Elliptio crassidens* (Elephantear)**

Description: The shell is somewhat triangular to subovate, thick, heavy, and moderately inflated. The anterior end is broadly rounded tapering to a bluntly pointed posterior end. The umbos are wide and slightly raised above the hinge line forming a very shallow beak cavity. Beak sculpture, if evident, consists of 2-3 coarse loops. The teeth are well-developed with a short, moderately wide interdentum. The periostracum is reddish brown, turning black with age. Juveniles may be highly rayed. Nacre is purple, pink, or salmon. Length to 6 inches.

Habitat and Distribution: In its natural habitat it prefers large rivers in coarse gravel and strongly-flowing water. It however has adapted to the impounded waters of the Ohio River. In WV, it has been found in the Kanawha River system below the fall line at Glenn Ferris. It was once a common component of the Elk River fauna below Sutton dam. However, a 1991-92 survey only revealed large individuals, indicating the lack of reproduction here (Clayton 1994), and it has continued to decline. Ortmann (1919) stated that the Elk River was one of the smallest streams from which he had collected this species. It is still a component of the Ohio River fauna and is reproducing within the Greenup Pool.

Life History: Short term brooder. Only the Skipjack Herring and Alabama Shad are known to have transformed juveniles. Of the 2, only the Skipjack Herring occurs in WV. As the Skipjack has never been reported from the Elk River, other hosts may still be unidentified.



Similar Species: *Actinonaias ligamentina* (Mucket)

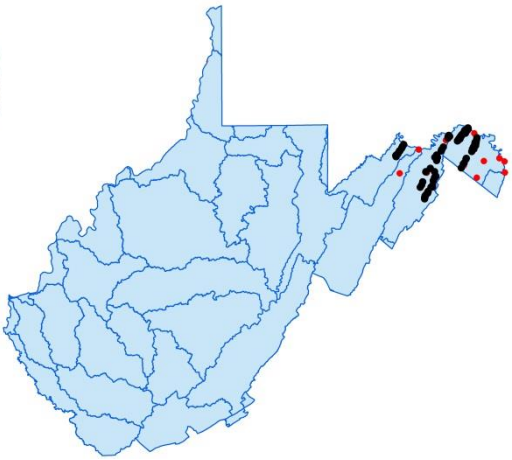
***Elliptio fisheriana* (Northern Lance)**

Description: The shell is small, elongate, lanceolate, and rather compressed. The anterior end is rounded, and the posterior end is pointed. A faint posterior ridge is evident. The umbo sits far anterior and is positioned fairly even with hinge line forming a shallow to indistinct beak cavity. Beak sculpture, if evident, consists of 3-4 parallel ridges. The teeth are well-developed though fine and delicate and without interdentum. The periostracum is yellowish green, reddish brown to brown, or almost black with faint green rays. Nacre is purple to pink. Length to 3.5 inches.

Habitat and Distribution: This species is generally found in larger creeks to rivers. It prefers slower moving water and occurs in substrates ranging from sand to gravel. In WV, it is restricted to the Potomac Watershed.

Life History: Short-term brooder. Appears to be a host generalist with Bluegill, Largemouth Bass, Johnny Darter and White Shiner all transforming juveniles.

Similar Species: *Elliptio complanata* (Eastern Elliptio), *Eurynia dilatata* (Spike) Ohio Basin



***Epioblasma obliquata* (Catspaw)**

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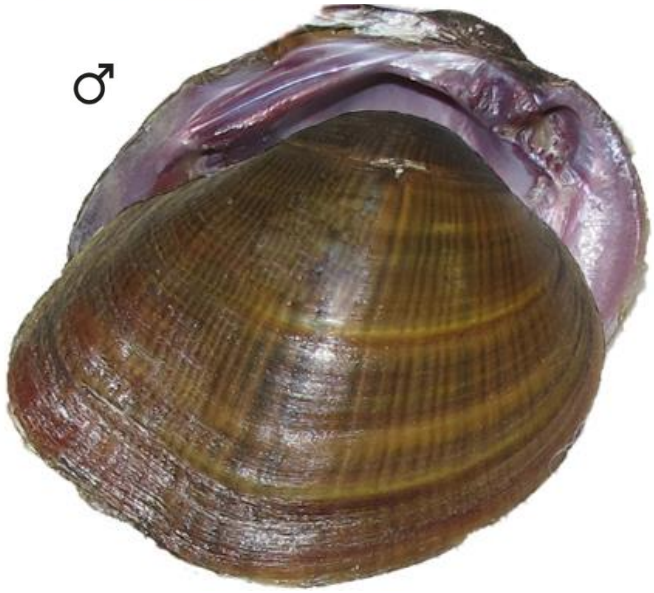
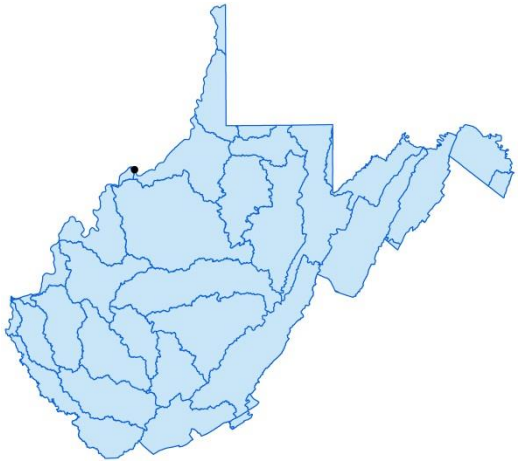


Description: This species is sexually dimorphic (female top, male bottom). The anterior end is rounded in both sexes and each has a low rounded posterior ridge and a median ridge forming a sulcus in between. The median ridge of the female is angled more posteriorly giving it a quadrate appearance. This gives the female the "cat's paw" appearance. In males, the posterior end is bluntly pointed. The umbo is low, producing a shallow wide beak cavity and position anterior. Beak sculpture has not been described. The teeth are well-developed with a short wide interdentum. The periostracum is reddish to yellowish brown with numerous dark green rays. Nacre is purple. Length to 2.75 inches (male) and 1.5 inches (female).

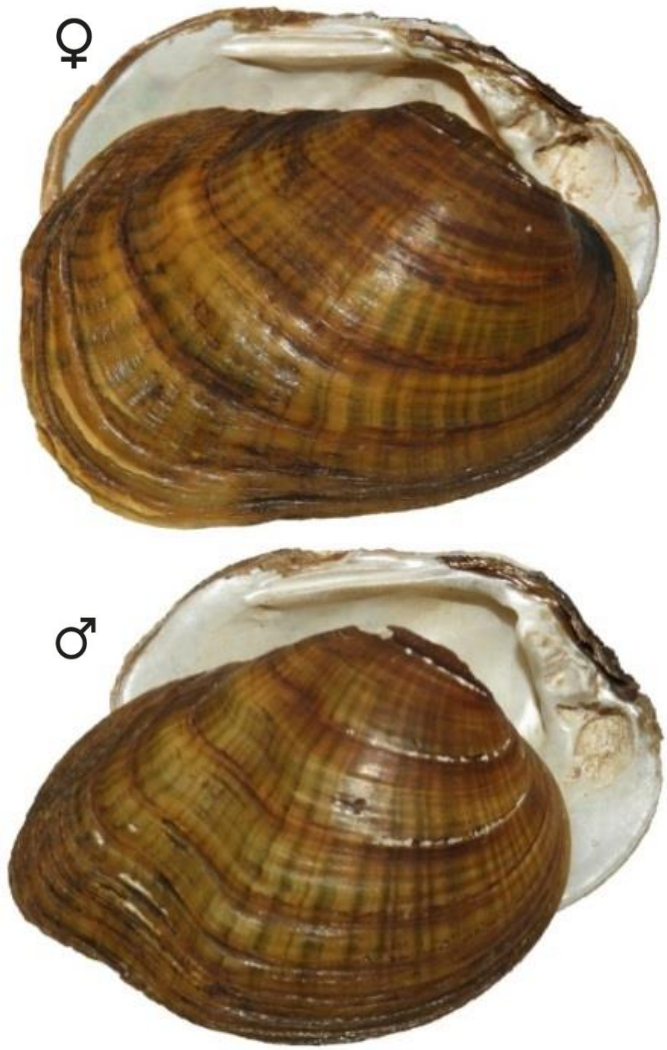
Habitat and Distribution: Occurrences are associated with gravel runs and riffles in medium to large rivers. Although no historic records for this species occurred in WV, it was historically found at the mouth of the Muskingum River which enters the Ohio River at Marietta, OH. It is critically endangered and naturally occurs in only one small stream in OH.
It has been reintroduced into the Ohio River upstream of the confluence with the Muskingum River via propagated juveniles. One juvenile to be stocked is shown siphoning in the substrate below.

Life History: Long-term brooder. A variety of hosts have been identified with Rockbass, darters, Mottled Sculpin and Stonecat all transforming larvae. Successful propagation via *in-vitro* methods by KY provided the juveniles stocked.



Similar Species: *Epioblasma rangiana* (Northern Riffleshell)

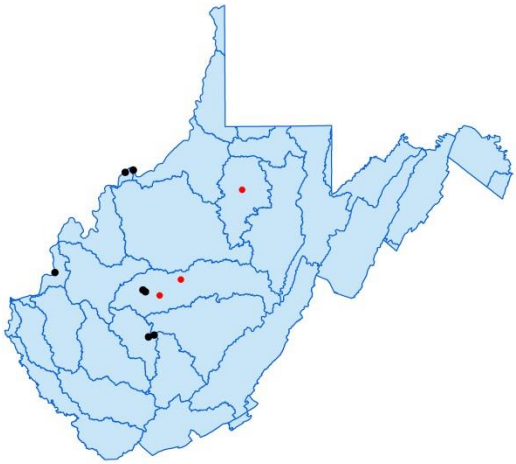
***Epioblasma rangiana* (Northern Riffleshell)**



Description: This species is sexually dimorphic (female top left, male bottom left). The shell of the female appears almost rectangular with a rounded anterior end and a broadly rounded posterior end. The posterior end is more bluntly pointed in the male with a slight sulcus anterior to the posterior ridge. The sulcus may be slightly evident in the more inflated female though both are relatively compressed. Remnants of tubercles may be evident on the median ridge. The umbo is situated far forward and rises slightly above the hinge line. It is only slightly swollen and the beak cavity is moderate. The beak sculpture, if evident, consists of a few faint double-looped bars. Teeth are well-developed with no interdentum. The periostracum is yellow to yellowish green or brown with green rays. Nacre is white. Length to 2 inches.

Habitat and Distribution: This species was historically found throughout the Ohio River Basin as far upstream as the West Fork River. The last known live individuals were observed in the Elk River in 2003 by Ecological Specialists. It prefers faster moving water with clean substrates of gravel to cobble.

Life History: Long-term brooder. The female moves to the substrate surface, opens her valves, and displays as shown above right. When an interested host fish pokes between the valves, she closes shut, the mantle forms a seal around the fish, and she then infests the fish with glochidia. Fish that have successfully transformed juveniles include members of the darter family, Mottled Sculpin and Brown Trout.



Similar Species: *Epioblasma obliquata* (Catspaw) - males

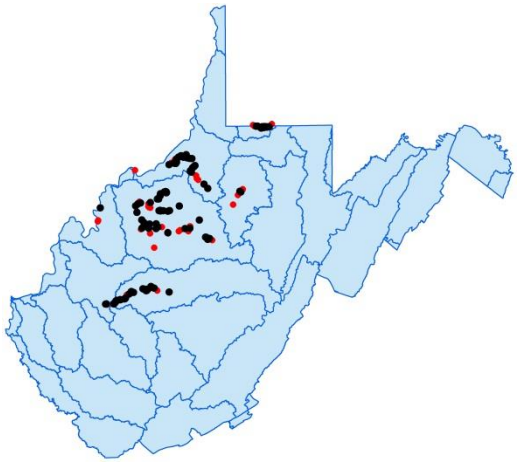
***Epioblasma triquetra* (Snuffbox)**

Description: This species is sexually dimorphic (female top, male bottom). The shell is heavy, triangular, and highly inflated. The posterior ridge is sharply angled, and the posterior slope is widely flattened. Females have a greatly enlarged and inflated posterior slope. The posterior slope may appear ribbed (especially in females). The anterior end is rounded and the posterior end is broadly (males) to sharply (females) pointed. The posterior margin of the female has sharp tooth-like projections used to hold its fish host. The umbo is situated just forward of midline and rises above the hinge line. The beak cavity is moderately deep, and beak sculpture consists of three to four faint, double-looped bars. The teeth are well-developed without an interdentum. The periostracum is yellowish brown with dark green rays which may appear broken and pointed. Nacre is white. Length to 2.5 inches.

Habitat and Distribution: This species is found in large creeks to large rivers. It is typically associated with clear stable riffles but can be found in slack pools and runs as well. It is typically buried for most of the year and is often under-sampled.

Tyler Herrn

Life History: Long-term brooder. The female rises to the substrate surface, opens her valves, and displays as shown right. When an interested host fish pokes between the valves, she closes shut, seals the mantle around the fish (above), and infests it with glochidia. Logperch and sculpin have been shown to successfully transform larvae.

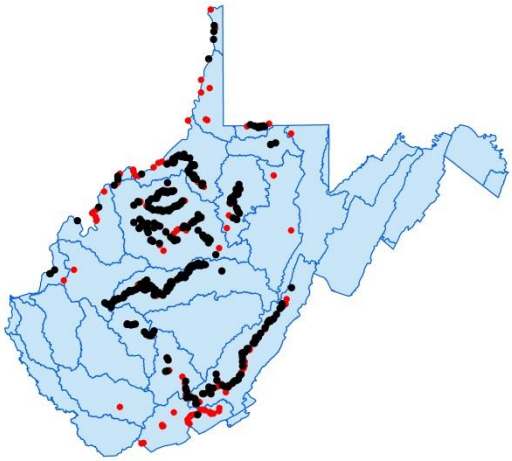


Similar Species: *Alasmidonta marginata* (Elktoe)

***Eurynia dilatata* (Spike)**

Description: The shell is elongate with a broadly rounded anterior end, tapering posteriorly to a somewhat blunt point at or below the midline. Shell is rather compressed with the posterior ridge broadly rounded yet evident. The umbo is positioned very anterior and about even with the slightly curved hinge line. The beak cavity is very shallow, and beak sculpture, if visible, consists of a few well-developed parallel bars. Teeth are well-developed and pronounced with a long narrow interdentum which may be absent in some individuals. The periostracum of young varies from dark yellowish brown to dark green to black, with green rays. Rays may become vague, and the periostracum may appear black in older individuals. Nacre is generally purple, pink, or white. Length to 5 inches.

Habitat and Distribution: This species is a habitat generalist. It occurs in moderate-sized creeks to large rivers and habitat ranging from riffles to pools. Although it can be found in all substrate types from mud to large boulders, it is most common in runs with sand/gravel/cobble substrate. In WV it is a common species but generally not found in large numbers except in a few localized areas where it can be the dominant species.



Life History: Short-term brooder. A host generalist it has been shown to transform larvae on members of the sunfish, perch, and sculpin fish families among others.

Similar Species: *Ptychobranchus fasciolaris* (Kidneyshell), *Cambarunio iris* (Rainbow), *Elliptio complanata* (Spike) Potomac Basin

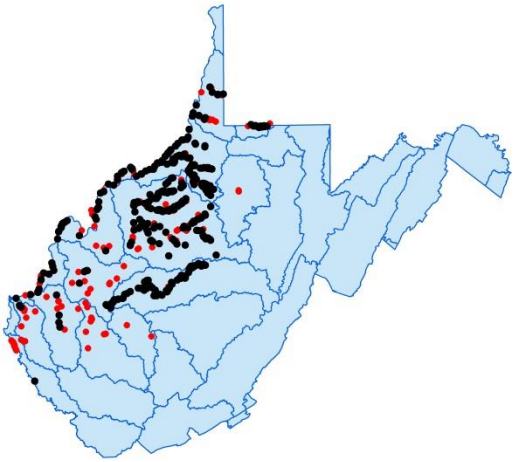
***Fusconaia flava* (Wabash Pigtoe)**

Description: The shell is highly variable. It is typically triangular but may be almost square to rectangular, compressed to moderately inflated, and heavy for its size. The posterior end is bluntly pointed ventral of the midline. One form has a distinct posterior ridge and median shallow sulcus. In other forms the posterior ridge is less angular and the posterior end is more pointed. The umbo is central and low but may be elevated above a slightly curved to straight hinge line. Opposing umbos face each other. The beak cavity is deep, and beak sculpture consists of few ridges, if evident. Teeth are well-developed, and the interdentum is short and moderate in width. The periostracum is generally light brown with indistinct green or brown rays in younger individuals becoming darker with age. Nacre is white to salmon. It may have an orange foot. Length to 3 inches.

Habitat and Distribution: This species is found from moderately small streams to large rivers and shell form varies depending on the habitat. It can be found in all flow regimes and all substrate types.

Life History: Short-term brooder. Releases pink to white conglutinates and has been shown to transform larvae using Creek Chubs and Silver Shiners.

Similar Species: *Pleurobema cordatum* (Ohio Pigtoe), *Pleurobema sintoxia* (Round Pigtoe), *Fusconaia subrotunda* (Longsolid)

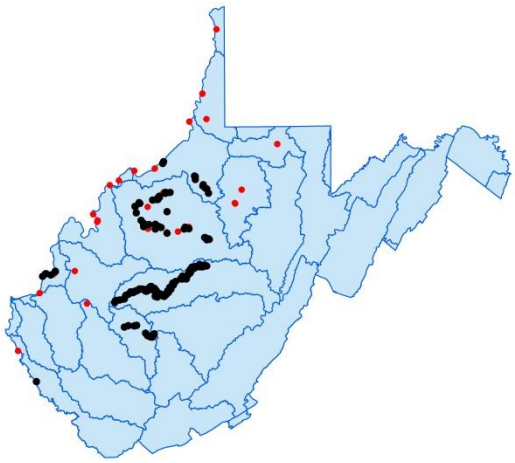


***Fusconaia subrotunda* (Longsolid)**

Description: The shell is heavy, ovate to sub-circular with a rounded anterior end and a bluntly pointed posterior. The posterior end becomes more drawn out in older individuals from where it receives its common name. The posterior ridge is broadly rounded, and the umbo is moderately inflated and situated far anteriorly and points forward. The hinge line is fairly straight to slightly curved. The beak cavity is very deep, and beak sculpture is not distinct. The teeth are well-developed with a short, wide interdentum. The periostracum of young individuals appears yellowish brown with broken green rays becoming darker, almost black with indistinct rays in older individuals. Nacre is white. The foot may be orange. Length to 5 inches.

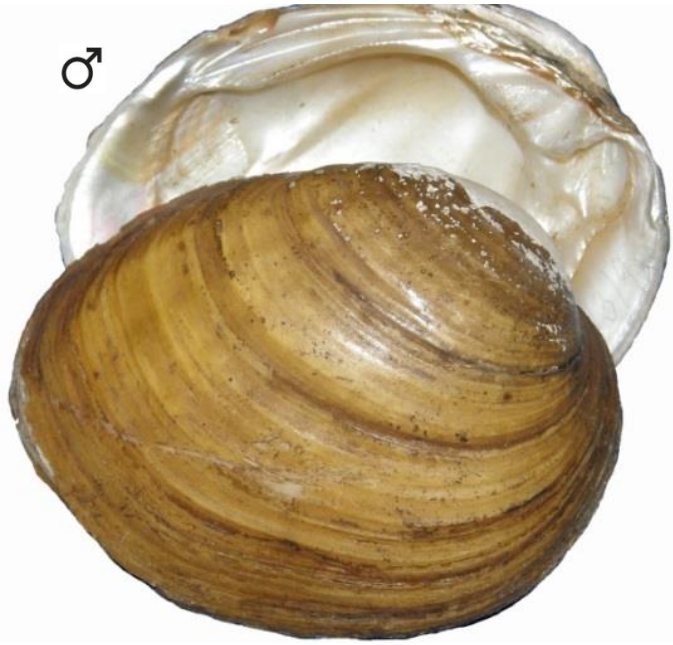
Habitat and Distribution: Prefers gravel with fairly strong current. Although probably once a common component of the Ohio River mussel fauna, today, in WV it is found there rarely. Within certain reaches of the Elk and Little Kanawha rivers it is fairly common and reproducing. In 2002 a relic mussel bed was located in the Monongahela River above Morgantown in which *F. subrotunda* was a component.

Life History: Short-term brooder. Unknown host.



Similar Species: *Pleurobema sintoxia* (Round Pigtoe), *Reginaia ebenus* (Ebonyshell)

***Lampsilis abrupta* (Pink Mucket)**

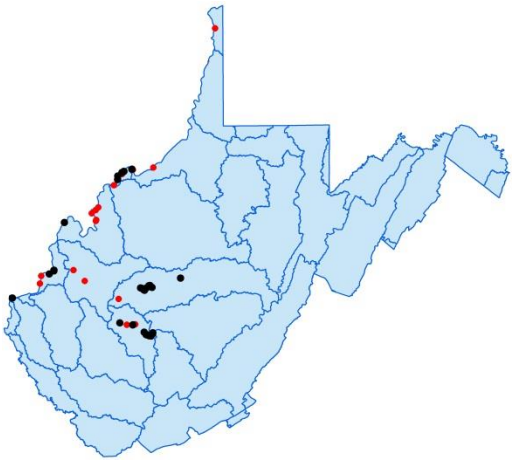


Description: This species is sexually dimorphic (female top, male middle). It has a very heavy shell and mature females are nearly spherical, very inflated and may resemble a large baseball. The males are generally less inflated and more extended posteriorly with a distinct posterior ridge for a short distance near the umbo. The posterior end of males is bluntly pointed at or near the midline. The umbo is nearly even with the hinge line and if beak sculpture is evident consists of 3-4 double-loops. The beak cavity is moderately deep. The teeth are well-developed with a moderate interdentum. The periostracum is generally yellowish to brownish yellow to dark brown without distinct rays in adults. Juveniles may be rayed as seen in the propagated juveniles (bottom left). Nacre is pale pink to white or iridescent. Length to 4 inches.

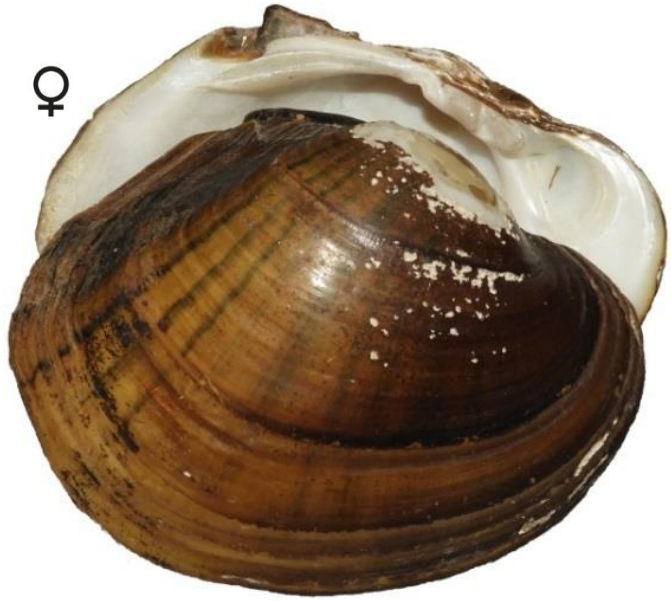
Habitat and Distribution: This is a large-river species preferring sand and gravel. It is able to survive the slower velocities of impoundment as found within the Ohio River. But it is more typically found within areas of good current such as the upper 5 miles of the un-impounded Kanawha River and lower reaches of the Elk River.

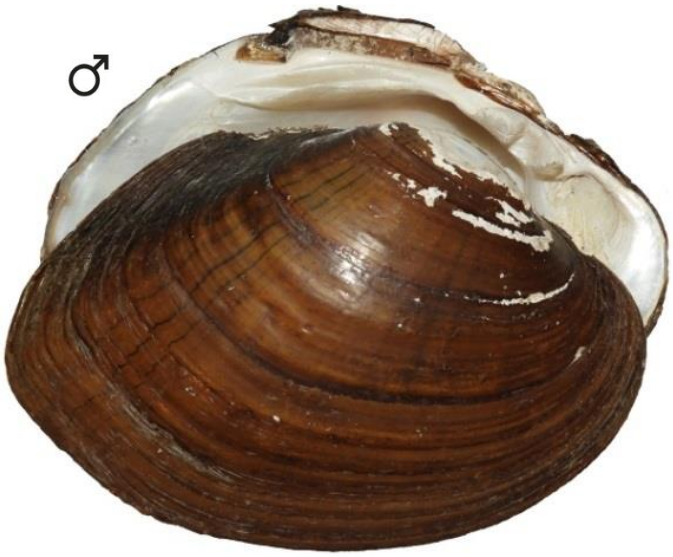
Life History: Long-term brooder. Species uses a minnow-like mantle lure to attract its host. Bass of the sunfish family and Walleye have been shown to transform juveniles.

Similar Species: *Actinonaias ligamentina* (Mucket)
See Pages 101 and 102.



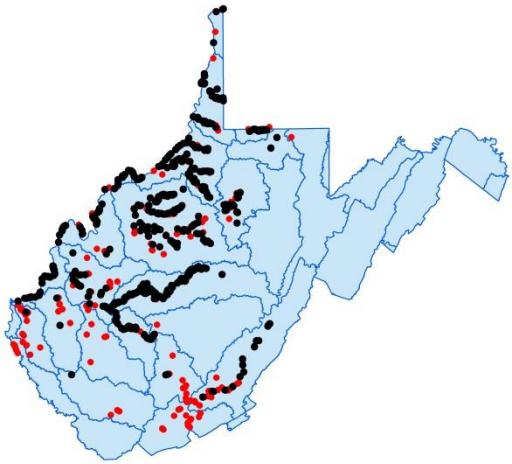
***Lampsilis cardium* (Plain Pocketbook)**

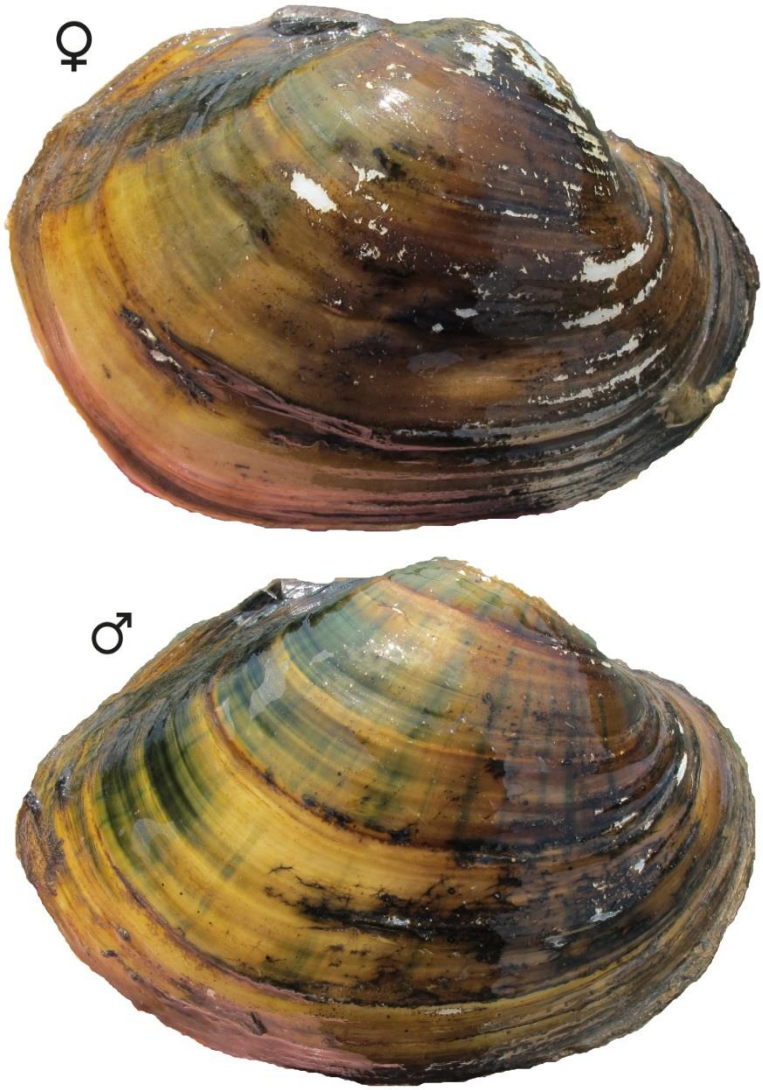




Description: This species is sexually dimorphic (female top, male bottom). The shell is rounded to oval and may be thin to moderately thick. The anterior end is rounded and posterior end is broadly rounded in females, appearing bluntly pointed in males. Females are more highly inflated with a broadly rounded posterior ridge. The posterior ridge in males is slightly to moderately angled, mostly near the umbo, and becoming more broadly rounded near the posterior margin. The umbo rises above a slightly curved to straight hinge line and the beak sculpture may appear as coarse bars or ridges. The umbo is inflated, forming a fairly large and deep beak cavity. The teeth are well-developed with a short to moderate and narrow to moderate-width interdentum. The periostracum is generally yellow to yellowish brown in older individuals typically with numerous green rays which may become obscure with age. Nacre is generally white to bluish white and may be iridescent posteriorly. Length to 7 inches.

Habitat and Distribution: This species is found in all habitats from fast-flowing riffles consisting of cobble and gravel to slow-moving sand and gravel pools. It is found throughout the Ohio River Basin. It may have been introduced into the Atlantic Slope by the early 1900's (Ortmann 1912b), where it may have hybridized or displaced *Lampsilis cariosa*.



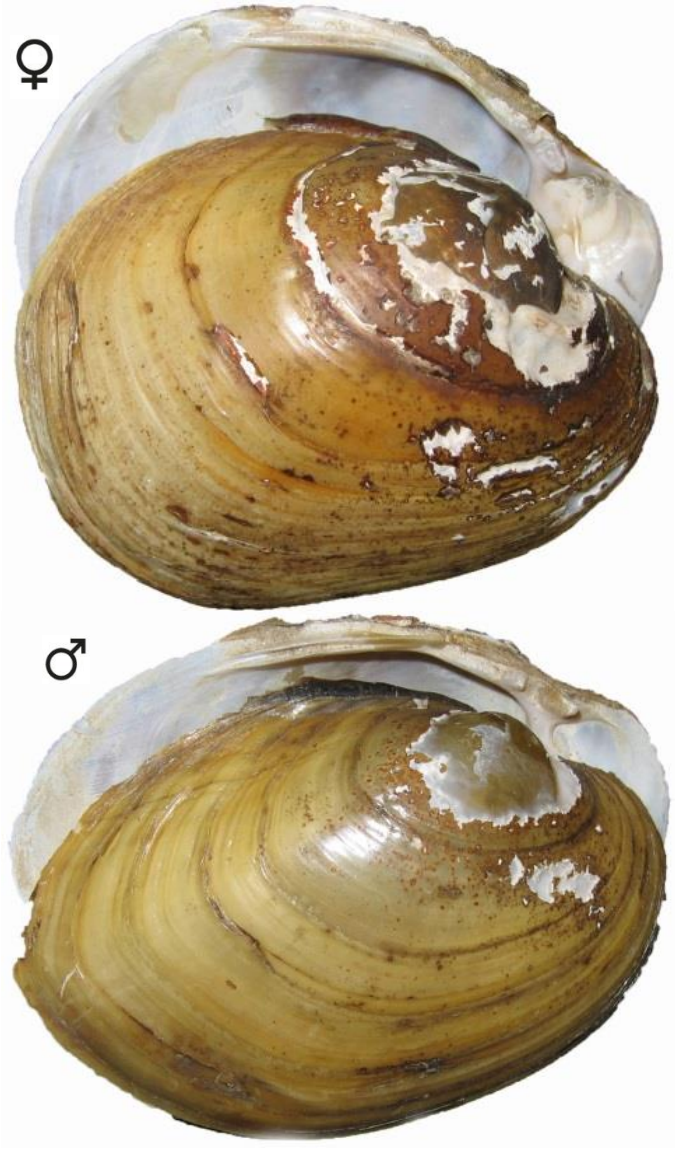


Life History: Long-term brooder. This species has a minnow-like lure which it uses to attract its fish host. Members of the sunfish family are the primary identified fish hosts. However Walleye, Sauger, Yellow Perch and others have also transformed juveniles including many exotic fish species.

Similar Species: *Lampsilis ovata* (Pocketbook), *Lampsilis fasciola* (Wavyrayed Lampmussel), *Lampsilis cariosa* (Yellow Lampmussel) Potomac Basin

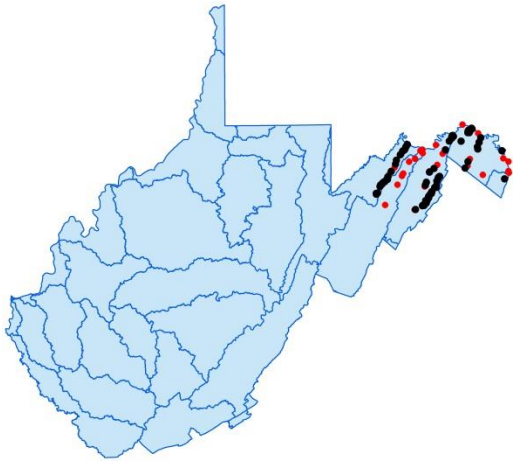
Left is the mantle lure of *L. cardium* that is mimicking a minnow. The mussel will give it jerky movements. The striated segments between the two sides of the lure are the swollen gill demibranchs filled with glochidia. When a fish is lured down to take a bite of the “minnow”, the ends of the gills will split open and the fish gets a mouth full of glochidia that will then attach to its gills.

***Lampsilis cariosa* (Yellow Lampmussel)**



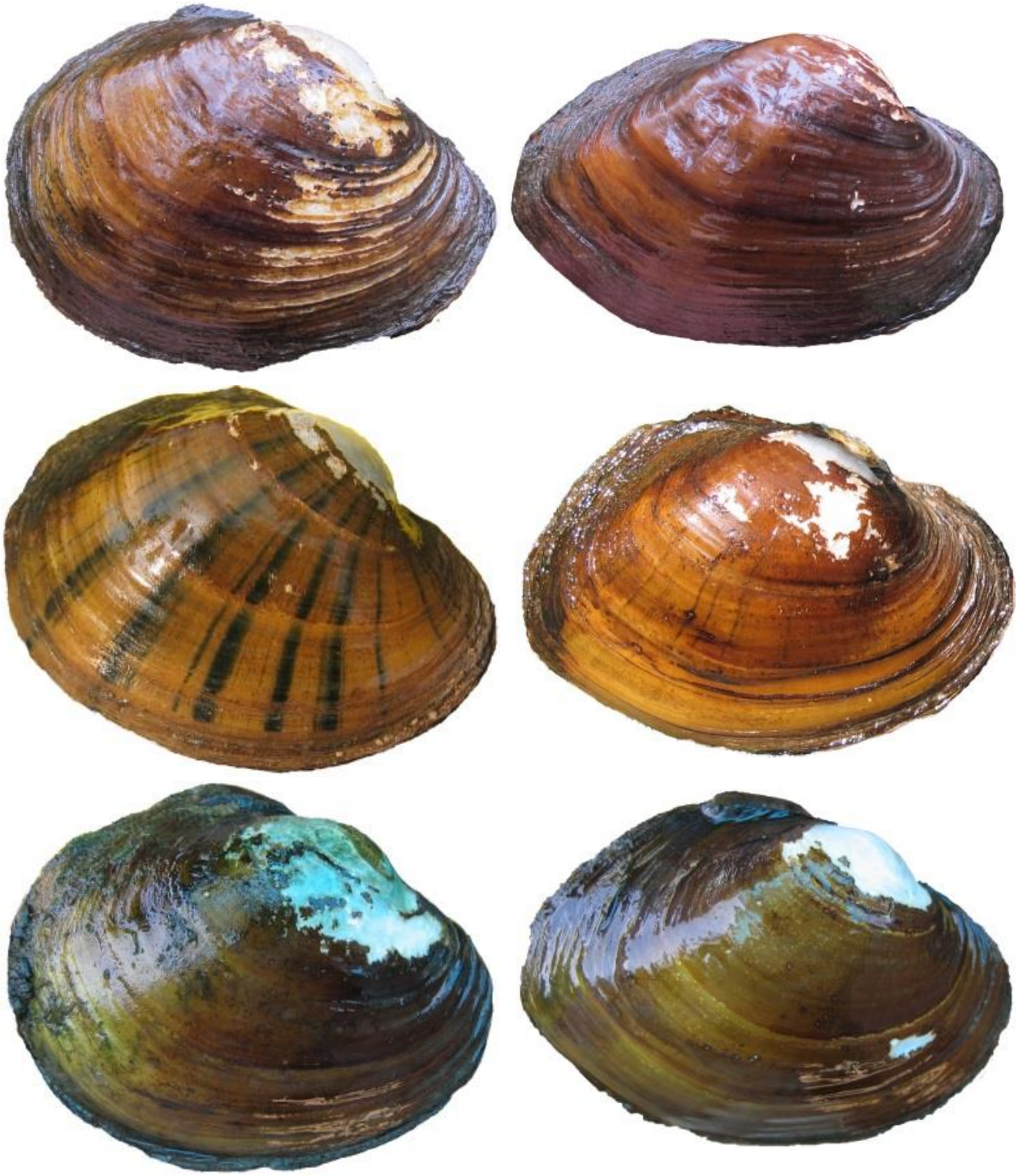
Description: This species is sexually dimorphic (female top, male bottom). Shell is rounded to oval and may be thin to moderately thick. The anterior end is rounded; in females the posterior end is broadly rounded to truncated, and is pointed in males. The posterior ridge is generally most evident in males near the umbo. The umbo rises above a slightly curved to straight hinge line and is inflated, forming a fairly large and deep beak cavity. Beak sculpture may appear as coarse bars or weakly double-looped, though typically not evident. Teeth are well-developed with a long thin interdentum. The periostracum is yellow to brownish yellow and may appear glossy. A few green rays, if present, are generally restricted to the posterior slope. Nacre is generally white to iridescent. Length to 5 inches.

Habitat and Distribution: This species is found in large creeks to larger rivers of the Potomac Watershed. It is typically found in riffles, deeply buried in gravel. Identification is questionable in WV due to the most likely introduction of *Lampsilis cardium* into the Potomac drainage (Ortmann 1912b). Ortmann further noted that if it was a new subspecies it would be called *Lampsilis ovata cohongoronta.* Several experts have looked at specimens collected from Patterson Creek and Cacapon River with identifications made of both species and then with numerous inter-grades between them. Some have numerous rays which are not typical of *L. cariosa*. Genetic material has been collected for numerous researchers but none have provided definitive results. The distribution map is for all *L. cariosa/cardium* found within the Potomac Watershed. While the two specimens on the previous page are true *Lampsilis cariosa* from the Delaware River, those below are from the Potomac Watershed.



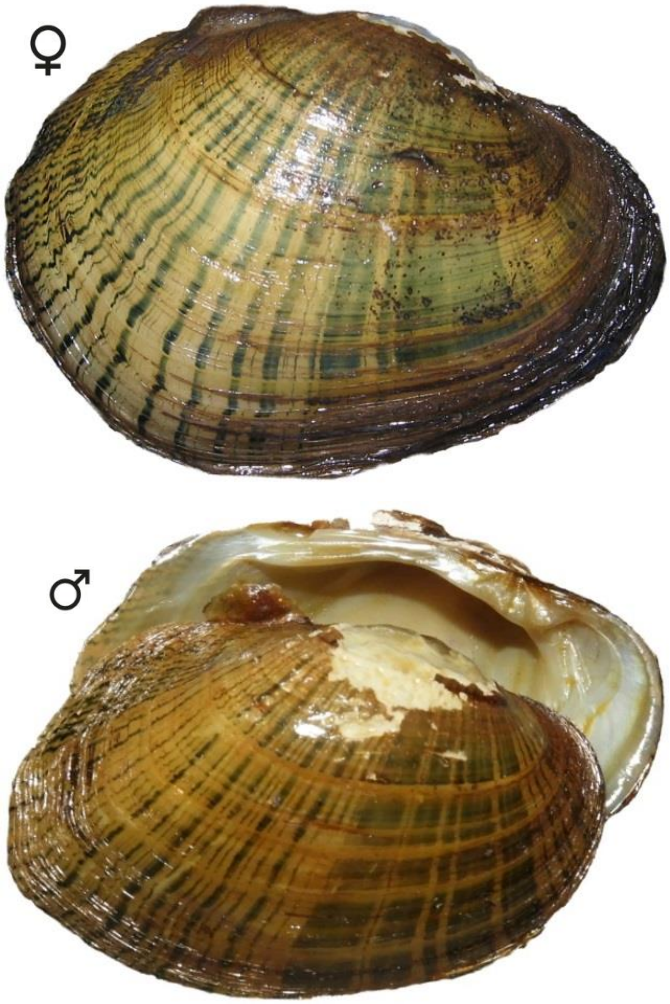
Life History: Long-term brooder. This species has a minnow-type lure and is only known to have successfully transformed juveniles on Yellow and White Perch.

Similar Species: *Lampsilis cardium* (Plain Pocketbook) – Ohio Basin



Above are various specimens observed throughout the Potomac Watershed.
Females left, males right. Top row, Patterson Creek. Middle row, Sleepy Creek. Bottom row, Cacapon River.

***Lampsilis fasciola* (Wavyrayed Lampmussel)**

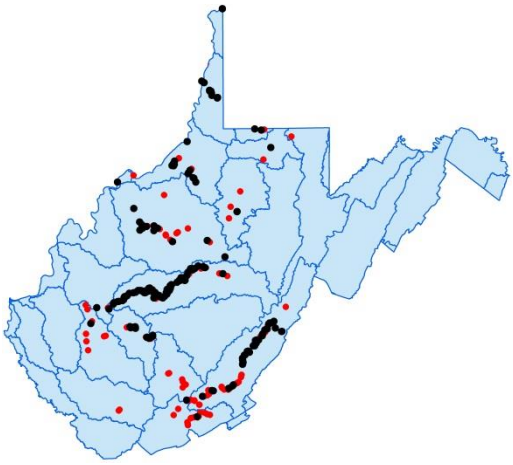


Description: This species is sexually dimorphic (female top, male bottom). The shell is relatively thin to moderately thick and generally ovate to rounded. The posterior ridge is broadly rounded and not distinct. The posterior end is broadly rounded in females and bluntly pointed in males at or below the midline. The females are also much more inflated. The umbo may rise slightly above the hinge line and is moderately inflated forming a moderately deep beak cavity. It is positioned just anterior of the midline. The beak sculpture if evident consists of several wavy ridges. The teeth are well-developed with a short to absent interdentum. The periostracum is yellow to yellowish brown or yellowish green and contains numerous fine wavy green rays. Nacre is generally white to iridescent. Length to 3.5 inches.

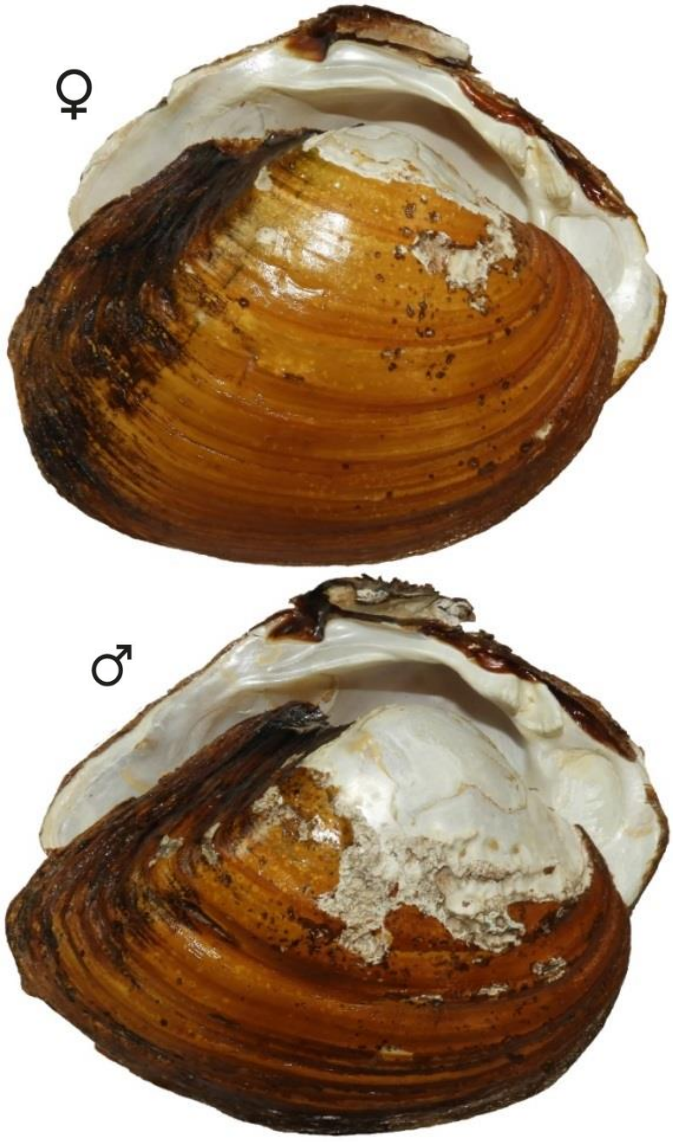
Habitat and Distribution: This species is typically found in riffles or runs of medium-sized creeks to large rivers although recently found within the impounded Ohio River. It has a very widespread distribution in the state but never is common.

Life History: Long-term brooder. This species appears to be somewhat of a host generalist. It has transformed larvae on Largemouth Bass, Smallmouth bass, Longear Sunfish, Bluntnose Minnow and Mottled Sculpin. Two different mantle lures have been observed in WV. One appears to mimic a darter (below) and the other, two large orange worms. Zanatta *et al.* 2007 reported at least four different lures and no genetic differentiation found between types.

S**imilar Species:** *Lampsilis cardium* (Plain Pocketbook)



***Lampsilis ovata* (Pocketbook)**

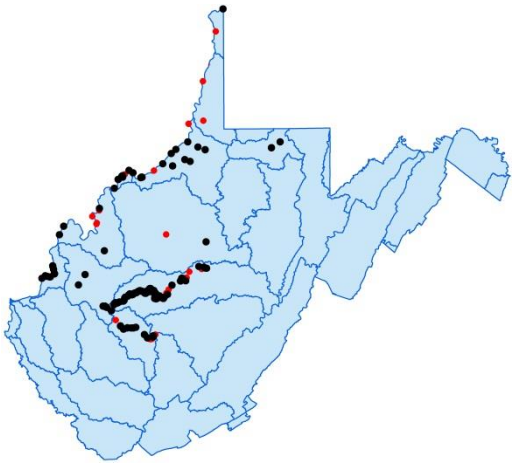


Description: This species is sexually dimorphic (female top, male bottom). The shell is rounded to oval and may be thin to moderately thick. The posterior ridge is evident in both males and females, though in males it is sharply angular and the posterior slope is flattened to concave. The posterior ridge in females is much less pronounced except near the umbo. As typical of most *Lampsilis* species the valves of the female are also more broadly inflated. The anterior end is rounded; and the posterior end is broadly rounded in females and bluntly pointed in males. The umbo rises above the hinge line and is inflated forming a fairly large and deep beak cavity. The beak sculpture if evident may appear as coarse bars. The teeth are well-developed with a moderately long narrow curved interdentum. The periostracum is generally yellow to yellowish brown with the posterior slope usually appearing darker brown. Light green rays are more evident in juveniles. Nacre is white to iridescent posteriorly. Length to 6 inches.

Habitat and Distribution: This species prefers medium to large rivers in strong current and gravel, although it has been able to survive impoundment of the Ohio and Kanawha rivers. Though this is a fairly large species it is generally found completely buried with only the siphons being evident. A few records occur for the New and Greenbrier rivers but the identification is questionable and most likely were *L. cardium*; as such it is not shown on the distribution map.

Life History: Long-term brooder. This species has a minnow-type lure that it uses to attract its fish host. It has transformed juveniles on Largemouth, Smallmouth and Spotted bass.

Similar Species: *Lampsilis cardium* (Plain Pocketbook), *Lampsilis cariosa* (Yellow Lampmussel) Potomac Watershed

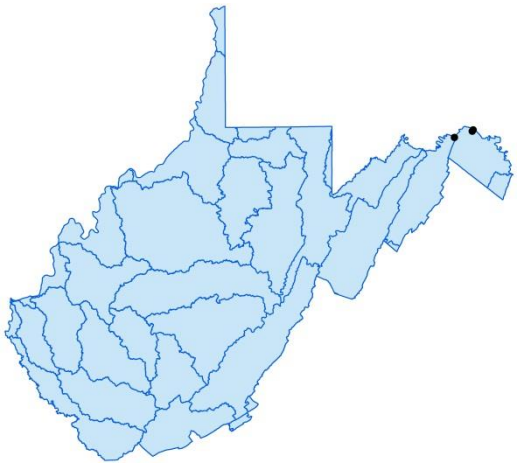


***Lampsilis radiata* (Eastern Lampmussel)**

Description: This species is sexually dimorphic (female top, male bottom). The posterior end of this elliptical shell is broadly rounded in females and bluntly pointed in males. The female may be moderately inflated and the male more compressed. The umbo rises slightly above the hinge line forming a shallow beak cavity. Beak sculpture if evident is double-looped. The teeth are well-developed but not heavy. There is no interdentum. The periostracum is light to dark yellowish brown or yellowish green with green rays. Nacre is white to bluish iridescent. Length to 4 inches.

Habitat and Distribution: This species if found in lakes and creeks to large rivers in all substrate types. This Potomac Basin species was first reported in WV in 2004 when it was located in Sleepy Creek, Morgan County near the mouth. More recently it is known from the lower reaches of the Cacapon River, Morgan County, indicating it may be slowly expanding its range up the Potomac River system.

Life History: Long-term brooder. Fichtel and Smith 1995 described the female having a mantle with conspicuous fleshy tubercles and a pigmented flap-like extension. Several members of the sunfish family as well as Yellow and White Perch have been shown to transform larvae.



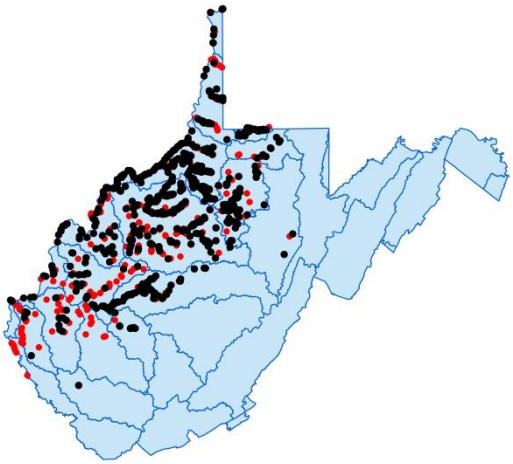
Similar Species: *Lampsilis siliquoidea* (Fat Mucket) Ohio Basin

***Lampsilis siliquoidea* (Fatmucket)**

Description: This species is sexually dimorphic. The shell is somewhat oblong-ovate. The posterior end is bluntly pointed at the midline in males (bottom) and broadly rounded to almost rectangular in females (top). The female develops a considerable swelling in the posterior region and the shell appears rather inflated and expanded in the ventral posterior region. The umbo is broad and rises slightly above the hinge line. The umbo region is somewhat inflated though juveniles appear compressed. The beak cavity is shallow to moderately deep and beak sculpture consists of 6 to 8 double-looped bars. The teeth are well-developed with a moderately narrow to absent interdentum. The periostracum is yellow to yellowish brown with green to black rays that may become indistinct in older individuals. Nacre is generally white and may appear iridescent posteriorly. Length to 5 inches.

Habitat and Distribution: This species can be found in almost any type of substrate, in moderate to slow moving water as well as lakes. It is very widespread in WV from small headwater creeks to the Ohio River.

Life History: Long-term brooder. This species has a minnow-type mantle lure to attract its fish hosts. It is a host generalist, having been shown to use members of the sunfish family, Walleye, Sauger, Yellow Perch, and several members of the minnow family, among others.



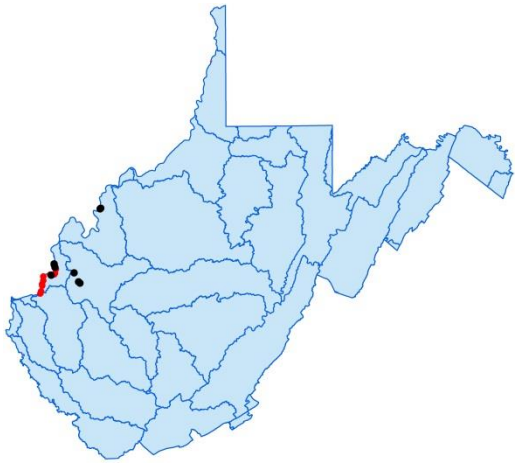
Similar Species: *Actinonaias ligamentina* (Mucket), *Leaunio lienosus* (Little Spectaclecase), *Lampsilis radiata* (Eastern Lampmussel) Potomac Basin

***Lampsilis teres* (Yellow Sandshell)**

Description: This species is sexually dimorphic (female top, male 2nd left). The shell is elongate and inflated. The posterior end in females is bluntly pointed dorsal of the midline, males are bluntly pointed at the midline. As with other *Lampsilis* species, the female becomes more inflated and protruding within the posterior region, causing the posterior end to appear more truncated. The umbos are slightly elevated above the hinge line and the beak cavity is moderately deep. The beak sculpture may consist of 4-6 double-looped indistinct ridges. The teeth are well-developed without an interdentum. The periostracum is yellow and may have green rays in younger individuals. Nacre is generally white with a flush of color in the beak cavity and iridescent posteriorly. Length to 6 inches.

Habitat and Distribution: This species is generally found in medium to large rivers in sand and gravel and in WV is only found in the Kanawha and Ohio rivers. WV appears to be at the upstream end of its range.

Life History: Long-term brooder. This species has been shown to use gar, several species of the sunfish family, and Greenbreast and Greenthroat darters to transform larvae.



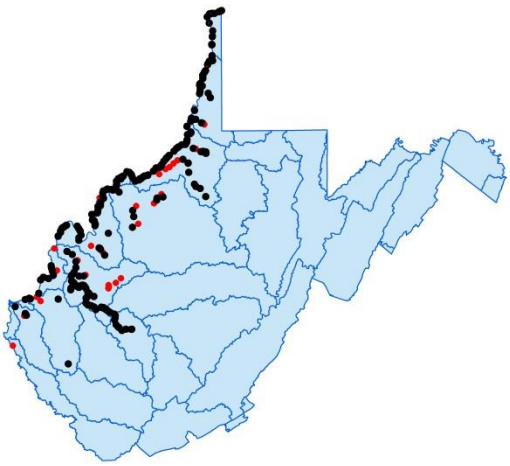
Similar Species: *Ligumia recta* (Black Sandshell): In 2019 Keogh and Simons described the species *Lampsilis sietmani* (Canary Kingshell) which was split from *L. teres*. It was suggested by Heidi Dunn (personal communication, 2022) that WV specimens may in fact be this new species. Further study is warranted.

***Lasmigona complanata* (White Heelsplitter)**

Patricia Morrison

Description: The dorsal margin and the posterior slope margin form a triangle in which the angle may reach 90 degrees. The ventral margin is broadly rounded. The shell is flat and compressed with the posterior slope is even more compressed, forming a wing which typically has small ridges or corrugations. The wing is best-developed in young individuals though may be poorly to highly developed in adults. The shell is very thin as juvenile and moderately thick as adult. The umbo is very low and not prominent, typically worn below the hinge line. The beak cavity is shallow and compressed to non-existent. The beak sculpture consists of two heavy bars followed by 2-3 double-looped bars. The lateral teeth are poorly developed and may only appear as slight swellings. The pseudocardinal teeth are prominent. The interdentum is very short and wide and typically indistinguishable. The periostracum of young individuals is generally yellowish to greenish brown and may have numerous green rays. Older individuals are darker brown to almost black with rays obliterated. Nacre is generally white but may appear cream colored in the beak cavity. Length to 8 inches.

Habitat and Distribution: This large to medium river species prefers quiet water with sandy muddy bottoms though occasionally found in riffles and gravel.



Life History: Long-term brooder. This species has been shown to transform larvae on several members of the sunfish family, White Sucker, Common Carp, Yellow Perch, and Banded Killifish.

Similar Species: *Potamilus alatus* (Pink Heelsplitter)

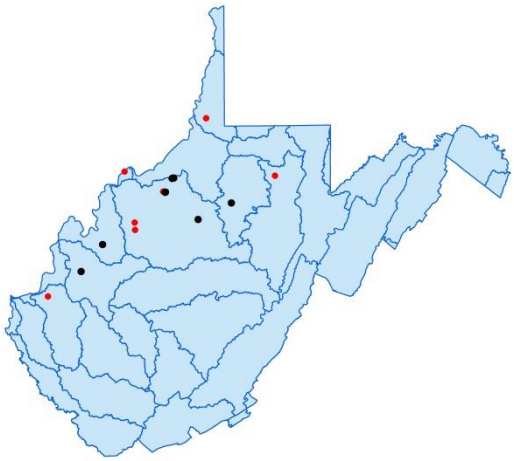
***Lasmigona compressa* (Creek Heelsplitter)**

Description: The shell is somewhat rectangular to ovate and rather thin and compressed, becoming thicker with age. The anterior end is rounded with a bluntly pointed posterior end. The posterior ridge is broadly rounded and not evident. The posterior slope is slightly flattened and forms a small posterior wing. The umbo is not prominent, rising slightly above the hinge line and placed just anterior of middle. The beak cavity is very shallow and beak sculpture consists of 4-5 strong to weak double-loops. The lateral teeth are developed enough to interlock but the pseudocardinal teeth appear somewhat rudimentary. No interdentum. The periostracum is yellowish to yellowish brown with fine green rays that may be so numerous that the shell appears green. Nacre is white to iridescent. This species has an orange foot. Length to 4 inches.

Habitat and Distribution: Very few records exist for this species in WV. It is typically found in creeks to small rivers in sand and gravel of various flow regimes.

Life History: Long-term brooder. This species is a host generalist, having transformed larvae using members of the sunfish, minnow, darter and sculpin families as well as others.

Similar Species: *Lasmigona costata* (Flutedshell)

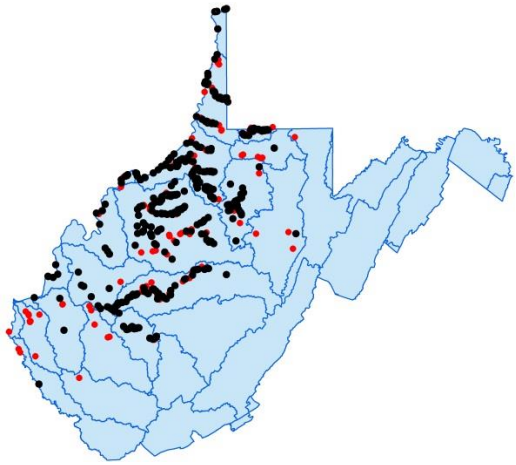


***Lasmigona costata* (Flutedshell)**

Description: The shell is rectangular to oval and rather flat and compressed. The posterior ridge is rounded but evident; several ridges, folds, or costations are found on the posterior slope. The anterior end is rounded and the somewhat squared posterior end slopes ventrally. The umbo is not prominent and slightly rises above the hinge line just anterior of centerline. The beak cavity is very shallow and beak sculpture consists of 4-5 heavy bars. The pseudocardinal teeth are present while the lateral teeth are rudimentary or absent. The periostracum is yellowish brown to green and may appear rayed. Nacre is white to iridescent. Foot color is typically orange. Length to 7 inches.

Habitat and Distribution: This species is found in small creeks to large rivers in a variety of habitats. Though never found in large numbers, the most abundant population observed by the author in WV was associated with the shallow area immediately above a riffle.

Life History: Long-term brooder. This species is a host generalist to the extreme. Many species of several fish families have been shown to transform larvae. Watters *et al.* (1998) suggests that this species may be able to forego the parasitic stage and autotransform. They further speculate that two types of glochidia may be produced at different times of the year.



Similar Species: *Lasmigona compressa* (Creek Heelsplitter)

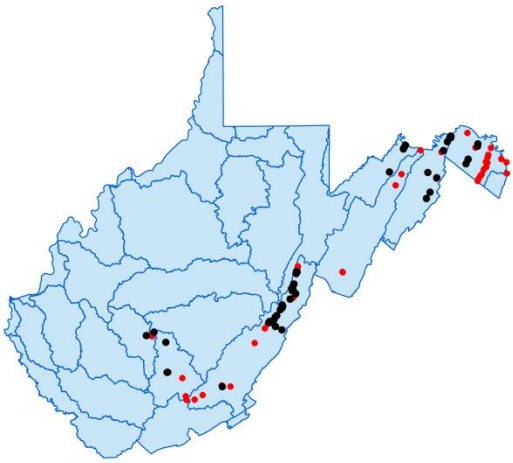
***Lasmigona subviridis* (Green Floater)**

Description: The shell is thin, fragile and somewhat ovate. The posterior ridge is rounded and swollen so that the whole shell appears inflated. Young may have a small dorsal wing. The umbo rises slightly above hinge line forming a shallow beak cavity. The beak sculpture consists of 4-6 double-loops. The pseudocardinal teeth and lateral teeth are well-developed but thin and delicate. The periostracum is yellowish to greenish brown or green generally with distinct green rays. Nacre is generally white to iridescent. Length to 1.5 inches.

Habitat and Distribution: This species prefers quiet waters with gravelly and sandy bottoms such as eddies and back channel areas as shown below on the Greenbrier River. It may be found in higher flow areas if substrate is stable or within sand and gravel pockets among boulders. This species is found within small creeks to large rivers in both the New River and Potomac watersheds. Specimens to the left were salvaged from an area on Knapps Creek that was undergoing restoration.

Life History: Long-term brooder. This species undergoes marsupial transformations and does not utilize a fish host.

Similar Species: *Strophitus undulatus* (Creeper)



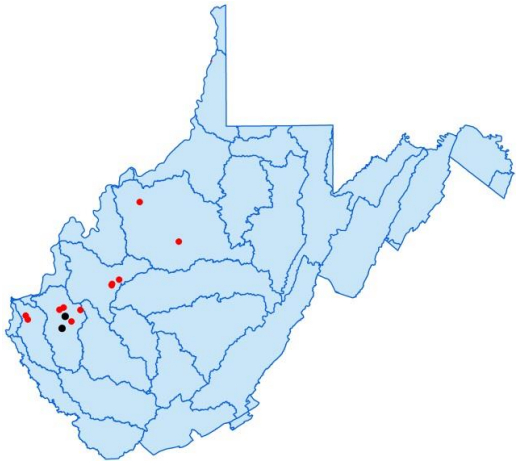
***Leaunio lienosus* (Little Spectaclecase)**

Description: This species is sexually dimorphic. The shell is small, thin to moderately thick, and ovate. The males tend to be somewhat inflated, while the females are more inflated. The anterior end is rounded and the posterior end is bluntly pointed in males (2nd left) and squared or truncated in females (top left). The posterior ridge is low and rounded. The umbo is moderately inflated and slightly elevated above the hinge line. The beak cavity is moderate, and beak sculpture consists of 4-7 v-shaped bars. The teeth are well-developed though the pseudocardinals appear somewhat compressed, and the lateral teeth are fine and sharp. No interdentum is present. The periostracum is green to dark brown, generally with green rays which become obscured with age. Nacre is white to deep purple and iridescent. Length to 2.5 inches.

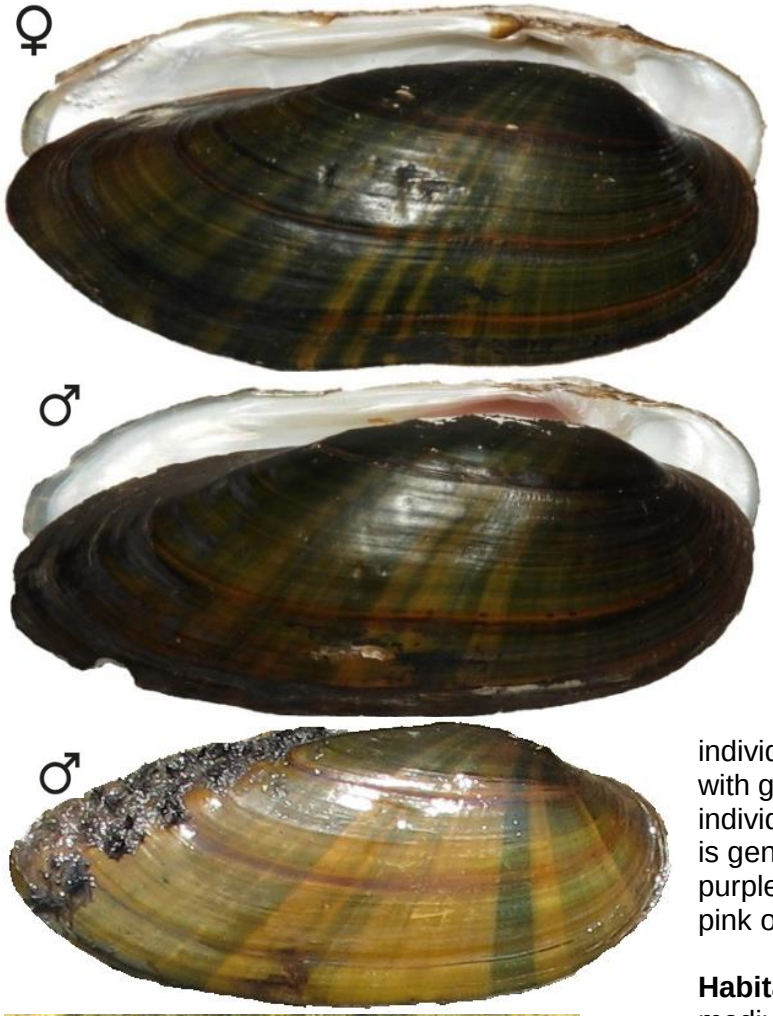
Habitat and Distribution: This species is found in small to medium-sized streams in sand or gravel substrates. This species is uncommon in WV and is at the extreme northern edge of its range.

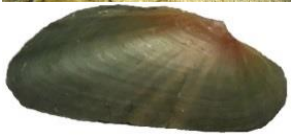
Life History: This species is believed to be a long-term brooder and transformation to juveniles has been seen on numerous members of the sunfish family and Channel Catfish.

Similar Species: *Lampsilis siliquoidea* (Fat Mucket), *Toxolasma parvum* (Lilliput), *Cambarunio iris* (Rainbow)



***Ligumia recta* (Black Sandshell)**

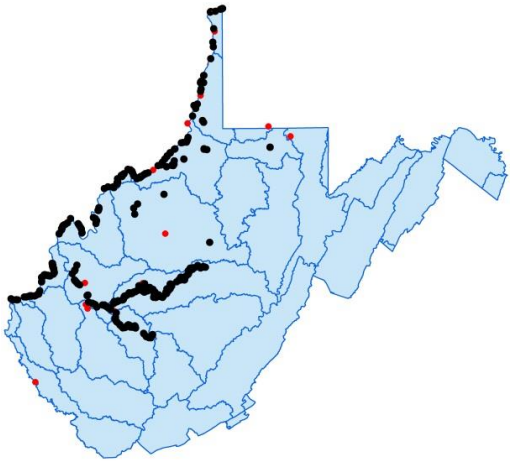




Description: This species is sexually dimorphic (female top left, male 2nd and 3rd left). The shell is elongate and moderately inflated and rather thick. The posterior end of the female is bluntly pointed dorsal of the midline with the ventral posterior margin extending further toward the posterior than males. This gives them a more rectangular appearance than males. The posterior end of the male is more pointed at the midline. The umbo is situated far forward and barely rises above the straight to slightly curved hinge line. The beak cavity is very shallow and beak sculpture consists of 2-3 double-looped bars. The teeth are well-developed with a narrow interdentum. The periostracum of younger individuals appears dark yellowish brown with green rays or nearly black, older individuals becoming almost black. Nacre is generally white with a flush of pink to purple in the beak cavity, rarely totally pink or purple. Length to 8 inches.

Habitat and Distribution: Found in medium to large rivers in gravel with moderate current.

Life History: Long-term brooder. Females, while brooding their larvae during their reproductive period, may be found lying on the substrate surface exposing modified mantle flaps as shown above. Several species of the sunfish family, minnow family, Walleye, Sauger, Yellow Perch, and Banded Killifish have been shown to transform larvae.



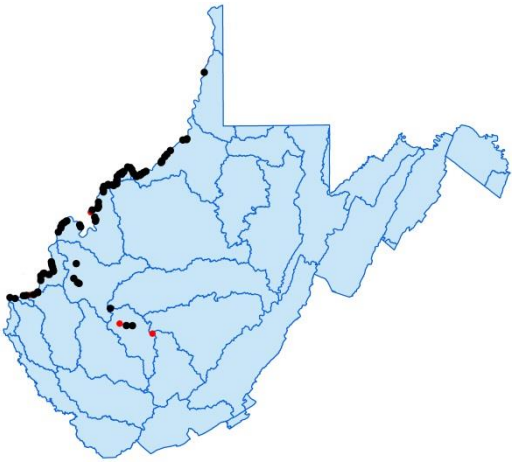
Similar Species: *Eurynia dilatata* (Spike), *Lampsilis teres* (Yellow Sandshell)

***Megalonaias nervosa* (Washboard)**

Description: The shell is sub-quadrate and relatively heavy. The anterior end is rounded and the posterior end is squared to bluntly pointed. The dorsal margin is slightly alate or winged and the posterior two-thirds of the shell has a series of large folds. The umbo is moderately inflated and tapers to a compressed posterior end. It is positioned far anterior and does not rise above the straight hinge line. The beak cavity is deep and open. The beak sculpture consists of double-looped ridges which enlarge to form bumps around the umbo. The juvenile is very compressed and highly sculptured throughout. The teeth are well-developed with a short, moderately wide interdentum. The periostracum is yellowish brown to green in young, becoming almost black with age. Nacre is white. Length to 10 inches.

Habitat and Distribution: This large river species is most commonly found within the Ohio River from the Belleville Pool downstream. In recent years it was not observed upstream of Willow Island Dam until 2007. Also known in low numbers from the Kanawha River, it may also exist in stream mouths of larger tributaries to the Ohio.

Life History: This species does not fit neatly into the long-term/short-term brooder categories. It has been observed releasing large numbers of individual glochidia (as opposed to conglutinates, Page 100) held within a mucous net that covered the stream bottom near the releasing mussel. Numerous species of many fish families have been shown to transform larvae.

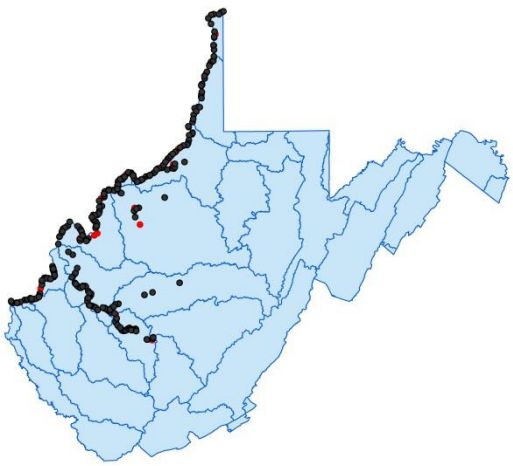


Similar species: *Amblema plicata* (Threeridge)

***Obliquaria reflexa* (Threehorn Wartyback)**

Description: This species may be weakly sexually dimorphic. The shell appears somewhat triangular, heavy and relatively inflated. The posterior ridge is evident and angular, dropping to a posterior slope that may have fine costations. The anterior end is broadly rounded and the posterior end is bluntly to sharply pointed about the midline. The posterior margin of the posterior slope may give the shell a truncated appearance. A row of large nodules runs from the umbo down the median face of each valve. The nodules alternate position with the corresponding nodule on the opposing valve. A shallow sulcus occurs between the row of nodules and the posterior ridge. The umbo rises slightly above the hinge line and angles forward forming a moderate beak cavity. Beak sculpture if evident consists of 4-5 heavy parallel ridges. Teeth are well-developed with a short, medium width interdentum. The periostracum is yellowish brown, may have fine to heavy green rays, and may be so heavily rayed that the shell appears green. Nacre is white. Length to 3 inches.

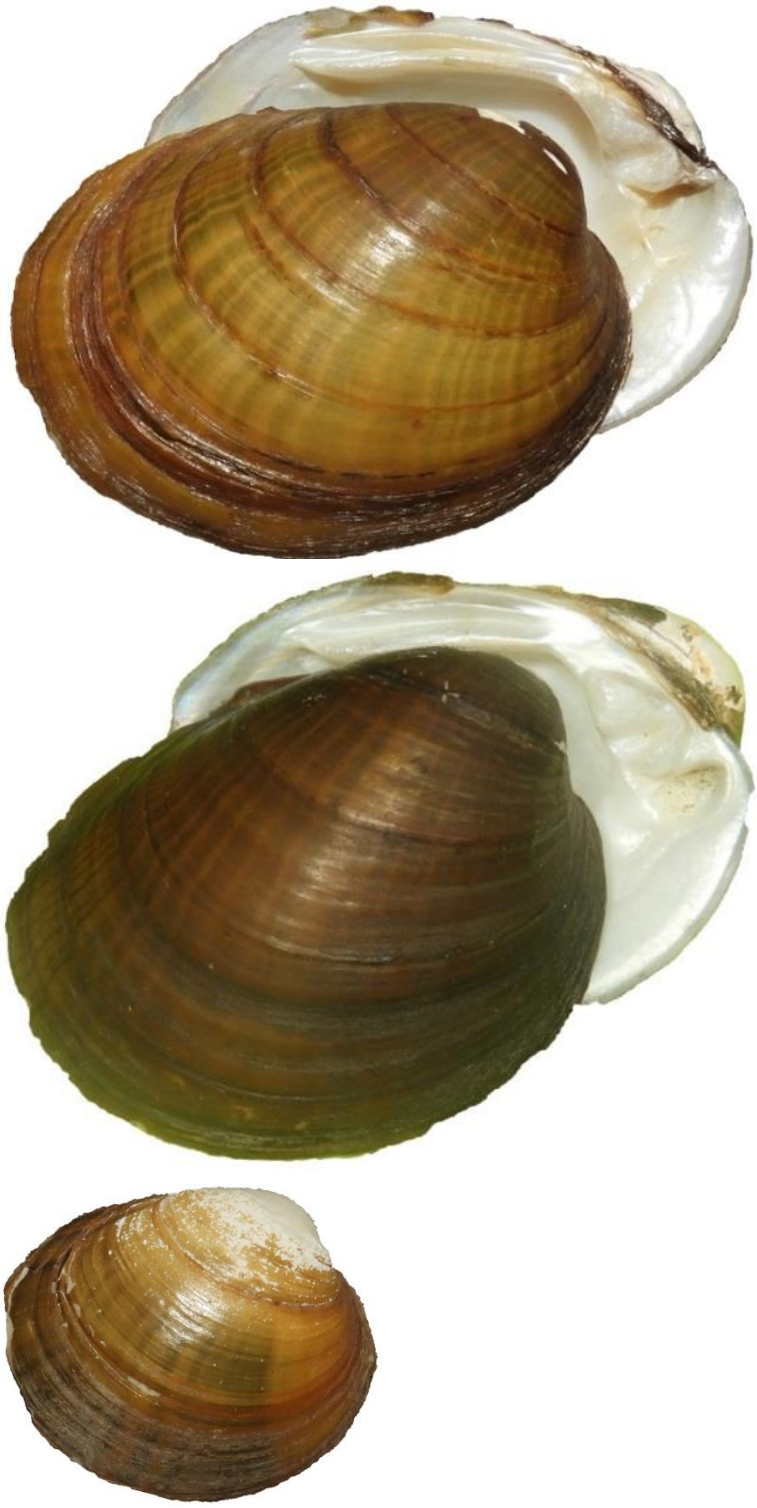
Habitat and Distribution: This species is most common in large rivers in sand and fine gravel. It does extend up into the lower reaches of medium-sized rivers.



Life history: Short-term brooder. This species has been shown to transform larvae using several minnow species, Freshwater Drum, Gizzard Shad, Walleye, Buffalo spp., and Largemouth Bass. Larvae have been reported to be released in solid, white, club-shaped conglutinates.

Similar Species: *Cyclonaias nodulata* (Wartyback), *Cyclonaias pustulosa* (Pimpleback)

***Obovaria olivaria* (Hickorynut)**

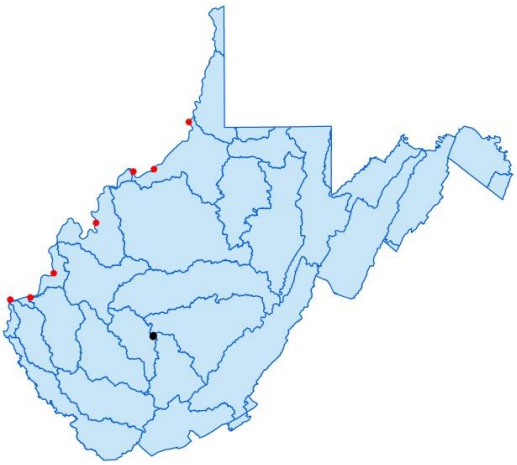


Description: This species may be weakly sexually dimorphic. The shell is oval and thick. The anterior and posterior ends are broadly rounded. The posterior ridge is broadly rounded and not evident. The umbo is broad but low, positioned far forward and angled forward. The beak cavity is wide, open and shallow. The beak sculpture consists of very fine 2-4 double-looped ridges. The teeth are well-developed with a short, moderate interdentum. The growth lines may be darkened and raised. The periostracum is olive to yellowish brown, typically with green rays as juveniles but may be lost with age. Nacre is white, iridescent posteriorly and may have a pink wash in the center. Length to 4 inches.

Habitat and Distribution: This species is generally found in rivers and lakes in muddy sand and gravel. It is very rare in WV.

Life History: Long-term brooder. This species has been shown to transform larvae using Sturgeon only.

Similar Species: *Reginia ebenus* (Ebonyshell), *Pleurobema sintoxia* (Round Pigtoe)



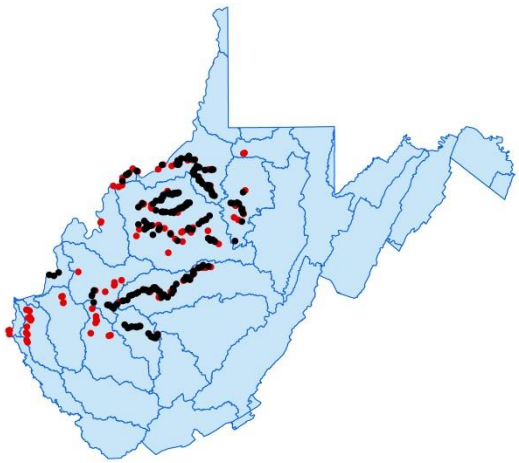
***Obovaria subrotunda* (Round Hickorynut)**

Description: This species is sexually dimorphic (female top, male bottom). The shell is small, thick and almost perfectly round in females and bluntly pointed in males. No posterior ridge is evident though the slope of the valve may increase towards the dorsal margin. The umbo is inflated and if not worn, rises slightly above the hinge line. The beak cavity is moderately deep and the beak sculpture is rudimentary, consisting of 4-5 weak bars. The teeth are well-developed with a short, moderate interdentum. The shell is smooth, cloth-like and growth lines may be darkened. The periostracum is yellowish brown to almost black with no rays except in very young. When observing fresh shells, the posterior slope usually appears a much lighter color (usually yellowish brown) than the rest of the shell which is buried in the substrate. Nacre is white, iridescent posteriorly and may rarely be washed with pink to purple. Length to 2 inches.

Habitat and Distribution: This species is generally found in large creeks to large rivers in sand and gravel in areas of moderate flow. The series below is from Middle Island Creek.

Life History: Long-term brooder. This species has been shown to transform larvae using various darter species and the Banded Sculpin.

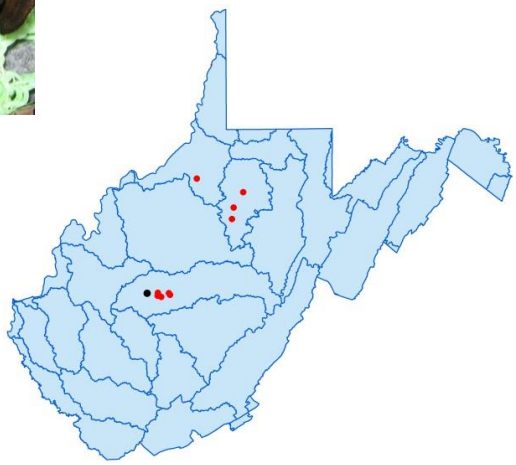
Similar Species: None extant



***Paetulunio fabalis* (Rayed Bean)**

Description: This species is sexually dimorphic. It is very small, ovate, and moderately inflated in females to somewhat compressed in males. The shell is very thick for its size. In both sexes the anterior end is rounded and the posterior end is rounded in females (top) to bluntly pointed about the midline in males (bottom). The posterior ridge is not evident being low and rounded. The umbo is slightly elevated above the hinge line though typically worn and positioned just anterior of the midline. There is no distinct posterior slope. The beak cavity is shallow and beak sculpture consists of 2-3 heavy ridges which may appear double-looped. The teeth are well-developed with a short, variable-width interdentum. The periostracum is yellowish to dark green and generally covered with green rays. Nacre is white or bluish white and iridescent. Length to 1.5 inches.

Habitat and Distribution: This species is generally found in lakes and small to large streams in sand or gravel. Ortmann (1919) described it being found in and near riffles generally in patches of waterweeds where it was deeply buried in the sand and gravel, bound together by their roots. Few records exist for this species in WV primarily due to lack of collections made prior to its extirpation. In 2010 individuals from the Allegheny River, PA (photo left) were re-introduced into the Elk River. Due to its small size this species is typically found with a byssal thread throughout much of its life.



Life History: Long-term brooder. This species has been shown to transform larvae on Logperch, numerous darter species, Mottled Sculpin, and Largemouth Bass.

Similar Species: *Toxolasma parvum* (Lilliput), *Leaunio lienosus* (Little Spectaclecase)

***Parvaspina collina* (James Spinymussel)**

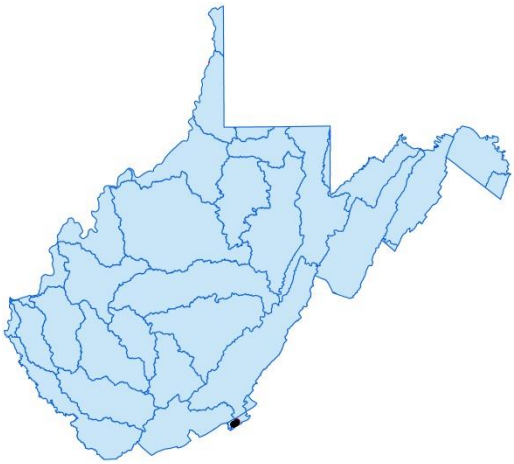
Ben Humphrey

Description: The shell is generally compressed and somewhat triangular. The posterior end is bluntly pointed ventral of the midline. The umbo is fairly even with the hinge line, and the posterior ridge is rounded and generally not evident. The beak cavity is shallow to moderately deep. Beak sculpture consists of widely spaced concentric ridges. Small remnant spines may be evident near the umbo in younger individuals although adults usually lack spines. The periostracum is bright yellow to greenish yellow in young specimens, becoming reddish brown to brown and without rays in older individuals. Nacre is pink to bluish white and is iridescent. Foot and mantle tissue are orange. Length to 2.5 inches.

Habitat and Distribution: In WV, this species is only found within the James River Basin, Monroe County. This species prefers free-flowing streams with a variety of flow regimes and found in a variety of substrates that are free from silt. Entire WV population is threatened by direct livestock access to streams.

Life History: Short-term brooder. Several minnow species have been shown to transform larvae.

Similar Species: *Strophitus undulatus* (Creeper)

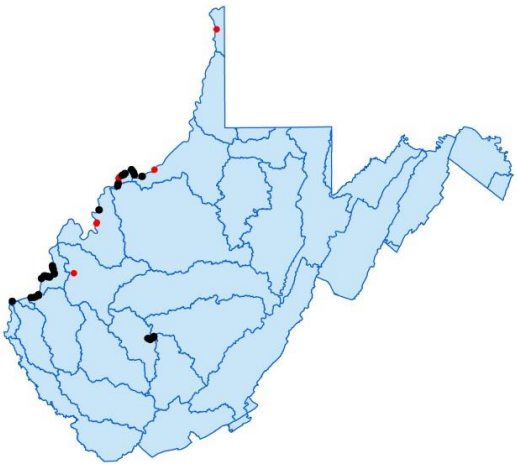


***Plethobasus cyphyus* (Sheepnose)**

Description: The shell is ovate, heavy, and moderately inflated. The anterior end is rounded and the posterior end is tapered and drawn out into a blunt point at the midline. The umbo sits far forward and rises just above the hinge line forming a shallow beak cavity. The beak sculpture consists of a few, thick, concentric ridges. Rather large irregular tubercles transverse the valve from the umbo to ventral margin forming a median ridge. Maximum shell inflation is from the umbo down the median ridge. A slight sulcus may be present between median and posterior ridges. The teeth are well-developed with a very short, wide interdentum. The periostracum is bright yellow in young to dark brown and highly polished with growth lines generally appearing darkened. Nacre is white. Soft parts are bright orange. Length to 5 inches.

Habitat and Distribution: Ortmann (1919) described it as preferring riffles with coarse gravel and strong current though today it is also found in the impounded sections of the Ohio and Kanawha rivers. Although it can be found in sand-dominated habitats, it is generally found in a mixture of substrate types.

Life History: Short-term brooder. It releases pink conglutinates which typically are observed in July in the Ohio River. It has been shown to transform larvae using a wide variety of minnow species.



Similar Species: *Actinonaias ligamentina* (Mucket)

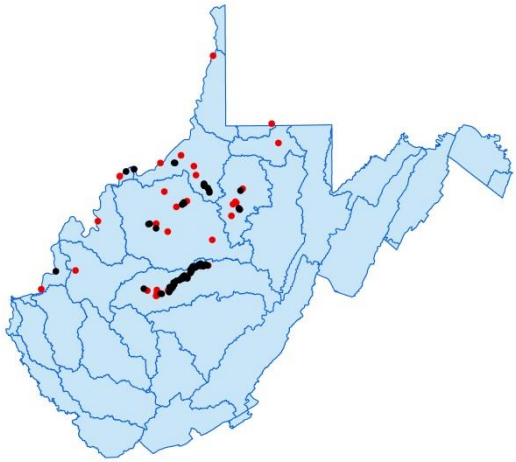
***Pleurobema clava* (Clubshell)**

Description: The shell is somewhat triangular with a tapered, extended posterior end (club-shaped). The anterior end is rounded, and the shell is rather heavy and inflated at the anterior end becoming compressed and bluntly pointed posteriorly. The umbo is positioned forward and only rises slightly above the hinge line forming a shallow beak cavity. Beak sculpture consists of 2-3 angular ridges if evident. The teeth are well-developed with very short, wide interdentum. The periostracum is yellowish brown and broad broken green rays usually extend from the umbo. Nacre is white. The foot may be white or orange. Length to 3.5 inches.

Habitat and Distribution: This species is typically found buried deeply in sand to cobble substrates usually above and below riffles. Found in large creeks to larger rivers. In larger streams it is typically found near current breaks just out of the main stream current. Recent reintroductions to the Ohio River have been made.

Life History: Short-term brooder. This species has been shown to transform larvae on an extensive variety of minnows as well as Logperch, Blackside Darter, and Northern Hog Sucker.

Similar Species: None

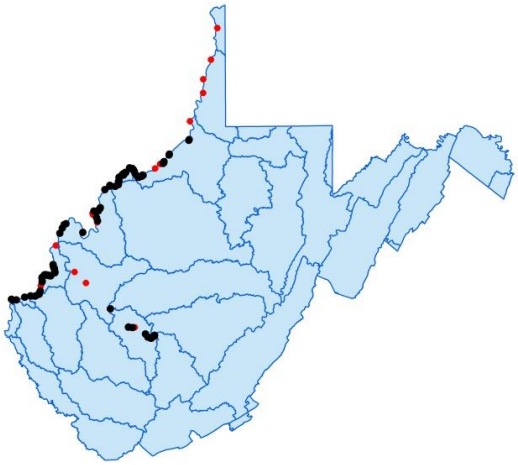


***Pleurobema cordatum* (Ohio Pigtoe)**

Description: The shell is triangular, heavy, and moderately inflated at the umbo. The anterior end is rounded and the posterior end is bluntly pointed. The posterior ridge is typically evident with a broad shallow sulcus just anterior of ridge. The umbo is situated far forward and projects forward, turning inward and rising above the hinge line. The beak cavity is very deep and compressed, and beak sculpture consists of 2-3 coarse, elevated ridges. The teeth are well-developed with a short, wide interdentum. The periostracum is yellowish brown in juveniles becoming reddish brown to dark brown. Green rays may be evident in juveniles. Nacre is usually white, but may be shades of pink. Length to 4 inches.

Habitat and Distribution: This species is found at various water depths but prefers moderately flowing water with stable gravel substrate. It is described as being found in riffles and immediately above them, in strong current, though that habitat no longer occurs where this species is currently found in the impounded sections of the Ohio and Kanawha rivers.

Life History: Short-term brooder. This species releases lattice-shaped conglutinates. Several species of minnows, White Sucker, Brook Stickleback, and a few others have been shown to transform larvae.



Similar Species: *Pleurobema sintoxia* (Round Pigtoe), *Fusconaia flava* (Wabash Pigtoe)

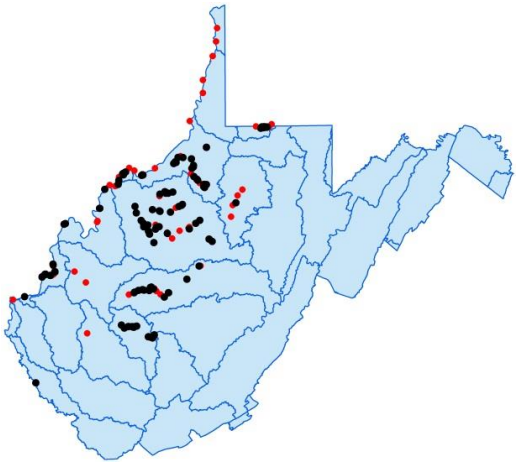
***Pleurobema sintoxia* (Round Pigtoe)**

Description: The shell is highly variable from triangular and highly compressed in creek form (top photo) to oval or teardrop-shaped and inflated in the big river form (third large photo). Midsized rivers like the Little Kanawha are intermediate (second large photo). The umbo is wide and low in creek form and narrow and prominent in big river form. In the big river form, the umbo projects forward. Beak cavity is very shallow. Beak sculpture if evident consists of 2-3 angular ridges. The periostracum is dull yellowish brown to deep reddish brown, darkening to black with age. Juveniles may have distinct green rays. Nacre is white to deep pink. Length to 4.5 inches.

Habitat and Distribution: This species is nowhere common. Found in midsized creeks to large rivers.

Life History: Short-term brooder. Several species of minnows and the Brook Stickleback have been shown to transform larvae.

Similar Species: *Fusconaia flava* (Wabash Pigtoe), *Fusconaia subrotunda* (Longsolid), *Pleurobema cordatum* (Ohio Pigtoe), *Reginaia ebenus* (Ebonyshell)

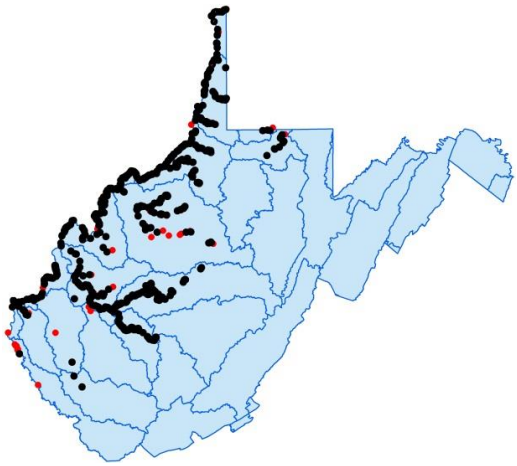


***Potamilus alatus* (Pink Heelsplitter)**

Description: Shell is oval typically with a pronounced posterior wing. Wing may be greatly reduced, and its size may be related to flow environment. It is thin, becoming thicker with age, and moderately inflated at the umbo. The inflation is mostly dorsal, but relatively parallel with the ventral margin. The umbo is located at approximately one-third the distance from anterior end and forms a shallow beak cavity that is wide and open. Beak sculpture consists of 3-4 narrow bars starting out concentric and then becoming double-looped. The teeth are well-developed although the pseudocardinal teeth are delicate, and there is no interdentum. The periostracum is yellow to greenish brown often with numerous fine green rays becoming dark brown to black with age. Nacre is pink or purple and is quite iridescent. Length to 7.5 inches.

Habitat and Distribution: This Ohio Basin species is wide-spread in all flow regimes and all substrate types from moderate-sized creeks to large rivers.

Life History: Long-term brooder. This species is known to use Freshwater Drum to transform larvae. Mortality due to reproductive stress may affect this species as dead gravid individuals are often observed during surveys in September during their reproductive period.



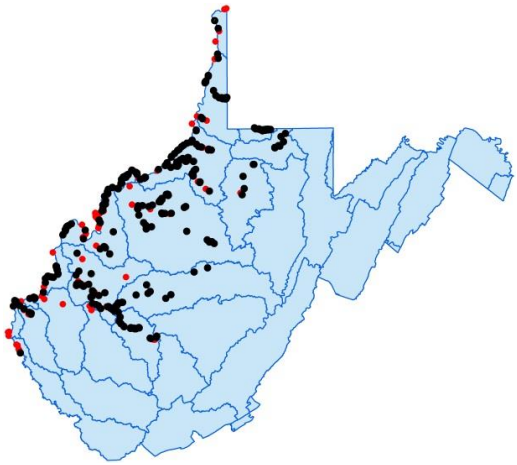
Similar Species: *Lasmigona complanata* (White Heelsplitter), *Potamilus ohiensis* (Pink Papershell), *Potamilus fragilis* (Fragile Papershell)

***Potamilus fragilis* (Fragile Papershell)**

Description: The shell is very thin, fragile and compressed though females may become more inflated. The shell tends to be oblong oval shaped with the posterior slope compressed into a weak wing. The posterior ridge is broadly rounded. The anterior end is rounded and may be compressed into a small anterior wing. The hinge is poorly developed and the umbo rises slightly above it. The beak cavity is wide and open and the beak sculpture consists of 3-4 faint, double-looped bars. The teeth are well-developed though fine and delicate without an interdentum. The periostracum is smooth and shiny yellow to yellowish green and may have numerous faint green rays. Nacre is pink to highly iridescent. Length to 6 inches.

Habitat and Distribution: This species can be found in all sizes of streams as well as most substrates from mud to gravel. Ortmann (1919) described finding this species in riffles where he found it crawling around frequently. Typically not found in smaller creeks. *A*ppears to be a pioneering species, being one of the first to recolonize following impacts as evidenced in the Monongahela River.

Life History: Long-term brooder. This species has been shown to use Freshwater Drum to transform larvae.



Similar Species: *Potamilus ohiensis* (Pink Papershell), *Potamilus alatus* (Pink Heelsplitter)

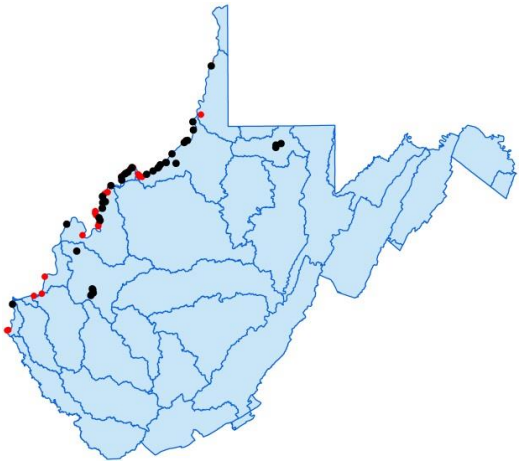
***Potamilus ohiensis* (Pink Papershell)**

Description: The shell is elongate oval, very thin, fragile, and compressed with rounded anterior and posterior ends. It typically has a moderate-sized posterior wing and a smaller anterior wing, both of which may be worn off. The umbo is flattened and not elevated above the hinge line. The beak cavity is very shallow and open. The beak sculpture consists of 3-4 thickened ridges. The teeth are well-developed though delicate. The periostracum is tan, greenish to light brown to golden and may become darker with age. Nacre is light purple or pink and is iridescent. Length to 7 inches.

Habitat and Distribution: This species is generally found in softer substrates and may be under-represented in current datasets due to a lack of surveys in its preferred habitat.

Life history: Long-term brooder. This species releases fragile, white conglutinates (Watters *et al.* 2009). Only Freshwater Drum have been shown to transform larvae.

Similar species: *Potamilus alatus* (Pink Heelsplitter) and *Potamilus fragilis* (Fragile Papershell)

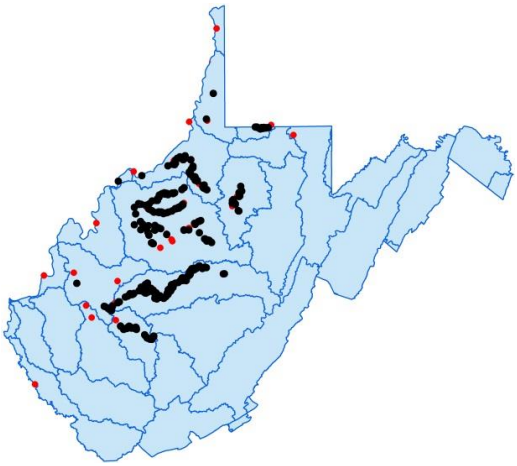


***Ptychobranchus fasciolaris* (Kidneyshell)**

Description: The shell is compressed and heavy. The anterior end is broadly rounded, and the posterior end is bluntly pointed at or ventral of the midline. The posterior ridge is mostly evident near the umbo where it is sharply angled to the narrow posterior slope. Towards the posterior end the slope becomes broadly rounded and not evident. The umbo is low and compressed and does not rise above the hinge line. Beak sculpture consists of indistinct fine wavy ridges. The beak cavity is very shallow and open. The teeth are well-developed with the lateral teeth being very thick. The interdentum is short and moderately-wide. The periostracum is yellowish brown to dark brown typically with dark green broken rays which can become obscure with age. Growth lines may be slightly raised giving the shell a rough appearance. Nacre is white. Length to 6 inches.

Habitat and Distribution: This species is generally associated with sand, gravel, and cobble substrates in flowing water. It is found in large creeks to large rivers, though rare in the Ohio River probably due to it being impounded.

Life History: Long-term brooder. This species has been documented to release two different types of conglutinates: one resembles a larval fish and the other a larval insect (Watters 2008). Larvae have been shown to transform on Rainbow and Fantail darters.



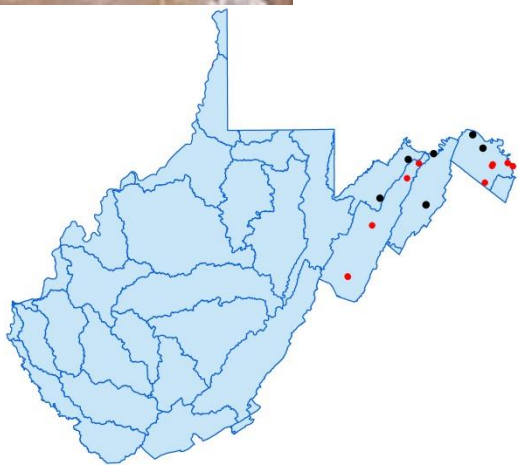
Similar Species: *Eurynia dilatata* (Spike)

***Pyganodon cataracta* (Eastern Floater)**

Description: This thin, elliptical shell is highly inflated. The anterior end is broadly rounded, and the posterior end is bluntly to somewhat sharply pointed about the midline. The dorsal posterior margin is straight. The umbo rises slightly above the straight hinge line forming a very shallow inflated beak cavity. The beak sculpture consists of delicate double-loops that become concentric. This shell has no teeth. The periostracum is yellow to yellowish green or greenish brown. Faint green rays may be evident. Two dark raised lines may be evident along the posterior ridge and mid-posterior slope. Nacre is silvery-white and iridescent. Length to 7 inches.

Habitat and Distribution: In WV this species is restricted to the Potomac Watershed and most commonly found within impoundments. The known distribution in WV is probably under-represented due to the lack of surveys within the numerous ponds within its range. It can also be found in pool habitats of rivers and creeks, preferring softer substrates.

Life History: Long-term brooder. This species has transformed larvae using White Sucker, Pumpkinseed, and Rock Bass.



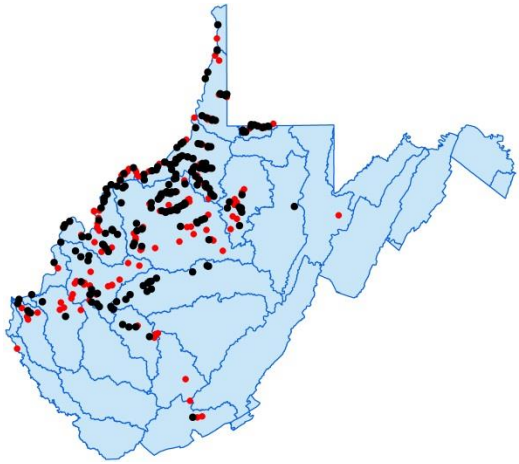
Similar Species: *Strophitus undulatus* (Creeper), *Pyganodon grandis* (Giant Floater – Ohio Basin), *Anodontoides ferussacianus* (Cylindrical Papershell – Ohio Basin)

***Pyganodon grandis* (Giant Floater)**

Description: This thin shell is elliptical in shape and moderately inflated in the creek/river form (top) and more spherical and inflated in the lake form (2nd photo). The anterior end is rounded, and the posterior end is bluntly to somewhat sharply pointed at the midline. The dorsal posterior margin is straight. The umbo rises above the hinge line forming a relatively shallow beak cavity. The beak sculpture is strongly double-looped. The periostracum in the creek and river forms tends to be greenish yellow to yellowish brown; coloration bands tend to follow that of the growth rings rather than rays which tend to be faint. The lake form is more yellow to yellowish brown, lacking most color bands.

Habitat and Distribution: This species is found throughout the Ohio River Watershed from small headwater creeks, lakes and ponds to margins of the Ohio River. Very few records exist upstream of Kanawha Falls and most likely are a result of infested fish host introductions. It has also been reported in the VA portion of the New River. It is found in varying substrate and flow types.

Life history: Long-term brooder. Glochidia are released in a tangle of mucous and larval threads (Utterback 1915). Several species of many fish families have been shown to transform larvae.



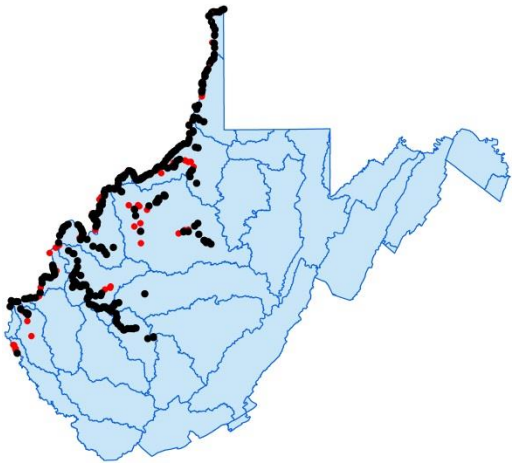
Similar Species: *Anodontoides ferussacianus* (Cylindrical Papershell), *Strophitus undulatus* (Creeper), *Pyganodon cataracta* (Eastern Floater-Potomac Basin)

***Quadrula quadrula* (Mapleleaf)**

Description: The shell is quadrate to slightly round, and moderately thick. The anterior end is rounded and posterior end is truncated. The umbo is slightly elevated above the hinge line forming a deep beak cavity. The beak sculpture consists of double-loops or zigzags which are carried down across the face of the shell as two rows of pustules. A slight sulcus appears between the two rows. Some individuals may have more pustules scattered over the face of the shell, and others may be almost completely devoid of all pustules. The posterior slope is somewhat compressed and contains small ridges or flutings. The teeth are well-developed with a short, fairly wide interdentum. The periostracum is yellowish brown to greenish brown becoming dark brown with age. Nacre is white. Length to 4 inches.

Habitat and Distribution: Found in medium to large rivers in all types of substrate. It prefers slow to moderate current and has been able to survive impoundment. Although a couple of individuals have been reported from the New River upstream of Kanawha Falls, these were most likely misidentified *Cyclonaias tuberculata* which are similar as juveniles and thus not represented in the distribution map.

Life History: Short-term brooder. Several species of catfish have been shown to transform larvae.

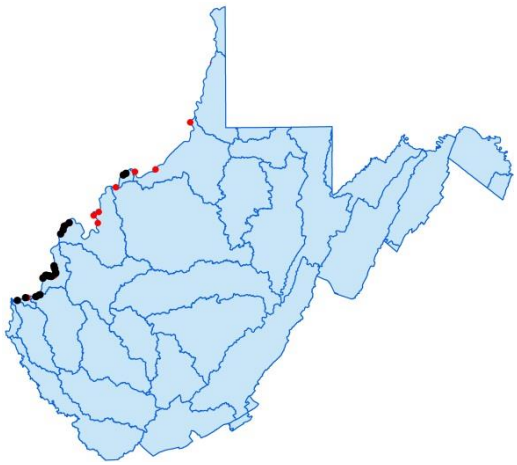


Similar Species: *Theliderma metanevra* (Monkeyface), *Cyclonaias tuberculata* (Purple Wartyback)

***Reginaia ebenus* (Ebonyshell)**

Description: The shell is oval to rounded, highly inflated, and heavy with the anterior end much thicker than the posterior. The anterior end is rounded and the posterior end is rounded to bluntly pointed in very old individuals. The inflated umbo rises above the hinge line and sits far forward on the shell. The umbo curves inward and anterior. It extends past the anterior shell margin. This species has the deepest beak cavity of all unionids. The beak sculpture consists of a few very weak ridges that are generally only evident in very young shells. The teeth are well-developed with a short, very wide interdentum. The main pseudocardinal tooth of each valve is almost parallel to the lateral teeth. The periostracum is light brown, chestnut, dark brown or black in older individuals. Young shells maybe yellow with faint green rays. Nacre is white. Length to 4 inches. Foot color may vary from white, cream, or orange.

Habitat and Distribution: In WV this species has only been found from the main Ohio River in heterogeneous substrates consisting mostly of gravel, sand and cobble. WV appears to be the upstream limits of this species within the Ohio River.



Life history: Short-term brooder. This species releases bright pink conglutinates. Though a few potential fish hosts have been identified, most notably the Skipjack Herring, none have been confirmed.

Similar species: *Fusconaia subrotunda* (Longsolid), *Obovaria olivaria* (Hickorynut), *Pleurobema sintoxia* (Round Pigtoe)

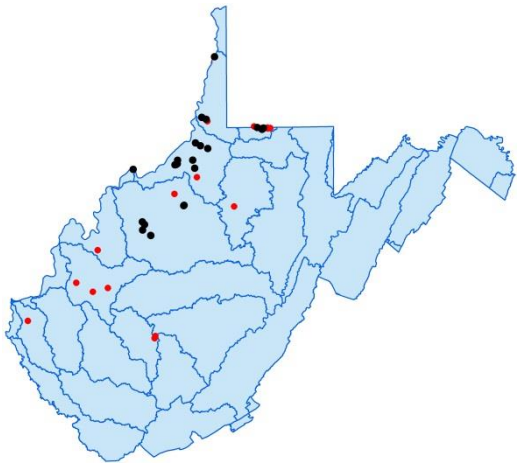
***Simpsonaias ambigua* (Salamander Mussel)**

Description: This shell is rather thin, small, and compressed in young individuals, becoming more inflated and cylindrical with age. Both the dorsal and ventral margins are nearly parallel. The anterior and posterior ends are rounded, and the posterior ridge is broadly rounded and not distinct. The umbo is positioned far anterior of center and rises only slightly above the hinge line. It is typically very eroded and appearing low. The beak sculpture consists of 3-4 double-loops usually not evident. The beak cavity is shallow, and there is only one single compressed pseudocardinal tooth in each valve and no lateral teeth. The smooth dull periostracum is yellowish brown to dark brown and rayless. Nacre is bluish white, or salmon, occasionally showing iridescence. Length to 2 inches.

Habitat and Distribution: This mussel is typically found under large flat rocks in large creeks to large rivers. Due to its secretive nature and small size, this species has probably been overlooked during many surveys.

Life History: This species is believed to be a long-term brooder that uses the Mud Puppy (*Necturus maculosus*) as its host.

Similar Species: *Toxolasma parvum* (Lilliput), *Paetulunio fabalis* (Rayed Bean)

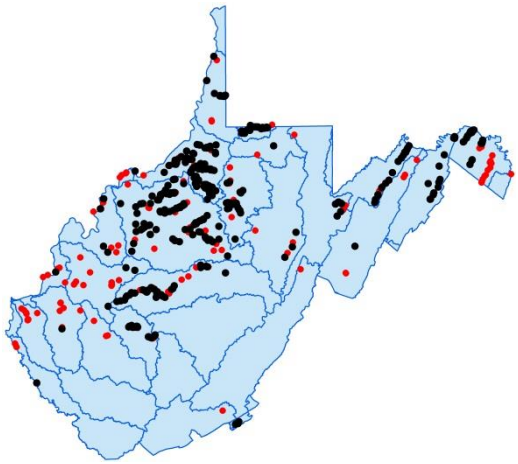


***Strophitus undulatus* (Creeper)**

Description: The shell is somewhat thin and elliptical with a broadly rounded anterior end. The posterior end is bluntly pointed, typically below the midline, to rounded. The dorsal posterior margin is slightly curved downward toward the ventral margin. The posterior ridge is indistinct with rounded posterior slope. The shell becomes more inflated with age. The umbo is situated slightly forward of center and is slightly elevated above the hinge line. The beak cavity is shallow to moderately deep, and beak sculpture consists of 4-5 heavy concentric bars. The lateral teeth are lacking, and the pseudocardinal teeth are represented only by a low swelled knob in the left valve. The periostracum is generally green to yellowish green with rays as juveniles and becoming dark brown to black with age. Nacre is generally salmon, cream, or bluish and iridescent. Typically salmon within the beak cavity and bluish white along the margins. This species typically possesses an orange foot. Length to 4 inches.

Habitat and Distribution: This species is widely distributed and will live in a variety of habitats. It is the only species in WV that is found within all three major watersheds. It appears to have been introduced into the Blackwater River above Davis, most likely due to host fish introductions.

Life History: Long-term brooder. This species releases conglutinates in the spring consisting of a white strand on which the individual glochidia are attached. It is a host generalist, having transformed larvae on numerous members of the sunfish, darter, and minnow families, and others.

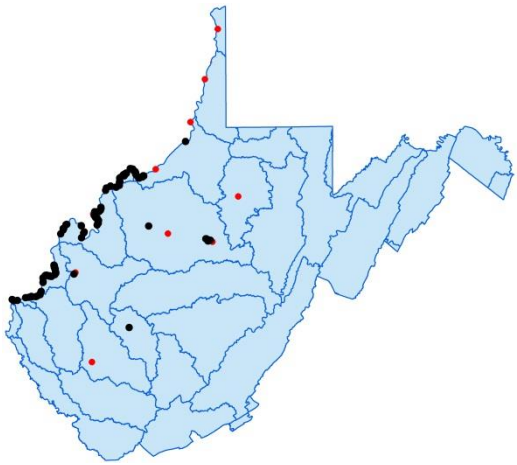


Similar Species: *Pyganodon grandis* (Giant Floater), *Anodontoides ferussacianus* (Cylindrical Papershell)

***Theliderma metanevra* (Monkeyface)**

Description: The shell is generally quadrate, solid, and moderately inflated. The anterior end is rounded. The posterior ridge is prominent and consists of several large knobs forming a bulge of the posterior/ventral margin. The posterior slope is somewhat compressed and is usually covered with small pustules. The posterior two-thirds of the shell are covered with numerous pustules and some may extend to the anterior end. The umbo rises slightly above the nearly straight hinge line. The beak cavity is moderately deep and beak sculpture consists of 2-3 concentric bars, which are angular and nodulous. The teeth are well-developed with a short, wide interdentum. The periostracum is yellowish brown to brown and may contain green chevron-shaped markings. Nacre is white. Length to 4 inches.

Habitat and Distribution: Prefers larger rivers such as the Ohio and occurs in coarse gravel substrates which historically had swiftly running water. Ortmann (1919) noted that it was frequently taken by the clam diggers in deep water in strong and steady currents below Wheeling. Most likely it historically ranged into the Kanawha River and other mid-sized rivers as it is currently found in low numbers within the Little Kanawha River and in the Kanawha River up to Kanawha Falls.



Life History: Short-term brooder. This species is known to use several minnow species to transform larvae. It has a lure consisting of a small fleshy protuberance.

Similar Species: *Quadrula quadrula* (Mapleleaf)

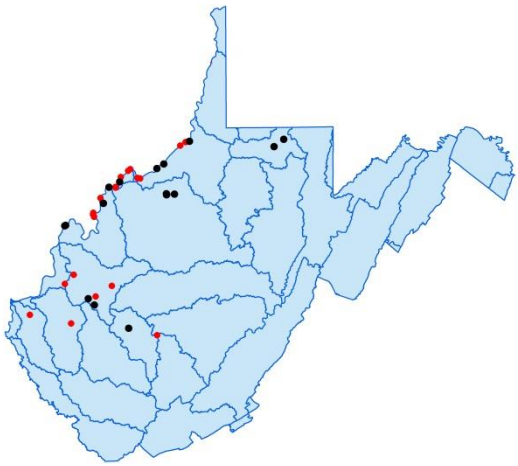
***Toxolasma parvum* (Lilliput)**

Description: This species is sexually dimorphic. The shell is small, elliptical and somewhat cylindrical and inflated. Both the anterior and posterior ends are rounded and there is a broadly rounded posterior ridge. Females (top) tend to have a more broadly rounded posterior margin and are more inflated. The umbo is inflated and rises slightly above the hinge line. The beak cavity is moderate and open, and the beak sculpture consists of 5-6 distinct concentric ridges. The teeth are fine and delicate, but well-developed and without an interdentum. The periostracum has a cloth-like texture and is yellowish green, darkening to brown with age and rayless. Nacre is generally bluish white and highly iridescent. Length to 1 ¾ inches.

Habitat and Distribution: Found most commonly along the silty sandy margins and embayments of large to small rivers but also found in similar habitat in small creeks. Ohio also reports it in impoundments (Watters *et al.* 2009). This species has probably been overlooked in most surveys as its preferred habitat is not typically associated with diverse mussel populations where most surveys occur.

Life History: Long-term brooder. Utterback (1916) suggested this species may be hermaphroditic. It has been shown to use several species of the sunfish family and Johnny Darter to transform larvae.

Similar Species: *Leaunio lienosus* (Little Spectaclecase), *Paetulunio fabalis* (Rayed Bean), *Simpsonaias ambigua* (Salamander Mussel)



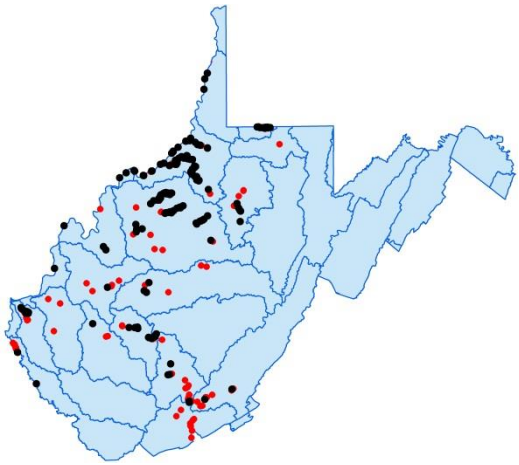
***Tritogonia verrucosa* (Pistolgrip)**

Description: This species is sexually dimorphic. The shell is elongate and somewhat rectangular and compressed. The anterior end is rounded, and the posterior end is truncate in males (2nd photo) and more elongate bluntly pointed in females (top). The posterior ridge ranges from large pustules and small knobs to a continuous bulbous ridge. The umbo rises only slightly above the hinge line. The beak cavity is moderately deep, and beak sculpture consists of 1-2 sub-concentric bars followed by additional double-looped bars. These bars break up into nodules indistinctly arranged in zigzag waves, which are continued throughout the valve face. The entire shell is typically covered with irregular pustules, at least in juveniles. The teeth are well-developed with a moderately wide interdentum. The periostracum is greenish brown to light brown, becoming dark brown to black in older individuals. Nacre is white. Length to 8 inches.

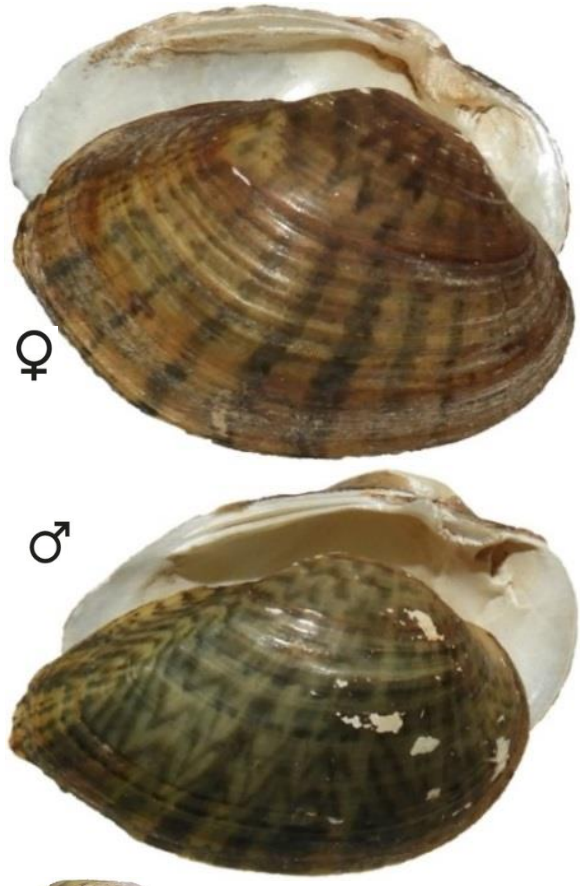
Habitat and Distribution: Found in large creeks to large rivers in substrates ranging from mud to gravel. It is most common in small rivers which may be due to its preference for flowing water. It is not usually buried very deep into the substrate. During active reproductive periods, gravid females often are seen lying on the substrate surface.

Life History: Short-term brooder. Females display a striated swollen fleshy mantle. Several species of catfish have been shown to transform larvae.

Similar Species: *Lasmigona costata* (Flutedshell)



***Truncilla donaciformis* (Fawnsfoot)**



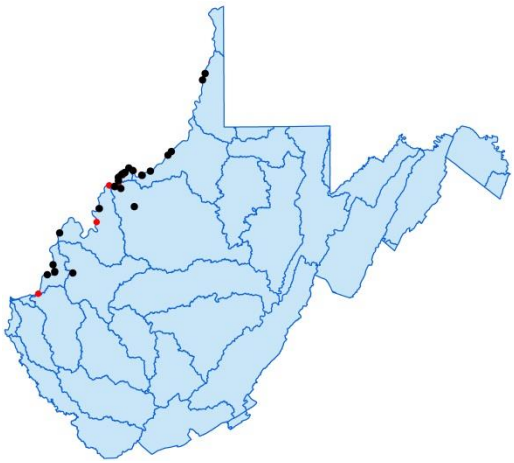
Description: This species demonstrates weak sexual dimorphism. The shell is small, oblong, slightly inflated, and somewhat bean-shaped. The anterior end is rounded, and the posterior end is bluntly pointed in females (top) and sharper in males (bottom). The posterior ridge is broadly rounded to slightly angled. The umbo is situated slightly anterior of center and elevated above the hinge line. The beak cavity is relatively shallow, and beak sculpture consists of 5-6 double-looped bars. Teeth are well-developed with no interdentum. The periostracum is yellow to greenish yellow with broad green rays consisting of small broken v-shaped lines. Nacre is white and may be iridescent. Length 2 inches.

Habitat and Distribution: This species is typically completely buried in sand and gravel of large rivers. In recent years it has been observed in strong current of the Little Kanawha River in gravel cobble habitat. This species is probably under estimated unless surveyor is digging into the substrate.

Life History: Long-term brooder. It is speculated that the female of this small mussel may come to the surface when gravid where it is likely eaten by a Freshwater Drum which subsequently becomes infested. Freshwater Drum are the only confirmed fish host and have pharyngeal teeth which they use to crush the shells as they feed upon mollusks (figure below). Watters *et al.* 2009 reports this species lying on the substrate surface in the summer attached by a byssal thread.

Above are pharyngeal teeth of a Freshwater Drum used to crush mussel shells.

Similar Species: *Truncilla truncata* (Deertoe)



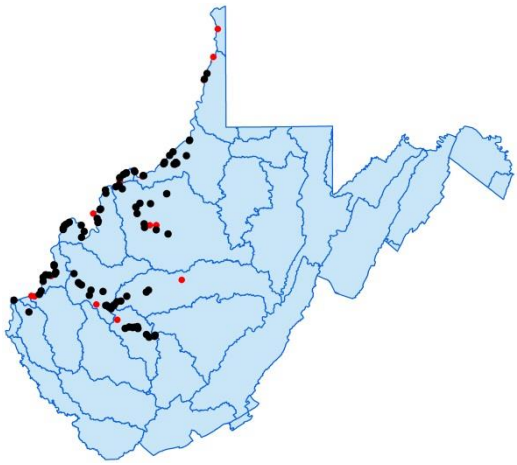
***Truncilla truncata* (Deertoe)**

Description: This shell is small, somewhat triangular, and thin to moderately thick. The anterior end is rounded, and the posterior end is bluntly pointed giving the shell its triangular appearance. The posterior ridge is strongly angled, approaching 90 degrees near the umbo. The posterior slope is truncated. The umbo is elevated above the hinge line and inflated though the beak cavity is shallow. The beak sculpture is rudimentary, rarely visible and consists of 3-5 double-looped ridges. Teeth are well-developed with a narrow interdentum which may be absent. The periostracum can be highly variable but is generally yellowish to yellowish brown with broad green rays made up of fine broken lines or v-shaped markings. Specimens have been observed solid yellow or so highly rayed they appear green. Nacre is white, appearing iridescent posteriorly. Length to 2 inches.

Habitat and Distribution: Found in large to medium-sized rivers in mud to gravel. Typically buried in the substrate.

Life History: Long-term brooder. Only Freshwater Drum have been confirmed to transform larvae.

Similar Species: *Truncilla donaciformis* (Fawnsfoot), *Epioblasma triquetra* (Snuffbox)



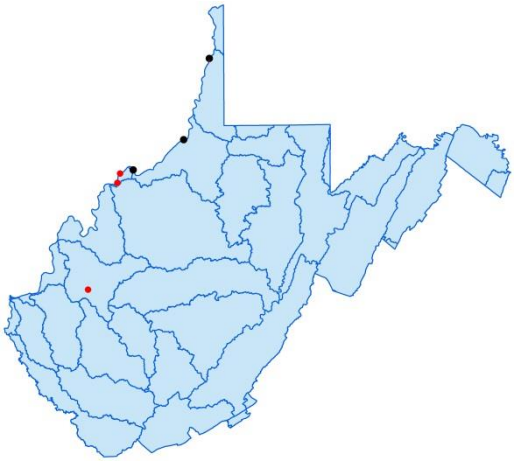
***Uniomerus tetralasmus* (Pondhorn)**

Description: This shell is thin to fairly solid and moderately inflated. The elongate shell has a rounded anterior end and the posterior end is bluntly pointed ventral of the midline. The posterior ridge is long and broadly rounded and the posterior slope typically has two longitudinal ridges. The umbo is slightly elevated above the hinge line forming a shallow beak cavity. Beak sculpture consists of 4-5 prominent concentric ridges. Teeth are well-developed without an interdentum. The periostracum is yellowish brown to dark brown and rayless though may be banded with lighter shades. Nacre is dull white. Length to 5 inches.

Habitat and Distribution: This species is typically found in muddy sand. Few individuals have been recorded from the Ohio River mainstem within WV although the first reported specimens in WV were collected from a private pond. In OH it has been reported in small creeks.

Life History: Little is known about the life history of this species but thought to be a long-term brooder. No fish hosts have been confirmed though larvae have been observed on Golden Shiners from the wild.

Similar Species: *Lampsilis teres* (Yellow Sandshell), *Pyganodon grandis* (Giant Floater)

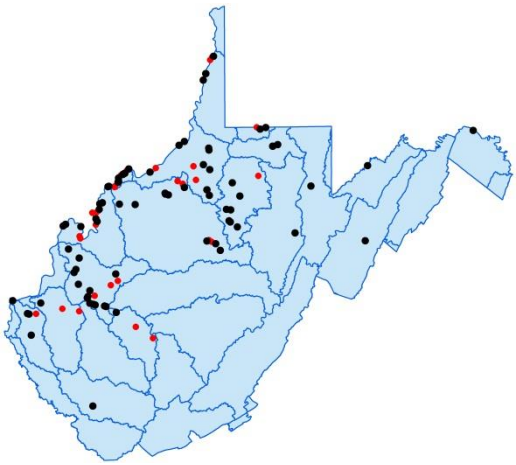


***Utterbackia imbecillis* (Paper Pondshell)**

Description: This shell is very thin and rather elongate with a rounded anterior end and blunt to sharply pointed posterior end at or dorsal of the midline. It may appear to have a slight posterior wing. The posterior dorsal margin is straight. The umbo is positioned slightly forward of center and is flush with the hinge line. The overall shell is somewhat inflated without a distinct umbo. The beak cavity is very shallow to nonexistent and the beak sculpture consists of double-looped wavy ridges. This species lacks all teeth. The periostracum is shiny light yellow, green to brownish green and may have fine green rays. Nacre is bluish iridescent to white. Length to 4 inches. Juvenile, bottom left, is extremely compressed and nearly transparent.

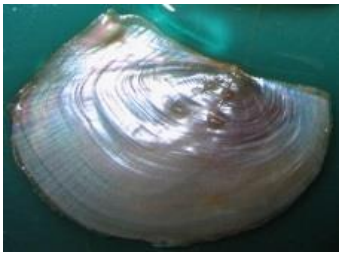
Habitat and Distribution: This species prefers softer substrates and quieter waters such as ponds, lakes and river embayments. This species is probably under-represented in WV due to the lack of surveys within its preferred habitat. It probably occurs throughout much of the Ohio Basin but locally not common except in ponds and lakes. It appears to have been introduced into the upper Potomac Basin most likely via fish stockings.

Life History: Long-term brooder. This species was reported in Watters *et al.* 2009 as releasing mucous strands containing glochidia. It is also reported to have marsupial transformation as well as being a host generalist. Members of the sunfish family, shiners, Channel Catfish, Yellow Perch, and many others including exotic fish have transformed juveniles.



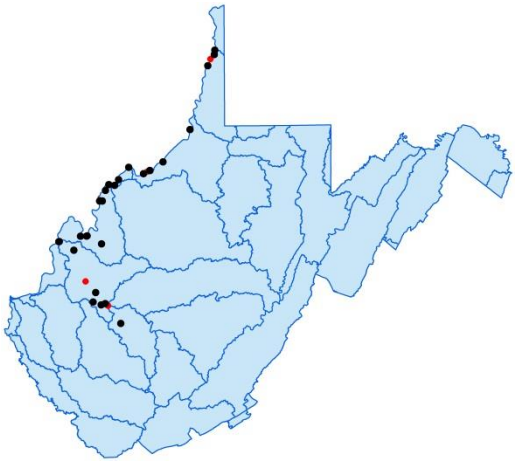
Similar Species: *Pyganodon grandis* (Giant Floater), *Anodontoides ferussacianus* (Cylindrical Papershell)

***Utterbackiana suborbiculata* (Flat Floater)**



Description: The shell is large, greatly compressed in young to slightly inflated and nearly circular in adults. The anterior end and ventral margins are broadly rounded. The posterior ridge is low but distinct and angled especially near the umbo. The posterior slope is small and may form a small wing. The dorsal posterior margin is straight to slightly curved with the posterior end bluntly pointed. The umbo is positioned just anterior of the midline and is not inflated forming a very shallow beak cavity. The beak sculpture is double-looped which mostly exhibits as a series of paired pustules in juveniles. The shell lacks all teeth though the hinge line is swollen. The periostracum is bluish silver in young, becoming yellow to yellowish brown to brown with fine green rays evident in some individuals. Nacre is white or pinkish to iridescent. Length to 7 inches.

Habitat and Distribution: In WV this species has been found in slow, sediment-laden embayments on the Ohio and Kanawha rivers and also known to occur in lakes and ponds. It was first reported in WV from the Ohio River in the early 1990s by ORINWR. It may have occurred here prior to this but sampling in its preferred habitat has been limited.

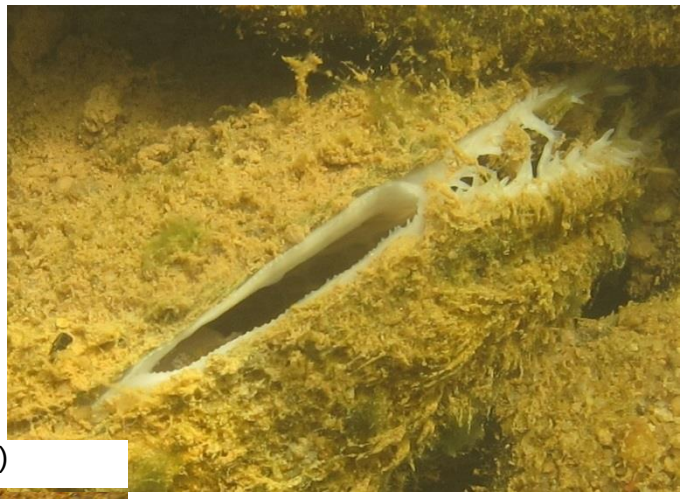


Life History: Long-term brooder. This species reportedly releases an extensive web of mucus that ensnares its host (Watters 2008). Members of the sunfish family, Golden Shiners, and Channel Catfish have transformed larvae.

Similar Species: *Lasmigona complanata* (White Heelsplitter)

The incurrent apertures of freshwater mussels can be quite ornate in both structure and color. Here are a few examples. While the excurrent aperture typically lacks structure it may have variations in color such as *P. alatus* below.

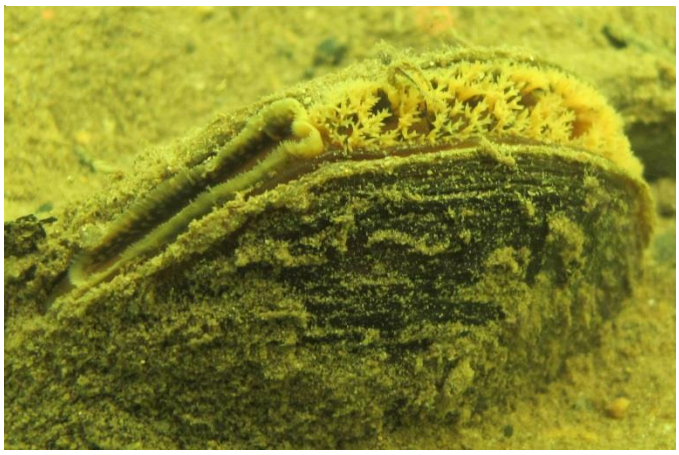
Fusconaia flava (Wasbash Pigtoe)



Actinonaias ligamentina (Mucket)

Potamilus alatus (Pink Heelsplitter)

Plethobasus cyphyus (Sheepnose)



Ligumia recta (Black Sandshell)

Cyprogenia stegaria (Fanshell)

Cambarunio iris (Rainbow)

Cyclonaias tuberculata (Purple Wartyback)

Tritogonia verrucosa (Pistolgrip)

Some mussel species use lures to attract fish hosts. Most are modified extensions of the mantle; however, that of *C. stegaria* is more like a conglutinate that remains attached to the mussel until dislodged. The lure of *L. recta* does an undulating motion and that of *C. iris* moves like a crayfish.

As previously noted, *L. fasciola* (Wavy-rayed Lampmussel) has multiple lure types. The one shown to the right has been observed on the Elk River and Kanawha River. The two orange fleshy mantle extensions wiggle like two worms to attract a potential fish host.

Amblema plicata (Threeridge)

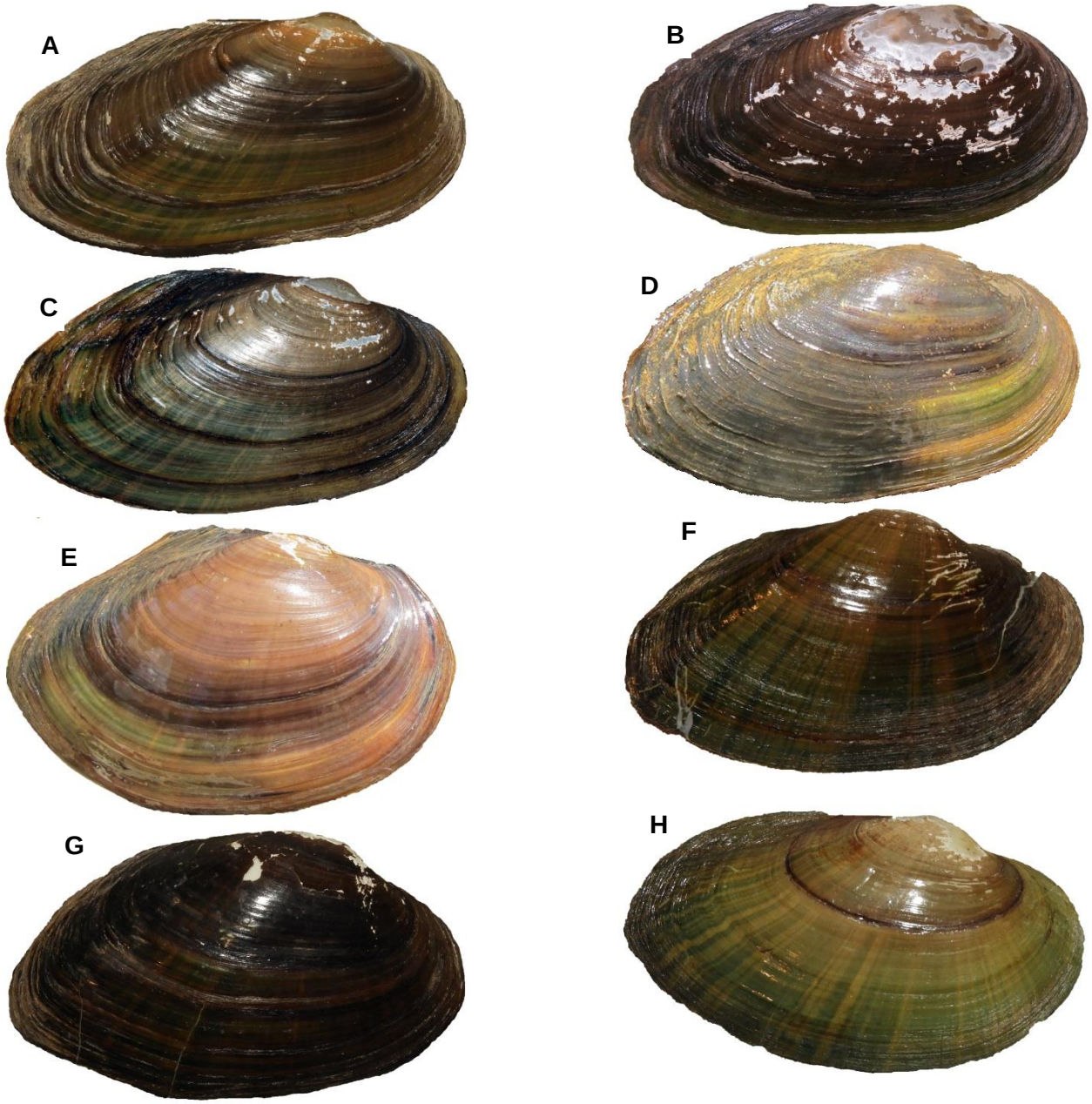
Non-lure producing mussels have other methods for enhancing the probability of glochidia attachment. One example is the glochidia-filled mucous strands produced by *Amblema plicata* (Threeridge) observed on the Elk River, Braxton County. Similarly, *Megalonaias nervosa* (Washboard) produce glochidia-filled mesh. This mesh was discharged and observed while holding in tanks at the Belleville Complex for propagation efforts.

Glochidia-filled mesh of *Megalonaias nervosa*

Helpful Hints
For
Identification of
Some
Confusing Species

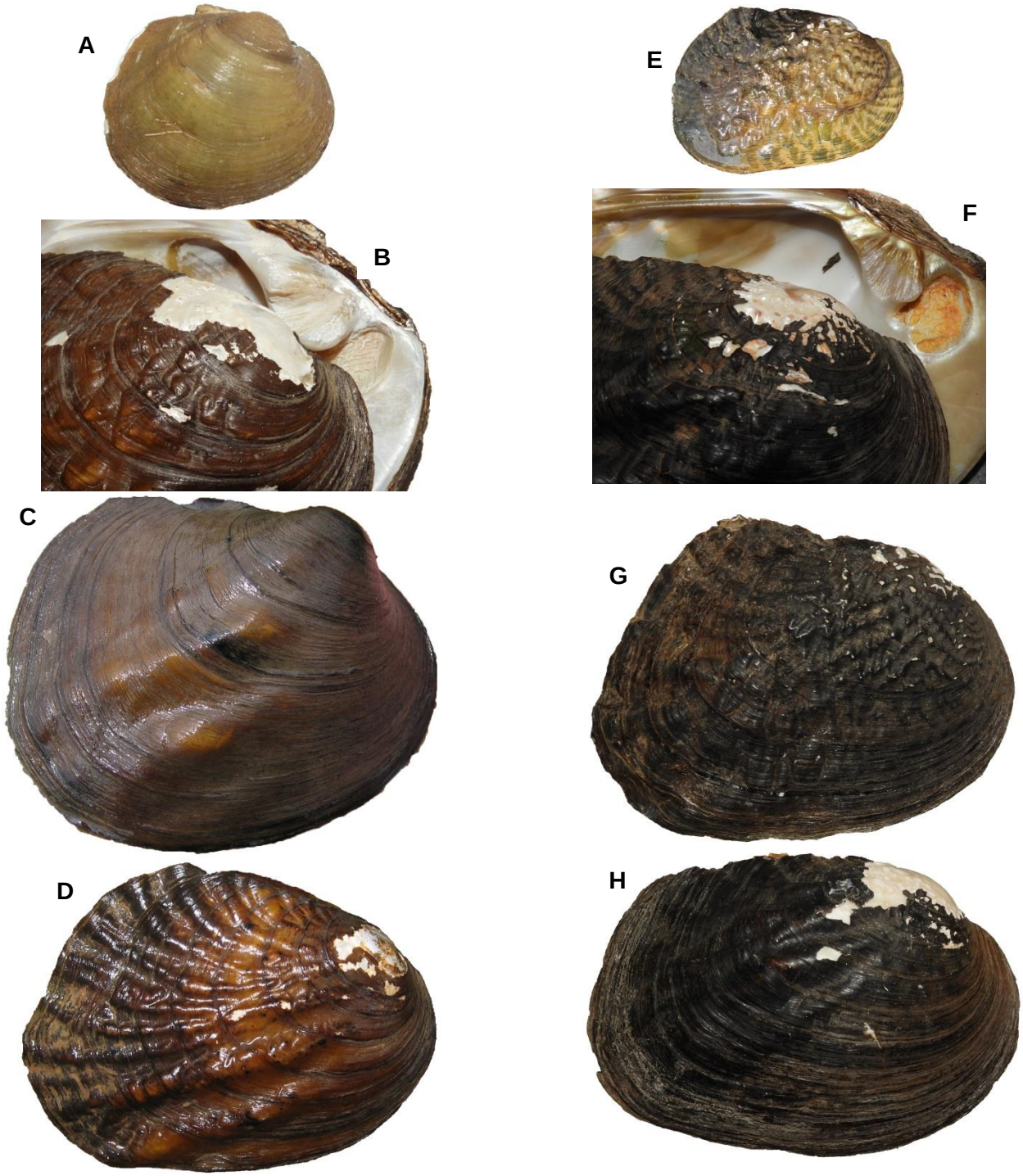
Anodontoides ferussacianus* vs *Pyganodon grandis* vs *Strophitus undulatus

Anodontoides ferussacianus (A-C), *P. grandis* (D, E), and *S. undulatus* (F-H) are often confused. *Pyganodon grandis* is the only species in the group that has heavy double-looped beak sculpture. Both *S.undulatus* (heavy) and *A. ferussacianus* (fine) have concentric beak sculpture. *Pyganodon grandis* has a straight posterior dorsal margin. *Strophitus undulatus* has a slightly curved posterior dorsal margin that is often angled ventrally. The posterior dorsal margin of *A. ferussacianus* has a fairly straight to slightly curved posterior dorsal margin. Coloration pattern of the periostracum can also be of assistance. While all are typically rayed, the main coloration of *P. grandis* tends to be around the growth bands with rays less evident. The main coloration pattern in *S.undulatus* tends to be the rays. Coloration pattern of *A. ferussacianus* is variable, falling between *P. grandis* and *S. undulatus*. *Pyganodon grandis* and *A. ferussacianus* are of similar elliptical shape with the umbo typically positioned very anterior. The height of *A. ferussacianus* is however shorter than *P. grandis*, giving it more of a cylindrical appearance. The umbo of *S.undulatus* tends to be more centrally positioned.



Amblema plicata* vs *Megalonaias nervosa

Amblema plicata (A-D) and *Megalonaias nervosa* (E-H) are misidentified most commonly when the *A. plicata* are very ornate (D). However, it is only the sculpturing that is anterior of the umbo that distinguishes these species. *Amblema plicata* has no sculpturing anterior of the umbo but *M. nervosa* does. Juveniles are easily separated with *A. plicata* lacking sculpture and inflated (A) and *M. nervosa* being highly sculptured throughout the entire shell and compressed (E). As *M. nervosa* ages, less sculpturing is evident which leads to the misidentification. Remnants of the juvenile sculpture are typically still evident near the umbo (F).



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Actinonaias ligamentina* vs male *Lampsilis abrupta

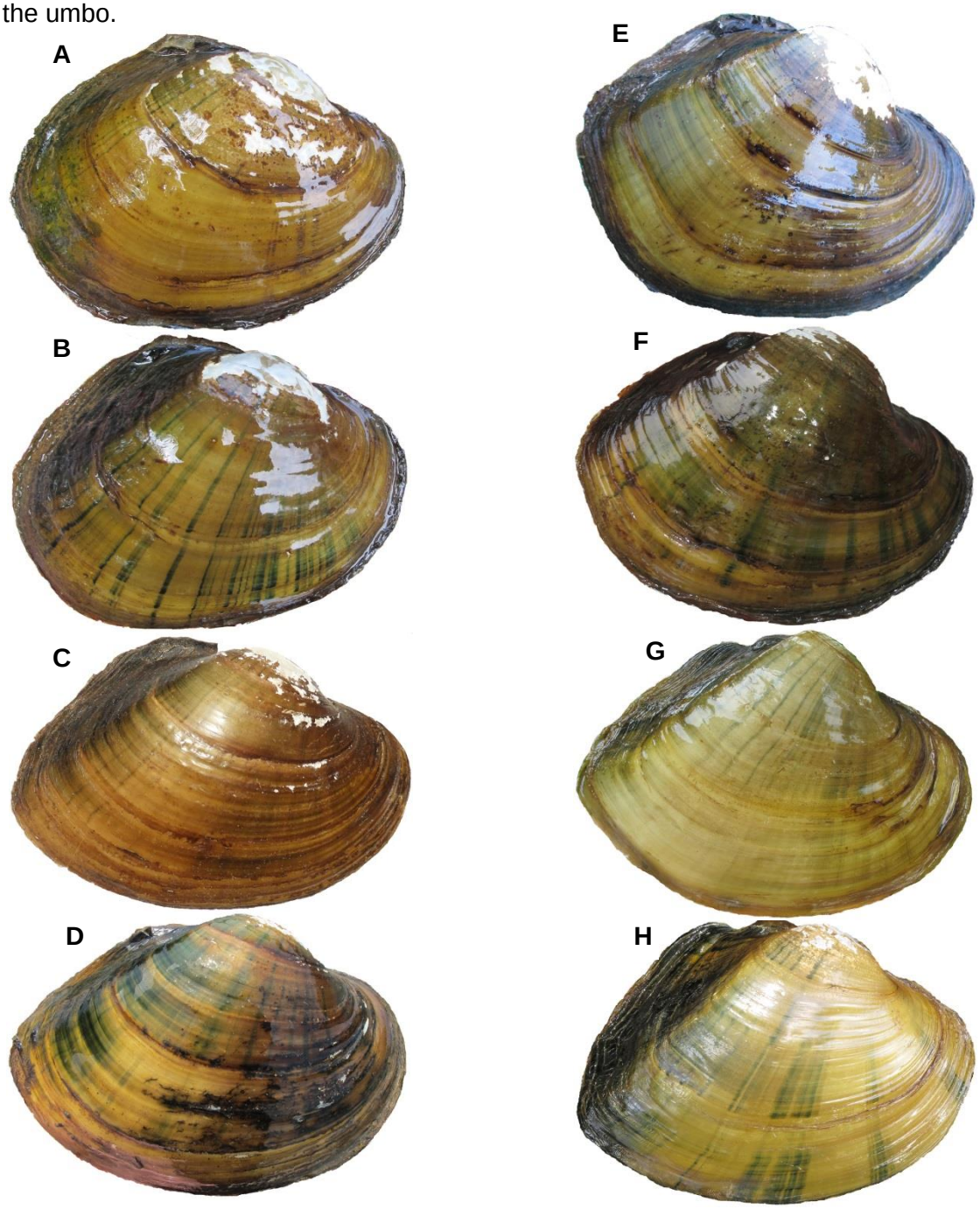
Lampsilis abrupta is sexually dimorphic and it is the male that can be easily confused with *Actinonaias ligamentina*. They co-exist within the Ohio, Kanawha, and Elk rivers. The juveniles of *L. abrupta* may be highly rayed but typically the adults are rayless or faintly rayed. *Actinonaias ligamentina* are typically highly rayed though rays may become obscure as the shell darkens with age. The periostracum of *L. abrupta* tends to be more yellowish, growth lines tend to be more evident due to faster growth, and shell tends to be more inflated for size. The umbo also tends to be more angled anteriorly. Some individuals are not identifiable based on shell characteristics only.

Actinonaias ligamentina

***Lampsilis abrupta* (Males)**

Lampsilis cardium* vs *Lampsilis ovata

These two species at one time were considered to be subspecies. The key characters in the separation (*L. cardium* A - D and *L. ovata* E - H) are the sharpness of the posterior ridge and coloration. Unfortunately you can take good typical specimens of each, lay them in a series and the shells will transition from one species to the other without a definite break. The sharpness of the posterior ridge also varies between sexes. A female *L. ovata* can be easily confused with a male *L. cardium* if you do not pay attention to sex (compare D to E below). Therefore, first decide whether the specimen you are trying to identify is female (A, B, E, F) or male (C, D, G, H). Typical *L. ovata* have very few or faint rays, males have a very sharp posterior ridge forming at times a scooped posterior slope. The females have a fairly sharp posterior ridge most evident near the umbo.



Pigtoes

The group commonly known as “Pigtoes” can be very difficult to distinguish. If you would throw representatives of all forms (within and between species) into a pile and then sort them, you would have one continuous series of shells which in WV is five species that includes *Fusconaia flava, F. subrotunda, Pleurobema cordatum, P. sintoxia*, and *Reginia ebenus*. Other states have additional species of pigtoes. The issue is that the shell shapes are variable with each species with the added variability in shell shape based on stream size. One other species that may be confused with this group is *Obovaria olivaria*.

Remember, the first thing about comparing species is to place the hinge in the same position. Characteristics to consider are the presence or absence of a sulcus, and the angle of the umbo both projecting anteriorly and how opposing umbos face each other.

Fusconaia flava is typically the most easily distinguished from the other pigtoes except for its large river form. The umbo is more central than in other pigtoes. Its large river form is most often confused with *P. cordatum*. Both have a sulcus; however, *F. flava* is much shorter in height for its length and the umbo is more centrally located and does not project forward. *Pleurobema cordatum* is the only other pigtoe in WV that has a sulcus. If you are lucky enough to see an orange foot, it is *F. flava*, but not all *F. flava* have orange feet.

In both *P. cordatum* and the big river form of *P. sintoxia*, the umbo projects strongly forward. It angles both anteriorly and inward toward the opposing umbo. *Pleurobema cordatum, P. sintoxia*, and *F. flava* are rather triangular in shape.

Both *F. subrotunda* and *O. olivaria* tend to be more oval in shape. The umbos do not project forward but *O. olivaria* is angled inward toward the opposing umbo. Again if you see an orange foot, it is *F. subrotunda* but not all *F. subrotunda* have orange feet.

Reginia ebenus is circular in shape, although as it ages it becomes more triangular. The umbos project strongly anteriorly, the most of all the WV pigtoes. The umbos also angle moderately inward. The periostracum, except for young, tends to be dark mahogany to black. This is the heaviest shell of all the WV pigtoes.

The following photos will compare this group of species in the same aspect.

Fusconaia flava (Wabash Pigtoe)

Pleurobema cordatum (Ohio Pigtoe)

Fusconaia subrotunda (Longsolid)

Pleurobema sintoxia (Round Pigtoe)

Obovaria olivaria (Hickorynut)

Reginaia ebenus Ebonyshell)

Fusconaia flava (Wabash Pigtoe)

Pleurobema cordatum (Ohio Pigtoe)

Fusconaia subrotunda (Longsolid)

Pleurobema sintoxia (Round Pigtoe)

Obovaria olivaria (Hickorynut)

Reginaia ebenus Ebonyshell)

Glossary

Adductor Muscles - two main muscles in unionids that hold valves together, one anterior, one posterior
Alae, Wing - (alate, adjective) an extension or wing on the dorsal margin of the shell that extends above the hinge line
Annual Growth Rings - dark concentric lines on shell that indicate periods of slower growth, much like the growth rings on a tree
Anterior - front, the short side of the valve when bisected through the umbo, end from which the foot protrudes
Beak - also known as umbo: the raised, inflated area on dorsal margin of the bivalve shell
Beak Cavity - the concave area or depression on the interior of a bivalve shell formed by the inside of the beak or umbo
Beak sculpture - raised ridges, undulations or bumps on the umbo or beak
Byssus or Byssal Threads- protein strands which attach true mussels to solid objects, though unionids may possess a single byssal thread as juveniles
Cilia - hairlike structures
Complex - a group of species that is difficult to separate
Compressed - flattened or squeezed together
Concentric - describes circles and spheres of different diameters with the same middle point
Conchiolin - the protein which makes up the shell periostracum or epidermis
Conglutinates - a cluster of several to thousands of individual glochidia; some conglutinates resemble other aquatic organisms such as insects or larval fish, thought to enhance the effectiveness of glochidia reaching fish host by mimicking natural food
Corrugated - having ridges, wrinkles, or grooves
Costations - ridges, folds, undulations
Denticle - small tooth or tooth-shaped projection
Diversity - a number of different kinds, as opposed to a lot of one kind
Dorsal - top or back, the hinge is along the dorsal edge on unionids
Endangered - this status refers to an organism in danger of extinction, and included on the US List of Endangered Species
Epidermis - periostracum, the exterior covering of the bivalve shell
Elliptical - having the form of an ellipse, elongated with similar height at both ends
Exhalant aperture – the area on the mantle margin where water and wastes are expelled from the mantle cavity
Extant - is presently found at that location
Extinct - a species which has no living representatives, gone forever
Extirpated - loss of a species within a portion of its range, correct term for locally extinct
Fluting - small rolling ridges, typically parallel, undulations
Gills, Pseudobranchs - paired structure within the mantle cavity which serves as a respiratory organ, and serves as the marsupium in female unionids, also called demibranchs
Glochidium (plural-glochidia) - the bivalve larvae of unionids which are generally parasitic on the gills or fins of fish
Globose - globe-like, spherical
Gravid - a female that has embryos/glochidia in the marsupium/gills
Hermaphroditic - a single individual that is both male and female
Hinge or hinge ligament - elongate elastic structure that joins the two valves
Hypolimnion - the bottom layer of a thermally stratified lake or pond that is generally cold and may be depleted of oxygen
Inhalant aperture - the area in the mantle where water is brought into the mantle cavity
Inflated - swelled, expanded, fat

Interdentum - a flattened area between the pseudocardinal and lateral teeth
Iridescent - showing a lustrous mixture of colors like those in a rainbow
Labial palps - a pair of thin flattened structures with cilia, responsible for moving food into the mouth
Lanceolate - tapering to a point like the head of a lance
Lateral teeth - elongate raised structure within the interior of a bivalve along the hinge line and posterior of the umbo, may be interlocking
Lentic - water body lacking flow
Lotic - flowing water body
Mantle - the soft tissue lining between shell and soft parts, responsible for producing the calcium and protein layers of the shell, also forms the exhalant and inhalant apertures or siphons, serves as a sensory receptor
Margin - edge
Marsupium - a brood pouch for eggs and developing glochidia, formed by the gills or portion of gills in unionid females
Median ridge - swelling directly below the umbo going down face of valve
Midden - piles of shells left by muskrats or Native Americans that feed or discard shells in the same place
Molluskivores - animals that eat mussels
Muscle scar - the area where a muscle attaches to the shell interior
Nacre - interior layer of a mussel shell, appears shiny in fresh dead shell material, made of calcium carbonate or mother of pearl
NatureServe - nongovernmental organization that serves as an source of comprehensive, decision-quality biodiversity data (https://explorer.natureserve.org/)
Nodule - a raised structure on the outside of a shell
Ovate - egg-shaped, broad and rounded tapering towards one end
Pallial line - an indented groove or line approximately parallel with the ventral margin of a bivalve shell which marks the line of attachment of the mantle to the shell
Papillae - small fleshy projections
Periostracum - (epidermis) exterior or outside layer of the shell made of acid resistant protein
Posterior - rear or back, long side of the valve when bisected through the umbo, the end of unionids containing the siphons
Posterior ridge - an exterior raised area of a bivalve shell that ends from the umbo to the rear margin
Posterior slope - the rear dorsal portion of the bivalve shell from the posterior ridge to the dorsal margin
Pustule - (tubercle) small raised structure on outside of shell
Pseudobranch - one half of a gill
Pseudocardinal teeth - triangular shaped teeth within the interior of a bivalve shell in the vicinity of the umbo
Pseudofeces - particulate material bound in mucus that are released before it is ingested
Quadrate, sub-quadrate - square or nearly so
Rare - seldom appearing, extremely few in number
Riparian Zone - the border of land along a body of water typically with unique vegetation, provides nutrients and shade to water body
Rhomboid, sub-rhomboid - having generally four distinct sides, two sides being longer than the others
Senile - has passed reproductive age
Serrated - notched or grooved, like teeth on a saw blade
Siphon - openings which allow water to be pumped in and out of the mussel

Species - group of interbreeding natural populations that are reproductively isolated from all other such groups
Subovate - not quite oval
Sulcus - a longitudinal furrow or depression
Truncate - having the end squared off
Tubercle - small, raised, rounded knob on the outside of the shell
Umbo - the raised inflated area on the dorsal margin of the bivalve shell, also called the beak
Undulation - pattern with wavy raised ridges or bars
Unionid - refers to any member of the freshwater bivalve mollusks which belong to the superfamily Unionoidea
Valve - one-half of a mussel shell
Ventral - underside or bottom, side of the unionid opposite the hinge
Wing - alae, an extension on the dorsal margin of the shell that extends above the hinge line, posterior wing extends above the lateral teeth

Kristin Schmidt

The author, Janet Clayton, along with Patricia Morrison, USFWS ORINWR biologist, with a federally endangered Cumberlandia monodonta (Spectaclecase) collected on the Kanawha River, Fayette County.

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WVDNR biologist - retired, Craig Stihler, sorts a substrate sample looking for mussels. Not all mussels are visible at the substrate surface, in particular juveniles. Some species may remain entirely buried during much of their life except when reproductively active. In order to get a true representation of a population, substrate samples are collected and sorted.

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Wicket Dam:
https://commons.wikimedia.org/wiki/File:Dam_number_6,_Ohio_River_Wickets_and_Props.jpg
Epioblasma triquetra holding fish: Tyler Hern, USFWS.
Lasmigona complanata juvenile: Patricia Morrison, USFWS - retired
Parvaspina collina with spine: Benjamin Humphrey
Smallmouth bass in lifecycle: Alyssa Jones
Blue catfish gut contents: Kathy Higgs
Janet Clayton and Patricia Morrison: Kristin Stockton Schmidt
Dive team and mussel brailing: Craig Stihler, WVDNR – retired

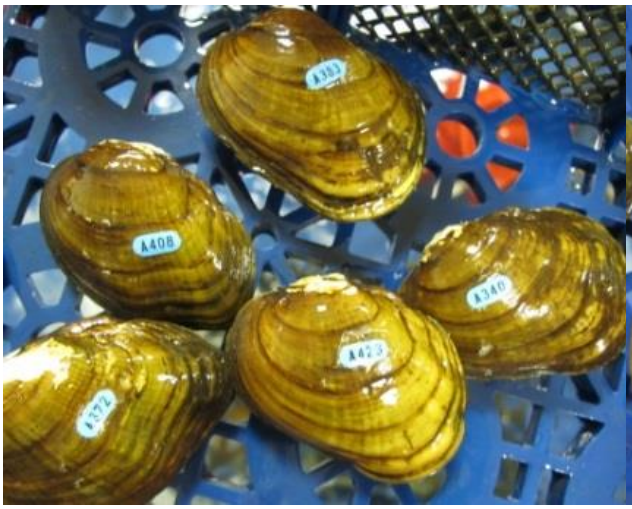
WVDNR biologists Janet Clayton (left) and Mike Everhart (right) with members of the USFWS dive team (Janet Gouvas, Julie Devers, and Patricia Morrison) aboard WVDNR's mussel dive boat, "Mussel Bound", following a day's work surveying the Marmet Pool of the Kanawha River in 2006. A systematic survey of the pool was conducted from 2006 through 2008 which was funded by the USCOE as mitigation for construction impacts from work on the Marmet Lock and Dam.

WVDNR biologists, Mike Everhart and Kristin Stockton (right), dig quadrat substrate samples, placing them into bags that were carried to shore and searched for mussels. This same method can also be conducted via SCUBA diving.

Stable mid-channel bars like this one below on the Greenbrier River provide essential mussel habitat. The channel along this right descending bank contains a mussel concentration that has been monitored since 2004. The area is broken into 2m-wide cells that span the width of the channel and all mussels observed are identified and measured. Long-term monitoring sites are typically assessed every five years.

In 2012 WVDNR cooperated with the PA Fish and Boat Commission and EnviroScience Inc. to obtain *E. rangiana* for restoration efforts on the Elk River. In 2014, efforts were expanded as the result of a large number of individuals being available due to a bridge salvage project on the Allegheny River, PA. Additional restoration sites were then added on the Kanawha and Ohio rivers.

Prior to stocking, all mussels for restoration were tagged with a poly tag (below left) that may be uniquely numbered for individual tracking or tagged with a blank tag. For federally listed species such as *Epioblasma rangiana*, a large number of them were also PIT-tagged (below right) which helps to locate mussels that are buried out of sight.



WVDNR biologists, Jack Wallace and Justin Rappold (left photo), scan the bottom of the stream with an antenna attached to a reader, attempting to locate PIT-tagged mussels.

Brailing was once used to survey for, and commercial harvest of freshwater mussels. A brail consists of a series of hooks attached to a pole that is dragged slowly downstream along the river bottom. When a hook drops into the gap of an open mussel, by reflex it closes tightly on the hook and thus is captured. After a period of time the brail is raised to the surface and the catch assessed. This method was only thought to effectively capture about 1% of the population. Some mussel species such as the heavy Washboard or the deeply buried *Lampsilis* species were not effectively sampled. With the onslaught of zebra mussels, which covered the gap and thus prohibited capture, this method became obsolete. At that time SCUBA diving became the best method for sampling deep rivers. Below USFWS staff assesses a brail haul ca.1985 on the Ohio River.

Craig Stihler

Craig Stihler

In January of 2005, a tow boat pushing a series of barges up the Ohio River locked through the Belleville Lock and Dam. The river was at flood stage and as the tow pushed out into the current it lost control as it was under-powered for the conditions. Several barges were overturned and went through the dam; 3 others got caught cross-wise in the dam and blocked 3 gates open. Upstream dams were directed to hold back as much water as they could so that salvage operations could be undertaken to free the barges. Over a month later they were removed but not before the Belleville Pool dropped 16 feet below normal pool. Mussels were exposed in freezing conditions which included the significant mussel beds at the heads of the islands. This photo shows the mussel kill assessment that was conducted at the head of Blennerhassett Island. This is an example of how surveys are conducted underwater as well. Replace two persons on hands and knees with two divers, swimming along the transect line looking for mussels within a half meter of the line.