Species Action Plan:
Salamander Mussel
(*Simpsonaias ambigua*)

Purpose: This plan updates the original 2015 SAP provides a five-year blueprint for the actions needed to attain near-term and, ultimately, long-term goals for the conservation and recovery of the state endangered Salamander Mussel. Given the complexity of managing and recovering this species, this plan will be continually updated to reflect progress toward the identified goals, and to incorporate new information. This SAP also includes a description of the species natural history, its distribution, and threats that have led to its rarity or imperilment.

Goal: The goal of this plan is to provide guidance for the maintenance, augmentation, and protection of extant populations of Salamander Mussel in the Commonwealth and to ensure sufficient distribution to adequately secure the species' Pennsylvania range.

Natural History

Taxonomy: Class Bivalvia, Order Unionoida, Family Unionidae (unionids), Salamander Mussel (*Simpsonaias ambigua*, Say, 1825). Nomenclature follows Williams et al. (2017) et seq.

Description: Parmalee and Bogan (1998) described the Salamander Mussel's shell characteristics as "thin, fragile, considerably elongated, and inflated, especially along the broadly rounded posterior ridge, which is sometimes more swollen in females. This is a small species – individuals rarely exceed 50 mm in length." The shell noticeably lacks rays and is differentiated from similar-looking Anodontine genera *Anodontoides, Pyganodon,* and *Strophitus* by having rudimentary cardinal teeth (Watters et al. 2009).

Figure 1. Salamander Mussel (*Simpsonaias ambigua*), Photo credit: Karen Little, Illinois State Museum

Habitat: The Salamander Mussel is found in riverine conditions underneath large, flat shelter rocks where it typically co-occurs with its only known host, the Common Mudpuppy (*Necturus maculosus*).

Life History: The maximum age of Salamander Mussels is approximately 10 years, although most individuals collected have been around 4-5 years of age (Watters et al. 2009). The Salamander Mussel is a long-term brooder (bradytictic) and releases its glochidia (larvae) in the spring. The Salamander Mussel is the only North

American unionid that uses an amphibian host. The Salamander Mussel diet is unknown, but presumed to be bacteria, detritus, phytoplankton, and zooplankton.

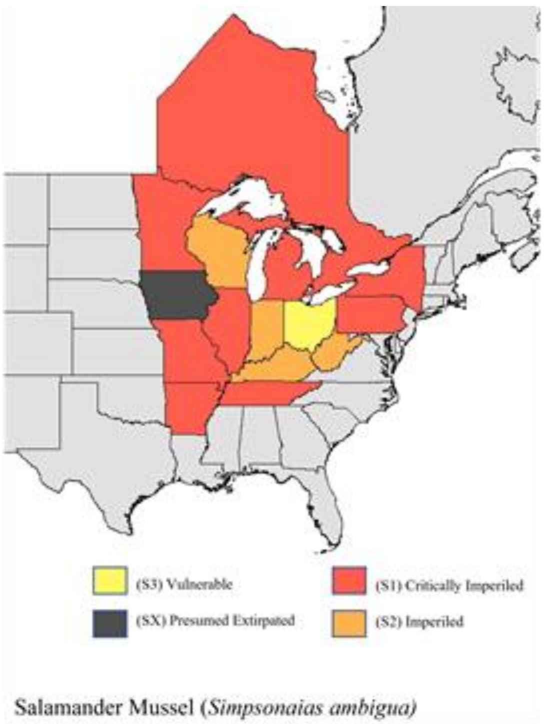

Figure 2. Salamander Mussel national range and conservation status (NatureServe 2022).

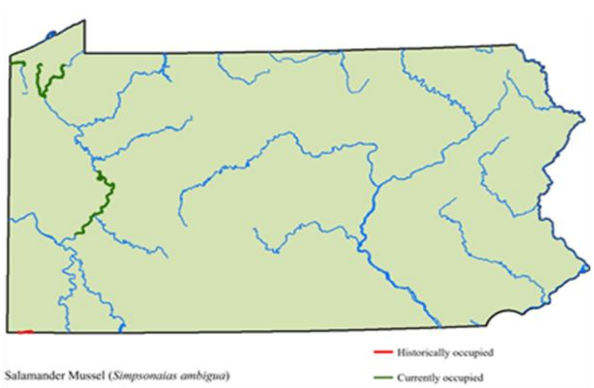

Figure 3. Salamander Mussel historic and extant occupied watersheds in Pennsylvania.

Distribution and Status

National Distribution: National Distribution: The Salamander Mussel is restricted to North American streams and rivers in the Great Lakes and the Mississippi and Ohio river basins of the following states: Arkansas, Illinois, Indiana, Iowa, Kentucky, Michigan, Minnesota, Missouri, New York, Ohio, Pennsylvania, Tennessee, West Virginia, Wisconsin and Ontario, Canada (NatureServe 2022) (Figure 2).

Pennsylvania Distribution: Little is known about the historical distribution of this species in Pennsylvania. Early surveys (e.g., Ortmann 1919) did not detect this species. The first occurrence of this species in Pennsylvania are specimens collected from Allegheny River pool 5 by D. Tanner (1968) and D. Stansbery (1970) (Clarke 1985).

Extant Salamander Mussel occurrences are known from the Allegheny River navigational pools 3, 5, 6, 8 and 9 (Bogan and Locy 2009; Lewis Environmental Consulting 2016). The Salamander Mussel is also known from the Ohio River in West Virginia (Morrison 2012) and from Lake Erie tributaries (Watters et al. 2009). An Ohio Conneaut Creek specimen was collected less than 1 km from the Pennsylvania/Ohio border of this shared waterway (Ohio DNR, personal communication).

Two shell specimens were collected from French Creek in 1985 and 1995 by C. Bier

(Western Pennsylvania Conservancy). EnviroScience recently collected live individuals from French Creek at Cambridge Springs and along Cussewago Creek, a French Creek tributary located near Meadville, Pennsylvania (Schwegman and Welte 2019).

The Salamander Mussel also occurred in Dunkard Creek prior to a 2009 toxic event, which destroyed the Dunkard Creek mussel fauna (Zeto 1982; Wood 1994; PFBC unpublished data).

Pennsylvania Legal Status: Endangered (58 Pa. Code §75.1).
State Rank: S1 – Critically Imperiled (assessed 2014)
Global Status: G3 – Vulnerable (assessed 2007)

The Salamander Mussel will be considered for delisting when 80% of the historically occupied streams contain three distinct naturally reproduced year classes (PABS Bivalve Committee listing criteria) and a minimum number of individuals in each stream. A minimum number will be determined after analysis of occupied streams. Historical populations can include yet-undiscovered populations. Populations that contain at least three distinct year classes and a minimum number of individuals will be considered viable. A viable population is defined as a naturally reproducing population large enough to maintain sufficient genetic variation to enable it to evolve and respond to natural environmental changes (Soule 1980).

Management Status

The Allegheny River, French Creek, Cussewago Creek, Dunkard Creek, and Conneaut Creek have all been surveyed within the past 25 years. Due to upstream and downstream occurrences, the Pennsylvania portion of the Ohio River is presumed occupied by Salamander Mussels, but at densities likely too low to detect.

Population trends:
In the absence of other information, the status of the Allegheny River and French Creek population is presumed stable. The Dunkard Creek mussel population was destroyed by a 2009 toxic event (PFBC, unpublished data). No live specimens of this species have been collected from the Pennsylvania portion of Conneaut Creek (PFBC, unpublished data).

Threats

Historical threats have resulted in a decline of Pennsylvania's Salamander mussel populations, e.g., Ortmann (1909). Due to the historical and recent distribution of Salamander Mussels over a broad swath of western Pennsylvania's landscape, qualitative uncertainty ranges were used to measure the scope of threats facing this species. The following broad threats categories follow Salafsky et al. (2008).

Existing and possible future threats to the Pistolgrip include the following:

1) Agriculture and aquaculture: Non-point source pollution from agricultural activities, particularly the introduction of nitrogen and phosphorus that contribute to stream and river eutrophication and sedimentation, has the potential to adversely affect mussel habitat or alter biological functioning within the stream or river. Sediment can clog the gills of mussels, affect filter-feeding of mussels, and decouple host fish from mussels during critical life stages (see Brim Box and Mossa 1999).

2) Energy production and mining: Commercial sand and gravel dredging and navigational channel maintenance dredging activities in the Allegheny River have historically resulted in the wholesale physical removal and loss of river habitat available for Salamander Mussel.

3) Transportation and service corridors
    a. Roads and railroads: Bridge projects on streams and rivers with Salamander Mussel populations may result in temporary or permanent habitat alteration, mussel mortality via direct impacts (e.g., crushing) or indirect impacts (e.g., sediment deposition), and mortality associated with relocating mussels out of harm's way.
    b. Utility and service lines: The threats associated with pipeline crossings could be locally severe; however, severity is reduced when stream crossings are accomplished using directional boring methods. Directional boring is preferred where feasible despite risks associated with inadvertent returns. Inadvertent returns may lead to the smothering of mussels or the choking of interstitial spaces or host fish habitat.

4) Invasives and other problematic species and genes
    a. Invasive non-native/alien species**:** French Creek and tributary populations are at risk due to the spread of the non-native, molluscivorous Round Goby (*Neogobius melanostomus*). The extent or magnitude of this threat is still under study, but of grave concern (Clark et al. 2022). The Round Goby threat level may be high due to observations that male

and female Round Gobies guard their nests under large rocks in LeBoeuf and French creeks (Kyle Clark, personal communication). This behavior may have dire impacts on the recruitment of both the Mudpuppy hosts and the mussels themselves (Kyle Clark, personal communication). The correlation between North American enigmatic mussel declines and the non-native Asian Clam (*Corbicula fluminea*), is also under study. The combined effects of increased salinity and the invasive Golden Algae (*Prymnesium parvum*) has had a deadly effect on the Dunkard Creek mussel population. The well documented adverse effects of dreissenid mussels (e.g., Zebra Mussel, *Dreissena polymorpha*) continue to be concern throughout large river navigation channels and other slow-moving portions of the Salamander Mussel's historical and extant range.

b. Problematic native species**:** The extent to which freshwater mussels, including Salamander Mussel, are vulnerable to native molluscan and non-molluscan diseases or pathogens is becoming better known (e.g., Richard et al. 2022).

5) Pollution

a. There are risks associated with industrial accidents or spills exist although the scope and severity of this particular risk is unpredictable. A single catastrophic pollution event could destroy a Pennsylvania stream or river population. The continued application of 3-trifluoromethol-4-nitrophenol (TFM) lampricide to Conneaut Creek, a Lake Erie tributary is likely to depress populations of both the Salamander Mussel and its host, the Mudpuppy (Brancato 2018; Matson 1990, 2013). The spring timing of TFM application approximately coincides with the discharge and inoculation of Mudpuppies by Salamander Mussel glochidia. TFM applied prior to or immediately after Mudpuppy inoculation may result in direct mortality or a poor Salamander Mussel recruiting class. Adverse effects associated with TFM would be expected along the entire stream length in both Pennsylvania and Ohio.

Mussels in general are particularly vulnerable to pH alterations, sodium, chlorides, ammonia, nickel, and other constituents with varying life stages (e.g., glochidia, juveniles) being particularly sensitive. The scope and severity of these constituents may vary throughout the Salamander Mussel's range depending upon the nature of the effluent.

b. Agricultural and forestry effluents: Increased sedimentation remains a threat to mussels, host fish, substrate integrity, and overall water quality.

Mussels that depend upon direct interactions with the host, or the host and their conglutinates, risk being decoupled during this critical life stage. Host fish that rely on clean swept substrates for critical life stages are also at risk in streams that suffer from excess sedimentation.

6) Climate change and severe weather:
   a. Habitat shifting and alteration
      Major shifts or alteration of water quantity, quality, and temperature can have severe effects on freshwater mussels (PFBC 2022). Abnormally high or low flows that disrupt mussel reproduction at key periods, such as fertilization and glochidia release, are likely to decouple male-female gamete interactions or result in host fish behavioral changes that decouple the transfer of larvae to hosts. Habitat alterations are anticipated with predicted increasing storm intensities and associated flooding or via fluctuations in wetted widths associated with drought conditions. These oscillations are likely to result in increased channel instability and bank failure contributing to habitat loss or degradation.

   b. Droughts:
      As aquatic animals, mussels are extremely sensitive to drought conditions which lower water levels, dewater formerly wetted channels, desiccate mussels, increase water temperatures, occlude mussels, and contribute knock-on effects such as toxicity via low dissolved oxygen levels, elevated temperatures, and concentrated pollutants.
   c. Temperature extremes:
      Extreme temperatures are anticipated to have a direct effect on freshwater mussel communities (e.g., Galbraith and Vaughn 2010). Mussels rely on thermal cues for feeding and reproduction and disruptions to these cues can result in decreased fecundity, brood abortion, increased parasite loads, or asynchronous timing of larval release with the presence of obligate host fish (PFBC 2022).
   d. Policy:
      Climate change policy that calls for drainage "improvement" or flood control measures have the potential to further altered flow patterns during the year, (flooding and drought), contribute to stream bank failure and riverbed destabilization, erratic temperatures, and perhaps demands to alter reservoir flow discharges to maintain downstream sport fisheries needs in direct competition with endangered species management.

Conservation and Recovery

Conservation and Recovery Goal: The goal of this plan is to implement actions that maintain, augment, protect, and enhance extant populations of Salamander Mussel in the Commonwealth and ensure sufficient distribution to adequately secure the species and allow its removal from the Pennsylvania list of endangered species (58 Pa. Code §75.1). The location of PFBC's Union City Aquatic Conservation Center's mussel propagation facility within the heart of the species Pennsylvania range and within close proximity to brood stock sources may allow PFBC to be an effective partner assisting future efforts to restore the species North American range.

In general, PFBC encourages the use of the online Pennsylvania Conservation Explorer environmental review tool and Conservation Opportunity Areas tool to restore degraded habitats and facilitate watershed-level water quality enhancements. Habitat conservation and protection in the form of riparian restoration via tree-plantings, land acquisition, or easements is encouraged; however, instream habitat management proposals for Salamander Mussel – unless related to natural shelter rock-type structures – are generally discouraged.

Allegheny and Ohio Rivers

1) Protect, conserve, and enhance existing Salamander Mussel populations located in the navigational pools
    a. Continue to gather baseline information
        i. Characterize Salamander Mussel populations
            1. Collect the following quantitative population demographic information:
                A. Age structure (e.g., shell thin-sectioning)
                B. Shell lengths
                C. Determine specific gravidity period, ratio of gravid/nongravid individuals using non-lethal methods
                D. Number of individuals
                E. Density, if practical
                F. Number of individuals found underneath each surveyable rock structure
        ii. Quantitatively and qualitatively characterize physical habitat
            1. Measure streamflow, water chemistry at known locations
            2. Measure length, width, depth of occupied rock structures
            3. Estimate number or density of rock structures in occupied areas
            4. Qualitatively describe surrounding habitat associated with occupied rock structures

    b. Improve or create habitat in the Allegheny and Ohio River navigational pools
        i. Concurrent with a silo study, design and implement an experimental habitat project
            1. Develop experimental design for silo and structure placement in the following areas:
                a. Pools with Salamander Mussels and mudpuppies
                b. Pools without Salamander Mussels but contain mudpuppies
            2. Determine source of structure material
            3. Place and monitor silos and structures

French Creek, Cussewago Creek, and French Creek tributaries

1. Protect, conserve, and enhance population
    a. When feasible, gather baseline quantitative information

i. Characterize French Creek basin Salamander Mussel populations
   1. Collect the following quantitative population demographic information:
      a. Age structure (e.g., shell thin-sectioning)
      b. Shell lengths
      c. Determine gravidity period of Pennsylvania
      d. Ratio of gravid/nongravid (using non-lethal methods)
      e. Number of individuals
      f. Density, if practical
      g. Number of individuals found underneath each surveyable rock structure

ii. If Salamander Mussel population found, characterize host (Mudpuppy) population
   1. Use same sampling methodology developed for the Allegheny River (see above)

Dunkard Creek

1) Restore Dunkard Creek Salamander Mussel population,
   a. Continue implementing PFBC Dunkard Creek mussel restoration plan
   b. Restore/recover mudpuppy population
   c. Restore native mussel community, including Salamander Mussel
   d. Maintain water volume and flow
      i. Work with USEPA, PADEP, WVDEP, AND WVDNR to develop flow recommendations that are protective of Salamander Mussel
   e. Ensure protection from pollution and invasive species
      i. Work with partners to monitor TDS and osmotic pressure
      ii. Work and communicate with partners to monitor golden algae (*Prymnesium parvum*) levels in Dunkard Creek including sampling for residual spores as feasible

Threat Mitigation

1) Identify and mitigate microscope threats to Pistolgrip (e.g., disease, pathogens)
2) Conduct DNA testing to address genetic concerns
3) Maintain existing habitats and facilitate genetic connectivity, where feasible

Long-term Monitoring

1) Begin long-term monitoring of Allegheny River populations
   a. Identify and establish long-term sentinel monitoring sites for Allegheny River (3 total sites)

Propagation, Augmentation, Reintroduction, and Habitat Restoration

1) Propagation
   a. Determine feasibility of establishing a Salamander Mussel propagation program at PFBC’s Union City Aquatic Conservation Center
   b. Develop Salamander Mussel propagation techniques
2) Augmentation
   a. Augment streams with known Salamander Mussel populations (e.g., Allegheny, Ohio, French Creek (and tributaries), and Dunkard Creek)
3) Habitat Restoration
   a. Using existing data and tools (e.g., Conservation Opportunity Areas tool), identify areas where

habitat restoration efforts would benefit Salamander Mussels
b. Determine shelter rock material (natural or man-made)

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