

**Snuffbox**  
**(*Epioblasma triquetra*)**

**5-Year Review:**  
**Summary and Evaluation**



Photo Credit: G. Thomas Watters, Ohio State University

**August 2018**

**U.S. Fish and Wildlife Service, Midwest Region**  
**Ecological Services Field Office**  
**Columbus, Ohio**

## 5-YEAR REVIEW

### Snuffbox – *Epioblasma triquetra*

#### 1.0 GENERAL INFORMATION

#### 1.1 Reviewers

**Lead Regional Office:** Region 3, Laura Ragan, (612) 713-5157

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**Cooperating Field Offices:**

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Pennsylvania Field Office, Bob Anderson, (814) 234-4090, ext. 7447

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West Virginia Field Office, Barb Douglas, (304) 636-6586, ext. 19

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**Cooperating Regional Offices:**

Region 4, Kelly Bibb, (404) 679-7132

Region 5, Mary Parkin, (617) 417-3331

#### 1.2 Methodology used to complete the review:

Public notice was given in the *Federal Register* (82 FR 18156) requesting new scientific or commercial data and information that may have a bearing on the snuffbox (*Epioblasma triquetra*) classification of endangered status. Pertinent data was obtained from the Final Rule (77 FR 8632), from recent reports of freshwater mussel surveys, and from data submitted by U.S. Fish and Wildlife Service (Service) Field Offices and State and Provincial natural resource agencies within the range of the species. This 5-year review was completed by Angela Boyer, Fish and Wildlife Biologist with the Ohio Ecological Services Field Office. The focus of this 5-year review is to summarize the current status of the snuffbox. The purpose of this 5-year review is to review new information since the last review of the species' status (the time of listing, 2012) and

consider whether any of this information indicates that a change in the listing status of the snuffbox may be warranted.

### **1.3 Background:**

#### **1.3.1 FR Notice citation announcing initiation of this review:**

82 FR 18156 (April 17, 2017) – Endangered and Threatened Wildlife and Plants; Initiation of a 5-Year Status Reviews of Eight Endangered Animal Species: Iowa Pleistocene snail (*Discus macclintocki*), Karner blue butterfly (*Lycaeides melissa samuelis*), Kirtland’s warbler (*Setophaga kirtlandii* [= *Dendroica kirtlandii*]), Ozark hellbender (*Cryptobranchus alleganiensis bishop*), rayed bean (*Villosa fabalis*), sheepnose (*Plethobasus cyphus*), snuffbox (*Epioblasma triquetra*), and spectaclecase (*Cumberlandia monodonta*).

#### **1.3.2 Listing history**

Original Listing

**FR notice:** 77 FR 8632

**Date listed:** February 14, 2012

**Entity listed:** Snuffbox (*Epioblasma triquetra*); Species

**Classification:** Endangered

#### **1.3.3 Associated rulemakings:** none

#### **1.3.4 Review History:** none

#### **1.3.5 Species’ Recovery Priority Number at start of 5-year review:** 5.

The “5” indicates a high degree of threat, low recovery potential, and a taxonomic classification as a species.

#### **1.3.6 Recovery Plan or Outline:** Recovery Outline completed June 27, 2012.

## **2.0 REVIEW ANALYSIS**

### **2.1 Application of the 1996 Distinct Population Segment (DPS) policy**

#### **2.1.1 Is the species under review a vertebrate?** No

### **2.2 Recovery Criteria**

#### **2.2.1 Does the species have a final, approved recovery plan containing objective, measurable criteria?** No

## 2.3 Updated Information and Current Species Status

### 2.3.1 Biology and Habitat

#### 2.3.1.1 New information on the species' biology and life history:

We have no new information on the biology and life history of this species since listing.

#### 2.3.1.2 Abundance, population trends (e.g. increasing, decreasing, stable), demographic features (e.g., age structure, sex ratio, family size, birth rate, age at mortality, mortality rate, etc.), or demographic trends:

The snuffbox was listed as endangered in 2012. At the time of listing, the snuffbox was thought to be extant in 79 streams in 14 states and 1 Canadian province: Alabama (Tennessee River, Paint Rock River, and Elk River), Arkansas (Buffalo River, Spring River, and Strawberry River), Illinois (Kankakee River and Embarras River), Indiana (Pigeon River, Salamonie River, Tippecanoe River, Sugar Creek, Buck Creek, Muscatatuck River, and Graham Creek), Kentucky (Tygarts Creek, Kinniconick Creek, Licking River, Slate Creek, Middle Fork Kentucky River, Red Bird River, Red River, Rolling Fork Salt River, Green River, and Buck Creek), Michigan (Grand River, Flat River, Maple River, Pine River, Belle River, Clinton River, Huron River, Davis Creek, South Ore Creek, and Portage River), Minnesota (Mississippi River, St. Croix River), Missouri (Meramec River, Bourbeuse River, St. Francis River, and Black River), Ohio (Grand River, Ohio River, Muskingum River, Walhonding River, Killbuck Creek, Olentangy River, Big Darby Creek, Little Darby Creek, Salt Creek, Scioto Brush Creek, South Fork Scioto Brush Creek, Little Miami River, and Stillwater River), Pennsylvania (Allegheny River, French Creek, West Branch French Creek, LeBoeuf Creek, Woodcock Creek, Muddy Creek, Conneaut Outlet, Little Mahoning Creek, Shenango River, and Little Shenango River), Tennessee (Clinch River, Powell River, Elk River, and Duck River), Virginia (Clinch River and Powell River), West Virginia (Ohio River, Middle Island Creek, McElroy Creek, Little Kanawha River, Hughes River, North Fork Hughes River, and Elk River), and Wisconsin (St. Croix River, Wolf River, Embarrass River, Little Wolf River, and Willow Creek); and Ontario, Canada (Ausable River and Sydenham River).

There are five additional streams (Cussewago Creek (PA), West Fork River (WV), Meathouse Fork (WV), South Fork Hughes River (WV), and Kanawha River (WV)) that may have extant populations of snuffbox that were not included in the final listing rule. In 2011, a single fresh dead snuffbox was found in Cussewago Creek, a tributary to French Creek in Pennsylvania, indicating that snuffbox may still be extant in this stream (Welte 2011, pers. comm.). In 1998 and 2001, a few live snuffbox were observed in Meathouse Fork of Middle Island Creek in West Virginia. One live snuffbox was observed in the South Fork Hughes River in 2001 and one in 2017 (Douglas 2016, pers. comm.);

Enviroscience 2017). One live snuffbox was found in the West Fork River in West Virginia in 2015 (Douglas 2016, pers. comm.). In 2016, one live snuffbox was found about two miles (3.2 km) downstream of the confluence with the Elk River. The species was assumed to be historically present in the Kanawha River but this was not noted at the time of listing (WVDNR 2016).

Two streams, Willow Creek (WI) and Kankakee River (IL), were reported as having extant populations of snuffbox at the time of listing but are considered to be extirpated or possibly never present, in the case of Willow Creek. The final listing rule included a report of a single observation of two live females in Willow Creek in 2001. Piette (2014) reports that the 2001 Willow Creek record was likely a misidentified elktoe (*Alasmidonta marginata*). The 2001 record was the only one for Willow Creek so it is possible that the snuffbox never occurred in that stream. The last record of a snuffbox in the Kankakee River was a fresh dead specimen in 1991. Tiemann (2016, pers. comm.) reports that the 1991 record should have been reported as a relic and that the snuffbox is considered to be extirpated from the Kankakee River.

With the noted changes above (the addition of 5 streams and removal of 2 streams), the snuffbox is currently considered to be extant in 82 streams. Table 1 provides a population summary for all streams thought to harbor extant snuffbox populations.

Butler (2007) categorized the extant populations into three groups based on population size: general distribution, evidence of recent recruitment, and assessment of current viability. Stronghold populations were described as having sizable populations; generally distributed over a significant, and more or less contiguous, length of stream (30 or more river mile (48 or more river km)), with ample evidence of recent recruitment; and currently considered viable. Significant populations were defined as small, generally restricted populations with limited recent recruitment and viability. Many significant populations are susceptible to extirpation, but this category has a broad range of quality. The third category, marginal populations, are defined as those which are very small and highly restricted, with little to no evidence of recent recruitment, of questionable viability, and that may be on the verge of extirpation in the immediate future. Following this criteria, there are currently 7 stronghold populations, 24 significant populations, and 51 marginal populations of snuffbox (Table 1).

Butler (2007) considered a population extant if live individuals or fresh dead specimens have been located since approximately 1985. In this 5-year review, this same approach is used. The Service has no standard timeframe for determining when a species is extant or extirpated from a stream based on the last year of observation. Often, a lack of observations in subsequent years may simply be due to a lack of survey effort. Difficulty in detecting snuffbox can also result in poorly defined distribution information. A population is considered to be

recruiting if there was recent (within approximately 10 years) evidence of subadults (generally, individuals less than or equal to 1.5 in (3.8 cm) long or less than or equal to 4 years).

Viability assessments are based on evidence of recent recruitment (generally, subadults are considered individuals  $\leq 1.5$  inches and/or  $\leq 4$  years) or the presence of individuals in multiple age classes, population size, and spatial extent of the population (occupying a significant linear reach of stream) (Butler 2007).

Butler (2007) also categorized populations according to their general size of small, medium, or large. Large populations are those that are generally distributed and common in  $>10$  river miles (16 river km). Medium populations are sporadic and generally uncommon throughout a stream or common only in a restricted reach ( $< 3$  river miles/ $<4.8$  km). Small populations are rare and restricted to at most a few sites.

The Service currently has no updated occurrence data information since the time of listing for the following 34 streams: Pigeon River (MI), Davis Creek (MI), South Ore Creek (MI), Portage River (MI), Meremec River (MO), Ohio River (OH, WV), Allegheny River (PA), West Branch French Creek (PA), Woodcock Creek (PA), Muddy Creek (PA), Conneaut Outlet (PA), Little Mahoning Creek (PA), McElroy Creek (WV), Walhonding River (OH), Hughes River (WV), Tygarts Creek (KY), Little Darby Creek (OH), Salt Creek (OH), Scioto Brush Creek (OH), South Fork Scioto Brush Creek (OH), Kinniconick Creek (KY), Little Miami River (OH), Licking River (KY), Slate Creek (KY), Middle Fork Kentucky River (KY), Red Bird River (KY), Red River (KY), Green River (KY), Buck Creek (IN), Muscatatuck River (IN), Graham Creek (IN), Buck Creek (KY), Tennessee River (AL), and Buffalo River (AR).

At the time of listing, the snuffbox population size for 3 of these 34 streams was considered to be medium. Twenty nine of the populations were considered to be small (rare and restricted to at most a few sites) and two had an unknown population size. The population trend for all of these 34 streams was considered to be either declining or unknown. Only 4 of these 34 streams were known to be recruiting at the time of listing with 3 of the 4 having a high potential viability. Based on the absence of any updated information, the status of these 34 populations (Table 1) remains unchanged since the species was listed in 2012. A summary of the status of these streams can be found in the final listing rule (77 FR 8632).

Table 1. Snuffbox extant stream population summary by stream of occurrence. (*italics indicate new populations discovered since the species was listed in 2012*) (Data provided by states and/or Service Field Offices).

| Stream (State)                | Last Observation | Recruiting     | Potential Viability | Population Size | Population Trend | Status Category |
|-------------------------------|------------------|----------------|---------------------|-----------------|------------------|-----------------|
| Wolf River (WI)               | 2017             | Yes            | High                | Large           | Declining        | Significant     |
| Embarrass River (WI)          | 2016             | Yes            | Low                 | Small           | Declining        | Marginal        |
| Little Wolf River (WI)        | 2016             | Yes            | Low                 | Medium          | Declining        | Marginal        |
| Grand River (MI)              | 2017             | Yes            | High                | Large           | Unknown          | Stronghold      |
| Flat River (MI)               | 2013             | Yes            | High                | Medium          | Unknown          | Significant     |
| Maple River (MI)              | 2014             | Unknown        | Unknown             | Small           | Unknown          | Marginal        |
| Pigeon River (IN)             | 1998             | Unknown        | Unknown             | Small           | Unknown          | Marginal        |
| Ausable River (ON)            | 2013             | Yes            | High                | Large           | Unknown          | Stronghold      |
| Pine River (MI)               | 2013             | Unknown        | Low                 | Small           | Unknown          | Marginal        |
| Belle River (MI)              | 2016             | Yes            | High                | Small           | Unknown          | Significant     |
| Clinton River (MI)            | 2013             | Yes            | High                | Large           | Declining        | Significant     |
| Sydenham River (ON)           | 2015             | Yes            | High                | Large           | Unknown          | Stronghold      |
| Huron River (MI)              | 2016             | Unknown        | Low                 | Medium          | Unknown          | Significant     |
| Davis Creek (MI)              | 2008             | Yes            | High                | Medium          | Unknown          | Significant     |
| South Ore Creek (MI)          | 1999             | Yes            | High                | Small           | Unknown          | Significant     |
| Portage River (MI)            | 1998             | Yes            | High                | Medium          | Unknown          | Significant     |
| Grand River (OH)              | 2016             | Yes            | High                | Medium          | Unknown          | Significant     |
| Upper Mississippi River (MN)  | 2013             | No             | Unknown             | Unknown         | Unknown          | Marginal        |
| St. Croix River (MN and WI)   | 2017             | Yes            | High                | Large           | Stable           | Significant     |
| Meramec River (MO)            | 1997             | Unknown        | Unknown             | Small           | Declining        | Marginal        |
| Bourbeuse River (MO)          | 2014             | Yes            | High                | Large           | Improving        | Stronghold      |
| Ohio River (OH, WV)           | 2001             | Unknown        | Low                 | Small           | Unknown          | Marginal        |
| Allegheny River (PA)          | 2001             | Unknown        | Unknown             | Small           | Unknown          | Marginal        |
| French Creek (PA)             | 2017             | Yes            | High                | Large           | Stable           | Stronghold      |
| West Branch French Creek (PA) | 2008             | Unknown        | Unknown             | Small           | Unknown          | Marginal        |
| LeBoeuf Creek (PA)            | 2014             | Yes            | Low                 | Small           | Unknown          | Marginal        |
| Woodcock Creek (PA)           | 2007             | Unknown        | Unknown             | Small           | Unknown          | Marginal        |
| Muddy Creek (PA)              | 2008             | Yes            | Low                 | Medium          | Unknown          | Significant     |
| <i>Cussewago Creek (PA)</i>   | <i>2011</i>      | <i>Unknown</i> | <i>Unknown</i>      | <i>Unknown</i>  | <i>Unknown</i>   | <i>Marginal</i> |

|                                     |             |                |                |                |                  |                 |
|-------------------------------------|-------------|----------------|----------------|----------------|------------------|-----------------|
| Conneaut Outlet (PA)                | 1997        | Unknown        | Unknown        | Small          | Unknown          | Marginal        |
| Little Mahoning Creek (PA)          | 1991        | Unknown        | Unknown        | Small          | Unknown          | Marginal        |
| <i>West Fork River (WV)</i>         | <i>2015</i> | <i>Unknown</i> | <i>Unknown</i> | <i>Unknown</i> | <i>Unknown</i>   | <i>Marginal</i> |
| Shenango River (PA)                 | 2015        | Yes            | Unknown        | Small          | Unknown          | Significant     |
| Little Shenango River (PA)          | 2013        | Unknown        | Unknown        | Small          | Unknown          | Significant     |
| Middle Island Creek (WV)            | 2016        | Yes            | Unknown        | Small          | Declining        | Marginal        |
| McElroy Creek (WV)                  | 2010        | Unknown        | Unknown        | Unknown        | Unknown          | Marginal        |
| <i>Meathouse Fork (WV)</i>          | <i>2001</i> | <i>Unknown</i> | <i>Unknown</i> | <i>Unknown</i> | <i>Declining</i> | <i>Marginal</i> |
| Muskingum River (OH)                | ~2014       | Unknown        | Unknown        | Small          | Unknown          | Marginal        |
| Walhonding River (OH)               | 1991        | Unknown        | Unknown        | Small          | Declining        | Significant     |
| Killbuck Creek (OH)                 | 2017        | Unknown        | Unknown        | Small          | Declining        | Marginal        |
| Little Kanawha River (WV)           | 2017        | Yes            | Unknown        | Unknown        | Unknown          | Significant     |
| Hughes River (WV)                   | 2009        | Unknown        | Unknown        | Unknown        | Unknown          | Marginal        |
| North Fork Hughes River (WV)        | 2014        | Unknown        | Low            | Small          | Declining        | Significant     |
| <i>South Fork Hughes River (WV)</i> | <i>2017</i> | <i>Unknown</i> | <i>Unknown</i> | <i>Unknown</i> | <i>Unknown</i>   | <i>Marginal</i> |
| <i>Kanawha River (WV)</i>           | <i>2016</i> | <i>Unknown</i> | <i>Unknown</i> | <i>Unknown</i> | <i>Unknown</i>   | <i>Marginal</i> |
| Elk River (WV)                      | 2017        | Unknown        | Low            | Medium         | Improving        | Significant     |
| Tygarts Creek (KY)                  | 1995        | Unknown        | Unknown        | Small          | Declining        | Marginal        |
| Olentangy River (OH)                | 2013        | Unknown        | Unknown        | Small          | Declining        | Marginal        |
| Big Darby Creek (OH)                | 2015        | Unknown        | Unknown        | Small          | Declining        | Marginal        |
| Little Darby Creek (OH)             | 1999        | Unknown        | Unknown        | Small          | Declining        | Marginal        |
| Salt Creek (OH)                     | 1987        | Unknown        | Unknown        | Small          | Unknown          | Marginal        |
| Scioto Brush Creek (OH)             | 1987        | Unknown        | Unknown        | Small          | Unknown          | Marginal        |
| South Fork Scioto Brush Creek (OH)  | 1987        | Unknown        | Unknown        | Small          | Unknown          | Marginal        |
| Kinniconick Creek (KY)              | 2005        | Unknown        | Low            | Small          | Declining        | Marginal        |
| Little Miami River (OH)             | 1991        | Unknown        | Unknown        | Small          | Unknown          | Marginal        |
| Licking River (KY)                  | 2006        | Unknown        | Low            | Small          | Unknown          | Marginal        |
| Slate Creek (KY)                    | 1992        | Unknown        | Unknown        | Small          | Declining        | Marginal        |
| Stillwater River (OH)               | 2014        | Unknown        | Unknown        | Small          | Unknown          | Marginal        |
| Middle Fork Kentucky River (KY)     | 1997        | Unknown        | Unknown        | Small          | Unknown          | Marginal        |
| Red Bird River (KY)                 | 1995        | Unknown        | Unknown        | Small          | Unknown          | Marginal        |
| Red River (KY)                      | ~2002       | Unknown        | Unknown        | Small          | Unknown          | Significant     |
| Rolling Fork Salt River (KY)        | 2016        | Unknown        | Unknown        | Small          | Unknown          | Marginal        |
| Green River (KY)                    | 1989        | Unknown        | Unknown        | Small          | Declining        | Marginal        |



|                          |         |         |         |        |           |             |
|--------------------------|---------|---------|---------|--------|-----------|-------------|
| Salamonie River (IN)     | 2017    | Yes     | Low     | Small  | Unknown   | Significant |
| Tippecanoe River (IN)    | 2015    | Unknown | Unknown | Small  | Declining | Marginal    |
| Embarras River (IL)      | 2014    | Yes     | Low     | Small  | Declining | Significant |
| Sugar Creek (IN)         | 2017    | Unknown | Unknown | Small  | Declining | Marginal    |
| Buck Creek (IN)          | 1990    | Unknown | Unknown | Small  | Unknown   | Marginal    |
| Muscatatuck River (IN)   | 1988    | Unknown | Unknown | Small  | Unknown   | Marginal    |
| Graham Creek (IN)        | 1990    | Unknown | Unknown | Small  | Declining | Marginal    |
| Buck Creek (KY)          | 1987–90 | Unknown | Unknown | Small  | Declining | Marginal    |
| Clinch River (TN and VA) | 2015    | Yes     | High    | Large  | Stable    | Stronghold  |
| Powell River (TN and VA) | 2013    | Unknown | Unknown | Small  | Declining | Marginal    |
| Tennessee River (AL)     | 2006    | Unknown | Unknown | Small  | Unknown   | Marginal    |
| Paint Rock River (AL)    | 2015    | Yes     | High    | Large  | Improving | Stronghold  |
| Elk River (TN and AL)    | 2015    | Yes     | Low     | Small  | Stable    | Significant |
| Duck River (TN)          | 2014    | Unknown | Unknown | Small  | Unknown   | Marginal    |
| St. Francis River (MO)   | 2014    | Yes     | High    | Medium | Stable    | Significant |
| Buffalo River (AR)       | 2006    | Unknown | Unknown | Small  | Unknown   | Marginal    |
| Black River (MO)         | 2012    | Unknown | Low     | Small  | Unknown   | Significant |
| Spring River (AR)        | 2017    | Unknown | Low     | Medium | Unknown   | Significant |
| Strawberry River (AR)    | 1997    | Unknown | Unknown | Small  | Unknown   | Marginal    |

The following summarizes new occurrence and/or threat information for 48 of the 82 streams that has been provided to the Service since the publication of the final listing rule. The 34 streams previously discussed that have no updates since listing are not included below.

#### Upper Great Lakes Sub-basin

The snuffbox is currently known from 7 streams in the upper Great Lakes sub-basin, down from 14 streams and lakes historically. Of these seven populations, five have shown recent evidence of recruitment. However, the trend for all of the upper Great Lakes populations are considered to be either declining or unknown. All but the Wolf, Grand, and Flat Rivers have populations that are considered marginal, though the Flat River population is restricted to only the lower half-mile of the river. The Grand River (MI) population is the only large, stronghold population in this sub-basin. The Fox River system in Wisconsin, particularly its major tributary, the Wolf River (and its tributaries), historically had a widespread and locally abundant population. The species is currently thought to be extant in seven sub-basin streams; however. As previously mentioned, the reported 2001 records for Willow Creek were misidentified as snuffbox and thus the snuffbox is

considered to be absent from this stream. Survey results of the Wolf River basin by Piette (2014) suggest that habitat fragmentation caused by multiple dams are preventing snuffbox from occupying much of their former range by disrupting logperch movements. Specifically, eight dams within the Wolf River basin appear to influence much of the snuffbox distribution within the Wolf River system. Snuffbox and logperch are either completely blocked from potential habitat by these dams or they are restricted to short reaches. Six of the seven extant streams have updated information since the time of listing.

*Wolf River* – The Wolf River is the major tributary of the Fox River draining a large portion of northeastern Wisconsin and flowing southward to join the Fox River at Lake Butte Des Morts, near Oshkosh, Wisconsin. There are historical snuffbox records from a 30-river-mile (48-river-km) reach in Shawano, Waupaca, and Outagamie Counties. Piette (2014) reports that snuffbox range in the Wolf River is now limited to a 4.5 mile (7.2 km) reach below the Shawano Dam, which prevents snuffbox from colonizing upstream. Piette (2014) also reports that snuffbox may be present upstream of the Balsam Row Dam on Menominee Tribal Lands, though permission to sample this reach has not been granted. At the time of listing, the Wolf River population was considered to be a stronghold population exhibiting a low level of recruitment (Butler 2007). Based on the limited reach of the current population (4.5 miles), this population is now considered to be significant rather than a stronghold (Piette 2014). Little else is known about the population though it is thought to be declining (Piette 2014). In 2016, Wisconsin Department of Natural Resources (DNR) recorded no evidence of snuffbox above the Shawano Dam. In 2016 and 2017, Wisconsin DNR conducted transect surveys (near Highway M) and recorded 12 live snuffbox, including 3 juveniles (Smith 2018, pers. comm.).

At the time of listing, the Wolf River population was considered to be a stronghold. Based on reporting by Piette (2014), the snuffbox is actually limited to a much shorter reach than previously reported. Therefore, this population no longer meets the definition of a stronghold population and is now categorized as a significant population.

*Embarrass River* – A western tributary of the lower Wolf River, the Embarrass River is 62.0 miles (100 km) long and parallels the western bank of the Wolf River before joining it at New London, Wisconsin. The river has four branches. The South and Middle Branches converge in Caroline, Wisconsin. Four miles east of this convergence, the South Branch and North Branch converge just upstream of Pella, Wisconsin. At the time of listing, snuffbox were only thought to occur in the mainstem below the dam in Pella, Wisconsin. Woolnough (2017, pers. comm.) reported that in 2016, 22 snuffbox were collected at one site in the South Branch near Hayman Falls Lane, Wisconsin. Piette (2014) reports that the snuffbox is currently limited to a 3.6 mile (5.8 km) reach of the mainstem, 2.8 miles (4.5 km) of the N. Branch Embarrass River below the Tilleda Dam, and 6.8 miles (10.9 km) of the S. Branch Embarrass River below the Caroline Dam. The

Caroline Dam prevents snuffbox colonization of the Middle Branch Embarrass River. At the time of listing, the population trend for the Embarrass River was unknown. New information from Piette (2014) indicates that the snuffbox appears to be declining in this stream. At the time of listing, it was unknown if the species was recruiting in the stream. Timed surveys upstream of the removed Hayman Falls Dam documented four live snuffbox, indicating recent recruitment (Piette 2014). In 2016 the Wisconsin DNR recorded two live snuffbox on the South Branch Embarrass River (near Hayman Falls Lane) and found only empty snuffbox shells on the North Branch (near North Branch Road) during quadrat sampling in 2016 (Smith 2018, pers. comm.).

*Little Wolf River* – The Little Wolf River is a western tributary of the lower Wolf River in Waupaca County, Wisconsin. At the time of listing, the snuffbox in the Little Wolf River was known only from a single live individual collected in 1988 at river mile 14 (river km 22.5), below the Mill Pond Dam at Manawa, Wisconsin (Butler 2007). Piette (2014) reports that the snuffbox occurs in an 11.4 mile (18.3 km) reach of the river extending downstream from the Mill Pond Dam to the Highway X Bridge. The Mill Pond Dam prevents upstream colonization. The dam was drawn down in 2012 for repairs and the effects on the mussel community are unknown at this time. The snuffbox also occurs in the lower five miles (8 km) of the South Branch Little Wolf River (Piette 2014). At the time of listing, it was unknown if this population was recruiting. Two juveniles were observed in 2013 and one in 2012 indicating that reproduction is occurring in this stream. In 2016, 22 snuffbox were collected during sampling in Manawa (Woolnough 2017, pers. comm.). In 2016, Wisconsin DNR compared the results of 2004 and 2016 quantitative surveys near Highway 22, which showed a significant decline in live snuffbox abundance (58 to 6 individuals) (Smith 2018, pers. comm.).

*Grand River* – The Grand River, a major Lake Michigan tributary, represents the largest lotic (moving water) watershed in Michigan and is located in the southwestern portion of the State. The snuffbox is sporadically distributed in at least a 30 river mile (48 river km) of the middle Grand River, approximately between the confluences of the Flat and Maple Rivers as well as a stretch of the river in Grand Rapids, Michigan (Pruden 2016, pers. comm.; Pruden 2018, pers. comm.). The population appears to be viable, with recruitment noted in 1999 (Badra 2008, pers. comm.; Zanatta 2011, pers. comm.). A mussel salvage in 2015 for the Lyons Dam removal project found and relocated 86 snuffbox. Threats in the Grand River watershed include dams; poor water quality due to agriculture, industry, and urban development; habitat loss and degradation; and invasive species (Pruden 2016, pers. comm.).

At the time of listing, the size of the Grand River population was thought to be medium and it was considered to be in the significant category. Data on this population obtained since listing has noted that the species likely occurs in a longer stretch of the river than previously known. Therefore, this warrants

changing the size category for this population to large and the status to a stronghold population (Pruden 2018, pers. comm.). Despite the recent data indicating that this population is larger and more widespread than previous known, the current trend of this population is still unknown.

*Flat River* – The Flat River is a tributary to the Grand River in Michigan. Zanatta (2011, pers. comm.) found 32 live snuffbox in the Flat River immediately upstream of the confluence with the Grand River in 2009. Nine live snuffbox, including one gravid individual, were found near the mouth in 2012 (Pruden 2016, pers. comm.). In 2013, 34 live snuffbox were found at this same location (Woolnough 2015, pers. comm.). The Flat River snuffbox population is considered to be significant, however snuffbox only occur in the lower portion for approximately 0.5 river mile (0.75 river km) from the mouth upstream to a major dam at State Route 21 (Zanatta 2011, pers. comm.). There are no changes to the status of this population since listing. This dam is particularly detrimental to fish passage and mussel health further up in the river (Pruden 2016, pers. comm.).

*Maple River* – The Maple River is a northeastern tributary of the Grand River draining south-central Michigan. At the time of listing, there was only a single snuffbox record (one live individual) from 2001 in southern Gratiot County, approximately 20 river miles (32 river km) upstream of the Grand River (Badra 2008, pers. comm.). Portions of the Maple River and several tributaries have been channelized, but the suitability of these channelized areas for the snuffbox is unknown (Badra 2010, pers. comm.). During a 2014 survey in Ionia County, three live snuffbox were found (EnviroScience 2014a) in Muir, Michigan. Barnett (2015) also found six live snuffbox in 2014 just below the Elsie Dam which documents the species much further upstream than was previously known. There are no changes to the status of this population since listing.

#### Lower Great Lakes Sub-basin

Currently, there are 10 extant populations of snuffbox in the lower Great Lakes sub-basin, down from 32 historically. Historically, sizable populations occurred in some streams (Belle, Clinton, Huron, Portage, and Niagara Rivers) and Lake Erie, but the species had become “characteristically uncommon” by the 1970s (Strayer 1980). A pre-zebra-mussel decline of unionids in Lake Erie was noted (Mackie *et al.* 1980), and the snuffbox appeared extirpated there by the late 1960s. The Lake St. Clair population of snuffbox persisted until around 1983 (Nalepa and Gauvin 1988; Nalepa 1994; Nalepa *et al.* 1996), which was the year the zebra mussel (*Dreissena polymorpha*) is thought to have invaded (Schloesser *et al.* 1998). Observations of live and fresh dead snuffbox from the Detroit River were made until 1994, but the mussel fauna has since been devastated by zebra mussels, and the snuffbox is now considered to be extirpated (Schloesser *et al.* 1998; Butler 2007). Other snuffbox populations in the sub-basin may also have suffered from zebra mussel invasions, but not those in the Ausable and Sydenham Rivers in Ontario. The lack of impounded area on these streams has likely

prevented the introduction or the establishment of zebra mussels (Dextrase *et al.* 2001; Ausable River Recovery Team 2005).

Of these 10 extant populations, 8 have shown recent evidence of recruitment. The Clinton River (MI) population is considered to be declining but the trend for the remaining nine lower Great Lakes populations is unknown. Two of the populations, the Ausable River (ON) and Sydenham River (ON) have large, stronghold snuffbox populations. Seven of the populations are considered to be significant and one of the populations (Pine River (MI)) is marginal. A single fresh dead valve was reported in 1998, from among 24 sites sampled in the Thames River, but no evidence of the snuffbox was found at 16 Thames sites in 2004 (McGoldrick 2005, pers. comm.). Currently, the species is considered extant in Canada only in the Ausable and Sydenham Rivers (Morris and BurrIDGE 2006). Seven of the 10 extant streams have new occurrence information since the time of listing.

*Ausable River* – The Ausable River is a southeastern tributary of Lake Huron, draining southwestern Ontario, Canada. A survey conducted in 2008 found that a sizable population of snuffbox occurs in the lower portion of the stream (Zanatta 2011, pers. comm.). The snuffbox occupies a 57 mile (91 km) stretch of the Ausable River from Elginfield Road through Nairn, with the core of the population occurring in the lower Arkona Gorge. At the time of listing, the Ausable River population was considered to be recruiting with a high probability of viability, large, and a stronghold population. New information from Morris (2015, pers. comm.) reaffirms the status of this population as reported when listed. COSEWIC (2011) estimates that there are 40,745 ( $\pm 7164$ ) snuffbox in the Ausable River, though Morris (2017, pers. comm.) reports that this estimate may be too high given the small detections and limited distribution. The Ausable River watershed is predominately agricultural with threats from high turbidity as well as pesticide and nutrient runoff (COSEWIC 2011).

*Pine River* – A tributary of the St. Clair River, the Pine River flows south and is located in St. Clair County, in southeastern Michigan. At the time of listing and currently, this population is apparently stable, although it is small, very restricted in range, and has a low potential for viability (Badra 2002, pers. comm.; Badra and Goforth 2003). In 2013, two live snuffbox were found at one site (Fleece 2013, pers. comm.). No other updates are available on this population since the time of listing. The population trend at the time of listing was considered to be stable. With no data to support the population trend as stable, the trend is now considered to be unknown.

*Belle River* – The Belle River is another tributary of the St. Clair River in St. Clair County, Michigan flowing in a southeasterly direction. Records for the snuffbox date to the early 1960s, but all live and fresh dead records over the past 40 years have been from the same lower mainstem site. Historically, a sizable population was found in the Belle River (65 specimens in 1965). In 2010, Zanatta (2010,

pers. comm.) found four live individuals at one site and one fresh dead at another site. The Belle River is located in a primarily agricultural watershed (Hoeh and Trdan 1985), and is impacted by sedimentation and runoff. The population has declined to the point of being small, but shows evidence of recruitment and viability (Badra 2002, pers. comm.; Badra and Goforth 2003; Sherman 2005, pers. comm.). Woolnough (2017, pers. comm.) reported finding five live individuals at one site in 2016. There are no changes to the status of this population since listing. Stream stability is a major threat, including hydrologic flashiness, channel incision and/or widening, excessive sedimentation, and channelization of tributary streams (Pruden 2016, pers. comm.).

*Clinton River* – The Clinton River is an eastward flowing chain-of-lakes tributary of Lake St. Clair in southeastern Michigan. The snuffbox population in the Clinton River is limited to around 10 river miles (16.2 river km) and lakeshore in the western suburbs of Pontiac, primarily between Cass and Loon Lakes. This significant population appears to be recruiting (Sherman Mulcrone 2004; Zanatta 2011, pers. comm.) and viable, although apparently in decline since the early 1990s (Badra 2002, pers. comm.; Butler 2007). Woolnough (2015, pers. comm.) reported that 16 out of 50 snuffbox collected from the Clinton River in 2013 were gravid. There are no changes to the status of this population since listing. Threats to mussels in the Clinton River include poor water quality and habitat degradation and loss (Pruden 2016, pers. comm.).

*Sydenham River* – The Sydenham River is a large, southeasterly flowing, eastern tributary of Lake St. Clair in extreme southwestern Ontario. The snuffbox was reported in the mid-1960s and early 1970s, but was overlooked during surveys in 1985 (except dead shells) and 1991 (Butler 2007). During the 1997–1999 sampling, a total of 10 live and fresh dead individuals were found from 4 of 12 sites, including the 3 1960s sites (Metcalf-Smith *et al.* 2003). The snuffbox was recorded at a rate of 0.22 per hour of effort during 1997–1998 (Metcalf-Smith *et al.* 2000). More recent sampling found 57 live and fresh dead individuals from 21 collection events (some individuals may have been counted multiple times) at six sites during 2000–2002. The increase in numbers relative to historical collections may be attributed to more intensive sampling methods rather than to improving population size (Metcalf-Smith *et al.* 2003), thus making population trend assessments difficult (Morris and Burrige 2006).

This stronghold population is recruiting, viable, and is currently known from approximately 58 river miles (93 river km) of the East Sydenham (Fisheries and Oceans Canada 2016). Intensive quantitative surveys were conducted between 1999 and 2003 throughout 12 sites in the historical Canadian range of the snuffbox with 17 live individuals found within a 58 miles (93 km) reach of the East Sydenham River (Metcalf-Smith *et al.* 2000; COSEWIC 2011). From 2002–2009, sections of the East Sydenham River were surveyed again during searches for gravid individuals and the total number of live animals found was over 200 (Fisheries and Oceans Canada 2016). In 2013–2015, the same 12 sites

from the 1999–2003 survey were surveyed with a total of 205 snuffbox being found at 10 of the sites. COSEWIC (2011) estimates that there are 21,000 ( $\pm 2880$ ) snuffbox in the Sydenham River. Morris (2017, pers. comm.) reports that using the same methodology as COSEWIC (2011) with the updated sampling results, the population is likely much larger than the Ausable River population. This population appears to be stable with good signs of recruitment (Morris 2015, pers. comm.). There are no changes to the status of this population since listing. The Sydenham River watershed is predominately agricultural with threats from high turbidity as well as pesticide and nutrient runoff (COSEWIC 2011).

*Huron River* – The Huron River is a major tributary of western Lake Erie draining a significant portion of southeastern Michigan. It is a complex system of flow-through chains-of-lakes and tributaries. The snuffbox is considered extant in two disjunct upper mainstem reaches. Individuals in the middle Huron River reach and in Davis Creek are considered a single population segment (Marangelo 2005, pers. comm.). Zebra mussels invaded the Huron River system in the early 1990s. Zebra mussel densities on individual mussels increased from less than 1 in spring 1995 to 245 in winter 1998 (Nichols *et al.* 2000). Despite the increasing presence of zebra mussels, the Huron population is probably recruiting and viable (Butler 2007). The only update for this population since listing is a 2016 record of 27 snuffbox collected at Silver Lake Road (Woolnough 2017, pers. comm.). There are no changes to the status of this population since listing.

*Grand River* – The Grand River is a 99-river-mile (159-river-km) tributary of Lake Erie, flowing north, then west to its confluence northeast of Cleveland, Ohio. Several museum snuffbox records date back to the 1800s. Dozens of fresh dead snuffbox were found washed up on the banks in the vicinity of the Interstate 90 crossing in Lake County, Ohio, following a major flood in 2006 (Butler 2007). The species is known from approximately 12 river miles (19.3 river km) downstream of Harpersfield Dam (Huehner *et al.* 2005; Zimmerman 2008a, pers. comm.). The sizable population was considered recruiting, based on the 1995 Huehner *et al.* (2005) survey. Six live and two fresh dead snuffbox were found at the Interstate 90 Bridge in 2013 (Hoggarth 2013). In 2016, five males were collected by Central Michigan University at one site (Woolnough 2017, pers. comm.). There are no changes to the status of this population since listing.

#### Upper Mississippi River Sub-basin

Records exist for Mississippi River Pools (MRPs) 3–4, 5a–6, and 14–16 (Kelner 2003), with early surveys summarized by van der Schalie and van der Schalie (1950). The snuffbox was considered to be extirpated from the mainstem of the Mississippi River until 2010, when it was reintroduced (Havlik and Sauer 2000; Davis and Pletta 2010). At the time of listing, the snuffbox was thought to be extant in the Kankakee River, though with the clarification of a 1991 record as a relic (Tiemann 2016, pers. comm.), the snuffbox is now considered to be extirpated from this stream.

Currently, there are 4 extant populations of snuffbox in the upper Mississippi River sub-basin, down from 17 historically. Two of the populations, the St. Croix River (MI, WI) and Bourbeuse River (MO) are considered to be large, stable or improving, and both have evidence of recent recruitment. The Bourbeuse River population is a stronghold population and the St. Croix River population is considered to be significant. The remaining two populations (Upper Mississippi River (MN) and Meramec River (MO)) are considered to be marginal. Three of the four extant streams have new occurrence information since the time of listing.

*Upper Mississippi River* – The Upper Mississippi River is the portion of the Mississippi River upstream of Cairo, Illinois. From the headwaters at Lake Itasca, Minnesota, the river flows approximately 1,250 miles (2,000 km) to Cairo, where it is joined by the Ohio River to form the Lower Mississippi River. The snuffbox was reported live in the upper river in the 1920s (Grier 1922; Grier 1926), but not from subsequent surveys (254 sites upstream of the Ohio River during 1930–1931 (Ellis 1931), MRPs 5–7 and 9 in 1965 (Finke 1966; Thiel 1981), MRPs 3–11 during 1977–79 (Thiel 1981)). The snuffbox has never been found upstream of St. Anthony Falls (Smith 2018, pers. comm.). A reintroduction effort into the Mississippi River was initiated in 2010, when 200 logperch inoculated with snuffbox glochidia were placed into cages in the St. Croix River near Hudson, Wisconsin (Davis and Pletta 2010; Delphey 2011, pers. comm.). Between 2007 and 2013, cage-reared and captively propagated snuffbox from St. Croix River broodstock were released into the Mississippi River (Sietman 2014, pers. comm.; Davis 2017, pers. comm.; Smith 2017, pers. comm.). It is not yet known if these reintroduction efforts have been successful. There are no changes to the status of this population since listing.

*St. Croix River* – The St. Croix River is a major south-flowing tributary of the upper Mississippi River and forms the border between southeastern Minnesota and northwestern Wisconsin. Densities of juvenile snuffbox declined at eight sites between 1992 and 2002 (Hornbach *et al.* 2003). Snuffbox density at Interstate Park (Chisago County, MN and Polk County, WI), declined significantly between 1988 and 2004 (WIDNR 2004). A flood in 2001 may have contributed to these declines in mussel density, but post-flood recruitment was also surprisingly low (WIDNR 2004). The St. Croix River snuffbox population currently occurs in a 18.4-mile (30 km) reach from the Northern States Power Dam, at river mile 35.8, to river mile 54.2 (river km 57.6 to river km 87.2) (MNDNR unpublished data; Heath 2005, pers. comm.). This represents the species' northernmost occurrence and remains one of the most significant populations rangewide. In 2013, 15 snuffbox (including recent recruits) were collected on the St. Croix River at Franconia, Chisago County (Sietman 2014, pers. comm.).

In June 2014, 10 cages with a total of 150-200 logperch inoculated with snuffbox glochidia were placed in the St. Croix River near Stillwater, Minnesota (Sietman



2014; Sietman 2015, pers. comm.). In 2016, 60 logperch inoculated with snuffbox glochidia were put into cages placed in the St. Croix River at Lakeland, Minnesota (Smith 2016, pers. comm.). In 2017, Wisconsin DNR collected 10 live snuffbox during an 8-hour timed survey near Osceola, Wisconsin (Smith 2018, pers. comm.). At the time of listing, this population was thought to be declining. However, the St. Croix River population is currently considered to be stable (Smith 2018, pers. comm.).

*Bourbeuse River* – The Bourbeuse River is a 149-mile (240-km), northeasterly flowing, northern tributary of the Meramec River in Missouri, joining it at river mile 68 (river km 109.4). The snuffbox is currently distributed over about 60 river miles (96.6 river km) upstream of river mile 16 (river km 25.7), plus a disjunct site at the mouth of the river. Although it was considered to have “greatly declined” by the late 1990s (Roberts and Bruenderman 2000), post-2000 sampling indicates that the population is recruiting, viable, and improving (McMurray 2006, pers. comm.). There are no changes to the status of this population since listing. The Bourbeuse, one of the seven stronghold snuffbox populations, was augmented with newly transformed laboratory propagated juveniles in 2002 and 2005 (Barnhart 2002; Barnhart and Kaiser 2005; Barnhart 2006). In 2014, five live snuffbox were collected in Franklin County, Missouri (McMurray 2016, pers. comm.). Bank and channel destabilization, water quality degradation, and gravel mining pose significant threats to mussel populations in the Meramec River Basin (Roberts and Bruenderman 2000; Roberts 2018, pers. comm.).

#### Lower Missouri River System

The snuffbox was historically known from four streams in this system. The highly disjunct occurrences suggest that it was more widespread historically (Butler 2007). All populations in the system were considered to be extirpated at the time of listing. At this time there is no updated information for the snuffbox in this system and the species is still considered to be extirpated from all the streams it historically occurred in within the lower Missouri River System.

#### Ohio River System

The Ohio River system once represented the largest block of available habitat for this species prior to the initiation of the navigational improvements in 1830 (Butler 2007). Nearly the entire Ohio River mainstem is now impounded with a series of locks and dams (Butler 2007). Sizable populations historically occurred in at least a dozen streams in the system.

Currently, there are 49 extant populations of snuffbox in the Ohio River System, down from 107 historically. While over half of all the extant snuffbox populations are found in the Ohio River System, only one of these populations, French Creek (PA), is considered to be large, stable and a stronghold for the

snuffbox. There are 10 populations considered to be significant, with 8 of these considered to be small populations and 2 of them medium-sized. Only 8 of the 49 extant populations have recent documentation of recruitment. Twenty-three of the 49 extant streams have new occurrence information since the time of listing, including 5 populations not identified in the listing rule (Cussawago Creek (PA), West Fork River (WV), Meathouse Fork (WV), South Fork Hughes River (WV), and Kanawha River (WV)). Seven of the 49 streams have updated threat information, but no updated occurrence information, including the Allegheny River (PA), West Fork French Creek (PA), Woodcock Creek (PA), Muddy Creek (PA), Little Mahoning River (PA), McElroy Creek (WV), and the Hughes River (WV).

*Allegheny River* – The 325-mile (523-km) Allegheny River drains northwestern Pennsylvania and a small portion of adjacent New York flowing south before joining the Monongahela River at Pittsburgh to form the Ohio River. Snuffbox collections are sporadically known since around 1900 in Pennsylvania from Forest County downstream to Armstrong County. The snuffbox is currently known from three disjunct sites over a 42-river-mile (67.6-river-km) reach centered in Venango County (Butler 2007). Its occurrence in the lower Allegheny River and lower French Creek could be considered a single population segment (Butler 2007). The viability status of the small population is unknown and there are no changes to the status of this population since listing. The river is threatened by gas extraction, including water withdrawals and release of brine waste. Flows are also highly regulated by three U.S. Army Corps of Engineers dams and the downstream navigation pool system isolates the population (Anderson 2016, pers. comm.).

*French Creek* – French Creek is a major tributary of the middle Allegheny River with its headwaters in western New York and flowing south into northwestern Pennsylvania. The snuffbox is known from the length of the stream in Pennsylvania in Erie, Crawford, Mercer, and Venango Counties. Most records date since approximately 1970 (Dennis 1971). Snuffbox collections made during 2002–2004 were summarized by Smith (2005). Live and fresh dead specimens were found at 19 sites throughout the stream. The size of the live individuals indicated that multiple year classes were represented, including subadults. The species stretches for approximately 80 river miles (128.7 river km) from around river mile 10 (river km 16.1), upstream. The population encompasses several of its tributary population segments as well, making it relatively more secure when compared to most of the other stronghold populations that are linearly distributed and, thus, more susceptible to stochastic events (Sydenham, Bourbeuse, and Clinch Rivers). There are no changes to the status of this population since listing. The French Creek snuffbox population is considered large and viable (Evans 2003a, pers. comm.; Zimmerman 2008c, pers. comm.), appears stable and is considered to be a stronghold population. The species was last observed in 2017. Threats are gas extraction and sedimentation due to agricultural and livestock farming (Anderson 2016, pers. comm.).

*West Branch French Creek* – West Branch of French Creek follows a southerly course to its parent stream in Erie County, Pennsylvania. The only record for the snuffbox dates from 1993, but the number of specimens and shell condition are unknown (Evans 2003b, pers. comm.). Union City Lake isolates the upper French Creek and West Branch French Creek population segment from the main French Creek population. The snuffbox was not found at three sites sampled in 2006 (Smith 2006, pers. comm.). Zimmerman (2008c, pers. comm.) documented 38 live individuals at a site near Wattsburg, Pennsylvania in 2008. There are no changes to the status of this population since listing. This population appears to be small and of unknown viability. The primary threat to this population is sedimentation due to agriculture (Anderson 2016, pers. comm.).

*LeBoeuf Creek* – LeBoeuf Creek is a small western tributary of upper French Creek flowing in a southerly direction just west of West Branch French Creek in Erie County, Pennsylvania. The first snuffbox collections in this creek were made 100 years ago (Ortmann 1909). Two fresh dead and 6 relic shells were reported in 1988 (Evans 2003b, pers. comm.), and 1 live, 16 fresh dead, and 8 relic specimens were found in 1991 (Butler 2007). Three live individuals were found at a site in 2006 (Smith 2006, pers. comm.; Smith *et al.* 2009). The snuffbox population occurs from the town of Waterford, Pennsylvania to the confluence with French Creek. It has recently recruited and exhibits some level of viability (Enviroscience 2014b) and there are no changes to the status of this population since listing. Threats include water withdrawal, sedimentation, zebra mussels, and treated waste water (Anderson 2016, pers. comm.). Round gobies (*Neogobius melanostomus*) have also recently been confirmed in LeBoeuf Creek which could threaten both young snuffbox and their host fish (Anderson 2018, pers. comm.).

*Woodcock Creek* – Woodcock Creek is an eastern tributary of upper French Creek in Crawford County, Pennsylvania. Until recently, the snuffbox was thought to be extirpated from this stream. In 2007, one live male was found at one of three sites sampled (Smith *et al.* 2009). Viability is unknown and there are no changes to the status of this population since listing. Snuffbox occurs in a short reach (less than a quarter of a mile) of the creek below Woodcock Creek Dam. This population may be an extension from French Creek and may not be independently viable (Anderson 2016, pers. comm.). The primary threat is changes in regulated flows from dam releases (Anderson 2016, pers. comm.).

*Muddy Creek* – Muddy Creek is an eastern tributary of upper French Creek in Crawford County, Pennsylvania. The snuffbox was not discovered until the summer of 2003. Forty-two live individuals were reported from 11 of 20 lower river sites (Morrison 2005, pers. comm.; Mohler *et al.* 2006). Low numbers were found at most sites, but 18 live individuals were collected from a site near the mouth of the river. This occurrence could be considered to be part of the more extensive French Creek snuffbox population (Butler 2007). There are no changes

to the status of this population since listing. Zimmerman (2008c, pers. comm.) documented one live female in 2008. The population is medium-sized, occurs along 8 river miles (12.9 river km) of the lower mainstem, and is recruiting, as recent juveniles were recorded (Morrison 2005, pers. comm.; Mohler *et al.* 2006). Much of the stream is on Erie National Wildlife Refuge. This low gradient stream is dynamic and silty and bank erosion can be pervasive (Anderson 2016, pers. comm.).

*Cussewago Creek* – The Service was not aware of this extant population at the time of listing and it was not included in the listing rule. Cussewago Creek is a tributary to French Creek in Crawford County, Pennsylvania. It joins French Creek in the City of Meadville. Welte (2011, pers. comm.) reported that a recently dead large male snuffbox was found immediately downstream of the Spring Street Bridge crossing in Meadville. Nothing else is known about the status of the snuffbox in this stream. Cussewago Creek is very low gradient, meandering, turbid, and difficult to survey due to these conditions (Anderson 2017, pers. comm.).

*Little Mahoning Creek* – Little Mahoning Creek is a tributary of Mahoning Creek, a lower eastern tributary of the Allegheny River northeast of Pittsburgh, Pennsylvania. The snuffbox was discovered in 1991 when sampling produced 2 fresh dead and 1 relic specimen at 1 of 12 sites in the system (Butler 2007). The lower 10 miles (16 km) of Little Mahoning Creek are subject to periodic inundation by a reservoir on Mahoning Creek (Butler 2010, pers. comm.). However, the impact of this periodic flooding on the snuffbox is not known. A 2007 survey failed to find any live or fresh dead snuffbox (Chapman and Smith 2008). Viability is unknown and there are no changes to the status of this population since listing. The threats to this population are impoundments and gas extraction (Anderson 2016, pers. comm.).

*West Fork River* – The West Fork River is a principal tributary of the Monongahela River in north-central West Virginia. It joins the Tygart Valley River in Fairmont to form the Monongahela River. The snuffbox was thought to be extirpated from the West Fork River until one live individual was found in 2015 (Douglas 2016, pers. comm.). Since this population is currently known from only one record, it has been categorized as marginal. The West Fork River has been impacted from acid mine drainage historically. A mine blowout in the late 1990s is also believed to have further impacted the system causing an extensive mussel kill within Hackers Creek, a tributary. The impact to the West Fork River is unknown. The available mussel habitat within much of the West Fork River is limited due to a series of impoundments that were built for water supply. With construction of Stonewall Jackson Dam, upstream of Weston, three of the old dams are no longer needed. The 3 dams were removed in 2017, restoring 12.5 miles (20.1 km) of the river to free flowing condition. Mussel salvage efforts during the dam removal effort collected over 1,400 mussels however, no additional snuffbox were found (Douglas 2018, pers. comm.). The

watershed is currently threatened by Marcellus gas exploration (Douglas 2016, pers. comm.).

*Shenango River* – The Shenango is a large tributary in the Beaver River system, a northern tributary of the upper Ohio River in west-central Pennsylvania. The snuffbox was reported from four sites on the Shenango River in 1908 (Ortmann 1919). Six live individuals were collected from three sites sampled in 2001–2002 between Jamestown and New Hamburg (about 25 river miles (40.2 river km)). Nelson and Vilella (2010) found 45 live individuals in 2010. The upper reach is considered the best habitat in the Shenango River. The population is small and has declined, although some recent reproduction is evident (Zimmerman 2008b, pers. comm.; Nelson and Vilella 2010) and there are no changes to the status of this population since listing. The species was last observed in the stream in 2015 (Anderson 2016, pers. comm.). Threats include gas extraction (includes brine disposal, water extraction, and sedimentation) and sedimentation due to agricultural and livestock farming (Anderson 2016, pers. comm.; Anderson 2018, pers. comm.).

*Little Shenango River* – The Little Shenango River is a small tributary of the upper Shenango River, Mercer County, Pennsylvania. This population was not located during limited surveys (Dennis 1971; Bursey 1987), but a single fresh dead museum record from 1991 exists. The species was reported to be relatively abundant and reproducing in the lower portion in 2002 (Zimmerman 2008b, pers. comm.). Viability of the small population is unknown and there are no changes to the status of this population since listing. The species was last observed in the stream in 2013 (Anderson 2016, pers. comm.). Gas extraction poses a threat to this population (Anderson 2016, pers. comm.).

*Middle Island Creek* – Middle Island Creek is a small tributary of the Ohio River in northwestern West Virginia. The first snuffbox records were made at six sites in 1969, when the species was locally common in Doddridge, Tyler, and Pleasants Counties (Taylor and Spurlock 1981). The snuffbox was later found at two sites in Tyler County in 1980, and the overall mussel population was considered to be “thriving” (Taylor and Spurlock 1981). Three live individuals were found in 2009 at two sites and four live individuals in 2010 at three sites (Clayton 2011, pers. comm.). This snuffbox population has declined, is currently rare, and has questionable viability (Zimmerman 2008b, pers. comm.).

The snuffbox occurs in a 55-mile (88-km) reach of Middle Island Creek in thirteen mussel beds. Four of these beds have been adversely affected by construction of bridges or water intake structures (Douglas 2018, pers. comm.). In 2013, eight live and three fresh dead snuffbox were found at the Lemaster Bridge in Tyler County (Enviroscience 2013). In 2014, one live and one fresh dead snuffbox were found near the Wells Bridge. In 2015, six snuffbox were relocated from the Shiloh Bridge site to the Falls Mills long-term monitoring sites prior to replacement of the bridge. These mussels were tagged with passive

integrated transponders (PIT). Subsequent monitoring at the relocation site found two alive, two eaten by river otters (*Lutra canadensis*), and the other two could not be located (WVDNR 2016). Five snuffbox were found near Falls Mills during eDNA tissue sample collection (WVDNR 2017). In 2016, 18 (2 female, 8 male, and 8 juvenile) snuffbox were found at the proposed construction site of a new water intake structure in Tyler County (Enviroscience 2016). At the time of listing, it was unknown whether there was recruitment in this population. These recent juvenile records document that recruitment is occurring in the stream.

Middle Island Creek is an area of intensive and expanding shale gas development and associated infrastructure that fragments or eliminates habitat and adds sediment loads to the streams. Spills containing brine fluids and hazardous materials and/or water withdrawals put aquatic species at risk. Because of the geology in this part of West Virginia, ground-disturbing activities can result in significant siltation of the streams (Douglas 2016, pers. comm.).

*McElroy Creek* – McElroy Creek is a tributary to Middle Island Creek in West Virginia. There are no historical records for the snuffbox in McElroy Creek. Clayton (2011, pers. comm.) reported finding one live individual in 2010 in Tyler County. The status of this snuffbox population is unknown and unchanged since listing. Threats to the McElroy Creek are the same as the threats to Middle Island Creek (Douglas 2016, pers. comm.).

*Meathouse Fork* – The Service was not aware of this extant population at the time of listing and it was not included in the listing rule. Meathouse Fork is a tributary of Middle Island Creek in Doddridge County, West Virginia. It joins Buckeye Creek in Smithburg to form Middle Island Creek. Snuffbox occurs in the lower 6 miles (9 km) of the river. It is unknown whether there is recruitment but it is doubtful (Douglas 2016, pers. comm.). This population is declining and the species was last observed in 2001. Surveys at the long-term monitoring site in Doddridge County in 2016 did not locate any snuffbox. A significant shift in bed load/channel configuration at the site was noted since the previous survey effort in 2011 (Douglas 2018, pers. comm.). Threats to the Meathouse Fork population are the same as the threats to Middle Island Creek with the primary threat being Marcellus gas exploration within the watershed (Douglas 2016, pers. comm.).

*Muskingum River* – The Muskingum River is a large, southerly flowing, northern tributary of the upper Ohio River draining a significant portion of east-central Ohio. The snuffbox, which has a long collection history dating to the early 1800s, occurred along the entire mainstem and was locally abundant. Two live individuals and two fresh dead shells were found in 1979, but no live or fresh dead snuffbox were found in surveys conducted in 1979–81 (Stansbery and King 1983) and in 1992–93 (Watters and Dunn 1993–94). A single live male was located during sampling for a construction project in 2005 near Dresden, Ohio (Jones *et al.* 2005). One fresh dead male snuffbox was found in 2014 during

monitoring near the AEP Dresden Facility (Droppelman 2014, pers. comm.). Viability of this population is unknown and the status is unchanged since listing.

*Killbuck Creek* – Killbuck Creek is a large tributary of the lower Walhonding River in Ohio, flowing south from southern Medina County to Coshocton County and entering the latter at approximately river mile 7 (river km 11.3). Live and fresh dead snuffbox were found by Hoggarth (1997) at eight sites from river mile 15 (river km 24.1) to the mouth. Its occurrence has become more sporadic in the last 10 years. In spring 2006, 4 live adults were found at 2 sites approximately 3 river miles (4.8 river km) apart, while 9 large live individuals and a single fresh dead specimen were collected near river mile 13 (river km 20.9) during fall 2006 (Ahlstedt 2007, pers. comm.; Butler 2007). One to several live snuffbox are typically observed each year at a single riffle in Coshocton County near Blissfield, Ohio (Ahlstedt 2010, pers. comm.; Ahlstedt 2011, pers. comm.; Ahlstedt 2012, pers. comm.; Ahlstedt 2014a, pers. comm.; Ahlstedt 2014b, pers. comm.; Ahlstedt 2015, pers. comm.; Ahlstedt 2016, pers. comm.; Ahlstedt 2017, pers. comm.). A shrinking distribution, declining population size, and lack of evidence of recent recruitment suggest that the population may be losing viability and trending towards extirpation. The status of this population is unchanged since listing.

*Little Kanawha River* – The Little Kanawha River is a 169-mile (269-km) long tributary of the Ohio River in western West Virginia. Schmidt *et al.* (1983) reported snuffbox from three sites during a 1981–82 survey. Snuffbox were not documented again in the Little Kanawha River until 2010, when four live individuals, including at least one young mussel, were found at a site in Gilmer County, West Virginia (Clayton 2011, pers. comm.). Additionally, two fresh dead specimens were found in 2010, below Wells Dam near Elizabeth, Wirt County, West Virginia (Clayton 2011, pers. comm.). Douglas (2016, pers. comm.) reported that multiple juveniles have been found at a long-term monitoring site established by the West Virginia DNR. This site was most recently monitored in 2016. These surveys found 67 live snuffbox over 4 sampling events resulting in an estimate of 1.00/m<sup>2</sup> snuffbox which was an increase from 2011 when density of snuffbox was estimated to be 0.58m<sup>2</sup> (WVDNR 2016). Based on these densities, West Virginia DNR estimates between 1,100 and 2,000 snuffbox at this site (Douglas 2018, pers. comm.). Enviroscience (2017) found 37 live snuffbox during a 2017 survey at a proposed river crossing. There are no changes to the status of this population since listing. Threats to the Little Kanawha River system populations (including the Hughes River, North Fork Hughes River, and South Fork Hughes River) mirror those of Middle Island Creek (Douglas 2016, pers. comm.).

*Hughes River* – The Hughes River is an 18-mile (29-km) long tributary of the Little Kanawha River in western West Virginia. Schmidt *et al.* (1983) reported snuffbox during a 1981–82 survey. No additional snuffbox were found in the Hughes River until 2008, when one fresh dead juvenile was found in Wirt County

(Clayton 2011, pers. comm.). The current status of this snuffbox population is unknown and unchanged since listing.

*North Fork Hughes River* – The North Fork Hughes River is a westerly flowing tributary of the Hughes River in the lower Little Kanawha River system in northwestern West Virginia. The snuffbox was found at one of six sites sampled during a 1981–1982 survey (Schmidt *et al.* 1983). In 1993, a total of 41 live adult individuals (23 reported as gravid) were reported at 5 sites located over a 1.5-mile (2.4-km) reach in North Fork State Park, Ritchie County (Butler 2007). At least 10 live individuals were found at a site in the park in 1997, and a single fresh dead specimen was collected at an additional site downstream in 2001 (Butler 2007). This small snuffbox population is declining and currently restricted to less than 4 river miles (6.4 river km), but may be viable. There are no changes to the status of this population since listing. West Virginia DNR collected a live snuffbox in 2014 in North Bend State Park (Douglas 2016, pers. comm.). This site has been adversely affected by dam repairs and bank stabilization efforts. Most recently, two live snuffbox were found at the long-term monitoring site in Ritchie County in 2017 and four snuffbox (2 males and 2 females) were found near Cairo also in Ritchie County (WVDNR 2017). The Cairo site has been adversely affected by the replacement of the bridge and was the subject of a biological opinion. The four snuffbox were relocated to the Ritchie County long-term monitoring site (WVDNR 2017).

*South Fork Hughes River* – The Service was not aware of this extant population at the time of listing and it was not included in the listing rule. The South Fork Hughes River is a westerly flowing tributary of the Hughes River in the lower Little Kanawha River system in northwestern West Virginia. One live snuffbox was observed in 2001 and one was observed in 2017 (Douglas 2016, pers. comm.; Enviroscience 2017). This population has been categorized as marginal due to these two individual records. No other information on this population is available.

*Kanawha River* – The Kanawha River is a 97-mile (156-km) tributary of the Ohio River in West Virginia. At the time of listing, the snuffbox was thought to be extirpated from the river. In 2016, one live male was found about two miles (3.2 km) downstream of the confluence with the Elk River (Douglas 2018, pers. comm.). Nothing else is currently known about the status of the snuffbox in the Kanawha River.

*Elk River* – The Elk River is a major, 181-mile (291-km) tributary in the lower Kanawha River system draining central West Virginia flowing west to the Kanawha River at Charleston. The snuffbox went undetected in a 1920's survey (Butler 2007). Ten live individuals were collected during 1991–1995, the smallest being about 5 years old (Butler 2007). Collectively, 16 live individuals were identified at 8 sites in a 13-river-mile (20.9-river-km) reach in Kanawha County in 2002, and 4 live individuals were found at 4 sites in 2004 over a 16.8-



river-mile (27-river-km) reach farther upstream (Douglas 2005, pers. comm.). This medium-sized population extends over 30 river mile (48.3 river km), is viable, and may have improved since the 1970s. There has been no change in the status of this population since listing. Energy development contributes to habitat loss, forest fragmentation, water pollution, and acid mine drainage. Additional water pollution problems arise from industrial and sewage discharges and spills. The Elk River is a warmwater stream, and although Sutton Dam has a multilevel release, high flows in the summer significantly reduce water temperatures when the dam is forced to release a large portion of its discharge from the bottom port. Cooler water temperatures from these bottom releases impact mussel reproduction (Douglas 2016, pers. comm.).

In 2014 a mussel kill was observed in the upper reaches of the lower Elk River where no mussel reproduction has been observed in over ten years. Likewise, significant algae blooms occur between Duck and Ivydale (Douglas 2016, pers. comm.). The last snuffbox observation in the Elk River was in 2017 when one individual was found at Camp Creek Bridge and a fresh dead specimen was found at the long-term monitoring site near Queen Shoals (WVDNR 2017). The Camp Creek location has been adversely affected by the replacement of the bridge and was the subject of a biological opinion. The snuffbox was relocated to one of the long-term monitoring sites (WVDNR 2017).

*Olentangy River* – The Olentangy River is a major headwater tributary of the Scioto River, draining central Ohio and flowing south to its confluence in Franklin County. Ohio State University Museum (OSUM) snuffbox records date to the 1870s, although most are from the 1950s and 1960s. The snuffbox was reported from 15 of 31 mainstem sites collected during a 1960–1961 survey, when it appeared “fairly common” in the lower river (Stein 1963). A single live individual in southern Delaware County and two fresh dead specimens in eastern Marion County were found among 30 sites in 1989, with relic shells at 7 other sites (Hoggarth 1990). The small population has declined (Hoggarth 1990), and its viability is unknown and the status is unchanged since listing. A fresh dead male snuffbox was found in 2013 downstream of the former Panhandle Dam location in Delaware, Ohio (Michael 2013, pers. comm.). The dam was removed in 2010.

*Big Darby Creek* – Big Darby Creek is one of the major tributaries draining the northwestern portion of the Scioto River system in central Ohio. Dozens of large OSUM lots of snuffbox date to the late 1950s; 6 Pickaway County collections in 1962 alone had 250 live and fresh dead specimens. Watters (1990) surveyed 42 mainstem sites in 1986 and 49 sites in 1990. Combining the data from both years, 80 live and fresh dead snuffbox were collected at 22 sites (Watters 1994). The population in 1990 occurred in a reach from approximately river mile 11.5 to river mile 42.5 (river km 18.5 to 68.4). At that time, the snuffbox was recruiting with four individuals found during both 1986 and 1990 being two to five years of age (Watters 1994). The overall population trend over the past 40 years has been

downward. Between 1986 and 1990, the number of live and fresh dead specimens was reduced from 54 to 16, and the population's distribution declined from 17 to 8 sites. Two fresh dead specimens were found at sites in Franklin (1996) and Pickaway (2000) Counties, and three other sites produced only relic specimens (OSUM records). In 2013, one live female was found at a riffle within the Battelle Darby Creek Metro Park in Franklin County (Boyer 2013, pers. ob.). One fresh dead snuffbox was found in 2014 and one live individual in 2015 during a streamwide survey conducted in 2014-2015 (Enviroscience 2015). This historically large snuffbox population is marginal status, and its viability is questionable. There has been no change in the status of this population since listing.

In October 2016, a die-off of mussels was discovered in Big Darby Creek. The die-off appears to have affected the entire stream from the headwaters to the mouth. The most common species that appeared to be affected were several *Lampsilis* species and *Elliptio dilatata*. No dead snuffbox were noted. No cause of the die-off has been determined and it is unclear if any snuffbox were affected. It also appears that no fish or macroinvertebrates were affected during this mussel die-off.

*Stillwater River* – The Stillwater River is a 67-mile (108-km), western tributary of the Great Miami River draining southwestern Ohio. The species was collectively known from eight sites throughout the river (Watters 1988). One fresh dead specimen below Englewood Dam in Montgomery County was found among 18 sites surveyed in 1987, with relic shells from 5 other sites (Watters 1988). Fourteen live and one fresh dead snuffbox were found in 2014 during a mussel salvage for the West Milton Dam removal project (Stantec 2015). The 14 live snuffbox were relocated to a suitable site downstream of the dam removal project (Stantec 2015). Two live snuffbox were also found at the relocation site during scouting for a suitable relocation sites. No other information on the small population is available, and its viability is unknown. There has been no change in the status of this population since listing.

*Rolling Fork Salt River* – The Rolling Fork is a major southern tributary of the Salt River in central Kentucky, flowing in a northwesterly direction to join the Salt near its mouth. The snuffbox was first reported in 1958 (Rosewater 1959). Seven fresh dead specimens and a single live subadult were collected in 1988, from four sites in Larue, Marion, and Nelson Counties (Cicerello 2003, pers. comm.; Haag 2006, pers. comm.). A survey of 12 mainstem and 30 tributary sites in the Rolling Fork system in 1998–1999 yielded no evidence of the snuffbox, prompting an investigator to consider it extirpated (Akers 2000), but occasional specimens may still be found (Butler 2007). The species is sporadically distributed over 40 river miles of the upper river (Cicerello 2006, pers. comm.). This snuffbox population has been augmented with fish and in vitro cultured juveniles using snuffbox broodstock from the river (McGregor 2017, pers.

comm.). The viability of this small population is unknown and its status is unchanged since listing.

*Green River* – A major southern tributary of the lower Ohio River, the Green River flows in a westerly direction and drains west-central Kentucky. Ortmann (1926) considered the snuffbox to be well-distributed over the system, but not abundant. Large museum collections of snuffbox were taken from Munfordville during 1961–1966, but only six relic shells were reported there in 1967. The snuffbox has been rare since. Five live and fresh dead snuffbox were collected at 4 of 42 sites during 1987–1989 sampling in Mammoth Cave National Park (Cicerello and Hannan 1990). Three live and six fresh dead snuffbox were reported in the upper Green River from 1984–1990 (Cicerello 2003, pers. comm.). A single live individual was collected in Taylor County in 1989 (Layzer 2009, pers. comm.), but no evidence of the snuffbox was reported at numerous other sites in 1999, 2000, 2001, and 2003 (Cicerello 2006, pers. comm.). Once abundant and occurring over 200 river mi (322 river km), the species has become exceedingly rare since the 1960s.

There has been no change in the status of this population since listing. Current snuffbox viability is unknown, and it may be nearing extirpation from the entire Green River system, where it was formerly known from eight tributaries. Snuffbox have not been observed in the Green River since 1989. However, juvenile snuffbox cultured in vitro from Rolling Fork Salt River broodstock were released at five sites in 2016–2017 in an effort to augment this population (McGregor 2017, pers. comm.).

*Salamonie River* – The Salamonie River is a southern tributary of the upper Wabash River, flowing in a northwesterly direction and draining east-central Indiana. Two historical museum records were found (Butler 2007). Nine sites were surveyed during 1993–1994, without finding any evidence of the snuffbox (Ecological Specialists 1995). The snuffbox was rediscovered in 2004, above Salamonie Reservoir, where two live individuals at one site and fresh dead shells, including a very small juvenile, were found at another site 2 miles (3 km) away (Fisher 2005, pers. comm.). There has been no change in the status of this population since listing. The small population is considered to be recruiting and viable at some level. Numerous snuffbox have been collected at multiple locations since listing (Pruitt 2016, pers. comm.).

The Indiana Department of Fish and Wildlife initiated captive propagation of snuffbox in 2014 when 8 gravid snuffbox were collected from the Salamonie River and used to inoculate 100 logperch. The logperch were kept in cages in Lake Shafer (Fisher 2014, pers. comm.). A small number of juveniles were produced from this effort. Techniques are being refined to improve the survival rate of juveniles from this effort (Pruitt 2016, pers. comm.). This effort was repeated with two cages in 2016. In August 2017, the cages were pulled and they contained 81, 16-month-old snuffbox 0.6-0.9 inches (15-23 mm) in length. The

snuffbox were returned to the cages to continue growing. In 2018, the snuffbox will be pulled from the cages, PIT tags will be attached, and they will be placed at augmentation sites further upstream from Lake Shafer in the Tippecanoe River (Fisher 2017).

*Tippecanoe River* – The largest tributary of the upper Wabash River system, the Tippecanoe River drains north-central Indiana and flows westerly, then southerly before joining the Wabash near Lafayette, Indiana. Nearly all records of the snuffbox were made in the past 30 years. Two weathered shells were found in the lower mainstem among 16 sites sampled in 1987 (Cummings *et al.* 1987; Cummings and Berlocher 1990) and 30 sites in 1991–1992 (Ecological Specialists 1993). One live individual and over 32 fresh dead specimens were found at a site at the upper end of Freeman Reservoir during a 1993 drawdown that may have contributed to their demise (Fisher 2003, pers. comm.). A single fresh dead specimen was found below Shafer Reservoir among 13 sites sampled in 2003 (Ecological Specialists 2003). There has been no change in the status of this population since listing. The viability of this declining population is unknown, but it appears close to extirpation (Fisher 2003, pers. comm.). Augmentation with propagated snuffbox from Salmonie River broodstock is scheduled for fall 2018 (Fisher 2017).

*Embarras River* – The Embarras River is a southerly flowing, western tributary of the lower Wabash River in southeastern Illinois. Museum lots represent collections dating to 1956 and contain snuffbox from nine mainstem and two tributary sites. A total of 9 live and 15 fresh dead specimens were collected at 4 sites in 1986, in Coles and Douglas Counties (Cummings *et al.* 1988). Although overall mussel abundance at the 21 sites sampled in both 1956 and 1986 dropped 86 percent, the snuffbox was one of only 5 species that showed a relatively stable population size over the 30-year period (Cummings *et al.* 1988). Since 1986, the small snuffbox population has occurred sporadically at 6 sites over 50 river miles (80 river km) of the upper river. The species was reported as significant and viable by Butler (2008 pers. comm.), but it has declined to some extent. Recent surveys, however, documented only one live individual in 2005 and five live adult males in 2008, indicating that the Embarras River population may be closer to a marginal population than a significant one (Tiemann 2010). Five live individuals were found at two sites in 2012 and four fresh dead specimens were found at one site in 2014 (Kieninger 2016, pers. comm.). There has been no change in the status of this population since listing.

*Sugar Creek* – Sugar Creek is a tributary in the upper East Fork White River system, draining central Indiana east and south of Indianapolis. The snuffbox population occurs sporadically over 35 river miles (56 km) to near the mouth. Only relic shells were found while resampling some historical sites in 1995, 1998, and 2001 (Butler 2007). After listing, one live snuffbox was found in Shelby County in 2012 (Pruitt 2016, pers. comm.). In 2017, one very fresh dead snuffbox (still with tissue) was collected in Hancock County (Fisher 2017). A

more intensive sampling effort is planned for Sugar Creek in 2018 (Fisher 2017). There has been no change in the status of this population since listing.

### Cumberland River System

Currently, there is only one extant snuffbox population in the Cumberland River System, down from seven populations historically. With few exceptions, most mainstem records were made prior to the 1920s, when the species was locally common (Wilson and Clark 1914). The snuffbox is considered extirpated from the mainstem. Currently, a single tributary population in Buck Creek (KY) may be extant, but is considered not viable. There are no new records or other updated information for Buck Creek since listing. Snuffbox was last documented in Buck Creek in 1990. The species is likely to become extirpated from the entire river system in the foreseeable future.

### Tennessee River System

The Tennessee River is the largest tributary of the Ohio River, draining seven southeastern states and joining the Ohio River in western Kentucky. The snuffbox originally was known from throughout all but the lower section of river and 17 of its tributaries. Hundreds of miles of large river habitat on the mainstem have been lost under nine reservoirs, with additional dams on several tributaries (Clinch, Holston, and Elk Rivers) (Tennessee Valley Authority 1971). The loss of mussel resources has been substantial (Watters 2000). Muscle Shoals, the 53-river-mile (85-river-km) reach in northwestern Alabama, historically harbored 69 mussel species, the most diverse mussel fauna ever known (Garner and McGregor 2001). The construction of three dams (Wilson in 1925, Wheeler in 1930, and Pickwick Landing in 1940) inundated most of the mussel beds. No live snuffbox have been reported at Muscle Shoals for around 100 years (Garner and McGregor 2001).

Currently, there are 6 extant snuffbox populations in the Tennessee River System, down from 18 historically. Two of the populations, Clinch River (TN, VA) and Paint Rock River (AL) are large, stable or improving, strongholds that have recent recruitment documented. One population, the Elk River (AL, TN) is considered to be significant, has recent documented recruitment, but is also considered to be a small population. The remaining three populations are all marginal, without documented recent recruitment, and their trends are either declining or unknown. Five of the six extant streams have new occurrence information since the time of listing.

*Clinch River* – The 350-mile (563-km) Clinch River is a major tributary of the upper Tennessee River originating in southwestern Virginia, and flowing in a southwesterly direction to its confluence near Kingston in eastern Tennessee. No other river in North America has extant populations of more federally endangered (15) species of mussels than does the upper Clinch River above Norris Reservoir.

Museum records from Hancock County, Tennessee, during 1965–1971 documented a very large population of snuffbox. The snuffbox is generally distributed from river mile 170 to river mile 195 (river km 274 to river km 314) in Hancock County, but is sporadic in Virginia in river miles 213–235 (river km 343–378), where it has recently declined (Butler 2007). At the time of listing it was unclear if this population was stable or declining. The snuffbox population is currently reported as stable and is recruiting and viable, although the size and range of the population as decreased from 40 years ago. The Clinch River ranks among the seven stronghold snuffbox populations rangewide. General threats to the Clinch River population include agriculture, timbering, coal mining and processing, natural gas extraction, power generation (fossil fuels), transportation (roads and railways), utility corridor development, and urbanization (Hylton 2016, pers. comm.).

Augmentation of snuffbox from cultured propagation efforts has occurred at several sites in the Clinch River in Virginia and Tennessee since 2005 (Hylton 2016, pers. comm.). These mussels were produced by Virginia Department of Game and Inland Fisheries at the Aquatic Wildlife Conservation Center (AWCC) and Virginia Tech’s Freshwater Mollusk Conservation Center (FMCC) from Clinch River broodstock (Hylton 2016, pers. comm.; Agbalog 2017, pers. comm.). Success of these efforts has not yet been documented. The AWCC plans to continue their snuffbox propagation efforts for the next several years (Agbalog 2017, pers. comm.).

The Clinch River population remains the strongest population in Tennessee with numerous individuals observed annually since its listing in 2012. However, a significant mussel die-off has occurred in the Clinch downstream of the TN/VA line beginning in the summer of 2016 and has continued through to winter 2017–2018 (Agbalog 2018, pers. comm.). The cause of this die-off and the impact to the mussel community has not yet been assessed, but Tennessee Wildlife Resource Agency plans to assist Virginia Tech and USFWS in an assessment at some of the long-term quantitative monitoring sites (Hubbs 2017, pers. comm.).

*Powell River* – The Powell River is the major tributary of the upper Clinch River flowing in a southwesterly direction parallel to and northwest of the Clinch River in southwestern Virginia and northeastern Tennessee. The snuffbox was reported at three sites by Ortmann (1918), five sites during 1973–1978 by Dennis (1981), four sites from 1975–1978 by Ahlstedt and Brown (1979), and four Virginia sites in 1988–1989 by Wolcott and Neves (1994). Large collections attest to its former abundance. The species was found live and fresh dead in the Powell River, Tennessee, during 1989–1990 (Hubbs *et al.* 1991). Johnson (2008) collected two live individuals at river mile 95 (river km 153). There has been no change in the status of this population since listing. The population is declining, viability is questionable, and its extirpation may be imminent (Butler 2007). Threats to the Powell River population include agriculture (row crops and livestock grazing), timbering, coal mining and processing, natural gas extraction, power generation

(fossil fuels), transportation (roads and railways), utility corridor development, and urbanization (Hylton 2016, pers. comm.). Augmentation of snuffbox from cultured propagation efforts has occurred at several sites in the Powell River in Virginia and Tennessee since 2012 (Hylton 2016, pers. comm.). These mussels were produced at the AWCC and FWCC from Clinch River broodstock (Hylton 2016, pers. comm.; Agbalog 2017, pers. comm.). Success of these efforts has not yet been documented.

*Paint Rock River* – The Paint Rock River is a southerly flowing, northern tributary of the southern bend of the Tennessee River in northeastern Alabama and adjacent Tennessee. The snuffbox was first reported from one of six mainstem sites by Ortmann (1925). No evidence of snuffbox was found in two surveys during 1965–1967 (Isom and Yokley 1973) and a 1980 survey (Butler 2007). Twelve live and fresh dead snuffbox were found at four sites between river miles 13 and 21 (river km 20.9 and 33.8) (Ahlstedt 1995–1996). The species was again absent from 10 upper mainstem sites surveyed in 2002 (Godwin 2002). Four fresh dead specimens of varying sizes were found at lower river sites in 2002 (Fraleay 2003, pers. comm.; Smith 2005, pers. comm.) and 2003–2006 (Freeman 2006, pers. comm.). One live and 11 fresh dead specimens were found at river mile 21 (river km 33.8) in 2005, and 2 live and 16 fresh dead were collected at river mile 31 (river km 49.9) in 2007 (Gangloff 2007, pers. comm.). In July 2008, Freeman (2008, pers. comm.) observed multiple age classes (sizes) of fresh dead snuffbox in middens (shell piles) between river mile 32.5 and 34.7 (river km 52.3 and 55.8). Fobian *et al.* (2008) collected 21 live snuffbox at 7 sites and fresh dead specimens at 8 sites between river mile 13.1 and 46.7 (river km 21.1 and 75.2).

The snuffbox occurs in approximately 34 miles (54.7 km) of the Paint Rock River from river mile 13.1 (river km 21.1) to river mile 46.7 (river km 75.1) in Jackson, Madison, and Marshall Counties, Alabama (Ford 2016, pers. comm.). Three snuffbox were found during a relocation for a bank stabilization project in September 2012. In 2013, 41 sites were surveyed between river miles 13.1 and 46.7 (river km 21.1 and 75.2) with 21 live snuffbox found at 7 sites and fresh dead snuffbox found at 8 sites (Fobian *et al.* 2014). At one location, the Jones Property site in Jackson County, Alabama, there were an estimated 500 snuffbox (Johnson 2017, pers. comm.). At the Butler Mill site in Madison County, Alabama, there were an estimated 200 snuffbox (Johnson 2017, pers. comm.).

There has been no change in the status of this population since listing. This stronghold snuffbox population is the most robust of the Alabama populations and is recruiting, viable, and has clearly improved since 1980. Threats to the watershed include erosion and siltation from agriculture along with residential and commercial development (Godwin 2002). Nonpoint source agricultural runoff and chemical spills are also a threat (Fobian *et al.* 2014).

*Elk River* – The Elk River is a large, northern tributary flowing 200 river miles (322 river km) in a southwesterly direction in the southern bend of the Tennessee River in south-central Tennessee and north-central Alabama. Snuffbox collections have been sporadic. The species was found at 2 sites in the mid-1960s (Isom *et al.* 1973), and a single live individual was found among 108 sites sampled in 1980 (Ahlstedt 1983). Single specimens were also reported from 4 sites sampled in the lower river in 1997 (Madison and Layzer 1998) and 16 sites sampled in 1999 (USFWS 1999). A very large fresh dead specimen was found at river mile 51 (river km 82) among 4 sites sampled in 2001 (Hubbs 2002; Butler 2007). A single live and a fresh dead snuffbox were found at a site in Giles County, Tennessee during qualitative sampling events at five sites in 2005 (Ahlstedt *et al.* 2006). Ford (2008, pers. comm.) reported collecting a fresh dead specimen at Stairstep Shoals in Giles County, Tennessee in July 2007. The last snuffbox observation was in 2015 (Ford 2016, pers. comm.).

There has been no change in the status of this population since listing. The small snuffbox population has recently recruited and exhibits some level of viability, and its numbers appear relatively stable in recent history. Operational changes occurred at the Tims Ford Dam between 2006 and 2008 to improve habitat below the dam for endangered fish and mussels. Starting in 2012, improvements in mussel density and recruitment below the dam have been observed during monitoring starting in 2012 (Howard 2017, pers. comm.). Habitat conditions are suitable further downstream into Alabama, especially now given the implementation of conservation flows by TVA below Tims Ford.

*Duck River* – The Duck River is the downstream-most large tributary of the Tennessee River draining south-central Tennessee and flowing 285 river miles (459 river km) west to its confluence near the head of Kentucky Reservoir. The snuffbox historically occurred throughout the Duck River and, based on museum records, was locally common 40 to 50 years ago, but was absent in surveys from river mile 180 (river km 289.7) downstream in the mid-1970s (Ahlstedt 1981; Dennis 1984). Two live individuals were collected from 2 of 99 sites surveyed in 1979 (Butler 2007). A single live individual was discovered in Maury County, Tennessee among 72 sites sampled during 2000–2003 (Ahlstedt *et al.* 2004), but none were found at 11 lower sites surveyed in 2000 (Schilling and Williams 2002). There has been no change in the status of this population since listing. The snuffbox is very rare, and its viability is uncertain.

In 2011 and 2012, propagated snuffbox were been released into the Duck River below Lillard’s Mill Dam in Tennessee. These mussels were a combination of Clinch River translocated adults and juveniles produced at the AWCC from Clinch River broodstock (Hubbs 2017, pers. comm.). Success of these efforts has not yet been documented.

#### Lower Mississippi River Sub-basin



The lower Mississippi River sub-basin includes 954 miles (1,535 km) of the Mississippi River from its confluence with the Ohio River at Cairo, Illinois, to its mouth in the Gulf of Mexico. Currently there are five extant snuffbox populations in this sub-basin and there are no additional streams that are known to have had historical populations. Of the five extant populations, three significant and two are marginal. Two of the three significant populations, the St. Francis River (MO) and Spring River (AR), are medium-sized with the St. Francis River being the only known stable population in this sub-basin. The third significant population is in the Black River (MO) and this population is considered to be small. Four of the five extant streams have new occurrence information since the time of listing. Recent recruitment has only been recently documented in the St. Francis River. Updated information on the Buffalo River (AR) is limited to additional information on threats.

*St. Francis River* – The St. Francis River is a major tributary of the lower Mississippi, with its headwaters in southeastern Missouri and flowing south into northeastern Arkansas. The only Arkansas records available for this 450-mile (724-km) river are from 1964, located approximately 1 mile (1.6 km) southwest of Parkin in Cross County (Bates and Dennis 1983; Harris *et al.* 2007). Snuffbox records exist for Butler, Wayne, and Stoddard Counties, Missouri, where it was considered “locally abundant” (Oesch 1984). The species is known from above Wappapello Reservoir, but was absent from Missouri surveys conducted below Wappapello Dam in 1983 (Bates and Dennis 1983), 1986 (Ahlstedt and Jenkinson 1991), and 2002 (Hutson and Barnhart 2004). The snuffbox has been collected more recently from the St. Francis River upstream of Wappapello Reservoir (Roberts 2018, pers. comm.). Twelve live snuffbox were sampled at sites in 2002 (Hutson and Barnhart 2004). Live individuals were found during collections at river mile 172.1 (river km 277) in 2005 and 2006 (Butler 2007). The snuffbox is restricted to a 10-mile (16-km) reach between river miles 172.1–182.0 (river km 277–292.9) on the northeastern edge of the Ozark Plateaus in the vicinity of Sam A. Baker State Park, Wayne County, Missouri (Hutson and Barnhart 2004). The most recent collections within this reach include three live individuals found in 2014 (McMurray 2016, pers. comm). There has been no change in the status of this population since listing. This medium-sized snuffbox population appears to be stable and viable, but restricted in distribution.

*Buffalo River* – The Buffalo River is a large, eastward-flowing tributary of the middle White River in north-central Arkansas. The snuffbox was not found during surveys in 1910 (26 sites; Meek and Clark 1912) or 1995 (40 sites; Harris 1996), but two live individuals were found at a single site among 60 sites surveyed in 2006 (Matthews 2007, pers. comm.). There has been no change in the status of this population since listing. The small population occurs in the lower river in Marion County, Arkansas and its viability is unknown. Threats include nonpoint source pollutants (nutrients and sediment) from a variety of land uses (e.g., livestock grazing, concentrated animal feeding operations, unpaved

roads). Gravel mining also occurs in some of the tributaries (Davidson 2016, pers. comm.).

*Black River* – The Black River is the largest tributary in the White River system, draining much of southeastern Missouri and northeastern Arkansas before flowing in a southerly direction into the White River near Newport, Arkansas. A long but sporadic collection history for the snuffbox appears in the 300-mile (483-km) Black River. A single, approximately 4-year-old live male was collected at river mile 65.5 (river km 105.4) in Wayne County, among 51 Missouri sites sampled in 2002 (Hutson and Barnhart 2004). This population of snuffbox appears rare, is likely limited to river reaches in Missouri and near the confluence of the Spring River in Arkansas, but viability is questionable. At the time of listing, this population was thought to be recruiting but at this time it is unknown if any recruitment is occurring. The last observation was in 2012. Threats include water withdrawal for agriculture, agricultural runoff (sediments, pesticides), and contaminants from municipal and industrial point source discharges (Davidson 2017, pers. comm.).

*Spring River* – The Spring River is a large tributary of the Black River that drains the eastern Ozark Plateaus in south-central Missouri and northeastern Arkansas. Based on pre-1986 records, the snuffbox was known in low numbers from at least four sites in approximately 20 river miles (34 river km) of the lowermost mainstem in Arkansas (Harris and Gordon 1987). A single live adult male was found in Lawrence County in 2005, and represents the first live specimen found in more than 20 years (Butler 2007). Further, 53 fresh dead snuffbox were collected in 4 large muskrat middens during the same time period (Harris *et al.* 2007). The extent of the population is not known, but it is probably limited to relatively few miles in the lower mainstem in Lawrence and Randolph Counties in Arkansas from Hardy, Arkansas downstream to the confluence with Black River. At one site downstream of Imboden, Arkansas, one female and seven males were collected in 2016 and two females and four males were collected in 2017 (Davidson 2017, pers. comm.). Historical threats include contaminant exposure from several train derailments and the collapse of the West Plains wastewater treatment plant lagoon in the 1980s. Current threats include extensive recreational use (canoeing), although this is more prevalent upstream of Hardy than downstream, and nonpoint source pollution from pastureland and sediment from unpaved roads (Davidson 2016, pers. comm.). There has been no change in the status of this population since listing. This population appears small, and its status and viability are unknown.

*Strawberry River* – The Strawberry River is a western tributary of the Black River draining a portion of the southeastern Ozark Plateaus in northeastern Arkansas. Snuffbox is only known from two relicts (1997, 2006) collected 0.06 mile (0.1 km) downstream of Mirey Branch and downstream of Arkansas Highway 117 (Davidson 2016, pers. comm.). No other details on these collections or the status of the population are known and its status has not changed since listing.

Considering the dearth of records, the snuffbox appears to be very rare in the Strawberry River, and its viability is unknown. Threats include gravel mining, sedimentation from unpaved roads, stream banks, and development around Horseshoe Bend and Ash Flat (Davidson 2016, pers. comm.).

**2.3.1.3 Genetics, genetic variation, or trends in genetic variation (e.g., loss of genetic variation, genetic drift, inbreeding, etc.):**

No new genetic information has been obtained since listing. Currently, a study is underway by Central Michigan University to determine the number of genetic populations for the snuffbox in the Great Lakes watershed. Once completed, the data from this study may help to develop a strategy for recovery implementation for the snuffbox in the Great Lakes watershed. Specifically, the results of the study will help ensure that any future propagation augmentations and reintroductions maintain the genetic integrity of the species.

West Virginia DNR is working with the U.S. Environmental Protection Agency to develop environmental DNA (eDNA) markers for snuffbox and to use these eDNA markers to assess streams for snuffbox presence. In 2016 and 2017, tissue samples were collected from 10 snuffbox and waters and sediment samples were collected from multiple streams, including several snuffbox streams (Middle Island Creek, McElroy Creek, Little Kanawha River, North Fork Hughes, and Elk River) (Douglas 2018, pers. comm.). Initial snuffbox markers that were developed from individuals outside the Ohio River watershed were found to not detect snuffbox presence in West Virginia, so additional tissue samples were collected to develop more sensitive markers (Douglas 2018, pers. comm.).

**2.3.1.4 Taxonomic classification or changes in nomenclature:**

There is no new taxonomic information since the species was listed (ITIS 2017).

**2.3.1.5 Spatial distribution, trends in spatial distribution (e.g. increasingly fragmented, increased numbers of corridors, etc.), or historical range (e.g. corrections to the historical range, change in distribution of the species' within its historical range, etc.):**

The snuffbox historically occurred in at least 211 streams and lakes in 18 States and 1 Canadian province: Alabama, Arkansas, Illinois, Indiana, Iowa, Kansas, Kentucky, Michigan, Minnesota, Mississippi, Missouri, New York, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia, and Wisconsin; and Ontario, Canada. At the time of listing in 2012, the species was known to be extant in 79 streams in 14 States and 1 Canadian province: Alabama, Arkansas, Illinois, Indiana, Kentucky, Michigan, Minnesota, Missouri, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia, and Wisconsin; and Ontario, Canada.

There are five additional streams (Cussewago Creek (PA), West Fork River

(WV), Meathouse Fork (WV), South Fork Hughes River (WV), and Kanawha River (WV)) that may have extant populations of snuffbox that were not included in the final listing rule. Four of the five streams are within watersheds with other known extant snuffbox populations and do not constitute range expansions for the species. One of the streams, the West Fork River, is a principal tributary to the Monongahela River. The West Fork River is currently the only stream in the Monongahela River watershed harboring the snuffbox. The West Fork River population is only known from one live snuffbox found in 2016. This population likely constitutes a remnant population, unknown at the time of listing, rather than a range expansion for the species.

Two streams (Willow Creek (WI) and Kankakee River (IL)) reported as having extant populations of snuffbox at the time of listing are now considered to be extirpated or possibly never present, in the case of Willow Creek.

The current status of the snuffbox, by sub-basin/system, is included in section 2.3.1.2.

**2.3.1.6 Habitat or ecosystem conditions (e.g., amount, distribution, and suitability of the habitat or ecosystem):**

There is no new information available on habitat or ecosystem conditions since the publication of the final rule in 2012. The snuffbox is found in small- to medium-sized creeks, to larger rivers, and in lakes (Cummings and Mayer 1992; Parmalee and Bogan 1998). The species occurs in swift currents of riffles and shoals and wave-washed shores of lakes over gravel and sand with occasional cobble and boulders. Individuals generally burrow deep into the substrate, except when spawning or attempting to attract a host (Parmalee and Bogan 1998).

**2.3.1.7 Other:**

N/A

**2.3.2 Five-Factor Analysis**

**2.3.2.1 Present or threatened destruction, modification or curtailment of its habitat or range:**

At the time of listing, destruction, modification, and curtailment of the species range was considered to be a threat to the species, primarily due to the construction of impoundments. Since the time of listing, five dam removals have occurred in snuffbox streams including the Lyons Dam on the Grand River (MI), West Milton Dam on the Stillwater River (OH) and three dams on the West Fork River (WV). The Lyons Dam removal restored 2.2 miles (3.6 km) of the Grand River to free flowing conditions (USFWS 2015). The West Milton Dam removal restored 2.2 miles (3.5 km) of the Stillwater River to free flowing condition

(Stantec 2014). The 3 dam removals on the West Fork River have restored 12.5 miles (20.1 km) of the river to free flowing condition (Douglas 2018, pers. comm.). An improvement to the status of the snuffbox populations in these streams has not yet been documented.

The snuffbox has experienced significant curtailment of its occupied range. The species has been eliminated from about 61 percent of the streams in which it historically occurred. Because multiple streams may comprise a single snuffbox population (French Creek system), the actual number of extant populations is fewer than 82. Realistically, much more than 61 percent of the habitat historically available for this species no longer supports its populations. Habitat losses measured in the thousands of miles have occurred rangewide. Available records indicate that 18 of 82 streams considered to harbor extant populations of the snuffbox are represented by only one or two recent live or fresh dead individuals (Pine River (MI), Ohio River (OH, WV), Woodcock Creek (PA), Cussewago Creek (PA), Hughes River (WV), South Fork Hughes River (WV), Kanawha River (WV), Olentangy River (OH), Big Darby Creek (OH), Kinniconick Creek (KY), Licking River (KY), Rolling Fork Salt River (KY), Sugar Creek (IN), Powell River (TN, VA), Tennessee River (AL), Duck River (TN), Buffalo River (AR), and Black River (MO)). In addition, there are 22 streams that have no occurrence records since the 1990's (Pigeon River (MI), South Ore Creek (MI), Portage River (MI), Meremec River (MO), Conneaut Outlet (PA), Little Mahoning Creek (PA), Walhonding River (OH), Tygarts Creek (KY), Little Darby Creek (OH), Salt Creek (OH), Scioto Brush Creek (OH), South Fork Scioto Brush Creek (OH), Little Miami River (OH), Slate Creek (KY), Middle Fork Kentucky River (KY), Red Bird River (KY), Green River (KY), Buck Creek (IN), Muskatatuck River (IN), Graham Creek (IN), Buck Creek (KY), Strawberry River (AR). The persistence of extant populations in most of these 22 streams is questionable. It should be noted that many of them have not been surveyed extensively since the snuffbox was last documented. Combined, these 17 and 22 streams (39 total) comprise 48 percent of all the streams that may have extant snuffbox populations.

The cause of range curtailment has been modification and destruction of river and stream habitats, primarily by the construction of impoundments. Ongoing threats to the snuffbox include water quality degradation from point and non-point sources including agricultural runoff, municipal effluents, industrial sources, and spills. These sources contribute sediment, organic compounds, heavy metals, pesticides, and a wide variety of newly emerging contaminants to the aquatic environment. Other factors contributing to the reduction in range include dredging and channelization, oil and gas production (including water withdrawal), and sand and gravel mining, and development.

Since the species was listed, there have been multiple projects (exact number unknown) that have had the potential to impact snuffbox populations. Some of these projects were subsequently modified to avoid all instream effects, thereby

avoiding adverse effects to the snuffbox. Instream effects could not be avoided for some projects due to the nature of these projects, which required instream work (e.g. bridge repair or replacement projects, dam removal). Through consultation with the local Service Field Offices, snuffbox, and other mussels, are typically relocated out of harm's way for these types of projects as a conservation measure for the species. Survival rates for relocated mussels can vary greatly and may depend on a variety of timing and habitat factors (Hamilton *et al.* 1997; Cope *et al.* 1995). Survival rates for relocated snuffbox will vary by site and streams and some level of mortality is likely. Five of these projects were for dam removals. While dam removals may have a short-term adverse effect on individual snuffbox, the overall result to the species, and the host fish, from habitat restoration is expected to be beneficial.

#### **2.3.2.2 Overutilization for commercial, recreational, scientific, or educational purposes:**

At the time of listing, overutilization was not considered to be a threat to the species. We have no new information regarding overutilization of the snuffbox since the species was listed. The snuffbox is not a commercially valuable species, though rare species like the snuffbox may increasingly be sought by lay and experienced collectors. Most stream reaches inhabited by this species are restricted, and the populations are generally small. Although scientific collecting is not thought to represent a significant threat, localized populations could become impacted and possibly extirpated by over-collecting, particularly if this activity is unregulated.

#### **2.3.2.3 Disease or predation:**

At the time of listing, disease and predation were not considered to be significant threats to the species. Little is known about diseases in freshwater mussels (Grizzle and Brunner 2007). However, mussel die-offs have been documented in snuffbox streams, and some researchers believe that disease may be a factor contributing to the die-offs (Buchanan 1986; Neves 1986). Since listing, mussel die-offs have occurred in three snuffbox streams (Elk River (WV), Big Darby Creek (OH) and Clinch River (TN)). The causes of these recent die-offs are not known. It is also not known if any snuffbox were affected during these events.

Mussel parasites include water mites, trematodes, oligochaetes, leeches, copepods, bacteria, and protozoa (Grizzle and Brunner 2007). Generally, parasites are not suspected of being a major limiting factor (Oesch 1984), but a study provides contrary evidence. Reproductive output and physiological condition were negatively correlated with mite and trematode abundance, respectively (Butler 2007). Stressors that reduce fitness may make mussels more susceptible to parasites (Butler 2007). Furthermore, nonnative mussels may carry diseases and parasites that are potentially devastating to native mussel fauna, including rayed bean and snuffbox (Strayer 1999).

The muskrat (*Ondatra zibethicus*) is cited as the most prevalent mussel predator (Kunz 1898; Hanson *et al.* 1989). Muskrat predation may limit the recovery potential of endangered mussels or contribute to local extirpations of previously stressed populations, according to Neves and Odom (1989), but they consider it primarily a seasonal or localized threat. The snuffbox ranked fourth among 12 species in a St. Croix River muskrat midden, being nearly four times more abundant than in quantitative surveys (Tyrrell and Hornbach 1998). Mussel numbers were too low to determine selectivity indices or statistics.

Other mammals (raccoon (*Procyon lotor*), mink (*Mustela vison*), river otter, striped skunk (*Mephitis mephitis*), hog (*Sus scrofa*), rat (*Rattus spp.*)), amphibians (hellbender (*Cryptobranchus alleganiensis*)), turtles, aquatic birds, and fishes (freshwater drum (*Aplodinotus grunniens*), redear sunfish (*Lepomis microlophus*)) feed on mussels (Kunz 1898; Meek and Clark 1912; Neck 1986; Tyrrell and Hornbach 1998). Hydra, non-biting midge larvae, dragonfly larvae, crayfish, and especially flatworms are invertebrate predators on newly metamorphosed juveniles (Zimmerman *et al.* 2003; Klocker and Strayer 2004). However, the overall threat posed by these predators on the snuffbox is not considered significant.

#### **2.3.2.4 Inadequacy of existing regulatory mechanisms:**

There is no new information on changes to regulatory mechanisms since the time of listing. Existing regulatory mechanisms have not been sufficient to significantly reduce or remove the threats to the snuffbox.

#### **2.3.2.5 Other natural or manmade factors affecting its continued existence:**

We have no new information regarding other natural or manmade factors affecting this species since the species was listed. The size and status of the remaining populations appear to be relatively unchanged since listing. The majority of the remaining populations of the snuffbox are generally small and geographically isolated, making natural repopulation of extirpated populations unlikely without human intervention. Furthermore, many of the remaining populations are likely below the effective population size, making future extirpations likely.

Factors associated with climate change likely to affect regional mussel populations include changes in stream temperature regimes and precipitation levels that may indirectly result in reduced habitat and declines in host fish stocks (Hastie *et al.* 2003). In addition, various exotic species are well established with the range of the snuffbox. Exotic species, including the zebra mussel, Asian clam (*Corbicula fluminea*), round goby, and black carp (*Mylopharyngodon piceus*), threaten the snuffbox, or its host fish, or both, through mechanisms such as habitat modification, competition, and predation. We are not aware of any new threats

from climate change and/or exotic species or a change in the magnitude of threats from any natural or manmade factors since the species was listed.

## 2.4 Synthesis

The snuffbox is a federally listed endangered species that is currently considered extant in 82 streams in Alabama, Arkansas, Illinois, Indiana, Kentucky, Michigan, Minnesota, Missouri, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia, Wisconsin, and Ontario, Canada. Records indicate that the species historically occurred in at least 213 streams and lakes and also historically occurred in Iowa, Kansas, Mississippi, and New York. The species has been extirpated from the lower Missouri River System and now only occurs in 7 streams in the upper Great Lakes sub-basin, 10 streams in the lower Great Lakes sub-basin, 4 streams in the upper Mississippi River sub-basin, 49 streams in the Ohio River System, 1 stream in the Cumberland River System, 6 streams in the Tennessee River System, and 5 streams in the lower Mississippi River sub-basin.

Only 5 (6 percent) of the remaining populations are considered to be large and stable or improving. Four of these populations are strongholds (Bourbeuse River (MO), French Creek (PA), Clinch River (TN, VA), and Paint Rock River (AL)) and one is a significant population (St. Croix River (MN, WI)). Three of the seven stronghold populations are either declining in numbers or the trend is unknown. Of the 82 extant populations, only 17 (21 percent), including all 7 of the strongholds and 10 of the significant populations, are thought to be recruiting with a high potential for having viable populations. Of the 24 significant populations, only 4 are thought to be stable or improving in numbers. Also, there are only 3 of the 24 populations that are considered to be large and 2 of the 3 are declining in numbers. Of the 51 marginal populations, none are considered to be stable.

The biology of the snuffbox is similar to other bivalved mollusks belonging to the family Unionidae. They are sexually dimorphic though the age of sexual maturity is unknown. The verified snuffbox host fish are the logperch (*Percina caprodes*), blackside darter (*P. maculata*), rainbow darter, Iowa darter (*E. exile*), blackspotted topminnow (*Fundulus olivaceus*), mottled sculpin, banded sculpin (*C. carolinae*), Ozark sculpin (*C. hypselurus*), largemouth bass, and brook stickleback (*Culaea inconstans*).

Successful propagation techniques for the snuffbox are fairly well established. Propagation and augmentation and/or reintroduction of snuffbox are ongoing in Indiana, Kentucky, Minnesota, Tennessee, Wisconsin, and Virginia. The methods being used include host fish inoculation and in vitro culture of glochidia without utilizing host fish. Where host fish are being utilized, the fish are inoculated with larvae then either released into a stream or kept in cages or tanks to grow juvenile mussels to a stockable size. Streams with ongoing efforts include the Mississippi River (MN), St. Croix River (MN, WI), Tippecanoe River (IN), Rolling Fork Salt River (KY), Green River (KY), Clinch River (TN, VA), Powell River (TN, VA), and Duck River (TN).

The Bourbeuse River, one of the few stronghold snuffbox populations rangewide, was augmented with laboratory propagated juveniles in 2002 and 2005 (Barnhart and Kaiser



2005; Barnhart 2006). Reintroduction efforts in the upper Mississippi River were initiated in 2007 using inoculated logperch held in cages (Davis 2017, pers. comm.). In 2013, captively propagated snuffbox were also released into the river at three locations (Sietman 2014, pers. comm.). Indiana is currently holding juvenile snuffbox in Lake Shafer in a cage to allow the mussels to grow to a stockable size to augment the Tippecanoe River population (Fisher 2017). Kentucky Department of Fish and Wildlife's Center for Mollusk Conservation has been culturing snuffbox using fish and in vitro methods using Rolling Fork Salt River broodstock. Juvenile snuffbox from this effort have been used to augment both the Rolling Fork Salt River and Green River populations (McGregor 2017, pers. comm.). Propagation facilities in Virginia have been propagating snuffbox using Clinch River adults since the early 2000s. Cultured snuffbox produced from these efforts have been placed in to the Clinch, Powell, and Duck Rivers in Virginia and Tennessee. The success of these efforts has not yet been determined.

Since listing, there has been no significant change in the species' spatial distribution, abundance, or historical range. One stream (Kankakee River (IL)) where the species was thought to be extant at the time of listing is now considered to be extirpated. The species was also thought to be extant in Willow Creek (WI), but a review of the only stream record has determined that the record was for another species that was misidentified as snuffbox. No other records exist to indicate that snuffbox historically occurred in Willow Creek. Four streams listed as extirpated in the final listing rule are now considered to have extant populations (Cussewago Creek (PA), West Fork River (WV), Meathouse Fork (WV), and South Fork Hughes River (WV)), though the size and viability of these populations is unknown. The Kanawha River (WV) population was considered to be extirpated at the time of listing by the West Virginia DNR, though this stream was not noted as an historical stream at that time. Due to the close proximity of these five newly discovered extant populations to other extant populations, these new records cannot be considered to be a range expansion for the species.

The overall snuffbox status has not improved since listing and threats have not been ameliorated. Threats persist for the remaining snuffbox populations, including habitat degradation and climate change. Only six percent of the extant populations are large and stable or improving. Although there are ongoing attempts to alleviate some threats, there appear to be no populations without current significant threats and many threats are without obvious or readily available solutions. Therefore, we are not recommending a change in status at this time.

## **RECOMMENDATIONS FOR FUTURE ACTIONS**

Develop a recovery plan for the species.

Maintain and increase vegetated riparian buffers of streams throughout the range of the species.

Initiate more watershed-level, community based riparian habitat restoration projects in streams harboring the snuffbox.

Investigate the U.S. Environmental Protection Agency's water quality criteria for pollutants to determine levels that would be protective of the snuffbox and other mussels.

Work with the U.S. Environmental Protection Agency to adjust the water quality to levels needed to protect the snuffbox (and other mussels) (see previous action).

Perform surveys in known streams to assess the status of known populations and to locate additional populations.

Rear juveniles in captivity using host fish and in-vitro techniques for future augmentation and reintroductions and develop a captive propagation and genetics management plan.

Investigate potential sites for future augmentation or reintroduction of captivity reared juveniles and/or adults.

Develop and implement a monitoring program to evaluate conservation efforts, monitor population levels and habitat conditions, and assess the long-term viability of extant, newly discovered, augmented, and reintroduced snuffbox populations.

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**U.S. FISH AND WILDLIFE SERVICE  
5-YEAR REVIEW of snuffbox (*Epioblasma triquetra*)**

**Current Classification:** Endangered

**Recommendation resulting from the 5-Year Review:**

- Downlist to Threatened
- Uplist to Endangered
- Delist
- No change needed

**Appropriate Delisting Priority Number:** N/A

**Review Conducted By:** Angela Boyer, Fish and Wildlife Biologist

**FIELD OFFICE APPROVAL:**

**Lead Field Supervisor, Fish and Wildlife Service**

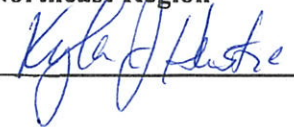
Approve  Date 8/14/2018

**REGIONAL OFFICE APPROVAL:**

**Lead Assistant Regional Director, Ecological Services, Fish and Wildlife Service**

Approve  Date 8/21/18

**Cooperating Assistant Regional Director, Ecological Services, U.S. Fish and Wildlife Service, Northeast Region**

Approve  Date 2-20-19

**Cooperating Assistant Regional Director, Ecological Services, U.S. Fish and Wildlife Service, Southeast Region**

Approve  Date 2/5/2019