DEPARTMENT OF THE INTERIOR

Fish and Wildlife Service

50 CFR Part 17

[Docket No. FWS–R3–ES–2010–0019; MO 92210–0–0008–B2]

RIN 1018–AV96

Endangered and Threatened Wildlife and Plants; Listing the Rayed Bean and Snuffbox as Endangered

AGENCY: Fish and Wildlife Service, Interior.

ACTION: Proposed rule.

SUMMARY: We, the U.S. Fish and Wildlife Service (Service), propose to list the rayed bean (*Villosa fabalis*) and snuffbox (*Epioblasma triquetra*) as endangered throughout their ranges, under Endangered Species Act of 1973, as amended (Act). This proposed rule, if made final, would extend the Act's protection to the rayed bean and the snuffbox. We have determined that designating critical habitat for these species is prudent, but not determinable at this time. The Service seeks data and comments from the public on this proposed listing rule.

DATES: We will consider comments we receive on or before January 3, 2011. We must receive requests for public hearings, in writing, at the address shown in the **FOR FURTHER INFORMATION CONTACT** section on or before December 17, 2010.

ADDRESSES: You may submit comments by one of the following methods:

- *Federal eRulemaking Portal: http://www.regulations.gov.* Follow the instructions for submitting comments on Docket No. FWS–R3–2010–0019.
- *U.S. mail or hand-delivery:* Public Comments Processing, Attn: FWS–R3–2010–0019; Division of Policy and Directives Management; U.S. Fish and Wildlife Service; 4401 N. Fairfax Drive, Suite 222; Arlington, VA 22203.

We will post all comments on *http://www.regulations.gov.* This generally means that we will post any personal information you provide us (*see* the Public Comments section below for more information).

FOR FURTHER INFORMATION CONTACT: Angela Boyer at the U.S. Fish and Wildlife Service, Ohio Ecological Services Field Office, 4625 Morse Road, Suite 104, Columbus, OH 43230; telephone 614–416–8993, ext. 22.

SUPPLEMENTARY INFORMATION:

Public Comments

Our intent is to use the best available commercial and scientific data as the foundation for all endangered and threatened species listing determinations. We therefore request comments or suggestions from other concerned governmental agencies, the scientific community, industry, or any other interested party concerning this proposed rule to list the rayed bean and snuffbox as endangered. We particularly seek comments concerning:

(1) Survey results for the rayed bean or snuffbox, as well as any studies that may show distribution, status, population size, or population trends, including indications of recruitment;

(2) Pertinent aspects of life history, ecology, and habitat use of the rayed bean or snuffbox;

(3) Current and foreseeable threats faced by the rayed bean or snuffbox, or both species, in relation to the five factors (as defined in section 4(a)(1) of the Act (16 U.S.C. 1531 *et seq.*));

(4) The specific physical and biological features to consider, and specific areas that may meet the definition of critical habitat and that should or should not be considered for a proposed critical habitat designation as provided by section 4 of the Act; and

(5) The data and studies to which this proposal refers.

You may submit your comments and materials concerning this proposed rule by one of the methods listed in the **ADDRESSES** section. We will not accept comments sent by e-mail or fax or to an address not listed in the **ADDRESSES** section. Comments must be submitted to *http://www.regulations.gov* before midnight (Eastern Time) on the date specified in the **DATES** section. Finally, we will not consider hand-delivered comments that we do not receive, or mailed comments that are not postmarked, by the date specified in the **DATES** section.

We will post your entire comment —including your personal identifying information—on *http://www.regulations.gov.* If you provide us personal identifying information such as your street address, phone number, or e-mail address, you may request at the top of your document that we withhold this information from public review. However, we cannot guarantee that we will be able to do so.

Comments and materials we receive, as well as supporting documentation we used in preparing this proposed rule, will be available for public inspection on *http://www.regulations.gov,* or by appointment, during normal business hours at the Ohio Ecological Services Field Office (*see* **FOR FURTHER INFORMATION CONTACT**).

Public Hearing

The Act provides for one or more public hearings on this proposal, if requested. We must receive requests by the date listed in the **DATES** section above. Such requests must be made in writing and addressed to the Field Supervisor of the Ohio Ecological Services Field Office (*see* **FOR FURTHER INFORMATION CONTACT**).

Background

Species Descriptions

The rayed bean is a small mussel usually less than 1.5 inches (in) (3.8 centimeters (cm)) in length (Cummings and Mayer 1992, p. 142; Parmalee and Bogan 1998, p. 244; West *et al.* 2000, p. 248). The shell outline is elongate or ovate in males and elliptical in females, and moderately inflated in both sexes, but more so in females (Parmalee and Bogan 1998, p. 244). The valves are thick and solid. The anterior end is rounded in females and bluntly pointed in males (Cummings and Mayer 1992, p. 142). Females are generally smaller than males (Parmalee and Bogan 1998, p. 244). Dorsally, the shell margin is straight, while the ventral margin is straight to slightly curved (Cummings and Mayer 1992, p. 142). The beaks are slightly elevated above the hingeline (West *et al.* 2000, p. 248), with sculpture consisting of double loops with some nodules (Parmalee and Bogan 1998, p. 244). No posterior ridge is evident. Surface texture is smooth and sub-shiny, and green, yellowish-green, or brown in color, with numerous wavy, dark-green rays of various widths (sometimes obscure in older, blackened specimens) (Cummings and Mayer 1992, p. 142; West *et al.* 2000, p. 248). Internally, the left valve has two pseudocardinal teeth (tooth-like structures along the hinge line of the internal portion of the shell) that are triangular, relatively heavy, and large, and two short, heavy lateral teeth (Cummings and Mayer 1992, p. 142). The right valve has a low, triangular pseudocardinal tooth, with possibly smaller secondary teeth anteriorly and posteriorly, and a short, heavy, and somewhat elevated lateral tooth (Parmalee and Bogan 1998, p. 244). The color of the nacre (mother-of-pearl) is silvery white or bluish and iridescent posteriorly. Key characters useful for distinguishing the rayed bean from other mussels is its small size, thick valves, unusually heavy teeth for a small mussel, and color pattern (Cummings and Mayer 1992, p. 142).

The snuffbox is a small- to medium-sized mussel with males reaching up to 2.8 in. (7.0 cm) in length (Cummings and Mayer 1992, p. 162; Parmalee and Bogan 1998, p. 108). The maximum length of females is about 1.8 in (4.5 cm) (Parmalee and Bogan 1998, p. 108). The shape of the shell is somewhat triangular (females), oblong, or ovate (males) with the valves solid, thick, and very inflated. The beaks are located somewhat anterior of the middle, swollen, turned forward and inward, and extended above the hingeline (Cummings and Mayer 1992, p. 162). Beak sculpture consists of three or four faint, double-looped bars (Cummings and Mayer 1992, p. 162; Parmalee and Bogan 1998, p. 108). The anterior end of the shell is rounded, and the posterior end is truncated, highly so in females. The posterior ridge is prominent, being high and rounded, while the posterior slope is widely flattened. The posterior ridge and slope in females is covered with fine ridges and grooves, and the posterioventral shell edge is finely toothed (Cummings and Mayer 1992, p. 162). When females are viewed from a dorsal or ventral perspective, the convergence of the two valves on the posterior slope is nearly straight due to being highly inflated. This gives the female snuffbox a unique broadly lanceolate or cordate perspective when viewed at the substrate and water column interface (Ortmann 1919, p. 329; van der Schalie 1932, p. 104). The ventral margin is slightly rounded in males and nearly straight in females. Females have recurved denticles on the posterior shell margin that aid in holding host fish (Barnhart 2008, p. 1). The periostracum (external shell surface) is generally smooth and yellowish or yellowish-green in young individuals, becoming darker with age. Green squarish, triangular, or chevron-shaped marks cover the umbone (the inflated area of the shell along the dorsal margin) but become poorly delineated stripes with age. Internally, the left valve has two high, thin, triangular, emarginate pseudocardinal teeth (the front tooth being thinner than the back tooth) and two short, strong, slightly curved, and finely striated lateral teeth. The right valve has a high, triangular pseudocardinal tooth with a single short, erect, and heavy lateral tooth. The interdentum (a flattened area between the pseudocardinal and lateral teeth) is absent, and the beak cavity is wide and deep. The color of the nacre is white, often with a silvery luster, and a gray-blue or gray-green tinge in the beak cavity. The soft anatomy was described by Oesch (1984, pp. 233–234), and Williams *et al.* (2008, p. 282). Key characters useful for distinguishing the snuffbox from other species include its unique color pattern, shape (especially in females), and high degree of inflation.

Taxonomy

The rayed bean is a member of the freshwater mussel family Unionidae and was originally described as *Unio fabalis* by Lea in 1831. The type locality is the Ohio River (Parmalee and Bogan 1998, p. 244), probably in the vicinity of Cincinnati, Ohio. Over the years, the rayed bean has been placed in the genera *Unio, Margarita, Margaron, Eurynia, Micromya,* and *Lemiox.* It was ultimately placed in the genus *Villosa* by Stein (1963, p. 19), where it remains today (Turgeon *et al.* 1998, p. 33). We recognize *Unio capillus, U. lapillus,* and *U. donacopsis* as synonyms of *Villosa fabalis.*

The snuffbox is a member of the freshwater mussel family Unionidae and was described as *Truncilla triqueter* (Rafinesque 1820, p. 300). The species name was later changed to *triquetra* (Simpson 1900, p. 517), from the Latin *triquetrous* meaning "having three acute angles," a reference to the general shape of the female. The type locality is the Falls of the Ohio (Ohio River, Louisville, Kentucky) (Parmalee and Bogan 1998, p. 108). The synonymy of the snuffbox was summarized by Johnson (1978, pp. 248–249), Parmalee and Bogan (1998, p. 108), and Roe (no date, p. 3). This species has also been considered a member of the genera *Unio, Dysnomia, Plagiola, Mya, Margarita, Margaron,* and *Epioblasma* at various times since its description. The monotypic subgenus *Truncillopsis* was created for this species (Ortmann and Walker 1922, p. 65). The genus *Epioblasma* was not in common usage until the 1970s (Stansbery 1973, p. 22; Stansbery 1976, p. 48; *contra* Johnson 1978, p. 248), where it currently remains (Turgeon *et al.* 1998, p. 34). *Unio triqueter, U. triangularis, U. triangularis longisculus, U. triangularis pergibosus, U. cuneatus,* and *U. formosus* are recognized as synonyms of *E. triquetra.* Tricorn pearly mussel is another common name for this species (Clarke 1981a, p. 354).

Life History

The general biology of the rayed bean and the snuffbox are similar to other bivalved mollusks belonging to the family Unionidae. Adults are suspension-feeders, spending their entire lives partially or completely buried within the substrate (Murray and Leonard 1962, p. 27). Adults feed on algae, bacteria, detritus, microscopic animals, and dissolved organic material (Silverman *et al.* 1997, p. 1859; Nichols and Garling 2000, p. 873; Christian *et al.* 2004, pp. 108–109; Strayer *et al.* 2004, pp. 430–431). Recent evidence suggests that adult mussels may also deposit-feed on particles in the sediment (Raikow and Hamilton 2001, p. 520). For their first several months, juvenile mussels employ foot (pedal) feeding, consuming settled algae and detritus (Yeager *et al.* 1994, p. 221). Unionids have an unusual mode of reproduction. Their life cycle includes a brief, obligatory parasitic stage on fish. Eggs develop into microscopic larvae called glochidia within special gill chambers of the female. The female expels the mature glochidia, which must attach to the gills or the fins of an appropriate fish host to complete development. Host fish specificity varies among unionids. Some species appear to use a single host, while others can transform on several host species. Following successful infestation, glochidia encyst (enclose in a cyst-like structure) and drop off as newly transformed juveniles. For further information on freshwater mussels, see Gordon and Layzer (1989, pp. 1–17).

Mussel biologists know relatively little about the specific life-history requirements of the rayed bean and the snuffbox. Most mussels, including the rayed bean and snuffbox, have separate sexes. The age at sexual maturity, which is unknown for the rayed bean and snuffbox, is highly variable among and within species (0–9 years) (Haag and Staton 2003, pp. 2122–2123), and may be sex dependent (Smith 1979, p. 382). Both species are thought to be long-term brooders; rayed bean females brood glochidia from May through October (Parmalee and Bogan 1998, p. 108; Ecological Specialists, Inc. (ESI) 2000, p. 5; Woolnough 2002, p. 23), and snuffbox brood glochidia from September to May (Ortmann 1912, p. 355; 1919, p. 327). The only published research identifies the Tippecanoe darter (*Etheostoma tippecanoe*) as a host fish for the rayed bean (White *et al.* 1996, p. 191). Other rayed bean hosts are thought to include the greenside darter (*E. blennioides*), rainbow darter (*E. caeruleum*), mottled sculpin (*Cottus bairdi*), and largemouth bass (*Micropterus salmoides*) (Woolnough 2002, p. 51). Based on inference of closely related species, additional hosts may be suitable, including other darter and sculpin species (Jones 2002, pers. comm.). Juvenile snuffbox have successfully transformed on logperch (*Percina caprodes*), blackside darter (*P. maculata*), rainbow darter, Iowa darter (*E. exile*), blackspotted topminnow (*Fundulus olivaceous*), mottled sculpin, banded sculpin (*C. carolinae*), Ozark sculpin (*C. hypselurus*), largemouth bass, and brook stickleback (*Culaea inconstans*) in laboratory tests (Sherman 1994, p. 17; Yeager and Saylor 1995, p. 3; Hillegass and Hove 1997, p. 25; Barnhart *et al.* 1998, p. 34; Hove *et al.* 2000, p. 30; Sherman Mulcrone 2004, pp. 100–103).

Habitat Characteristics

The rayed bean is generally known from smaller, headwater creeks, but occurrence records exist from larger rivers (Cummings and Mayer 1992, p. 142; Parmalee and Bogan 1998, pp. 244). They are usually found in or near shoal or riffle areas, and in the shallow, wave-washed areas of glacial lakes, including Lake Erie (West *et al.* 2000, p. 253). In Lake Erie, the species is generally associated with islands in the western portion of the lake. Preferred substrates typically include gravel and sand. The rayed bean is oftentimes found among vegetation (water willow (*Justicia americana*) and water milfoil (Myriophyllum *sp.*)) in and adjacent to riffles and shoals (Watters 1988b, p. 15; West *et al.* 2000, p. 253). Specimens are typically buried among the roots of the vegetation (Parmalee and Bogan 1998, pp. 245). Adults and juveniles appear to produce byssal threads (thin, protein-based fibers) (Woolnough 2002, pp. 99–100), apparently to attach themselves to substrate particles.

The snuffbox is found in small to medium-sized creeks to larger rivers and in lakes (Cummings and Mayer 1992, p. 162; Parmalee and Bogan 1998, p. 108). 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, p. 108).

Strayer (1999a, pp. 471–472) demonstrated in field trials that mussels in streams occur chiefly in flow refuges, or relatively stable areas that displayed little movement of particles during flood events. Flow refuges conceivably allow relatively immobile mussels to remain in the same general location throughout their entire lives. He thought that features commonly used in the past to explain the spatial patchiness of mussels (water depth, current speed, sediment grain size) were poor predictors of where mussels actually occur in streams.

Rayed Bean Historical Distribution

The rayed bean historically occurred in 112 streams, lakes, and some human-made canals in 10 States: Illinois, Indiana, Kentucky, Michigan, New York, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia; and Ontario, Canada. The mussel occurred in parts of the upper (Lake Michigan drainage) and lower Great Lakes systems, and throughout most of the Ohio and Tennessee River systems. During historical times, the rayed bean was fairly widespread and locally common in many Ohio River system streams based on collections made over a several-decade period. The species was once fairly common in the Belle, South Branch Thames, Detroit, Scioto, Wabash, and Duck Rivers; several tributaries in the Scioto system (Olentangy River, and Big Darby and Alum Creeks); and Tippecanoe Lake based on literature and museum records (Call 1900; Watters 1994, p. 105; West *et al.* 2000, p. 251; Badra 2002, pers. comm.). The rayed bean was last reported from some streams several decades ago (North Branch Clinton, Auglaize, Ohio, West Fork, Beaver, Shenango, Mahoning, Mohican, Scioto, Green, Barren, Salamonie, White, Big Blue, Tennessee, Holston, South Fork Holston, Nolichucky, Clinch, North Fork Clinch, and Powell Rivers; Wolf, Conewango, Oil, Crooked, Pymatuning, Mill, Alum, Whetstone, Deer, Lick, and Richland Creeks; and Buckeye, Tippecanoe, Winona, and Pike Lakes). The rayed bean population in Lake Erie was once considerable (Ohio State University Museum of Biological Diversity (OSUM) collections), but has been eliminated by the zebra mussel.

Rayed Bean Current Distribution

Extant populations of the rayed bean are known from 28 streams and 1 lake in six States and one Canadian province: Indiana (St. Joseph River (stream) (Fish Creek (tributary)), Tippecanoe River (Lake Maxinkuckee, Sugar Creek)), Michigan (Black River (Mill Creek), Pine River, Belle River, Clinton River), New York (Allegheny River (Olean Creek, Cassadaga Creek, French Creek)), Ohio (Swan Creek, Fish Creek, Blanchard River, Tymochtee Creek, Walhonding River, Mill Creek, Big Darby Creek, Scioto Brush Creek), (Great Miami River, Little Miami River (East Fork Little Miami River), Stillwater River), Pennsylvania (Allegheny River (French Creek (Cussewago Creek))), and West Virginia (Elk River); and Ontario, Canada (Sydenham River, Thames River).

Rayed Bean Population Estimates and Status

Based on historical and current data, the rayed bean has declined significantly rangewide and is now known from only 28 streams and 1 lake (down from 112), a 74 percent decline (Table 1). This species has also been eliminated from long reaches of former habitat in hundreds of miles of the Maumee, Ohio, Wabash, and Tennessee Rivers and from numerous stream reaches and their tributaries. In addition, this species is no longer known from the States of Illinois, Kentucky, Tennessee, and Virginia. The rayed bean was also extirpated in West Virginia until the 2006 reintroduction into the Elk River (Clayton 2007, pers. comm.).

In this proposed rule, mussel shell collection records have been classified according to the condition of shell material. Fresh dead (FD) shells still have flesh attached to the valves, they may or may not retain a luster to their nacre, and their periostracum is non-peeling, all indicating relatively recent death (generally less than 1 year) (Buchanan 1980, p. 4). Relic (R) shells have lost the luster to their nacre, have peeling or absent periostracum, may be brittle or worn, and likely have been dead more than a year (Buchanan 1980, pp. 4–5; Zanatta *et al.* 2002, p. 482). Generally, FD shells indicate the continued presence of the species at a site (Metcalf 1980, p. 4). The presence of R shells only, along with repeated failure to find live (L) animals or FD shells, likely signifies that a population is extirpated (Watters and Dunn 1993–94, pp. 253–254). Shells labeled R may originally have been reported by collectors as either weathered dead (or weathered dry) or subfossil. If no details on shell condition were provided for a record, the shell is simply referred to as dead. In this document, a population is considered viable if it is reproducing and has enough individuals to sustain the population at its current level for the foreseeable future.

TABLE 1—RAYED BEAN STATUS AT HISTORICAL LOCATIONS

River basin	Stream	Last observed (R = relic)	Current status	Comments
Upper Great Lakes Sub-basin.	Pigeon River	1996 (R)	Extirpated	
Lower Great Lakes Sub-basin.	Black River	2001	Unknown	Small and of questionable viability.
	Mill Creek	2002	Unknown	Unknown.
	Pine River	2002	Declining	Recruiting.
	Belle River	2003	Unknown	
	Clinton River	1992	Unknown	Recruiting.
	North Fork Clinton River	1933	Extirpated	
	Sydenham River (Canada)	2003	Stable	Recruiting.
	Thames River	2008	Unknown	Unknown.
	Detroit River	1983	Extirpated	
	Rouge River	<1914	Extirpated.	
	Huron River	1931–32	Extirpated.	
	Raisin River	1941	Extirpated.	
	Macon Creek	1976–78 (R)	Extirpated.	
	Maumee River	1913	Extirpated.	
	Swan Creek	2009	Stable	Recruiting.
	St. Joseph River	1998	Declining	Probably not recruiting.
	West Branch St. Joseph River	1997 (R)	Extirpated.	
	Fish Creek	2009	Declining	Unknown.
	Cedar Creek	1985	Extirpated.	
	Feeder Canal to St. Joseph River	1988 (R)	Extirpated.	
	Auglaize River	1964	Extirpated.	
	Ottawa River	1998 (R)	Extirpated.	
	Blanchard River	2009	Unknown	Recruiting.
	Sandusky River	1978	Extirpated.	
	Tymochtee Creek	1996	Unknown	Unknown.
	Wolf Creek	1971 (R)	Extirpated.	
	Lake Erie	1977–87	Extirpated.	
Ohio River system	Ohio River mainstem	<1960	Extirpated.	
	Allegheny River	2007	Stable	Recruiting.
	Chautauqua Lake outlet	<1919	Extirpated.	
	Chautauqua Lake	<1919	Extirpated.	
	Olean Creek	2000	Unknown	Recruiting.
	Cassadaga Creek	1994	Unknown	Recruiting.
	Conewango Creek	~1908	Extirpated.	
	Oil Creek	<1970	Extirpated.	
	French Creek	2005	Stable	Recruiting.
	Cussewago Creek	1991	Unknown.	
	Crooked Creek	~1908	Extirpated.	
	West Fork River	<1913	Extirpated.	
	Beaver River	~1910	Extirpated.	
	Shenango River	~1908	Extirpated.	
	Pymatuning Creek	~1908	Extirpated.	
	Mahoning River	<1921	Extirpated.	
	Middle Island Creek	1980 (R)	Extirpated.	
	Muskingum River	1980 (R)	Extirpated.	
	Tuscarawas River	?	Extirpated.	
	Walhonding River	1991–95	Declining	Probably not recruiting.
	Mohican River	1969	Extirpated.	
	Elk River	2008	Reintroduced in 2006.	
	Scioto River	1964	Extirpated.	
	Mill Creek	2007	Unknown.	
	Alum Creek	1970	Extirpated.	
	Blacklick Creek	?	Extirpated.	
	Olentangy River	1962	Extirpated.	
	Whetstone Creek	1961	Extirpated.	
	Big Walnut Creek	1961	Extirpated.	
	Walnut Creek	1994 (R)	Extirpated.	
	Big Darby Creek	2008	Declining	Unknown.
	Little Darby Creek	1990 (R) or 1986 (R)	Extirpated.	
	Deer Creek	1981	Extirpated.	
	Sugar Creek	<1900	Extirpated.	
	Scioto Brush Creek	1987	Unknown	Probably not recruiting.
	Cedar Creek	?	Extirpated.	
	Buckeye Lake	?	Extirpated.	
	Ohio and Erie Canal	?	Extirpated	
	Great Miami River	2009	Unknown	Unknown.
	Little Miami River	1990–91	Unknown	Probably not recruiting.
	East Fork Little Miami River	1990–91	Unknown.	

TABLE 1—RAYED BEAN STATUS AT HISTORICAL LOCATIONS—Continued

River basin	Stream	Last observed (R = relic)	Current status	Comments
	Stillwater River	1987	Unknown	Probably not recruiting.
	South Fork Licking River	1982 (R)	Extirpated.	
	North Fork Elkhorn Creek	1982 (R)	Extirpated.	
	Eagle Creek	1981 (R)	Extirpated.	
	Brashears Creek	1983 (R)	Extirpated.	
	Green River	1964	Extirpated.	
	Nolin River	1983 (R)	Extirpated.	
	Barren River	<1900, ?	Extirpated.	
	Wabash River	1962 (R)	Extirpated.	
	Salamonie River	1971	Extirpated.	
	Mississinewa River	1994 (R)	Extirpated.	
	Tippecanoe River	1995	Declining	Possibly recruiting.
	Tippecanoe Lake	<1920	Extirpated.	
	Winona Lake	1934	Extirpated.	
	Pike Lake	1906	Extirpated.	
	Lake Maxinkuckee	1997	Declining	Unknown.
	Vermilion River	1999 (R)	Extirpated.	
	Salt Fork Vermilion River	1956–57	Extirpated.	
	Middle Fork Vermilion River	1991	Extirpated.	
	North Fork Vermilion River	1995 (R)	Extirpated.	
	Embarras River	1956	Extirpated.	
	Sugar Creek	1998	Unknown	Unknown.
	White River	<1903	Extirpated.	
	West Fork White River	1989–91 (R)	Extirpated.	
	East Fork White River	?	Extirpated.	
	Big Blue River	1944	Extirpated.	
	Walnut Creek	1992 (R)	Extirpated.	
	Mill Creek	1992 (R)	Extirpated.	
	Fall Creek	?	Extirpated.	
	Sugar Creek	1950	Extirpated.	
Tennessee River system.	Tennessee River mainstem	<1939	Extirpated.	
	Holston River	1914–15	Extirpated.	
	North Fork Holston River	1913	Extirpated.	
	South Fork Holston River	1914	Extirpated.	
	Nolichucky River	1968	Extirpated.	
	Lick Creek	1967 (R)	Extirpated.	
	First Creek	?	Extirpated.	
	Clinch River	1965	Extirpated.	
	North Fork Clinch River	<1921	Extirpated.	
	Powell River	1913–15	Extirpated.	
	Elk River	1965	Extirpated.	
	Richland Creek	1892	Extirpated.	
	Duck River	1982	Extirpated.	

Upper Great Lakes Sub-Basin

The rayed bean was not known from the upper Great Lakes sub-basin until 1996, when relic specimens were documented from a tributary to the St. Joseph River, a tributary to Lake Michigan. No extant populations of the rayed bean are currently known from this system.

Lower Great Lakes Sub-Basin

Of the 112 water bodies from which the rayed bean was historically recorded, 27 are in the lower Great Lakes system. The species is thought to be extant in 12 streams, which are discussed below, but historically significant populations have been eliminated from Lake Erie and the Detroit River.

Black River—A tributary of the St. Clair River, linking Lakes Huron and St. Clair, the Black River is located in southeastern Michigan. Hoeh and Trdan (1985, p. 115) surveyed 17 sites in the Black River system, including 12 mainstem sites, but failed to find the rayed bean. The rayed bean was not discovered there until the summer of 2001 when a single live (L) individual was found in the lower river in the Port Huron State Game Area (PHSGA) (Badra 2002, pers. comm.). A survey in 2003 failed to find any rayed bean, and two surveys in 2005 found only two valves (Badra 2008, pers. comm.). An additional survey was performed in 2005 at six sites, but no rayed bean were found (Badra 2008, pers. comm.). The status of this population cannot be accurately assessed at this time, but would appear to be small and of questionable viability (Butler 2002, p. 8).

Mill Creek—Mill Creek is a tributary of the Black River, St. Clair County, in southeastern Michigan. The rayed bean was discovered in Mill Creek in August 2002. Five dead specimens were found approximately 0.5 miles (mi) (0.8 kilometers (km)) above its confluence with the Black River in the PHSGA (Badra 2002, pers. comm.). A Mill Creek site 0.25 mi (0.4 km) from the confluence of the Black River was surveyed in 2003 and 2004 with one rayed bean shell found during each survey (Badra 2008, pers. comm.). Similar to the population in the Black River, the status of this newly discovered population cannot be accurately assessed at this time.

Pine River—Another tributary of the St. Clair River, the Pine River is located in southeastern Michigan. The rayed bean was apparently not collected in the Pine River until 1982 when specimens were found at three sites (Hoeh and Trdan 1985, p. 116). These collections included 5 L individuals and 23 FD specimens (Badra 2002, pers. comm.). Hoeh and Trdan (1985, p. 116) considered it to be "rare," semi-quantitatively defined as occurring at a rate of less than one specimen per person-hour sampling effort. In 1997, two L individuals were found. The last survey in the Pine River occurred in 2002 (Badra 2008, pers. comm.), and one L rayed bean was documented (Badra and Goforth 2003, p. 6). The species may have declined significantly since the 1980s, but is probably still viable in the Pine River.

Belle River—The Belle River is a third tributary of the St. Clair River harboring an extant population of the rayed bean. This species was first collected from the Belle River in 1965, when 17 FD specimens were collected (OSUM 1965:0106). The same site was revisited in 1978, but only one FD shell is represented in OSUM 1978:0013. Since that time, L individuals or FD specimens have been found in 1983 and 1992, while only R shells were found in 1994 (Badra 2008, pers. comm.). During summer 2002 sampling, single L specimens were found at two new sites, with an additional four and two FD specimens, respectively, also found from these sites (Badra 2008, pers. comm.). The status of the population is still not well known, but appears to be small.

Clinton River—The rayed bean was first recorded from the Clinton River in 1933 (Badra 2008, pers. comm.). The mussel fauna in the entire mainstem of the Clinton River downstream of Pontiac, Michigan, was apparently wiped out by pollution between 1933 and 1977 (Strayer 1980, p. 147). In 1992, Trdan and Hoeh (1993, p. 102) found 26 L individuals using a suction dredge from a bridge site slated for widening where Strayer (1980, p. 146) found only R shells. The rayed bean represented 1.2 percent relative abundance of the 10 species collected at the site. The population is probably viable but currently restricted to about 3 mi (4.8 km) of stream in the western suburbs of Pontiac. Its long-term status appears to be highly precarious.

Sydenham River—The rayed bean in the Sydenham River represents one of the largest rayed bean populations remaining. West *et al.* (2000, pp. 252–253) presented a highly detailed collection history of the rayed bean in the Sydenham River. The rayed bean is currently thought to exist in an approximately 75-mi (120-km) reach of the middle Sydenham, from the general vicinity of Napier, Ontario, downstream to Dawn Mills. The species appears to be most abundant in the lower half of this river reach. Although the range has remained relatively consistent over time, abundance data at repeatedly sampled sites from the 1960s to the late 1990s indicate a general decline of the rayed bean. Based on the range of sizes and roughly equal number of specimens in various size classes of the L and FD material they gathered, West *et al.* (2000, p. 256) considered the population to be "healthy" and "reproducing" (recruiting). Data from sampling in 2001 shows evidence of recruitment and variable size classes for both sexes from most of the sites (Woolnough 2002, p. 50). Based on this data, the rayed bean population in the Sydenham River is doing considerably better than West *et al.* (2000, pp. 252–253) suggested. Woolnough and Morris (2009, p. 19) estimates that there are 1.5 million mature rayed bean in the Sydenham River living in the 38-mile (61-km) stretch between Napier Road near Alvinston, Ontario, and Dawn Mills, Ontario.

Thames River—The Thames River flows west through southwestern Ontario. The rayed bean was historically known from only the south branch until 2008, when it was discovered in the north branch. In July 2008, six gravid (full of eggs) females were collected at two north branch sites (Woolnough 2008, pers. comm.). In September 2008, four L females and two L males were collected at two different north branch sites (Woolnough 2008, pers. comm.). All of these individuals were collected within a 4.5-mi (7.2-km) reach of the river (Woolnough 2008, pers. comm.). Woolnough and Morris (2009, p. 19) estimates that there are 4,300 mature rayed bean in the Thames River.

Maumee River System—The Maumee River system, which flows into the western end of Lake Erie, was once a major center of distribution of the rayed bean. The species was historically known from eight streams in the system in addition to the mainstem Maumee. Further, an additional population was discovered in the system in 2005 in Swan Creek.

Swan Creek—Swan Creek is a tributary of the lower Maumee River in northwestern Ohio. This population was discovered in 2005. Surveys conducted in 2006 and 2007 found that the Swan Creek population is limited to about 3 river mi (5 river km) between river mile (RM) 18.3 and 15.3 (Grabarkiewicz 2008, p. 11). The rayed bean was the fourth most abundant unionid present within the 2006–2008 sample area, reaching densities of eight individuals per square meter in some areas and comprising about 14.1 percent of the total mussel community (Grabarkiewicz 2008, p. 10). The rayed bean population in Swan Creek is viable and, although limited to a short reach, may be one of the most robust remaining populations.

St. Joseph River—The St. Joseph River is one of the two major headwater tributaries to the Maumee, with a drainage area in southeastern Michigan, northwestern Ohio, and northeastern Indiana. The mainstem flows in a southwesterly direction to its confluence with the St. Mary's River to form the Maumee in Ft. Wayne, Indiana. The rayed bean was historically known from numerous sites on the river, but now apparently persists only at a couple of sites in the lower St. Joseph River in Allen and DeKalb Counties, Indiana (Watters 1988b, p. 15; 1998, Appendix C); a few FD specimens were found in both studies, but no live individuals were found. Grabarkiewicz and Crail (2008, p. 13) surveyed six sites on the West Branch St. Joseph River in 2007, but did not encounter any rayed bean.

Fish Creek—A tributary of the St. Joseph River that begins in Ohio, Fish Creek flows west then south through Indiana, then eventually east into Ohio before joining the St. Joseph River at Edgerton. The rayed bean persists in Williams County, Ohio, and possibly DeKalb County, Indiana. Based on the appearance of 2 L individuals and FD shells, it inhabits the lower 10 mi (16.1 km) or less of the stream (Watters 1988b, p. 18; Grabarkiewicz 2009, pers. comm.). Watters (1988b, p. ii) considered Fish Creek to be "the most pristine tributary of the St. Joseph system." A major diesel fuel spill from a ruptured pipeline in DeKalb County in 1993 resulted in a mussel kill in the lower portion of the stream (Sparks *et al.* 1999, p. 12). It is not known if the rayed bean was affected by the spill. Surveys in 2004 (at 64 qualitative sites) and 2005 (at 11 quantitative sites) failed to detect the species (Brady *et al.* 2004, p. 2; 2005, p. 3). However, Grabarkiewicz (2009, pers. comm.) reported finding two L and three FD rayed bean in 2005 at the County Road 3 bridge in Ohio. In 2009, two FD rayed bean were found in lower Fish Creek in Ohio (personal observation). The viability and status of this population is uncertain (Fisher 2008, pers. comm.).

Blanchard River—The Blanchard River is a tributary of the Auglaize River in the Maumee River system, in northwestern Ohio. First discovered in

1946, this population is one of the largest of the rayed bean rangewide. The rayed bean in the Blanchard River is restricted to 25–30 river mi (40–48 river km) in the upper portion of the stream in Hardin and Hancock Counties upstream of Findley (Hoggarth *et al.* 2000, p. 22). Hoggarth *et al.* (2000, p. 23) reported the rayed bean to be the fourth most common species in the drainage. The population is considered to be viable.

Tymochtee Creek—Tymochtee Creek is a tributary to the upper Sandusky River in north-central Ohio, which flows into the southwestern portion of Lake Erie. The rayed bean is known from three sites in a reach of stream in Wyandot County and was first collected in 1970. All collections of the rayed bean have been small, with not more than five FD shells found in any one collection effort. The last record is for 1996, when a pair and three unpaired valves were collected. The condition of at least one of the valves indicated that the rayed bean is probably still extant in the stream, although no L individuals were observed (Athearn 2002, pers. comm.). The rayed bean status in Tymochtee Creek is therefore currently unknown.

Ohio River System

The rayed bean was historically known from the Ohio River in the vicinity of Cincinnati, Ohio, downstream to the Illinois portion of the river. It undoubtedly occurred elsewhere in the upper mainstem. Few historical records are known (mostly circa 1900), and no recent collections have been made, indicating that it became extirpated there decades ago. It was historically known from 71 streams, canals, and lakes in the system, representing roughly two-thirds of its total range. Ortmann (1925, p. 354) considered the rayed bean to be “abundant in small streams” in the Ohio River system. Currently, only 16 streams and a lake are thought to have extant rayed bean populations in the system.

Allegheny River System—Nine streams and Chautauqua Lake historically harbored rayed bean populations in the Allegheny River system. Currently, the rayed bean is found in half of these water bodies, but in good numbers in two streams (Allegheny River and French Creek) in this drainage.

Allegheny River—The Allegheny River drains northwestern Pennsylvania and western New York joining the Monongahela River at Pittsburgh, Pennsylvania, to form the Ohio River. Ortmann (1909a, p. 179; 1919, p. 262) was the first to report the rayed bean from the Allegheny. The population once stretched from Cataraugus County, New York, to Armstrong County, Pennsylvania. Based on historical collections, it appears that the rayed bean is more abundant now than it was historically in the Allegheny River. This may indicate that the rayed bean population in the Allegheny has expanded in the past 100 years. Many streams in western Pennsylvania have improved water quality since Ortmann’s time, when he reported on the wholesale destruction of mussels in several streams (Ortmann 1909b, pp. 11–12). It currently occurs in Pennsylvania downstream of Allegheny (Kinzua) Reservoir in Warren County to the pool of Lock and Dam 8 in northern Armstrong County, a distance of over 100 river mi (161 river km) (Villella Bumgardner 2008, pers. comm.). The Allegheny population is viable and one of the most important remaining rangewide today.

Olean Creek—Olean Creek is a tributary of the Allegheny River in western New York. A small population of the rayed bean is known from the lower portions of the stream. Strayer *et al.* (1991, p. 67) reported the rayed bean from three sites during 1987–90 sampling, although just one L individual was located with R shells from the other two sites. Only R shells were found in Olean Creek in 1994, but three L individuals were found in 2000, at the proposed construction site of the City of Olean Water Treatment Plant (ESI 2000, p. 8). Collected only during their quantitative sampling effort, the rayed bean represented a relative abundance of 11.5 percent of the seven L species sampled. The rayed bean age distribution of these specimens also indicates recent recruitment into the population (ESI 2000, p. 9). Relic specimens are now known from an 8-mi (13-km) reach of stream, with L individuals known from less than 1.5 mi (2.4 km) of the lower creek. The Olean Creek population appears viable, but is small and tenuous (Butler 2008, pers. comm.)

Cassadaga Creek—Cassadaga Creek is a tributary of Conewango Creek in the Allegheny River system, in western New York. A small population of the rayed bean is known from a single riffle (Ross Mills) in the lower creek north of Jamestown. Four L specimens were found in 1994 (Strayer 1995). Muskrat middens collected during the winter of 2002 produced 38 FD specimens with a size range of 0.8–1.7 in (2.0–4.3 cm) (Clapsadl 2002, pers. comm.). Although the rayed bean is not known from other sites in the stream, it appears to be viable at this site. The highly restricted extent of the population combined with its proximity to roads and retail development, including a gas station close to the flood zone upstream, makes it extremely susceptible to a stochastic event (such as a toxic chemical spill).

French Creek—French Creek is a major tributary of the middle Allegheny River, in western New York and northwestern Pennsylvania. One of the largest rayed bean populations known is found in much of the lower portions of the stream in four Pennsylvania counties (the species is not known from the New York portion of stream). Ortmann (1909a, p. 188; 1919, p. 264) reported the species from two counties, Crawford and Vanango. Not until circa 1970 did the population become more thoroughly known, with museum lot sizes indicating sizable populations at several sites, particularly in the lower reaches of the stream. Recent collections indicate that population levels remain high with the rayed bean occurring throughout the mainstem (Villella Bumgardner 2002, pers. comm.; Smith and Crabtree 2005, pp. 15–17; Enviroscience 2006, p. 5).

Cussewago Creek—Cussewago Creek is a tributary of lower French Creek, with its confluence at Meadville, Crawford County, Pennsylvania. A small population was reported in 1991 from Cussewago Creek (Proch 2001, pers. comm.). The rayed bean is thought to persist in the stream, but its current status is unknown.

Walhonding River—The Walhonding River is a tributary of the upper Muskingum River system, in central Ohio, forming the latter River at its confluence with the Tuscarawas River at Coschocton. Small numbers of rayed bean shells are represented in OSUM collections from the 1960s and 1970s. During 1991–93, Hoggarth (1995–96, p. 161) discovered one L individual and one FD specimen at one site, while four R specimens were found at three other sites. A small rayed bean population is thought to remain in the Walhonding River; its status is unknown, but is deemed highly tenuous given the small population size. The population is probably nearing extirpation (Hoggarth 2008a, pers. comm.).

Elk River—The Elk River is a major 181-river-mi (291-river-km) tributary in the lower Kanawha River system draining central West Virginia and flowing west to the Kanawaha River at Charleston. The rayed bean was extirpated in the Elk River sometime in the 1990s. In 2006 and 2007, approximately 600 adults were reintroduced into the Elk River above Clendenin. In 2008, an effort was made to monitor the reintroduction. A 30-

minute search yielded two L individuals, but efforts were discontinued due to high water and excessive habitat disturbance caused by the search effort (Clayton 2008, pers. comm.). The translocated adults are thought to persist in the stream, but it is unknown if this new population is reproducing.

Scioto River system—The Scioto River system, in central and south-central Ohio, is a major northern tributary of the Ohio River. A historically large meta-population of the rayed bean occupied at least 11 streams, the Ohio and Erie Canal, and Buckeye Lake. Sizable populations were noted in at least the Olentangy River, and Alum and Big Darby Creeks, based on OSUM collections primarily from the 1960s. A series of system reservoirs mostly north of Columbus reduced habitat and contributed to the elimination of some populations in several streams (Alum, Big Walnut, and Deer Creeks; Olentangy and Scioto Rivers). The location of the Columbus Metropolitan Area in the heart of the watershed has also taken a major toll on the species. The historical Scioto rayed bean meta-population has since been decimated by anthropogenic factors. Currently, remnant populations are known only from Mill Creek, Big Darby Creek, and Scioto Brush Creek.

Mill Creek—Mill Creek is a tributary of the Scioto River in central Ohio that joins the Scioto River at the O'Shaughnessy Reservoir northwest of the City of Columbus. In 2004, seven FD specimens were found during a survey in the City of Marysville (Hoggarth 2005, p. 7). In 2007, Hoggarth (2007a, pp. 5–6) found two L rayed bean at the same site and one L individual at an additional site. No other information is available on the status of this population.

Big Darby Creek—Big Darby Creek is one of the major tributaries draining the northwestern portion of the Scioto River system in central Ohio. A sizable rayed bean population was noted in Big Darby Creek from OSUM collections primarily from the 1960s. Watters (1994, p. 105) reported finding a few FD specimens in 1986, but none in 1990, and indicated that the rayed bean was probably extirpated from Big Darby Creek. In 2006, one L individual was found at the U.S. Highway 42 bridge replacement project site (Hoggarth 2006, p. 6). This individual was relocated to a site upstream out of the impact zone of the bridge project, and nine additional L individuals were subsequently found at the relocation site (Hoggarth 2006, p. 6). In 2007, three L rayed bean were found at the relocation site (Hoggarth 2007b, p. 9). Hoggarth (2008b, pers. comm.) visited the same relocation site in 2008, and reported finding "numerous living specimens" of the rayed bean. The status of this population cannot be accurately assessed at this time, but would appear to be small and of questionable viability.

Scioto Brush Creek— Scioto Brush Creek is a small western tributary of the lower Scioto River in Scioto County, south-central Ohio. Watters (1988a, p. 45) discovered the rayed bean in this stream in 1987, reporting two FD and two R specimens from a site, and a R specimen from a second site among the 20 sites he collected. This population's current status is uncertain.

Great Miami River—The Great Miami River is a major northern tributary of the Ohio River in southwestern Ohio that originates from Indian Lake in west-central Ohio and flows into the Ohio River west of Cincinnati. The occurrence of the rayed bean in the Great Miami River was discovered in August 2009, during a mussel survey for a bridge project in Logan County, Ohio. Only one individual was documented, a male approximately 7 to 8 years of age (Hoggarth 2009, pers. comm.). The status of this newly discovered population is not known.

Little Miami River—The Little Miami River is a northern tributary of the Ohio River in southwestern Ohio, flowing into the latter at the eastern fringe of the Cincinnati metropolitan area. Hoggarth (1992, p. 248) surveyed over 100 sites in the entire system. He found one L individual at a site in Warren County and possibly a subfossil shell at another site, although there is contradictory data in his paper (Butler 2002, p. 17). The latter site may have been the same as that reported for a pre-1863 record (Hoggarth 1992, p. 265). The rayed bean appears to be very rare in the Little Miami, having been found extant at only 1 of 46 mainstem sites. Hoggarth (1992, p. 267) highlighted the "fragile nature" of the extant mussel community in the system, while noting that localized reaches of the Little Miami were "severely impacted." The species status in the river is uncertain, but apparently very tenuous and probably headed toward extirpation (Butler 2002, p. 17).

East Fork Little Miami River—The East Fork Little Miami River is an eastern tributary of the lower Little Miami River, with its confluence at the eastern fringe of the Cincinnati metropolitan area. According to OSUM records, eight FD specimens were reported from a site in eastern Clermont County in 1973. Hoggarth (1992, p. 265) reported one L, three FD, and one R rayed bean from three sites in a 7-river-mi (11-river-km) stretch of the stream in western Clermont and adjacent Brown County (including the 1973 site). Harsha Reservoir on the East Fork destroyed several miles of potential stream habitat for the rayed bean a few miles downstream of the extant population. The status of the rayed bean in the river is uncertain but probably of doubtful persistence (Butler 2002, p. 17).

Stillwater River—The Stillwater River is a western tributary of the middle Great Miami River in southwestern Ohio. The rayed bean is known from two specimens, one FD and one R, collected in 1987 at two sites spanning the Miami–Montgomery County line (OSUM records). Both sites occur in the footprint of Englewood Reservoir (constructed circa 1920), which serves as a retarding basin (a constructed empty lake used to absorb and contain flooding in periods of high rain) that is normally a free-flowing river except in times of flood, therefore continuing to provide riverine habitat that is normally destroyed by permanently impounded reservoirs. The rayed bean in the Stillwater River may be extant, but its status is currently unknown and considered highly imperiled.

Tippecanoe River—The Tippecanoe River is a large northern tributary of the middle Wabash River in north-central Indiana. The first records for the rayed bean date to circa 1900 (Daniels 1903, p. 646). Historically, this species was known from numerous sites in six counties in the Tippecanoe River. A total of 12 FD specimens from 5 of 30 sites were found when sampled in 1992. The rayed bean "is apparently on the decline" in the river (ESI 1993, p. 87). The Tippecanoe rayed bean population was thought to be recruiting by Fisher (2008, pers. comm.), but appears tenuous and its long-term viability is questionable.

Lake Maxinkuckee—Lake Maxinkuckee is a glacial lake in the headwaters of the Tippecanoe River in north-central Indiana. The rayed bean has been known from the lake for more than a century (Blatchley 1901). A 1997 OSUM record included seven FD specimens collected at its outlet to the Tippecanoe River. Fisher (2002, pers. comm.), who made the 1997 OSUM collection, noted that many native mussels had zebra mussels attached to their valves and were apparently contributing to their mortality. The status of the rayed bean in Lake Maxinkuckee is therefore highly tenuous, and its long-term persistence questionable.

Sugar Creek—Sugar Creek is a tributary of the East Fork White River, in the lower Wabash River system in south-central Indiana. A rayed bean population was first reported there in

1930. Harmon (1992, p. 33) sampled 27 mainstem and 16 tributary sites finding FD specimens at 3 mainstem sites and R specimens from 2 other sites. The sites with FD material were found in the lowermost 6 mi (9.7 km) of stream. The status and viability of this tenuous population is uncertain (Fisher 2008, pers. comm.).

Tennessee River System

Historically, the rayed bean was known from the Tennessee River and 12 of its tributary streams. Ortmann (1924, p. 55) reported that the rayed bean had a "rather irregular distribution"; however, museum lots show that it was fairly common in some streams (North Fork Clinch, Duck Rivers). The last L rayed bean records from the system, with the exception of the Duck River, were from the 1960s or earlier. The species held on in the Duck until the early 1980s. Recent intensive sampling in the Duck watershed has failed to locate even a R shell of the rayed bean (Ahlstedt *et al.* 2004, p. 29). Tributaries in this system have been extensively sampled over the past 25 years. It is highly probable that this species is extirpated from the entire Tennessee River system.

A project was initiated in 2008 to reintroduce rayed bean into the Duck River by translocating over 1,000 adults from the Allegheny River system. Although the rayed bean was extirpated from the Duck River about 25 years ago, major improvements in water quality and physical habitat conditions have occurred in the past 15 years. In response to these improvements, recruitment of nearly all extant mussel species has been documented and suggests that reintroduction of the rayed bean might be successful (Anderson 2008, pers. comm.). The reintroduction has not yet occurred.

The information presented in this document indicates that the rayed bean has experienced a significant reduction in range and most of its populations are disjunct, isolated, and with few exceptions, appear to be declining (West *et al.* 2000, p. 251). The extirpation of this species from over 80 streams and other water bodies within its historical range indicates that substantial population losses have occurred. Relatively few streams are thought to harbor sizable viable populations (Sydenham, Swan, Blanchard, and Allegheny Rivers, and French Creek). Small population size and restricted stream reaches of current occurrence are a real threat to the rayed bean due to the negative genetic aspects associated with small, geographically isolated populations. This can be especially true for a species, like rayed bean, that was historically widespread and had population connectivity among mainstem rivers and multiple tributaries. The current distribution, abundance, and trend information illustrates that the rayed bean is imperiled.

Snuffbox Historical Distribution

The snuffbox historically occurred in 208 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. The major watersheds of historical streams and lakes of occurrence include the upper Great Lakes sub-basin (Lake Michigan drainage), lower Great Lakes sub-basin (Lakes Huron, Erie, and Ontario drainages), upper Mississippi River sub-basin, lower Missouri River system, Ohio River system, Cumberland River system, Tennessee River system, lower Mississippi River sub-basin, and White River system.

Snuffbox Current Distribution

Extant populations of the snuffbox are known from 74 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, Maple River, Pine River, Belle River, Clinton River, Huron River, Davis Creek, South Ore Creek, and Portage River), Minnesota (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, Le Boeuf Creek, Muddy Creek, Conneaut Outlet, Little Mahoning Creek, Dunkard 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, Dunkard Creek, Middle Island Creek, North Fork Hughes River, and Elk River), Wisconsin (St. Croix River, Wolf River, Embarrass River, Little Wolf River, and Willow Creek), and Ontario (Ausable River and Sydenham River). It is probable that the species persists in some of the 134 streams or lakes where it is now considered extirpated (Butler 2007, p. 16); however, if extant, these populations are likely to be small and not viable.

Snuffbox Population Estimates and Status

Based on historical and current data, the snuffbox has declined significantly rangewide and is now known from only 74 streams (down from 208 historically), representing a 65 percent decline in occupied streams (Table 2). Since multiple streams may comprise a single snuffbox population (French Creek system), the actual number of extant populations is less than 74. Extant populations, with few exceptions, are highly fragmented and restricted to short reaches. Available records indicate that 24 of 74, or 33 percent, of streams considered to harbor extant populations of the snuffbox are represented by only one or two recent L or FD individuals (Embarrass, Little Wolf, Maple, Pigeon, Kankakee, Meramec, Ohio, Muskingum, Olentangy, Stillwater, Green, Powell, Duck, and Black Rivers; and Little Mahoning, Middle Island, Big Darby, Little Darby, Salt, South Fork Scioto Brush, Slate, and Buck (Indiana), Graham, Buck (Kentucky) Creeks.

Butler (2007, pp. 70–71) 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 mi (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 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 6 stronghold populations, 23 significant populations, and 45 marginal populations of snuffbox.

A population is considered extant if L individuals or FD specimens have been located since approximately 1985. 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).

TABLE 2—SNUFFBOX EXTANT STREAM POPULATION SUMMARY BY STREAM OF OCCURRENCE

Stream (state)	Last observed	Recruiting	Potential viability	Population size	Population trend	Status category
Wolf River (WI)	2006	Yes	High	Large	Declining	Stronghold.
Embarrass River (WI).	1995	?	?	Small	?	Marginal.
Little Wolf River (WI).	1999	?	?	Small	?	Marginal.
Willow Creek (WI)	2001	?	?	Small	?	Marginal.
Grand River (MI)	2002	Yes	High	Medium	?	Significant.
Maple River (MI)	2001	?	?	Small	?	Marginal.
Pine River (MI)	2002	?	Low	Small	Stable	Marginal.
Belle River (MI)	2002	Yes	High	Small	?	Significant.
Clinton River (MI)	2003	Yes	High	Large	Declining	Significant.
Huron River (MI)	2001	?	Low	Medium	?	Significant.
Davis Creek (MI)	2005	Yes	High	Medium	?	Significant.
South Ore Creek (MI).	1999	Yes	High	Small	?	Significant.
Portage River (MI)	1998	Yes	High	Medium	?	Significant.
Grand River (OH)	2006	Yes	High	Medium	?	Significant.
St. Croix River (MN and WI).	2004	Yes	High	Large	Declining	Significant.
Kankakee River (IL)	1991	?	?	Small	?	Marginal.
Meramec River (MO).	1997	?	?	Small	Declining	Marginal.
Bourbeuse River (MO).	2006	Yes	High	Large	Improving	Stronghold.
Ohio River (OH)	2001	?	Low	Small	?	Marginal.
Muskingum River (OH).	2005	?	?	Small	?	Marginal.
Walhonding River (OH).	1991	?	?	Small	Declining	Significant.
Killbuck Creek (OH)	2009	?	?	Small	Declining	Marginal.
Olentangy River (OH).	1989	?	?	Small	Declining	Marginal.
Big Darby Creek (OH).	2008	?	?	Small	Declining	Marginal.
Little Darby Creek (OH).	1999	?	?	Small	Declining	Marginal.
Salt Creek (OH)	1987	?	?	Small	?	Marginal.
Scioto Brush Creek (OH).	1987	?	?	Small	?	Marginal.
South Fork Scioto Brush Creek (OH).	1987	?	?	Small	?	Marginal.
Little Miami River (OH).	1991	?	?	Small	?	Marginal.
Stillwater River (OH).	1987	?	?	Small	?	Marginal.
Pigeon River (IN)	1998	?	?	Small	?	Marginal.
Salamonie River (IN).	2004	Yes	Low	Small	?	Significant.
Tippecanoe River (IN).	2003	?	?	Small	Declining	Marginal.
Embarras River (IL)	2008	Yes	Low	Small	Declining	Significant.
Sugar Creek (IN)	1990	?	?	Small	Declining	Marginal.
Buck Creek (IN)	1990	?	?	Small	?	Marginal.
Muscatatuck River (IN).	1988	?	?	Small	?	Marginal.
Graham Creek (IN)	1990	?	?	Small	Declining	Marginal.
St. Francis River (MO).	2006	Yes	High	Medium	Stable	Significant.
Black River (MO)	2002	Yes	Low	Small	?	Significant.
Tygarts Creek (KY)	1995	?	?	Small	Declining	Marginal.
Kinniconick Creek (KY).	2005	?	Low	Small	Declining	Marginal.
Licking River (KY)	2006	?	Low	Small	?	Marginal.
Slate Creek (KY)	1992	?	?	Small	Declining	Marginal.
Middle Fork Kentucky River (KY).	1997	?	?	Small	?	Marginal.

TABLE 2—SNUFFBOX EXTANT STREAM POPULATION SUMMARY BY STREAM OF OCCURRENCE—Continued

Stream (state)	Last observed	Recruiting	Potential viability	Population size	Population trend	Status category
Red Bird River (KY)	1995	?	?	Small	?	Marginal.
Red River (KY)	~2002	?	?	Small	?	Significant.
Rolling Fork Salt River (KY).	~2005	?	?	Small	?	Marginal.
Green River (KY)	1989	?	?	Small	Declining	Marginal.
Buck Creek (KY)	1987–90	?	?	Small	Declining	Marginal.
Clinch River (TN and VA).	2006	Yes	High	Large	Stable or Declining	Stronghold.
Powell River (TN and VA).	2008	?	?	Small	Declining	Marginal.
Tennessee River (AL).	2006	?	?	Small	?	Marginal.
Paint Rock River (AL).	2008	Yes	High	Large	Improving	Stronghold.
Elk River (TN and AL).	2007	Yes	Low	Small	Stable	Significant.
Duck River (TN)	2001	?	?	Small	?	Marginal.
Buffalo River (AR)	2006	?	?	Small	?	Marginal.
Spring River (AR)	2005	?	Low	Medium	?	Significant.
Strawberry River (AR).	1997	?	?	Small	?	Marginal.
Allegheny River (PA).	2001	?	?	Small	?	Marginal.
French Creek (PA)	2008	Yes	High	Large	Stable	Stronghold.
West Branch French Creek (PA).	2008	?	?	Small	?	Marginal.
Le Boeuf Creek (PA).	2006	Yes	Low	Small	?	Marginal.
Muddy Creek (PA)	2008	Yes	Low	Medium	?	Significant.
Conneaut Outlet (PA).	1997	?	?	Small	?	Marginal.
Little Mahoning Creek (PA).	1991	?	?	Small	?	Marginal.
Dunkard Creek (PA and WV).	2009	?	?	Small	Declining	Significant.
Shenango River (PA).	2002	?	?	Small	?	Marginal.
Little Shenango River (PA).	2002	?	?	Small	?	Significant.
Middle Island Creek (WV).	2001	?	?	Small	Declining	Marginal.
North Fork Hughes River (WV).	2001	?	Low	Small	Declining	Significant.
Elk River (WV)	2004	?	Low	Medium	Improving	Significant.
Ausable River (ON)	2006	Yes	High	Medium	Declining	Significant.
Sydenham River (ON).	2002	Yes	High	Large	?	Stronghold.

Upper Great Lakes Sub-Basin

The snuffbox was formerly known from 15 streams and lakes in the upper Great Lakes sub-basin. The Fox River system in Wisconsin, particularly its major tributary the Wolf River (and its tributaries), had a widespread and locally abundant population. The species is thought to be extant in seven sub-basin streams; however, all but the Wolf and Grand Rivers have populations that are considered marginal.

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. Snuffbox records are known from Shawano, Waupaca, and Outagamie Counties. The snuffbox is known from a 30-river-mi (48-river-km) reach of the Wolf River (Butler 2007, p. 21). It is one of the few stronghold populations, but appears to exhibit a low level of recruitment. Only 4 of 257 individuals collected in the mid-1990s were less than 6 years old (Butler 2007, p. 21). A bridge replacement project on the south side of Shawano, scheduled to begin in 2010, may adversely impact the large snuffbox bed located just downstream (ESI 2006, p. 10). The zebra mussel occurs in this river, with a 0.7 percent infestation rate on unionids sampled in 2006 (ESI 2006, p. 6). This large population continues to be viable but appears to be in decline (Butler 2008, pers. comm.).

Embarrass River—A western tributary of the lower Wolf River, the Embarrass River parallels the western bank of the Wolf River before joining it at New London, Wisconsin. A population of the snuffbox is located in the headwaters below a small dam at Pella, Wisconsin. Records exist for three L individuals and two dead specimens during 1987–1988 and a single D specimen in 1995 (Butler 2007, p. 22). Its current status is unknown.

Little Wolf River—The Little Wolf River is a western tributary of the lower

Wolf River in Waupaca County, Wisconsin. The snuffbox is known from a single L individual collected in 1988 at RM 14 below the Mill Pond dam at Manawa (Butler 2007, p. 22). Five D specimens were found during 1999 at RM 2, where shells were abundant in a muskrat midden (Butler 2007, p. 22). Nothing else is known regarding this population.

Willow Creek—Willow Creek flows eastward into Lake Poygan, a large flow-through lake of the Wolf River system, in Waushara County, Wisconsin. The snuffbox is known from a single observation of two L females in 2001 (Butler 2007, p. 22). No other information is available on the status of this population.

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 approximately 25 river mi (40 river km) of the middle Grand River, approximately between the confluences of the Flat and Maple Rivers. The medium-sized population appears to have a low level of viability, with recruitment noted in 1999 (Badra 2008, pers. comm.).

Maple River—The Maple River is a northeastern tributary of the Grand River draining south-central Michigan. A single snuffbox record (one L individual) is known from 2001 in southern Gratiot County, approximately 20 river mi (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.). The current status of this small population is unknown.

Pigeon River—The Pigeon River is a headwater tributary of the St. Joseph River system of Lake Michigan, flowing westward across northern-most Indiana, crossing the State border to its confluence in southwestern Michigan. One very large FD specimen was found in 1998, among thousands of shells in LaGrange County, Indiana (Butler 2007, p. 24). The same site was sampled in 1996 without evidence of this species, and R shells were found at three of nine sites sampled in 2004 (Butler 2007, p. 24). The snuffbox occupied reach historically covered more than 10 river mi (16.1 river km) in north-central LaGrange County. The species is very rare in this river, and its viability is unknown.

Lower Great Lakes Sub-Basin

Of all the water bodies from which the snuffbox was historically recorded, 32 are in the lower Great Lakes sub-basin, including several chains-of-lakes, springs, and channels in some systems (Clinton, Huron Rivers). Historically sizable populations occurred in some streams (Lake Erie; Belle, Clinton, Huron, Portage, and Niagara Rivers), but the species had become "characteristically uncommon" by the 1970s (Strayer 1980, p. 147). A pre-zebra mussel decline of unionids in Lake Erie was noted (Mackie *et al.* 1980, p. 101), 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, p. 414; Nalepa 1994, p. 2231; Nalepa *et al.* 1996, p. 361), which was the year the zebra mussel is thought to have invaded (Schloesser *et al.* 1998, p. 70). Observations of L and FD 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 p. 69; Butler 2007, p. 25). 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 (Ausable River Recovery Team 2005, p. 12; Dextrase *et al.* 2000, p. 10). The snuffbox is considered extant in 10 streams of the lower Great Lakes sub-basin, including a stronghold population in the Sydenham River and sizable but reach-limited populations in the Clinton River and Davis Creek. A single FD 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, p. 9). Both of these populations are viable.

Ausable River—The Ausable River is a southeastern tributary of Lake Huron, draining southwestern Ontario, Canada. A survey conducted in 2006 found that a sizable population of snuffbox occurs in the lower portion of the stream in over 23 river mi (37 river km) (McGoldrick 2007, pers. comm.). The size range of individuals found in the 2006 survey indicates recent recruitment in the viable population (McGoldrick 2007, pers. comm.; Staton 2007, pers. comm.).

Pine River—A tributary of the St. Clair River, the Pine River flows south and is located in St. Clair County, in southeastern Michigan. Although apparently stable, the snuffbox population is small, very restricted in range, and has a low potential for viability (Badra 2002, pers. comm.; Badra and Goforth 2003, p. 23).

Belle River—The Belle River is another tributary of the St. Clair River in St. Clair County, flowing in a southeasterly direction. Records for the snuffbox date to the early 1960s, but all L and FD records over the past 40 years have been from the same lower mainstem site. Historically, a sizable population was found in the Belle (65 specimens, 1965). The Belle is located in a primarily agricultural watershed (Hoeh and Trdan 1985, p. 115), 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, p. 24; Sherman 2005, 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 mi (16.2 river km) and lakeshore in the western suburbs of Pontiac primarily between Cass and Loon Lakes. This population appears to be recruiting (Sherman Mulcrone 2004, p. 64) and viable, although apparently in decline since the early 1990s (Badra 2002, pers. comm.; Butler 2007, p. 27).

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 D shells) and 1991 (Butler 2007, p. 28). During the 1997–99 sampling, a total of 10 L and FD individuals were found from 4 of 12 sites, including the 3 1960s sites (Metcalfe-Smith *et al.* 2003, p. 41). The snuffbox was recorded at a rate of 0.22 per hour of effort during 1997–98 (Metcalfe-Smith *et al.* 2000, p. 728). More recent sampling found 57 L and FD individuals from 21 collection events (some individuals may have been counted multiple times) at six sites during 2000–02. The increase in numbers relative to historical collections may be attributed to more intensive sampling methods rather than to improving population size (Metcalfe-Smith *et al.* 2003, p. 46), thus making population trend assessments difficult (Morris and Burridge 2006, p. 12). This stronghold population is recruiting (Butler 2007, p. 28), viable, and is currently known from approximately 30 river miles (48 km) of the middle Sydenham.

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 2005a, 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, p. 72). Despite the increasing presence of zebra mussels, the Huron population is probably recruiting and viable (Butler 2007, p. 29).

Davis Creek—Davis Creek is a chain-of-lakes in the upper Huron River system, primarily in southeastern Livingston County, Michigan. The snuffbox appears to be limited to the lower 3 river mi (4.8 river km), comprising a single population with one of the extant Huron River population segments in this area. This viable population appears to be sizable and is experiencing recent recruitment (Marangelo 2005a, pers. comm.; Zanatta 2005, pers. comm.).

South Ore Creek—South Ore Creek is a northern tributary of the Huron River, forming a southward flowing chain-of-lakes draining southeastern Livingston County, Michigan. The snuffbox was discovered in 1999, just upstream of Ore Lake, which is near the Huron River confluence (Butler 2007, p. 31). Three subadult snuffbox (two age 2, one age 3–4) were recorded. Despite the lack of additional information, the small population appears to be viable based on recent recruitment.

Portage River—The Portage River is a chain-of-lakes in the northwestern portion of the Huron River system. Two University of Michigan Museum of Zoology (UMMZ) records suggest historical abundance (Badra 2002, pers. comm.). The species was reported as "rare" in the lower river during 1976–78 (Strayer 1979, p. 94). At least 22 L, young (age 4 and younger) individuals were identified in 1998 at one of three sites upstream of Little Portage Lake and Portage Lake (Butler 2007, p. 31). The localized population appears to be medium-sized and viable.

Grand River—The Grand River is a 99-river-mi (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 FD 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, p. 32). The species is known from approximately 12 river mi (19.3 river km) downstream of Harpersfield Dam (Huehner *et al.* 2005, p. 59; Zimmerman 2008a, pers. comm.). The sizable population was considered recruiting based on the 1995 Huehner *et al.* (2005, p. 59) survey.

Upper Mississippi River Sub-basin

The snuffbox was historically known from 17 streams in the upper Mississippi River sub-basin. Records exist for Mississippi River Pools (MRPs) 3–4, 5a–6, and 14–16 (Kelner no date, p. 6), with early surveys summarized by van der Schalie and van der Schalie (1950, p. 456). The species was reported L in the upper river in the 1920s (Grier 1922, p. 15; Grier 1926, p. 119) but not from subsequent surveys (254 sites upstream of the Ohio River during 1930–1931 (UMMZ, Ellis 1931, pp. 1–10), MRPs 5–7 and 9 in 1965 (Finke 1966, Table 2; Thiel 1981, p. 16), MRPs 3–11 during 1977–79 (Thiel 1981, p. 16)) and is now extirpated from the mainstem of the Mississippi River (Havlik and Sauer 2000, p. 4). Only 4 of 17 historical populations remain, but they include two of the largest rangewide (St. Croix and Bourbeuse Rivers). Three populations, including the St. Croix, appear to be declining.

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, p. 344). Snuffbox density at Interstate Park 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 snuffbox population occurs from the Northern States Power Dam (NSPD) at RM 54.2 to RM 36.8 (Heath 2005, pers. comm.), represents the species' northernmost occurrence, and despite recent observed declines, remains one of the six stronghold populations rangewide.

Kankakee River—The Kankakee River is a major, westward-flowing, upper Illinois River tributary with its headwaters in northwest Indiana and northeast Illinois. The snuffbox was reported over a century ago (Baker 1906, p. 63), but surveys in 1911 (43 sites; Wilson and Clark 1913, pp. 41–50), 1978 (13 sites; Suloway 1981, p. 236), 1975–2000 (18 samples from an unknown number of Will County, Illinois, sites; Sietman *et al.* 2001, p. 279), and 1999 (4 sites, Stinson *et al.* 2000, Appendix C) failed to find it. It was considered extirpated from the Kankakee by Cummings *et al.* (1988, p. 16), but single FD specimens in Illinois (Will County in 1988, Kankakee County in 1991) were subsequently found. Only R shells have been found since 1991. The Kankakee River population, if extant, appears small, localized, and of doubtful viability.

Meramec River—The Meramec River is a 236-mi (380-km) tributary that flows northeasterly into the Mississippi River downstream of St. Louis and drains the northeastern slope of the Ozark Plateaus in east-central Missouri. Early species lists failed to report the snuffbox (Grier 1916, p. 518; Utterback 1917, p. 28). Buchanan (1980, p. 63) found FD specimens at three sites and R shells at two other sites sampled in 1977–78. Roberts and Bruenderman (2000, p. 85) sampled 42 sites in 1997, including 26 of Buchanan's (1980, p. 5) sites, and found FD specimens at RM 33.5, 48.8, and 59.8; and one L individual at RM 39.8. The L individual (2.4 in (6.1 cm), approximately 6 years old) was reported from a reach where a die-off, perhaps attributable to disease, was reported in 1978 (Buchanan 1986, p. 44). There was an obvious decline of mussels in the system based on catch-per-unit-effort data over the 20-year period (Roberts and Bruenderman 2000, p. 8). The Meramec snuffbox population is rare, sporadically distributed over approximately 26 river mi (41.8 river km), and of unknown viability.

Bourbeuse River—The Bourbeuse River is a 149-mi (240-km), northeasterly flowing, northern tributary of the Meramec River, joining it at RM 68. The snuffbox is currently distributed over about 60 river mi (96.6 river km) upstream of RM 16, 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, p. 15), post-2000 sampling indicates that the population is recruiting, viable, and improving (McMurray 2006, pers. comm.). The Bourbeuse, one of the few stronghold snuffbox populations rangewide, has been augmented with laboratory propagated juveniles since 2002 (McMurray 2006, 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. All populations in the system are considered extirpated (Butler 2007, p. 36).

Ohio River System

Half of the water body occurrences for the snuffbox rangewide are known from the Ohio River system, which collectively represented the largest block of available habitat for this species. Sizable populations historically occurred in at least a dozen streams in the system. Today, only French Creek is considered to have a stronghold population, although nine others are also significant. Currently, the species is known from 40 of the 107 streams of historical occurrence.

Ohio River—The Ohio River is the largest eastern tributary of the Mississippi, with its confluence marking the divide between the upper and lower portions of the latter system. Numerous historical records are known from throughout the River. Recently, single FD and L specimens have been reported from just below Belleville Lock and Dam, Ohio and West Virginia, in 1995 and 2001, respectively (ESI 2002, p. 27). Having persisted in this highly modified river may indicate that the small population exhibits a low level of viability.

Allegheny River—The 325-mi (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-mi (67.6-river-km) reach centered in Venango County (Butler 2007, p. 37). Its occurrence in the lower Allegheny River and lower French Creek could be considered a single population segment. The viability status of the small population is unknown.

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, p. 97). Snuffbox collections made during 2002–2004 were summarized by Smith (2005, pp. 3–9). Live and FD specimens were found at 19 sites throughout the stream. The size of the L individuals indicated that multiple year classes were represented, including subadults. The species stretches for approximately 80 river mi (128.7 river km) from around RM 10, 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). The French Creek snuffbox population is considered large and viable (Evans 2003a, pers. comm.; Zimmerman 2008c, pers. comm.), appears stable, and may represent the best stronghold population rangewide.

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 L individuals at a site near Wattsburg, Pennsylvania. This population appears to be small and of unknown viability.

Le Boeuf Creek—Le Boeuf 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. The first snuffbox collections in this creek were made 100 years ago (Ortmann 1909a, p. 188). Two FD and 6 R shells were reported in 1988 (Evans 2003b, pers. comm.), and 1 L, 16 FD, and 8 R specimens were found in 1991 (Butler 2007, p. 40). Three L individuals were found at a site in 2006 (Smith 2006, pers. comm.). The snuffbox population has recently recruited and exhibits some level of viability, but appears to be very limited in extent.

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 L individuals were reported from 11 of 20 lower river sites (Morrison 2005, pers. comm.). Low numbers were found at most sites, but 18 L individuals were collected from a site near the mouth. This occurrence is considered to be part of the more extensive French Creek snuffbox population. Zimmerman (2008c, pers. comm.) documented one L female in 2008. The population is medium-sized, occurs along 8 river mi (12.9 river km) of the lower mainstem, and is recruiting, as recent juveniles were recorded (Morrison 2005, pers. comm.).

Conneaut Outlet—This stream forms the outlet to Conneaut Lake, flowing in a southeasterly direction until its confluence with middle French Creek, Crawford County. The snuffbox was first reported by Ortmann (1909a, p. 188), and was rediscovered L in 1997, but without collection details (Butler 2007, p. 40). No specimens were found at a site sampled in 2006 (Smith 2006, pers. comm.). The snuffbox is considered rare in this stream and its viability is unknown.

Little Mahoning Creek—Little Mahoning Creek is a tributary of Mahoning Creek, a lower eastern tributary of the Allegheny River northeast of Pittsburgh. The snuffbox was discovered in 1991, when sampling produced two FD and one R specimen at 1 of 12 sites in the system (Butler 2007, p. 41). The lower 10 miles of Little Mahoning Creek is 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. Viability is unknown.

Dunkard Creek—Dunkard Creek is an easterly flowing, western tributary of the middle Monongahela River, straddling the Pennsylvania and West Virginia State lines. Snuffbox records occur in both States from several museum collections from 1969–74. Small numbers of specimens, of undocumented condition, were found at four sites during 1993–94 sampling in Pennsylvania (Bogan 1993, p. 8; Evans 2003b, pers. comm.). Eight specimens, of undocumented condition, were collected at a West Virginia site in 1997. On September 1, 2009, a fish kill was reported in Dunkard Creek due to an unknown cause (Clayton 2009, pers. comm.). The Upper Monongahela River Association (2009) reported that 161 aquatic species including fish, mussels, and plants died along Dunkard Creek due to this toxic event. According to Clayton (2009, pers. comm.), the event may have killed 100 percent of the mussel fauna in the entire stream. The status of this population is not known at this time, but the snuffbox may now be extirpated from Dunkard Creek.

Shenango River—The Shenango River 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 in 1908 (Ortmann 1919, p. 328). Six L individuals were collected from three sites sampled in 2001–02 between Jamestown and New Hamburg (about 25 river mi (40.2 river km)). 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.).

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, p. 97; Bursey 1987, p. 42), but a single FD 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.

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, p. 157). 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, p. 157). The most recent record was for a single L individual collected in Tyler County in 2001 (Zimmerman 2008b, pers. comm.). This snuffbox population has declined, is currently rare, and its viability is questionable (Zimmerman 2008b, 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 L individuals and two FD shells were found in 1979, but no L or FD snuffbox were found in surveys conducted in 1979–81 (Stansbery and King 1983) and in 1992–93 (Watters and Dunn 1993–94, p. 241). A single L specimen was located during sampling for a construction project in 2005 near Dresden (Taylor 2006, pers. comm.). Viability of this population is unknown.

Walhonding River—The Walhonding River is a short (23.3 river mi (37.5 river km)), east flowing tributary of the Muskingum River in central Ohio, forming the latter river at its confluence with the Tuscarawas River, and formed by the confluence of the Mohican and Kokosing Rivers. The snuffbox historically occurred throughout the river. The extant snuffbox reach (RM 1.8–6.8) is downstream from Killbuck Creek. The population had apparently declined in range and size by the early 1990s and possibly further since. A once productive site about 0.25 mi (0.40 km) downstream of the Killbuck Creek confluence yielded only a few mussels of very common species in 2006, but no snuffbox (Butler 2007, p. 44). The Walhonding River population is considered small and of unknown viability.

Killbuck Creek—Killbuck Creek is a large tributary of the lower Walhonding River, flowing south from southern Medina County to Coshocton County and entering the latter at approximately RM 7. Live and FD snuffbox were found by Hoggarth (1997, p. 33) at eight sites from RM 15 to the mouth. Its occurrence has become more sporadic in the last 10 years. In spring 2006, 4 L adults were found at 2 sites approximately 3 river mi (4.8 river km) apart, while 9 large L individuals and a single FD specimen were collected near RM 13 during fall 2006 (Ahlstedt 2007, pers. comm.; Butler 2007, p. 45). 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.

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 North Fork sites sampled during a 1981–82 survey of the Little Kanawha River system (Schmidt *et al.* 1983). A total of 41 L adult individuals (23 reported as gravid) were reported at 5 sites located over a 1.5-mi (2.4-km) reach in North Fork State Park, Richie County, in 1993 (Butler 2007, p. 46). At least 10 L individuals were found at a site in the park in 1997 (Butler 2007, p. 46), and a single FD specimen was collected at an additional site downstream in 2001 (Butler 2007, p. 46). This small snuffbox population is declining and currently restricted to less than 4 river mi (6.4 river km), but may be viable.

Elk River—The Elk River is a major, 181-mi (291-km) tributary in the lower Kanawha River system draining central West Virginia flowing west to the Kanawha at Charleston. The snuffbox went undetected in a 1920s survey (Butler 2007, p. 46). Ten L individuals were collected during 1991–1995, the smallest being about 5 years old (Butler 2007, pp. 46–47). Collectively, 16 L individuals were identified at 8 sites in a 13-river-mi (20.9-river-km) reach in Kanawha County in 2002, and 4 L individuals were found at 4 sites in 2004 over a 16.8-river-mi (27-river-km) reach further upstream (Douglas 2005, pers. comm.). This medium-sized population extends over 30 river mi (48.3 river km), is viable, and may have improved since the 1970s.

Tygarts Creek—Tygarts Creek is a small, north-flowing, southern tributary of the Ohio River in northeastern Kentucky. Thirteen snuffbox were reported from one of five sites sampled in 1977 (Taylor 1980, p. 90). FD specimens are also known from 1981 and 1987 (Cicerello 2003, pers. comm.). Nine L (Butler 2007, p. 47) and 36 FD specimens were found at 2 sites, respectively, in 1988, while 1 L and 2 FD were reported from at least 2 sites in 1995 (Cicerello 2003, pers. comm.). The overall mussel population appeared "healthy" in 1977 (Taylor 1980), but the small snuffbox population has recently declined, and its viability is unknown.

Scioto River System—The Scioto River system in central and south-central Ohio is a major northern tributary of the upper Ohio River. The system was one of the most routinely sampled watersheds for mussels (mostly OSUM records), and historically harbored a large and thoroughly dispersed snuffbox population in the mainstem and 16 tributaries. The system was either exceptional for its snuffbox population, or it provided a general historical perspective of what researchers may have found if other systems had been as thoroughly sampled. Sizable populations were noted in at least the Olentangy River, Big Darby Creek, and Big Walnut Creek. Development associated with the Columbus metropolitan area has taken a major toll on the aquatic fauna. Pollutants from the 1800s included wastes from sawmills, breweries, and slaughterhouses (Butler 2007, p. 48). Only a few fish species were found in the Scioto River 100 years ago (Trautman 1981, p. 33). Currently, 90 to 95 percent of the normal summer-fall flow in the river consists of wastewater treatment plant (WWTP) discharges (Yoder *et al.* 2005, p. 410). Museum records indicate that the snuffbox had completely disappeared from the mainstem by the 1970s. A series of reservoirs around Columbus fragmented habitat and eliminated or reduced populations (Olentangy and Scioto Rivers; Alum, Big Walnut and Deer Creeks). Currently, remnant populations remain in six streams, making the snuffbox precariously close to extirpation throughout this once rich system.

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. 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 1960–61 survey, when it appeared "fairly common" in the lower river (Stein 1963, p. 138). A single L individual in southern Delaware County and two FD specimens in eastern Marion County were found among 30 sites in 1989, with R shells at 7 other sites (Hoggarth 1990, pp. 20–27). The small population has declined (Hoggarth 1990, p. 14), and viability is unknown.

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; six Pickaway County collections in 1962 alone had 250 L and FD specimens. Watters (1990, p. 4; 1994, p. 100) surveyed 42 mainstem sites in 1986 and 49 sites in 1990. Combining the data from both years, 80 L and FD snuffbox were collected at 22 sites (Watters 1994, p. 101). The population in 1990 occurred in a reach from approximately RM 11.5 to RM 42.5. The snuffbox was recruiting (Watters 1994, p. 101); four individuals during both 1986 and 1990 were 2 to 5 years of age. The overall population trend over the past 40 years has been downward. Between 1986 and 1990, the number of L and FD specimens was reduced from 54 to 16 and its distribution declined from 17 to 8 sites. Two FD specimens were found at sites in Franklin (1996) and Pickaway (2000) Counties, and three other sites produced only R specimens (OSUM records). This historically large snuffbox population has declined to marginal status and its viability is questionable.

Little Darby Creek—Little Darby Creek is the major tributary in the Big Darby Creek system, flowing in a southeasterly direction to its confluence in southwestern Franklin County, Ohio. The 25 OSUM lots for this species are small (fewer than five specimens per lot), date to the early 1960s, and represent lower mainstem sites in Madison County. Single FD and R specimens were collected in 1999 from a Union County site (OSUM 66740), where L individuals were collected in 1964 (Stein 1966, p. 23). This site yielded only R specimens in 1990 (Watters 1990, Appendix A.11; 1994, p. 102). Overall, the snuffbox was historically known from 35 river mi (56 river km). The well documented OSUM collection history illustrates the steady decline of a snuffbox population nearing extirpation.

Salt Creek—Salt Creek is an eastern tributary in the Scioto River system, south-central Ohio. All records (OSUM) were collected in the lower mainstem (Ross County) beginning in 1958. A single L individual from 1987 represents the last known record. The mussels in this system "have been heavily impacted, apparently by the towns of Adelphi and Laurelville" (Watters 1992, p. 78). The current status of this snuffbox population is unknown.

Scioto Brush Creek—Scioto Bush Creek is a small, western tributary of the lower Scioto River in Scioto County, south-central Ohio. The snuffbox was discovered here in the 1960s (Watters 1988a, p. 45). Three L and FD specimens from 2 sites and R shells from 2 other sites were collected during a 1987 survey covering 11 sites (Watters 1988a, pp. 210–220). The snuffbox population, collectively known from five fragmented sites along the lower two-thirds of stream, is small, and its viability is unknown.

South Fork Scioto Brush Creek—South Fork Scioto Brush Creek is a small tributary of Scioto Brush Creek, in the lower Scioto River system. A single snuffbox was found during a survey of five sites in 1987 (Watters 1988a, pp. 210–220). The South Fork and Scioto Brush Creek populations can be considered a single population unit, the viability of this unit is uncertain.

Kinniconick Creek—Kinniconick Creek is a small, southern tributary of the Ohio River in northeastern Kentucky. Snuffbox was reported L from 4 of 15 sites sampled in 1982 with R shells from an additional 2 sites (Warren *et al.* 1984, pp. 48–49). Single FD and L snuffbox were collected in 2001 and 2004, respectively, from sampling efforts at several sites (Butler 2007, p. 51), and a single FD specimen was found while resurveying four sites in 2005 (Butler 2007, p. 51). The snuffbox declined in the past few decades, is considered rare, and its viability is uncertain.

Little Miami River—The Little Miami River is a northern tributary of the Ohio River in southwestern Ohio, flowing south into the latter at the eastern fringe of the Cincinnati metropolitan area. Snuffbox records from the Little Miami date to the mid-1800s, but most collections are from the past several decades. Seven FD specimens were found at 4 of 46 mainstem sites surveyed during 1990–91, with 10 R shells at 6 other sites (Hoggarth 1992, p. 265). The FD specimens were found in approximately 20 river mi (32.2 river km), mostly in Warren County. Current viability of this small population is unknown.

Licking River—The Licking River is a southern tributary of the Ohio River in northeastern Kentucky, flowing in a northwesterly direction to its confluence across from Cincinnati. The snuffbox occurred at 13 of 60 historical mainstem sites below Cave Run Reservoir (Laudermilk 1993, p. 45) and a preimpoundment site in the reservoir footprint (Clinger 1974, p. 52). The population extended approximately 50 river mi (80.5 river km). All collections of snuffbox are small in number (Butler 2007, p. 52). A single L individual and a FD specimen were found at 2 sites and R shells were reported from 7 other sites among 49 sites sampled in 1991 (Laudermilk 1993, p. 45). Single L and FD snuffbox were collected in 1999 (Cicerello 2003, pers. comm.), and a single L individual was found in 2006 (Butler 2007, p. 53). The snuffbox has become very rare, sporadic in occurrence, and its viability is questionable.

Slate Creek—Slate Creek is a southern tributary of the Licking River below Cave Run Dam in east-central Kentucky. Historically, the snuffbox was considered "extremely abundant throughout the stream" (Taylor and Spurlock 1983) and collectively known from six sites (Laudermilk 1993, p. 45). Seventeen D specimens were recorded from a site in 1987 (Cicerello 2003, pers. comm.). A single FD and seven R specimens were found at three sites sampled in 1991 (Butler 2007, p. 53), when it was considered "occasional" in distribution (Laudermilk 1993, p. 45). Twelve L individuals were found in 1992 (Cicerello 2003, pers. comm.). Subsequent sampling has produced no additional snuffbox; two sites and four sites yielded only R specimens in 2001 and 2002, respectively (Cicerello 2005, pers. comm.). If extant, the population is marginal at best, with unlikely viability.

Stillwater River—The Stillwater River is a 67-mi (108-km), western tributary of the Great Miami River draining southwestern Ohio. The species was collectively known from eight sites throughout the River (Watters 1988a, pp. 59–71; OSUM records). One FD specimen below Englewood Dam in Montgomery County was found among 18 sites surveyed in 1987, with R shells from 5 other sites (Watters 1988a, pp. 59–71). No other information on the small population is available, and its viability is unknown.

Middle Fork Kentucky River—The Middle Fork is one of three headwater tributaries (with the North and South Forks) forming the Kentucky River, flowing in a northerly then westerly direction and draining a portion of southeastern Kentucky. The snuffbox was first reported in 1966. Three L individuals and a R shell were found at three sites in 1996, and a single L individual was collected from another site in 1997 (Cicerello 2003, pers. comm.). All sites occur within a 10-river-mi (16-river-km) reach above Buckhorn Reservoir in Leslie County. This small population has unknown viability.

Red Bird River—The Red Bird River is a north-flowing headwater tributary of the South Fork Kentucky River in Clay County, southeastern Kentucky, forming the latter at its confluence with Goose Creek. Ten FD specimens were recorded from two sites in 1988, and three L and one FD snuffbox were collected from four sites in 1995 (Cicerello 2003, pers. comm.). This small population occurs sporadically in the lower 20 river mi (32 river km), and viability is unknown (Cicerello 2003, pers. comm.; 2006, pers. comm.).

Red River—The Red (or North Fork Red) River is a westerly flowing tributary of the upper Kentucky River in eastern Kentucky. No L snuffbox were found in surveys of the 9-river-mi (15-river-km) reach of the Wild River section during surveys of 1980, 1986, and 1991 (Houp 1980, p. 56; 1993, p. 96), but two FD and one L snuffbox were found at three sites in 1988, while five L individuals were found in 1996 (Cicerello 2006, pers. comm.). Mostly males have been found since 2002, and they are being held in captivity for future culture efforts (Butler 2007, p. 55). A small population persists over a 10-river-mi (16-river-km) reach in the lower section of the Red River Gorge Geological Area of the Daniel Boone National Forest in Menifee, Wolfe, and Powell Counties (Cicerello 2006, pers. comm.). Viability of this population is unknown.

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, p. 62). Seven FD specimens and a single L 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 1998–99 yielded no evidence of the snuffbox, prompting an investigator to consider it extirpated (Akers 2000, p. 13), but occasional specimens may still be found (Butler 2007, p. 55). The species is sporadically distributed over 40 river miles of the upper river (Cicerello 2006, pers. comm.). If it is still extant, the viability of this small population is unknown.

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, p. 182) considered the snuffbox to be well distributed over the system, but not abundant. Large museum collections of snuffbox were taken from Munfordville during 1961–66, but only six R shells were reported there in 1967. The snuffbox has been rare since. Five L and FD snuffbox were collected at 4 of 42 sites during 1987–89 sampling in Mammoth Cave National Park (Cicerello and Hannan 1990, pp. 16–17). Three L and six FD snuffbox were reported in the upper Green River from 1984–90 (Cicerello 2003, pers. comm.). A single L 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. 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.

Wabash River System—The Wabash River is the second largest sub-basin within the Ohio River system, the watershed of the 350-mi (563-km) river encompassing much of Indiana, west-central Ohio, and southeastern Illinois. The mainstem and at least 27 streams had one of the largest snuffbox population clusters. The species persists today as seven small populations in the system; the viability of these populations is unknown (Butler 2007, p. 57).

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. Nine sites were surveyed during 1993–94 without finding any evidence of the snuffbox (ESI 1995, p. 19). The snuffbox was rediscovered in 2004 above Salamonie Reservoir, where two L individuals at one site and FD shells, including a very small juvenile, were found at another site 2 mi (3 km) away (Fisher 2005, pers. comm.). The small population is considered to be recruiting and viable at some level.

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. Nearly all records of the snuffbox were made in the past 20 years. Two weathered shells were found in the lower mainstem among 16 sites sampled in 1987 (Cummings *et al.* 1987, p. 25; Cummings and Berlocher 1990, p. 93) and 30 sites in 1991–92 (ESI 1993, p. 68). One L individual and over 32 FD 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 FD specimen was found below Shafer Reservoir among 13 sites sampled in 2003 (ESI 2003, p. 9). The viability of this declining population is unknown, but it appears close to extirpation (Fisher 2003, pers. comm.).

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 L and 15 FD specimens were collected at four sites in 1986 in Coles and Douglas Counties (Cummings *et al.* 1988, p. 8). Although overall mussel abundance at the 21 sites sampled in both 1956 and 1986 dropped 86 percent, the snuffbox was one of only five species that showed relatively stable population size over the 30-year period (Cummings *et al.* 1988, p. 9). Additional L and FD snuffbox from museum collections were recorded from single sites in 1988. Three L and eight FD snuffbox were found at two sites in 1992, and one L and three FD were found at three of six sites surveyed during 2001–2002. Since 1986, the small snuffbox population has occurred sporadically at six sites over 50 river mi (80 river km) of the upper river. The species was reported as significant and viable by Butler (2007 pers. comm.), but has declined to some extent. Recent surveys, however, documented only one L individual in 2005 and one L and one FD in 2008, indicating that the Embarras River population may be closer to a marginal population than a significant one (Tiemann 2009, pers. comm.).

Sugar Creek—Sugar Creek is a tributary in the upper East Fork White River system, draining central Indiana east and south of Indianapolis. A single L individual from one site, FD specimens from seven sites, and R shells from an additional eight sites were reported in 1990 (Harmon 1992, pp. 40–41 1998). The snuffbox population occurred sporadically over 35 river mi (56 km) to near the mouth. Only R shells were found while resampling some historical sites in 1995, 1998, and 2001 (Butler 2007, p.59). It is questionable whether the population remains extant.

Buck Creek—Buck Creek is a southerly flowing, western tributary of Sugar Creek in the upper East Fork White River system east of Indianapolis. A FD snuffbox was found near the mouth and R specimens at an upstream site in 1990 (Harmon 1992, p. 41. Similar to the parent stream population in Sugar Creek, the snuffbox may already be extirpated in Buck Creek (Fisher 2003, pers. comm.).

Muscatatuck River—The Muscatatuck River is a large, westerly flowing tributary of the upper East Fork White River in southeastern Indiana. The snuffbox was first reported from the stream by Daniels (1903, p. 646). FD specimens (unknown number) were recorded at a site downstream from Graham Creek that was sampled in 1988 (Harmon 1989, p. 118). Status and viability of snuffbox in the Muscatatuck River are unknown.

Graham Creek—Graham Creek flows southwesterly to join Big Creek in forming the Muscatatuck River in the East Fork White River system in southeastern Indiana. The species was found FD (numbers unknown) at six sites over 10 river mi (16 river km) of the lower stream in Jennings County in 1988 (Harmon 1989, p. 117), and a single FD specimen was found in 1990 (Harmon 1998). Viability of these small population is unknown.

Cumberland River System—Snuffbox populations are known from the mainstem Cumberland River and 6 of its tributaries. With few exceptions, most mainstem records were made prior to the 1920s when the species was locally common (Wilson and Clark 1914, p. 45). The snuffbox is considered extirpated from the mainstem. Currently, a single tributary population may be extant, but is considered not viable. The species is likely to become extirpated from the entire river system in the foreseeable future.

Buck Creek—Buck Creek is a southerly flowing, northern tributary of the upper Cumberland River below Cumberland Falls in southeastern Kentucky. One D valve was found at a site in 1981 (Clarke 1981b, Appendix), and two L and one FD snuffbox were reported from three sites during 1983–84 (Schuster *et al.* 1989, p. 82). The species was also reported L from a lower mainstem site among seven sites sampled from 1987–90 (Layzer and Anderson 1992, p. 16). A recent survey found only R shells at 3 of 23 sites (Hagman 2000, p. 21). If extant, the declining snuffbox population in Buck Creek is likely to become extirpated 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 near its mouth 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 (TVA) 1971, p. 4). The loss of mussel resources has been substantial (Watters 2000, p. 262). Muscle Shoals, the 53-river-mi (85-river-km) reach in northwestern Alabama, historically harbored 69 mussel species, the most diverse mussel fauna ever known (Garner and McGregor 2001, p. 155). The construction of three dams (Wilson in 1925, Wheeler in 1930, and Pickwick Landing in 1940) inundated most of the mussel beds. No L snuffbox have been reported at Muscle Shoals for around 100 years (Garner and McGregor 2001, p. 162). The snuffbox may persist in the mainstem at a very low density and in only five tributaries. The Clinch River maintains a stronghold population, but highly restricted populations persist in the other streams.

Clinch River—The 350-mi (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 Knoxville in northeastern Tennessee. No other river in North America has extant populations of more federally endangered (15) and candidate (4) species of mussels than does the upper Clinch River above Norris Reservoir. The snuffbox was reported from nine sites by Ortmann (1918, pp. 601–606). Museum records from Hancock County, Tennessee, during 1965–71 documented a very large population of snuffbox. The snuffbox is generally distributed from RM 170 to RM 195 in Hancock County, but is sporadic in Virginia (RM 213–235), where it has recently declined (Butler 2007, p. 62). The snuffbox population is recruiting, viable, and currently stable, although decreased in size and range from 40 years ago. The Clinch River ranks among the six stronghold snuffbox populations rangewide.

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, pp. 597–598), five sites during 1973–78 by Dennis (1981, p. 3), four sites from 1975–78 by Ahlstedt and Brown (1979, p. 42), and four Virginia sites in 1988–89 by Wolcott and Neves (1994, p. 7). Large collections attest to its former abundance. The species was found L and FD in the Powell River, Tennessee, during 1989–90 (Hubbs *et al.* 1991, Appendix A). Johnson (2008) collected two L individuals at RM 95. The population has declined, viability is questionable, and its extirpation may be imminent (Butler 2007, p. 63).

Tennessee River—The snuffbox originally was known from all but the lower section of the river. Butler (2007, p. 61) reported the snuffbox as "believed to be extirpated from the entire Tennesssee River." However, Yokley (2002, p. 1) collected a single FD male in 2002 at the U.S. 231 Bridge, Madison and Morgan Counties. In 2006, one L female was found at the same location, though it was the only snuffbox out of 8,978 mussels collected at the site (Yokley 2006, p. 1). Nothing further is known about the status of the snuffbox in the Tennessee River mainstem.

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, p. 359). No evidence of snuffbox was found in two surveys during 1965–67 (Isom and Yokley 1973, p. 444) and a 1980 survey (Butler 2007, p. 64). Twelve L and FD snuffbox were found at four sites between RMs 13 and 21 (Ahlstedt 1995–96, p. 70). The species was again absent from 10 upper mainstem sites surveyed in 2002 (Godwin 2002, p. 9). Four FD specimens of varying sizes were found at lower river sites in 2002 (Fraley 2003, pers. comm.; Smith 2005, pers. comm.) and 2003–2006 (Freeman 2006, pers. comm.). One L and 11 FD specimens were found at RM 21 in 2005, and 2 L and 16 FD were collected at RM 31 in 2007 (Gangloff 2007, pers. comm.). In July 2008, Freeman (2008, pers. comm.) observed multiple age classes (sizes) of FD snuffbox in middens between RM 34.7 and 32.5. Fobian *et al.* (2008, p. 14) collected 21 L snuffbox at 7 sites and FD specimens at 8 sites between RM 46.7 and 13.1. The stronghold snuffbox population exists between RMs 13 and 44, and is recruiting, viable, and has clearly improved since 1980.

Elk River—The Elk River is a large, northern tributary flowing 200 river mi (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, p. 440), and a single L individual was found among 108 sites sampled in 1980 (Ahlstedt 1983, p. 47). Single specimens were also reported from 4 sites sampled in the lower river in 1997 (Madison and Layzer 1998, Table 6) and 16 sites sampled in 1999 (Service 1999, p. 3). A very large FD specimen was found at RM 51 among 4 sites sampled in 2001 (Hubbs 2002, p. 5; Butler 2007, p. 65). A single L and a FD snuffbox were found at a site in Giles County during qualitative sampling events at five sites in 2005 (Ahlstedt *et al.* 2006). Ford (2008, pers. comm.) reported collecting FD specimens at Stairstep Shoals in Giles County, Tennessee, in July 2007. The small snuffbox population has recently recruited, exhibits some level of viability, and its numbers appear relatively stable in recent history.

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 RM 180 downstream in the mid-1970s (Ahlstedt 1981, p. 62; Dennis 1984, p. 38). Two L individuals were collected from 2 of 99 sites surveyed in 1979 (Butler 2007, p. 66). A single L individual was discovered in Maury County among 72 sites sampled during 2000–03 (Ahlstedt *et al.* 2004, p. 119), but none were found at 11 lower sites surveyed in 2000 (Schilling and Williams 2002, p. 409). The snuffbox is very rare, and its viability is uncertain.

Lower Mississippi River Sub-Basin

The Lower Mississippi River Sub-basin includes 954 miles of the Mississippi River from its confluence with the Ohio River at Cairo, Illinois, to its mouth in the Gulf of Mexico. The snuffbox is known from a single stream in this sub-basin, outside of the White River system.

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-mi (724-km) river are from 1964, located approximately 1 mi southwest of Parkin in Cross County (Bates and Dennis 1983, p. 63; Harris *et al.* 2007, p. 10). Snuffbox records exist for Butler, Wayne, and Stoddard Counties, Missouri, where it was considered "locally abundant" (Oesch 1984, p. 235). The species is known from above Wappapello Reservoir, but was absent from Missouri surveys conducted below Wappapello Dam in 1983 (Bates and Dennis 1983, p. 63) and 1986 (Ahlstedt and Jenkinson 1991, p. 240). Twelve L snuffbox were sampled at sites in 2002 (Hutson and Barnhart 2004, pp. 84–85). Live individuals were found during collections at RM 172.1 in 2005 and 2006 (Butler 2007, p. 67). The snuffbox is restricted to a 10-mi (16-km) reach (RM 172.1–182.0) on the northeastern edge of the Ozark Plateaus in the vicinity of Sam A. Baker State Park, Wayne County (Hutson and Barnhart 2004, p. 85). This medium-sized snuffbox population appears to be stable and viable, but restricted in distribution.

White River System—The 690-mi (1,110-km) White River is a large tributary system of the western bank of the Mississippi River. A snuffbox population once occurred in the mainstem and six of its larger tributaries. The last record from the mainstem in Arkansas is pre-1921 (Harris *et al.* 2007, p. 10). Highly restricted populations persist in four streams.

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, p. 13) and 1995 (40 sites; Harris 1996, p. 9), but two L individuals were found at a single site among 60 sites surveyed in 2006 (Matthews 2007, pers. comm.). The small population occurs in the lower river in Marion County, and its viability is unknown.

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-mi (483-km) Black River. A single, approximately 4-year-old L male was collected at RM 65.5, Wayne County, among 51 Missouri sites sampled in 2002 (Hutson and Barnhart 2004, p. 154). The species has become extirpated from the lower river on the Mississippi Embayment, including Arkansas. The snuffbox appears rare but viable at some level.

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 mi (34 river km) of the lowermost mainstem in Arkansas (Harris and Gordon 1987, p. 53). A single L adult male was found in Lawrence County in 2005, and represents the first L specimen found in Arkansas in more than 20 years (Butler 2007, p. 69). Further, 53 FD snuffbox were collected in four large muskrat middens (Harris *et al.* 2007, p. 15). 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. 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. The only snuffbox records were from around 1983 and 1997 in the middle mainstem in Sharp County (Butler 2007, p. 69). No other details on these collections or the status of the population are known. Considering the dearth of records, the snuffbox appears to be very rare in the Strawberry River, and of unknown viability.

Summary of Snuffbox Population Estimates and Status

The snuffbox has declined rangewide and appears to be extant in 74 of 208 streams and lakes of historical occurrence, a 65 percent decline in occupied streams. Realistically, much more than 65 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. Since multiple streams may comprise single snuffbox population segments (for example, the French Creek system), the actual number of extant populations is somewhat less. Extant populations, with few exceptions, are highly fragmented and restricted to short reaches. The elimination of this species from scores of streams and thousands of miles of stream reaches indicates catastrophic population losses and a precipitous decline in overall abundance. It is reasonable to estimate that total range reduction and overall population losses for the snuffbox each approximate, if not exceed, 90 percent.

Previous Federal Action

We identified the rayed bean as a Category 2 species in a notice of review published in the **Federal Register** on May 22, 1984 (49 FR 21664). The rayed bean remained a Category 2 species in subsequent notices including January 6, 1989 (54 FR 554), November 21, 1991 (56 FR 58804), and November 15, 1994 (59 FR 58982). Prior to 1996, a Category 2 species was one that we were considering for possible addition to the Federal List of Endangered and Threatened Wildlife but for which conclusive data on biological vulnerability and threats were not available to support a proposed rule. We stopped designating Category 2 species in the February 28, 1996, Notice of Review (61 FR 7596). We now define a candidate species as a species for which we have on file sufficient information to propose it for protection under the Act. We designated the rayed bean as a candidate species on May 4, 2004 (69 FR 24876).

We identified the snuffbox as a Category 2 species in the notice of review published in the **Federal Register** on November 21, 1991 (56 FR 58804). The snuffbox remained a Category 2 in the subsequent notice on November 15, 1994 (59 FR 58982) but was dropped from the list in the February 28, 1996, Notice of Review (61 FR 7596), when we stopped designating Category 2 species. The snuffbox is not currently listed as a candidate species for listing.

Summary of Information Pertaining to the Five Factors

Section 4 of the Act (16 U.S.C. 1533), and its implementing regulations at 50 CFR part 424, set forth the procedures for adding species to the Federal lists of Endangered and Threatened Wildlife and Plants. Under section 4(a)(1) of the Act, we may determine a species to be endangered or threatened due to one or more of the following five factors: (A) The present or threatened destruction, modification, or curtailment of its habitat or range; (B) overutilization for commercial, recreational, scientific, or educational purposes; (C) disease or predation; (D) the inadequacy of existing regulatory mechanisms; or (E) other natural or manmade factors affecting its continued existence. Listing actions may be warranted based on any of the above threat factors, singly or in combination. Each of these factors is discussed below.

A. The Present or Threatened Destruction, Modification, or Curtailment of Their Habitat or Range.

Both species have experienced significant curtailment of their occupied habitats (*see* Background, above). The rayed bean has been eliminated from about 74 percent of the streams it historically occurred in. This species has also been eliminated from long reaches of former habitat in hundreds of miles of the Maumee, Ohio, Wabash, and Tennessee Rivers and from numerous stream reaches in their tributaries. The snuffbox has been eliminated from about 65 percent of the streams in which it historically occurred. Furthermore, extant populations, with few exceptions, are highly fragmented and restricted to short reaches. Available records indicate that 33 percent of streams considered to harbor extant populations of the snuffbox are represented by only one or two recent L or FD individuals. The primary cause of range curtailment for both species has been modification and destruction of river and stream habitats, primarily by the construction of impoundments.

Impoundment—Impoundments result in the dramatic modification of riffle and shoal habitats and a resulting loss of mussel resources, especially in larger rivers. Neves *et al.* (1997, pp. 63–64) and Watters (2000, pp. 261–262) reviewed the specific effects of impoundments on freshwater mollusks. Dams interrupt a river's ecological processes by modifying flood pulses; controlling impounded water elevations; altering water flow, sediments, nutrients, and energy inputs and outputs; increasing depth; decreasing habitat heterogeneity; decreasing stability due to subsequent sedimentation; blocking host fish passage; and isolating mussel populations from fish hosts. Even small, low-head dams can have some of these effects on mussels.

The reproductive process of riverine mussels is generally disrupted by impoundments, making the rayed bean and snuffbox unable to successfully reproduce and recruit under reservoir conditions. Population losses due to impoundments have likely contributed more to the decline and imperilment of the rayed bean and snuffbox than has any other single factor. Neither species occurs in reservoirs lacking riverine characteristics, and only the snuffbox persists in large rivers with dams (Ohio River), and then only in sections retaining riverine characteristics (generally tailwaters). Both species, however, historically occurred in the wave-washed shallows of several glacial lakes, an environment very different from that found in impoundments.

Stream habitat throughout major portions of the range of both species has been impounded. The majority of the Tennessee and Cumberland River mainstems and many of their largest tributaries are now impounded. There are 36 major dams located in the Tennessee River system, and about 90 percent of the Cumberland River downstream of Cumberland Falls is either directly impounded by U.S. Army Corps of Engineers (Corps) structures or otherwise impacted by cold tailwater released from dams. Watters (2000, pp. 262–263) summarizes the tremendous loss of mussel species from various portions of the Tennessee and Cumberland River systems. The rayed bean has been eliminated from the Tennessee River system and the snuffbox, once widespread throughout both systems, now persists in only five Tennessee River tributaries and one Cumberland River tributary.

This impoundment scenario is similar in many other parts of the range of the rayed bean and snuffbox, and includes numerous navigational locks and dams (Ohio, Allegheny, Muskingum and Green Rivers), major dams (Shenango, Elk, Walhonding, Scioto, Little Miami, Green, Nolin, Barren, Tippecanoe, Wabash, Mississinewa, Salamonie, and Duck Rivers), and low-head dams (Pine, Belle, Clinton, Huron, Maumee, Auglaize, Sandusky, Mahoning, Tuscarawas, Walhonding, Scioto, Olentangy, Wabash, Mississinewa, East Fork White, West Fork White, and Duck Rivers; and Middle Island, Big Walnut, Alum, Big Darby, Little Darby, Sugar, and Richland Creeks) that have contributed to the loss of the species' habitat. Sediment accumulations behind dams of all sizes generally preclude the occurrence of the rayed bean and snuffbox.

Dredging and Channelization—Dredging and channelization activities have profoundly altered riverine habitats nationwide. Hartfield (1993, pp. 131–141), Neves *et al.* (1997, pp. 71–72), and Watters (2000, pp. 268–269) reviewed the specific effects of channelization on freshwater mollusks. Channelization impacts a stream's physical (accelerated erosion, reduced depth, decreased habitat diversity, geomorphic instability, and riparian canopy loss) and biological (decreased fish and mussel diversity, changed species composition and abundance, decreased biomass, and reduced growth rates) characteristics (Hartfield 1993, p. 131; Hubbard *et al.* 1993, pp. 136–145). Channel construction for navigation has been shown to increase flood heights (Belt 1975, p. 189). This is partially attributed to a decrease in stream length and increase in gradient (Hubbard *et al.* 1993, p. 137). Flood events may thus be exacerbated, conveying into streams large quantities of sediment, potentially with adsorbed contaminants. Channel maintenance may result in profound impacts downstream (Stansbery 1970, p. 10), such as increases in turbidity and sedimentation, which may smother benthic (bottom-dwelling) organisms such as the rayed bean and snuffbox.

The only known rayed bean populations that remain in navigation channels are in the upper two navigation pools of the Allegheny River. Activities associated with navigation channels may have contributed to the elimination of the rayed bean from the Ohio, lower Allegheny, and Muskingum Rivers, and potentially others. Channel maintenance operations for barge navigation have impacted habitat for the snuffbox in several large rivers. Impacts associated with barge traffic, which include construction of fleeting areas, mooring cells, docking facilities, and propeller wash, also disrupt habitat. Navigation maintenance activities may continue to adversely affect this species in the upper Ohio River. Hundreds of miles of rayed bean (Olentangy, Salamonie, Mississinewa, Vermilion, North Fork Vermilion, Embarras Rivers) and snuffbox (Grand, Kankakee, Sangamon, Kaskaskia, Olentangy, Salamonie, Mississinewa, Eel, Vermilion, and North Fork Vermilion, Embarras, Paint Rock, and St. Francis Rivers; and Tonawanda, Killbuck, Chickamauga, and Bear Creeks) streams were dredged and channelized decades ago, and some populations have been eliminated from these streams. The entire length of the Kankakee River in Indiana was channelized by 1917. In addition, hundreds of drains (formed from ditching low-gradient creeks and swales) were created around 100 years ago in Illinois, Michigan, and other midwestern States. Stream channelizations were attempts to reduce flooding, drain low-lying areas, and "improve" storm flow runoff.

Chemical Contaminants—Chemical contaminants are ubiquitous throughout the environment and are considered a major threat in the decline of freshwater mussel species (Cope *et al.* 2008, p. 451; Richter *et al.* 1997, p. 1081; Strayer *et al.* 2004, p. 436; Wang *et al.* 2007, p. 2029). Chemicals enter the environment through both point and nonpoint discharges, including spills, industrial sources, municipal effluents, and agricultural runoff. These sources contribute organic compounds, heavy metals, pesticides, and a wide variety of newly emerging contaminants to the aquatic environment. As a result, water and sediment quality can be degraded to the extent that mussel populations are adversely impacted.

Chemical spills can be especially devastating to mussels because they may result in exposure of a relatively immobile species to extremely elevated concentrations that far exceed toxic levels and any water quality standards that might be in effect. Some notable spills that released large quantities of highly concentrated chemicals resulting in mortality to mussels include: massive mussel kills on the Clinch River at Carbo, Virginia, occurred from a power plant alkaline fly ash pond spill in 1967 and a sulfuric acid spill in 1970 (Crossman *et al.* 1973, p. 6); approximately 18,000 mussels of several species including 750 individuals from three endangered mussel species were eliminated from the upper Clinch River near Cedar Bluff, Virginia, in 1998, when an overturned tanker truck released 1,600 gallons (6,056 liters) of a chemical used in rubber manufacturing (Jones *et al.* 2001, p. 20; Schmerfeld 2006, p. 12); and an ongoing release of sodium dimethyl dithiocarbamate, a chemical used to reduce and precipitate hexachrome, starting in 1999 impacted approximately 10 river miles (16 km) of the Ohio River and resulted in an estimated loss of one million mussels, including individuals from two federally listed species (DeVault 2009, pers. comm.; Clayton 2008, pers. comm.). These are not the only instances where chemical spills have resulted in the loss of high numbers of mussels (Brown *et al.* 2005, p. 1457; Neves 1991, p. 252; Jones *et al.* 2001, p. 20; Schmerfeld 2006, pp. 12–13), but are provided as examples of the serious threat chemical spills pose to mussel species. The rayed bean and snuffbox are especially threatened by chemical spills because these spills can occur anywhere there are highways with tanker trucks, industries, or mines and where these overlap with rayed bean and snuffbox distribution.

Exposure of mussels to lower concentrations of contaminants more likely to be found in aquatic environments can also adversely affect mussels and result in the decline of freshwater mussel species. Such concentrations may not be immediately lethal, but over time, can result in mortality, reduced filtration efficiency, reduced growth, decreased reproduction, changes in enzyme activity, and behavioral changes to all mussel life stages. Frequently, procedures which evaluate the "safe" concentration of an environmental contaminant (for example, national water quality criteria) do not have data for freshwater mussel species or exclude data that is available for freshwater mussels (March *et al.* 2007, pp. 2066–2067, 2073).

Current research is now starting to focus on the contaminant sensitivity of freshwater mussel glochidia and newly-released juvenile mussels (Goudreau *et al.* 1993, pp. 219–222; Jacobson *et al.* 1997, p. 2390; Wang, 2007a, pp. 2041–2046; Valenti 2005, pp. 1244–1245; Valenti 2006, pp. 2514–2517; March 2007, pp. 2068–2073) and juveniles (Bartsch *et al.* 2003, p. 2561; Augspurger *et al.* 2003, p. 2569; Mummert *et al.* 2003, p. 2549, Wang, 2007b, pp. 2053–2055, Wang, 2007a, pp. 2041–2046, Valenti 2005, pp. 1244–1245; Valenti 2006, pp. 2514–2517; March 2007, pp. 2068–2073) to such contaminants as ammonia, metals, chlorine, and pesticides. The toxicity information presented in this section focuses on recent water-only laboratory acute (sudden and severe exposure) and chronic (prolonged or repeated exposure) toxicity tests with early life stages of freshwater mussels using the standard testing methodology published by the American Society for Testing and Materials (ASTM) (American Society for Testing and Materials 2008, pp. 1442–1493). Use of this standard testing method generates consistent, reliable toxicity data with acceptable precision and accuracy (Wang *et al.* 2007a, p. 2035) and was used for toxicity tests on ammonia, copper, chlorine, and select pesticides (Augspurger *et al.* 2007, p. 2025; Bringolf *et al.* 2007a, p. 2087; Bringolf *et al.* 2007c, p. 2101; Wang *et al.* 2007a, p. 2029; Wang *et al.* 2007b, p. 2036; Wang *et al.* 2007c, p. 2048). Use of these tests has documented that while mussels are sensitive to some contaminants, they are not universally sensitive to all contaminants (Augspurger *et al.* 2007, pp. 2025–2026).

One chemical that is particularly toxic to early life stages of mussels is ammonia. Sources of ammonia include agricultural sources (animal feedlots and nitrogenous fertilizers), municipal wastewater treatment plants, and industrial waste (Augspurger *et al.* 2007, p. 2026), as well as precipitation and natural processes (decomposition of organic nitrogen) (Goudreau *et al.* 1993, p. 212; Hickey and Martin 1999, p. 44; Augspurger *et al.* 2003, p. 2569; Newton 2003, p. 1243). Therefore, ammonia is considered a limiting factor for survival and recovery of some mussel species due to its ubiquity in aquatic environments, high level of toxicity, and because the highest concentrations typically occur in mussel microhabitats (Augspurger *et al.* 2003, p. 2574). In addition, studies have shown that ammonia concentrations increase with increasing temperature and low-flow conditions (Cherry *et al.* 2005, p. 378; Cooper *et al.* 2005, p. 381), which may be exacerbated by the effects of climate change, and may cause ammonia to become more problematic for juvenile mussels. The Environmental Protection Agency's established ammonia water quality criteria (EPA 1985, p. 94–99) may not be protective of mussels (Augspurger *et al.* 2003, p. 2572; Sharpe 2005, p. 28) under current and future climate conditions.

Mussels are also affected by metals (Keller and Zam 1991, p. 543), such as cadmium, chromium, copper, mercury, and zinc, which can negatively affect biological processes such as growth, filtration efficiency, enzyme activity, valve closure, and behavior (Naimo 1995, pp. 351–355; Keller and Zam 1991, p. 543; Jacobson *et al.* 1997, p. 2390; Valenti *et al.* 2005, p. 1244). Metals occur in industrial and wastewater effluents and are often a result of atmospheric deposition from industrial processes and incinerators. Glochidia and juvenile freshwater mussels have recently been studied to determine the acute and chronic toxicity of copper to these life stages (Wang 2007a, pp. 2036–2047; Wang 2007b, pp. 2048–2056). The chronic values determined for copper ranged from 8.5 to 9.8 micrograms per liter (ug/L) for survival and from 4.6 to 8.5 ug/L for growth of juveniles. These chronic values are below the EPA's 1996 chronic water quality criterion of 15 ug/L (hardness 170 mg/L) for copper (Wang 2007b, pp. 2052–2055). March (2007, pp. 2066, 2073) identifies that copper water quality criteria and modified State water quality standards may not be protective of mussels.

Mercury is another heavy metal that has the potential to negatively affect mussel populations, and it is receiving attention due to its widespread distribution and potential to adversely impact the environment. Mercury has been detected throughout aquatic environments as a product of municipal and industrial waste and atmospheric deposition from coal burning plants. One recent study evaluated the sensitivity of early life stages of mussels to mercury (Valenti 2005, p. 1242). This study determined that, for the mussel species used (rainbow mussel, *Villosa iris*), glochidia were more sensitive to mercury than were juvenile mussels, with the median lethal concentration value of 14 ug/L compared to 114 ug/L for the juvenile life stage. The chronic toxicity tests conducted determined that juveniles exposed to mercury greater than or equal to 8 ug/L exhibited reduced growth. These observed toxicity values are greater than EPA's Criteria Continuous Concentration and Criteria Maximum Concentration, which are 0.77 ug/L and 1.4 ug/L, respectively. Based on these data we believe that EPA's water quality standards for mercury should be protective of juvenile mussels and glochidia, except in cases of illegal dumping, permit violations, or spills. However, impacts to mussels from mercury toxicity may be occurring in some streams. According to the National Summary Data reported by States to the EPA, 3,770 monitored waters do not meet EPA standards for mercury in the United States (*http://iaspub.epa.gov/waters10/attains_nation_cy.control?p_report_type=T,* accessed 6/28/2010). Acute mercury toxicity was determined to be the cause of extirpation of a diverse mussel fauna for a 70-mile (112-km) portion of the North Fork Holston River (Brown *et al.* 2005, pp. 1455–1457).

In addition to ammonia, agricultural sources of chemical contaminants include two broad categories that have the potential to adversely impact mussel species: Nutrients and pesticides. Nutrients (such as nitrogen and phosphorus) can impact streams when their concentrations reach levels that cannot be assimilated, a condition known as over-enrichment. Nutrient over-enrichment is primarily a result of runoff from livestock farms, feedlots, and heavily fertilized row crops (Peterjohn and Correll 1984, p. 1471). Over-enriched conditions are exacerbated by low-flow conditions, such as those experienced during typical summer-season flows and that might occur with greater frequency and magnitude as a result of climate change. Bauer (1988, p. 244) found that excessive nitrogen concentrations can be detrimental to the adult freshwater pearl mussel (*Margaritifera margaritifera*), as was evident by the positive linear relationship between mortality and nitrate concentration. Also, a study of mussel life span and size (Bauer 1992, p. 425) showed a negative correlation between growth rate and eutrophication, and longevity was reduced, as the concentration of nitrates increased. Nutrient over-enrichment can result in an increase in primary productivity, and the subsequent respiration depletes dissolved oxygen levels. This may be particularly detrimental to juvenile mussels that inhabit the interstitial spaces in the substrate where lower dissolved oxygen concentrations are more likely than on the sediment surface where adults tend to live (Sparks and Strayer 1998, pp. 132–133).

Elevated concentrations of pesticide frequently occur in streams due to pesticide runoff, overspray application to row crops, and lack of adequate riparian buffers. Agricultural pesticide applications often coincide with the reproductive and early life stages of mussels, and thus impacts to mussels due to pesticides may be increased (Bringolf *et al.* 2007a, p. 2094). Little is known regarding the impact of currently used pesticides to freshwater mussels even though some pesticides, such as glyphosate (Roundup), are used globally. Recent studies tested the toxicity of glyphosate, its formulations, and a surfactant (MON 0818) used in several glyphosate formulations, to early life stages of the fatmucket (*Lampsilis siliquoidea*), a native freshwater mussel (Bringolf *et al.* 2007a, p. 2094). Studies conducted with juvenile mussels and glochidia determined that the surfactant (MON 0818) was the most toxic of the compounds tested and that *L. siliquoidea* glochidia were the most sensitive organism tested to date (Bringolf *et al.* 2007a, p. 2094). Roundup, technical grade glyphosate isopropylamine salt, and isopropylamine were also acutely toxic to juveniles and glochidia (Bringolf *et al.* 2007a, p. 2097). The impacts of other pesticides including atrazine, chlorpyrifos, and permethrin on glochidia and juvenile life stages have also recently been studied (Bringolf *et al.* 2007b, p. 2101). This study determined that chlorpyrifos was toxic to both *L. siliquoidea* glochidia and juveniles (Bringolf *et al.* 2007b, p. 2104). The above results indicate the potential toxicity of commonly applied pesticides and the threat to mussel species as a result of the widespread use of these pesticides. All of these pesticides are commonly used throughout the range of the rayed bean and snuffbox.

A potential, but undocumented, threat to freshwater mussel species, including rayed bean and snuffbox, are contaminants referred to as "emerging contaminants" that are being detected in aquatic ecosystems at an increasing rate. Pharmaceuticals, hormones, and other organic contaminants have been detected downstream from urban areas and livestock production (Kolpin *et al.* 2002, p. 1202). A large potential source of these emerging contaminants is wastewater being discharged through both permitted (National Pollutant Discharge Elimination System (NPDES)) and non-permitted sites throughout the country. Permitted discharge sites are ubiquitous in watersheds with rayed bean and snuffbox populations, providing ample opportunities for contaminants to impact the species (for example, there are more than 250 NPDES sites in the Meramec River, Missouri system, which harbors a declining population of snuffbox; Roberts and Bruenderman 2000, p. 78).

The information presented in this section represents some of the threats from chemical contaminants that have been documented both in the laboratory and field and demonstrates that chemical contaminants pose a substantial threat to the rayed bean and snuffbox. This information indicates the potential for contaminants to contribute to declining rayed bean and snuffbox populations—from spills that are immediately lethal to species to chronic contaminant exposure, which results in death, reduced growth, or reduced reproduction of rayed bean and snuffbox.

Mining—The low pH commonly associated with coal mine runoff can reduce glochidial encystment rates, thus impacting mussel recruitment (Huebner and Pynnönen 1992, p. 2350). Additionally, adverse impacts from heavy metal-rich drainage from coal mining and associated sedimentation has been documented in portions of historical rayed bean and snuffbox habitat in the upper Ohio River system in western Pennsylvania (Ortmann 1909c, p. 97), West Virginia, and southeastern Ohio. Likewise, coal mining has impacted rayed bean habitat in the upper Tennessee River system, Virginia (Kitchel *et al.* 1981, p. 21), and snuffbox habitat in eastern Kentucky (lower Ohio and Mississippi River systems in southeastern Illinois and western Kentucky; upper Cumberland River system in southeastern Kentucky and northeastern Tennessee; and upper Tennessee River system in southwestern Virginia) (Ortmann 1909c, p. 103; Neel and Allen 1964, pp. 428–430; Kitchel *et al.* 1981, p. 21; Anderson *et al.* 1991, pp. 6–7; Gordon 1991, p. 2; Bogan and Davis 1992, p. 2; Layzer and Anderson 1992, pp. 91–94; Ahlstedt and Tuberville 1997, p. 75; Milam *et al.* 2000, p. 53; Warren and Haag 2005, p. 1394). Acid mine drainage was implicated in the mussel die-off in the Little South Fork Cumberland River, Kentucky (Anderson *et al.* 1991, pp. 6–7; Layzer and Anderson, 1992, p. 94; Ahlstedt and Saylor 1995–96, pp. 92–93; Warren and Haag 2005, p. 1394). Tailings pond failures have also impacted aquatic resources (Powell River, Virginia; Butler 2007, p. 83). A decline of the snuffbox and other imperiled mussels in the Powell River was blamed on coal mining impacts (Ahlstedt and Tuberville 1997, p. 75). Increased mining activities in the upper Clinch River system is resulting in "blackwater" events (Jones and Neves 2004, p. 2). Anecdotal evidence suggests that coal fines are increasing in the Clinch River reach that harbors a stronghold snuffbox population (Butler 2007, p. 84). A coal-fired power plant planned for the upper Clinch River in Virginia would further increase mining in the Clinch and Powell watersheds.

Currently, coal mining activities occur only in the Elk River in West Virginia (Douglas 2010, pers. comm.). However, if coal mining activities are reinitiated in western Pennsylvania, they could become a threat to populations of both species in the lower French Creek and the Allegheny River.

Instream and alluvial (clay, silt, sand, or other material deposited by running water) gravel mining has been implicated in the destruction of several mussel populations (Hartfield 1993, pp. 135–136; Brown and Curole 1997, pp. 239–240). Negative impacts associated with gravel mining include stream channel modifications (altered habitat, disrupted flow patterns, sediment transport), water quality modifications (increased turbidity, reduced light penetration, increased temperature), macroinvertebrate population changes (elimination, habitat disruption, increased sedimentation), and changes in fish populations (impacts to spawning and nursery habitat, food web disruptions) (Kanehl and Lyons 1992, pp. 26–27; Roell 1999, p. 5). Gravel mining may continue to be a localized threat to rayed bean and snuffbox populations (Kankakee, Bourbeuse, Walhonding, Elk (Tennessee), and Strawberry Rivers; Big Darby and Buck (Kentucky) Creeks).

Other mining activities that impact snuffbox populations include mining for metals (lead, cadmium, zinc) in Missouri. Mining has been implicated in the decline of mussels from the upper St. Francis River (Hutson and Barnhart 2004, pp. 86–87). Lead and barite mining is common in the Big River, a Meramec River tributary. A tailings-pond blowout discharged 81,000 cubic yards of mine tailings in 1977 that impacted approximately 80 river mi (129 river km) (Buchanan 1980, p. 9; Roberts and Bruenderman 2000, p. 24). As of 2000, high levels of heavy metals were still detected in the system (Roberts and Bruenderman 2000, p. 24) and may continue to hinder stream recovery. Forty-five tailings ponds and numerous tailings piles remain in the watershed (Roberts and Bruenderman 2000, p. 24).

Oil and gas production may have contributed to the decline of the rayed bean and snuffbox in certain drainages (Sangamon River in the upper Mississippi River system; Slippery Rock and Connoquenessing Creeks in the upper Ohio River system; Green, Kentucky, Salamonie, and Mississinewa Rivers in the lower Ohio River system) (Ortmann 1909c, p.104; Schanzle and Cummings 1991, p. 1; ESI 1995, p. 39; Cicerello 1999, p. 11). Pollutants include brines, high levels of potassium, and numerous organic compounds (Imlay 1971, p. 39). An increasing demand for domestic energy resources is expected to accelerate oil and gas exploration in certain rayed bean and snuffbox streams in the foreseeable future.

Siltation—Excessive sedimentation affects an estimated 46 percent of all U.S. streams (Judy *et al.* 1984), including the majority of the streams with extant rayed bean and snuffbox populations. Sedimentation has been implicated in the decline of mussel populations nationwide, and is a threat to rayed bean and snuffbox (Kunz 1898, p. 328; Ellis 1936, pp. 39–40; Marking and Bills 1979, p. 204; Vannote and Minshall 1982, pp. 4105–4106; Dennis 1984, p. 212; Wolcott and Neves 1990, pp. 74–75; Brim Box 1999, p. 79; Fraley and Ahlstedt 2000, p. 194; Poole and Downing 2004, pp. 119–120). Specific biological impacts include reduced feeding and respiratory efficiency from clogged gills, disrupted metabolic processes, reduced growth rates, limited burrowing activity, and physical smothering (Ellis 1936, pp. 39–40; Stansbery 1971, p. 6; Imlay 1972, p. 76; Marking and Bills 1979, p. 210; Vannote and Minshall 1982, p. 4105; Waters 1995, p. 7).

Studies indicate that excessive sediment level impacts are sublethal, with detrimental effects not immediately apparent (Brim Box and Mossa 1999, p. 101). Physical habitat effects include altered suspended and bed material loads, and bed sediment composition associated with increased sediment production and run-off; clogged interstitial habitats and reduced interstitial flow rates and dissolved oxygen levels; changed channels in form, position, and degree of stability; altered depth or width-depth ratio that affects light penetration and flow regime; aggraded (filling) or degraded (scouring) channels; and changed channel positions that dewater mussel beds (Vannote and Minshall 1982, p. 4105; Gordon *et al.* 1992, pp. 296–297; Kanehl and Lyons 1992, pp. 26–27; Brim Box and Mossa 1999, p. 102).

Interstitial spaces in the substrate provide essential habitat for juvenile mussels. When clogged, interstitial flow rates and spaces may become reduced (Brim Box and Mossa 1999, p. 100), thus reducing juvenile habitat availability. The rayed bean burrows deep into interstitial substrates, making it particularly susceptible to degradation of this habitat. Sediment may act as a vector for delivering contaminants such as nutrients and pesticides to streams. Juveniles can readily ingest contaminants adsorbed to silt particles during normal feeding activities. These factors may explain, in part, why so many mussel populations, including those of the rayed bean and snuffbox, appear to be experiencing recruitment failures.

Agricultural activities produce the most significant amount of sediment that enters streams (Waters 1995, pp. 17–18). Neves *et al.* (1997, p. 65) stated that agriculture (including both sediment and chemical run-off) affects 72 percent of the impaired river miles in the country. Unrestricted access by livestock is a significant threat to many streams and their mussel populations (Fraley and Ahlstedt 2000, p. 193). Soil compaction for intensive grazing may reduce infiltration rates and increase run-off, and trampling of riparian vegetation increases the probability of erosion (Armour *et al.* 1991, pp. 8–10; Trimble and Mendel 1995, pp. 238–239; Brim Box and Mossa 1999, p. 103).

The majority of extant rayed bean and snuffbox populations are threatened by some form of agricultural runoff (e.g., nutrients, pesticides, sediment). The Maumee River system, for example, has a drainage area that contains approximately 89 percent agricultural land (Sanders 2002, p. 10.1). The decline of rayed bean and snuffbox in this system may be largely attributed to stream habitat impacts resulting from intensive farming and associated runoff. The rayed bean and snuffbox once occurred in the Maumee River mainstem, as well as in up to nine of its tributaries. Currently, the snuffbox is extirpated from the Maumee River system and the rayed bean is only found in distinct but small reaches of the St. Joseph River, Fish Creek, Swan Creek, and Blanchard River. All of these remaining populations (which comprise about 20 percent of all remaining rayed bean populations rangewide) are currently threatened by ongoing agricultural activities. This scenario is echoed across the remaining extant range of the rayed bean and snuffbox.

Other Activities Affecting Rayed Bean and Snuffbox Habitat—Activities associated with urbanization can be detrimental to stream habitats (Couch and Hamilton 2002, p. 1) and were summarized by Feminella and Walsh (2005, pp. 585–587). Developmental activities may impact streams and their mussel fauna where adequate streamside buffers are not maintained and erosion of impacted land is allowed to enter streams (Brainwood *et al.* 2006, p. 511). Types of development may include highway construction, parking lots, building construction, general infrastructure (utilities, sewer systems), and recreation facilities. Factors impacting rayed bean and snuffbox populations in urban and suburban areas include lawn care chemicals (Conners and Black 2004, pp. 366–367), sedimentation, toxic effluents, domestic sewage, road salts, and general runoff.

Impervious surfaces are detrimental to mussel habitat by altering various hydrological factors, including: Increased volumes of flow, annual flow rates, peak flows and duration, and temperature; decreased base flow; and changes in sediment loadings (Galli 1991, p. 28; EPA 1997, p. 4; DeWalle *et al.* 2000, p. 2655; Myers-Kinzie *et al.* 2002, p. 822). These factors result in flooding, erosion, channel widening, altered streambeds, channel instability, riparian and instream habitat loss, and loss of fish populations (EPA 1997, p. 4). As little as 10 percent of a watershed being impervious can cause channel instability and a host of other stream habitat effects (Booth 1991, p. 98; Booth and Reinelt 1993, p. 549). Impervious surfaces may reduce sediment input into streams but result in channel instability by accelerating stormwater runoff, which increases bank erosion and bed scouring (Brim Box and Mossa 1999, p. 103). Stream channels become highly unstable as they respond to increased flows by eroding a groove in the bottom of the channel (incising), which increases the force of the water against the channel (shear stress) and bed mobilization (Doyle *et al.* 2000, p. 156). Hydrological variability influences the distribution of mussels in streams, with distinct communities associated with hydrologically flashy and hydrologically stable streams (Di Maio and Corkum 1995, p. 669). High shear stress, peak flows, and substrate movement limits mussel communities, reduces abundance (particularly for juveniles), and increasingly dislodges mussels and moves them downstream (Layzer and Madison 1995, p. 337; Myers-Kinzie *et al.* 2002, p. 822; Gangloff and Feminella 2006, p. 70). Recruitment is also significantly reduced in high discharge years (Howard and Cuffey 2006, p. 688). Most rayed bean and snuffbox streams have been impacted by general developmental activities and increased impervious surface levels (Butler 2007, p. 88; Butler 2002, p. 25).

All rayed bean or snuffbox streams are crossed by bridges and roads. Effects from these structures were reviewed by Wheeler *et al.* (2005). Categories of impacts include primary effects (construction), secondary effects (post-construction), and indirect effects (development associated with highway presence) (Angermeier *et al.* 2004, pp. 21–24). Culverts act as barriers to fish passage (Wheeler *et al.* 2005, p. 149), particularly by increasing flow velocity (Warren and Pardew 1998, p. 637). Stream channels become destabilized when culverted or improperly bridged by interrupting the transport of woody debris, substrate, and water (Wheeler *et al.* 2005, p. 152).

Anthropogenic activities can lower water tables, making rayed bean, snuffbox, and other mussel populations susceptible to depressed flow levels. Water withdrawals for irrigation, municipal, and industrial water supplies are an increasing concern. U.S. water consumption doubled from 1960 to 2000 and is likely to increase further (Naiman and Turner 2000, p. 960). Therefore, we anticipate water withdrawals and potential stream dewatering to be a threat to rayed bean and snuffbox in the foreseeable future.

We have identified a number of threats to the habitat of the rayed bean and snuffbox which have operated in the past, are impacting the species now, and will continue to impact the species in the foreseeable future. On the basis of this analysis, we find that the present and threatened destruction, modification, or curtailment of the species' habitats is a threat to the rayed bean and snuffbox throughout all of their range. Based on our analysis of the best available information, we have no reason to believe that the present or threatened destruction, modification, or curtailment of rayed bean or snuffbox habitat will change in the foreseeable future. The decline of the freshwater mussels in the eastern United States is primarily the result the long-lasting effects of habitat alterations such as impoundments, channelization, chemical contaminants, mining, and sedimentation. Although efforts have been made to restore habitat in some areas, the long-term effects of large-scale and wide-ranging habitat modification, destruction, and curtailment will last far into the foreseeable future.

B. Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

The rayed bean and snuffbox are not commercially valuable species. Rare species like the rayed bean and snuffbox may increasingly be sought by lay and experienced collectors. Most stream reaches inhabited by these species are restricted, and their 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. Native Americans were known to harvest the rayed bean for food, but because of its size, utilization rates were very low (Bogan 1990, p. 134). Localized declines of snuffbox from use as bait by fishermen has been noted (Cumberland River; Wilson and Clark 1914, p. 45), although it is unlikely that exploitation activities have eliminated any snuffbox populations.

On the basis of this analysis, we find that overutilization for commercial, recreational, scientific, or educational purposes is not now a threat to the rayed bean or snuffbox in any portion of their range or likely to become a significant threat in the foreseeable future.

C. Disease or Predation

Little is known about diseases in freshwater mussels (Grizzle and Brunner 2007). However, mussel die-offs have been documented in rayed bean and snuffbox streams (Neves 1986, p. 9), and some researchers believe that disease may be a factor contributing to the die-offs (Buchanan 1986, p. 53; Neves 1986, p. 11). 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, p. 16), but a recent study provides contrary evidence. Reproductive output and physiological condition were negatively correlated with mite and trematode abundance, respectively (Gangloff and Feminella 2004). Stressors that reduce fitness may make mussels more susceptible to parasites (Butler 2007, p. 90). Furthermore, nonnative mussels may carry diseases and parasites that are potentially devastating to native mussel fauna, including rayed bean and snuffbox (Strayer 1999b, p.88).

The muskrat (*Ondatra zibethicus*) is cited as the most prevalent mussel predator (Kunz 1898, p. 328; Hanson *et al.* 1989, p. 15). 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, p. 940), 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, p. 304). Numbers were too low to determine selectivity indices or statistics.

Muskrats were not thought to be a threat to the rayed bean by West *et al.* (2000, pp. 255–256), due to their general selection of mussels larger than 1.4–1.6 in (3.6–4.1 cm) long (Convey *et al.* 1989, p. 656; Hanson *et al.* 1989, p. 24). Neves and Odom (1989, pp. 938–939) also noted that muskrats did not select for small mussels. Nevertheless, some muskrat predation on the rayed bean has recently been documented in Cassadaga Creek, New York, but is generally considered insignificant.

Other mammals (raccoon (*Procyon lotor*), mink (*Mustela vison*), river otter (*Lutra Canadensis*), 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, p. 328; Meek and Clark 1912, p. 6; Neck 1986, p. 64; Tyrrell and Hornbach 1998, p. 301). Hydra, non-biting midge larvae, dragonfly larvae, crayfish, and especially flatworms are invertebrate predators on newly metamorphosed juveniles (Zimmerman and Neves 2003, p. 28; Klocker and Strayer 2004, p. 174). The overall threat posed by these predators on the rayed bean and snuffbox is not considered significant.

Studies indicate that in some localized areas, disease and predation may have a negative impact on mussel populations. However, based on our analysis of the best available information, we do not believe that disease or predation is a significant threat to the overall status of rayed bean or snuffbox, nor do we believe that it is likely to become a significant threat in the foreseeable future.

D. The Inadequacy of Existing Regulatory Mechanisms

Most States with extant rayed bean and snuffbox populations prohibit collection of mussels without a State collecting permit. However, enforcement of this permit requirement is difficult.

Sources of nonpoint source pollution include timber clearcutting, clearing of riparian vegetation, urbanization, road construction, and other practices that allow bare earth to enter streams (The Nature Conservancy 2004, p. 13). Current laws do not adequately protect rayed bean and snuffbox habitat from nonpoint source pollution, as the laws to prevent sediment entering waterways are poorly enforced. Best management practices for sediment and erosion control are often recommended or required by local ordinances for construction projects; however, compliance, monitoring, and enforcement of these recommendations are often poorly implemented. Furthermore, there are currently no requirements within the scope of Federal environmental laws to specifically consider the rayed bean or snuffbox during Federal activities, or to ensure that Federal projects will not jeopardize their continued existence.

Point source discharges within the range of the rayed bean and snuffbox have been reduced since the inception of the Clean Water Act (33 U.S.C. 1251 *et seq.*), but this may not provide adequate protection for filter-feeding organisms that can be impacted by extremely low levels of contaminants (*see* Chemical Contaminants discussion under Factor A). There is no specific information on the sensitivity of the rayed bean and snuffbox to common industrial and municipal pollutants, and very little information on other freshwater mussels. Therefore, it appears that a lack of adequate research and data prevents existing regulations, such as the Clean Water Act (administered by the EPA and the U.S. Army Corps of Engineers), from being fully used or effective.

Despite these existing regulatory mechanisms, the rayed bean and snuffbox continue to decline due to the effects of habitat destruction, poor water quality, contaminants, and other factors. We find that these regulatory measures have been insufficient to significantly reduce or remove the threats to the rayed bean and snuffbox and, therefore, that the inadequacy of existing regulatory mechanisms is a threat to these species throughout all of their range.

Based on our analysis of the best available information, we have no reason to believe that the aforementioned regulations, which currently do not offer adequate protection to the rayed bean and snuffbox, will be improved in the foreseeable future.

E. Other Natural or Manmade Factors Affecting Its Continued Existence

Other factors have played a role in the decline of rayed bean and snuffbox populations. Reduced numbers of host fish have an indirect impact by contributing to reduced recruitment (Watters 1996, p. 83; Khym and Layzer 2000, p. 183). 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, p. 44). Remedial (such as flood control structures) and preventative (for example, more renewable energy from hydroelectric facilities to reduce greenhouse gas emissions) measures to address climate change issues (Hastie *et al.* 2003, p. 45) may impact rayed bean and snuffbox populations in the future.

Population Fragmentation and Isolation—The majority of the remaining populations of the rayed bean and snuffbox are generally small and geographically isolated. The patchy distributional pattern of populations in short river reaches makes them much more susceptible to extirpation from single catastrophic events, such as toxic chemical spills (Watters and Dunn 1993–94, p. 257). Furthermore, this level of isolation makes natural repopulation of any extirpated population unlikely without human intervention. Population isolation prohibits the natural interchange of genetic material between populations, and small population size reduces the reservoir of genetic diversity within populations, which can lead to inbreeding depression (Avise and Hambrick 1996, p. 461).

The Scioto River system provides a good example of the impacts of population fragmentation and isolation. Historically, the rayed bean and snuffbox were widespread and locally abundant in the mainstem and numerous tributaries. The Scioto River became highly contaminated over a century ago (Trautman 1981, p. 33; Yoder *et al.* 2005, p. 410), and these species eventually died out in the mainstem and most tributaries. The population segments that persist have become increasingly isolated due to impoundments and other factors; all are very small, highly fragmented, and appear to be on a trend towards extirpation.

Many rayed bean and snuffbox populations are potentially below the effective population size (EPS) required to maintain genetic heterogeneity and population viability (Soulé 1980, p. 162). Isolated populations eventually die out when population size drops below the EPS or threshold level of sustainability. Recruitment reduction or failure is a potential problem for many small rayed bean and snuffbox populations rangewide, a condition likely exacerbated by their reduced range and increasingly isolated populations. Evidence of recruitment has not been documented in many populations, indicating that recruitment reduction or outright failure is possible. Many populations of both species may be experiencing the bottleneck effect of not attaining EPS. Small, isolated, below EPS-threshold populations of short-lived species (most host fishes) theoretically die out within a decade or so, while below-threshold populations of long-lived species (like the rayed bean and snuffbox) might take decades to die out even given years of total recruitment failure.

We find that fragmentation and isolation of small remaining populations of the rayed bean and snuffbox are current and ongoing threats to both species throughout all of their range that will continue into the foreseeable future.

Exotic Species—Various exotic or nonnative species of aquatic organisms are firmly established in the range of the rayed bean and snuffbox. The exotic species that poses the most significant threat to the rayed bean and snuffbox is the zebra mussel (*Dreissena polymorpha*). The invasion of the zebra mussel poses a threat to the mussel fauna in many regions, and species extinctions are expected as a result of its continued spread in the eastern United States (Ricciardi *et al.* 1998, p. 616). Strayer (1999b, pp. 77–80) reviewed in detail the mechanisms by which zebra mussels impact native mussels. The primary means of impact is direct fouling of the shells of live native mussels. Zebra mussels attach in large numbers to the shells of live native mussels and are implicated in the loss of entire native mussel beds. Fouling impacts include impeding locomotion (both laterally and vertically), interfering with normal valve movements, deforming valve margins, and locally depleting food resources and increasing waste products. Heavy infestations of zebra mussels on native mussels may overly stress the animals by reducing their energy stores. They may also reduce food concentrations to levels too low to support reproduction, or even survival in extreme cases.

Another way zebra mussels may impact native mussels is through filtering their sperm and possibly glochidia from the water column, thus reducing reproductive potential. Habitat for native mussels may also be degraded by large deposits of zebra mussel pseudofeces (undigested waste material passed out of the incurrent siphon) (Vaughan 1997, p. 11). Additionally, an indirect impact is the proliferation of aquatic plants from increased water clarity in lakes, which in turn has prompted managers to increase the use of herbicides that may threaten mussels via food reduction (Marangelo 2005b, pers. comm.).

Zebra mussels are thoroughly established in the Great Lakes drainages and much of the Ohio River system, overlapping much of the current range of the rayed bean and snuffbox. Zebra mussels have eliminated populations of the rayed bean in Lakes Erie and Tippecanoe and the Detroit River. The greatest current potential for zebra mussels to impact the rayed bean and snuffbox are in the Lake St. Clair drainages, Allegheny River, Tippecanoe River, French Creek, and Lake Maxinkuckee. In addition, there is long-term potential for zebra mussel invasions into other systems that currently harbor rayed bean and snuffbox populations. However, zebra mussels are not always a serious threat to rayed bean and snuffbox (Tippecanoe River, Fisher 2005, pers. comm.; Clinton River, Butler 2007, p. 94; French Creek, Butler 2007, p. 94). Significant but highly fluctuating zebra mussel populations remain largely restricted to navigational waterways, although smaller streams have also had their mussel fauna virtually eliminated by them (Martel *et al.* 2001, p. 2188). At least two of the stronghold snuffbox populations (Wolf River and French Creek) presently have low numbers of zebra mussels.

The Asian clam (*Corbicula fluminea*) has spread throughout the range of the rayed bean and snuffbox since its introduction in the mid-1900s. Asian clams compete with native mussels, especially juveniles, for food, nutrients, and space (Neves and Widlak 1987, p. 6; Leff *et al.* 1990, p. 415) and may ingest sperm, glochidia, and newly metamorphosed juveniles of native mussels (Strayer 1999b, p. 82; Yeager *et al.* 2001, p. 257). Dense Asian clam populations actively disturb sediments that may reduce habitat for juvenile mussels (Strayer 1999b, p. 82).

Asian clam densities vary widely in the absence of native mussels or in patches with sparse mussel concentrations, but clam density is never high in dense mussel beds, indicating that the clam is unable to successfully invade small-scale habitat patches with high unionid biomass

(Vaughn and Spooner 2006, p. 335). The invading clam therefore appears to preferentially invade sites where mussels are already in decline (Strayer 1999b, p. 82; Vaughn and Spooner 2006, p. 332) and does not appear be a causative factor in the decline of mussels in dense beds. However, an Asian clam population that thrives in previously stressed, sparse mussel populations can exacerbate unionid imperilment through competition and impeding mussel population expansion (Vaughn and Spooner 2006, p. 335).

The round goby (*Neogobius melanostomus*) is another exotic fish species released into the Great Lakes that is well established and likely to spread through the Mississippi River system (Strayer 1999b, pp. 87–88). This species is an aggressive competitor of similar sized benthic fish (sculpins, darters) as well as a voracious carnivore despite its size (less than 10 in. (25.4 cm) in length), preying on a variety of foods, including small mussels and fishes that could serve as glochidial hosts (Strayer 1999b, p. 88; Janssen and Jude 2001, p. 325). Round gobies may therefore have indirect effects on the rayed bean and snuffbox through negative impacts to their host fishes.

Additional exotic species will invariably become established in the foreseeable future (Strayer 1999b, pp. 88–89). These include *Limnoperna fortunei,* a biofouling mussel (an animal that undesirably accumulates on wetted surfaces) from southeast Asia that has already spread to Japan and South America, and "probably will have strong effects" on native mussels (Strayer 1999b, p. 89). Exotic species could carry diseases and parasites that may be devastating to the native biota. Because of our ignorance of mollusk diseases and parasites, "it is imprudent to conclude that alien diseases and parasites are unimportant" (Strayer 1999b, p. 88).

Exotic species, such as those described above, are an ongoing threat to the rayed bean and snuffbox—a threat that is likely to increase as these exotic species expand their occupancy within the range of the rayed bean and snuffbox.

Summary of Threats

The decline of the rayed bean and snuffbox (described by Butler 2002, 2007) is primarily the result of habitat loss and degradation (Neves 1991, p. 252). These losses have been well documented since the mid-19th century (Higgins 1858, p. 551). Chief among the causes of decline are impoundments, channelization, chemical contaminants, mining, and sedimentation (Neves 1991, pp. 260–261; 1993, p. 4–5; Williams *et al.* 1993, p. 7; Neves *et al.* 1997, pp. 60–72; Watters 2000, p. 269). These stressors have had profound impacts on rayed bean and snuffbox populations and their habitat.

The majority of the remaining populations of the rayed bean and snuffbox are generally small and geographically isolated (Butler 2002, 2007). The patchy distributional pattern of populations in short river reaches makes those populations much more susceptible to extirpation from single catastrophic events, such as toxic chemical spills (Watters and Dunn 1993–94, p. 257). Furthermore, this level of isolation makes natural repopulation of any extirpated population virtually impossible without human intervention. Various nonnative species of aquatic organisms are firmly established in the range of the rayed bean and snuffbox; however, the exotic species that poses the most significant threat to the rayed bean and snuffbox is the zebra mussel (*Dreissena polymorpha*) (Butler 2002, p. 27; 2007, p. 93).

Proposed Determination

Section 3 of the Act defines an endangered species as any species that is "in danger of extinction throughout all or a significant portion of its range" and a threatened species as any species that "is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." We find that the rayed bean and snuffbox are presently in danger of extinction throughout their entire range, based on the immediacy, severity, and scope of the threats described above. 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, on the basis of the best available scientific and commercial information, we propose listing the rayed bean and snuffbox as endangered in accordance with sections 3(6) and 4(a)(1) of the Act.

Under the Act and our implementing regulations, a species may warrant listing if it is endangered or threatened throughout all or a significant portion of its range. Threats to the rayed bean and snuffbox occur throughout their range. Therefore, we assessed the status of the species throughout their entire range. The threats to the survival of the species occur throughout the species' ranges and are not restricted to any particular significant portion of those ranges. Accordingly, our assessment and proposed determination applies to the species throughout their entire range.

Available Conservation Measures

Conservation measures provided to species listed as endangered or threatened under the Act include recognition, recovery actions, requirements for Federal protection, and prohibitions against certain practices. Recognition through listing results in public awareness and conservation by Federal, State, Tribal, and local agencies, private organizations, and individuals. The Act encourages cooperation with the States and requires that recovery actions be carried out for all listed species. The protection required by Federal agencies and the prohibitions against certain activities are discussed, in part, below.

The primary purpose of the Act is the conservation of endangered and threatened species and the ecosystems upon which they depend. The ultimate goal of such conservation efforts is the recovery of these listed species, so that they no longer need the protective measures of the Act. Subsection 4(f) of the Act requires the Service to develop and implement recovery plans for the conservation of endangered and threatened species. The recovery planning process involves the identification of actions that are necessary to halt or reverse the species' decline by addressing the threats to its survival and recovery. The goal of this process is to restore listed species to a point where they are secure, self-sustaining, and functioning components of their ecosystems.

Recovery planning includes the development of a recovery outline shortly after a species is listed, preparation of a draft and final recovery plan, and revisions to the plan as significant new information becomes available. The recovery outline guides the immediate implementation of urgent recovery actions and describes the process to be used to develop a recovery plan. The recovery plan identifies site-specific management actions that will achieve recovery of the species, measurable criteria that determine when a species may be downlisted or delisted, and methods for monitoring recovery progress. Recovery plans also establish a framework for agencies to coordinate their recovery efforts and provide estimates of the cost of implementing recovery tasks. Recovery teams (comprised of species experts, Federal and State agencies, non-government organizations, and stakeholders) are often established to develop recovery plans. When completed, the recovery outline, draft recovery plan, and the final recovery plan will be available on our Web site (*http://www.fws.gov/endangered*), or from our Ohio Ecological Services Field Office (*see* **FOR FURTHER INFORMATION CONTACT**).

Implementation of recovery actions generally requires the participation of a broad range of partners, including other Federal agencies, States, Tribal, non-governmental organizations, businesses, and private landowners. Examples of recovery actions include habitat restoration (*e.g.,* restoration of native vegetation), research, captive propagation and reintroduction, and outreach and education. The recovery of many listed species cannot be accomplished solely on Federal lands because their range may occur primarily or solely on non-Federal lands. To achieve recovery of these species requires cooperative conservation efforts on private, State, and Tribal lands.

If this species is listed, funding for recovery actions will be available from a variety of sources, including Federal budgets, State programs, and cost share grants for non-Federal landowners, the academic community, and nongovernmental organizations. Additionally, under section 6 of the Act, we would be able to grant funds to the States of Illinois, Indiana, Kentucky, Michigan, New York, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia for management actions promoting the conservation of the rayed bean and to the States of Alabama, Arkansas, Illinois, Indiana, Iowa, Kansas, Kentucky, Michigan, Minnesota, Mississippi, Missouri, New York, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia, and Wisconsin for the conservation of the snuffbox. Information on our grant programs that are available to aid species recovery can be found at: *http://www.fws.gov/grants.*

Although the rayed bean and snuffbox are only proposed for listing under the Act at this time, please let us know if you are interested in participating in recovery efforts for these species. Additionally, we invite you to submit any new information on these species whenever it becomes available and any information you may have for recovery planning purposes; if you submit information after the date listed in the **DATES** section above, you will need to send it to the street address provided in the **FOR FURTHER INFORMATION CONTACT** section.

Section 7(a) of the Act requires Federal agencies to evaluate their actions with respect to any species that is proposed or listed as endangered or threatened and with respect to its critical habitat, if any is being designated. Regulations implementing this interagency cooperation provision of the Act are codified at 50 CFR part 402. Section 7(a)(4) requires Federal agencies to confer informally with us on any action that is likely to jeopardize the continued existence of a proposed species or result in destruction or adverse modification of proposed critical habitat. If a species is listed subsequently, section 7(a)(2) of the Act requires Federal agencies to ensure that activities they authorize, fund, or carry out are not likely to jeopardize the continued existence of such a species or to destroy or adversely modify its critical habitat. If a Federal action may affect a listed species or its critical habitat, the responsible Federal agency must enter into formal consultation with us.

Federal agency actions that may require conference or consultation as described in the preceding paragraph include the issuance of permits for reservoir construction, stream alterations, wastewater facility development, water withdrawal projects, pesticide registration, agricultural assistance programs, mining, road and bridge construction, and Federal loan programs. Activities will trigger consultation under section 7 of the Act if they may affect the rayed bean or snuffbox, or both species, addressed in this proposed rule.

Jeopardy Standard

Prior to and following listing and designation of critical habitat, if prudent and determinable, the Service applies an analytical framework for jeopardy analyses that relies heavily on the importance of core area populations to the survival and recovery of the species. The section 7(a)(2) analysis is focused not only on these populations but also on the habitat conditions necessary to support them.

The jeopardy analysis usually expresses the survival and recovery needs of the species in a qualitative fashion without making distinctions between what is necessary for survival and what is necessary for recovery. Generally, if a proposed Federal action is incompatible with the viability of the affected core area populations(s), inclusive of associated habitat conditions, a jeopardy finding is considered to be warranted, because of the relationship of each core area population to the survival and recovery of the species as a whole.

Section 9 Take

The Act and implementing regulations set forth a series of general prohibitions and exceptions that apply to all endangered and threatened wildlife. If we finalize listing of the rayed bean and snuffbox, these prohibitions would be applicable to the rayed bean and snuffbox. The prohibitions of section 9(a)(2) of the Act, codified at 50 CFR 17.21 for endangered wildlife, in part, make it illegal for any person subject to the jurisdiction of the United States to take (includes harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt any of these), import or export, deliver, receive, carry, transport, or ship in interstate or foreign commerce in the course of commercial activity, or sell or offer for sale in interstate or foreign commerce any listed species. It also is illegal to possess, sell, deliver, carry, transport, or ship any such wildlife that has been taken illegally. Further, it is illegal for any person to attempt to commit, to solicit another person to commit, or to cause to be committed, any of these acts. Certain exceptions apply to our agents and State conservation agencies.

We may issue permits to carry out otherwise prohibited activities involving endangered wildlife under certain circumstances. We codified the regulations governing permits for endangered species at 50 CFR 17.22. Such permits are available for scientific purposes, to enhance the propagation or survival of the species, or for incidental take in the course of otherwise lawful activities.

It is our policy, published in the **Federal Register** on July 1, 1994 (59 FR 34272), to identify, to the maximum extent practicable at the time a species is listed, those activities that would or would not constitute a violation of section 9 of the Act and associated regulations at 50 CFR 17.21. The intent of this policy is to increase public awareness of the effect of this proposed listing on proposed and ongoing activities within a species' range. We believe, based on the best available information, that the following actions will not result in a violation of the provisions of section 9 of the Act, provided these actions are carried out in accordance with existing regulations and permit requirements:

(1) Activities authorized, funded, or carried out by Federal agencies (*e.g.,* bridge and highway construction, pipeline construction, hydropower licensing, *etc.*), when such activities are conducted in accordance with the consultation and planning requirements for listed species under section 7 of the Act.

(2) Any action carried out for scientific research or to enhance the propagation or survival of the rayed bean or snuffbox that is conducted in

accordance with the conditions of a 50 CFR 17.22 permit.

(3) Any incidental take of rayed bean or snuffbox resulting from an otherwise lawful activity conducted in accordance with the conditions of an incidental take permit issued under 50 CFR 17.22. Non-Federal applicants may design a habitat conservation plan (HCP) for the species and apply for an incidental take permit. HCPs may be developed for listed species and are designed to minimize and mitigate impacts to the species to the greatest extent practicable.

We believe the following activities would be likely to result in a violation of section 9 of the Act; however, possible violations are not limited to these actions alone:

(1) Unauthorized killing, collecting, handling, or harassing of individual rayed bean or snuffbox, or both species, at any life stage.

(2) Sale or offer for sale of rayed bean or snuffbox in addition to delivering, receiving, carrying, transporting, or shipping in interstate or foreign commerce any rayed bean or snuffbox.

(3) Unauthorized destruction or alteration of the species' habitat (instream dredging, channelization, impoundment, streambank clearing, discharge of fill material) that actually kills or injures individual rayed bean or snuffbox by significantly impairing their essential behavioral patterns, including breeding, feeding, or sheltering.

(4) Violation of any discharge or water withdrawal permit within these species' occupied ranges that results in the death or injury of individual rayed bean or snuffbox by significantly impairing their essential behavioral patterns, including breeding, feeding, or sheltering.

(5) Discharge or dumping of toxic chemicals or other pollutants into waters supporting the species that actually kills or injures individual rayed bean or snuffbox by significantly impairing their essential behavioral patterns, including breeding, feeding, or sheltering.

We will review other activities not identified above on a case-by-case basis to determine whether they may be likely to result in a violation of section 9 of the Act. We do not consider these lists to be exhaustive, and provide them as information to the public.

You should direct questions regarding whether specific activities may constitute a future violation of section 9 of the Act to the Field Supervisor of the Service's Ohio Ecological Services Field Office (*see* **FOR FURTHER INFORMATION CONTACT** section). Requests for copies of regulations regarding listed species and inquiries about prohibitions and permits should be addressed to the U.S. Fish and Wildlife Service, Ecological Services Division, Henry Whipple Federal Building, 1 Federal Drive, Fort Snelling, MN 55111 (Phone 612–713–5350; Fax 612–713–5292).

Critical Habitat

Background

Critical habitat is defined in section 3 of the Act as:

(i) The specific areas within the geographical area occupied by a species, at the time it is listed in accordance with the Act, on which are found those physical or biological features

(I) Essential to the conservation of the species and

(II) That may require special management considerations or protection; and

(ii) Specific areas outside the geographical area occupied by a species at the time it is listed, upon a determination that such areas are essential for the conservation of the species.

"Conservation" is defined in section 3 of the Act as meaning the use of all methods and procedures needed to bring the species to the point at which listing under the Act is no longer necessary.

Critical habitat receives protection under section 7 of the Act through the prohibition against Federal agencies carrying out, funding, or authorizing the destruction or adverse modification of critical habitat. Section 7(a)(2) requires consultation on Federal actions that may affect critical habitat. The designation of critical habitat does not affect land ownership or establish a refuge, wilderness, reserve, preserve, or other conservation area. Such designation does not allow the government or public to access private lands. Such designation does not require implementation of restoration, recovery, or enhancement measures by non-Federal landowners. Where a landowner seeks or requests Federal agency funding or authorization for an action that may affect a listed species or critical habitat, the consultation requirements of section 7(a)(2) of the Act would apply, but even in the event of a destruction or adverse modification finding, Federal action agency's and the applicant's obligation is not to restore or recover the species, but to implement reasonable and prudent alternatives to avoid destruction or adverse modification of critical habitat.

For inclusion in a critical habitat designation, the habitat within the geographical area occupied by the species at the time it was listed must contain the physical and biological features essential to the conservation of the species, and be included only if those features may require special management considerations or protection. Critical habitat designations identify, to the extent known using the best scientific and commercial data available, habitat areas that provide essential life cycle needs of the species (areas on which are found the physical and biological features (PBFs) laid out in the appropriate quantity and spatial arrangement for the conservation of the species). Under the Act and regulations at 50 CFR 424.12, we can designate critical habitat in areas outside the geographical area occupied by the species at the time it is listed only when we determine that those areas are essential for the conservation of the species and that designation limited to those areas occupied at the time of listing would be inadequate to ensure the conservation of the species.

Section 4 of the Act requires that we designate critical habitat on the basis of the best scientific and commercial data available. Further, our Policy on Information Standards Under the Endangered Species Act (published in the **Federal Register** on July 1, 1994 (59 FR 34271)), the Information Quality Act (section 515 of the Treasury and General Government Appropriations Act for Fiscal Year 2001 (Pub. L. 106–554; H.R. 5658)), and our associated Information Quality Guidelines, provide criteria, establish procedures, and provide guidance to ensure that our decisions are based on the best scientific data available. They require our biologists, to the extent consistent with the Act and with the use of the best scientific data available, to use primary and original sources of information as the basis for recommendations to designate critical habitat.

When we are determining which areas should be designated as critical habitat, our primary source of information is generally the information developed during the listing process for the species. Additional information sources may include the recovery plan for the species, articles in peer-reviewed journals, conservation plans developed by States and counties, scientific status surveys and studies, biological assessments, or other unpublished materials and expert opinion or personal knowledge.

Habitat is often dynamic, and species may move from one area to another over time. Furthermore, we recognize that critical habitat designated at a particular point in time may not include all of the habitat areas that we may later determine are necessary for the recovery of the species. For these reasons, a critical habitat designation does not signal that habitat outside the designated area is unimportant or may not be required for recovery of the species.

Areas that are important to the conservation of the species, but are outside the critical habitat designation, will continue to be subject to conservation actions we implement under section 7(a)(1) of the Act. Areas that support populations are also subject to the regulatory protections afforded by the section 7(a)(2) jeopardy standard, as determined on the basis of the best available scientific information at the time of the agency action. Federally funded or permitted projects affecting listed species outside their designated critical habitat areas may still result in jeopardy findings in some cases. Similarly, critical habitat designations made on the basis of the best available information at the time of designation will not control the direction and substance of future recovery plans, habitat conservation plans (HCPs), or other species conservation planning efforts if new information available at the time of these planning efforts calls for a different outcome.

Prudency Determination

Section 4(a)(3) of the Act, as amended, and implementing regulations (50 CFR 424.12), require that, to the maximum extent prudent and determinable, we designate critical habitat at the time we determine that a species is endangered or threatened. Our regulations (50 CFR 424.12(a)(1)) state that the designation of critical habitat is not prudent when one or both of the following situations exist: (1) The species is threatened by taking or other human activity, and identification of critical habitat can be expected to increase the degree of threat to the species, or (2) such designation of critical habitat would not be beneficial to the species.

There is currently no imminent threat of take attributed to collection or vandalism under Factor B (overutilization for commercial, recreational, scientific, or educational purposes) for the rayed bean or snuffbox, and identification of critical habitat is not expected to initiate such a threat. In the absence of finding that the designation of critical habitat would increase threats to a species, if there are any benefits to a critical habitat designation, then a prudent finding is warranted. The potential benefits include: (1) Triggering consultation under section 7(a)(2) of the Act, in new areas for actions in which there may be a Federal nexus where it would not otherwise occur because the species may not be present; (2) focusing conservation activities on the most essential habitat features and areas; (3) increasing awareness of important habitat areas among State or county governments, or private entities; and (4) preventing inadvertent harm to the species.

Critical habitat designation includes the identification of the physical and biological features of the habitat essential to the conservation of each species that may require special management and protection. As such, these designations will provide useful information to individuals, local and State governments, and other entities engaged in activities or long-range planning that may affect areas essential to the conservation of the species. Conservation of the rayed bean and snuffbox and essential features of their habitats will require habitat management, protection, and restoration, which will be facilitated by disseminating information on the locations and the key physical and biological features of those habitats. In the case of the rayed bean and snuffbox, these aspects of critical habitat designation would potentially benefit the conservation of the species. Therefore, since we have determined that the designation of critical habitat will not likely increase the degree of threat to these species and may provide some measure of benefit, we find that designation of critical habitat is prudent for the rayed bean and snuffbox.

Critical Habitat Determinability

As stated above, section 4(a)(3) of the Act requires the designation of critical habitat concurrently with the species' listing "to the maximum extent prudent and determinable." Our regulations at 50 CFR 424.12(a)(2) state that critical habitat is not determinable when one or both of the following situations exist:

(i) Information sufficient to perform required analyses of the impacts of the designation is lacking, or

(ii) The biological needs of the species are not sufficiently well known to permit identification of an area as critical habitat.

When critical habitat is not determinable, the Act provides for an additional year to publish a critical habitat designation (16 U.S.C. 1533(b)(6)(C)(ii)).

In accordance with sections 3(5)(A)(i) and 4(b)(1)(A) of the Act and regulations at 50 CFR 424.12, in determining which areas to propose as critical habitat, we must consider those physical and biological features essential to the conservation of the species. These include, but are not limited to:

(1) Space for individual and population growth and for normal behavior;

(2) Food, water, air, light, minerals, or other nutritional or physiological requirements;

(3) Cover or shelter;

(4) Sites for breeding, reproduction, and rearing (or development) of offspring; and

(5) Habitats that are protected from disturbance or are representative of the historical, geographical, and ecological distribution of a species.

We are currently unable to identify the physical and biological features essential for the conservation of the rayed bean and snuffbox because information on those features for these species is not known at this time. The apparent poor viability of the species' occurrences observed in recent years indicates that current conditions are not sufficient to meet the basic biological requirements of these species in many rivers. Since the rayed bean and snuffbox have not been observed for decades in many of their historical locations, and much of the habitat in which they still persist has been drastically altered, the optimal conditions that would provide the biological or ecological requisites of these species are not known. Although we can surmise that habitat degradation from a variety of factors has contributed to the decline of these species, we do not know specifically what essential physical or biological features of that habitat are currently lacking for the rayed bean and snuffbox.

Key features of the basic life history, ecology, reproductive biology, and habitat requirements of most mussels, including the rayed bean and snuffbox, are unknown. Species-specific ecological requirements have not been determined (for example, minimum water flow and effects of particular pollutants). Population dynamics, such as species' interactions and community structure, population trends, and population size and age class structure necessary to maintain long-term viability, have not been determined for these species. Of particular concern to both species is that many of the remaining rayed bean and snuffbox populations consist of very low densities, which limit our ability to investigate their population dynamics. Basics of reproductive biology for these species are unknown, such as age and size at earliest maturity, reproductive longevity, and the level of recruitment needed for species' survival and long-term viability. As we are unable to identify many physical and biological features essential to the conservation of the rayed bean and snuffbox, we are unable to identify areas that contain these features. Therefore, although we have determined that the designation of critical habitat is prudent for the rayed bean and snuffbox, because the biological and physical requirements of these species are not sufficiently known, we find that critical habitat for the rayed bean and snuffbox is not determinable at this time.

Peer Review

In accordance with our policy, "Notice of Interagency Cooperative Policy for Peer Review in Endangered Species Act Activities," that was published on July 1, 1994 (59 FR 34270), we will seek the expert opinion of at least three appropriate independent specialists regarding this proposed rule. The purpose of such review is to ensure listing decisions are based on scientifically sound data, assumptions, and analysis. We will send copies of this proposed rule to the peer reviewers immediately following publication in the **Federal Register**. We will invite these peer reviewers to comment, during the public comment period, on the specific assumptions and the data that are the basis for our conclusions regarding the proposal to list rayed bean and snuffbox as endangered and our proposal regarding critical habitat for this species.

We will consider all comments and information we receive during the comment period on this proposed rule during preparation of a final rulemaking. Accordingly, our final decision may differ from this proposal.

Public Hearings

The Act provides for one or more public hearings on this proposal, if requested. Requests must be received within 45 days after the date of publication of this proposal in the **Federal Register** (*see* **DATES**). Such requests must be sent to the address shown in the **FOR FURTHER INFORMATION CONTACT** section. We will schedule public hearings on this proposal, if any are requested, and announce the dates, times, and places of those hearings, as well as how to obtain reasonable accommodation, in the **Federal Register** and local newspapers at least 15 days before the hearing.

Persons needing reasonable accommodation to attend and participate in a public hearing should contact the Ohio Ecological Services Field Office at 614–416–8993, ext. 22, as soon as possible. To allow sufficient time to process requests, please call no later than one week before the hearing date. Information regarding this proposed rule is available in alternative formats upon request.

Required Determinations

Clarity of Rule

We are required by Executive Orders 12866 and 12988 and by the Presidential Memorandum of June 1, 1998, to write all rules in plain language. This means that each rule we publish must:

(a) Be logically organized;

(b) Use the active voice to address readers directly;

(c) Use clear language rather than jargon;

(d) Be divided into short sections and sentences; and

(e) Use lists and tables wherever possible.

If you feel that we have not met these requirements, send us comments by one of the methods listed in the **ADDRESSES** section. To better help us revise the rule, your comments should be as specific as possible. For example, you should tell us the names of the sections or paragraphs that are unclearly written, which sections or sentences are too long, the sections where you feel lists or tables would be useful, etc.

Paperwork Reduction Act (44 U.S.C. 3501, et seq.)

This proposed rule does not contain any new collections of information that require approval by the Office of Management and Budget (OMB) under the Paperwork Reduction Act. This rule will not impose new recordkeeping or reporting requirements on State or local governments, individuals, businesses, or organizations. We may not conduct or sponsor and you are not required to respond to a collection of information unless it displays a currently valid OMB control number.

National Environmental Policy Act (42 U.S.C. 4321 et seq.)

We have determined that we do not need to prepare an environmental assessment, as defined under the authority of the National Environmental Policy Act of 1969, in connection with regulations adopted under section 4(a) of the Act. We published a notice outlining our reasons for this determination in the **Federal Register** on October 25, 1983 (48 FR 49244).

References Cited

A complete list of all references cited in this proposed rule is available on the Internet at *http://www.regulations.gov* or upon request from the Field Supervisor, Ohio Ecological Services Field Office (*see* **FOR FURTHER INFORMATION CONTACT** section).

Author

The primary author of this proposed rule is Angela Boyer of the Ohio Ecological Services Field Office (*see* **FOR FURTHER INFORMATION CONTACT** section).

List of Subjects in 50 CFR Part 17

Endangered and threatened species, Exports, Imports, Reporting and recordkeeping requirements, Transportation.

Proposed Regulation Promulgation

Accordingly, we propose to amend part 17, subchapter B of chapter I, title 50 of the Code of Federal Regulations, as follows:

PART 17—[AMENDED]

1. The authority citation for part 17 continues to read as follows:

Authority: 16 U.S.C. 1361–1407; 16 U.S.C. 1531–1544; 16 U.S.C. 4201–4245; Pub. L. 99–625, 100 Stat. 3500; unless otherwise noted.

2. Amend § 17.11(h) by adding new entries for "Mussel, rayed bean" and "Mussel, snuffbox" in alphabetical order under CLAMS to the List of Endangered and Threatened Wildlife as follows:

§ 17.11 Endangered and threatened wildlife.

* * * * *

Species		Historic range	Vertebrate population where endangered or threatened	Status	When listed	Critical habitat	Special rules
Common name	Scientific name						
*	*	*	*	*	*	*	

Species		Historic range	Vertebrate population where endangered or threatened	Status	When listed	Critical habitat	Special rules
Common name	Scientific name						
CLAMS							
*	*	*	*	*	*	*	
Mussel, rayed bean	*Villosa fabalis*	U.S.A. (IL, IN, KY, MI, NY, OH, PA, TN, VA, WV, WI).	NA	E	....	NA	NA
*	*	*	*	*	*	*	
Mussel, snuffbox	*Epioblasma triquetra*	U.S.A. (AL, AR, IL, IN, IA, KS, KY, MI, MN, MS, MO, NY, OH, PA, TN, VA, WV, WI).	NA	E	....	NA	NA
*	*	*	*	*	*	*	

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Dated: October 15, 2010.

Gary D. Frazer,

Acting Director, U.S. Fish and Wildlife Service.

[FR Doc. 2010–27413 Filed 11–1–10; 8:45 am]

BILLING CODE 4310–55–P