

**Appalachian Monkeyface**  
***Quadrula sparsa* (Lea, 1841)**

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



Photo by Tim Lane, Virginia Department of Wildlife Resources

**U.S. Fish and Wildlife Service**  
**Southwestern Virginia Field Office**  
**Abingdon, Virginia**

**August 2020**

**5-YEAR REVIEW**  
**Appalachian Monkeyface/*Quadrula sparsa***

**1.0 GENERAL INFORMATION**

**1.1 Reviewers**

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**1.2 Methodology used to complete the review:** This review was completed internally by a U.S. Fish and Wildlife Service (Service) biologist located in the Southwestern Virginia Field Office (SVFO). A notice announcing initiation of the review and a request for information was published in the Federal Register on 9/4/2019. Subsequently, the SVFO biologist solicited new or updated information on *Quadrula sparsa* from partners and agencies and compiled the responses and information submitted. Information from the solicitation was combined with published literature, reports, and internal files. All pertinent literature and documents on file at SVFO were used for this review. All literature and documents used for this 5-year review are on file at SVFO and are cited below in the References section.

**1.3 Background**

**1.3.1 FR Notice citation announcing initiation of this review:** 84 FR 46562-46563; 09/04/2019.

### 1.3.2 Listing history

#### Original Listing

**FR notice:** 41 FR 24062-24067

**Date listed:** 06/14/1976

**Entity listed:** Species

**Classification:** Endangered

**1.3.3 Associated rulemakings:** Establishment of Nonessential Experimental Population Status for 15 Freshwater Mussels, 1 Freshwater Snail, and 5 Fishes in the Lower French Broad River and in the Lower Holston River, Tennessee; 72 FR 52433-52461

Effective date: October 15, 2007

**1.3.4 Review History:** In 2008, initiation of a 5-year review was announced (73 FR 76373-76375) and a draft document was prepared in 2010 (Service 2010), but it was not finalized.

**1.3.5 Species' Recovery Priority Number at start of 5-year review:** 5. This designation is based on the high degree of threat, low recovery potential, and taxonomic standing as a species.

### 1.3.6 Recovery Plan or Outline

**Name of plan or outline:** Recovery Plan for the Appalachian Monkeyface Pearly Mussel, *Quadrula sparsa* (Lea, 1841)

**Date issued:** 07/09/1984

## 2.0 REVIEW ANALYSIS

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

**2.1.1 Is the species under review a vertebrate?** The Appalachian Monkeyface is an invertebrate; therefore, it is not covered by the DPS policy.

### 2.2 Recovery Criteria

**2.2.1 Does the species have a final, approved recovery plan containing objective, measurable criteria?** Yes.

## 2.2.2 Adequacy of recovery criteria.

**2.2.2.1 Do the recovery criteria reflect the best available and most up-to date information on the biology of the species and its habitat? Yes.**

**2.2.2.2 Are all of the 5 listing factors that are relevant to the species addressed in the recovery criteria (and is there no new information to consider regarding existing or new threats)? No.**

## 2.2.3 List the recovery criteria as they appear in the recovery plan, and discuss how each criterion has or has not been met, citing information:

The 1984 recovery plan does not consider reclassification. The objective and criteria are for delisting. These criteria are listed below.

- 1) A viable population of *Q. sparsa* exists in the Powell River from the backwaters of Norris Reservoir upstream to approximately PRM [Powell River Miles] 130, and in the Clinch River from the backwaters of Norris Reservoir upstream to St. Paul, Virginia (CRM [Clinch River Miles] 256). These two populations are dispersed throughout each river so that it is unlikely that any one event would cause the total loss of either population.

This criterion has not been met. The remaining Powell River population is considered declining, and live individuals are rarely found. Because the Powell River population is limited geographically (approximately 46 river miles), it remains highly vulnerable to any event that may occur. The Clinch River population has likely been extirpated.

The Service funded a 2-year comprehensive survey of the Powell River, initiated in 2008, to determine the status of the mussel fauna, particularly the Appalachian Monkeyface and the Cumberland Monkeyface (*Quadrula intermedia*) (Johnson et al. 2010). The survey, which utilized random timed searches, systematic searches, and quadrat sampling over 21 sites, detected 16 live individuals of Appalachian Monkeyface among 7 survey sites between the Bar below Brooks Bridge (PRM 152.6) and Sewell Bridge (PRM 230.9) (Johnson et al. 2012). One young individual Appalachian Monkeyface found at Brooks Bridge was estimated to be 5 to 7 years old, representing some level of recruitment occurring within the last decade (Johnson et al. 2012); however there has been no observed increase in population density or area of occurrence, indicating that the long-term viability of this species in the Powell River is improbable.

Except for one live individual found in the Clinch River at Cleveland Island in 2002 (Eckert and Pinder 2010), no live individuals have been found in the Clinch River since 1983. A comprehensive survey was repeated at the Cleveland Island site in 2008 and no live Appalachian Monkeyface were found (Eckert and Pinder 2010). If there are individuals remaining in the Clinch River, the population is likely not viable and considered functionally extirpated.

- 2) Through reestablishments and/or discoveries of new populations, viable populations exist in one additional river. This river will contain a viable population that is distributed such that a single event would be unlikely to eliminate *Q. sparsa* from the river.

This criterion has not been met. No new populations of this species have been found and no historical populations have been reestablished.

The Virginia Department of Wildlife Resources' (VDWR) Aquatic Wildlife Conservation Center (AWCC) is currently working to evaluate host fish suitability and identify suitable methods for holding and caring for this species in captivity over an extended time period, which will provide valuable information on culture techniques as well as captive care protocols. If successful, this may enable reestablishment of new populations in an additional river.

- 3) The species and its habitat are protected from present and foreseeable human-related and natural threats that may interfere with the survival of any of the populations.

This criterion has not been met. The threats as described in the recovery plan for the Appalachian Monkeyface have not been abated. This recovery criterion is addressed by Factors A and D of the listing factors. The decline of this species is primarily due to anthropogenic causes, such as impoundments, channelization, pollution, sedimentation, development, and other factors. The species and its habitats continue to be impacted by excessive sediment, nutrients, and pollution primarily resulting from nonpoint-source loading from land-use practices. Other impacts include the extraction and processing of coal. The species' restricted range and low population levels increase its vulnerability to stochastic events and the deleterious effects of genetic isolation.

- 4) Noticeable improvements in coal-related problems and substrate quality have occurred in the Powell River, and no increase in coal-related siltation occurs in the Clinch River.

This criterion has not been met. This recovery criterion is addressed by Factors A and D of the listing factors. Although there have been some improvements since the recovery plan was finalized, coal-related problems and poor substrate quality still exist in the Powell River. Coal extraction and processing continue to negatively impact the Powell and Clinch River watersheds, and pre-Surface Mining Control and Reclamation Act (SMCRA) mine features continue to contribute to poor water quality and effects to aquatic organisms.

### **2.3 Updated Information and Current Species Status**

A prior 5-year status review has not been completed for this species. One was drafted in 2010, but not finalized (Service 2010). New information from research, surveys, and observations available to the Service since the Recovery Plan (Service 1984) was developed is included below.

### **2.3.1 Biology and Habitat**

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

During host fish trials for this species at the AWCC, Appalachian Monkeyface were documented to have a mantle lure that mimics their conglutinate. Lane (T. Lane, VDWR, email to R. Agbalog, Service, May 8, 2020) suggested that they may 'chum' the water earlier in the brooding period with unfertilized conglutinates to habituate fish to feed on the conglutinates. When the mussels brood and if the mantle lure is made visible, small disturbances can trigger the glochidia to be released as a cloud, instead of the formed conglutinates. It has been noted that brooding females are extremely sensitive to stimuli during this time.

At AWCC Appalachian Monkeyface females have brooded at least twice in the same year. The fecundity for 1 brood averaged 2,000-3,000 viable glochidia, and for 1 female the second brood was 15,000 viable glochidia. The mean length and height of glochidium was 177 micrometers ( $\mu\text{m}$ ) (standard deviation [SD] 5.4), and 191  $\mu\text{m}$  (SD 7.01), respectively (T. Lane, VDWR, email to R. Agbalog, Service, May 19, 2020). According to Heard and Guckert (1970), spawning in *Quadrula* was presumed to occur from May to July, based on reproductive patterns noted in congeners. In a more recent study looking at mantle displays and glochidia release behaviors in 5 quadrunline species, Sietnan et al. (2012) found that *Quadrula metanevra* displayed for about 3 months within 1 year, from mid-April to late July, when daily water temperature ranged from 13.9 to 24.6 °C. Lane (T. Lane, VDWR, email to R. Agbalog, Service, May 8, 2020) obtained viable glochidia from captive Appalachian Monkeyface females in early April, which was earlier than expected. Early brooding may have been triggered by warmer conditions in January and February, although the Cumberland Monkeyface in the trials were noted to brood later in May and June. Lane indicated that the early brooding could be a function of the species' ability to brood more than once in a year.

Host fish are currently unknown for this species, but cyprinids and ictalurids are suspected to be suitable hosts. The AWCC is performing host fish testing trials for Appalachian Monkeyface, although results to date have been inconclusive (Lane et al. 2019).

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

**trends:** The recovery plan summarized the documented occurrences of this species prior to 1984. In the recovery plan, the Appalachian Monkeyface was considered extremely rare in the Powell and Clinch Rivers, which harbored the last remaining populations of this species. Occurrence records of this species through the 1970s and early 1980s were represented by a few live or fresh dead specimens during any given sampling event (Service 1984). The most recent occurrence record presented in the recovery plan was a survey conducted in the Powell River in 1981 by Tennessee Valley Authority (TVA) biologists at McDowell Ford (PRM 106.6). This effort detected 6 live specimens of the Appalachian Monkeyface.

During a 2-year survey effort in the Powell River from 2008 to 2010, Johnson et al. (2012) detected 16 live individuals of Appalachian Monkeyface among 7 survey sites (out of 21 total sites), between the Bar below Brooks Bridge (PRM 152.6) and Sewell Bridge (PRM 230.9). One young individual found at Brooks Bridge was estimated to be 5 to 7 years old, indicating some level of recruitment within the last decade. In 2018, Phipps et al. (2018) resurveyed the McDowell Ford site and detected 1 live Appalachian Monkeyface. They estimated that the species occurred at a density of 0.01/meter<sup>2</sup> (m) at that site. During surveys to collect Appalachian Monkeyface for a host fish study, the Virginia Department of Game and Inland Fisheries (now the VDWR) found 5 individuals at 8 sites between May 2018 and May 2019, representing 78 person/hours (Lane et al. 2019). Mussel surveys in the Powell River have documented variable low densities of the Appalachian Monkeyface at several sites indicating low abundance, sporadic occurrence, and persistent vulnerability to extirpation (Johnson et al. 2010, Ahlstedt et al. 2016). Appalachian Monkeyface are extremely rare in the Powell River and have likely declined from pre-1984 levels. Redundancy and resiliency remain low.

From 1978 to 1983, Ahlstedt (1991) surveyed 204 sites on the Clinch River and detected 2 live Appalachian Monkeyface. One was found near Grays Island, Scott County, VA, and 1 below the Benges Creek confluence, Scott County, VA. Except for 1 live individual found in the Clinch River at Cleveland Island in 2002 (Eckert and Pinder 2010), no live individuals have been found in the Clinch River since Ahlstedt's survey, despite numerous quantitative and qualitative surveys throughout the Clinch River. A comprehensive survey was repeated at the Cleveland Island site in 2008 and no live Appalachian Monkeyface were found (Eckert and Pinder 2010). If there are individuals remaining in the Clinch River, the population is likely not viable and considered functionally extirpated.

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

information on the genetic status of the Appalachian Monkeyface is available. Based on mitochondrial ND1 sequences, Serb et al. (2003) maintain Cumberland Monkeyface and Appalachian Monkeyface as separate phylogenetic species, although the sample size was very low with 3 and 2 animals, respectively.

According to Soulé (1980), it is likely that small and geographically isolated populations are below their effective population size or the level required to preserve long-term genetic viability. There have been no observed increases in population density or area of occurrence, indicating that the representation of this species is low and long-term viability is improbable.

**2.3.1.4 Taxonomic classification or changes in nomenclature:** There have been no changes in the classification of this species since it was listed. Cummings and Graf (2010) conducted a taxonomic review and recommended resurrection of the genus name *Theliderma*, which was later accepted (Williams et al. 2017). All species formerly under the genus *Quadrula* either remain in *Quadrula*, or are now under *Theliderma* or *Cyclonaias*.

**2.3.1.5 Spatial distribution, trends in spatial distribution (e.g. increasingly fragmented, increased numbers of corridors, etc.), or historic range (e.g. corrections to the historical range, change in distribution of the species' within its historic range, etc.):** A detailed description of the historical distribution of the Appalachian Monkeyface is in the recovery plan (Service 1984). Early records are confusing because Ortmann (1918) lumped *Quadrula intermedia* (Cumberland Monkeyface), *Q. tuberosa* (Rough Rockshell), and *Q. sparsa* under the name *Q. intermedia*. Assuming that *Q. sparsa* and *Q. tuberosa* are synonymous, the form Ortmann (1912) called *Q. sparsa* was also in the headwaters of the Cumberland River. However, the only confirmed records of *Q. sparsa* are from headwaters of the upper Tennessee River drainage, which includes the Holston River (the type locality), the upper Powell River, and the unimpounded portion of the Clinch River above Norris Dam (Stansbery 1973, 1976; Bates and Dennis 1978; Ahlstedt 1991). Archaeological specimens have been identified from the lower Clinch River, Roane County, TN (Parmalee and Bogan 1986) and the Hiwassee River, Bradley County, TN (Parmalee and Hughes 1994).

Presently, the species is known only from the unimpounded reaches of the Powell River and Clinch Rivers above Norris Reservoir, although with so few animals detected during decades of sampling, the Clinch River population is likely extirpated. Failure to produce live individuals from numerous surveys has left significant doubt that the species occurs anywhere within its historical range other than the Powell River.

One live individual was discovered during a June 2002 survey of the Cleveland Island reach of the Clinch River (CRM 270.7), Russell County, VA (Eckert and Pinder 2010). This record represents the furthest upstream occurrence of the Clinch River population. Prior to 2002, the last live specimen found in the Clinch River was documented in 1983.

The population in the Powell River has declined by over 12 miles from 1989, and now exists in a 46-mile reach, located between Yellow Shoals Ford, Claiborne County, TN (PRM 84.8) and Flanary Bridge, Lee County, VA (PRM 130.6); however, Parmalee and Bogan (1998) observed that the species had “nearly disappeared” from the river. Live specimens in the Powell River have become increasingly rare and there has been no recruitment noted outside a 0.5-mile linear stretch of the river in the last decade (Johnson 2011).

**2.3.1.6 Habitat or ecosystem conditions (e.g., amount, distribution, and suitability of the habitat or ecosystem):** No new or additional information is available indicating that the habitat or ecosystem conditions listed in the species' recovery plan (Service 1984) have changed. More recent literature and studies have indicated that coal mining (Ahlstedt et al. 2005, 2016; Zipper et al. 2016), and other land use practices (Diamond et al. 2002, Soucek et al. 2003) continue to contribute to the decline of aquatic fauna in the Powell River. This is discussed in greater detail in section 2.3.2.1.

**2.3.1.7 Other:** None.

## **2.3.2 Five-Factor Analysis (threats, conservation measures, and regulatory mechanisms)**

The purpose of a 5-year review is to recommend whether a listed taxon continues to warrant protection under the Endangered Species Act (ESA) and, if so, whether it should be reclassified (from threatened to endangered or from endangered to threatened). This task requires that the analysis of the threats to the species be performed while assuming that the species is not receiving the regulatory protections, funding, recognition, and other benefits of ESA listing. Summaries of ongoing applications of ESA protections may shed light on some future activities that constitute threats to the species. However, the analysis under Factor D (Inadequacy of Existing Regulatory Mechanisms) focuses on the availability of existing alternative (i.e., non-ESA) mechanisms to address the continuing and foreseeable threats.

**2.3.2.1 Present or threatened destruction, modification or curtailment of its habitat or range:** The current status of the species is likely still attributable to the threats described in the recovery plan (Service 1984). Impoundments, urbanization, poor silvicultural, agricultural and mining

practices, and toxic spills remain threats to the remaining Appalachian Monkeyface population. The recovery plan identifies 3 major stressors that precipitate from these threats and are likely causing the decline of the Appalachian Monkeyface. These include impoundments, siltation, and pollution.

Mussel declines in the Powell River have been largely attributed to habitat degradation. Non-point source pollution from land surface runoff can originate from a variety of common land use activity such as coal mining and agricultural activities and may be correlated with impervious surfaces and storm water runoff from urban areas. Pollutants entering the watershed may include sediments, fertilizers, nutrients, herbicides, pesticides, volatile organic compounds, animal wastes, pharmaceuticals, straight pipes, septic tank and gray water leakage, and petroleum products (Hampson et al. 2000; U.S. Environmental Protection Agency [EPA] 2002; Diamond et al. 2002; Soucek et al. 2003). Common land uses within the Clinch-Powell watershed include urban, industrial, commercial, and residential development; livestock production; agricultural cropping including tobacco and corn; coal mining, reclaimed coal mined lands, and “abandoned” coal mined lands (i.e., lands affected by mining prior to SMCRA that were not reclaimed properly); road and railroad networks; and silvicultural practices (EPA 2002). Mine effluents and spills appear to have the greatest overall effect on mussels and fish, as compared to other human-activity sources in the Clinch-Powell watershed (Hampson et al. 2000).

The following provides additional information relevant to the magnitude of threat specifically associated with coal extraction and processing activities. The role of mineral extraction, particularly coal mining, on the decline of freshwater mussels in the Powell River was recognized in the early 20th century by Ortmann (1918). Ahlstedt et al. (2005) considered mussel distributions and abundances within the Powell River watershed to be heavily influenced by the location of mined lands, and declines have been largely attributed to coal activities (Ahlstedt et al. 2016, Zipper et al. 2016). Zipper et al. (2016) found that 29% of the watershed upstream of PRM 179.2 had been disturbed by surface mining. Between 1979 and 2004, mean mussel densities (mussels/m<sup>2</sup>) at 4 long-term monitoring sites in the Powell River watershed declined by 63% (Ahlstedt et al. 2016). Phipps and Ortiz (2018) noted that density and diversity of mussels were severely depressed throughout the upper Powell and South Fork Powell Rivers.

A detailed description of the impacts of coal mining on freshwater mussels is discussed in the Recovery plan for Cumberland Elktoe, Oyster Mussel, Cumberlandian Combshell, Purple Bean, and Rough Rabbitsfoot (Service 2004). In summary, changes in pH and heavy metal-rich drainage from

coal mining and associated sedimentation are toxic to mussels and have adversely affected many stream reaches. Likewise, polycyclic aromatic compounds are indicative of coal fines in the bottom sediments of streams and are known to be toxic to mussels and fishes. Polycyclic aromatic compounds have been found at relatively high levels in the upper portions of the Clinch and Powell Rivers in Virginia.

During the course of a U.S. Geological Survey study on water quality from 1995 to 1999, there were 5 documented coal-fine spills in the Clinch-Powell Rivers (Hampson et al. 2000). In 1996, the failure of a coal slurry impoundment associated with the Lone Mountain coal processing plant resulting in the release of 6 million gallons of coal slurry to the Powell River watershed. The mixture of coal fines, water, and associated contaminants from the release extended downstream into Tennessee, approximately 65 miles from the spill discharge, impacting fish, mussels, benthic organisms, and supporting aquatic habitat. These events highlight the high potential for unauthorized or accidental discharges to eliminate the remaining Appalachian Monkeyface population.

According to Annual Coal Reports (U.S. Energy Information Administration 2001-2018), coal production in Virginia and Tennessee has consistently decreased over the last few decades. The Energy Information Administration projects that coal production in Appalachia will continue to decline through 2025 because of retiring coal-fired electric generating capacity, but then federal rule compliance and higher natural gas prices will lead to coal production leveling off moving into 2050 (U.S. Energy Information Administration 2020).

The construction of dams have isolated mussel and host fish populations in the Upper Tennessee River Basin that were once connected across hundreds of river miles. The presence of the Norris Reservoir, a TVA impoundment, has eliminated potential Appalachian Monkeyface habitat as well as created a permanent barrier to connectivity between the Clinch and Powell Rivers populations. The Appalachian monkeyface now exists in a relatively small, free-flowing reach of the Powell River. This reach of the Powell River and the Clinch River, where the other extant population existed until recently, were once connected before the Norris Dam was closed in 1936. It will be impossible for the reestablishment or recovery of extirpated Appalachian Monkeyface populations without human intervention.

Impacts to aquatic and riparian habitat are prevalent in the Powell River watershed, and there are many factors on the landscape contributing to pollution and sedimentation. The Norris Reservoir that impounded the Clinch and Powell rivers remains one of the most significant impacts to the species and habitat. These threats continue to contribute to the decline

of the Appalachian Monkeyface, while the small population size and limited range make this species especially vulnerable to chemical spills or contaminants that affect water quality.

**2.3.2.2 Overutilization for commercial, recreational, scientific, or educational purposes:** Overutilization is not likely a factor in the decline of this species given its rarity, that the shell of the species is smaller than commercially collected shells, and that the species distribution is outside of commercially harvested waters. No new information exists to indicate that this has changed.

**2.3.2.3 Disease or predation:** The recovery plan does not discuss disease or predation as limiting factors for this species, although there is evidence that disease and predation may be relevant factors contributing to declining populations of freshwater mussels (Service 2004). The different life stages of mussels are preyed upon by a variety of invertebrate and vertebrate predators and are infested by various parasites as part of natural ecosystem dynamics.

Predators have typically been thought to have minimal significant impacts on Cumberlandian Region fauna. However, the muskrat (*Ondatra zibethicus*) has long been recognized in the literature (e.g., Apgar 1887) as probably foremost among mussel predators. Muskrat predation on rare mussels has been shown to be potentially detrimental to their recovery (Neves and Odom 1989) and continues to be a significant problem, but apparently is seasonal and periodical in localized stream reaches in the upper Tennessee River system. For instance, Watson (1999) surmised that muskrats in lower Indian Creek had potentially reduced the adult and subadult purple bean (*Villosa perpurpurea*) population by approximately 20%, which, coupled with predation on the tan riffleshell (*Epioblasma walkeri*), prompted a program to trap and remove muskrat.

Other predators may also affect mussels, particularly predators that prey on newly metamorphosed juveniles. According to Zimmerman and Neves (2003), some flatworm species are voracious predators on newly metamorphosed juvenile mussels in culture facilities. Young juveniles may also fall prey to other invertebrates (e.g., hydra, nonbiting midge larvae, dragonfly larvae, crayfish) (Service 2010). The overall threat to this species from predation is not known.

Although parasitism is not thought to be a significant problem in mussels (Parmalee and Bogan 1998), excessive trematode infestations in their gonads have been implicated in inducing mussel senescence (Zale and Neves 1982).

Recent reviews of freshwater mussel diseases and disorders (Grizzle and

Brunner 2009, Carella et al. 2016) indicated that diseases and pathogens have scarcely been considered as potential factors related to population declines and mass die-offs. Observations of mass mussel die-offs in the U.S. (Waller and Cope 2019) and emerging research on the potential role of pathogens in mussel population declines (Leis et al. 2019) indicates that these aspects may pose a more significant risk than previously thought.

As summarized by Haag (2019), disease is rarely considered as a factor in mussel declines, except for its potential role in mussel die-offs (Neves 1987). At this time, few potential pathogens of freshwater mussels have been identified in North America, and none have been linked conclusively to mussel declines or die-offs (reviewed in Grizzle and Brunner 2009, Haag 2012). Because of our ignorance of mollusk diseases and parasites, "it is imprudent to conclude that alien diseases and parasites are unimportant" (Strayer 1999); however we have no data indicating if, or to what extent, nonnative species or diseases are affecting the Appalachian Monkeyface.

**2.3.2.4 Inadequacy of existing regulatory mechanisms:** The inadequacy of existing regulatory mechanisms was not specifically considered to be a limiting factor in the recovery plan; however, 2 of the 3 major stressors identified in the recovery plan, siltation and pollution, are influenced by the efficacy of State and Federal regulations. These threats have not been abated are likely causing the continued decline of the Appalachian Monkeyface.

The Appalachian Monkeyface is listed as endangered by the states of Virginia and Tennessee. The species is afforded protections by the State of Virginia under Title 29.1 of their Game, Inland Fisheries, and Boating laws (Chapter 5, Article 6) (Virginia Code Annotated § 29.1-564, (1972) c. 329, § 29-232; (1977) c. 377; (1987) c. 488), and the State of Tennessee by the Tennessee Nongame and Endangered or Threatened Wildlife Species Conservation Act (1974) (Tennessee Code Annotated 70-8-101 through 70-8-112). Regulations in Virginia prohibit the taking, transportation, processing, sale, or offer for sale within the commonwealth of any fish or wildlife listed as a federal threatened and endangered species, except as permitted by the Board of VDWR for zoological, educational, scientific, or captive propagation for preservation purposes. Additionally, under Virginia's endangered species regulations, if a landowner is conducting an activity that could alter existing habitat, they are required to minimize negative effects on threatened and endangered species. According to regulations in Tennessee, it is unlawful for any person to take, attempt to take, possess, transport, export, process, sell or offer for sale or ship nongame wildlife, or for any common or contract carrier knowingly to transport or receive for shipment nongame wildlife. Further, regulations included in the Tennessee Wildlife Resources

Commission Proclamation 00-15 Endangered Or Threatened Species state the following: except as provided for in Tennessee Code Annotated, Section 70-8-106 (d) and (e), it shall be unlawful for any person to take, harass, or destroy wildlife listed as threatened or endangered or otherwise to violate terms of Section 70-8-105 (c) or to destroy knowingly the habitat of such species without due consideration of alternatives for the welfare of the species listed in (1) of this proclamation, or (2) the United States list of Endangered fauna. Potential collectors of this species would be required to have a state collection permit.

The Appalachian Monkeyface and its habitats are afforded some protections from water quality degradation under the Clean Water Act (CWA) of 1977 (33 U.S.C. 1251 et seq.), SMCRA of 1977 (30 U.S.C. 1234 – 1328), and state laws, such as Virginia's State Water Control Act of 1950 (§ 62.1), Virginia's Water Protection Permit Program (9 VAC 25-210 and Tennessee's Water Quality Control Act of 1977 (T.C.A. 69-3-101). It is difficult to determine whether these statutes and regulations adequately address the habitat and water quality threats to the Appalachian Monkeyface; however, as demonstrated under Factor A, some population declines and degradation of habitat for this species are ongoing despite the protection afforded by these statutes and associated regulations. The aforementioned laws focus primarily on point-source discharges, and although the ongoing implementation of these laws has resulted in some improvements in water quality and stream habitat for aquatic life in these watersheds over time, many water quality problems are likely generated by non-point source discharges or are not regulated under the purview of current programs. Therefore, these laws and corresponding regulations have been inadequate in limiting the continued degradation of habitat and population declines of Appalachian Monkeyface. Furthermore, the species is afforded greater protection under these laws and regulations due to its status as a federally endangered species; were the species not listed under the ESA, these laws and regulations would be even less effective in limiting habitat degradation and impacts to the species.

According to a 1996 nonjeopardy biological opinion (BO) and conference report issued to the U.S. Office of Surface Mining Reclamation and Enforcement (OSM) regarding surface coal mining and reclamation operations under SMCRA, Species Specific Protective Measures (SSPMs) were to be developed with the objective of minimizing potential take of federally listed species during lawful mining activity (Service 1996). Term and Condition 1 of the BO states "The regulatory authority, acting in accordance with the applicable SMCRA regulatory program, must implement and require compliance with any species-specific protective measures developed by the Service field office and the regulatory authority (with the involvement, as appropriate, of the permittee and OSM)." Although draft SSPMs were developed by the Service and the

Virginia Department of Mines Minerals and Energy, Division of Mined Land Reclamation (DMLR), with input from OSM and the VDGIF in 2009, they were never finalized. Consequently, SMCRA, as implemented, has been inadequate in reducing the stressors associated with coal-related sedimentation and contamination of streams. As a federally endangered species, the Appalachian Monkeyface is afforded greater protection under SMCRA; were the species not listed under the ESA, SMCRA would be even less effective in limiting habitat degradation, and the terms and conditions of the 1996 BO, which requires the implementation of SSPMs to minimize effects to species, would not apply.

Freshwater mussels are sensitive to a variety of contaminants found in aquatic systems, especially during early life stages. The prevalence of some toxic compounds like ammonia and pesticides makes them strong candidates for enigmatic mussel declines or declines where obvious sources of stress are not apparent (Haag 2012). Freshwater mussels appear to exhibit more sensitivity to some pollutants than organisms typically used in toxicity testing. As a result, some of the water quality criteria established by the EPA under the CWA to protect aquatic life may not be protective of freshwater mussels. Currently, EPA water quality criteria for primary pollutants (such as chlorine and copper) and nonpriority pollutants (such as ammonia) are derived from a toxicity database that does not include available data for freshwater mussels. Toxicological studies on freshwater mussels have demonstrated that EPA water quality criteria for ammonia and copper are not protective of all life stages of many freshwater mussel species (Augsburger et al. 2003; Wang et al. 2007a, 2007b). According to a report by the EPA (2002), discharges from coal processing plants and mine sites are monitored for parameters including pH, total iron, total manganese, and total residue. Other potentially toxic compounds, such as hydraulic fluids, frothing agents, modifying reagents, pH regulators, dispersing agents, flocculants, and media separators that are used in mining and coal processing are unregulated and not monitored, and may also be discharged to waterways, and the compliance of these discharges is unknown. Other components of discharges from mine sites like total suspended sediments (TSS), sulfates, and conductivity, that are known to affect aquatic taxa (Timapano 2011), do not have set effluent limits or state standards, thus limits at outfalls or instream are not imposed for these types of parameters. As a federally endangered species, the Appalachian Monkeyface is afforded greater protection under the CWA; were the species not listed under the ESA, the CWA would be even less effective in halting habitat degradation.

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

Restricted range/small population size/reduced genetic fitness

The 1984 recovery plan did not mention the deleterious effects of rarity, habitat fragmentation, and population isolation. The limited geographic range and small population size of the Appalachian Monkeyface leaves the species extremely vulnerable to localized extinctions from stochastic disturbances and decreased fitness from reduced genetic diversity. Species that are restricted in range and population size are more likely to suffer loss of genetic diversity due to genetic drift, potentially increasing their susceptibility to inbreeding depression and decreasing their ability to adapt to environmental changes (Allendorf and Luikart 2007).

#### Nonnative species

A thorough synopsis of impacts to freshwater mussels from nonnative species is provided in the Recovery Plan for Cumberland Elktoe, Oyster Mussel, Cumberlandian Combshell, Purple Bean, and Rough Rabbitsfoot (Service 2004). The following summarizes those impacts that are also applicable to the Appalachian Monkeyface. Nonnative aquatic species are a factor in streams throughout most of the continent. The nonnative Asian clam (*Corbicula fluminea* [Müller 1774]) was first reported from the Cumberlandian Region around 1959 (Sinclair and Isom 1961). This species has been implicated as a competitor with native mussels for resources such as food, nutrients, and space (Heard 1977, Kraemer 1979, Clarke 1986), particularly as juveniles (Neves and Widlak 1987). According to Strayer (1999), dense populations of Asian clams may ingest large numbers of unionid sperm, glochidia, and newly metamorphosed juveniles. He also thought they actively disturb sediments, so dense populations may reduce habitable space for juvenile native mussels. Periodic die-offs of Asian clams may produce enough ammonia and consume enough oxygen to kill native mussels (Strayer 1999). However, specific impacts on native mussels remain largely unresolved (Heard 1977; Leff et al. 1990; Strayer 1997, 1999). Yeager et al. (2000) determined that high densities of Asian clams negatively impacted the survival and growth of newly metamorphosed juvenile mussels and thus reduced recruitment. From laboratory experiments, they determined that Asian clams readily ingested glochidia, clam density and juvenile mussel mortality were positively correlated, mussel growth rates were reduced with the presence of clams, and juvenile mussels were displaced in greater numbers downstream. In his review of enigmatic declines in freshwater mussels, Haag (2019) summarized previous work analyzing the impacts of *Corbicula* on freshwater mussels and concluded that they are “the most compelling single explanation for enigmatic declines.”

Nonnative species potentially carry diseases and parasites that may be devastating to native biota; however we have no data indicating if nonnative species carry or transmit diseases that affect the Appalachian Monkeyface.

### Climate Change

Global climate change is well-documented and generally accepted within the scientific community, and now included in general conservation planning (Heino et al. 2009, Poff et al. 2012). The National Climate Assessment indicates that average temperatures across the nation have risen over the past century and will continue to rise. Virginia's average temperature could increase by as much as 7°F by 2100 (Melillo et al. 2014). According to Runkel et al. (2017), annual precipitation, the number and intensity of heavy precipitation events, and droughts are expected to increase. Freshwater mussels are among the most sensitive and rapidly declining taxa in the world (Haag and Williams 2013), and their unique life cycles make them particularly susceptible to disruption by environmental stressors like temperature.

Hastie et al. (2003) suggest that rising ambient temperatures and exposure to extreme thermal events could pose additional risks to imperiled mussel species. According to Pandolfo et al. (2010), climate change could put mussels closer to their thermal limits, while additional heat inputs from thermal discharges, drought, or landuse changes could further alter the thermal environment. They found that small increases in temperature can lead to significant reductions in survival. A summary of additional sublethal effects from increased stream temperatures to mussels noted in Pandolfo et al. (2010) are summarized, and include: changes in filtration rate or immune response (Chen et al. 2007, Loayza-Muro and Elias-Letts 2007); warm temperatures create a higher demand on metabolic energy and can interfere with behavior, maintenance, and reproductive processes (Dudgeon and Morton 1984, Parker et al. 1984, Weaver et al. 1991, Roberts and Barnhart 1999, Bartsch et al. 2000); temperature shifts can alter timing of reproduction (Barnett 1972), leading to decreased fertilization and recruitment success (Walther et al. 2002, Philippart et al. 2003); changing temperatures can lead to asynchrony, resulting in a mismatch between life-history events and environmental conditions, where for example, a mismatch between the timing of gravidity and glochidial release and the presence of necessary host fish could inhibit freshwater mussel reproduction (Visser and Holleman 2001, Philippart et al. 2003). Changing climate regimes can also affect species composition and ecological processes over time. The following is also summarized from Pandolfo et al. (2010): extreme thermal events can cause significant changes in aquatic community structure in relatively short amounts of time, and mollusk communities might be slow to recover if they have already experienced a gradual warming of their environment (Mouthon and Daufresne 2006). Freshwater mussel species respond uniquely to different thermal regimes, and these differences correspond with variable filtration and excretion rates. Therefore, changes in thermal regime that alter species composition can also affect ecological processes (Spooner and Vaughn 2008, 2009; Vaughn et al. 2008). The effects of a changing

climate could impact the remaining Appalachian Monkeyface population and alter the aquatic community on which they depend.

## **2.4 Synthesis**

Early survey records and archeological finds of the Appalachian Monkeyface indicate the species once occurred in the headwaters of the Cumberland River system and the upper Tennessee River system (Service 1984). However, the species has only been confirmed from the Powell, Clinch, and Holston Rivers in the upper Tennessee River system. The population in the Holston River system was extirpated at the time of listing. Little is known about the population in the Clinch River due to the rarity of records. One individual discovered during a 2002 survey was the first live individual documented in the Clinch River since 1983. If there are individuals remaining in the Clinch River, the population is likely not viable and is considered functionally extirpated. The population in the Powell River persists at low levels in a 46-mile reach, located between Yellow Shoals Ford, Claiborne County, TN (PRM 84.8) and Flanary Bridge, Lee County, VA (PRM 130.6) and finding live specimens has become increasingly rare. With only one population remaining, this species has a high probability of extinction within the foreseeable future. The AWCC is currently working to evaluate host fish suitability and identify suitable methods for holding and caring for this species over an extended time period, which will provide valuable information on culture techniques as well as captive care protocols. Propagation, augmentation, and reintroduction will be essential for the survival and recovery of this species.

Threats described in the recovery plan (Service 1984) are still applicable. Impoundments; urbanization; poor silvicultural, agricultural and mining practices; and with a limited distribution in one river system, chemical spills, drought, and other stochastic events remain major threats to the Appalachian Monkeyface. The recovery plan identified three major stressors that precipitate from these threats and continue to affect the Appalachian Monkeyface. These include impoundments, siltation, and pollution. In addition to the recovery plan's description of the various threats that contribute to these stressors, there are additional continued threats from development and operation of coal and gas resources. Although existing regulatory mechanisms including the CWA and SMCRA provide some protections to the Appalachian Monkeyface, they have been inadequate in protecting the Appalachian Monkeyface from habitat degradation.

Additional threats to the remaining Appalachian Monkeyface population include climate change; the restricted range and small population size, which leaves the species extremely vulnerable to localized extinctions or other stochastic disturbances; reduced genetic diversity; and impacts from nonnative species and disease. Given its highly restricted distribution (redundancy), the vulnerability and declining status of the remaining population (resiliency) and the low genetic diversity (representation), the Appalachian Monkeyface continues to meet the definition of endangered.

### 3.0 RESULTS

#### 3.1 Recommended Classification:

  X   No change is needed

#### 3.2 New Recovery Priority Number: No change needed. Retain as 5.

**Brief Rationale:** Remains subject to a high degree of threat and has a low recovery potential.

### 4.0 RECOMMENDATIONS FOR FUTURE ACTIONS

1. Continue life history studies and determine suitable hosts for propagation.
2. Continue captive propagation and culture techniques.
3. Pursue reintroduction of propagated animals to the Clinch River or translocation of Powell River animals to the Clinch River.
4. Establish SSPMs to satisfy Term and Condition 1 of the 1996 Biological Opinion, titled Section 7 Formal Consultation and Conference Report on Surface Coal Mining and Reclamation Operations under the Surface Mining Control and Reclamation Act of 1977.
5. Pursue and adopt protective water quality criteria of known and suspected pollutants.
6. Identify and characterize the magnitude of specific threats (e.g., coal mining, oil and gas drilling, agriculture, urbanization, silviculture, Abandoned Mine Land [AML] sites) to allow implementation of effective measures to reduce stressors to this species.
7. Through various means of land protection (land acquisition, Best Management Practices programs, conservation easements) abate nonpoint source impacts and direct habitat loss.

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**U.S. FISH AND WILDLIFE SERVICE  
5-YEAR REVIEW of *Quadrula sparsa***

**Current Classification:** Endangered

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

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

**Appropriate Listing/Reclassification Priority Number, if applicable:** NA

**Review Conducted By:** Rose Agbalog, Fish and Wildlife Biologist, Southwestern Virginia Field Office

**REGIONAL OFFICE APPROVAL:**

**Lead Regional Director, Fish and Wildlife Service**

Approve \_\_\_\_\_ Date \_\_\_\_\_