

Rough Pigtoe
Pleurobema plenum

5-Year Review:
Summary and Evaluation



Pleurobema plenum - Holotype, Length 41 mm. Collected from Ohio River, Cincinnati, Ohio.
Unio plenus (= *Pleurobema plenum*) Holotype USNM 84677, photo credit Lorene Steinberg of the Smithsonian Museum of Natural History.

U.S. Fish and Wildlife Service
South Atlantic-Gulf Region
Kentucky Ecological Services Field Office
Frankfort, Kentucky

5-Year Review

Rough Pigtoe (*Pleurobema plenum*)

I. GENERAL INFORMATION

A. Methodology used to complete the review:

The U.S. Fish and Wildlife Service (Service) conducts status reviews of species on the List of Endangered and Threatened Wildlife and Plants (50 CFR 17.11 and 17.12) as required by section 4(c)(2) of the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531 et seq.). We provided public notice of this 5-Year Review in the *Federal Register* on June 20, 2019 (84 FR 28850) and opened a 60-day public comment period. In the notice, the Service requested new information regarding the Rough Pigtoe that has become available since the last 5-year review for the species. The National Council for Air and Stream Improvement, Inc. submitted comments, see Appendix A for details on the specific comments and how the Service addressed them.

In conducting this 5-year review, we relied on available information pertaining to historic and current distributions, life history, and habitat of this species. Our sources include the Recovery Plan; peer-reviewed scientific publications; unpublished field observations by Service, State, and other experienced biologists; unpublished survey reports; and notes and communications from other qualified biologists or experts. All literature and documents used for this review are on file at the Tennessee Ecological Services Field Office in Cookeville, Tennessee.

Santiago Martín and Anthony Ford with the Tennessee Field Office drafted and Mike Floyd in the Kentucky Field Office finalized this review. The Service did not consider this 5-year review to be “influential” under the Service’s policy for Information Quality Guidelines and Peer Review; therefore, no external peer review was conducted. Per the guidelines, the Service will seek peer review when we can reasonably determine that dissemination of influential information “...will have or does have a clear and substantial impact on important public policy or private sector decisions, and thus, a decision or action to be taken by the Director”, such as a change in listing status (i.e., delisting, downlisting, or uplisting of a species). Jess Jones and Mike Floyd with the Virginia and Kentucky Ecological Services Field Offices, respectively, provided comments during an internal review. Appendix A provides a brief summary of the review approach.

B. Reviewers

Lead Region

South Atlantic-Gulf Region: Carrie Straight, (404) 679-7226

Cooperating Regions

Great Lakes Region: Laura Ragan, (612) 713-5157

North Atlantic-Appalachian Region: Martin Miller, (413) 253-8615

Lead Field Office

Kentucky Ecological Services Field Office: Michael Floyd, (502) 695-0468, ext. 102

Cooperating Field Offices

North Atlantic-Appalachian Region

Virginia Ecological Services Field Office: Jess Jones, (540) 231-2266

Great Lakes Region

Indiana Ecological Services Field Office: Marissa Reed, (812) 334-4261, ext. 213

South Atlantic-Gulf Region

Tennessee Ecological Services Field Office: Anthony Ford, (931) 525-4982

Alabama Ecological Services Field Office: Evan Collins, (251) 441-5837

C. Background

1. Federal Register Notice citation announcing initiation of this review:

June 20, 2019; 84 FR 28850

2. Listing history

Original Listing

FR notice: 41 FR 24062

Date listed: June 14, 1976

Entity listed: Species

Classification: Endangered

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. September 13, 2007; 72 FR 52434.

4. Review History:

Each year, the Service reviews and updates listed species information for inclusion in the required Recovery Report to Congress. Through 2013, we submitted information for the annual recovery data call that included status determinations for the Rough Pigtoe.

The Service completed a 5-Year Review for the Rough Pigtoe on September 1, 2014 (Service 2014). In this review, the Service did not recommend a change to the species' designation or recovery priority.

Before 2014, the Service conducted a 5-Year Review for all species listed prior to January 1, 1991 under the Endangered Species Act (ESA) of 1973, as amended (56 FR 56882). In this review, the status of 578 species in the U.S. and 514 foreign species were simultaneously evaluated with no species-specific, in-depth assessment of the five factors as they pertained to the different species. The published notice summarily listed these species and stated that no change in their designation was warranted at that time.

5. Species' Recovery Priority Number at start of review (48 FR 43098):

5, indicating that the Rough Pigtoe is categorized as a species, has a high degree of threat, and a low potential for recovery.

6. Recovery Plan

Name of plan: Recovery Plan for the Rough Pigtoe Pearly Mussel, *Pleurobema plenum* (Lea, 1840)

Date issued: August 6, 1984

II. REVIEW ANALYSIS

A. Application of the 1996 Distinct Population Segment (DPS) policy

The ESA defines “species” as including any subspecies of fish, wildlife, or plant, and any DPS of any species of vertebrate wildlife. This definition limits listing DPSs to only vertebrate species of fish and wildlife. Because the species under review is an invertebrate, the DPS policy is not applicable and will not be addressed further in this review.

B. Recovery Criteria

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

Yes

2. Adequacy of recovery criteria.

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

No. The criteria are vague, in that: 1) population viability is not well defined; and 2) the separation distance (between sub-populations) necessary to ameliorate catastrophic events is not identified.

b. Are all of the 5 listing factors that are relevant to the species addressed in the recovery criteria?

No. Freshwater mussel diseases and their role in mussel die-off have come under increased scrutiny (e.g., recent mussel die-off in the Clinch River). This emerging threat needs to be considered in recovery plans as it may be a significant factor in the success of translocation and propagation efforts. See discussion in section II.C.2.c., below.

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 recovery plan does not list criteria to downlist the species from endangered to threatened. The recovery plan says that to remove the Rough Pigtoe from the *Federal List of Threatened and Endangered Species*, the following criteria must be met:

(1) A viable population¹ of P. plenum exists in the Tennessee, Clinch, Cumberland, and Green Rivers. These four populations are dispersed through each river so that it is unlikely that any one event would cause the total loss of any population.

Status: This criterion has not been met. This criterion specifies a reproducing population is necessary to be considered viable. Natural recruitment has only been documented recently in the Green (Kentucky) and Clinch (Tennessee) rivers.

(2) Through reestablishments and/or discoveries of new populations, viable populations exist in two additional rivers. Each of these rivers will contain a viable population that is distributed such that a single event would be unlikely to eliminate P. plenum from the river system. For reestablished populations, surveys must show that three year-classes including one year-class 10 years old or older have been naturally produced within the river system.

Status: This criterion has not been met. No new Rough Pigtoe populations have been discovered since the recovery plan (Service 1984) was completed. A historical record in the lower Licking River, Pendleton County, Kentucky, was omitted from the recovery plan (Ohio State University Museum. OSUM: 1963:0081, Catalog Number 8458). Additional observations have been made for this species in the same general area since that time (Laudermilk 1993; Illinois Natural History Survey, Mollusk Collection, Catalog Number 43752). More recently (2016), the Kentucky Department of Fish and Wildlife Resources (KDFWR) translocated 10 adult individuals from the Green River to the Licking River in an area near the Clay Wildlife Management Area. These individuals were observed alive again in 2019 (M. McGregor, KDFWR, pers. comm. 2020). Currently, we do not consider this population to be viable based upon its limited occurrence and population demographics.

(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.

Status: This criterion has not been met. Detailed discussion of ongoing threats for this species can be found in the Five-Factor Analysis in section II.C.2.

(4) Noticeable improvements in siltation problems and substrate quality have occurred.

Status: This criterion has not been met. Jones *et al.* (2018) noted that water quality in the Clinch River has not improved over the last decade and attributed the mussel decline in the Clinch River to a variety of factors, including degraded water and sediment quality associated with coal-mining activities. Jones *et al.* (2018) summarized data and analyses available in Krstolic *et al.* (2013), Johnson *et al.* (2014), Price *et al.* (2014) Zipper *et al.* (2014), and Cope and Jones (2016). Jones *et*

¹ Viable population: a reproducing population that is large enough to maintain sufficient genetic variation to enable it to evolve and respond to natural habitat changes. The number of individuals needed to meet this criterion will be determined as one of the recovery tasks.

al. (2018) concluded that water quality in the upper reaches of the Clinch River is adversely affected by increased levels of contaminants, including dissolved solids, trace metals, and polycyclic aromatic hydrocarbons, which, in turn, may limit mussel survival and reproduction.

Based on observations made after the removal of the Green River Lock and Dam (GR L&D) 6 (Compton *et al.* 2017), the Service also anticipates a short-term increase in sediments in the Green and Barren rivers downstream of the planned L&D removals. The expected sedimentation will occur due to the release of impounded sediments and bank failures upstream of the planned removal of GR L&D 5 and Barren River Lock and Dam (BR L&D) 1. Sedimentation effects are expected to be temporary because natural river flows will transport and disperse impounded sediments downstream, ultimately leading to an overall improvement in habitat conditions in these restored river reaches.

C. Updated Information and Current Species Status

1. Biology and Habitat

a. New information on the species' biology and life history:

Period of Gravidity

Recent work by the Virginia Department of Wildlife Resources' Aquatic Wildlife Conservation Center (AWCC) validated previous assumptions about the tachytictic (short-term brooding) reproductive strategy for this species (Parmalee and Bogan 1998; Watters *et al.* 2009; Lane *et al.* 2021). In 2018, Lane *et al.* (2021) collected eight Rough Pigtoe mussels from three sites in the Clinch River, Tennessee. In preparation for fish host trial experiments, subsequent laboratory observations of these individuals revealed that gravid females produced conglutinates (egg packets) with viable glochidia (larvae) from the end of May to the end of July.

Fish Host(s)

From 2019-2020, Lane *et al.* (2021) conducted fish exposure trials with 21 fish species to determine potential host species for the Rough Pigtoe. Four fish species, all members of the minnow family Leuciscidae, produced live Rough Pigtoe juveniles during the study – Spotfin Shiner (*Cyprinella spiloptera*), Striped Shiner (*Luxilus chrysocephalus*), Longnose Dace (*Rhinichthys cataractae*), and Western Blacknose Dace (*R. obtusus*) (Table1). The most juveniles (69) were recovered from Western Blacknose Dace (69), followed by Striped Shiner (43), Spotfin Shiner (2), and Longnose Dace (1). In total, the trials resulted in the recovery of 115 juveniles with an excystment period ranging from 9–34 days. The project produced four live juveniles that are being cultured at AWCC. The Western Blacknose Dace is unlikely to be a natural host to the Rough Pigtoe due to its occurrence in small, headwater streams (1st -2nd order); however, it appears the species can be used for laboratory glochidial infestations to enhance numbers of transformations during captive propagation efforts.

Table 1. Summary of 2019-2020 host fish exposure trials using viable glochidia obtained from Rough Pigtoe brood stock from the Clinch River (Lane *et al.* 2021).

Fish Host	# Tested	# Survived	Days to Excyst	# Juveniles Recovered
Striped Shiner	35	19	9-34	43
Spotfin Shiner	1	1	14-15	2
Longnose Dace	1	1	16	1
Western Blacknose Dace	15	15	9-23	69
TOTAL	52	36	9-34	115

b. Abundance, population trends (e.g., increasing, decreasing, stable), demographic features, or demographic trends:

All streams containing known Rough Pigtoe populations are discussed below. All these streams occur within the Ohio River basin. There is no indication that this species' distribution has changed substantially since the recovery plan was prepared. In addition, recent surveys have documented persistence of the Rough Pigtoe in several Ohio River tributaries (C. Carey, VTU, pers. comm. 2020; Garner 2019; Lewis 2017a, 2017b, 2019; M. McGregor, KDFWR, pers. comm. 2020).

Licking River

A historical record in the lower Licking River, Pendleton County, Kentucky, was omitted from the recovery plan (Ohio State University Museum. OSUM: 1963:0081, Catalog Number 8458). Relict shells were observed again in the same general area by Lauder milk (1993) and again in 2012 by experienced malacologists (Illinois Natural History Survey, Mollusk Collection Data, Catalog Number 43752).

In 2016, KDFWR translocated 10 adults from the Green River to the Licking River near Clay Wildlife Management Area in Fleming and Nicholas counties. KDFWR wanted to determine if the species could survive in upstream reaches of the Licking River drainage. Live translocated individuals were observed again by KDFWR in 2019 (M. McGregor, KDFWR, pers. comm. 2020). Although the documented survival of these individuals is promising, the small population size puts these individuals at risk from a single catastrophic event (e.g., flood) in the introduction area. At this time, it is unknown if these reintroduced individuals will reach an average lifespan for the species or result in recruitment of additional age-classes to the drainage.

Green River

The Green River in Kentucky probably contains the best remaining population of the species. Based on surveys conducted in the Green River since 2009, the Rough Pigtoe is known to occur from the tailwaters of GR L&D 3 (Green River Mile [GRM] 108.5), near Rochester, Kentucky, upstream to a mussel bed near Munfordville, Kentucky, excluding the area between GR L&D 5 and 6 (GRM

168.1-181.7; McGregor *et al.* 2015; Lewis 2011, 2013, 2017a, 2017b, 2019). In 2012, Lewis Environmental Consulting observed 48 live individuals in the former GR L&D 4 pool (GRM 155.4 to 168.40). The species' relative abundance in the mussel community was 1.11%. Various size classes were observed with age estimates of 5-20 years, suggesting successful recruitment in the former GR L&D 4 pool (Lewis 2013).

In 2009, KDFWR translocated 33 Rough Pigtoe mussels upstream from the GR L&D 5 tailwaters to a long-term Green River monitoring site near Munfordville, where the species occurred historically. No Rough Pigtoe individuals were observed at the site during monitoring efforts in 2014 or 2019; however, the lack of detection may be due to the species' low abundance at the site (McGregor *et al.* 2015; M. McGregor, KDFWR, pers. comm. 2020).

The U.S. Army Corps of Engineers and the Service, along with other conservation partners, removed GR L&D 6 in the spring of 2017, and GR L&D 5 is scheduled for removal in 2021. The Service anticipates that mussel populations will respond favorably to the removal of GR L&D 5 as natural flows are re-established and substrate conditions improve (sedimentation decreases).

Barren River

The Rough Pigtoe is known to occur in the Barren River from BR L&D 1 near Greencastle, Kentucky (Barren River Mile [BRM] 14.6), downstream to the confluence with the Green River (GRM 149.5), an approximate 14-mi river reach. In the early 1990s, Weiss and Layzer (1993) detected the species at four of five sampling sites downstream of BR L&D 1. Lewis (2008) conducted the most recent survey in the Barren River, reporting one live and two dead individuals.

Cumberland River

The Rough Pigtoe is considered rare in the Cumberland River, where it has been observed periodically in commercial shell harvests since at least the 1980s (Parmalee and Bogan 1998). In 2008, the Tennessee Wildlife Resources Agency (TWRA) collected two Rough Pigtoe mussels during surveys focused in two locations in the Rome Ferry sanctuary (Cumberland River Mile 292.5 – 313.5; TWRA 2008). More intensive survey efforts are needed to determine the status of this species in the Cumberland River.

Tennessee River

The Rough Pigtoe is considered extremely rare in the Tennessee River mainstem, and its current status and population trend is uncertain. Since the last 5-Year Review, very few observations have been made for this species in the tailwaters below Guntersville Dam, Alabama; Wilson Dam, Alabama; and Pickwick Landing Dam, Tennessee (AST Environmental 2017; Lewis 2017c; Garner 2019). Jeff Garner, malacologist with the Alabama Department of Conservation and Natural Resources, conducted extensive qualitative mussel surveys in the tailwaters of Wilson Dam in 2017 and 2018 (Garner 2019). This survey yielded 18 Rough Pigtoe mussels after 178 hours of searching. The

relative abundance of Rough Pigtoe for this qualitative study was 0.17% (0.17% of all mussels observed; Garner 2019).

Clinch River

Like the Green River, the Clinch River contains one of the best remaining Rough Pigtoe populations. The species is known to occupy 17.4 river miles, extending from Kyles Ford (Clinch River Mile [CRM] 189.6) downstream to Swan Island (CRM 172.2; T. Lane, AWCC, pers. comm. 2020a). Recruitment for this species has been observed at Kyles Ford and Frost Ford (CRM 181.3). Long-term monitoring efforts (1979–2014) have yielded a total of 52 Rough Pigtoe mussels in the Tennessee portion of the Clinch River between Swan Island and Wallen Bend (CRM 172.2-192.4; Ahlstedt *et al.* 2016; Jones *et al.* 2014; Jones *et al.* 2018). The Rough Pigtoe is considered to be uncommon in the Clinch River based on these long-term quantitative surveys; the overall relative abundance for this species was 0.26 % (0.26% of all mussels observed), and the average density for Rough Pigtoe was 0.07/m² (Jones *et al.* 2018).

Caitlin Carey, a Research Associate and Ph.D. student at Virginia Polytechnic Institute and State University (VTU), used mussel count and density data from the long-term monitoring efforts (see Jones *et al.* 2018) to calculate population estimates for all mussel species found in the Clinch River. Frost Ford, one of the few areas where the species is still present and reproducing, has the most complete dataset of population estimates across time. Population estimates between 2004 and 2019 ranged from zero to almost 6,000; however, given this variability, there is too much uncertainty in the estimates to detect changes in abundance over time.

East Fork White River

The most recent Indiana record of a live Rough Pigtoe was obtained during a 1992 dive survey in the East Fork White River in Martin County (B. Fisher, Indiana Department of Natural Resources, pers. comm. 2020). The identification was confirmed by the late Dr. David Stansbery of The Ohio State University.

c. Genetics, genetic variation, or trends in genetic variation:

Recent genetic studies support the Rough Pigtoe as a valid species. A genetic characterization of extant populations of the Rough Pigtoe mussel in the Clinch River, Tennessee, and Green River, Kentucky, was conducted by Jones *et al.* (2015). Individuals from these two populations were shown to be closely related based on phylogenetic analyses of mitochondrial DNA sequences and analyses of variation at nine hypervariable nuclear DNA microsatellite loci. Individuals from both populations grouped together into a monophyletic clade. No discernable differences were observed in mitochondrial DNA sequences between the Clinch River and Green river populations. Furthermore, Inoue *et al.* (2018) conducted phylogenetic analyses of mitochondrial DNA sequences to examine the relationships within two genera (*Fusconaia* and *Pleurobema*) in the tribe Pleurobemini. Constraint models in this study supported the recognition of Rough Pigtoe as a genetically distinct species. Many individuals in the Clinch River first thought to be the Ohio Pigtoe (*Pleurobema cordatum*) were

genetically identified as *P. plenum*, indicating that the Rough Pigtoe may be more common in the Clinch River and other systems than previously reported (Olivera-Hyde 2020, Lane *et al.* 2021).

d. Taxonomic classification or changes in nomenclature:

No changes to taxonomic classification or nomenclature have occurred since this species was listed. Nomenclature is consistent and follows that in Williams *et al.* (2017).

e. Spatial distribution, trends in spatial distribution, or historic range (e.g. corrections to the historical range, change in distribution of the species within its historic range, etc.):

Since the last 5-year review, the Service has documented the persistence of Rough Pigtoe populations in the Green, Clinch, and Tennessee rivers, and a small population (10 individuals) was reintroduced into the Licking River. Other known populations in the Barren, Cumberland and East Fork White rivers have not been relocated in recent years, potentially due to low densities and the lack of comprehensive survey efforts.

The Green and Clinch rivers continue to harbor the largest Rough Pigtoe populations and have the longest occupied reaches, 102 and 18 river miles, respectively. In addition, these reaches show the only evidence of recruitment since the last 5-year review. Table 2 in Appendix B lists extant Rough Pigtoe populations and their estimated distribution, sizes, and trends.

f. Habitat:

This species is endemic to the Ohio River basin and is found in stable substrates composed of a mixture of relatively firm and clean gravel, sand, and silt. They are often associated with other riverine mussels that also prefer this type of habitat. Lane *et al.* (2021) reported that the Rough Pigtoe did not appear to follow any type of perceivable pattern concerning microhabitat preference. They observed individuals at the surface in runs leading up to glides and riffles while other individuals were observed in high flow areas buried several inches below the surface of the streambed.

Since the Rough Pigtoe was listed under the ESA, significant water and habitat quality improvements have been made in the Green River basin. The Kentucky Chapter of The Nature Conservancy (TNC) and the U.S. Army Corps of Engineers (USACE) worked together in 2000 to change the operations at the Green River Lake Dam to better mimic the natural flow regime in the upper Green River, Kentucky. TNC's conservation action plan for the Green River includes comprehensive strategies intended to abate threats to freshwater mussel viability by improving water quality, habitat quality, and river flows for mussels.

Additional efforts by TNC have included a partnership with the Natural Resource Conservation Service (NRCS) to focus agriculture initiatives in the Green River basin through the Conservation Reserve Enhancement Program. The goal of the program was to restore up to 100,000 acres of agricultural land

along the upper Green River as riparian buffers and sediment-capturing native warm season grass fields. TNC and NRCS have successfully enrolled 101,917 acres in this program, meeting their objective.

The Service is working with its conservation partners (e.g., USACE, TNC, KDFWR, and Kentucky Waterways Alliance, among others) to restore the flow of the Green River to a more natural state. Prior to 1886, the Commonwealth of Kentucky developed a navigation system in the Green River and its tributaries. The system consisted of four lock and dams on the Green River, below the confluence with the Barren River, and one lock and dam on the Barren River. Under authorization of the River and Harbor Act of 1888, the U. S. Government purchased the structures from the Commonwealth of Kentucky and expanded the navigation system by adding three additional lock and dams: GR L&D 6 in 1906, GR L&D 5 in 1934 and Rough River L&D 1 in 1897.

Starting in the 1950s, the USACE ceased operation of lock and dams due to marked declines in navigation traffic (GR L&D 5 and 6 in 1951; GR L&D 3 in 1981) or dam failures (GR L&D 4 failed in 1965, making navigation to the Barren River impossible). The Service and its conservation partners removed GR L&D 6 in 2017, the first removal of several obsolete lock and dams on the Green and Barren rivers.

Based on the improvements seen in the mussel fauna in the former pool and tailwaters of GR L&D 4 since its breach in 1965, the Service anticipates that the removal of other locks and dams in the Green and the Barren rivers will benefit the Rough Pigtoe (Lewis 2011). The Service and its conservation partners plan to remove GR L&D 5 and BR L&D 1 in the near future.

2. Five-Factor Analysis

The purpose of a 5-Year Review is to recommend whether a listed taxon continues to warrant protection under the 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 adequacy of existing alternative mechanisms (i.e., non-ESA) to address the continuing and foreseeable threats.

a. Present or threatened destruction, modification or curtailment of its habitat or range:

Although there have been improvements to habitat noted above, ongoing threats to the Rough Pigtoe include water quality degradation from point and non-point sources, particularly in tributaries that have limited capability to dilute and assimilate sewage, agricultural runoff, and other pollutants. In addition,

hydrologic and water quality alterations resulting from the operation of impoundments such as Green River Reservoir, Pickwick Lake Reservoir, Wilson Lake Reservoir, Guntersville Lake Reservoir, and Cordell Hull Reservoir negatively affect this species. The presence of impoundments may have ameliorated the effects of downstream siltation, but these structures also control river discharges and the many environmental parameters influenced by discharge, which may profoundly affect the ability of Rough Pigtoe populations to occupy or successfully reproduce in downstream habitats.

A variety of instream activities (*e.g.*, sand and gravel dredging, road construction) continue to threaten Rough Pigtoe populations and their habitats. Protecting these populations from the direct physical disturbance of such activities depends on accurately identifying the location of the populations, which is difficult with a cryptic species such as the Rough Pigtoe. The indirect effects of altering the streambed configuration may cause changes in previously suitable habitat some distance from the disturbance and result in decreased survival or reproduction.

Coal, oil, and natural gas resources are present in some of the watersheds known to support Rough Pigtoe mussels, especially the Green, Barren, and Clinch rivers. Exploration and extraction of these resources can result in increased siltation and an altered hydrograph and water quality, even at some distance downstream from the mine or well field.

Land-based development near occupied habitats, including residential development and agriculture, often results in loss of riparian habitat and subsequent increases in stream temperature, increased stormwater runoff due to increased impervious surfaces, increased sedimentation due to loss of streamside vegetation, and subsequent degradation of stream banks.

b. Overutilization for commercial, recreational, scientific, or educational purposes:

The Rough Pigtoe mussel is not a commercially valuable species; however, as noted in the recovery plan, this species was harvested as part of commercial activity in the past (Service 1984). The Rough Pigtoe is more likely to occur in harvests from brailing than diving, since brailing is relatively indiscriminate with regard to the mussel species it takes. This threat may have diminished in recent years since brailing is on the decline in most of the species' range, including the Tennessee River downstream of Pickwick Landing Dam.

Overutilization for recreational, scientific, or educational purposes was not considered to be a threat in the recovery plan. There is no new information to indicate this has changed.

c. Disease or predation:

This species has a number of natural predators, including muskrats, raccoons, otters, fish, and some invertebrates. Such predation could locally reduce

populations of the Rough Pigtoe, but the overall impact of this threat on the species is not known.

Reviews of freshwater mussel diseases and disorders (Grizzle and Brunner 2009, Carella *et al.* 2016) indicate that diseases and pathogens have scarcely been considered as potential factors related to population declines and mass die-offs of mussels in the U.S. Observations of mass mussel die-offs in the U.S. (Richard *et al.* 2020; 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.

In 2016, 2017, and 2019, tens of thousands of mussels of various species, including Rough Pigtoe, died of unknown cause(s) in several miles of the Clinch River between Kyles Ford, Tennessee and the Tennessee/Virginia border. In 2016, 3,553 fresh dead mussels were recovered and brought to the McClung Museum at the University of Tennessee for archiving, which included 254 Rough Pigtoe mussels. In 2017, 663 fresh dead mussels were recovered and brought to the McClung Museum for archiving, which included 8 Rough Pigtoe mussels (G. Dinkins, McClung Museum of Natural History and Culture, pers. comm. 2020).

The Service and its partner agencies have no other information on disease or predation of the Rough Pigtoe, but ongoing mussel die-offs in the mussel community of the Clinch River near the Tennessee/Virginia border has the potential to be a limiting factor for the long-term viability of the Rough Pigtoe in the Clinch River.

d. Inadequacy of existing regulatory mechanisms:

The Rough Pigtoe and its habitats are afforded limited protection from water quality degradation under the Clean Water Act of 1977 (33 U.S.C. 1251 *et seq.*), Surface Mining Control and Reclamation Act of 1977 (30 U.S.C. 1234 – 1328), and state laws, such as Tennessee’s Water Quality Control Act of 1977 (Tennessee Code Annotated 69-3- 101), Alabama’s Water Quality Program (ADEM Admin. Code r. 335-6), Kentucky’s Agriculture Water Quality Act of 1994 (KRS 224.71-140), and Virginia’s State Water Control Act (Code of Virginia § 62.1-44.2). These laws focus on point-source discharges; however, while they have resulted in some improvements in water quality and stream habitat for aquatic life, many water quality problems are generated by non-point source discharges. Therefore, these laws and corresponding regulations have been inadequate to halt population declines and degradation of habitat for the Rough Pigtoe.

The Rough Pigtoe is state protected in Alabama, Indiana, Kentucky, Tennessee, and Virginia. Under the Tennessee Nongame and Endangered or Threatened Wildlife Species Conservation Act of 1974 (Tennessee Code Annotated §§ 70-8-101- 112), “...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.” Potential collectors of this species would be required to have a state collection permit. In Virginia, the Rough Pigtoe is listed as Endangered and is protected under State law (4VAC15-20-130). It is unlawful to “...take, transport, process, sell, or offer for sell within the Commonwealth any threatened or endangered species of fish or wildlife except as authorized by law” (Virginia Code Annotated §§ 29.1-563 – 570). A State permit is required for the taking, exportation, or possession of any threatened or endangered species of fish or wildlife for zoological, educational, or scientific purposes, and for propagation of such fish and wildlife in captivity for preservation purposes (§ 29.1-568). In Alabama, it is protected under their Invertebrate Species Regulation (Alabama Administrative Code 220-2-.98). Under this regulation, it is unlawful to “take, capture, kill, or attempt to take, capture, or kill; possess, sell, trade for anything of monetary value, or offer to sell or trade for anything of monetary value” the Rough Pigtoe without the proper permit. In Kentucky (Kentucky Revised Statutes Annotated § 150.180, 183, 260, 280, 990), no person shall import, transport, possess for resale or sell any endangered species of wildlife. While these laws offer some protections to the species itself, they do little to address habitat degradation or protecting the species from uninformed individuals.

e. Other natural or manmade factors affecting its continued existence:

Invasive Species

The non-native Asian Clam (*Corbicula fluminea*) is common throughout the range of the Rough Pigtoe, where it can alter benthic substrates, filter mussel sperm or glochidia, compete with native species for limited resources, and cause ammonia spikes in surrounding water when they die off in large numbers (Scheller 1997). The Asian Clam is hermaphroditic, enabling fast colonization, and it is believed to practice self-fertilization, enabling rapid colony regeneration when populations are low (Cherry *et al.* 2005). Asian Clams are prone to have die-offs that reduce available dissolved oxygen and increase ammonia, which can cause stress and mortality to native mussels such as the Rough Pigtoe (Cherry *et al.* 2005).

Zebra mussels have continued to spread in North American waterways since their accidental introduction in the 1980s. Large zebra mussel populations in Lake St. Clair, the Detroit River, and Lake Erie appear to have eliminated most native mussels from colonized areas, although the species may persist in refugia where habitat is less suitable for zebra mussels. Presently, zebra mussel populations appear to have had little negative effect on known Rough Pigtoe populations; however, this could change in the future.

The Black Carp (*Mylopharyngodon piceus*), an invasive molluscivore, has been reported in Arkansas, Illinois, Indiana, Kentucky, Louisiana, Mississippi, Missouri, Tennessee, and West Virginia (Nico and Neilson 2020). It is established in Louisiana (since the early 1990s) and was observed most recently in 2019 and 2020 in Tennessee and Kentucky, respectively (Nico and Neilson

2020). The Black Carp is also listed as Injurious Wildlife under the Lacey Act. The species is present in the lower Ohio, Cumberland, and Tennessee River systems. There is high potential that the Black Carp will negatively affect aquatic communities and especially native mussels and snails by direct predation, thus reducing populations, many of which are considered endangered or threatened (Nico and Neilson 2020).

Other invasive Asian Carps, like the Bighead Carp (*Hypophthalmichthys nobilis*) and the Silver Carp (*Hypophthalmichthys molitrix*) have been observed in 27 states (Nico *et al.* 2020a, 2020b). These species are present in the lower Tennessee River, lower Cumberland River, and middle Green River. The impact of these species in the United States is not adequately known, but it is likely that these species negatively affect native mussel populations where they are locally abundant by altering foodwebs. Bighead and Silver Carps are planktivorous and may cause a decline in the availability of plankton, which can lead to reductions in populations of native species that rely on plankton for food, including all larval fishes, some adult fishes, and native mussels (Nico *et al.* 2020a, 2020b).

Climate Change

Climate change can influence freshwater mussel habitat by increasing or decreasing water temperatures and precipitation patterns that increase flooding, prolong droughts, or reduce stream flows (Nobles and Zhang 2011).

An increase in the number of days with heavy precipitation over the next 25 to 35 years is expected across the Ohio River Basin (<https://science2017.globalchange.gov/chapter/7/>). As mentioned in the Poff *et al.* (2002) report on Aquatic Ecosystems and Global Climate Change, impacts of climate change on aquatic systems can potentially include:

- Increases in water temperatures that may alter fundamental ecological processes, thermal suitability of aquatic habitats for resident species, and their geographic distribution.
- Changes and shifts in seasonal patterns of precipitation and runoff, which can alter the hydrology of stream systems, affecting species composition and ecosystem productivity. Aquatic organisms are sensitive to changes in frequency, duration, and timing of extreme precipitation events such as floods or droughts, potentially resulting in interference of reproduction. Further, increased water temperatures and seasonally reduced streamflow can alter many ecosystem processes, including increases in nuisance algal blooms.
- Cumulative or synergistic impacts that can occur when considering how climate change may be an additional stressor to sensitive freshwater systems, which are already adversely affected by a variety of other human impacts, such as altered flow regimes and deterioration of water quality.

- Adapting to climate change may be limited for some aquatic species depending on their life history characteristics and resource needs. Reducing the likelihood of significant impacts would largely depend on human activities that reduce other sources of ecosystem stress to ultimately enhance adaptive capacity, which could include, but not be limited to: maintaining riparian forests, reducing nutrient loading, restoring damaged ecosystems, minimizing groundwater and stream withdrawal, and strategically locating any new reservoirs to minimize adverse effects.
- Changes in presence or combinations of native and nonnative, invasive species could result in specific ecological responses to changing climate conditions that cannot be easily predicted at this time. These types of changes (e.g., increased temperatures that are more favorable to a nonnative, invasive species compared to a native species) can result in novel interactions or situations that may necessitate adaptive management strategies.
- Shifts in mussel community structure, which can stem from climate-induced changes in water temperatures since sedentary freshwater mussels have limited refugia from disturbances such as droughts and floods, and since they are thermo-conformers whose physiological processes are constrained by water temperature within species-specific thermal preferences (Galbraith et al. 2010).

Drought combined with limited habitat and small population sizes can potentially threaten the Rough Pigtoe. Haag and Warren (2008) found that impacts from severe drought were correlated to watershed size, with small streams suffering declines of 65-83%, while the larger streams (larger buffering capacity) showed less significant change in pre- and post-drought abundances. Droughts can have negative impacts on water quality (e.g., dissolved oxygen) and waste dissemination of point source discharges. Droughts may also reduce the amount of habitat available to mussels through dewatering and that may also cause direct mortality by stranding mussels. Drought may also fragment sections of stream into isolated pools. However, in some cases, droughts can also concentrate host fish and therefore, increase the probability of glochidia (larval mussel) to host contact.

D. Synthesis

Populations of the Rough Pigtoe currently exist in portions of the Clinch, Tennessee, Cumberland, Green, Barren, and Licking rivers. The species was observed in the East Fork White River in Indiana in 1992, but the species has not been observed there since that time. Currently, the Clinch (Tennessee) and Green (Kentucky) rivers represent the only populations with evidence of successful reproduction.

Rough Pigtoe mussels typically do not exist in populations large enough to support translocation. However, recent host trials may provide hope that propagation can be

successful in producing juvenile mussels for recovery actions (reintroductions at extirpated sites or augmentation of existing populations). As such, future reintroductions, augmentations, and translocations of individuals will likely be accomplished through introductions of captively-propagated juveniles.

Numerous threats persist for Rough Pigtoe populations, including habitat alteration (e.g., impoundments), land use changes, competition from invasive species, large-scale die-offs and subsequent small population size, and point and non-point source pollution. Due to these threats and the species' limited distribution and small population size, the Rough Pigtoe mussel continues to meet the definition of endangered. The species continues to show declines; it is limited to only a few small populations, with evidence of reproduction in only the Clinch River and Green River; it continues to be influenced by high magnitude threats; and the criteria for delisting or downlisting have not been met. The recovery priority number for the Rough Pigtoe should remain at 5, as the species has a high degree of threat and a low recovery potential.

III. RESULTS

A. Recommended Classification:

 X No change is needed

IV. RECOMMENDATIONS FOR FUTURE ACTIONS

The following recovery actions should be undertaken to help achieve recovery for the species:

- 1) Continue life history studies and determine suitable hosts for captive propagation and culture techniques, including 'in vitro' transformation of the glochidia.
- 2) Develop a captive propagation/reintroduction plan for the species:
 - a. Captive holding of Rough Pigtoe mussels may provide additional options for the species' recovery and re-establishment into historic habitat. Captive husbandry methods should be developed.
 - b. An assessment of historic habitat should be completed to identify sites where Rough Pigtoe mussel augmentation and re-establishment can be achieved. Restoration of these habitats should be made a priority to support this activity.
 - c. Implement the plan by reintroducing the species into historic habitats and augmenting populations as appropriate.
- 3) Continue monitoring existing populations. More exhaustive surveys are needed in the Barren, Cumberland, and Licking rivers where information about the Rough Pigtoe is lacking.
- 4) Determine target population sizes for recovery of the species within its current range.
- 5) Determine sensitivity of each life stage for selected contaminants that are likely to be found in streams in which this species exists and at potential augmentation and reintroduction sites.

- 6) Through various means of land protection and restoration (land acquisition, best management practices (BMPs), conservation easements), abate non-point source impacts and direct habitat loss.

V. REFERENCES

- Ahlstedt, S.A., M.T. Fagg, R.S. Butler, J.F. Connell, and J.W. Jones. 2016. Quantitative monitoring of freshwater mussel populations from 1979-2004 in the Clinch and Powell River of Tennessee and Virginia, with miscellaneous notes on the fauna. *Freshwater Mollusk Biology and Conservation* 19:1-18.
- AST Environmental. 2017. Protected species survey / relocation year 2 monitoring report, Lacey's Spring docking facility, Tennessee River, Morgan County, AL. Report for project JS15-120. 36 pp.
- Carella, F., G. Villari, N. Maio, and G. De Vico. 2016. Disease and disorders of freshwater Unionid mussels: A brief overview of recent studies. *Frontiers in Physiology* 7:489.
- Carey, C. 2020. Virginia Polytechnic Institute and State University, Blacksburg, Virginia. Unpublished database by email, June 29, 2020.
- Cherry, D. S., J. L. Scheller, N. L. Cooper, and J. R. Bidwell. 2005. Potential effects of Asian clam (*Corbicula fluminea*) die-offs on native mussels (Unionidae) I: water column ammonia levels and ammonia toxicity. *Journal of the North American Benthological Society* 24:369-380.
- Compton, M., B. D. Yahn, and L. T. Phelps. 2017. Preliminary ecological assessment of the Green and Nolin rivers in Mammoth Cave National Park, Kentucky, following the removal of lock and dam #6. Report Prepared by Kentucky State Nature Preserves Commission for U.S. Fish and Wildlife Service, Frankfort, Kentucky. 73 pages.
- Cope, G., and J. W. Jones. 2016. Recent precipitous declines of endangered freshwater mussels in the Clinch River: An in situ assessment of water quality stressors related to energy development and other land-use. Final report. U.S. Fish and Wildlife Service, Cookeville, Tennessee, and Abingdon, Virginia. 244 pp.
- Dinkins, G. 2020. University of Tennessee, McClung Museum of Natural History and Culture. Personal communication by email on June 30, 2020.
- Fisher, B. 2020. Indiana Department of Natural Resources. Indianapolis, Indiana. Personal communication by e-mail, July 31, 2020.
- Galbraith, H. S., D. E. Spooner, and C. C. Vaughn. 2010. Synergistic effects of regional climate patterns and local water management on freshwater mussel communities. *Biological Conservation* 143:1175-1183.

- Garner, J. 2019. *Plethobasus cicatricosus* (White Wartback) search in Wilson Dam tailwater, Tennessee River. Report by the Alabama Department of Conservation and Natural Resources, Florence, AL. 8 pp.
- Grizzle, J. M. and C. J. Brunner. 2009. Infectious diseases of freshwater mussels and other freshwater bivalve mollusks. *Reviews in Fisheries Science* 17:425-467.
- Haag W.R. and M.L. Warren, Jr. 2008. Effects of severe drought on freshwater mussel assemblages. *Transactions of the American Fisheries Society* 137:1165-1178.
- Inoue, K., D. M. Hayes, J. L. Harris, N. A. Johnson, C. L. Morrison, M. S. Eackles, T. L. King, J. W. Jones, E. M. Hallerman, A. D. Christian, and C. R. Randklev. 2018. The Pleurobemini (Bivalvia: Unionida) revisited: molecular species delineation using a mitochondrial DNA gene reveals multiple conspecifics and undescribed species. *Invertebrate Systematics* 32: 689-702.
- Johnson, G. C., J. L. Krstolic, and B. J. K. Ostby. 2014. Influences of water and sediment quality and hydrologic processes on mussels in the Clinch River. *Journal of the American Water Resources Association* 50:878–897.
- Jones, J. W., S. A. Ahlstedt, B. J. K. Ostby, B. Beaty, M. Pinder, N. Eckert, R. S. Butler, D. Hubbs, C. Walker, S. Hanlon, J. Schmerfeld, and R. J. Neves. 2014. Clinch River freshwater mussels upstream of Norris Reservoir, Tennessee and Virginia: A quantitative assessment from 2004–2014. *Journal of the American Water Resources Association* 50:820–836.
- Jones, J. W., N. Johnson, P. Grobler, D. Schilling, R. J. Neves, and E. M. Hallerman. 2015. Endangered Rough Pigtoe Pearlymussel: assessment of phylogenetic status and genetic differentiation of two disjunct populations. *Journal of Fish and Wildlife Management* 6(2): 338-349.
- Jones, J., T. Lane, B. Ostby, B. Beaty, S. Ahlstedt, R. Butler, D. Hubbs, and C. Walker. 2018. Collapse of the Pendleton Island mussel fauna in the Clinch River, Virginia: setting baseline conditions to guide recovery and restoration. *Freshwater Mollusk Biology and Conservation* 21:36-56.
- Krstolic, J. L., G. C. Johnson, and B. J. K Ostby. 2013. Water quality, sediment characteristics, aquatic habitat, geomorphology, and mussel population status of the Clinch River, Virginia and Tennessee, 2009– 2011. U.S. Geological Survey Data Series 802. 14 p. Appendix tables A1–A25 (Excel). Available at <http://pubs.usgs.gov/ds/0802/>. Accessed July 1, 2017.
- Lane, T. W., T. C. Leach, S. L. Colletti, and J. F. Ferraro. 2021. Fish host identification for five endangered short-term brooder mussel species. Final report of Virginia Department of Game and Inland Fisheries, Aquatic Wildlife Conservation Center, submitted to U.S. Fish and Wildlife Service, Southwest Virginia Field Office. Grant Award F18AP00098. 69 pp.
- Lane, T. W. 2020a. Virginia Department of Game and Inland Fisheries, Aquatic Wildlife

- Conservation Center. Personal communication by phone on May 29, 2020.
- Lane, T. W. 2020b. Virginia Department of Game and Inland Fisheries, Aquatic Wildlife Conservation Center. Personal communication by email July 6, 2020.
- Laudermilk, E. L. 1993. A survey of the unionids (Bivalvia: Unionidae) of the mainstem Licking River and selected tributaries below Cave Run Reservoir, Kentucky. MS Thesis, Eastern Kentucky University, Richmond, Kentucky. 71 pp.
- Leis, E., S. Erickson, D. Waller, J. Richard and T. Goldberg. 2019. A comparison of bacteria cultured from unionid mussel hemolymph between stable populations in the Upper Mississippi River and a mortality event in the Clinch River. *Freshwater Mollusk Biology and Conservation* 22(2):70-80.
- Lewis, C. 2008. Mussel Survey at Barren River Miles 7.7, 9.7, 12, and 14. Report Prepared by Lewis Environmental Consulting, LLC, for Gulfstar, LLC, Morgantown, Kentucky. 85 pp.
- . 2011. 2010 Mussel Survey of Green River Pools 2, 3, and 4. Report Prepared by Lewis Environmental Consulting, LLC, for U.S. Army Corps of Engineers, Louisville, Kentucky. 201 pp.
- . 2013. 2012 Mussel Survey of Green River Pool 4, Butler and Warren Counties, Kentucky. Report Prepared by Lewis Environmental Consulting, LLC, for U.S. Fish and Wildlife Service, Frankfort, Kentucky. 46 pp.
- . 2017a. Mussel Survey of Green River Pool 5 in Butler, Warren, and Edmonson Counties, Kentucky, 2017. Report Prepared by Lewis Environmental Consulting, LLC, for U.S. Fish and Wildlife Service, Frankfort, Kentucky. 72 pp.
- . 2017b. Endangered Mussel Species Survey within Mammoth Cave National Park in Edmonson County, Kentucky, 2017. Report prepared by Lewis Environmental Consulting, LLC, for U.S. Fish and Wildlife Service, Frankfort, Kentucky. 24 pp.
- . 2017c. Collection of Orangefoot Pimpleback mussels (*Plethobasus cooperianus*) from the Tennessee River to be used for propagation at the KDFWR Center for Mollusk Conservation. Report prepared by Lewis Environmental Consulting, LLC, for U.S. Fish and Wildlife Service, Frankfort, Kentucky. 8 pp.
- . 2019. Mussel Survey of The Green River Downstream of Lock and Dam 5 Butler and Warren Counties, Kentucky, 2019. Report Prepared by Lewis Environmental Consulting, LLC, for U.S. Fish and Wildlife Service, Frankfort, Kentucky. 65 pp.
- McGregor, M., A. C. Shepard, C. Owen, T. Bailey, A. McDonald, F. Vorisek, and D. Cravens. 2015. Community changes in a freshwater mussel bed from 2004 to 2014 in the Green River, Kentucky. *Annual Research Highlights 2014*, Kentucky Department of Fish and Wildlife Resources. 38 pp.
- McGregor, M. 2020. Kentucky Department of Fish and Wildlife Resources, Center of

- Mollusk Conservation. Personal communication by email on March 2, 2020.
- Nico, L. G., P. Fuller, and J. Li. 2020a. *Hypophthalmichthys molitrix* (Valenciennes in Cuvier and Valenciennes, 1844): U.S. Geological Survey, Nonindigenous Aquatic Species Database, Gainesville, FL, <https://nas.er.usgs.gov/queries/FactSheet.aspx?speciesID=549>, Revision Date: 12/3/2019, Peer Review Date: 1/22/2015, Access Date: 7/23/2020
- Nico, L., P. Fuller, and J. Li. 2020b. *Hypophthalmichthys nobilis* (Richardson, 1845): U.S. Geological Survey, Nonindigenous Aquatic Species Database, Gainesville, FL, <https://nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=551>, Revision Date: 12/3/2019, Peer Review Date: 1/22/2015, Access Date: 7/23/2020
- Nico, L.G., and M.E. Neilson. 2020. *Mylopharyngodon piceus* (Richardson, 1846): U.S. Geological Survey, Nonindigenous Aquatic Species Database, Gainesville, FL, <https://nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=573>, Revision Date: 10/1/2019, Peer Review Date: 3/15/2012, Access Date: 7/23/2020.
- Nobles, T., and Y. Zhang. 2011. Biodiversity Loss in Freshwater Mussels: Importance, Threats, and Solutions. Chapter 6 (pp. 137-162) in Biodiversity Loss in a Changing Planet, edited by O. Grillo and G. Venora (2011). InTech, Rijeka, Croatia. 328 pp.
- Parmalee, P. W., A. E. Bogan. 1998. The freshwater mussels of Tennessee. University of Tennessee Press, Knoxville, Tennessee. 328 pp.
- Poff, N. L., M. M. Brinson, and J. W. Day, Jr. 2002. Aquatic ecosystems and Global climate change: Potential Impacts on Inland Freshwater and Coastal Wetlands Ecosystems in the United States. Pew Center on Global Climate Change. 56 pp.
- Price, J. E., C. E. Zipper, J. W. Jones, and C. W. Frank. 2014. Water and sediment quality in the Clinch River of Virginia and Tennessee, 1964–2010. *Journal of the American Water Resources Association* 50:837–858.
- Richard, J. C., E. Leis, C. D. Dunn, R. Agbalog, D. Waller, S. Knowles, J. Putnam, and T. L. Goldberg. 2020. Mass mortality in freshwater mussels (*Actinonaias pectorosa*) in the Clinch River, USA, linked to a novel densovirus. *Scientific Reports* 10, Article number: 14498.
- Scheller, J. L. 1997. The effects of die-offs of Asian Clams (*Corbicula fluminea*) on native freshwater mussels (Unionidae). M.S. Thesis. Virginia Polytechnic Institute and State University. 100 pp.
- Tennessee Wildlife Resources Agency (TWRA). 2008. 2008 TWRA Cumberland River survey. Unpublished Report, Nashville, Tennessee. 3 pp.
- U.S. Fish and Wildlife Service (Service). 1984. Rough Pigtoe Pearly Mussel Recovery Plan. Atlanta, Georgia., 51 pp.

- . 2014. Rough Pigtoe (*Pleurobema plenum*) 5-Year Review: Summary and Evaluation. 17 pp.
- Waller, D. L. and W. G. Cope. 2019. The status of mussel health assessment and a path forward. *Freshwater Mollusk Biology and Conservation* 22:26-42.
- Watters, G. T., M. A. Hoggarth, and D. H. Stansbery. 2009. The freshwater mussels of Ohio. The Ohio State University Press, Columbus, Ohio. 421 pp.
- Weiss, J. L., and J. B. Layzer. 1983. Seasonal and spatial variation in glochidial infections of fish in the Barren River, Kentucky. Pages 72-75 in K.S. Cummings, A.C. Buchanan, and L.M. Koch, eds. Conservation and management of freshwater mussels. Proceedings of a UMRCC symposium, 12-14 October 1992, St. Louis, Missouri. Upper Mississippi River Conservation Committee, Rock Island, Illinois.
- Williams, J. D., A. E. Bogan, R. S. Butler, K. S. Cummings, J. T. Garner, J. L. Harris, N. A. Johnson, and G. T. Watters. 2017. A revised list of the freshwater mussels (Mollusca: Bivalvia: Unionida) of the United States and Canada. *Freshwater Mollusk Biology and Conservation* 20:33–58.
- Zipper, C. E., B. Beaty, G. C. Johnson, J. W. Jones, J. Krstolic, B. J. K. Ostby, and W. Wolfe. 2014. Freshwater mussel population status and habitat quality in the Clinch River, Virginia and Tennessee, USA: A featured collection. *Journal of the American Water Resources Association* 50:807–819.

U.S. FISH AND WILDLIFE SERVICE
5-Year Review of Rough Pigtoe (*Pleurobema plenum*)

Current Classification: Endangered.

Recommendation resulting from the 5-Year Review:

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

Review Conducted By: Anthony Ford and Santiago Martín, Tennessee Ecological Services Field Office and Mike Floyd, Kentucky Ecological Services Field Office.

FIELD OFFICE APPROVAL:

Lead Field Supervisor, Fish and Wildlife Service

Approve _____ Date May 10, 2021

*Since 2014, Southeast Region Field Supervisors have been delegated authority to approve 5-Year Reviews that do not recommend a status change.

OTHER REGIONAL OFFICE APPROVAL:

We emailed this 5-Year Review to the following regional and/or field offices for their concurrence prior to finalizing the document: Great Lakes and North Atlantic-Appalachian regions. We will retain any comments that we received, as well as verification of concurrence from other regions, in the administrative record for this 5-Year Review.

APPENDIX A: Summary of peer review for the 5-Year Review of *Pleurobema plenum*

Peer Review Method:

This 5-year review was not considered to be “influential” under the Service’s policy for Information Quality Guidelines and Peer Review. Therefore, no external peer review was conducted.

Public Comments:

We received the following comments from the National Council for Air and Stream Improvement, Inc. (NCASI) on August 19, 2019: 1) forestry best management practices (BMPs) are implemented at high rates nationally and in the ranges of the Rough Pigtoe, 2) forestry BMPs are effective for protecting water quality and habitat for at-risk species, 3) forestry BMPs are effective for protecting aquatic biota, and 4) contributions of forestry BMPs to conservation of aquatic organisms has previously been recognized by the Service.

The comments submitted by NCASI are the same as other public comments the organization has made for other aquatic species (e.g. Bluemask Darter, Slender Chub, Duskytail Darter, and Snail Darter). In this 5-year review, we discuss threats from stream inflows of sediment due to resource extraction, agricultural practices, and urbanization (see in Section II.C.2.a.). However, we did not identify forestry as a threat for this species because we have not observed instances where forestry practices have threatened the species.

APPENDIX B

Table 2: Rough Pigtoe extant populations in the Ohio River Basin.

¹ Stream / Reach or Tributary within the stream	Year of Last Live or Fresh Dead Observation	² Year of Last Known Survey	³ Evidence of juveniles \leq 5 yrs	⁴ Population Size	⁵ Estimated number of occupied river miles	⁶ Current Population Trend	Notes
Barren River (KY)	2008	2008	No	Small	~ 14	Unknown	
Green River (KY)	2019	2019	Yes	Medium	~ 102	Stable	Potential for range expansion following removal of GR L&D 5, 6 and BR L&D 1
<i>From Green River Lake Dam to former GR L&D 6</i>	2019	2019	No	Small	30	N/A	KDFWR translocated 33 Rough Pigtoe mussels to a long-term monitoring site upstream of Munfordville, KY in 2009 from the population in the tailwaters of GR L&D 5. No evidence of recruitment or individuals were found in the 2014 and 2019 monitoring efforts.
<i>Former GR L&D 6 tailwater to GR L&D 5</i>	N/A	2017	No	N/A	0		Rough Pigtoe has never been reported in this area since this section of the Green River was impounded.
<i>GR L&D 5 tailwater to former GR L&D 3, including area from BR L&D 1 tailwaters to the confluence of the Barren and Green rivers</i>	2012	2012	Yes	Large	73		GR L&D 4 washed out in May 1965. Original pool extended for 19 miles from GR L&D 4 to 5, and included the lower 14 miles of the Barren River up to BR L&D 1.
<i>Downstream of GR L&D 3</i>	2010	2010	No	Small	2		
Licking River (KY)	2019	2019	No	Small	Unknown	Unknown	First observed by Stansbery and Stein in 1963 as a relic shell (OSUM 1963:0081, Catalog #8458). Also seen by Tiemann, Ahlstedt, and Butler in 2012 (INHS 43752). KDFWR translocated 10 adult individuals from the Green River in 2016 to a site near Clay WMA
Cumberland River (TN)	2008	2008	No	Small	1	Unknown	Mussel Survey in the Rome Ferry sanctuary (CRM 292.5 to CRM 313.5; TWRA 2008)

Tennessee River (AL, KY, TN)	2018	2018	No	Small	< 3	Declining	
<i>Pickwick Dam tailwater (TN)</i>	1982	2017	No	Unknown	N/A	N/A	
<i>Wilson Dam tailwater (AL)</i>	2018	2018	No	Small			18 individuals observed by J. Garner (2019)
<i>Guntersville Dam tailwater (AL)</i>	2017	2017	No	Small			1 Individual (TL 58 mm) collected by ATS Environmental
Clinch River (TN, VA)	2019	2019	Yes	Medium	~ 18	Declining	
<i>Kyles Ford (TN)</i>	2018	2019	Yes	Small	N/A	N/A	Mussel die-offs observed in the last 4 years near the TN/VA border. A total of 262 dead Rough Pigtoe mussels have been collected
<i>Brooks Island (TN)</i>	2004	2004	Unknown	Small			
<i>Frost Ford (TN)</i>	2019	2019	Yes	Medium			
<i>Swan Island (TN)</i>	2014	2019	Unknown	Small			
East Fork White River (IN)	1992	1992	Unknown	Unknown	Unknown	Unknown	

¹**Stream:** Extant populations by stream are presented in bold, with information further summarized for individual occupied stream segments (non-bold text), where applicable (e.g., if data were notably dissimilar in different stream segments).

²**Year of Last Known Survey:** Estimated based on available information.

³**Evidence of Juveniles:** Evidence of individuals ≤ 5 years old during last survey.

⁴**Population Size:** We categorized the extant populations (typically, occupying distinct river segments) trends into four groups.

Small: 5 or fewer individuals observed during most recent surveys.

Medium: 6-29 individuals observed during most recent surveys.

Large: 30-74 or more individuals observed during most recent surveys.

Extra Large: 75 or more individuals observed during most recent surveys.

Unknown: Insufficient evidence to place population into a size category.

⁵**Estimated number of occupied river miles:** Derived from communication with local resource professionals or applying an approximately one-river mile buffer to the up- and downstream most collection records.

Unknown: not enough data to make judgement on the species occupancy

N/A: an estimate of occupied river miles is not applicable for small reaches or sampling sites.

⁶**Current Population Trend:** Trends were determined by professional opinion and other gathered information, and do not necessarily represent statistically significant analyses.

Increasing: Evidence that the numbers of individuals have been on a significantly increasing trend over the past 20 years or more.

Stable: Evidence that the numbers of individuals have remained relatively stable over the past 20 years.

Declining: Evidence that the numbers of individuals have been on a significantly decreasing trend over the past 20 years or more.

Unknown: Insufficient evidence to estimate trends.