Alabama pearlshell
(*Margaritifera marrianae*)

5-Year Review:
Summary and Evaluation

Photo credit: James D. Williams

May 2023

U.S. Fish and Wildlife Service
Southeast Region
Alabama Ecological Services Field Office
Daphne, Alabama

5-YEAR REVIEW
Alabama pearlshell (*Margaritifera marrianae*)

I. GENERAL INFORMATION

A. Methodology used to complete the review:

While conducting this 5-year review, we relied on the best available information pertaining to historical and current distributions, life history, genetics, habitats, and potential threats to this species. We announced this review and requested information in a published *Federal Register* (FR) notice with a 60-day comment period in May 2018 (83 FR 20092).

There were no comments received during the public comment period. This review was completed by the U.S. Fish and Wildlife Service (Service), Alabama Ecological Services Field Office (AFO), Daphne, Alabama. The primary sources of information used in this analysis were the 2012 final rule listing this species under the Endangered Species Act (77 FR 61663), peer-reviewed scientific publications, unpublished survey data and reports, and personal communications with recognized experts. All literature and documents used for this review are on file at the AFO. All recommendations resulting from this review are the result of thoroughly reviewing the best available information on the Alabama pearlshell. Comments and suggestions received from peer reviewers outside of the Service were evaluated and incorporated as appropriate (see Appendix A).

B. Reviewers

Lead Region:

Southeast Region, Atlanta, Georgia:
Carrie Straight, 404-679-7226

Lead Field Office:

Alabama Ecological Services Field Office (ESFO), Daphne, AL:
Erin Padgett, 251-441-5842
Morgan Brizendine, 251-441-5839

C. Background

1. Federal Register Notice citation announcing initiation of this review
May 7, 2018. 83 FR 20092

2. Listing History
Original Listing
FR notice: 77 FR 61663
Date listed: October 10, 2012
Entity listed: Species
Classification: Endangered

3. **Associated Rulemakings**
   Critical Habitat
   Critical habitat was designated in Big Flat Creek, Burnt Corn Creek, Murder Creek, and Sepulga River and published along with the original listing rule on October 10, 2012 (77 FR 61663).

4. **Review History**
   Historically, the Service reviews and updates listed species information for inclusion in its Recovery Report to Congress. Through 2016, we performed a recovery data call that assigned Recovery Priority Number 5, which represents a high degree of threat with low recovery potential, for this species. Each year the AFO generally assesses any completed activities and critical species needs.

   This document represents the first 5-year review for this species.

5. **Species' Recovery Priority Number at start of review (48 FR 43098)**
   Recovery Priority Number: 5
   Entity: Species
   Threat: High
   Recovery Potential: Low

6. **Recovery Plan or Outline**
   Title: Recovery Outline for Alabama Pearlshell, Round Ebonyshell, Southern Kidney, Choctaw Bean, Tapered Pigtoe, Narrow Pigtoe, Southern Sandshell, and Fuzzy Pigtoe.

   Date: November 13, 2012.

II. REVIEW ANALYSIS

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

Not applicable. The Endangered Species Act (ESA) defines species as including any subspecies of fish or wildlife or plants and any distinct population segment of any species of vertebrate wildlife. This definition limits listing DPSs to only vertebrate species of fish and wildlife. Because the Alabama pearlshell is an invertebrate and is not covered by the DPS policy, it will not be discussed further.

B. Recovery Criteria

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

   No. A recovery outline was prepared for this mussel in 2012. As of this review, a recovery plan for Alabama pearlshell has not yet been finalized.

C. Updated Information and Current Species Status

Detailed information on the Alabama pearlshell's biology, habitat, abundance, and threats are outlined in the final listing rule (77 FR 61663; Service 2012). Details below are provided for summary information, new information, and to provide context for the species status since its listing in 2012.

1. Biology and Habitat

a. Biology and life history:

The Alabama pearlshell is a freshwater mussel endemic to select tributaries in the Alabama River and Conecuh/Escambia River basins located in south central Alabama (Figure 1). Its shell is medium in size, and this species grows up to 95 millimeters (3.7 inches) in length with an oblong outline (Johnson 1983, see cover image). It ranges in coloration from olivaceous or blackish brown to yellowish brown (Johnson 1983). The inside nacre or shell layer is white to purplish and moderately iridescent (Johnson 1983).

Although little is known about the life history of Alabama pearlshell, some surveys of the mussel have identified a propensity for them to occur in male/female pairs (Shelton 1996). However, this species is not known as sexually dimorphic or to exhibit characteristics not related to reproduction that visually differentiate male and female individuals (Williams et al. 2008). Field observations and laboratory propagation trials conducted by the Alabama Department of Conservation and Natural Resources' (ADCNR) Alabama Aquatic Biodiversity Center (AABC), concluded that brooding and gravidity appear to occur in early to mid-March (Fobian et al. 2018). In 2017, AABC's entire propagation population expired when water temperatures exceeded 31 ℃ (87.8 °F; Fobian et al. 2018). This unfortunate event identified a vital thermal threshold for the Alabama pearlshell and will factor into future conservation plans for the mussel. AABC also identified the redfin pickerel (*Esox americanus*) (Fobian et al. 2018) and chain pickerel (*Esox niger*) (Fobian et al. 2019) as good laboratory host fishes for Alabama pearlshell, and speckled madtom (*Noturus leptacanthus*) as a marginally successful host fish (Fobian et al. 2013). These three species overlap with the range of Alabama pearlshell and are relatively common and widespread below the Fall Line in Alabama (Boschung and Mayden 2004).

b. Abundance, population trends, demographic features, or demographic trends:

Since its first known collection in the early 1900s to the time of this review, the Alabama pearlshell has only been found in the Alabama and Conecuh/Escambia River basins in south central Alabama (Figure 1). The range of this species, including historic and current populations, is comprised of 16 streams located in four counties in Alabama:

- Monroe County: Big Flat Creek, Brushy Creek, and Limestone Creek
- Conecuh County: Autrey Creek, Beaver Creek, Bottle Creek, Burnt Corn Creek, Gin Creek, Hunter Creek, Jordan Creek, Little Cedar Creek, Murder Creek, Otter Creek, and Sandy Creek

- Escambia County: Amos Mill Creek
- Crenshaw County: Horse Creek

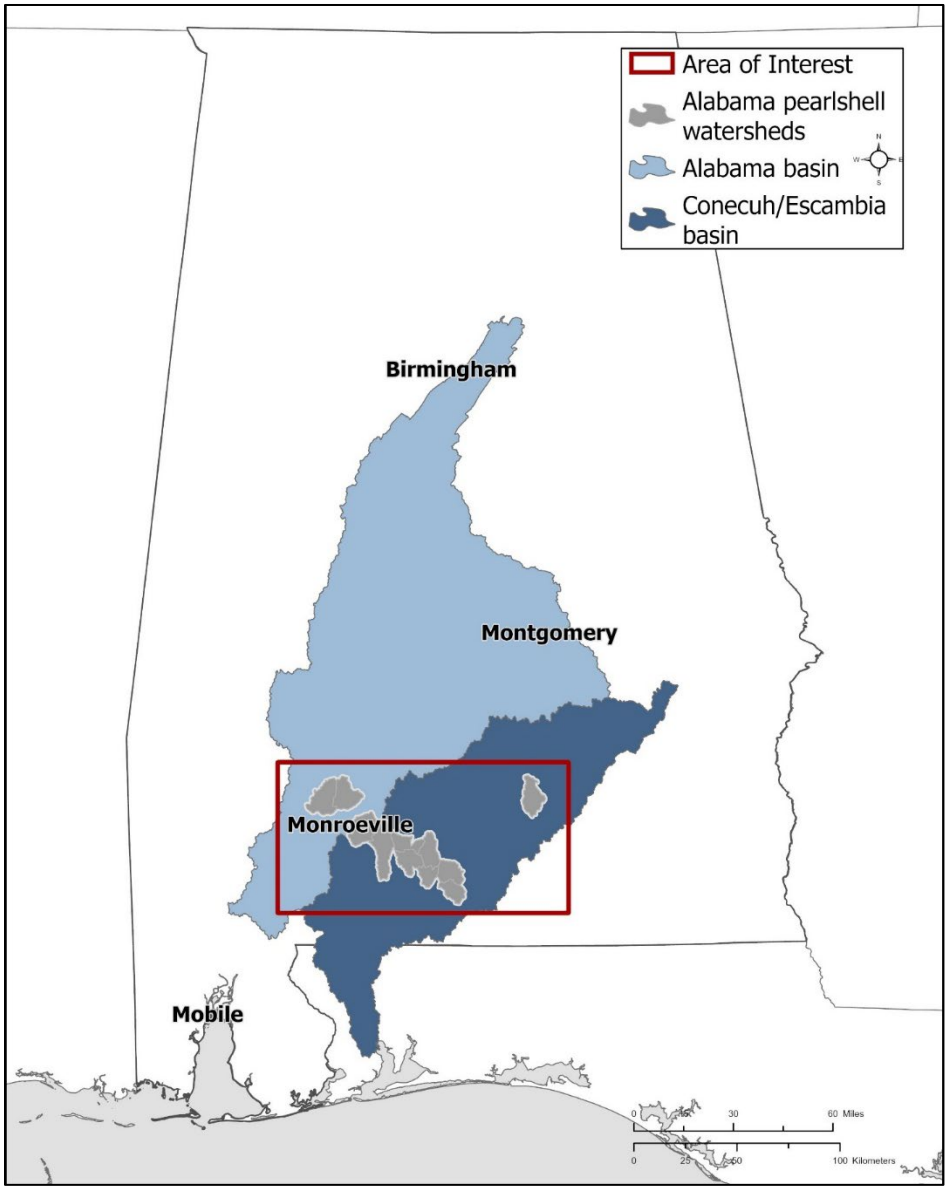

Figure 1. The Alabama River basin, Conecuh/Escambia River basin, and Alabama pearlshell watersheds within Alabama. Created by the Alabama Ecological Services Field Office.

For this species, we delineate populations by sub-watershed, which includes specific streams and their tributaries, as noted below. No genetic studies have been conducted at this time to assess gene exchange and dispersal of host fishes. We will incorporate any new information as it is received to update the population structure.

The following paragraphs summarize the population status by historical (extirpated) and current stream occurrence (Table 1). Maps identifying both the historical and current species occurrences are presented in Figures 2 and 3. Populations are considered extirpated if no live or freshly dead individuals, weathered dead shells, or relic shells have been collected from the stream over the last 20 years. Although evidence of relic and weathered dead shells may not indicate the presence of a population, it does indicate likely continued presence of individuals in the stream.

In the 2012 listing rule, the Service identified 16 populations of Alabama pearlshell and classified seven populations as historical and nine as occupied. Since survey efforts have not documented presence of the species in the Alabama River basin since 1995, we believe the Alabama pearlshell is most likely extirpated from the basin, which includes the loss of the Big Flat Creek population. In the Conecuh/Escambia River basin, Bottle Creek may be an extirpated population due to its lack of recorded individuals since 1999. However, three relic shells were collected from Ard Creek, a tributary to Bottle Creek that is considered part of the Bottle Creek population, in 2021 which may indicate continued presence of Alabama pearlshell downstream in Bottle Creek. A relic shell was collected in Horse Creek in the Conecuh/Escambia River basin in 2019, which indicates presence of Alabama pearlshell in this system. As of this review, seven populations are considered extirpated, and nine are considered current or likely to have live individuals still present. The status of three current populations, including Bottle, Burnt Corn, and Horse creeks, is based solely on records of weathered dead or relic shells. The status of the remaining current populations was based on records of live individual records; however, most surveys or observations recorded less than 10 live individuals. Surveys of Jordan, Little Cedar, and Sandy creeks have documented higher numbers of adults and presence of gravid females which indicate that these populations may be the largest and most stable. Details on each population can be found below.

Alabama River Basin Populations

Big Flat Creek—The first and only known record of Alabama pearlshell from Big Flat Creek was a freshly dead individual found in 1995 at the State Highway 41 crossing northwest of Monroeville (Shelton 1995). The 2012 listing rule considered this population current. However, since the last known specimen was collected from this system over 25 years ago, and no live mussels or shells were collected by ADCNR during site surveys from 2010-2013 and in 2017 (Fobian et al. 2018), we now consider this population extirpated.

Brushy Creek—The first recorded collection of three individuals from Brushy Creek occurred in 1917 by C.A. Burke (UMMZ 2019). No known collections have been made since that time. Because of limited recent collections, the 2012 listing rule considered this population historical. The Service still considers this population extirpated.

Table 1. Summary of the Alabama pearlshell's historical and current populations.

Table 1a. Populations in the Alabama River Basin.

Population	2012 Listing Rule Status (Service 2012)	Most Recent Observation (Year / Type)	2021 Status
Big Flat Creek	Current	1995 / Relic	Extirpated
Brushy Creek	Historical	1917 / Unknown	Extirpated
Limestone Creek	Historical	1991 / Relic	Extirpated

Table 1b. Populations in the Conecuh/Escambia River Basin.

Population	2012 Listing Rule Status (Service 2012)	Most Recent Observation (Year / Type)	2021 Status
Amos Mill Creek	Current	2019 / Live	Current
Autrey Creek	Historical	1964 / Unknown	Extirpated
Beaver Creek	Historical	1910 / Unknown	Extirpated
Bottle Creek	Current	2021 / Relic	Current
Burnt Corn Creek	Current	2010 / Relic	Current
Gin Creek	Historical	Historical / Relic	Extirpated
Horse Creek	Historical	2019 / Relic	Current
Hunter Creek	Current	2019 / Relic	Current
Jordan Creek	Current	2021 / Live	Current
Little Cedar Creek	Current	2021 / Live	Current
Murder Creek	Historical	Historical / Unknown	Extirpated
Otter Creek	Current	2019 / Live	Current
Sandy Creek	Current	2018 / Live	Current

Limestone Creek—J. D. Williams first reported the Alabama pearlshell as commonly found in Limestone Creek in 1974 (Service 2012). In 1991, he recorded two shell fragments at the Monroe County Road 20 crossing. He also reported the site contained an excessive amount of sand along with the occurrence of numerous other mussel species (J. D. Williams unpublished data). We still agree with the listing document that this population is extirpated.

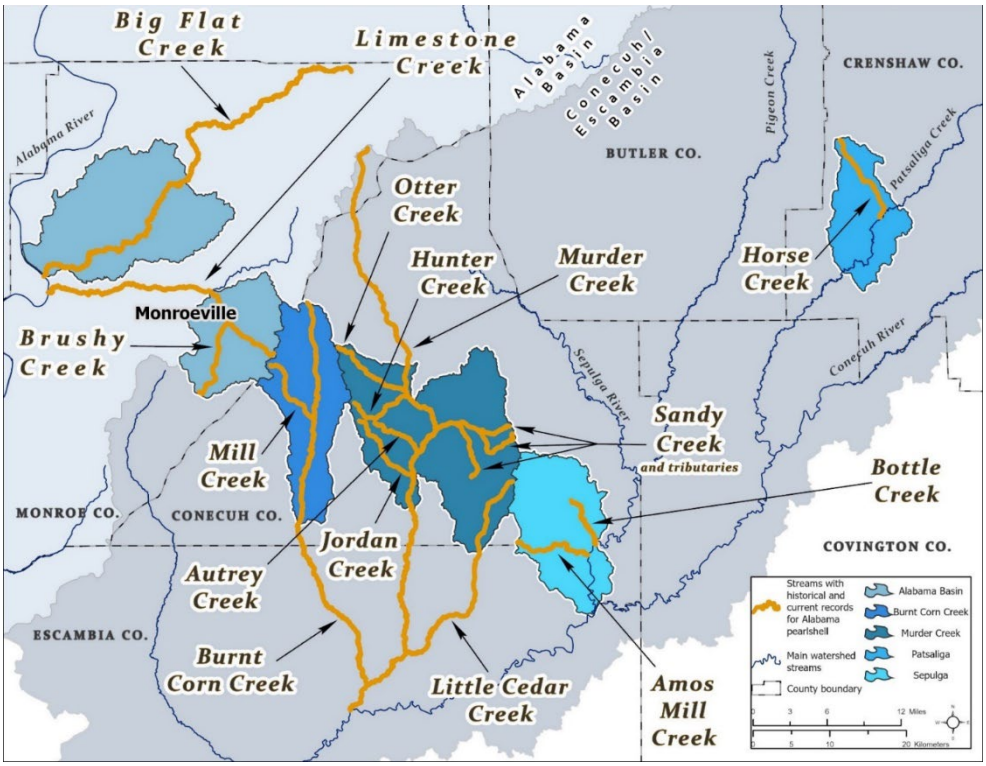

Figure 2. Known historic and current range of the Alabama pearlshell.

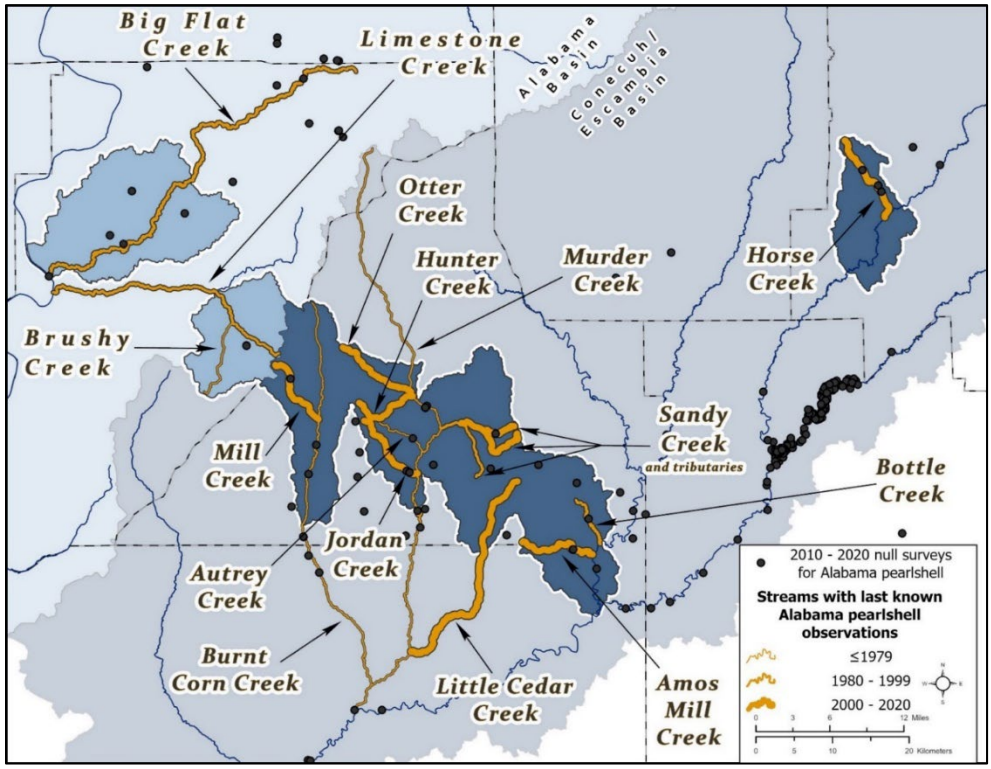

Figure 3. Known stream range of the Alabama pearlshell delineated by last known observation. Circles represent surveys conducted between 2010 and 2017 where no Alabama pearlshells were found (unpublished data).

Conecuh/Escambia River Basin Populations

Amos Mill Creek (includes Polly Creek)—Three individuals and several relic shells were discovered in Amos Mill Creek at the Escambia County Road 69 crossing in 2010 by J. Powell and A. Ford, Service biologists (Service 2012). This record was the first report of Alabama pearlshell in this stream (Service 2012). Todd Fobian, ADCNR biologist, documented their presence again in 2017 (Fobian et al. 2018) and in 2019 (T. Fobian pers. comm. 2021). One living and one weathered dead individual were observed by E. Spadgenske and E. Padgett, Service, in 2019 (Spadgenske, Service, pers. obs. 2019). T. Fobian also collected two live Alabama pearlshell and 15 weathered dead and relic shells in Polly Creek, a tributary to Amos Mill Creek in 2021 (Fobian et al. 2021). Due to these collections, we consider this population current.

Autrey Creek—The only known collection of Alabama pearlshell in Autrey Creek was in 1964 by H.D. Athearn and J.P.E. Morrison (specimen MFM 11645) (NCSM 2019). We consider this population extirpated.

Beaver Creek—The only known collection of Alabama pearlshell from Beaver Creek was in 1910 by H.H. Smith (specimen ANSP 100570; ANSP 2019). Beaver Creek was recorded as located in Conecuh County, but its locations cannot be verified and are not included on the maps in this document. A historical map from 1837 from the Alabama Department of Archives and History indicates the southern branch of Sandy Creek was called Beaver Creek; however, we have not included Beaver Creek in the Sandy Creek population because of the uncertainty of its exact location. Alabama pearlshell is considered extirpated in Beaver Creek.

Bottle Creek (includes Ard Creek)—Relic shells were first reported for Bottle Creek in the 1990s. J.D. Williams found one shell in 1995 (J.D. Williams unpublished data) and another in 1999 (McGregor 2000) during site visits at the crossing of County Road 43. Further upstream at County Road 42 crossing, one freshly dead and two weathered dead shells were discovered in 1995 (Shelton 1995) and one relic shell in 1999 (McGregor 2000). A. Ford and J. Powell failed to find any live Alabama pearlshell or relics in 2010 (Powell, Service, pers. obs. 2019). Three relic shells were collected from Ard Creek, a tributary to Bottle Creek that is considered part of the Bottle Creek population, in 2021 which may indicate continued presence of Alabama pearlshell downstream in Bottle Creek (Fobian et al. 2021). Because of the recent shell collections, we consider this population current.

Burnt Corn Creek (includes Mill Creek)—Reports of Alabama pearlshell in Burnt Corn Creek begin in the early 1900s (NCSM, ANSP, UMMZ 2019); however, Alabama pearlshell was not found again until 2010. During this 2010 site visit, one weathered dead shell was located in Mill Creek, a tributary to Burnt Corn Creek, two miles south of Bermuda on Langham Road (Fobian et al. 2018). Therefore, Burnt Corn Creek was listed as a current population in 2012. We still consider this population current.

Gin Creek —Relic specimens were collected by C.A. Burke at an unknown date in Gin Creek (specimen UMMZ 163701; UMMZ 2019). Burke primarily collected specimens in Alabama from 1915-1918. Current maps show Gin Creek is a tributary to the Sepulga River and is located south of Amos Mill Creek in Escambia County. We assume Gin Creek is a smaller tributary and that these records reflect a more extensive historical presence than current conditions. For the purposes of this document, we have considered this population extirpated.

Horse Creek—C.A. Burke first reported the Alabama pearlshell in 1915 from Horse Creek near Luverne, Alabama (UMMZ 2019), and 12 individuals were found in 1981 by D. Smith (J.D. Williams unpublished data). Since these were the only known records at the time of the Alabama pearlshell's listing, Horse Creek was considered extirpated (Service 2012). However, in both 2016 and 2017, Fobian discovered one weathered dead shell at the crossing of Country Road 35 (Fobian et al. 2013 and Fobian et al. 2018). Another Alabama pearlshell relic was discovered again in 2019 (T.B. Fobian unpublished data), which indicates possible presence of this species in the Horse Creek watershed. Based on these recent findings, we consider this population current.

Hunter Creek—Throughout the 1990s, Hunter Creek near Highway 84 had a well-documented Alabama pearlshell population (Shelton 1995, Shelton 1996, J.D. Williams unpublished data). In 2005, Shelton and Powell found three freshly dead individuals near the bridge crossing (J. Powell, Service, unpublished data 2005). T. Fobian collected one weathered dead shell in 2019 (T. Fobian pers. comm. 2021). Given this data, we consider this population current.

Jordan Creek—In 1982, four individuals were found in Jordan Creek by J.P.E. Morrison (OSU 2019). From 1995-1996, Shelton conducted numerous site visits at the crossings of Highway 31 and County Road 17 (Shelton 1995). Typically, 15-30 individuals, which included a combination of living, freshly dead, and/or weathered dead specimens, were seen during these surveys (Shelton 1995). The individuals were generally found partially exposed in sand and gravel substrates (Shelton 1995). Shelton also noted that the individuals at the Highway 31 crossing appeared smaller, with average shell lengths less than 67 mm long, than the mussels he observed in Hunter Creek (Shelton 1995). Several live individuals were found by Powell and Shelton in 2005 (J. Powell, Service, unpublished data 2005) and by Fobian in 2010 (Fobian et al. 2013). In March 2020, AABC staff found live individuals, including gravid females, approximately 100 m downstream of the train trestle near Jordan Creek's confluence with Murder Creek, which is the furthest downstream Alabama pearlshell have been documented in Jordan Creek. Gravid females from this site were used for production of juveniles in 2020 (P. Johnson, pers. comm. 2020). Live individuals were observed again in 2021 (T. Fobian pers. comm. 2021). We consider this population current.

Little Cedar Creek—Little Cedar Creek supported high numbers of Alabama pearlshell in the 1990s, and 54 individuals were found in 1998 (Service 2012). Surveys for the mussel in subsequent years produced reports of a few specimens in 2005 and 2006 (Service 2012). Six live mussels were found in 2008 (Fobian 2013). Two separate surveys in the spring of 2011 found a combined total of 36 live Alabama pearlshells (Fobian et al. 2013). Sixteen individuals, including nine gravid females, were found in 2016 (Fobian et al. 2018). Individuals from this population contributed to AABC propagation trials in 2019 (Fobian et al. 2019). As of 2019, Little Cedar Creek contained a living and fecund population (E. Spadgenske, Service, pers. obs. 2019). M. Brizendine observed one live individual during a brief site visit in 2021 (Brizendine, Service, pers. obs.). We consider this population current.

Murder Creek—Murder Creek is considered a historical stream for the Alabama pearlshell. At the time of this review, only one known report for this stream has been documented (location and collection date unknown) and is part of the University of Michigan Mollusk Collection (specimen UMMZ 54042; UMMZ 2019). Several of Murder Creek's larger tributaries such as Otter Creek, Hunter Creek, Sandy Creek, and Jordan Creek all contain recent, positive surveys for Alabama pearlshell. This population is still considered extirpated.

Otter Creek—Ten individuals were documented in Otter Creek in 2010 (Fobian et al. 2013) for the first time since 1981 (Service 2012). More individuals were successfully located in this creek in 2012 (Fobian et al. 2018), and two live individuals were observed in 2019 (T. Fobian pers. comm. 2021). Given these findings, we consider this population current.

Sandy Creek—In 1995, Shelton observed a population of Alabama pearlshell in Sandy Creek at the crossing of County Road 29. He noted that they did not appear to be thriving at this location and judged them to be near extirpation from this stream (Shelton 1995). However, a population of more than 50 live individuals were discovered at Sandy Creek's southern branch crossing at Hagood Road by Fobian and Grunewald in 2011 (J. Grunewald, Service, unpublished data). In 2011, one live individual was recorded at another unnamed tributary to Sandy Creek at its northern branch crossing at Hagood Road (Fobian et al. 2013). Two gravid females and one freshly dead subadult shell were found in 2013 at the southern, unnamed tributary (Fobian et al. 2013). During surveys in 2017 and 2018, T. Fobian confirmed presence of populations for the Alabama pearlshell at both the northern and southern branches (Fobian et al. 2018). We consider this population current.

c. Genetics, genetic variation, or trends in genetic variation:
In 2018, the Margaritiferidae family was expanded and redefined (Lopes-Lima et al. 2018). This study confirmed the status of Alabama pearlshell as a separate species from Louisiana pearlshell (*Margaritifera hembeli*) and conducted

molecular clock calculations, which estimate that these species were separated 5-8 million years ago.

d. Taxonomic classification or changes in nomenclature:
Prior to the 1980s, Alabama pearlshell was identified as Louisiana pearlshell, a freshwater mussel now known to be endemic to central Louisiana (Johnson 1983). In 1983, Richard Johnson identified differences in shell morphology between the Alabama pearlshell and Louisiana pearlshell, and subsequently established two distinct species. The ventral margin of Alabama pearlshell is highly curved and displays elaborate sculpture on the posterior slope and disk (Johnson 1983). The ventral margin of Louisiana pearlshell is generally straight and, if any sculpture occurs, it is faintly discernable on the posterior slope and ridge (Johnson 1983). In 2001, Smith included Alabama pearlshell in the genus *Pseudunio* (Haas, 1910) (Smith 2001); however, this classification was not widely accepted because it was based on shell characters and soft anatomy and was not verified with genetic analysis. Since the listing rule in 2012 (Service 2012), a phylogenetics review of the Margaritiferidae family confirmed the status of Alabama pearlshell as a distinct species within the genus *Margaritifera* (Lopes-Lima et al. 2018).

e. Spatial distribution, trends in spatial distribution, or historical range:
Alabama pearlshell is known to historically occur in 16 streams within the Alabama and Conecuh/Escambia River basins (Figures 1, 2, and 3). Our current information documents this species' presence in nine watersheds. We consider these nine watersheds as separate, current populations of Alabama pearlshell (Table 1 and Section 1.b.). Decline of the species has occurred across its range within the past few decades. Biologists from ADCNR conducted extensive survey efforts throughout the historical range of Alabama pearlshell from 2010-2013 and re-surveyed some of these sites in 2017 (Fobian et al. 2018). Of 158 sites surveyed in 72 streams, they documented live Alabama pearlshell at seven sites and weathered dead shells at an additional two sites (Fobian et al. 2018). Since the 2012 listing rule, the lack of positive findings for Alabama pearlshell within the Alabama River basin suggest that these populations may be extirpated. Limited fresh dead or live individuals in Amos Mill Creek, Bottle Creek, Burnt Corn Creek, Horse Creek, and Hunter Creek populations within the Conecuh/Escambia River basin also suggest limited viability of the species in these populations. Although there have been some new records and reaffirmations of populations within the Conecuh/Escambia River basin, Alabama pearlshell has not been documented in many of these streams do not have records since the early 2000s, which may indicate further extirpations of populations in this basin (Table 1).

Figure 2 displays the spatial distribution for the Alabama pearlshell. Figure 3 shows the locations from 2010-2017 of surveys conducted by AABC and Service that found no evidence of Alabama pearlshell presence. The following paragraphs summarize the trends in Alabama pearlshell spatial distribution by basin.

Alabama River Basin

Historical occurrences of Alabama pearlshell have been recorded for Big Flat, Brushy, and Limestone creeks. Brushy and Limestone creeks were considered historical populations in the 2012 listing rule and are still considered extirpated populations. While the 2012 listing rule recognized Big Flat Creek as a current population, it is now considered extirpated.

From the late 1990s to the time of listing, more than 70 locations within the Alabama River basin were surveyed for mollusks with 35 of these locations in the Limestone and Big Flat Creek drainages. No live Alabama pearlshells were reported (Service 2012). During research conducted by AABC from 2010-2013 and in 2017, 26 sites in 14 streams within this basin were surveyed, and no living or relic individuals were collected (Fobian et al. 2018).

The loss of populations in the Alabama River basin reduces the spatial distribution of this species, which makes it more vulnerable to threats like climate change and habitat degradation. Because of the distance and barriers between streams in the Alabama and Conecuh/Escambia River basins and the decline in habitat quality in the Alabama River basin, it is unlikely that Alabama pearlshell will be able to recolonize these streams.

Conecuh/Escambia River Basin

Alabama pearlshell occupy four main drainages in the Conecuh/Escambia River basin, including Burnt Corn Creek, Murder Creek, Sepulga River, and Patsaliga Creek (Figure 1). Surveys conducted by AABC from 2010-2013 and in 2017 were used to help define the spatial distribution within the Conecuh/Escambia River basin in this review. Fobian and AABC also conducted additional surveys at 15 sites in 13 streams throughout the Conecuh River and Escambia River drainage systems. These sites do not have historical records for the Alabama pearlshell but were surveyed to assess reintroduction potential. None of the sites produced any positive surveys for the Alabama pearlshell. These streams included Clear Creek, Folley Creek, Grab Mill Creek, Poley Creek, Teel Creek, Eden Creek, Escambia Creek, Corely Creek, Big Escambia Creek, Camp Creek, Adams Creek, Copeland Creek, and Smith Creek.

At the time of listing, these four drainage systems encompassed 13 populations of Alabama pearlshell, including eight current populations and five extirpated populations. As of this review, one population, Horse Creek, was previously thought to be extirpated but has been reclassified as current. We believe there are nine current and four extirpated populations in the Conecuh/Escambia River basin.

Even though the total number of current populations in the Conecuh/Escambia River basin has remained unchanged, we believe the status of the Alabama pearlshell in this basin is tenuous. The inability of AABC to find evidence of Alabama pearlshell in numerous Conecuh/Escambia River basin streams, the lack

of recent reconfirmation of known populations, and the limited number of live or recently dead shell records indicate a likely reduction in this species' spatial distribution. Fragmentation between populations in this basin can lead to inbreeding and loss of genetic diversity, which can further hinder conservation and recovery efforts.

Burnt Corn Creek Drainage

- *Burnt Corn Creek population*

Burnt Corn Creek system's first record for Alabama pearlshell was in 1910 in the mainstem of Burnt Corn Creek. From 2010-2013, 23 sites in four streams in this drainage system were surveyed. These surveys documented the only other known population of Alabama pearlshell in this drainage, which is located in a tributary called Mill Creek.

Murder Creek Drainage

- *Autrey Creek population*
- *Jordan Creek population*
- *Little Cedar Creek population*
- *Sandy Creek population*
- *Hunter Creek population*
- *Otter Creek population*
- *Murder Creek population*

Murder Creek drainage has historically been included as part of the Alabama pearlshell's spatial range. More recent surveys reaffirm the historical record and have determined locations for this mussel within several large tributaries to Murder Creek. Fobian conducted 25 site surveys within 12 streams in the Murder Creek drainage (Fobian et al. 2018). Four of these streams, including Otter Creek, Jordan Creek, Little Cedar Creek, and Sandy Creek, all contained live individuals (Fobian et al. 2018). Given survey results, this drainage may be the remaining stronghold for this species.

Sepulga River Drainage

- *Amos Mill population*
- *Bottle Creek population*

The Amos Mill Creek population, discovered in 2010, represents the newest population of Alabama pearlshell (Service 2012). It may also represent the only known surviving population in the Sepulga River drainage (Service 2012). The most recent record from Bottle Creek's population was three relic shells from Ard Creek in 2021, which is the only record since 1999. Since 2010, 42 sites in 21 streams connected to the Sepulga River have been surveyed, including one site within Bottle Creek. Amos Mill Creek was the only stream to produce a positive finding for live individuals of this species (Fobian et al. 2018), and the relic shells from Ard Creek are the only other recent records for this drainage.

Patsaliga Creek Drainage

- *Horse Creek population*

Horse Creek within the Patsaliga Creek drainage was considered to only have one historical occurrence for the Alabama pearlshell prior to 2016 (Service 2012). Fobian surveyed 20 sites in eight streams within this drainage system, and only one site in Horse Creek produced one weathered dead individual (Fobian et al. 2018).

f. Habitat:

Alabama pearlshell has typically been found in small headwater streams with slow to moderate current and substrates that consist of mixed sand, gravel, or sandy mud (Service 2012). In 1996, Shelton and the Alabama Malacological Research Center surveyed 57 sites in 31 streams in Butler, Conecuh, Covington, Crenshaw, Escambia, Monroe, and Pike counties. Six of these streams provided positive results for either living or relic Alabama pearlshell (Shelton 1996). Of the six locations, most either had no aquatic vegetation or had limited quantities of *Ludwigia* spp., *Justicia* spp., and/or filamentous algae (Shelton 1996). Where Alabama pearlshell was encountered, streams were generally between three and six meters (9.8 and 19.6 feet) wide with a typical water depth of less than one meter (3.3 feet) (Shelton 1996). Fobian encountered Alabama pearlshell during his surveys in 2013 in five streams within Conecuh County, which included Otter Creek, Jordan Creek, Little Cedar Creek, and two branches to Sandy Creek. Two of the survey locations within Jordan Creek found Alabama pearlshell in water depths greater than 0.5 meters (Fobian et al. 2013). The other stream locations were characterized by braided channeling or by stable pools and riffles (Fobian et al. 2013).

g. Other:

In 2010, the Plan for the Population Restoration and Conservation of Freshwater Mollusks of the Mobile River Basin was developed to implement the reintroduction and controlled propagation of priority mollusks (MRBMRC 2010). In accordance with the plan, AABC has been developing propagation techniques and leading relocation efforts for Alabama pearlshell (Fobian et al. 2013). Gravid brood stock has been captured and incubated in AABC laboratories to refine culture techniques and discover suitable host fish for the glochidia (Fobian et al. 2018). In addition, surveys have been conducted to identify potential reintroduction sites within the historical range of Alabama pearlshell (Fobian et al. 2018). Several streams with suitable habitat for successful reintroduction have been identified, including Simmon's Creek (Conecuh County), Beaver Creek (Butler County), Brushy Creek (Monroe County), and an unnamed tributary to the Sepulga River near Wilcox, Alabama (Conecuh County) (Fobian et al. 2021). Biologists at AABC are also studying interstitial flow through stream substrates (Geist and Auerswald 2007) at sites with reintroduction potential to evaluate possible juvenile survivorship post release at these locations (Fobian et al. 2021).

To date, no reintroduction activities have been completed with juvenile Alabama pearlshell.

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 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 (i.e., non-ESA) mechanisms to address the continuing and foreseeable threats.

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

The final rule listing Alabama pearlshell as endangered (Service 2012) suggests that range curtailment from historical systems is most likely a result of past and present land use patterns. These patterns include poor agricultural and forestry practices and negligent development of urban and suburban areas (Lydeard et al. 1999). The 2012 listing rule discussed the negative impacts from sedimentation and erosion in streams and from the degradation of water quality through increasing water temperatures and the introduction of non-point source pollution, including pesticides and other toxicants, as threats to Alabama pearlshell. We believe these threats are occurring throughout the range of Alabama pearlshell and will continue to negatively affect populations in the future. We further discuss these threats in the following paragraphs.

Sedimentation/Erosion. Many land use activities increase the rate and quantity of sediment introduced into aquatic systems. Sedimentation can cause direct mortality of freshwater mussels by deposition and suffocation (Ellis 1936) and can eliminate or reduce the recruitment of juvenile mussels (Negus 1966). Juvenile species of pearl mussel remain in interstitial substrate habitat for 3-5 years (Geist and Auerswald 2007) and similar observations have been made for Louisiana pearlshell (P. Johnson pers. comm. 2020). Because of the similarity and close relationship between those species and Alabama pearlshell, we believe this behavior also occurs in Alabama pearlshell and makes them more susceptible to sedimentation. Suspended sediment can also interfere with feeding activity (Dennis 1984). In addition, characteristics of stream microhabitats such as depth and current velocity can be directly altered due to sedimentation (Niraula et al. 2016). Studies that focused on microhabitats threatened mussels occupy in the nearby Choctawhatchee River watershed in southeast Alabama and Florida and on the Louisiana pearlshell from the Red River in Louisiana, suggest a correlation between current velocities and population occurrence (Niraula et al. 2016).

Greater current velocities, and thereby higher amounts of dissolved oxygen, were determined to be important, positive indicators for streams with mussel populations in the Choctawhatchee River and the Red River (Niraula et al. 2016). Sediment loading could lead to declines in stream velocity and dissolved oxygen and may lead to declines in populations of Alabama pearlshell.

Sources of sand and other sediment accumulation in south-central Alabama stream channels include cultivated fields, silviculture practices, cattle grazing, and unpaved road drainage that occur close to streams with minimal riparian buffers (Service 1999). Certain silvicultural and agricultural activities cause erosion, riparian buffer degradation, and increased sedimentation of stream habitats. Uncontrolled access to small streams by cattle may result in destruction of riparian vegetation, bank degradation and erosion, and localized sedimentation of stream habitats. The impacts of these activities, which have occurred throughout a majority of Alabama and in the range of Alabama pearlshell in the past, could result in similar impacts as described above, which could lead to population declines.

Toxicants/Pesticides. Sediment-bound toxicants can be introduced into streams along with extrinsic sediments (Niraula et al. 2016). Toxicants, which include pesticides, ammonia, metals, and ions such as potassium, chloride, and sulfate, can disrupt growth, feeding, and reproduction in freshwater mussels, and prolonged exposure to toxicants can lead to death (Naimo 1995; Newton et al. 2003; Bringolf et al. 2007; Wang et al. 2016; Ciparis et al. 2019). Wang et al. (2016) also found that freshwater mussels are underrepresented in toxicity databases that are used to determine water quality criteria; furthermore, the few species that have been tested in studies are often common species that may be less sensitive to toxicants than species with a narrow endemic range. In addition, some life stages of freshwater mussels may be more sensitive to toxicants, and all life stages need to be tested in order to provide adequate data to managers.

Pesticide residues from agricultural, residential, or silvicultural activities likely have impacted and continue to impact Alabama pearlshell populations. There is no information on the sensitivity of these species to common pesticides. As mentioned in the final listing rule, numerous studies have documented that certain pesticides are lethal to mussels, particularly to the highly sensitive early life stages (Bringolf et al. 2007). Alabama pearlshell may be more susceptible to pesticide residues than test organisms currently used in bioassays; therefore, pesticide label restrictions may be inadequate to protect them.

Water Quality (Temperature). Not only do habitat alterations increase the risk for sedimentation in the Alabama pearlshell range, but they can also contribute to the rise of stream temperatures. As mentioned earlier, temperatures above 31 degrees Celsius are fatal for the mussel (Fobian et al. 2018). This is a lower thermal threshold compared to other freshwater mussels (Fobian et al. 2018), and it illustrates the sensitive nature of the Alabama pearlshell.

Habitat and water quality degradation continue to threaten the Alabama pearlshell throughout its range, and sedimentation and erosion will continue to degrade habitat throughout this species' range in the future. Toxicants, including pesticides, that are introduced through sedimentation and erosion and occasional direct spraying near waterways may also affect Alabama pearlshell, and more studies are needed to fully understand the sensitivity of this species. Declining water quality, especially increasing water temperatures, will also continue to threaten survival of Alabama pearlshell in the future.

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

In the 2012 listing rule, overutilization was not considered to be a threat to the species. The Alabama pearlshell- is not a commercially valuable mussel, although rare species like Alabama pearlshell have the potential to be sought after by collectors. We do not expect overutilization to become a threat in the future; however, over-collecting for scientific or educational purposes could impact localized populations if this activity is performed by unregulated activities.

c. Disease or predation:

At the time of listing, neither disease nor predation were considered as threats to the species, and there is still no evidence to indicate that they are currently threats to Alabama pearlshell. However, since the 1970s, episodic mass mortality of freshwater mussels around the world has been documented (Richard et al. 2020). There has been a lack of evidence directly linking these events to specific environmental changes; however, this trend has prompted speculation that viral infections could be the driving force behind these events (Richard et al. 2020). Since 2016, massive mortality events for the mussels in the Clinch River in Tennessee have been observed (Richard et al. 2020). Analysis of the affected mussels has shown a strong correlation between a novel densovirus and morbidity (Richard et al. 2020). Densoviruses can cause lethal epidemic diseases in other invertebrates such as shrimp, cockroaches, and moths (Richard et al. 2020). Continued studies are warranted to undisputedly link this virus or other viral infections to these massive mussel mortality events. Regardless of the cause, it appears that there is currently an unknown disease devastating freshwater mussel communities on a global level that could potentially become a threat to Alabama pearlshell populations in the future.

d. Inadequacy of existing regulatory mechanisms:

Alabama pearlshell is afforded protection by the State of Alabama under their Invertebrate Species Regulation (Alabama Administrative Code 220-2-.98), which prohibits taking, capturing, killing, or attempting to take, capture, or kill; possession, selling, trading for anything of monetary value; or offering to sell or trade for anything of monetary value for the species without a permit.

Regardless of the regulatory mechanism, enforcement of these regulations is necessary to provide the intended protections. In addition, many private operations are likely unaware of this species' presence and protected status, may not be able to identify the species, and may not take any additional precautionary measures to aid in the avoidance of impact to or recovery of this species.

Current State and Federal regulations that establish limits on pollutants that are discharged into waterbodies are assumed to be protective of freshwater mollusks; however, this species may be more susceptible to some pollutants than test organisms commonly used in bioassays. For example, studies indicate that previous U.S. Environmental Protection Agency (EPA) criteria for ammonia were not protective of freshwater mussels (Augspurger et al. 2003, 2007; Newton et al. 2003; Newton and Bartsch 2007; Mummert et al. 2003) and helped support the 2013 revision to the water quality criteria for ammonia in freshwater systems. In a review of the effects of eutrophication on mussels, Patzner and Muller (2001) noted that narrowly tolerant species disappear as waters become more eutrophic from excess nutrients, plant, and algal growth. Patzner and Muller (2001) also refer to studies that associate increased levels of nitrate with the decline and absence of juvenile mussels. In addition, other studies have also suggested that early life stages of mussels are sensitive to inorganic chemicals such as chlorine, metals, and ammonia (Keller and Zam 1991; Goudreau et al. 1993; Jacobson et al. 1993).

Water quality issues appear to disproportionately threaten the Alabama pearlshell. During March 2019, AABC's captive propagation efforts experienced a setback when the entire propagation population of Alabama pearlshell was lost due to an unknown water quality event at the lab (P. Johnson pers. comm. 2019). The event began as a filamentous algal bloom and progressed into an extensive water quality issue (P.D. Johnson pers. comm. 2019). Other species at the lab were also affected but not to the extent of the Alabama pearlshell (P.D. Johnson pers. comm. 2019). Again, the outcome of this event illustrates the sensitivity of this species to changes in its environment. Current water quality criteria may not fully protect Alabama pearlshell, and the lack of adequate research and data continues to prevent existing authorities, such as the Clean Water Act (CWA), which is administered by EPA and the U.S. Army Corps of Engineers, from being fully protective of the aquatic environment for this species.

The CWA is the primary federal law in the United States governing water pollution. One of its primary roles is to regulate the point source discharge of pollutants to surface waters. These pollutants are regulated by the permit process with a permit from the National Pollutant Discharge Elimination System (NPDES). The NPDES permit process is usually delegated by EPA to its state agency counterpart. In Alabama, this authority has been delegated to the Alabama Department of Environmental Management (ADEM). Currently ADEM (Alabama Administrative Code, Title 22, Section 22-22-1 et seq.) requires that discharges not exceed state water quality standards. Since there is no information

on this species' sensitivity to common pollutants, Federal (i.e., CWA) and state water quality laws may or may not protect Alabama pearlshell, as described above.

However, Section 303d of CWA does require each state to list its polluted water bodies and to set priorities for their clean up under the direction of a watershed restoration plan. Several Alabama pearlshell streams have been identified as impaired for water quality under Section 303d. Table 2 summarizes these impaired streams, which can be an indication of concerns for the viability of Alabama pearlshell in those waters.

Table 2. Summary of impaired, Alabama pearlshell streams as classified by Section 303d of CWA (ADEM 2020).

Stream	County	Cause	Sources
Burnt Corn Creek	Escambia	Metals (Mercury)	Atmospheric deposition
Murder Creek	Escambia	Metals (Mercury)	Atmospheric deposition
Sandy Creek	Conecuh	Pathogens (E. coli)	Pasture grazing
Sepulga River	Conecuh	Metals (Mercury)	Atmospheric deposition

Section 404 of the CWA regulates the discharge of dredged or fill material into waters of the United States, including wetlands. Any activities in waters of the United States are regulated under this program, and often include fill related to development, such as water resource projects, infrastructure development, and mining projects. While a single project will usually not jeopardize the continued existence of the Alabama pearlshell, the collective impact from multiple development projects on the Alabama pearlshell's finite habitat is often not assessed on a permit-by-permit case.

e. Other natural or manmade factors affecting its continued existence:
The final listing rule contains details related to random catastrophic events, reduced genetic diversity, host fish considerations, and nonindigenous species that are all still a significant concern to the persistence of Alabama pearlshell (Service 2012). Additional details are provided below.

Climate change is considered a potential threat to Alabama pearlshell. The Fifth Assessment Report by the Intergovernmental Panel on Climate Change (IPCC) concluded that the warming of the climate system is unequivocal (IPCC 2014). Numerous long-term climate changes have been observed including changes in arctic temperatures and ice, widespread changes in precipitation amounts, ocean salinity, wind patterns, and aspects of extreme weather including droughts, heavy precipitation, heat waves, and the intensity of tropical cyclones (IPCC 2014). There is uncertainty about the specific effects of climate change and its magnitude on the Alabama pearlshell; however, climate change is almost certain to affect aquatic habitats in the streams it occupies. Climate change has the potential to increase the vulnerability of this species to random catastrophic events, primarily through more intense or frequent droughts or rapid flooding events.

Droughts can potentially have negative impacts on water quality (e.g., dissolved oxygen) and reduced dissemination of point source discharges into waterways, resulting in reduced oxygen for aquatic biota and more concentrated pollutants. Droughts may also reduce the amount of habitat available to the species by dewatering habitat and may also lead to direct mortality by stranding mussels. Additionally, drought may isolate sections of stream into stagnate pools with increased water temperatures. In Alabama, moderate to extreme drought conditions were recorded in 26% of months between the years 2010 and 2019 and approximately 8% of the months in this time period were considered severe droughts (NOAA 2020).

The majority of the Alabama pearlshell's known stream range flows through privately owned land. A large section of this privately owned land is utilized by the oil and gas industry (Figure 4). The first discovery well for oil in Conecuh County was dug in 1994. Currently, there are 288 active and non-active well sites in the drainages that contain the Alabama pearlshell's known range (GSA 2019). As mentioned in the final listing rule, human-induced random events such as toxic spills could also jeopardize Alabama pearlshell if pollutants are spilled within stream reaches it occupies. The known extent of habitat occupied by Alabama pearlshell is already limited; therefore, a single spill event could substantially reduce its known range. In addition, small and fragmented populations, inbreeding depression, and loss of genetic variation would all inhibit natural recolonization after local extirpation.

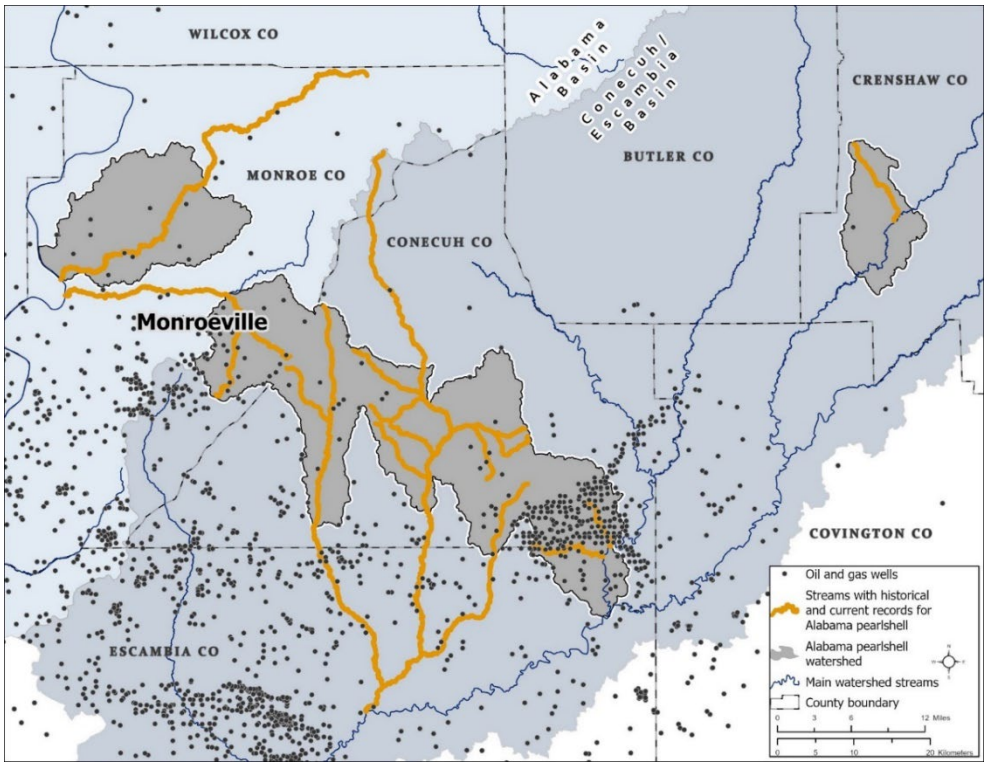

Figure 4. Location of oil and gas wells in the counties that contain the Alabama pearlshell's known range (GSA 2019).

D. Synthesis

The Alabama pearlshell is a medium-sized freshwater mussel that is endemic to select tributaries of the Alabama and Conecuh/Escambia River drainages in south central Alabama. Currently, we consider Alabama pearlshell extirpated from 8 of 16 known populations. The species has declined from half of its historic range, and encountering live individuals continues to become rarer across the landscape. Since no new records for this mussel have been documented in the Alabama River basin since the 1990s, the Big Flat Creek population is now classified as extirpated, and Alabama pearlshell are considered extirpated from the basin. In the Conecuh/Escambia River basin, four populations are considered extirpated, which includes the recent change of the Horse Creek population from historical to current. The discovery of the Amos Mill Creek population in 2010 increased the species' range. Although still considered current, limited fresh dead or live individuals in Bottle Creek, Burnt Corn Creek, and Horse Creek populations within the Conecuh/Escambia River basin suggest limited viability of the species in these populations. Threats such as sedimentation, riparian buffer loss, water quality degradation, and climate change persist and negatively impact Alabama pearlshell throughout its range. Additionally, the limited range of this species, small population size, and its apparent limited reproduction makes it vulnerable to single catastrophic events and makes large portions of its range vulnerable to impacts related to hurricanes or flooding, drought, and contaminant spills. As the populations become smaller and more fragmented, recolonization into extirpated watersheds becomes less likely. Fragmentation also increases the risks of inbreeding depression and the loss of genetic variation in remaining populations of Alabama pearlshell. Based on the scientific information we have at the time of this review, the Alabama pearlshell still meets the definition of an endangered species.

III. RECOMMENDATIONS FOR FUTURE ACTIVITIES

Because we have no final approved final Recovery Plan for the species, we provide the activities indicated below as activities to inform and improve the species recovery.

- Develop a captive propagation plan for the species.
    - Continue to develop and refine propagation techniques for future augmentation and reintroduction.
    - Continue to investigate potential sites for reintroduction of captive reared individuals.
- Conduct quantitative surveys within known occupied areas and continue surveys in other areas to find additional populations.
- Conduct formal toxicity testing to understand sensitivity of Alabama pearlshell to pollution threats in these systems.
- Continue to develop partnerships and conservation initiatives with landowners within the range of the Alabama pearlshell in the Alabama and Conecuh/Escambia basins.

- Restore and improve conditions of Alabama pearlshell habitat through activities such as bank stabilization, riparian buffer maintenance/augmentation, adherence to BMPs, and other conservation efforts.

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U.S. FISH AND WILDLIFE SERVICE
5-Year Review of Alabama pearlshell (*Margaritifera marrianae*)

Current Classification: Endangered

Recommendation resulting from the 5-Year Review:

_____ Downlist to Threatened
_____ Uplist to Endangered
_____ Delist
_X_ No change needed

Review Conducted By: Erin Padgett and Morgan Brizendine, Alabama Ecological Services Field Office.

FIELD OFFICE APPROVAL:

Field Supervisor, Alabama Ecological Services Field Office, U.S. Fish and Wildlife Service

Approve: WILLIAM PEARSON Digitally signed by WILLIAM PEARSON Date: 2023.05.24 12:04:30 -05'00'

REGIONAL OFFICE APPROVAL:

***For* Assistant Regional Director – Ecological Services, U.S. Fish and Wildlife Service**

Approve: AARON VALENTA Digitally signed by AARON VALENTA Date: 2023.05.16 10:00:33 -04'00'

Appendix A. Summary of peer review for the 5-year review of Alabama pearlshell (*Margaritifera maarrianae*)

A. Peer Review Method:

Requests were e-mailed to each per reviewer of the 5-year review on August 4, 2021. We chose reviewers based on their expertise and the feedback they could offer in giving a thorough review. Each reviewer was asked to consider the reassessment of the Alabama pearlshell's status and to ensure that the best available data and analyses were used for this assessment.

Peer Reviewers:

Requests for peer review were e-mailed to Jeff Garner, Todd Fobian, and Dr. Nathan Johnson. In addition, Dr. Paul Johnson provided new and updated information for this review. Dr. Paul Johnson is a recognized mollusk expert and the program supervisor at the Alabama Aquatic Biodiversity Center in Marion, Alabama. Credentials for the reviewers are provided below.

B. Peer Review Charge:

Jeff Garner is the supervisor of the Mussel Management division of the Alabama Department of Conservation and Natural Resources (ADCNR). Over his long career with ADCNR, he has become well known as one of the state's premier malacologists. He co-authored *Freshwater Mussels of Alabama and the Mobile Basin in Georgia, Mississippi, and Tennessee,* which was first published in 2008 and remains the most extensive catalog of Alabama's many freshwater mussels.

Todd Fobian is the supervisor of the Environmental Coordinator division of ADCNR. Over his career with ADCNR, he has been involved with field surveys and propagation efforts for Alabama pearlshell. Mr. Fobian also has broad ranging knowledge of freshwater mussels and experience with reintroduction efforts.

Dr. Nathan Johnson is a research biologist at the Wetland and Aquatic Research Center of the U.S. Geological Survey in Florida. Dr. Johnson's research has focused on conservation genetics and propagation of endangered freshwater mussels in the Southeast. Dr. Johnson is currently the Associate Editor of *Nature, Scientific Reports*.

C. Summary of Peer Review Comments:

Jeff Garner: Mr. Garner noted that although some research has found that Alabama pearlshells occur in male/female pairs, this species is not sexually dimorphic. He provided information about the possible location of Gin Creek and provided a reference from 2001 that discussed possible changes in taxonomic classification. In addition, he suggested adding more details about toxicity testing. Finally, Mr. Garner made several edits to improve clarity of this review.

Todd Fobian: Mr. Fobian made several notes about recent ADCNR surveys for Alabama pearlshell. He also added some information about the possible location of Beaver and Gin Creeks and more details about priority reintroduction sites.

Dr. Nathan Johnson: No changes were suggested.

D. Response to Peer Review:

Jeff Garner: We added a qualifying statement that informs readers that Alabama pearlshell that although one study identified male/female pairs of Alabama pearlshell, the species is not sexually dimorphic. We subsequently deleted any additional discussion of sexual dimorphism in the document. We added the reference from 2001 that suggested changing the taxonomic classification of Alabama pearlshell and the additional information provided about toxicity testing. Finally, we incorporated the edits Mr. Garner provided to improve overall clarity of this review.

Todd Fobian: We appreciate all of Mr. Fobian's updates on recent surveys and priority reintroduction sites and have incorporated those into this review. We also added more information about the possible locations of Beaver and Gin Creeks.

Dr. Nathan Johnson: No changes were suggested or incorporated.