Arkansas Fatmucket
(Lampsilis powellii)

5-Year Review:
Summary and Evaluation

Photo: Chris Davidson, U.S. Fish and Wildlife Service

U.S. Fish and Wildlife Service
Mississippi Basin Region
Arkansas Ecological Services Field Office
Conway, Arkansas

5-YEAR REVIEW
Arkansas Fatmucket (*Lampsilis powellii* I. Lea, 1852)

I. GENERAL INFORMATION

A. Methodology used to complete review

In 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 April 2019 (84 FR 14669). We obtained pertinent status data from the Recovery Plan (U.S. Fish and Wildlife Service 1992; hereafter not cited but referred to as "Recovery Plan"), the 2013 five-year review (Service 2013), published papers, unpublished reports, museum records, and personal communications from governmental biologists and other Arkansas Fatmucket experts. The species' recovery lead biologist in the Arkansas Ecological Services Field Office compiled all known and pertinent data on the status of the species and completed the review in its entirety. A draft of the 5-year review was peer reviewed by three experts familiar with the species (see Appendix A for a summary of the peer review). We evaluated and incorporated their comments into this final document as appropriate.

B. Reviewers

Lead Region – Southeast Region: Kelly Bibb, (404) 679-7132

Lead Field Office – Conway, Arkansas: Chris Davidson, (501) 513-4481

Cooperating Field or Regional Office: None, Arkansas endemic species.

C. Background

1. **Federal Register Notice initiating this review:** April 11, 2019 (84 FR 14669)

2. **Species Status:** Declining (see *Updated Information and Current Species Status* below for further detail)

3. **Recovery Achieved:** 1 (1=0-25% species' recovery objectives achieved)

4. **Listing History**
   Original Listing
   FR notice: 55 FR 12797
   Date listed: April 5, 1990
   Entity listed: Species
   Classification: Threatened

5. Review History

Documents containing comprehensive summaries of the species' status illustrate the nature of available information. We incorporate relevant findings or observations from these and other documents as appropriate in *Updated Information and Current Species Status* below.

In addition, each year, the Service reviews and updates listed species information for inclusion in the required Recovery Report to Congress. Through 2013, we did a recovery data call that included status recommendations such as Declining for this species. We continue to show that species status recommendation as part of our 5-year reviews (see C.2. above). Our last evaluation for this species to benefit the Recovery Report to Congress occurred in 2019.

5-Year Reviews
U.S. Fish and Wildlife Service. 2013. Arkansas Fatmucket (*Lampsilis powellii*). Conway, Arkansas 24 pp.

In this review, Arkansas Fatmucket was extant throughout most of its historical range, but was experiencing severe population declines and reduced distribution. Increasingly small and isolated populations were becoming more susceptible to stochastic and catastrophic events and ongoing or increasing threats. Increasing urbanization in the Saline and Caddo River headwaters and associated water quality, hydrological, and geomorphological stressors threaten the remaining strongholds for the species. A variety of other land uses (e.g., conversion of forested areas to pastureland, unpaved roads, etc.) poses threats to the species throughout its range. We recommended a change in classification to endangered.

U.S. Fish and Wildlife Service, 1991
In this review, we evaluated multiple species simultaneously with no species specific, in-depth assessment of the five factors or threats as they pertained to each species' recovery. The notices summarily listed these species and stated no changes in the designation of these species were warranted at that time, including no changes to the status of this mussel.

Agency Status Reviews
Harris, J.L. and M.E. Gordon. 1988. Status survey of *Lampsilis powelli* (Lea, 1852). Prepared for U. S. Fish and Wildlife Service, Jackson, MS. 43 pp. + appendices.

The FWS and Arkansas Game and Fish Commission (AGFC) conducted a range wide Arkansas Fatmucket status assessment in 2006 – 2007 and 2014 – 2015. Data from these surveys are available in our files and presented. We discuss data collected during these status assessments in *Updated Information and Current Species Status* below.

Other Relevant Reviews and Documents

Gordon, M.E. and J.L. Harris. 1985. Distribution of *Lampsilis powelli* (Lea) (Bivalvia: Unionacea). The Nautilus 99(4):142-144.

Harris, J.L. and M.E. Gordon. 1987. Distribution and status of rare and endangered mussels (Mollusca: Margaritiferidae, Unionidae) in Arkansas. Journal of the Arkansas Academy of Science 41:49-55.

Harris, J.L., P.J. Rust, A.C. Christian, W.R. Posey II, C.L. Davidson, and G.L. Harp. 1997. Revised status of rare and endangered Unionacea (Mollusca: Margaritiferidae, Unionidae) in Arkansas. Journal of the Arkansas Academy of Science 51:66-89.

Harris, J.L., W.R. Hoeh, A.D. Christian, J. Walker, J.L. Farris, R.L. Johnson, and M.E. Gordon. 2004. Species limits and phylogeography of Lampsilinae (Bivalvia: Unionida) in Arkansas with emphasis on species of *Lampsilis*. Prepared for Arkansas Game and Fish Commission and U. S. Fish and Wildlife Service. 61 pp. + appendix.

Scott, M. 2004. Life history and population biology of the Arkansas Fatmucket, *Lampsilis powellii* (Lea, 1852). M. S. thesis. Arkansas State University. 97 pp. + appendix.

Christian, A.D., J.L. Farris, J.L. Harris, and M. Scott. 2006. Life history and population biology of the federally threatened Arkansas Fatmucket [*Lampsilis powellii* (I. Lea 1852)] and the state special concern Ouachita creekshell [*Villosa arkansasensis* (I. Lea 1862)]. Final Report submitted to U.S. Forest Service, Ouachita National Forest, Hot Springs, AR. 83 pp.

6. **Species' Recovery Priority Number at start of review**: 5
   The degree of threat to Arkansas Fatmucket is high as urbanization and development continue to increase in the Saline and Caddo River headwaters, and lands are converted from forests to other land uses (e.g. pasture land, urban development). Recovery potential is low because of the increase in and limited ability to reduce existing threats from urbanization and difficulty in implementing conservation actions. We have a good understanding of the species biology and propagation and other conservation efforts are underway. However, recovery of this species remains problematic.

7. **Recovery Plan**
   Name of plan: Arkansas Fatmucket Mussel (*Lampsilis powelli*) Recovery Plan
   Date issued: February 10, 1992

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 Arkansas Fatmucket is an invertebrate, and therefore, not covered by the DPS policy, we will not discuss it further.

B. Recovery Plan and 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

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

3. List the recovery criteria and discuss how each task has or has not been achieved? The Recovery Plan (FWS 1992) includes three recovery criteria.

(1) *There are viable populations in the Ouachita River, South Fork Ouachita River, Alum, Middle, and North Forks Saline River, and main stem Saline River*. Scott (2004) and Christian et al. (2006) surveyed 30 Arkansas Fatmucket sites from Harris and Gordon (1988) and 3 new sites. Arkansas Fatmucket abundance was significantly lower across 29 sites compared to Harris and Gordon (1988). These surveys provide the first statistical documentation of Arkansas Fatmucket range wide decline since listing in 1990. Based on several surveys since 2004, the species extirpation from the Ouachita River basin appears imminent generally with one individual/site at 2 – 3 sites/extant river (Ouachita, South Fork Ouachita, and Caddo rivers) (C. Davidson, Service, pers. comm.). No specific information assessing population viability exists. However, all populations, except the Saline River, are declining with <50 individuals in the Ouachita River, <25 individuals in the Caddo River, <100 individuals in each of the South Fork Ouachita, North Fork Saline and Middle Fork Saline, and 250 – 500 individuals in the Alum Fork Saline (K. Moles, AGFC, pers. comm.; C. Davidson, Service, pers. comm.).

(2) *The habitat for these populations is fully protected*. The FWS approved a range wide Safe Harbor Agreement (SHA) in 2016. Implementation of the SHA is experiencing challenges (no enrollments to date) due to staffing issues and lack of incentives. In 2019, the State Technical Committee approved adding ranking criteria (points) to landowners who enrolled, or are pending enrollment, in the SHA. Final approval is pending the Natural Resources Conservation Services acceptance. We will not meet this criterion until we achieve the SHA's landowner enrollment goals, assuming there are no substantial remaining threats.

(3) *Viable population levels are maintained for a period of at least 20 years.* The recovery plan defines a viable population as a population with the reproductive capability to sustain itself without immigration of individuals from another population. We have not achieved this criterion (see Criterion 1).

This last review included a recommendation to revise the recovery criteria. Criterion 1 is a measurable criterion, but further expert elicitation is necessary to determine the appropriate number of meta-populations in the Ouachita and Saline basins necessary to achieve recovery. Recent genetic analyses indicate the existence of two populations (Ouachita and Saline basins), each containing unique mtDNA haplotypes and microsatellite alleles (Berg et al. 2017). Protection of these two populations is important to maintain the unique genetic structure of the species. Criterion 3 is redundant with Criterion 1, since viable populations exhibit a stable or increasing trend, natural recruitment, multiple age classes, and spatial distribution sufficient to protect against stochastic and catastrophic disturbance events.

Criterion 2 implicitly addresses threats (Factors A, B, D, E) identified in the final listing rule. There is no evidence to support Factor B as a current threat. Revising this criterion to state threats have been addressed and/or managed to the extent that the species will remain viable into the foreseeable future seems appropriate.

Recovery Tasks

Task 1.1 - Use legislation to protect habitat

The Arkansas Department of Environmental Quality (ADEQ) has designated the four forks of the Saline River, Caddo River, South Fork Ouachita River, and mainstem Ouachita River upstream of Lake Ouachita as ecologically sensitive waterbodies (APCEC 2007). These same rivers, with the exception of South Fork Ouachita River, also are designated as extraordinary resource waterbodies (APCEC 2007). These designations under ADEQ's Regulation 2, pursuant to the Arkansas Water and Air Pollution Control Act and Clean Water Act, provide more stringent water quality criteria, restrict certain activities that may degrade water quality or habitat (*e.g.,* instream gravel mining), and provide higher priority for receiving technical and financial assistance for voluntary watershed and water

quality protection projects. However, more stringent water quality criteria (particularly related to ammonia) are necessary to protect mussels.

Task 1.2 - Develop and implement a plan to protect habitat
We will accomplish this task through the completion of Tasks 3.1 and 3.3.

Task 2.1 - Characterize habitat
Harris and Gordon (1988), Harris (1994), Scott (2004), and Christian et al. (2006) describe preferred habitat types for adult Arkansas Fatmucket. Harris and Gordon (1988) describe four microhabitat types that include:

1. long pools with cobble and rock as primary substrate types,
2. backwater areas downstream of peninsulas or islands covered with water willow (*Justicia americana*) with cobble and sand as the dominant substrate,
3. slow moving pools upstream from water willow islands with sand, gravel, and cobble substrate, and
4. overflow, secondary channel pools, and tributary confluence areas with sand, cobble, and some rock substrate.

Since Arkansas Fatmucket habitat is fragmented and sporadic, it is extremely difficult, if not impossible, to quantify the total amount of microhabitat available versus inhabited (historical and current). Micro-scale substrate preference is not easily discernable (Harris 1994). This also makes determination of reliable population estimates difficult.

Task 2.2 - Determine associate species
Many surveys have documented associate mussel species, composition, and population dynamics in the upper Ouachita River basin (Harris and Gordon 1988, Brown and Brown 1989, Harris 1989, 1991, 1994, 1999, Burns and McDonnel 1992a, 1992b, Harris et al. 1992, Johnston et al. 1993, Davidson and Clem 2002, 2004, Davidson and Gosse 2003, Scott 2004, Christian et al. 2006).

Task 2.3 - Develop life history data
Scott (2004) and Christian et al. (2006) determined reproductive patterns, including fish host identification and refined artificial propagation techniques, for Arkansas Fatmucket. Black basses (*Micropterus punctulatus, M. salmoides* and *M. dolomieu*) were the optimal fish hosts, while other sunfish (Centrarchidae) appear to be marginal hosts with a low percent (< 1) of successfully transforming juveniles (Scott 2004, Christian et al. 2006).

There are no age and growth analyses on Arkansas Fatmucket. Several surveys provide size frequency data for Arkansas Fatmucket (Harris and Gordon 1988, Harris 1989, 1991, 1994, 1999; Burns and McDonnel 1992a, 1992b; Harris et al. 1992; Scott 2004; Christian et al. 2006; FWS & AGFC unpubl. survey data). Harris and Gordon (1988) report mean size for Arkansas Fatmucket (n = 137) as

86.9 ± 14.9 mm in length, 34.3 ± 6.7 mm in width, and 49.8 ± 8.1 mm in depth. Scott (2004) and Christian et al. (2006) more recently reported measured lengths ranging from 26.9 – 125.5 mm compared to 58.7 – 122.5 mm by Harris and Gordon (1988). In two survey efforts since 2006, FWS and AGFC report similar results.

Harris et al. (2004) investigated the limits and phylogeography of Lampsilinae in Arkansas with emphasis on species of *Lampsilis*. The *Lampsilis siliquoidea/powellii* group (Group B) supported a monophyletic group. However, specimens identified as Arkansas Fatmucket specimens did not form a monophyletic group, and the sequence divergence between *L. powellii* and *L. siliquoidea* was relatively slight. This interpretation of mtDNA evidence did not support species-level distinction for Arkansas Fatmucket.

As part of a phase two study, conducted in 2007 using additional mtDNA and nuclear DNA sequences, the genetic data from *Lampsilis powellii* and *L. siliquoidea* showed relatively low genetic divergence. However, some *L. powellii* mtDNA haplotypes were absent in *L. siliquoidea*. These observations are consistent with the hypothesis that Arkansas Fatmucket is a valid species that is currently experiencing mtDNA introgression due to limited interspecific hybridization with *L. siliquoidea* (Hoeh and Breton 2012). Walters et al. (in review) analyzed the genetic diversity of Arkansas Fatmucket using the mitochondrial COI gene and 14 microsatellites. They found relatively low genetic diversity and significant population structure, consistent with low gene flow between Ouachita and Saline River populations.

Chase et al. (2018) published the complete male-type mitochondrial genome for Arkansas Fatmucket. This information is valuable for studying patterns of molecular evolution of DUI genomes. Robicheau et al. (2018) evaluated the utility of the female specific mitochondrial *f-orf* gene for population genetic, phylogeographic and systematic studies in mussels. Their preliminary results indicate the *f-orf* gene may represent a viable molecular marker for population and species level studies.

Task 3.1 - Develop plan to restore historic[al] habitat

A conservation action plan for the upper Saline River basin identified strategies necessary to conserve existing biodiversity, established clear monitoring needs for the watershed, and identified resources available to complete these tasks (DeClerk et al. 2006). In 2016, FWS approved a programmatic SHA for the upper Ouachita River basin (includes entire species range) to protect, enhance, and restore current and historical Arkansas Fatmucket habitat (see Criterion 2).

Task 3.2 - Develop plan for reestablishing mussel populations

We have not completed this task. However, Scott (2004) and Christian et al. (2006) have determined reproductive patterns, including fish host identification, and refined artificial propagation techniques for Arkansas Fatmucket.

In 2017, FWS and AGFC released 31 2+ year old individuals at the gravel pit site in the Ouachita River basin. They also released 80 individuals at two sites in the South Fork Ouachita River. All individuals ranged in length from 48.7 – 87.8 mm with a mean of 67.2 mm.

In 2018, FWS and AGFC released 212 2+ year old individuals in the Saline River basin (Saline (45), Alum Fork Saline (66), and Middle Fork Saline (55), and North Fork (46) rivers) (see Section II.C.1.a. below for additional information). AGFC also is ramping up propagation capacity for Arkansas Fatmucket in its hatchery system.

Task 3.3 - Implement plan to restore historic[al] habitat
Several natural resource agencies are implementing conservation strategies outlined in DeClerk et al. (2006) in the upper Saline River watershed. See Criterion 2 for status of SHA implementation.

Task 3.4 - Implement plan to reestablish population in historic[al] habitat
We have not initiated this task.

Task 4.1 - Determine minimum population levels
We have not initiated this task.

Task 4.2 - Develop plan to monitor populations
FWS and AGFC assessed the range wide status of Arkansas Fatmucket populations in 2007 and 2015. Biological monitoring is a required component of the SHA. The Nature Conservancy developed a unified monitoring plan that will be a critical component to executing the SHA.

Task 4.3 - Implement monitoring plan
FWS and AGFC are monitoring the species status at a 7-year interval. Additional monitoring may occur in conjunction with the SHA and population augmentation and reintroduction efforts.

C. Updated Information and Current Species Status

1. Biology and Habitat

a. Spatial distribution, abundance and population trends

The Arkansas Fatmucket is endemic to the Ouachita Mountains region of Arkansas. Prior to the Harris and Gordon (1988) status assessment, the species known range was restricted to 10 localities in the Ouachita River basin; one in the upper Ouachita River, two in the South Fork Ouachita River, two in the Caddo River, and five in the Saline River and forks (Gordon and Harris 1985). The historical range likely included:

- Caddo River from Norman, Arkansas, to the Ouachita River (approximately 64 river miles [rm]),
- South Fork Caddo River (approximately 4 rm),
- Ouachita River from the confluence of the Caddo River upstream to near Mena, Arkansas (approximately 160 rm),
- South Fork Ouachita River (approximately 29 rm),
- Alum Fork Saline River (approximately 53 rm),
- Middle Fork Saline River (approximately 30 rm),
- North Fork Saline River (approximately 22 rm),
- South Fork Saline River (approximately 15 rm), and
- Saline River from its formation to U.S. Highway 270 (approximately 44 rm).

The current range is restricted to the:

- Caddo River from the confluence of Collier Creek (between Norman and Caddo Gap, Arkansas) to Arkansas Highway 84 (near Amity, Arkansas; 24.3 rm),
- Ouachita River from Irons Fork confluence to the Pine Ridge public access (26.9 rm),
- South Fork Ouachita River from Montgomery County Road 17 to the inundation pool of Lake Ouachita (14.3 rm),
- Middle Fork Saline River from Arkansas Highway 7 to its confluence with the Alum Fork Saline River (30.2 rm),
- Alum Fork Saline River from Love Creek to the inundation pool of Lake Winona (5.6 rm),
- Alum Fork Saline River from Lake Winona Dam downstream to the Middle Fork Saline River confluence (28.0 rm),
- Alum Fork Saline River from the North Fork Saline River confluence upstream approximately 6.0 rm,
- North Fork Saline River from Arkansas Highway 9 to Arkansas Highway 5 (21.7 rm),
- Saline River from its formation downstream to U.S. Highway 270 (43.6 rm).

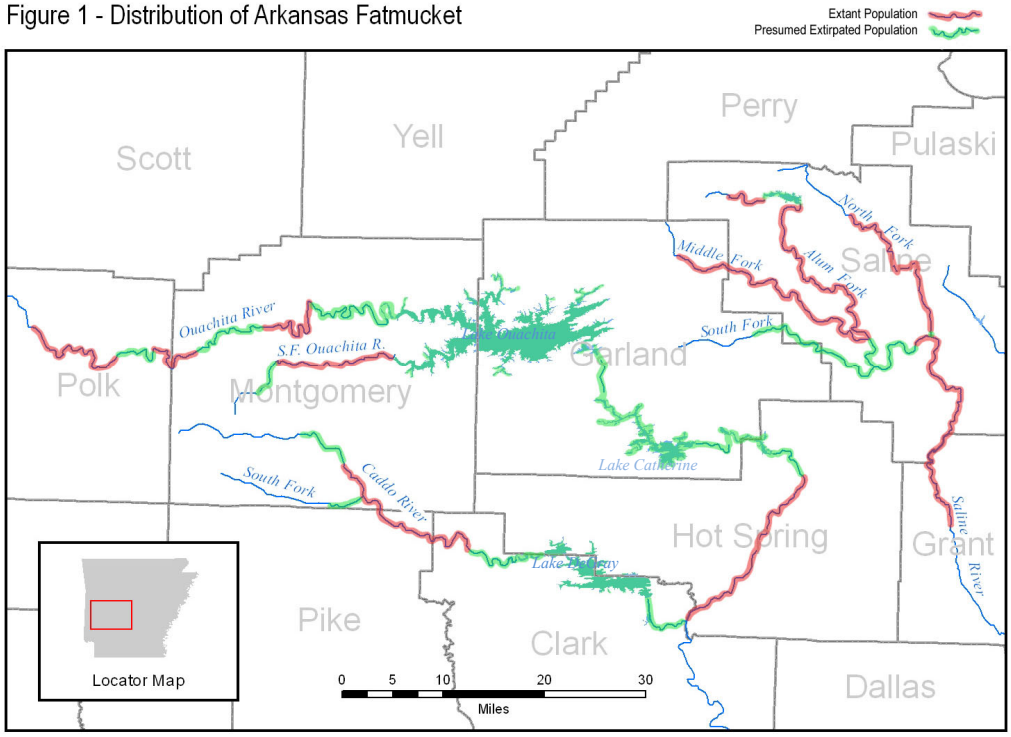
While the species distribution suffered approximately a 30% reduction in occupied stream reaches since listing (C. Davidson, Service, pers. comm.; Figure 1), the number of extant sites and abundance is substantially lower range wide.

Scott (2004) and Christian et al. (2006) surveyed 30 Harris and Gordon (1988) sites, plus three new sites. They collected 137 Arkansas Fatmucket specimens from 19 of 33 sites. They documented a significant reduction in Arkansas Fatmucket numbers across 29 sites. These surveys provide the

first statistical documentation of a range wide decline of Arkansas Fatmucket since federal listing in 1990.

Scott (2004) and Christian et al. (2006) focused their survey effort on previously documented Arkansas Fatmucket sites from Harris and Gordon (1988). In 2006 – 2007, the FWS, AGFC, and U.S. Forest Service conducted a range wide status assessment focused on determining current distribution and abundance. They repeated the survey in 2014 – 2015. We discuss their results and previous data below by river. Appendix B provides a summary of literature on the Arkansas Fatmucket.

Figure 1 - Distribution of Arkansas Fatmucket



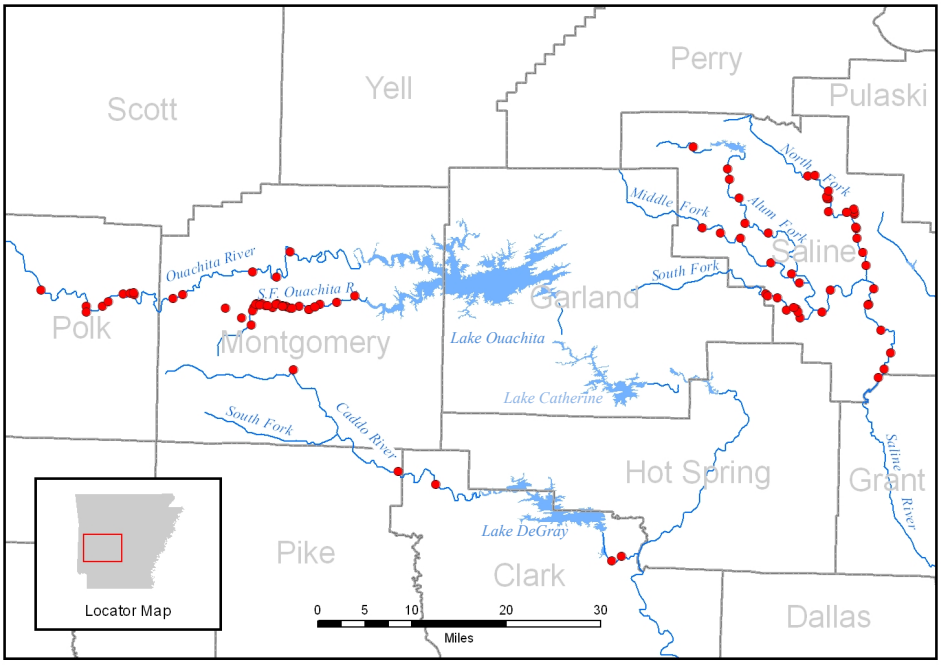
Caddo River – Harris (1989) found five live Arkansas Fatmucket specimens at one site downstream of Lake DeGray in the Caddo River (Figure 2). Harris and Doster (1992) collected 159+ live mussels representing 12 species from two Caddo River sites downstream of Interstate 30, but no Arkansas Fatmucket (Figure 2). However, Scott (2004) found one live Arkansas Fatmucket at one of these sites. John Harris previously collected the species at this site in 1981. A 2007 survey of the Caddo River from Lake DeGray dam to the Ouachita River failed to locate live Arkansas Fatmucket and found only one live mussel (Figure 3; C. Davidson, Service, pers. comm.). The decline of mussels in this reach of the Caddo River may be attributable to the operation of Lake DeGray Dam or more likely susceptibility to stochastic events due to small

population size and limited interaction or isolation from the lower Ouachita River population.

Arkansas Fatmucket occurrences upstream of Lake DeGray (Caddo River) also are sparse, with only five sites identified in the past 25 years. All sites had < 5 individuals present. FWS and AGFC collected six live Arkansas Fatmucket in the upper Caddo River since 2006 (C. Daivdson, Service, pers. comm.; Figures 2 – 3).

Ouachita River – At the time of listing, Arkansas Fatmucket was widely distributed upstream of Lake Ouachita (Figure 2). Scott (2004) and Christian et al. (2006) collected five live Arkansas Fatmucket from two of Harris' 1988 sites. FWS and AGFC began systematically surveying the Ouachita River from near Mena to Lake Ouachita's inundation point in 2007 and again in 2015. These surveys yielded three live individuals from three sites. Collections of live Arkansas Fatmucket since Harris and Gordon (1988) are restricted to approximately 27 miles between the Iron's Fork confluence and Pine Ridge public access (C. Davidson, Service, pers. comm.; Figure 3).

Figure 2 - Live and fresh dead occurrences of Arkansas Fatmucket, 1981-1996

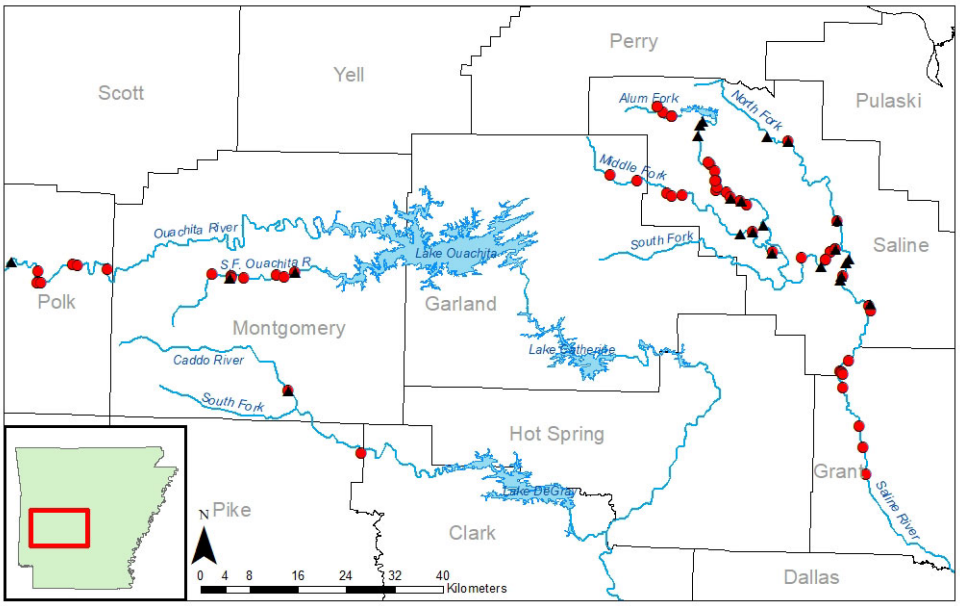


Addressing threats alone is insufficient to ensure population viability due to small population size and stochastic events such as multiple large flood events in past decade and increasing urbanization that contributed to increased sedimentation and reductions in number of sites and individuals.

In 2017, FWS and AGFC released 31 two plus year old Arkansas Fatmucket at the gravel pit site upstream of Rocky Shoals. Subsequent monitoring at the site in 2018 failed to relocate any of these individuals (K. Moles, AGFC, pers. comm.). Land use activities that increase sedimentation, alter hydrology and stream geomorphology, and gravel mining are the primary sources of stressors in the upper Ouachita River.

Harris (1999) found one live specimen downstream of the main stem Ouachita River reservoirs (Figure 3). Scott (2004) found one live Arkansas Fatmucket in the lower Caddo River near Caddo Valley. Therefore, it is possible that a small population is still extant in the lower Ouachita River from near Malvern to the Caddo River confluence, but there are no surveys since Harris (1999) and the population's status is unknown.

Figure 3. Live Arkansas Fatmucket records (▲= 2014 – 2015; ● = 2000 - 2013)



South Fork Ouachita River – Brown and Brown (1989) reported the first declines in Arkansas Fatmucket in the South Fork Ouachita River due to increased sedimentation from dam construction on a tributary, which Harris (1991) confirmed later. Harris (1994) described microhabitat and mussel community population estimates at Site 1 in South Fork Ouachita River. Arkansas Fatmucket population estimates for this site in 1990 and 1993 were 31 ± 38 and 10 ± 19, respectively. FWS and AGFC found no live mussels at this site in 2007.

Harris et al. (1992) relocated 44 Arkansas Fatmucket at U.S. Highway 270, but in 2007, FWS and AGFC only found four live Arkansas Fatmucket from the relocation site. Since 2014, FWS and AGFC located Arkansas Fatmucket at seven localities in two disjunct reaches totaling approximately

two river miles (Figure 3), but abundance is less than reported in the early 1990s.

Addressing threats alone is insufficient to ensure population viability due to small population size and stochastic events such as multiple large flood events in past decade and increasing urbanization that contributed to increased sedimentation and reductions in number of sites and individuals. In 2017, FWS, AGFC, and the USFS released 79 two plus year old Arkansas Fatmucket at two sites in South Fork Ouachita River. AGFC located four of these individuals in 2018. AGFC also found seven additional untagged Arkansas Fatmucket in close proximity to the released individuals (K. Moles, AGFC, pers. comm.).

In the South Fork Ouachita River, increased channel instability and sedimentation in the upper reaches is prevalent and presumed to be the reason for the extirpation of mussels. Land use practices adjacent to the South Fork Ouachita River between Arkansas Highway 379 and U.S. Highway 270 have decreased forested riparian habitat subsequently leading to bank destabilization and increased sedimentation, nutrients and channel instability.

Saline River Basin

South Fork Saline River – In 1991 and 1992, Burns and McDonnell (1992a, 1992b) collected live Arkansas Fatmucket specimens from 15 of 24 sites surveyed in the North Fork Saline River (Figure 2). In 2006, FWS and AGFC collected no live Arkansas Fatmucket (C. Davidson, Service, pers. comm.; Figure 3), and only two live mussels, in the South Fork Saline River. This represents a major decline since Burns and McDonnell (1992a), where they collected 94 mussels, including 21 live Arkansas Fatmucket, representing 15 species from 10 sites. AGFC and FWS have not conducted additional surveys since 2006.

North Fork Saline River – There are 19 historical locations (1987 - 1992) for Arkansas Fatmucket in the North Fork Saline River (Burns and McDonnell 1992a, b; C. Davidson, Service, pers. comm.). Scott (2004) resurveyed one of these sites, but did not locate any live or relict Arkansas Fatmucket. FWS and AGFC conducted a comprehensive survey of the North Fork Saline River in 2006. They found four live Arkansas Fatmucket specimens at two of 15 historical sites and no new sites. They repeated this survey in 2015 and found three live Arkansas Fatmucket at three sites (Figure 3). These included the two sites from 2006 and one new site (C. Davidson, Service, pers. comm.). The apparent, catastrophic decline of the North Fork Saline River population is perplexing, but likely a result of increased urban development and other land use activities in the watershed.

Addressing threats alone is insufficient to ensure population viability due to small population size and stochastic events such as multiple large flood events in past decade and increasing urbanization that contributed to increased sedimentation and reductions in number of sites and individuals. In 2018, AGFC released 46 two plus year old Arkansas Fatmucket at three sites in the North Fork Saline. At the time of this review, no post-release monitoring data is available.

Middle Fork Saline River – There are 6 historical locations (1981 and 1987) for Arkansas Fatmcket in the Middle Fork Saline River (Harris and Gordon 1988; C. Davidson, Service, pers. comm.). Scott (2004) found 23 live Arkansas Fatmucket at 4 of 7 sites. Harris and Gordon's (1988) Site MFSR03 supported one of the largest Arkansas Fatmucket meta-populations, but it was extirpated by 2003 (Christian et al. 2006).

Arkansas Fatmucket distribution in the Middle Fork Saline River is similar when comparing collections from the 1980s and 2003 – 2015 (Figures 2 and 3). However, Arkansas Fatmucket abundance declined at all sites in the Middle Fork Saline River during the same period (Christian et al. 2006; C. Davidson, Service, pers. comm.). Scott (2004), Christian et al. (2006), and the FWS and AGFC surveys (2006 and 2015; C. Davidson, Service, pers. comm.) discovered five previously undocumented Arkansas Fatmucket sites, but abundance was low at all sites.

Addressing threats alone is insufficient to ensure population viability due to small population size and stochastic events such as multiple large flood events in past decade and increasing urbanization that contributed to increased sedimentation and reductions in number of sites and individuals. In 2018, AGFC released 55 two plus year old Arkansas Fatmucket in the Middle Fork Saline River. At the time of this review, no post-release monitoring data is available.

Alum Fork Saline River – In the Alum Fork Saline River, 50% (3) of Harris and Gordon's (1988) original status assessment sites remain extant and 67% occur immediately upstream of low water bridges that help stabilize habitat in the immediate vicinity. FWS and AGFC identified 17 previously undocumented sites since 2006, 94% with < 5 Arkansas Fatmucket. During the last 5-year review, the Alum Fork Saline River was stable. There appears to be greater variability (i.e. historical sites disappear, newly established sites appear) with small habitat patches than previously thought. Number of sites and total individuals were similar between 2006 and 2015 surveys. In 2018, AGFC released 66 two plus year old Arkansas Fatmucket at six sites in the Alum Fork Saline River. At the time of this review, no post-release monitoring data is available.

Saline River – Harris and Gordon (1988) found 11 live Arkansas Fatmucket at 8 of 14 sites. In 1989, Arkansas Department of Transportation (ArDoT) found 18 live individuals within the project area for the County Road 5 bridge construction. Davidson and Clem (2002) and Davidson and Gosse (2003) found 23 live individuals at 10 sites between Interstate 30 and U.S. Highway 270. In 2016, ArDoT relocated 4 individuals for the Interstate 30 expansion project.

Addressing threats alone is insufficient to ensure population viability due to small population size and stochastic events such as multiple large flood events in past decade and increasing urbanization that contributed to increased sedimentation and reductions in number of sites and individuals. In 2018, AGFC released 45 two plus year old Arkansas Fatmucket at four sites in the Saline River. At the time of this review, no post-release monitoring data is available.

Summary

With increased distance between occupied habitat patches, reduced abundance, and continuing or increasing threats to Arkansas Fatmucket, this species is facing potential extinction without continued propagation and widespread conservation to minimize threats. The demise of population strongholds during a relatively short period (late 1980s – early 2000s) is perplexing. Brown and Brown (1989) first noted Arkansas Fatmucket declines in the South Fork Ouachita River basin due to sedimentation and stream channel instability. FWS and AGFC noted widespread sedimentation and channel instability in the Ouachita River basin (Ouachita, South Fork Ouachita, and Caddo rivers) (K. Moles, AGFC, pers. comm.; C. Davidson, Service, pers. comm.). The Saline River basin experienced several substantial flood events (Figures 4 – 5) since 2008 that potentially destabilized mussel habitat and contributed to greater variability in habitat patch size and distribution. Increased urbanization near Benton and Hot Springs Village is increasing impervious surfaces in the Saline River basin, possibly leading to higher magnitude and more frequent flooding and sedimentation. Davidson (2015) noted changes in mussel community composition towards species more tolerant of finer sediments in the lower Saline River compared to 1996 data (Davidson 1997). While the source is unknown, anecdotal observations suggest increasing urbanization in the Saline River headwaters may be the primary source of the change in the mussel community (C. Davidson, Service, pers. comm.).

Scott (2004) and Christian et al. (2006) analyzed 137 Arkansas Fatmucket specimens from the Saline and Ouachita River systems for sex, size, and gravidity status. Sex ratio was skewed towards males (50 females, 87 males), but it did not deviate significantly from the expected 1:1 ratio.

Figure 4. U.S. Geological Survey (Station ID 07362587) Alum Fork Saline River discharge data for 1991 – 2008.

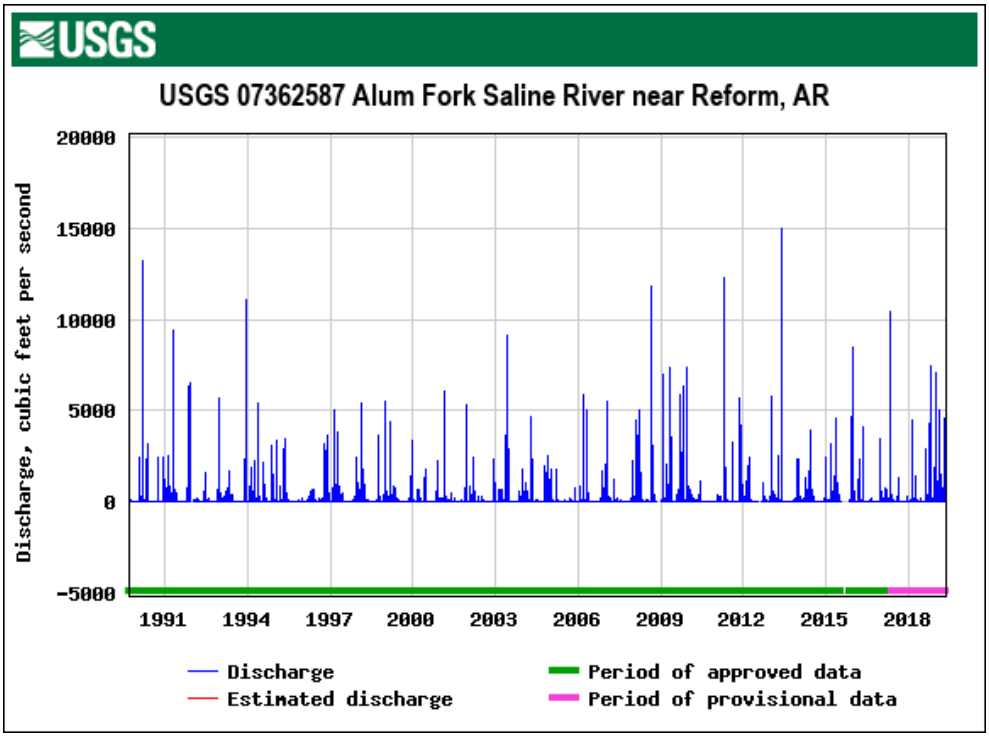
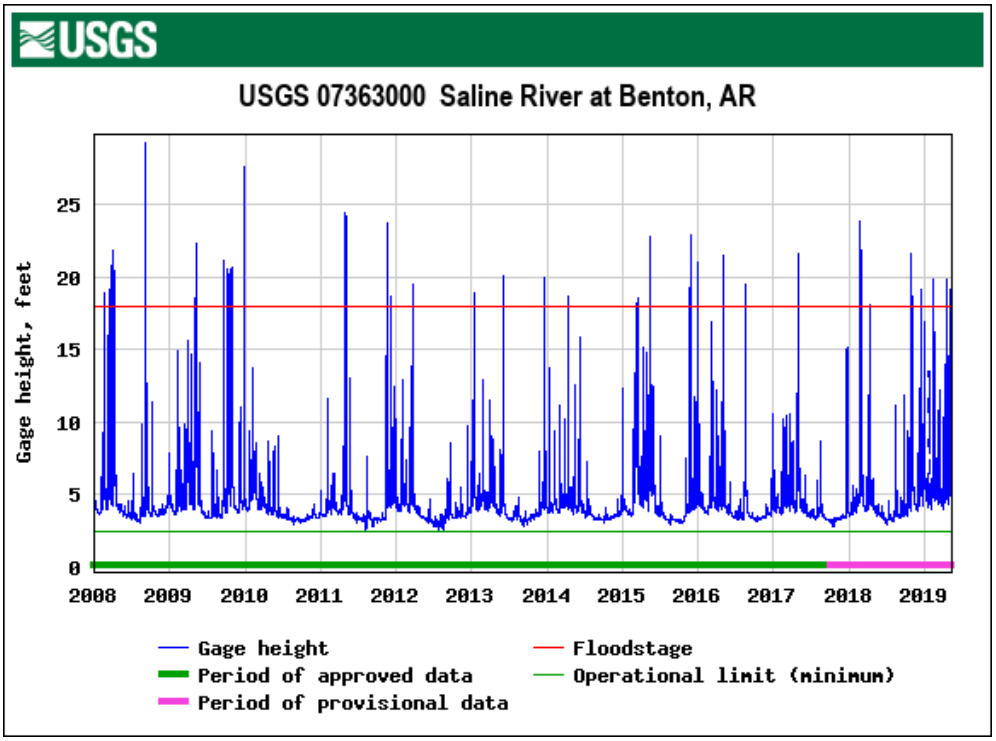


Figure 5. U.S. Geological Survey (Station ID 07363000) Saline River discharge data for 2008 - 2019.



Mean size measurements for all Arkansas Fatmucket specimens examined during Scott's research were 86.9 ± 14.9 mm in length, 34.3 ± 6.7 mm in width, and 49.8 ± 8.1 mm in depth. Males are significantly larger than females with a mean size 5.87 mm longer, 0.18 mm wider, and 1.35 mm deeper (Scott 2004, Christian et al. 2006). FWS and AGFC report similar results in 2006 (length = 89.3 ± 8.8 mm, width = 33.7 ± 4.1 mm, height = 50.8 ± 5.3 mm; n = 55). Table 1 shows mean (standard deviation) length and sex ratio for each river for pre- and post-2000 periods.

b. Demographic characteristics

The Arkansas Fatmucket reproductive cycle is similar to other native freshwater mussels. Males release sperm into the water column. The females take in the sperm through their siphons during feeding and respiration. The females retain fertilized eggs in their gill marsupium until the larvae (glochidia) fully develop. The female releases her glochidia when a suitable fish host attacks the gill marsupium.

The Arkansas Fatmucket is gravid from March through October (Scott 2004). Scott (2004) and Christian et al. (2006) tested 26 fish species and one amphibian, the Red River mudpuppy (*Necturus maculosus louisianensis*) for their potential as suitable host. Glochidia successfully transformed on sunfishes (Centrarchidae), with greatest success occurring with the spotted bass (*M. punctulatus*) and largemouth bass (*M. salmoides*; Table 2).

Table 1. Mean length (standard deviation) and male to female ratios for Arkansas Fatmucket (*Lampsilis powellii*), pre-2000 and 2000 – 2019 (compiled from all available literature and unpublished survey data – see Section I.C.5; C. Davidson, Service, pers. comm.)

River	Mean Length (SD) Pre-2000	Mean Length (SD) 2000 - 2019	Male: Female Pre-2000	Male:Female 2000 - 2019
Saline River	86.9 (11.1)	84.7 (9.2)	--	1:1
Alum Fork Saline River	90.0 (9.9)	87.6 (11.6)	2.3:1	2.2:1
Middle Fork Saline River	84.6 (9.8)	90.8 (9.0)	2.1:1	1.7:1
North Fork Saline River	89.9 (14.0)	87.5 (20.3)	1.9:1	0.5:1
South Fork Saline River	83.9 (7.5)	*extirpated*	1.5:1	*extirpated*
Ouachita River	96.0 (11.7)	88.9 (4.8)	1.4:1	0:1
South Fork Ouachita River	90.1 (13.6)	85.4 (10.5)	1.8:1	1.5:1
Caddo River	98.5 (10.9)	88.6 (4.4)	0.7:1	1:1

Table 2. Suitable fish host from Scott's (2004) fish host suitability trials for the Arkansas Fatmucket (*Lampsilis powellii*).

Scientific Name	Common Name
Ambloplites ariommus	Shadow Bass
Lepomis cyanellus	Green Sunfish
Lepomis macrochirus	Bluegill
Lepomis megalotis	Longear Sunfish
Micropterus dolomieu	Smallmouth Bass
Micropterus punctulatus	Spotted Bass
Micropterus salmoides	Largemouth Bass

c. Habitat

Harris and Gordon (1988) identified four microhabitats for the Arkansas Fatmucket. Pool segments with the substrate comprised primarily of cobble with interspersion of sand and gravel and sufficient current to keep fine silt particles swept clean. Backwater areas downstream of islands or peninsulas covered with American water willow (*Justicia americana*). Pools upstream of water willow islands with depositional substrates consisting of sand, gravel, and cobble. Overflow and secondary channels with permanent and backwater ponds located at the confluence of minor tributaries.

2. Five Factor Analysis (threats)

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

In the upper Saline River watershed, DeClerk et al. (2006) identified several threats in the upper Saline River watershed. These include:

- A landscape level analysis of major land use changes within the watershed between 1986 and 2004 quantified changes in the watershed and determined anthropogenic impacts. Results indicate:
    - The largest change (47 percent increase) in landscape classification was the increasing urbanization of the watershed characterized by the expansion of Benton and Hot Springs Village into rural areas.
    - There was an increase in golf course coverage by 231 percent within Hot Springs Village.
    - Pine-dominated forest increased by 24 percent with a corresponding decrease in the natural mixed woods forest matrix by 22 percent. This change is indicative of increasing

timber production activities.

Changing land uses may lead to altered hydrology and stream geomorphology and increased pollutant inputs (*e.g.*, sedimentation, nutrients, and other contaminant from storm water runoff).

- Unrestricted cattle access into streams, water withdrawal for agricultural and recreational purposes (*i.e.,* golf courses), lack of adequate riparian buffers, construction and maintenance of county roads, and non-point source pollution arising from a broad array of activities, particularly rapid urbanization around Benton and Hot Springs Village, continue to increase and degrade suitable habitat for Arkansas Fatmucket in the upper Saline River watershed.

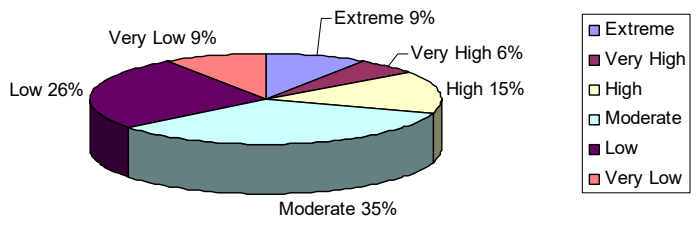
- Instream gravel mining in the South Fork and Middle Fork Saline River.

- Eroding stream banks depositing sediment in downstream reaches resulting in a reduction of habitat quantity and quality. Figure 4 provides an evaluation of bank erosion for approximately 40 miles of the Middle Fork Saline River.

- There are 19 impoundments located within the upper Saline River watershed. Construction of nine new dams in the Middle Fork Saline River watershed occurred in conjunction with development of Hot Springs Village (the largest gated community in Arkansas).

- The expansion of water withdrawals and diversions may be a contributing factor to hydrologic alterations and geomorphic instability in the four forks of the Saline River. U.S. Geological Survey gaging stations on the Middle Fork Saline River exhibited an increasing trend in the annual number of zero-flow days (1986 – 2004), a trend consistent with increased consumptive water withdrawals within the tributary watersheds.

Figure 6
Range of Bank Erosion Hazard Index Values
Middle Fork Saline River



DeClerk et al. 2006

Since 2010, annual growth rate for Benton, Arkansas ranges from 1.4 – 4.5 percent annually (http://worldpopulationreview.com/us-cities/benton-ar-population). From Hot Springs Village founding in 1970 through 1990, the Village grew to nearly 6,500 residents. The population more than doubled to 14,000 by 2010. However, the population remained nearly unchanged to through 2019 (13,900).

Galloway et al. (2008) found nutrient concentrations were generally higher downstream of Mill Creek, the receiving stream for Hot Springs Village wastewater treatment plant effluent, and decreased with further distance from Mill Creek. They also found flow-weighted suspended sediment concentrations were intermediate to relatively undeveloped sites across the Nation and Arkansas. Overall, water quality is somewhat poorer than least disturbed stream regionally and nationally and aquatic habitat is suboptimal and most often affected by factors related to sedimentation, bank stability, or riparian vegetative width.

The construction of a reservoir on Big Cedar Creek resulted in the first documented catastrophic decline of Arkansas Fatmucket in the South Fork Ouachita River circa 1989 due to increased sedimentation during construction.

Instream gravel mining contributes to habitat instability in the Ouachita River and in headwater tributaries of the Caddo River, as well as the river proper. FWS collected > 150 fresh dead mussels in spoil material associated with a 2006 incident of illegal gravel mining in the Ouachita River at Cherry Hill. However, FWS did not recover any fresh dead Arkansas Fatmucket despite this being a documented Arkansas Fatmucket locality. FWS collected 19 individuals representing five species and no Arkansas Fatmucket at this site one year later compared to 73 individuals representing 11 species including one Arkansas Fatmucket in 1988 (Harris and Gordon 1988).

The Service documented numerous “muddy” tributaries draining into the Caddo River following storm events during 2007 mussel surveys, while numerous others remained generally clear to slightly turbid. This turbidity appeared to be attributable to several sources including urban development near Glenwood, unstable stream banks, and unpaved roads.

ADEQ’s 2016 303(d) list includes the Alum Fork Saline River (10 miles) and Saline River (19 miles) as impaired streams due to pH and turbidity, respectfully. Their draft 2018 impaired streams includes Alum Fork Saline River (27 miles for dissolved oxygen and pH), Saline River (60 miles due to turbidity and 27 miles due to pH and dissolved oxygen), North Fork Saline River (38 miles due to dissolved oxygen), South Fork

Ouachita River (26 miles due to dissolve oxygen), and South Fork Ouachita (4.8 miles)

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

There is no evidence to suggest that overutilization is a threat.

c. Disease or predation

Muskrats (*Ondatra zibethicus*) and several aquatic turtle species prey on mussels in general and likely Arkansas Fatmucket. We have no data that indicates natural predation is a significant threat.

d. Inadequacy of existing regulatory mechanisms:

Clean Water Act

The objective of the Federal Water Pollution Control Act, commonly referred to as the Clean Water Act (CWA) (33 U.S.C. 1251 et seq.), is to restore and maintain the chemical, physical, and biological integrity of the nation's waters by preventing point and nonpoint pollution sources. States are responsible for setting and implementing water quality standards that align with the requirements of the CWA. Overall, implementation of the CWA could benefit Arkansas Fatmucket through the point and nonpoint programs.

Nonpoint source (NPS) pollution comes from many diffuse sources, unlike pollution from industrial and sewage treatment plants. As the runoff moves, it transports natural and human-made pollutants (nonpoint source). States report that nonpoint source pollution is the leading remaining cause of water quality problems. Sources of NPS pollution within the watersheds occupied by Arkansas Fatmucket include timber clear-cutting, clearing of riparian vegetation, urbanization, road construction, and other practices that allow bare earth to enter streams. Currently, the CWA may not adequately protect Arkansas Fatmucket habitat from NPS pollution. There is no information concerning the implementation of the CWA regarding NPS pollution specific to protection of Arkansas Fatmucket. However, insufficient implementation could threaten Arkansas Fatmucket.

Despite some reductions in point source discharges, the CWA may not provide adequate protection for filter-feeding organisms that are sensitive to extremely low levels of contaminants (see Chemical Contaminants discussion). There is no specific information known about the sensitivity of Arkansas Fatmucket to common point source pollutants like industrial and municipal pollutants and very little information on other freshwater mussels. Because there is very little information known about water quality parameters necessary to protect freshwater mussels, it is difficult to determine whether the CWA is adequately addressing threats to Arkansas Fatmucket.

State and Federal Water Quality Programs

Current State regulations regarding pollutants are protective of aquatic organisms. However, freshwater mollusks may be more susceptible to some pollutants than the test organisms commonly used in bioassays. Additionally, water quality criteria may not incorporate data available for freshwater mussels (March et al. 2007). A multitude of bioassays conducted on mussel species (Augspurger et al. 2007; Wang et al. 2007a – d, 2010) show that freshwater mollusks are more sensitive to some chemical pollutants, including chlorine, ammonia, certain metals, fungicides, and herbicide surfactants. Another study found that nickel and chlorine were toxic to a federally threatened mussel species at levels below the current criteria (Gibson 2015). The study also found mussels are sensitive to SDS (sodium dodecyl sulfate), a surfactant commonly used in household detergents, for which water quality criteria do not currently exist. Several studies have demonstrated that the criteria for ammonia developed by EPA in 1999 were not protective of freshwater mussels (Augspurger et al. 2003; Newton et al. 2003; Mummert et al. 2003). However, in 2013 EPA revised its recommended criteria for ammonia. The new criteria are more stringent and reflect new toxicity data on sensitive freshwater mollusks (78 FR 52192, August 22, 2013; p. 2). However, Arkansas has not yet adopted the new ammonia criteria.

In summary, despite existing authorities such as the Clean Water Act, pollutants continue to impair the water quality throughout the current range of the Arkansas Fatmucket. State and Federal regulatory mechanisms have helped reduce the negative effects of point source discharges since the 1970s, yet these regulations are difficult to implement and regulate. While new water quality criteria are being developed that take into account mollusks, most criteria currently do not. We expect that it will take several years to implement new water quality criteria throughout the range.

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

Population Fragmentation and Isolation

The majority of the remaining Arkansas Fatmucket populations are generally small and becoming more geographically isolated. The patchy distributional pattern in short stream reaches makes them more susceptible to extirpation due to the low potential for recolonization from other populations. Single catastrophic events, such as toxic chemical spills or other stochastic events, could cause the extirpation of any of these small, isolated Arkansas Fatmucket occurrences. Increasing levels of isolation make natural repopulation of any extirpated population improbable without human intervention. Population isolation also prohibits the natural interchange of genetic material between populations.

Arkansas Fatmucket populations in the Ouachita, South Fork Ouachita, and Caddo Rivers are likely below the effective population size (EPS– the number of individuals in a population who contribute offspring to the next generation), and achieving the EPS is necessary for a population to adapt to environmental change and maintain long-term viability. Extirpation of isolated populations eventually occurs when population size drops below the EPS or threshold level of sustainability (Soulé 1980). Evidence of recruitment in these populations is scant, making recruitment reduction or outright failure suspect. These populations may be experiencing the bottleneck effect of not attaining the EPS. Without genetic interchange, small, isolated populations could be slowly expiring, a phenomenon termed the extinction debt (Tilman et al. 1994, pp. 65–66). Even given the absence of existing or new anthropogenic threats, disjunct populations may be lost if they are below-threshold effective population size. Additionally, evidence indicates that general habitat degradation continues to decrease habitat patch size, further contributing to the decline of this species.

Various invasive aquatic species (e.g., Asian clam (*Corbicula fluminea*)) occur in the range of the Arkansas Fatmucket. Asian clam populations appear to be increasing in recent years in degraded streams, such as the Middle Fork Saline River.

AGFC recently introduced a Tennessee strain smallmouth bass in the upper Ouachita River for recreational purposes. It is currently unknown whether Tennessee strain smallmouth bass are suitable host for Arkansas Fatmucket. The replacement or diffusion of native Ouachita River smallmouth bass genetics with the Tennessee strain may reduce host availability for Arkansas Fatmucket. However, the implications of stocking Tennessee strain smallmouth bass in the Ouachita River is unknown at this time.

Temperature

Impoundments, tail water releases from dams, industrial and municipal effluents, changes in riparian habitat, and droughts may alter natural temperature regimes. Exact critical thermal limits for Arkansas Fatmucket survival and normal physiological functions are unknown, but closely related species are classified as thermally sensitive (e.g., *Lampsilis cardium* and *Lampsilis teres*; Spooner and Vaughn 2008). However, high temperatures can reduce dissolved oxygen concentrations in the water, which slows growth, reduces glycogen stores, impairs respiration, and may inhibit reproduction (Fuller 1974). Low temperatures can significantly delay or prevent metamorphosis (Watters and O'Dee 1999). Water temperature increases shorten the period of glochidial encystment, reduce righting speed (various reflexes that tend to bring the body into normal position in space and resist forces acting to displace it out of

normal position), increase oxygen consumption, and slow burrowing and movement responses (Fuller 1974; Bartsch et al. 2000; Watters et al. 2001; Schwalb and Pusch 2007). Several studies documented the influence of temperature on the timing aspects of mussel reproduction (Gray et al. 2002; Allen et al. 2007; Steingraeber et al. 2007). Peak glochidial releases are associated with water temperature thresholds that can be thermal minimums or maximums, depending on the species (Watters and O'Dee 2000).

Climate Change

In its Fifth Assessment Report, the Intergovernmental Panel on Climate Change (IPCC) concluded that 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). Species that are dependent on specialized habitat types, limited in distribution, or at the extreme periphery of their range may be most susceptible to the impacts of climate change (see 75 FR 48911, August 12, 2010); however, while continued change is certain, the magnitude and rate of change is unknown in many cases.

To the extent possible, we use ‘‘downscaled’’ climate projections which provide higher resolution information that is more relevant to the spatial scales used to assess effects to a given species (see Glick et al. 2011 for a discussion of downscaling). With regard to Arkansas Fatmucket, downscaled projections of climate change are available, but projecting precise effects on the species from downscaled models is difficult because of the large inhabited geographic area. However, projections for the change in annual air temperature by the year 2080 for the Arkansas Fatmucket ranges between an increase of 7 to 8 degrees Fahrenheit (°F) in annual air temperature (Maura et al. 2007, as displayed on http://www.climatewizard.org/# 2012).

Mussel species are thermally sensitive or thermally tolerant, according to their response to warm summer water temperatures greater than 35 °C (95 °F) (Spooner and Vaughn 2008). Although we do not have physiological data on Arkansas Fatmucket, a closely related species, *L. cardium*, is thermally sensitive (Spooner and Vaughn 2008). Data for the Kiamichi River in Oklahoma suggests that over a 17-year period as water and air temperatures increased, mussel beds once dominated by thermally sensitive species transitioned to dominance by thermally tolerant species (Galbraith et al. 2010; Spooner and Vaughn 2008). Ficke et al. (2005; 2007) described the general potential effects of climate change on freshwater fish populations worldwide. Overall, they expect the

distribution of fish species to change, including range shifts and local extirpations. Because freshwater mussels are entirely dependent upon a fish host for successful reproduction and dispersal, any changes in local fish populations would also affect freshwater mussel populations. Therefore, mussel populations will reflect local extirpations or decreases in abundance of fish species.

Climate change has the potential to increase the vulnerability of the Arkansas Fatmucket to random catastrophic events (McLaughlin *et al*. 2002, Thomas *et al.* 2004). We expect an increase in both severity and variation in climate patterns, with extreme floods, strong storms, and droughts becoming more common (Cook *et al.* 2004, Ford *et al*. 2011, IPCC 2014). Thomas *et al.* (2004) report that frequency, duration, and intensity of droughts are likely to increase in the Southeast due to global climate.

Cumulative Effects of Threats (Factors A, D, E)
The life-history traits and habitat requirements of the Arkansas Fatmucket, and other freshwater mussels in general, make them extremely susceptible to environmental change. Unlike other aquatic organisms (e.g., aquatic insects and fish), mussels have limited refugia from stream disturbances (e.g., droughts, sedimentation, chemical contaminants). Mechanisms leading to the decline of Arkansas Fatmucket, as discussed above, range from local (e.g., riparian clearing, chemical contaminants, etc.), to regional influences (e.g., altered flow regimes, channelization, etc.), to global climate change. The synergistic (interaction of two or more components) effects of threats are often complex in aquatic environments, making it difficult to predict changes in mussel and fish host(s) distribution, abundance, and habitat availability that may result from these effects. While these stressors may act in isolation, it is more probable that many stressors are acting simultaneously (or in combination) (Galbraith et al. 2010) on Arkansas Fatmucket populations.

D. Synthesis

At the time of listing in 1990, Arkansas Fatmucket was extant in the Ouachita River upstream of Lake Ouachita, South Fork Ouachita River upstream of Lake Ouachita, Alum, Middle, North forks of the Saline River, Saline River upstream of the Fall Line, and Caddo River. There are new range extensions within the Ouachita and Saline rivers since listing, but not since the last 5-year review. While extant populations of Arkansas Fatmucket occur throughout most of the historical range, Scott (2004) and Christian et al. (2006) documented significant population declines and reduced distribution. The AGFC and Service conducted two rangewide, comprehensive surveys since these assessments, the most recent occurring in 2015, and document further declines in distribution and abundance (K. Moles, AGFC, pers. comm.; C. Davidson, Service, pers. comm.). The demise of population strongholds

during a relatively short period (late 1980s – 2015) is perplexing. With increased distance between occupied habitat patches, reduced abundance, and continuing or increasing threats to Arkansas Fatmucket, this species faces potential extirpation from the Ouachita, South Fork Ouachita, Middle Fork Saline, North Fork Saline, and Caddo rivers. Populations believed to be strongholds in the Saline River headwaters (Alum, Middle, North forks) during the last 5-year review now face potential extirpation due to recent substantial population declines (fewer sites and individuals) from 2007 – 2015. Potential extinction is imminent without continued propagation and widespread conservation to minimize threats. Addressing threats alone is insufficient to ensure population viability due to small population size and stochastic events such as multiple large flood events in past decade and increasing urbanization that contributed to increased sedimentation and reductions in number of sites and individuals. Increasingly small and isolated populations in the Saline River basin are becoming increasingly more susceptible to stochastic events and ongoing and/or increasing anthropogenic effects (see *Five Factor Analysis*). The Alum Fork Saline River and Saline River appear to be the strongholds for this species, but these populations face threats associated with encroaching urbanization.

A number of factors continue to affect extant populations and/or limit recovery of the species. Urbanization into rural areas of the upper Saline and Caddo watersheds continues to increase and appears to be a primary source of habitat and water quality degradation. Percent urban land use in the Saline and Caddo watersheds was 5 and 6 percent, respectively, in 2016. From 2011 – 2016, percent urban land cover increased 0.5 and 0.9 percent, respectively, in these watersheds (2016 Land Use Land Cover dataset). However, the majority of this conversion to urban in the Saline River watershed is occurring in the headwaters (Benton, Bryant, Haskell, Salem) where Arkansas Fatmucket occurs, which likely means the percent land conversion within the headwaters region is greater than 1%.. Threats appear to be stable since the last 5-year review in the Ouachita River headwaters.

The expansion of consumptive water withdrawals, diversions, and impoundments is another contributing factor to increases in elevated turbidity during storm events, soil erosion/sediment instability, and hydrologic alteration in the upper Saline River watershed. Extant populations vary in levels of protection, and effects from these threats may be difficult to alleviate. Encouraging private landowners, corporations, and local, state, and federal governments to be more proactive in implementing conservation measures that benefit both terrestrial and aquatic habitats in these watersheds is critical.

Captive propagation, augmentation, and reintroduction are necessary to increase resiliency and achieve sufficient redundancy. Due to the restricted range, geographic isolation of most extant populations, and small population size, the species is likely suffering genetic isolation and reduced adaptive capacity throughout much of its range, resulting in lower representation. Given current and expected future decreases in resiliency, populations become more vulnerable to extirpation from stochastic events resulting in concurrent losses in representation and redundancy.

The synergistic (interaction of two or more components) effects of threats are often complex in aquatic environments, making it difficult to predict changes in mussel and fish host(s) distribution, abundance, and habitat availability that may result from these effects. While these stressors may act in isolation, it is more probable that many stressors are acting simultaneously (or in combination) on Arkansas Fatmucket populations. Given increases in threats in the Saline River headwaters and Caddo River and decreases in population range and size (see Section II.C), we conclude that the Arkansas Fatmucket is in danger of extinction throughout all or a significant portion of its range; and therefore, we recommend reclassification to endangered.

III. RESULTS

A. Recommended Classification:

The Arkansas Fatmucket should be reclassified to endangered.

B. Recovery Priority Number __5___

C. Listing and Reclassification Priority Number:

Reclassification (from Threatened to Endangered) Priority Number: 2

The degree of threat to the Arkansas Fatmucket is high because there is a continual threat to its habitat (*e.g.* primarily from land use practices that are detrimental to habitat and water quality, illegal activities such as gravel mining, and habitat fragmentation). The recovery potential is moderate because the biology is understood, as well as ecological factors affecting the biology.

IV. RECOMMENDATIONS FOR FUTURE ACTIONS

1. Continue propagation and augmentation efforts in the Ouachita and Saline basins.

2. Implement the range wide programmatic Safe Harbor Agreement for Arkansas Fatmucket.

3. Implement high priority strategic actions outlined by DeClerk (2006).

4. Implement population health monitoring.

5. Collect age and growth data.

6. Conduct a thermal tolerance study with Arkansas Fatmucket and its fish hosts that then models the possible effects of climate change over the last 50 years.

7. Determine status of fish hosts in relationship to Arkansas Fatmucket distribution.

8. Determine habitat requirements of fish hosts, condition/status of habitat (i.e., pristine, degraded, etc), and restoration/protection needs.

9. Conduct an analysis of historical sub-watershed and local buffer land use land cover, development, and impervious surface analyses, as well as a cumulative watershed sediment analyses.

10. Actively use the U.S. Fish and Wildlife Service's Partners for Fish and Wildlife Program and U.S.D.A. Natural Resources Conservation Service's Farm Bill program to foster a working partnership with landowners, municipalities, industry, NGOs, and state and federal agencies to address and minimize threats.

11. Recent genetic analyses indicate the existence of two populations (Ouachita and Saline basins), each containing unique mtDNA haplotypes and microsatellite alleles. Protection of these two populations is important to maintain the unique genetic structure of the species.

12. Develop a population viability model.

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U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW OF ARKANSAS FATMCUKET (*Lampsilis powellii*)

Current Classification: Threatened.

Recommendation resulting from the 5-Year Review:

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

Review Conducted By: Chris Davidson, Arkansas Ecological Services Field Office.

FIELD OFFICE APPROVAL:

Lead Field Supervisor, Fish and Wildlife Service

Approve MELVIN TOBIN Digitally signed by MELVIN TOBIN Date: 2020.05.06 11:46:00 -05'00' Date _____

OTHER REGIONAL OFFICE APPROVAL: None required (Arkansas endemic)

Appendix A
Peer Review

A. Peer Review Method: The Service's unified South Atlantic-Gulf and Mississippi Basin Regions coordinated peer review. They selected four peer reviewers for their knowledge of and expertise with Neosho Mucket. They received individual responses from two reviewers, but only one reviewer provided comments.

B. Peer Reviewers: Peer reviewers included personnel from:
Arkansas Game and Fish Commission
Arkansas State University
Clarkson University
U.S. Forest Service

C. Peer Review Charge: We asked reviewers to conduct a scientific review of technical information. We did not request reviewers to review the legal status determination.

D. Summary of Peer Review Comments and Our Response: The reviewer from Clarkson University agreed that populations continue to decline since the baseline 1988 survey based on recent surveys since the early 2000s. He stated there is little evidence of habitat protection and viable populations being sustained for 20 years. He opined that the recovery plan is failing and offered some fundamental life history and environmental research needs to aid species recovery. *Our Response:* We incorporated the reviewer's suggestions for fundamental life history and environmental research into Section IV – Recommend Future Actions. Regarding conservation genetics followed by population augmentation, recent genetic analyses indicate the existence of two populations (Ouachita and Saline basins), each containing unique mtDNA haplotypes and microsatellite alleles (Berg et al. 2017). The Service and Arkansas Game and Fish Commission are currently working to augment these populations.

Appendix B
A Summary of Literature Relevant to Arkansas Fatmucket

Prior to federal listing:

Johnson (1980) monograph includes distributional information based on published accounts and some museum material.

Gordon and Harris (1985) examined museum specimens, published accounts, and recent collections to better delineate the known distribution of Arkansas Fatmucket.

Harris and Gordon (1987) considered Arkansas Fatmucket a state threatened species restricted to upper portions of the Saline and Ouachita rivers and Caddo River.

Harris and Gordon (1988) represent the first comprehensive status survey of Arkansas Fatmucket. They sampled 139 localities in the upper Ouachita River, Saline River, Caddo River and Little Missouri River basins. Arkansas Fatmucket was present at 36 of 95 localities (151 live individuals) that yielded native mussels. The species distribution and status included the Alum Fork Saline River (population estimate [PE] 5,000 – 10,000), Middle Fork Saline River (PE 5,000 – 10,000), North Fork Saline River (PE < 1,000), Saline River from confluence of four forks to Tull, AR (PE 1,000 – 5,000), South Fork Ouachita River (PE 5,000 – 10,000), and Ouachita River upstream of Lake Ouachita (PE 1,000 – 5,000), and Caddo River (PE < 1,000 individuals). They identified four microhabitats during this survey.

Brown and Brown (1989) focused on gathering more information on Arkansas Fatmucket populations in the Ouachita National Forest, specifically the South Fork Ouachita River and Alum Fork Saline River drainage basins. Thirteen (13) live Arkansas Fatmucket were collected from four sites in the South Fork Ouachita River and one site in the Alum Fork Saline River. Live Arkansas Fatmucket specimens were restricted to the South Fork Ouachita River upstream of Big Cedar Creek. Data from this report provided the first evidence of catastrophic population declines throughout the South Fork Ouachita River. They identified heavy sedimentation downstream of Big Cedar Creek as a factor affecting distribution within the lower South Fork Ouachita River.

Harris (1989) surveyed approximately one mile of the Caddo River extending downstream from the DeGray Reservoir Reregulating Dam. Five live Arkansas Fatmucket specimens were collected from one site (relative abundance = 8.7 percent).

Since federal listing:

Harris (1991) surveyed approximately 1.4 stream miles in the South Fork Ouachita River Project area proposed planned for inundation by construction of a Soil Conservation Service project. Two live Arkansas Fatmucket specimens were collected during this survey and abundance was determined to be very low within this reach. This survey also confirmed the issues with sedimentation discussed in Brown and Brown (1989).

Burns & McDonnell, Inc. (1992a) surveyed 18 locations on the North Fork Saline River, including three historical locations, from the confluence of Turkey Creek to Arkansas Highway 5. They collected Arkansas Fatmucket (28 live individuals) from 66 percent of the sites, but none at two historical sites, AR Highway 5 and Steel Bridge Road.

Burns & McDonnell, Inc. (1992b) surveyed the North Fork Saline River from Kanis Road to the Turkey Creek confluence; Hurricane Creek from Hurricane Lake Spillway to Bauxite Junction; the South Fork Saline River from near Lonsdale, AR to the confluence with the Alum Fork Saline River; the Alum Fork Saline River from Lake Winona Spillway downstream approximately 2 river miles; and Ouachita River from the Cherry Hill Access to the Pine Ridge Access.

Harris et al. (1992) relocated 44 Arkansas Fatmucket specimens due to the planned replacement of the functionally obsolete, substandard bridge crossing the South Fork Ouachita River on U. S. Highway 270 in Mt. Ida, Arkansas.

Harris and Doster (1992) surveyed the Caddo River from 100 feet upstream to 1,500 feet downstream of Interstate 30. No Arkansas Fatmucket specimens were collected within the survey area.

Johnston et al. (1993) surveyed four streams in the Alum Fork Saline River drainage for mussels as part of an ecosystem level project aimed at understanding the effects of forest management practices on aquatic systems. No Arkansas Fatmucket specimens were collected.

Harris (1994) conducted a microhabitat and population analysis of Arkansas Fatmucket in South Fork Ouachita River at two sites. Arkansas Fatmucket population estimates at Site 1 were 31 ± 38 and 10 ± 19 for 1990 and 1993, respectively. Population estimates for Site 2 were 48 ± 68 and 20 ± 39 for 1991 and 1993, respectively. He tagged 57 Arkansas Fatmucket during the mark-recapture portion of this study.

Arkansas Highway and Transportation Department (1994) conducted a mussel survey from approximately 50 meters upstream of Clark County Road 218 to 500 meters downstream of Arkansas Highway 84. They encountered 96 mussels representing 15 species during the survey. This includes two live and one fresh dead Arkansas Fatmucket specimens.

Harris et al. (1997) re-evaluated the status of Arkansas' rare and endangered mussels.

Harris (1999) evaluated the types of mussels present downstream of Carpenter-Remmel Project (FERC hydroelectric facility) in the Ouachita River. He surveyed 119 sites and 28 sites had mussel aggregations. He found a single specimen of Arkansas Fatmucket in the study area.

U.S. Department of Agriculture, Forest Service. 1999. Ozark-Ouachita Highlands Assessment: aquatic conditions. Report 3 of 5. Gen. Tech. Rep. SRS-33. Ashville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 317 pp.

Davidson and Clem (2002) surveyed 98.7 rm of the Saline River from near Tull, Arkansas to Arkansas Highway 15. They discovered nine new Arkansas Fatmucket sites, extending the known range 26 rm downstream.

Davidson and Gosse (2003) surveyed approximately 2.5 rm of the Saline River near the confluence of Holly Creek. The objective was to locate mussel beds and document species composition and community estimates. They found Arkansas Fatmucket at two of five sites. The population estimate for Site B2 was 19 ± 40 individuals.

Davidson and Clem (2004) surveyed 50.6 rm of the Saline River from Arkansas Highway 15 to Felsenthal National Wildlife Refuge. No Arkansas Fatmuckets were collected from the lower Saline River.

Scott (2004) determined the relative abundance and population demographics of Arkansas Fatmucket, examined reproductive biology, identified suitable fish host, and characterized and assessed habitat use.

Christian and Harris (2004) conducted a comprehensive mussel survey of the Little Missouri River. They did not find any Arkansas Fatmucket, but this negative data is significant because the University of Oklahoma Science and Arts collection contains several specimens from the Antoine River (a tributary to the Little Missouri River) that appear to be Arkansas Fatmucket based on morphological characteristics.

Christian et al. (2006) conducted studies of Arkansas Fatmucket status within its known range, made habitat assessments of mussel beds and surrounding habitat, compared identified fish hosts with species distribution.

U. S. Fish and Wildlife Service with cooperation from Arkansas Game and Fish Commission and U. S. Forest Service conducted a range-wide status assessment of Arkansas Fatmucket in 2006 and 2007.

Hoeh and Breton (2012) and Harris et al. (2004) evaluated genetic divergence between Arkansas Fatmucket (*Lampsilis powellii*) and Fatmucket (*Lampsilis siliquoidea*).

Berg et al. (2017) quantify within population genetic variation for the South Fork Ouachita River, and compare genetic variation between this population and the Saline River basin using mtDNA.

Chase et al. (2018) published the complete male-type mitochondrial genome for Arkansas Fatmucket. This information is valuable for studying patterns of molecular evolution of DUI genomes.

Robicheau et al. (2018) evaluated the utility of the female specific mitochondrial *f-orf* gene for population genetic, phylogeographic and systematic studies in mussels. Their preliminary results indicate the *f-orf* gene may represent a viable molecular marker for population and species level studies.

Walters et al. (in review) analyzed the genetic diversity of Arkansas Fatmucket using the mitochondrial COI gene and 14 microsatellites. They found relatively low genetic diversity and significant population structure, consistent with low gene flow between Ouachita and Saline River populations.