Oyster Mussel
(*Epioblasma capsaeformis,* Lea, 1831)

5-Year Status Review:
Summary and Evaluation

Male (top) and female (bottom) oyster mussel.
Photo by Anthony Ford, U.S. Fish and Wildlife Service.

U.S. Fish and Wildlife Service
Southeast Region
Tennessee Ecological Services Field Office
Cookeville, Tennessee

October 2024

5-YEAR STATUS REVIEW
Oyster Mussel (*Epioblasma capsaeformis*)

GENERAL INFORMATION

Current Classification: Endangered

Lead Field Office: Tennessee Ecological Services, Anthony Ford.

Reviewers:

Lead Regional Office: Southeast Region, Carrie Straight

Cooperating Field Office(s): Alabama Ecological Services, Evan Collins; Virginia Ecological Services, Jess Jones.

Cooperating Regional Office(s): Northeast Region, Martin Miller.

Date of original listing: February 10, 1997 (62 FR 1647; January 10, 1997).

Associated rulemakings:

Critical habitat final rule: September 30, 2004 (69 FR 53136; August 31, 2004).

Experimental population designation: July 16, 2001 (66 FR 32250; June 14, 2001). Establishment of nonessential experimental population status for 16 freshwater mussels (including the oyster mussel) and one freshwater snail in the free-flowing reach of the Tennessee River below the Wilson Dam, Colbert and Lauderdale Counties in Alabama.

Experimental population designation: October 15, 2007 (72 FR 52434; September 13, 2007). Establishment of nonessential experimental population status for 15 freshwater mussels, 1 freshwater snail, and 5 fishes in the lower French Broad River and in the lower Holston River, TN.

Methodology used to complete the review: In accordance with section 4(c)(2) of the Endangered Species Act of 1973, as amended (Act), the purpose of a status review is to assess each threatened species or endangered species to determine whether its status has changed and if it should be classified differently or removed from the Lists of Threatened and Endangered Wildlife and Plants (50 CFR 424.11). The U.S. Fish and Wildlife Service (Service) evaluated the biology, habitat, and threats of the oyster mussel to inform this status review.

We announced initiation of this review in the Federal Register on May 11, 2023 (88 FR 30324) with a 60-day comment period. We received one comment letter from the National Council for Air and Stream Improvement, Inc. The comment received refers to best management practices for silviculture practices and their benefit, when employed, to water quality. These comments were reviewed and incorporated into the discussion of threats, below. We received updates from two conservation partners regarding the species in

response to an information request sent to them concurrent with the public notice. New information received from them has been incorporated into this review. The primary sources of information used in this analysis were the 2004 final listing rule (69 FR 53136), the 2004 recovery plan, peer-reviewed literature, agency reports, unpublished survey data and reports, and personal communication with recognized experts. This review was completed by the Service, Tennessee Ecological Services Field Office, Cookeville, TN. All literature and documents used for this review are on file at the Field Office. All recommendations resulting from this review are the result of thoroughly reviewing the best available information on the oyster mussel.

We have not received significant new information or interpreted previously reviewed information in a new, significant light since the last review of the species, and this review has a low level of public interest and is noncontroversial; therefore, no peer review was conducted.

Species' Recovery Priority Number at start of 5-year review (48 FR 43098)**:**
The oyster mussel's recovery priority number is 5, indicating a high degree of threat and low potential for recovery.

Review History:
Previous 5-Year Reviews:

5-Year Review noticed on September 20, 2005 (70 FR 55157) and completed on July 12, 2011. The Service did not recommend a change to the species' endangered status.

5-Year Review noticed on August 30, 2016 (81 FR 59650) and completed on March 12, 2019. The Service did not recommend a change to the species' endangered status.

REVIEW ANALYSIS

Taxonomy and nomenclature

The oyster mussel was recognized as *Epioblasma capsaeformis* [Lea, 1834] at the time of listing and when the recovery plan was written in 2004. In 2010, Jones and Neves described a new morphologically and genetically diagnosable species in the oyster mussel complex. The new species *Epioblasma ahlstedti* (Duck River dartersnapper) is described from the Duck River and likely occurred historically in the Buffalo River, the Tennessee River at Muscle Shoals, and Shoal Creek, Lauderdale County, Alabama. It is likely that both species co-occurred at Muscle Shoals and in the lower tributaries of the larger streams in this reach of the Tennessee River (Jones pers. comm. 2024). The Freshwater Mollusk Conservation Society (FMCS) recognizes the oyster mussel and the Duck River dartersnapper as a distinct species in the checklist of freshwater mussels (Mollusca: Bivalvia: Unionida) of the United States and Canada (Williams et al. 2017; FMCS 2023).

For a complete list of morphological and genetic diagnostic features for the Duck River dartersnapper see Jones and Neves (2010). We also included a detailed discussion of taxonomy in the 2019 5-year status review (Service 2019). For our status reviews we are tasked with

evaluating the species as listed. For this review, we will address the entire oyster mussel complex that addresses the listed entity of oyster mussel.

A species status assessment would inform our understanding of the current and future resiliency, redundancy, and representation of the Duck River dartersnapper and oyster mussel and enable a well-documented and biologically sound determination of the conservation status of both species under the Act.

Distinct Population Segment (DPS) (61 FR 4722)
The Act 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 of a DPS to only vertebrate species. Because the species under review is a not a vertebrate, the DPS policy does not apply.

Recovery Criteria

Recovery Plan or Outline
Recovery Plan for Cumberland Elktoe (*Alasmidonta atropurpurea*), Oyster Mussel (*Epioblasma capsaeformis*), Cumberlandian Combshell (*Epioblasma brevidens*), Purple Bean (*Villosa perpurpurea*) and Rough Rabbitsfoot (*Quadrula cylindrica strigillata*), May 4, 2004.

Recovery plans are not regulatory documents and are intended to provide guidance to the Service, States, and other partners on methods of minimizing threats to listed species and on criteria that may be used to determine when recovery is achieved. If the recovery criteria defined in the plan are still valid, meeting recovery criteria can indicate that the species no longer requires protections under the Act. However, when recommending whether a listed species should be delisted, the Service must apply the factors in section 4(a) of the Act (84 FR 45020).

Criteria for delisting

(1) At least nine distinct viable stream populations of the oyster mussel in the Cumberland River system, upper Tennessee River system, and/or lower Tennessee River system. This will be accomplished by:

> *(1) Protecting all extant stream populations (i.e., lower Clinch River, Nolichucky River in the upper Tennessee River system; Duck River in the lower Tennessee River system) and ensuring that all of these have viable population status.*
>
> *(2) Reestablishing six viable stream populations in any of the following streams: (a) Cumberland River system (e.g., Rockcastle River, Buck Creek, Big South Fork, Little South Fork, Red River); (b) upper Tennessee River system (e.g., upper Clinch River, Powell River, upper Holston River/North Fork Holston River, lower Holston River, French Broad River); and/or (c) lower Tennessee River system (e.g., Paint Rock River, Elk River, Tennessee River at Muscle Shoals, Shoal Creek, Bear Creek, Buffalo River).*

The Service believes these criteria are appropriate and relevant; however, no criteria have yet been met.

Biology and Habitat Summary

At the time of listing in 1997, oyster mussel was believed to occur within the Cumberland River drainage within Buck Creek (KY) and Big South Fork (TN/KY) and within the Tennessee River drainage in the Powell River (VA/TN), Clinch River (VA/TN), Copper Creek (VA) a Clinch River tributary, and the Duck River (TN), with possible occurrences with the Nolichucky River (TN) and Little Pigeon River (TN) (62 FR 1647).

The oyster mussel complex is now believed to be extirpated from the Cumberland River drainage, and the only remaining natural populations occur in the Clinch, Nolichucky, and Duck rivers. It has been reintroduced into the Powell (TN) and Paint Rock (AL) rivers, with limited or failed reintroduction efforts attempted in Bear Creek (AL), and the Emory (TN), Hiawassee (TN), and Elk (TN) rivers (figure 1).

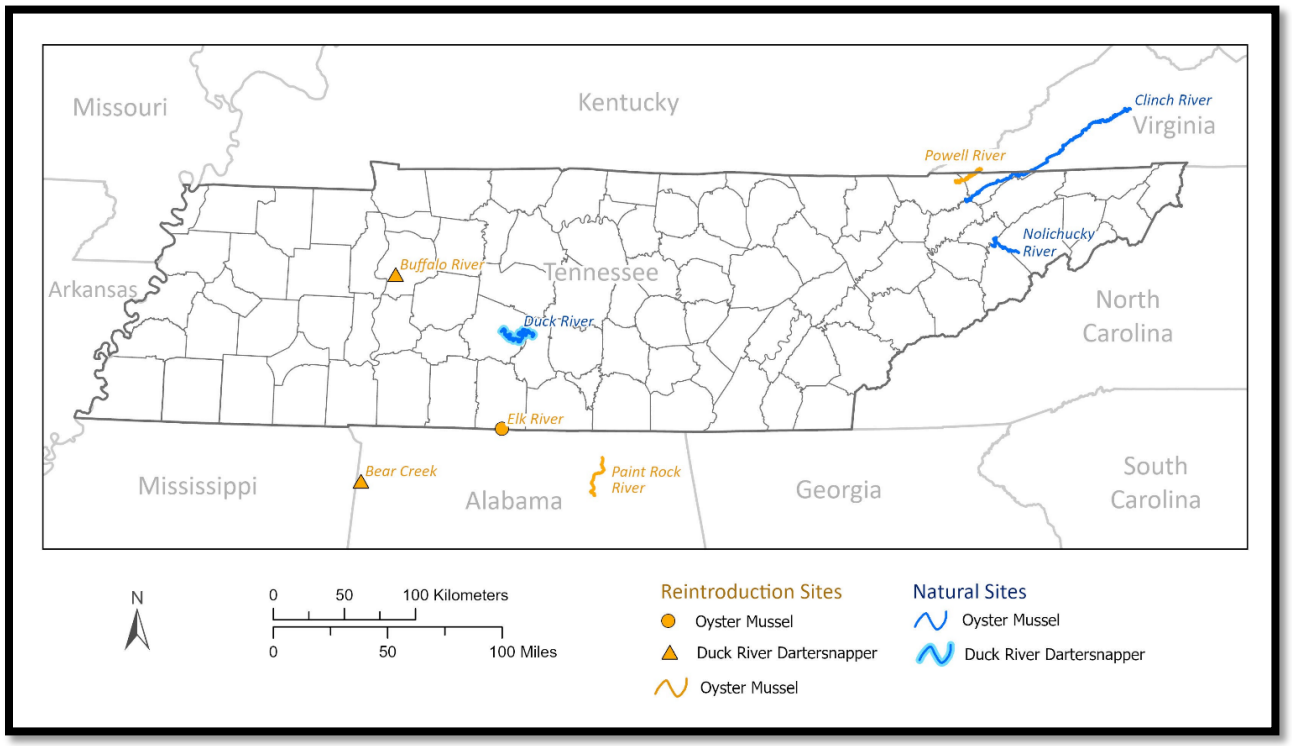

Figure 1. Map of the extant range of the oyster mussel/Duck River dartersnapper mussel to include natural and reintroduced populations.

Oyster Mussel

Powell River (VA/TN)

The Virginia Department of Wildlife Resources Aquatic Wildlife Conservation Center has released 3,545 individuals and Virginia Tech (Freshwater Mollusk Conservation Center) has released 57,389 individual oyster mussels (a mix of adults, sub-adults, and juveniles) into the Powell River at 8 release sites between 2004 and 2019 (figure 2) (Lane et al. 2023). Monitoring at these sites continues

to show these stocked animals are persisting in the Powell River, but no recruitment has yet been documented.

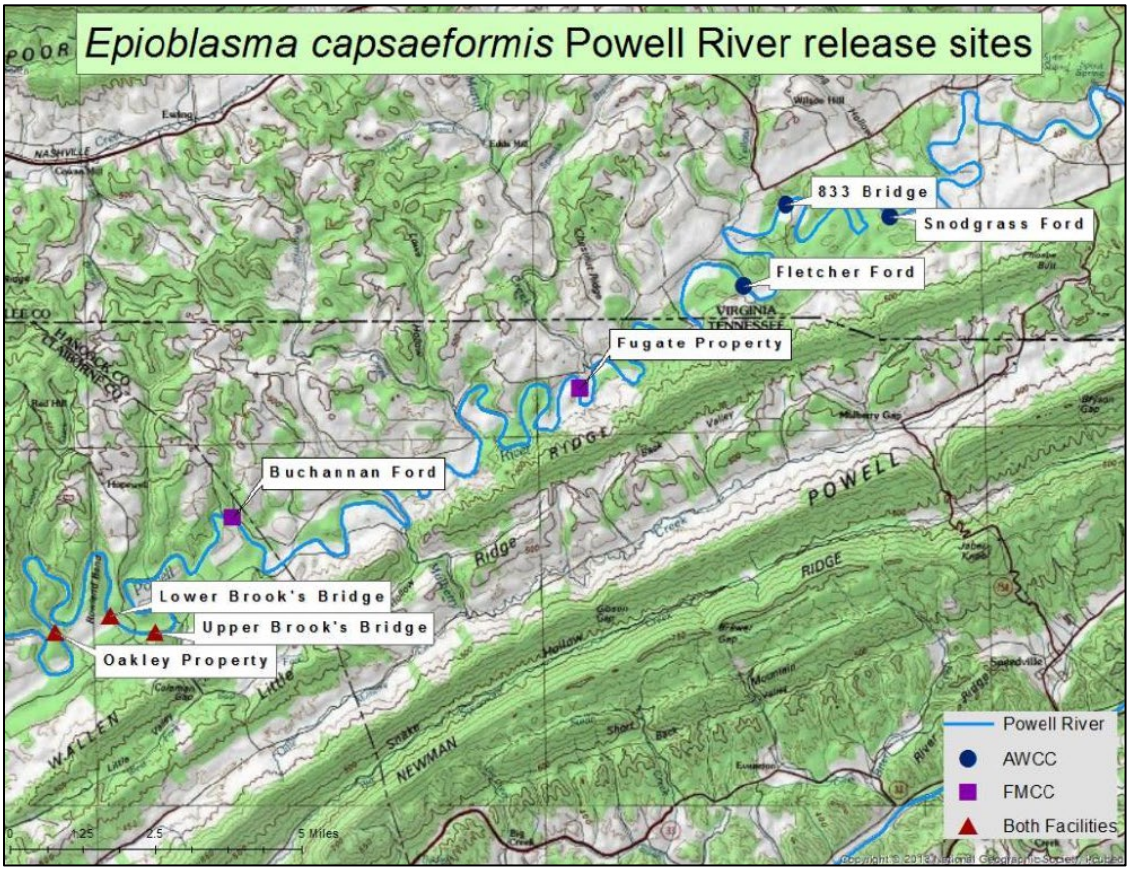

Figure 2. Map of stocking locations of oyster mussel by Virginia Department of Wildlife Resources - Aquatic Wildlife Conservation Center and Virginia Tech - Freshwater Mollusk Conservation Center within the Powell River (VA/TN). Map from Lane et al (2023).

Clinch River (VA/TN)

The Clinch River is the only remaining stronghold population for the oyster mussel, it is estimated to contain over 500,000 individuals in the most abundant portion of the range in the Hancock County, TN (Jones et al. 2020). The Virginia portion of the Clinch River range is less resilient, but over 52,000 juvenile oyster mussels have been propagated and released in the upper portions of the Clinch River in Virginia (12 sites) since 2005 to increase the resiliency of in this portion of the Clinch River (Lane et al. 2023). Natural recruitment has been documented at Bennett Island and Cleveland Island, Russell County, Virginia in 2021, 2022, and 2023, and is evidence that reintroduction efforts in this portion of the Clinch River are beginning to result in a self-sustaining population (Lane pers. comm. 2023).

Lane et al. (2021) recently analyzed annual variation in population density and size, recruitment rate, mortality rate, sex ratios, and female fecundity of oyster mussel at three fixed sites (2004-2014) spanning 21 river miles in the Clinch River, Hancock County, TN. This study found

evidence that stream discharge was associated with fluctuations in population size and impacted demographic factors like recruitment of juveniles and population growth. The authors found that these Clinch River sites (Swan Island, Frost Ford, and Wallen Bend) grew at an annual rate of 6 percent during this 10-year period, growth rate was negatively associated with number of days with extreme high discharge, and that oyster mussel exhibited an opportunistic strategy (r-selected). Opportunistic strategy in mussels is characterized by short life span, early maturity, and high fecundity (Haag 2012), and with the oyster mussel requires a large population size of brooders that must contribute recruits early and often to ensure a stable population growth (Lane et al. 2021). The Frost Ford site (highest density) seems to have experienced a decline in oyster mussel densities in recent years that may be attributed to severe bank erosion at the site (Lane pers. comm. 2023).

Table 1. Summary of oyster mussel densities at four long-term monitoring sites on the upper Clinch River, TN (2004-2023). Densities are reported as individuals per square meter (individuals/m^2). Sampling sites are Swan Island at Clinch River Mile 172.2 (SI), Frost Ford at Clinch River Mile 181.3 (FF), Kyles Ford at Clinch River Mile 189.6 (KF), and Wallen Bend at Clinch River Mile 192.4 (WB) (Carey and Ostby 2024).

Year	SI Densities	FF Densities	KF Densities	WB Densities
2004	0.67	7.47	2.36	1.87
2005	0.60	5.40	---	1.40
2006	0.13	7.40	---	1.33
2007	1.27	21.93	---	5.07
2008	0.73	37.47	---	8.93
2009	1.56	18.81	---	5.60
2010	1.93	21.33	---	3.93
2011	2.27	22.73	---	2.18
2012	3.50	19.65	---	3.80
2013	1.20	15.55	---	3.14
2014	1.25	13.85	---	3.05
2015	---	---	---	---
2016	---	---	2.58	---
2017	0.30	6.26	2.70	3.08
2018	0.92	7.55	3.66	0.79
2019	0.82	2.72	2.26	1.72
2020	1.87	4.16	2.43	1.91
2021	3.34	6.81	3.47	5.21
2022	4.60	9.48	3.08	5.71
2023	4.44	7.27	2.31	4.13
Estimate Mean Population Size	9,702	178,193	36,028	22,569

Nolichucky River

The remaining naturally extant population in the Nolichucky River is small and occurs within the lower third of the river. Jones et al. (2020) estimates that hundreds up to a few thousand still occur in this portion of the range. The natural population covers approximately 4 to 5 miles of the lower end of the river. There are several year classes documented present at four locations.

Genetic analyses have shown that the natural Nolichucky River population contains lower genetic diversity than the Clinch River population (Lane 2016 unpublished data; Jones 2024, unpublished manuscript).

The Tennessee Wildlife Resources Agency (TWRA) has conducted augmentation efforts using propagated and translocated individuals from Clinch River stock and released mussels approximately 20 river miles upstream of the extant native population. Over 10,000 oyster mussels have been stocked into the Nolichucky River at two sites (Hale Bridge and Evans Island) in Greene County, TN, since 2007 (Hubbs 2020; Lane et al. 2023). This includes a mix of adults, sub-adults, and juveniles and includes propagated and translocated animals (Hubbs 2020; Lane et al. 2023). Early evidence of success has been documented with female oyster mussels observed displaying lures and some natural recruitment at these augmentation sites observed in 2013 (Hubbs 2015a, 2020).

Paint Rock River

Beginning in 2012, the Virginia Department of Wildlife Resources, Aquatic Wildlife Conservation Center produced and transferred 2,707 oyster mussels (Clinch River brood stock) to the Alabama Department of Conservation and Natural Resources (ADCNR) to stock in the Paint Rock River, Alabama (ADCNR 2019; Lane et al. 2023). Alabama reintroductions into the Paint Rock River have occurred at three sites (Butler Mill, Jones Property, and Tractor Ford) in Jackson and Madison Counties, Alabama. Monitoring efforts have shown early signs of viability and natural recruitment in 2022. A fresh dead individual shell (female) was found, measuring 48 millimeters, likely 6 to 7 years old at death. The age of this individual suggests natural recruitment as its estimated age is younger than the initial mussels stocked in 2012 at the time of discovery (10 to 11 years old in 2022) (Johnson pers comm. 2022). Additionally, female oyster mussels have been documented displaying lures (spawning conditions) during recent monitoring efforts (Johnson 2023). Recruitment and spawning conditions of female oyster mussels likely indicate good conditions for long-term reintroduction success in the Paint Rock River (Johnson pers. comm. 2022). Future releases of oyster mussel are planned for the Paint Rock River in 2024 (P. Johnson pers comm. 2024).

Elk River

Oyster mussels were stocked in the Elk River in 2016 and 2017. In 2016, the Tennessee Wildlife Resources Agency stocked 104 adults at the Elk River at Winding Stair Bluff, Giles County, TN, using individuals translocated from the Clinch River and collected at Kyle's Ford. In 2017, 500 propagated juvenile (11-24 millimeter) oyster mussels (Clinch River brood stock) were stocked at the Veto Fish Trap site (Hubbs 2020; Lane et al. 2023). We have no additional information on the status of the released animals.

Emory River and Hiwassee River

Emory River (Oakdale bridge) was stocked with 200 propagated individuals in 2013 and 154 individuals in 2014 (Clinch River brood stock), while the Hiwassee (McClary Island) was stocked with 500 individuals in 2012 (Clinch River brood stock). Both stockings failed to establish populations as followup monitoring found few of the released mussels remaining

(Phipps et al. 2018). The physical habitat in the Emory River at the relocation site appeared to be inadequate for a riffle-dwelling species (i.e., oyster mussel) with the two recaptured oyster mussels in poor condition (Phipps et al. 2018). Water temperature at the Hiwassee River site appeared unsuitable (temperature in July was 17°C). Low temperatures were likely due to being located downstream of the discharge of the Apalachia Powerhouse, which introduces cold water flows to the river downstream. Two individuals found in the Hiwassee River in 2016 appeared in poor condition, emaciated and weak (Ahlstedt et al. 2016; Phipps et al. 2018). Hence, the Emory River and Hiwassee River oyster mussel reintroductions were determined not to be successful and stocking in these rivers ceased in 2016 (Phipps et al. 2018). Additional investigation regarding site selection would inform future decisions related to renewing reintroduction efforts and increasing their effectiveness.

Duck River Dartersnapper

Duck River

The Duck River contains the only natural population of the Duck River dartersnapper. This population is currently only known to occur within a 46-mile stretch of river between Lillard's Mill Dam (Duck River Mile 179.2) and Columbia Mill Dam (Duck River Mile 133.5).

Ahlstedt et al. (2004) established four monitoring sites on the Duck River in 2004 that were adopted by the Tennessee Wildlife Resources Agency as fixed monitoring sites in 2010, which have been monitored every 5 years (Hubbs et al. 2010; Hubbs 2015b; Wisniewski 2020). The Duck River dartersnapper populations at these sites fluctuated in densities over the past 20 years (table 2). The species went from being undetected at the Hooper Island site in 2004 to being the most populous site for the species (1.52 individuals/square meter) in 2020. The sites at both Venable Spring and Lillard's Mill have had decreases during the same time frame, 34 percent and 41 percent respectively. Between 2010 and 2020, Duck River dartersnapper populations dropped by 84 percent at Lillards Mill, though the population did rebound to some degree in 2020 (Wisneiwski 2020).

Table 2. Summary of Duck River dartersnapper densities at three long-term monitoring sites on the upper Duck River, TN (2010, 2015, and 2020). Densities are reported as individuals per square meter (individuals/m^2). Sampling sites are Hooper Island at Duck River Mile 163.1 (HI), Venable Spring at Duck River Mile 176.8 (VS), and Lillard's Mill at Duck River Mile 179.2 (Ahlstedt et al. 2004; Hubbs et al. 2010, Hubbs 2015b; Wisniewski 2020).

Year	Hooper Island Densities	Estimated Population	Venable Spring Densities	Estimated Population	Lillard's Mill *Densities*	Estimated Population
2004	0.00	---	2.27	---	2.20	---
2010	0.25	685	2.65	7,950	4.70	15,745
2015	0.45	1,260	0.75	2,250	0.75	1,530
2020	1.52	3,490	0.77	2,776	0.90	3,076

Buffalo River

A reintroduction effort was initiated in 2022 by the Tennessee Wildlife Resources Agency's Cumberland River Aquatic Center (CRAC) for the Duck River dartersnapper at a site (Mayberry Property) in the lower Buffalo River utilizing propagated individuals from Duck River brood stock. Two releases in 2022 and 2023 (total of 93 individuals) have been made to date with additional releases planned (Hua 2023). Good growth and survival were documented in 2023, eight recaptured individuals grew from 20 to 27 millimeters at stocking to 32 to 42 millimeters in a year with individuals showing signs of sexual maturity including dimorphic differences (figure 3) (Hua 2023).

Figure 3. Recaptured Duck River dartersnapper from the Buffalo River release site in 2023. Photo credit: Dan Hua, Tennessee Wildlife Resources Agency.

Bear Creek (AL)

A single release of six individual Duck River dartersnappers was made into Bear Creek (AL) near the confluence of Rock River adjacent to the Natchez Trace Parkway in 2019 (Johnson and Hubbs 2019). The stocked individuals measured 12 to 25 millimeters at the time they were stocked. No additional releases have been made within Bear Creek as some uncertainty now exists, after additional examination of museum shell material, as to whether it was oyster mussel or Duck River dartersnapper or both that historically occurred within this drainage. While it is doubtful such a low-level stocking effort will be enough to reestablish a viable population, a 2024 monitoring effort at this site did recapture one of the original stocked individuals (a female). This recaptured individual measured approximately 54 millimeters at the time of recapture (figure 4), seemingly indicating good growth and site conditions. Further evaluation of appropriate brood source is needed before additional stocking efforts of either Duck River dartersnapper or oyster mussel in Bear Creek.

Figure 4. Recaptured Duck River dartersnapper from the Bear Creek release site in 2024. Photo credit: Alabama Aquatic Biodiversity Center, Alabama Department of Conservation and Natural Resources.

Life History

A study into the reproductive biology of the oyster mussel was recently conducted by Jones et al. (2020) to enhance propagation efforts at mussel hatcheries. This study documented the roles that males play in fertilizing females to produce glochidia (larval mussel). A 1:1 male to female ratio produced the greatest mean glochidia count along with the greatest fertilization rate in a hatchery setting, this is similar ratios seen in nature (> 50 percent in the Clinch River in September and October) (Jones et al. 2020). However, a low level of fertilization occurred with no males indicating self-fertilization may have occurred via hermaphroditism among females in this study. According to Jones et al. (2020), the treatment without males had significantly lower mean number of total eggs observed (4,533 vs. 5,868 to 7,330), with fewer viable glochidia (1,354 vs. 5,645 to 6,920). Most of the eggs in the treatment without males were unfertilized at experiment completion (3,179 vs. 206 to 410), with a much lower percentage of transformed glochidia (27 percent vs. 94 to 97 percent). This study indicated that *in situ* collection of gravid mussels may not be required for successful propagation of oyster mussels, instead, oyster mussels may be able to fully complete adult spawning and brooding by females with controlled spawning techniques at hatchery facilities.

Threats (Five-Factor Analysis) Summary

The status of a species is determined from an assessment of factors specified in section 4(a)(1) of the Act. A detailed summary of threats to the oyster mussel can be found in the 2004 final recovery plan and the 2019 5-year review. The summary of these threats is below.

Factor A. The present or threatened destruction, modification or curtailment of its habitat or range:
Impoundments, channelization, mineral extraction, gravel mining, contaminants, toxic chemical spills, and sedimentation remain threats to the oyster mussel (Service 2019). We have evidence that water demand (water withdrawal impacting water quality) may be an increasing threat to the species (see information below). Non-point source pollution from land surface runoff can originate from virtually any land use activity that does not enact appropriate best management practices to prevent impacts to receiving waters (such as coal mining and agricultural activities).

Recent studies have continued to show that major ions and trace elements (mining related contaminants) continue to impact portions of Powell River and have negative effects on freshwater mussel growth and survival (Phipps 2019; Timpano et al. 2023). Phipps (2019) suggests that major ions and trace elements (Ba, Ni, Fe, Se, and Sr) have negatively affected growth of exposed mussels, and conditions in some portions of the Powell River may not be appropriate for mussel reintroduction efforts due to continued mining contamination. Timpano et al. (2023) examined trace elements within both surface (water-column) and pore (substrate interstitial) water at nine sites over 157 river kilometers in the Powell River (VA and TN) in an area impacted by coal mining. They found that trace elements in pore water samples containing fine sediment particles (measuring less than 300 micrometer) exceeded chronic water quality criteria (EPA 2024) for all toxic elements except arsenic (Timpano et al. 2023). Timpano et al. (2023) also found seasonal temporal variation among many trace elements concentrations increased summer through autumn when many mussels are in critical life cycle phases (e.g., reproduction, recruitment, and increased growth). These results indicate that toxicity from trace elements associated with past and current coal mining within the watershed likely continues to impact the oyster mussel and other mussels within this watershed.

The demand of the Duck River as a municipal water source continues to increase as it is currently the primary water source to seven water utilities and provides water to over 250,000 people in the middle Tennessee region. The Duck River also largely supports the Nashville Metropolitan Statistical Area of which the population is forecast to grow by 58.4 percent by 2070 (University of Tennessee 2022). With recent population growth and infrastructure expansion, water demand has grown from 26.2 million gallons a day in 2015 to a projected 42.7 million gallons a day in 2040, a demand growth of 48 percent (TVA 2024). As a result, the Duck River is likely to face increased water quality issues (increased water temperatures and chlorophyll concentrations; decreased wetted perimeter, dissolved oxygen, and wastewater assimilative capacity) during drought conditions (TVA 2024).

Factor B. Overutilization for commercial, recreational, scientific, or educational purposes:
The overutilization for commercial, recreational, scientific, or educational purposes is not considered to be a limiting factor for this species.

Factor C. Disease or predation:
The recovery plan (Service 2004) stated that there is little data indicating that disease or predation are limiting factors for this species. We have no other information on disease or predation of the oyster mussel. We continue to believe that disease and/or predation are not limiting factors for this species.

Factor D. Inadequacy of existing regulatory mechanisms:
Protections afforded to the oyster mussel through regulatory mechanisms appear to be improving habitat quality and availability for the oyster mussel. TVA has invested approximately $60 million in improving the ecological integrity of the Tennessee River watershed since the early 1990s through their authorities under the TVA Act and towards achieving their mission. In 2021, the TVA strengthened their commitment as a steward of the Southeast's natural resources through the adoption of a Biodiversity Policy (TVA 2021). This policy recognizes the importance of biodiversity to the quality of life experienced by residents within TVA's service area and communicates TVA's commitment to, among other things, "minimize the adverse impact of TVA operations on biodiversity and ecosystems, including by protecting endangered species" (TVA 2021). This policy strengthens TVA's commitment to fulfill responsibilities that Federal agencies share under the Endangered Species Act for recovering threatened and endangered species. Major stressors identified in the listing rule, sedimentation, nutrients, and non-point source pollutants, are influenced by the efficacy of State and Federal regulations. The Clean Water Act and Surface Mining Control and Reclamation Act of 1977 have also provided some improvements in water quality and habitat conditions. These regulatory mechanisms, however, remain inadequate in fully protecting the species and its habitats, as the many of the rivers and tributaries supporting the oyster mussel continue to be listed as impaired (TDEC 2022; VDEQ 2024). The information available to us at this time does not indicate that the magnitude or imminence of this threat is likely to be appreciably reduced in the foreseeable future.

The final recovery plan specifically mentioned that the CWA may not have been fully utilized in the protection of aquatic systems (Service 2004). EPA establishes national recommended water quality criteria (Section 304(a) of the CWA) for the protection of human and aquatic life and to support designated uses (Section 305(b) of the CWA), but these standards may not be protective of mussels if these criteria are developed using less sensitive taxa or fail to consider the combined toxicity of multiple toxins (see discussion of Timpano et al 2022 below).

The Surface Mining Control and Reclamation Act regulates the environmental effects of coal mining in the United States, and the prominence of mining in the Powell River and Clinch River has been studied for its impacts to the mussels of those rivers (Johnson et al. 2014; Zipper et al. 2016; Rogers et al. 2018; Cope et al. 2021; Timpano et al. 2023). Mining remains a main source of contaminants in the Clinch River and Powell River and continues to negatively affect growth and survival of freshwater mussels (Johnson et al. 2014; Phipps 2019). Major stressors identified in the final listing rule, sedimentation, and pollution, are influenced by the efficacy of State and Federal regulations. These threats have not been abated and continue to show impacts on mussel populations (Johnson et al. 2014; Zipper et al. 2016; Rogers et al. 2018; Cope et al. 2021; Timpano et al. 2023) and are likely causing continued decline of the oyster mussel. Timpano et al. (2022) noted that trace metals rarely contaminate freshwater systems independently and found that the combined effects of trace metals were compounded in laboratory tested mussels.

Regulatory limits based on single metal toxicity may therefore result in limits that do not adequately protect freshwater mussels when multiple metals are present in the environment (Timpano et al. 2022). As such, it is likely that existing regulatory mechanisms have been inadequate to protect the species and its habitat from these threats.

Uncertainties related to the toxic synergistic effects of trace metals associated with mining pose a potential threat to the oyster mussel as well as to other aquatic species and humans that managers and regulators need to better understand. Research on the uncertainty of these combined effects of trace metals would allow agencies to prescribe a more protective water quality standard that increase the feasibility and effectiveness of the management actions.

Factor E. Other natural or manmade factors affecting its continued existence:

Climate Change

In its Sixth Assessment Report, the Intergovernmental Panel on Climate Change (IPCC) concluded that warming of the climate system is unequivocal (IPCC 2023). In Tennessee, Virginia, and Alabama, future climate is expected to increase in temperature, drought frequency, duration, and intensity, and more incidents of extreme temperatures (heat and cold waves) and extreme precipitation (days with 2 inches or more of precipitation) (Runkle et al. 2022a, b, c). These changes are expected to exacerbate water quality declines issues described above through reducing water at times, changing temperatures, and increases in runoff from surrounding lands during extreme precipitation events.

Stream temperatures across the United States including the Southeast have increased roughly 0.2 to 0.4 ºC per decade since the 1950s and are expected to continue increasing as air temperature increases (Kaushal *et al.* 2010). Lethal thermal tolerance thresholds are known for only a small percentage of freshwater mussels, but a recent review indicates that overall mean lethal temperatures for North American mussels were 32.8 ºC for glochidia (19 species examined), 35.0 ºC for juveniles (13 species examined), and 36.3 ºC for adults (4 species examined) (Fogelman et al. 2023). While we don't know the specific temperature tolerances for oyster mussel, many freshwater mussels may already be living close to their upper thermal tolerances in some systems and, may be at risk from rising environmental temperatures (Pandolfo et al. 2010). Daraio et al. (2014) suggested that thermal tolerance thresholds for some mussels in the upper Tar River basin in North Carolina could even be exceeded within the next 50 years based on models designed to simulate daily mean stream temperatures associated with climate change and land use change in that system. These increased temperatures and will likely have adverse impacts on recruitment in freshwater mussels like the oyster mussel as river temperatures will likely exceed optimum conditions. Carey et al. (2013) determined 26 ºC was optimum for growth of juvenile oyster mussels in a hatchery setting.

Species with limited ranges, fragmented distributions, and small population sizes, such as the oyster mussel, are assumed to be especially vulnerable to the effects of climate change (Byers and Norris 2011). Key uncertainties related to the effect that projected changes in climate may have on the foreseeable extinction risk of the oyster mussel include thermal tolerance of the oyster mussel and its fish hosts, changes in temperature regime to spawning and recruitment, and impacts on water and habitat quality parameters vital to the oyster mussel. Research focused on understanding these uncertainties would enable more reliable inferences about climate-related

factors that may be limiting to the oyster mussel and inform conservation decisions related to habitat and population objectives and increase the feasibility and effectiveness of the management actions.

Undefined Threats

We are still learning much about threats to the oyster mussel and other freshwater mussels. A number of streams have experienced "enigmatic declines" in their mussel fauna since the 1960s, including several within the historical range of the oyster mussel (e.g., Buck Creek, Harpeth River, Buffalo River, upper Holston River) (Haag 2019), and with the extant populations of the Duck River (Ahlstedt et al. 2017) and Clinch River (Dennis 1987; Jones et al. 2018). These declines have been similar in that they were relatively rapid (often with faunal collapse within 10 years), affected all species of mussels but no other aquatic taxa, and appear to have specifically affected recruitment (Haag 2019). The cause of these enigmatic declines has not been identified, though many factors have been hypothesized (e.g., agricultural effects, disease, introduction of Asian clam), but is concerning and remains a priority of ongoing research.

Synthesis

The oyster mussel is a freshwater mussel that was historically distributed across the Tennessee River and Cumberland River systems and across six states (Alabama, Georgia, Kentucky, North Carolina, Tennessee, and Virginia). It is now considered extirpated from the Cumberland River system. Natural populations still exist in the Clinch River (VA, TN), Nolichucky River (TN), and the Duck River (TN). The Clinch River and Duck River populations appear relatively stable but show fluctuations in population numbers from year to year and continue to exhibit good numbers and recruitment. One site in the Clinch River, Frost Ford, which has the highest density, seems to have experienced a decline in oyster mussel densities in recent years. The Nolichucky River population remains small with limited recruitment. Reintroductions efforts have taken place in the Powell River (VA, TN), Emory River (TN), Hiwassee River (TN), Paint Rock River (AL), Elk River (TN), Bear Creek (AL), and Buffalo River (TN). The Paint Rock River effort has shown early signs of success, while the Powell River and Buffalo River efforts have shown persistence of stocked individuals but have not yet documented natural recruitment. Impoundments, channelization, mineral extraction, gravel mining, contaminants, toxic chemical spills, and sedimentation still threaten the species. Additionally, water withdrawal demands on the Duck River appears to be a growing concern given with population growth surrounding the Duck River watershed. While climate change and other enigmatic declines need additional research as it relates to potential future impacts to the oyster mussel. For these reasons, the oyster mussel remains a species at risk of extinction throughout it range, this species continues to meet the definition of an endangered species.

RECOMMENDED FUTURE ACTIVITIES

Implement conservation actions recommended in the recovery plan (Service 2004), the Tennessee Wildlife Action Plan (https://www.tn.gov/content/tn/twra/wildlife/action-plan.html), Alabama Wildlife Action Plan (https://www.outdooralabama.com/research/state-wildlife-grants), Virginia Wildlife Action Plan (https://dwr.virginia.gov/wildlife/wildlife-action-plan/wildlife-action-plan-2015), and the National Strategy for the Conservation of Native Freshwater Mollusks

(FMCS 2016). A detailed discussion of recovery actions is presented in the oyster mussel recovery plan (Service 2004), we recommend continue implementing actions from the recovery plan.

Recovery Activities

We recommend that efforts should continue to expand the range of extant populations to ensure their viability, and efforts should continue to reestablish populations within the historical range where suitable habitat and quality exists.

Monitoring and Research Activities

Monitoring of wild, augmented, and reintroduced populations should continue..

REFERENCES

Ahlstedt, S., C. Howard, M. Reed, C. Saylor, and J. Herrig. 2016. Evaluation of freshwater mussels in the Hiwassee River Apalachia Cutoff (Polk County, Tennessee), following high flow releases from Apalachia Dam (2016). Report prepared for Cherokee National Forest and Tennessee Valley Authority. 19 pp.

Ahlstedt, S.A., J.R. Powell, R.S. Butler, M.T. Fagg, D.W. Hubbs, S.F. Novak, S.R. Palmer, and P.D. Johnson. 2004. Historical and current examination of freshwater mussels (Bivalvia: Margaritiferidae, Unionidae) in the Duck River basin Tennessee. Final Report to the Tennessee Wildlife Resources Agency. 213 pp.

Ahlstedt, S.A., J.R. Powell, R.S. Butler, M.T. Fagg, D.W. Hubbs, S.F. Novak, S.R. Palmer, and P.D. Johnson. 2017. Historical and current examination of freshwater mussels (Bivalvia: Margaritiferidae, Unionidae) in the Duck River basin Tennessee, U.S.A. Malacological Review 45:1-163.

Alabama Department of Conservation and Natural Resources (ADCNR). 2019. *Epioblasma capsaeformis* – Oyster Mussel, Paint Rock River Reintroduction Summary, AABC Mollusk Release Report Form. ADCNR, Alabama Aquatic Biodiversity Center, Marion, Alabama. 2 pp.

Byers, E. and S. Norris. 2011. Climate change vulnerability assessment of species of concern in West Virginia. Report. West Virginia Division of Natural Resources, Elkins, West Virginia. 72 pp.

Carey, C.S. and B.J.K. Ostby. 2024. Essential monitoring in the Clinch and Powell rivers needed to assess the status and distribution of federally listed freshwater mussel populations and evaluate long-term success of restoration efforts across the Upper Tennessee River Basin. Final Report, Grant No. F18AC00430, prepared for USFWS Southwestern Virginia Field Office, Abingdon, VA. 43 pp.

Carey, C.S., J.W. Jones, E.M. Hallerman, and R.S. Butler. 2013. Determining optimum temperature for growth and survival of laboratory-propagated juvenile freshwater mussels. North American Journal of Aquaculture 75:532-542.

Cope, W.G., C.M. Bergeron, J.M. Archambault, J.W. Jones, B. Beaty, P.R. Lazaro, D. Shea, J.L. Callihan, and J.J. Rogers. 2021. Understanding the influence of multiple pollutant stressors on the decline of freshwater mussels in a biodiversity hotspot. Science of the Total Environment 773:1-15.

Daraio, J.A., J.D. Bales, and T.J. Pandolfo. 2014. Effects of land use and climate change on steam temperature II: Threshold exceedance duration projections for freshwater mussels. Journal of the American Water Resources Association 50:1177-1190.

Dennis, S.D., 1987. An unexpected decline in populations of the freshwater mussel, *Dysnomia (=Epioblasma) capsaeformis*, in the Clinch River of Virginia and Tennessee. Virginia. Journal of Science 38:281-288.

Environmental Protection Agency (EPA). 2024. National recommended water quality criteria for aquatic life. https://www.epa.gov/wqc/national-recommended-water-quality-criteria-aquatic-life-criteria-table

Fogelman, K.J., J.M. Archambault, E. Irwin, M. Walsh, S. Brewer, and J.A. Stoeckel. A review of lethal thermal tolerance among freshwater mussels (Bivalvia: Unionida) within the North American faunal region. Environmental Reviews 31:278-297.

Freshwater Mollusk Conservation Society (FMCS). 2016. A national strategy for the conservation of native freshwater mollusks. Freshwater Mollusk Biology and Conservation 19: 1-21.

Freshwater Mollusk Conservation Society (FMCS). 2023. The 2023 checklist of freshwater bivalves (Mollusca: Bivalvia: Unionida) of the United States and Canada. Considered and approved by the Bivalve Names Subcommittee October 2023. 8 pp.

Haag, W.R. 2012. North American Freshwater Mussels Natural History, Ecology, and Conservation. Cambridge University Press, New York, New York. 505 pp.

Haag, W.R. 2019. Reassessing enigmatic mussel declines in the United States. Freshwater Mollusk Biology and Conservation 22:43-60.

Hua, D. 2023. Annual progress report, propagation and restoration of aquatic animals. Submitted to USFWS, Division of Environmental Review, Atlanta, GA. 19 pp.

Hubbs, D. 2015a. 2014 annual mussel recovery activity report for Project 7775. Tennessee Wildlife Resources Agency, Fisheries Report 14-06. 95 pp.

----. 2015b. 2015 Duck River quantitative mussel survey. Tennessee Wildlife Resources Agency, Fisheries Report 16-06. 60 pp.

Hubbs, D. 2020. 2019 annual mussel recovery activity report for project 7775. Tennessee Wildlife Resources Agency, Fisheries Report 20-01. 84 pp.

Hubbs, D., S. Chance, L. Colley, and B. Butler. 2010. 2010 Duck River quantitative mussel survey. Tennessee Wildlife Resources Agency, Fisheries Division Report 11-04. 48 pp.

Intergovernmental Panel on Climate Change (IPCC), 2023. Summary for Policymakers. In: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland. 34 pp.

Johnson, G.C., J.L. Krstolic, and B.J.K. Ostby. 2014. Influences of water and sediment quality and hydrologic processes on mussels in the Clinch River. Journal of the American Water Resources Association 50:878-897.

Johnson, P. 2022. Personal communication. Program Supervisor, Alabama Aquatic Biodiversity Center. Email correspondence between Johnson to Jeff Powell and Evan Collins, Alabama Ecological Services Field Office, reporting a likely natural recruitment of oyster mussel from the 2012 initial stocking effort in the Paint Rock River.

Johnson, P. 2023. Threatened and endangered species report for 2022 (TE130300-6). Annual report submitted to the U.S. Fish and Wildlife Service by the Alabama Department of Conservation and Natural Resources, Alabama Aquatic Biodiversity Center, Marion, Alabama. February 24, 2023. 119 pp.

Johnson, P. 2024. Personal communication. Program Supervisor, Alabama Aquatic Biodiversity Center. Phone conversation between Johnson and Anthony Ford, Tennessee Ecological Services Field Office, discussing reintroduction efforts for oyster mussel in the Paint Rock River and Duck River dartersnapper in Bear Creek. May 24, 2024.

Johnson, P.D. and D. Hubbs. 2019. Proposed reintroduction of Duck River dartersnapper, *Epioblasma ahlstedti* (Jones and Neves 2010), in Bear Creek, Colbert Co., Alabama. Alabama Department of Conservation and Natural Resources and Tennessee Wildlife Resources Agency. 11 pp.

Jones, J.W. 2024. Unpublished manuscript. Email correspondence between Jones to Anthony Ford, Tennessee Ecological Services Field Office, providing unpublished manuscript comparing genetic results of oyster mussel and Cumberlandian combshell populations in the Clinch, Powell, and Nolichucky rivers. June 12, 2024.

Jones, J.W. and R.J. Neves. 2010. Description of a new species and a new subspecies of freshwater mussels, *Epioblasma ahlstedti* and *Epioblasma Florentina aureola* (Bivalvia: Unionidae), in the Tennessee River drainage, USA. Nautilus 124:77-92.

Jones, J.W., W.F. Henley, A.J. Timpano, E. Frimpong, and E.M. Hallerman. 2020. Spawning and gravidity of the endangered freshwater mussel *Epioblama capsaeformis* (Bivalvia:

Unionidae) in captivity for production of glochidia. Invertebrate Reproduction and Development 64(4):312-325.

Jones, J., T. Lane, B. Ostby, B. Beaty, S. Ahlstedt, R. Butler, D. Hubbs, and G. Walker. 2018. Collapse of the Pendleton Island mussel fauna in the Clinch River, Virginia: Setting baseline conditions to guide recovery and restoration. Freshwater Mollusk Biology and Conservation 21:36-56.

Kaushal, S.S., G.E. Likens, N.A. Jaworski, M.L. Pace, A.M. Sides, D. Seekell, K.T. Belt, D.H. Secor, and R.L. Wingate. 2010. Rising stream and river temperatures in the United States. Frontiers in Ecology and the Environment 8:461-466.

Lane, T. 2016. Unpublished data. Southwest Virginia Mussel Recovery Coordinator. Nolichucky River Quantitative Mussel Survey. Raw data in spreadsheet. Survey dates: May 26-27, 2016.

Lane, T. 2023. Personal communication. Southwest Virginia Mussel Recovery Coordinator. Email correspondence between Lane to Anthony Ford, Tennessee Ecological Services Field Office, providing requested new information for the oyster mussel status review. July 13, 2023.

Lane, T., J. Jones, B. Ostby, and R. Butler. 2021. Long-term monitoring of two endangered freshwater mussels (Bivalvia: Unionidae) reveals how demographic vital rates are influenced by species life history traits. PloS One 16(8):e0256279. https://doi.org/10.1371/journal.pone.0256279

Lane, T., S. Colletti, and T. Leach. 2023. Species profiles for federally endangered mussels cultured and stocked by the Aquatic Wildlife Conservation Center. Report by Aquatic Wildlife Conservation Center, Virginia Department of Wildlife Resources. 101 pp.

North Carolina Interagency Leadership Team (NCILT). 2012. Climate Ready North Carolina: Building a Resilient Future. Raleigh, NC. 152 pp.

Pandolfo, T.J., W.G. Cope, C. Arellano, R.B. Bringolf, M.C. Barnhart, and E. Hammer. 2010. Upper thermal tolerances of early life stages of freshwater mussels. Journal of North American Benthological Society 29:959-969.

Phipps, A. 2019. Evaluation of the effects of mining related contaminants on freshwater mussels (Bivalvia: Unionidae) in the Powell River of Virginia and Tennessee. Thesis. Virginia Polytechnic Institute and State University, Blacksburg, Virginia. 102 pp.

Phipps, A., M. Hyde, and J. Jones. 2018. Monitoring freshwater mussels at population restoration sites in the upper Tennessee River Basin, Tennessee and Virginia. Final Report. Freshwater Mollusk Conservation Center, Department of Fish and Wildlife Conservation, Blacksburg, Virginia. 62 pp.

Rogers, J.J., W.F. Henley, A.G. Weberg, J.W. Jones, and W.G. Cope. 2018. Assessment of growth, survival, and organ tissues of caged mussels (Bivalvia: Unionidae) in a river-scape influenced by coal mining in the southeastern USA. Science of the Total Environment 645:1273-1286.

Runkle, J., K.E. Kunkel, D.R. Easterlng, L.E. Stevens, B.C. Stewart, R. Frankson, L. Romolo, J. Neilsen-Gammon, T.A. Joyner, and W. Tollefson. 2022a. Tennessee State Climate Summary 2022. NOAA Technical Report NESDIS 150-TN. NOAA/NESDIS, Silver Spring, MD, 5 pp. https://statesummaries.ncics.org/chapter/tn/

Runkle, J., K.E. Kunkel, L.E. Stevens, S.M. Champion, B.C. Stewart, R. Frankson, W. Sweet, and S. Rayne. 2022b. Virginia State Climate Summary 2022. NOAA Technical Report NESDIS 150-VA. NOAA/NESDIS, Silver Spring, MD, 5 pp. https://statesummaries.ncics.org/chapter/va/

Runkle, J., K.E. Kunkel, L.E. Stevens, R. Frankson, and Sandra Rayne. 2022c. Alabama State Climate Summary 2022. NOAA Technical Report NESDIS 150-AL. NOAA/NESDIS, Silver Spring, MD, 4 pp. https://statesummaries.ncics.org/chapter/al/

Timpano, A.J., J.W. Jones, B. Beaty, M. Hull, D.J. Soucek, and C.E. Zipper. 2022. Combined effects of copper, nickel, and zinc on growth of a freshwater mussel (*Villosa iris*) in an environmental relevant context. Aquatic Toxicology 242 (2022):106038.

Timpano, A.J., A. Taylor, and J. Jones. 2023. Contaminated interstitial sediment is a reservoir of trace elements with exposure potential for freshwater mussels. Environmental Advances 12:1-15.

Tennessee Department of Conservation (TDEC). 2022. Tennessee's Final 2022 List of Impaired and Threatened Waters. Accessed online on August 23, 2024: https://www.tn.gov/content/dam/tn/environment/water/watershed-planning/wr_wq_303d-2022-final.xlsx.

Tennessee Valley Authority (TVA). 2021. TVA Biodiversity Policy. Tennessee Valley Authority, Knoxville, Tennessee. 1pp. [accessed online July 19, 2023] https://tva-azr-eastus-cdn-ep-tvawcm-prd.azureedge.net/cdn-tvawcma/docs/default-source/about-tva/board-of-directors/november-10-2021/tva-biodiversity-policy5756e37a-f416-40d6-ba04-d5c962f933a2.pdf?sfvrsn=48370c02_3

---. 2024. Normandy Reservoir optimization of reservoir releases draft environmental assessment Bedford, Coffee, Marshall, and Maury counties, Tennessee. Prepared by the Tennessee Valley Authority in partnership with the Tennessee Duck River Development Agency, Knoxville, Tennessee. 220 pp.

University of Tennessee. 2022. Tennessee Population: 2020-2070 Projection Excel Workbook. Tennessee State Data Center, Boyd Center for Business and Economic Research, University of Tennessee Knoxville. https://tnsdc.utk.edu/estimates-and-projections/boyd-center-population-projections/. Accessed online: July 2, 2024.

U. S. Fish and Wildlife Service (Service). 2004. Recovery Plan for Cumberland Elktoe, Oyster Mussel, Cumberlandian Combshell, Purple Bean, and Rough Rabbitsfoot. Atlanta, Georgia. 168 pp.

----. 2011. Oyster mussel (*Epioblasma capsaeformis*, Lea 1831) 5-year review: Summary and evaluation. U.S. Fish and Wildlife Service, Southeast Region, Cookeville, Tennessee. 20 pp.

----. 2019. Oyster mussel (*Epioblasma capsaeformis*, Lea 1831) 5-year review: Summary and evaluation. U.S. Fish and Wildlife Service, Southeast Region, Cookeville, Tennessee. 28 pp.

Virginia Department of Environmental Quality (VDEQ). 2024. Virginia Department of Environmental Quality Appendix 1a - 2024 Impaired Waters - 303(d) List Category 5 - Waters Needing Total Maximum Daily Load Study. Accessed online on August 23, 2024: https://www.deq.virginia.gov/our-programs/water/water-quality/assessments/integrated-report.

Williams, J.D., A.E. Bogan, R.S. Butler, K.S. Cummings, J.T. Garner, J.L. Harris, N.A. Johnson, and G.T. Watters. 2017. A revised list of the freshwater mussels (Mollusca: Bivalvia: Unionida) of the United States and Canada. Freshwater Mollusk Biology and Conservation 20:33-58.

Wisniewski, J. 2020. 2020 Duck River quantitative mussel survey. Tennessee Wildlife Resources Agency, Fisheries Report 16-06. 39 pp.

Zipper, C.E., P.F. Donavan, J.W. Jones, J. Li, J.E. Price, and R.E. Stewart. 2016. Spatial and temporal relationships among watershed mining, water quality, and freshwater mussel status in an eastern USA river. Science of the Total Environment 541:603-615.

RESULTS / SIGNATURES

U.S. Fish and Wildlife Service
Status Review of Oyster Mussel

Status Recommendation:

On the basis of this review, we recommend the following status for this species. A 5-year review presents a recommendation of the species status. Any change to the status requires a separate rulemaking process that includes public review and comment, as defined in the Act.

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist:
____ *The species is extinct*
____ *The species does not meet the definition of an endangered or threatened species*
____ *The listed entity does not meet the statutory definition of a species*
__X_ No change needed

Acting Field Supervisor, Tennessee Ecological Services Field Office, Fish and Wildlife Service

Approve NICOLE SIKULA Digitally signed by NICOLE SIKULA Date: 2024.10.16 13:53:39 -05'00'

* Since 2014, Field Supervisors in the Region have been delegated authority to approve 5-year reviews that do not recommend a status change.

COOPERATING REGIONAL OFFICE APPROVAL:
We emailed this 5-year review to the Northeast Regional Office for their concurrence prior to finalizing the document. We will retain any comments that we received, as well as verification of concurrence from other regions, in the administrative record for this 5-year review.