Tar River Spinymussel
(Parvaspina (=Elliptio) steinstansana)

5-Year Review:
Summary and Evaluation

Photo credit: C. Eads 2012

U.S. Fish and Wildlife Service
South Atlantic–Gulf and Mississippi Basin Regions

Raleigh Ecological Services Field Office
Raleigh, North Carolina

†Please see Addendum 1 at the end of this, our original 5-year review, document. The Addendum provides the limited new information we have gathered for our second 5-year review for this endangered mussel that was initiated in the Federal Register (84 FR 28850; June 20, 2019) and the analysis we have shared to explain the basis for continuing to recommend no change in status for this species.

5-YEAR REVIEW

Tar River spinymussel/*Elliptio steinstansana*

I. GENERAL INFORMATION

A. Methodology used to complete the review

We provided public notice of this five-year review in the *Federal Register* on July 6, 2009 (74 FR 31972) and opened a 60-day public comment period. We obtained pertinent information on the status of this species from the recovery plan, peer reviewed scientific literature and published papers, unpublished reports, and also experts on this mussel species from State agencies, local universities, etc. Once all known and pertinent data were collected for this species, the status information was compiled and the review was drafted by the Asheville Ecological Services Field Office, North Carolina, with assistance from the North Carolina Wildlife Resources Commission and the North Carolina Natural Heritage Program. Final edits were compiled by the species' recovery lead biologist in the Service's Raleigh Ecological Services Field Office, North Carolina. A draft of the five year review was peer reviewed by several experts familiar with the Tar River spinymussel. Comments received were evaluated and incorporated as appropriate (see Appendix A).

B. Reviewers

Lead Region: Southeast Region: Kelly Bibb, 404/679-7132

Lead Field Office: Raleigh, North Carolina: Sarah McRae, 919-856-4520x16

Cooperating Field Office(s): Asheville, North Carolina: John Fridell, 828-258-3939x225

C. Background

1. Federal Register Notice citation announcing initiation of this review: 74 FR 31972; July 6, 2009

2. Species status: (2014) Decreasing; Monitoring and other surveys for the Tar River spinymussel have documented a continued decline in nearly all of the surviving populations of the species.

3. Recovery achieved: (2014) 1 (1=0-25% species' recovery objectives achieved)

4. Listing history

Original Listing
FR notice: 50 FR 26572
Date listed: June 27, 1985
Entity listed: species
Classification: endangered

5. Associated rulemakings: N/A

6. Review History:

Recovery Plan: May 5, 1992
Recovery Data Call: 1994 – 2014
Five Year Review: November 6, 1991. In this review (56 FR 56882), different species were simultaneously evaluated with no species-specific, in-depth assessment of the five factors as they pertained to the different species' recovery. In particular, no changes were proposed for the status of this mussel in the review.
Spotlight Species Action Plan: August 10, 2009

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

5C. This number indicates a high degree of threat and a low recovery potential.

8. Recovery Plan

Name of plan: (Revised) Recovery Plan for the Tar spinymussel (Elliptio (Canthyria) steinstansana) Johnson and Clarke
Date originally issued: January 16, 1987
Date of revision: May 5, 1992

II. REVIEW ANALYSIS

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

The Tar River spinymussel is an invertebrate, and therefore, not covered by the DPS policy, and therefore, the policy will not be addressed further in this review.

B. Recovery Criteria

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

2. Adequacy of recovery criteria.

a. Do the recovery criteria reflect the best available and most up-to-date information on the biology of the species and its habitat? No.

Although the criteria still adequately reflect the species' biology and habitat, discoveries of occurrences of the species in other watersheds subsequent to the recovery plan revisions made in 1992 may warrant revision of criteria 1 and 2 in the existing revised recovery plan.

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

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

The Service's recovery plan for the Tar River spinymussel (Service 1992) states that the species will be considered for downlisting to threatened status when the following criteria are met:

1. All three existing populations of *E. steinstansana* in both the Tar River and Swift Creek show evidence of reproduction and recruitment; i.e., gravid females and host fish must be present and populations must contain at least two year classes, including one year class at age 4 or younger.

At the time of development of the revised recovery plan for the Tar River spinymussel (Service 1992), the Tar River spinymussel was known only from the mainstem of the Tar River and from one of its tributaries, Swift Creek; and, believed to be endemic only to the Tar River system in North Carolina. However, current available information indicates the species is endemic to both the Tar River and Neuse River systems in North Carolina (North Carolina Wildlife Resources Commission's (NCWRC) 1999; NCWRC freshwater mussel survey data base (NCWRC database 2014); Sarah McRae, North Carolina Natural Heritage Program (NCNHP) personal communication, 2010). In the Tar River system, the species has been documented only from the mainstem of the Tar River and a few of its tributaries, Shocco Creek, Fishing Creek, Little Fishing Creek, Swift Creek, and Sandy Creek – Sandy Creek is a headwater stream forming Swift Creek (NCWRC data base 2014). In the Neuse River system, the species has been documented from the mainstem of the Little River (NCWRC database 2014; McRae personal communication, 2010), as well as the mainstem of the Neuse River (J Smith, NC Museum of Natural Sciences, pers. comm., 2014).

Monitoring and other surveys for the Tar River spinymussel have documented a continued decline in nearly all of the surviving populations of the species (NCWRC database 2014). Based on the most recent survey data from the NCWRC's database, the species may be extirpated from the

mainstem of the Tar River (last observation was two live individuals in 2001; no live or shells were found during surveys in 2002, 2007, or 2013) and Shocco Creek (last and only record was a shell found in 1993, many surveys since have not located the species) (NCWRC database 2014). Surveys in Swift Creek from 1987-2002 found a total of 353 spinymussels (61 live (some likely duplicative records of the same individual found on multiple surveys, as individuals were not tagged) and 292 shells), yet only one individual was found during surveys in Swift Creek in 2005 and none during surveys since (covering 2006-2014) (NCWRC database 2014; C Eads, pers. comm., 2014); in addition, none have been recorded from Sandy Creek since 1988 (NCWRC database 2014). A total of 67 individuals have been observed in Little Fishing Creek, during surveys from 1993-2014 (some potential duplicative records; NCWRC database 2014; C Eads, pers. comm., 2014); only a total of 7 individuals in Fishing Creek during surveys from 1999-2014 (NCWRC database 2014, C Eads, pers. comm., 2014). A total of only 4 individuals have ever been recorded from the Little River (Neuse River basin) – one each in 1998, 2005, 2010, and 2011; repeated surveys since have not recorded any additional specimens (NCRWC database 2014; T Savidge, pers. comm., 2010). Only two unusually large specimens have been documented from the mainstem of the Neuse River (R Nichols and J Smith, pers. comm., 2014).

Additional surveys are needed to determine the status of the Tar River spinymussel in the mainstem of the Tar River, Shocco Creek, and the mainstem of the Neuse River; however, based on all available information there is no evidence of reproduction and recruitment within these populations and all three populations may now be extirpated. More intensive survey efforts are needed in the Sandy/Swift Creek basin to determine if the species continues to persist. Although limited levels of reproduction and recruitment may be occurring within the Little Fishing Creek/Fishing Creek and the Little River populations, the amount of recruitment occurring does not appear to be at levels high enough to maintain these populations. All of these populations appear to be at extremely low levels. Because there are so few individuals, the proximity of males and females may be limiting their reproductive success.

2. <u>The reestablishment or the discovery of two additional viable populations has occurred (excluding the Tar River populations in Edgecombe and Nash Counties and the Swift Creek population). These populations should occur in two additional sections of the Tar River (or other streams if new information identifies them as historical habitat of the species), one each in Franklin and Pitt Counties, North Carolina -- areas historically supporting populations of *E. steinstansana*. A viable population is defined as a naturally reproducing population that is large enough to maintain sufficient genetic variation to enable it to evolve and respond to natural environmental changes. The number of individuals needed to reach a</u>

viable population will be determined as one of the recovery tasks. Each population should contain at least three subpopulation centers (a continuous river segment or a series of closely spaced river segments containing habitat and *E. steinstansana* as a breeding unit) dispersed such that a single catastrophic event would not eliminate the Tar spinymussel from newly reestablished locations. The subpopulation centers should be at least 1 river mile apart. These new subpopulations should also show evidence of reproduction and recruitment as described for criterion 1.

As indicated under the first criterion above, in addition to the mainstem Tar River and Sandy Creek/Swift Creek populations of the Tar River spinymussel, three additional populations (and one relict population) have been discovered since development of the 1992 revised recovery plan for the species – the Shocco Creek population, Little Fishing Creek/Fishing Creek population, and the Little River population, and shells from the Neuse River mainstem. However, as also stated above, the mainstem Tar River, Shocco Creek, and mainstem Neuse River populations may now be extirpated, though additional surveys are needed to determine this. Furthermore, detection of individuals in the Sandy/Swift Creek population has declined markedly over the past 15 years. In addition, of the other remaining populations, only the Little Fishing Creek/Fishing Creek population appears to meet this criterion and even its viability is questionable due to the low numbers and lack of recruitment that has been observed in recent years.

3. The population units and their habitats are protected from any present and foreseeable threats that would jeopardize their continued existence.

Although several partnerships and conservation initiatives have contributed to the protection and restoration of lands and riparian buffers at scattered sites in the upper Tar River system (through acquisition/transfer of lands from, memoranda of agreements, and conservation agreements with major timber companies and other landowners in the watershed), existing and potential future land-uses within the watersheds of streams supporting the species continue to affect and threaten the surviving populations. The surviving populations appear to be extremely small, highly fragmented, isolated from each other, and restricted to short stream reaches where they continue to be highly vulnerable to extirpation from stochastic and chronic events (e.g., drought, toxic spills, runoff, problems associated with wastewater discharges, even large trees that fall into the stream and change local hydrology and sediment transport dynamics) associated with existing and potential future land uses. In 2005-2006, the Swift Creek population was impacted by land clearing and development of a residence that resulted in large amounts of sediment runoff directly into Tar River spinymussel habitat. The primary factors affecting and endangering the species and its habitat

appear to be impacts (e.g., water pollution, sedimentation, bank instability, loss of instream habitat stability and diversity, etc.) associated with: 1) the loss of forest lands and forested riparian buffers; 2) increases in woody debris and blow-downs of large trees into the stream which change local hydrology and sediment transport dynamics; 3) poorly controlled stormwater runoff and pollutants from forestry and agricultural (livestock and crop farming) activities, residential and commercial development, and road construction, use, and maintenance; 4) municipal and industrial wastewater discharges; 5) reduced base flows due to increased runoff and reduced infiltration from cleared lands and increased imperious surfaces, water withdrawal for irrigation, and reoccurring and prolonged drought conditions; 6) reservoir/water supply construction and operation; 7) alteration of lotic habitat by beavers, and, 8) likely impacts from invasion, expansion in range, and increased densities of the Asiatic clam [*Corbicula fluminea*]) (adapted from Service et al., 2005).

Past and on-going crop and livestock farming and forestry operations threaten several of the populations with loss of hardwood and mixed forest lands and forested riparian buffers; runoff of silt and other sediments; fertilizer, insecticide, and herbicide drift, runoff, and contamination of groundwater entering the streams; and, destabilization of stream banks and substrate (from excessive stormwater runoff, loss of bank vegetation, livestock entering streams, etc.). Pesticide runoff or discharge has been implicated as the cause of a massive die-off of the Tar River spinymussel in Swift Creek in1990 (Fleming et. al. 1995). The degradation of aquatic habitat associated with forestry and timbering operations have been identified as a major cause of habitat degradation in the Swift Creek (Alderman, 2005; J Fridell, pers. obs., 2005, 2009, and 2010) and Shocco Creek watersheds (J. Fridell, pers. obs., 1993). Increased beaver activity, likely resulting from loss of large trees and an increase in a food supply of small trees and shrubs in close proximity to the streams following timbering operations (Alderman, 2005), is affecting and fragmenting habitat in Swift Creek (Alderman, 2005; S Ward, USFWS Raleigh, NC pers. comm., 2010; J Fridell, pers. obs., 2009 and 2010) and the Little River (pers. obs., 2014). The Tar River and Fishing Creek watersheds are also considered to have a high potential for, and to have suffered water and habitat quality degradation from, nonpoint source pollution, especially from croplands and animal operations (Service et. al., 2005).

Point source discharges also continue to impact/threaten habitat quality in the Tar River (Service, 1992), Swift Creek, and Fishing Creek drainages (Service et al., 2005); and in 2008 Wake County, North Carolina proposed a new wastewater discharge which threatens habitat for the Little River population of the species, although that project is not currently being pursued (T Augspurger, pers. comm., 2008, pers. obs., 2014). In 1999, the North Carolina Division of Water Quality (NCDWQ) (1999) identified

wastewater treatment plant discharges as sources limiting water quality in the Fishing Creek Basin, and two small permitted discharges in lower Swift Creek have a history of violating their permit limits (Service et al., 2005).

Prolonged and reoccurring drought conditions pose a significant threat to all of the surviving populations. Reduced water quality/bioclassification ratings in portions of the Swift Creek and Fishing Creek Watersheds in 2003 were likely attributed to basin-wide drought conditions in 2001 and 2002 (NCDWQ, 2003; Service et al., 2005). In addition, the entire range of the Tar River spinymussel was encompassed in the exceptional drought afflicting large portions of the southeast from fall 2006 through 2008 (the National Oceanic and Atmospheric Administration's worse category of drought conditions, NOAA 2008). Habitat of all of the surviving populations was severely compromised by record low flows and extensive mussel mortality was documented in several areas. In addition to stranding and desiccation, mussels were exposed to increased predation and concentrated pollutants from wastewater discharges in streams with unprecedented low stream flows and, hence, no or inadequate dilution of pollutants. Reproduction and fish host availability were also likely eliminated or significantly reduced.

Dams and impoundments on the Tar River in the vicinity of Rocky Mount, North Carolina, also continue to fragment and limit mussel habitat availability in the Tar River. In addition, in order to accommodate future increased water supply demands from existing and future residential and industrial growth in the surrounding area, the City of Raleigh in Wake County, North Carolina has proposed a new water supply reservoir on the Little River. In addition to providing for increased growth, and the effects associated with this growth, this reservoir threatens the hydrology and aquatic habitat quality of the river, and will fragment and isolate upstream and downstream habitat and populations of aquatic species. The lasting economic downturn (2008-2013) stymied the immediate need for the water supply project, although it is highly probable that the reservoir project will be resurrected when there is an uptick in growth, and concurrent increased demand for water in Wake County.

Since development of the revised recovery plan for the Tar River spinymussel (Service 1992), the Asiatic clam has invaded all of the streams supporting populations of the Tar River spinymussel and has reached high density levels in many areas within these streams, especially in areas where the substrata has become degraded by excessive siltation and fine sand (J Alderman, pers. comm., 2010; C Eads, pers. comm., 2010; pers. obs. 2014). Although the extent of threat that the Asiatic clam presents to the Tar River spinymussel is unknown and requires further study, it is probable there is competition for food, oxygen, and space

between the clam and native mussels (Alderman 2005), especially at the juvenile stage (Neves and Widlak, 1987).

4. Where habitat has been degraded, noticeable improvements in water and stratum quality have occurred.

   Since the early 1990s, habitat quality has declined significantly in the Sandy Creek/Swift Creek watershed, primarily as a result of large scale timber operations within the watersheds of these streams, but also from the effects of other land use activities within their watersheds and increased beaver activity within the streams (Alderman 2005). Beginning in the late 1980s and early 1990s, and continuing to date, extensive clear-cutting and conversion of large landscapes to pine plantations and the associated loss and of narrowing riparian buffers resulted in significant increased stormwater runoff and soil erosion and, in many areas along the creeks where only narrow buffers were left, windfall and other wind damage of remaining stream-side trees. This has lead to an excessive amount of fine sediments, woody debris, and log jams within the streams' channel, changing the stream bottom substrate in large reaches of the creek from the coarse sand and gravel substrate preferred by the Tar River spinymussel to unsuitable, unstable, silty-sand substrates (Alderman 2005; J Fridell, pers. obs., 2005; 2009; and 2010; C Eads, pers. comm., 2014).

   All of the streams supporting populations of the Tar River spinymussel were affected by severe - exceptional drought conditions which persisted from the fall of 2006 through 2008. Flow in reaches of several of the streams supporting the species was significantly reduced and in places completely dried up (R Nichols and C Wood, NCWRC, Raleigh NC, pers. comm., 2008; J Fridell, pers. obs., 2008). However, with the exception of the effects of this drought, impacts to Tar River spinymussel habitat within the other streams supporting the species have been more localized than that experienced in Swift Creek (R Nichols pers. comm., 2010; S McRae, NCNHP, pers. comm., 2010; J Fridell, pers. obs., 2008).

5. Monitoring of all population units indicates no downward trends over a period of 15 to 20 years.

   Monitoring and other surveys for the Tar River spinymussel have documented a decline in numbers and distribution throughout the species' range, including likely extirpation of populations in the mainstem of the Tar River and Shocco Creek (NCWRC database 2014) (see II.B.3.1. above).

C. Updated Information and Current Species Status

1. Biology and Habitat

a. Abundance, population trends (e.g. increasing, decreasing, stable), demographic features, or demographic trends:
Although there have been discoveries of additional occurrences of the Tar River spinymussel since the species was listed as endangered in 1985 (specifically, Little Fishing/Fishing Creek, Shocco Creek, Little River, and relict shells from the Neuse River), the species continues to have a very fragmented, relict distribution and available trend information (NCWRC database 2014) indicates that the species is rapidly declining throughout its range. Based on available survey data, all extant populations are extremely small in numbers and three of these populations, the Tar River, Shocco Creek, and Neuse River populations, may possibly be extirpated, though additional surveys are needed to confirm this (S McRae pers. comm., 2010). Surveys in the Sandy/Swift Creek basin have also shown dramatic declines in numbers, and intensive survey efforts are needed to determine whether the species continues to persist. Although a very low level of successful reproduction may be occurring in the Little Fishing/Fishing Creek and Little River populations, all of the surviving populations appear to be well below self-maintenance levels (see discussion of Recovery criteria #1 above).

b. Genetics, genetic variation, or trends in genetic variation:
No information is currently available concerning genetic health of the surviving populations. However, due to the extremely small size of the surviving populations (see discussion of Recovery criteria #1 above), the genetic viability of the populations is of high concern (although R Nichols (pers. comm. 2014) notes that some mussels with small populations size may not have problems with genetic variation, as doubly uniparental inheritance (as seen in several bivalve species) highly reduces the genetic problems of small populations); in fact, most, if not all, of the populations appear to be well below the numbers necessary to successfully reproduce at levels necessary to maintain themselves.

c. Taxonomic classification or changes in nomenclature:
Preliminary results from recent phylogeographic studies by Appalachian State University indicate that Tar River spinymussel is very closely related (i.e., putative sister taxa) to the James spinymussel (*Pleurobema collina*), and that both the Tar River spinymussel and James spinymussel likely belong to a genus other than *Elliptio* or *Pleurobema* (Perkins et al. 2014). This study also indicted historical gene flow between the Neuse and Tar populations of the Tar River spinymussel.

d. Spatial distribution, trends in spatial distribution, or historic range:
Current available information indicates the species is endemic to both the Tar River and Neuse River systems in North Carolina. While the species' known historic and current ranges have been expanded since development of the 1992 recovery plan, the species' distribution remains highly fragmented. All surviving populations are small to extremely small in numbers, restricted in range, and, based on the most recent survey data within each river system, each of the surviving populations appears to be isolated from the other populations in the same river system by impoundments and/or extensive unoccupied stream reaches (NCWRC database 2014).

e. Habitat:
Suitable habitat for the Tar River spinymussel appears to be extremely limited throughout the species' range, as evidenced by the low numbers of individuals within each population. Within the Tar River system, the species currently has a highly fragmented, relict distribution. Based on historic and recent records for the species (NCWRC database 2014), the surviving occurrences exist as small population fragments, restricted primarily to short reaches of tributary streams.

The species' historic distribution within the Neuse River system is less certain. Within the Neuse River system, the species has been recorded from two sites in the mainstem of the Little River and one in the Neuse River (NCWRC database 2010; J Smith, pers. comm., 2014) and Tar River spinymussel habitat within the Little River, although still present, appears to be limited and patchily distributed (T Savidge, pers. comm., 2010; S McRae pers. comm., 2010).

Suitable aquatic habitat in the streams currently supporting occurrences of the species, which appears to be already extremely limited in most of these streams, is presently either in decline or threatened with decline by existing and future changes in land use activities – agricultural and forestry activities, reservoir construction, residential and commercial development activities, point and non-point source pollutant discharges, and reoccurring drought conditions.

f. Other:
The Service has been working with the NCWRC and the NCSU to establish captive refugia populations of the Tar River spinymussel and conduct controlled propagation of the species for population augmentation and reintroduction as necessary and feasible. Through these efforts, some aspects of the species' life history have been determined, including the time of gravidity (early April thru mid-July) and likely fish host species (listed below) for Tar River spinymussel glochidia (larvae) (C Eads, pers.

comm., 2010). Also, it has been learned that females of the species release conglutinates (packets of glochidia) and release up to four or five times during their brooding season (C Eads, pers. comm., 2010).

List of fish species that successfully transformed Tar River spinymussel glochidia in the lab:
Hosts:
White shiner (*Luxilus albeolus*)
Pinewoods shiner (*Lythrurus matutinus*)
Bluehead chub (*Nocomis leptocephalus*)
Satinfin shiner (*Cyprinella analostana*)

Marginal hosts:
Creek chub (*Semotilus atromaculatus*)
Swallowtail shiner (*Notropis procne*)

2. Five-Factor Analysis

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

Based on available data, there are six known populations, and likely only three surviving populations of the Tar River spinymussel in two river basins. All surviving populations of the Tar River spinymussel are small to extremely small in size, highly fragmented and isolated from one another, and appear to be in serious decline. We have evidence that all of the surviving populations continue to be threatened by many of the same factors identified in Service's revised recovery plan for the species as leading to the loss and decline of the species throughout significant portions of its historic range and threats to surviving populations, including habitat fragmentation, loss, and alteration resulting from impoundments, wastewater discharges, loss of forested lands and riparian buffers, and the runoff of silt and other pollutants from ground disturbance activities (see section II-B-3(3) above). For example, despite repeated surveys, no live individuals of the species have been observed in the Sandy/Swift Creek watershed since 2005. This can be attributed to the cumulative effects of multiple threats - the pesticide-induced die off, drought, and large scale clearing of timber within the watershed. The Neuse River basin population(s) will likely face development-related pressures as several Wake County municipalities (e.g., Raleigh, Rolesville, Zebulon and Wendell) expand and grow. If the water supply reservoir and wastewater discharge on the Little River in Wake County are pursued, the population in the Little River will be under imminent threat from decreased flows and chemical contaminants from discharged effluent.

Water quality continues to be an issue affecting habitat quality, as freshwater mussels are some of the most sensitive forms of aquatic life to toxicity of common pollutants in surface waters, such as ammonia, chlorine, chloride, copper, nickel, lead, potassium, sulfate, and zinc (Augspurger et al. 2003; Wang et al. 2007a, 2007b, 2010). Recent studies indicate that Tar River spinymussels are sensitive to contaminants (T Augspurger, pers. comm. 2014), thus pollutants are important to consider in managing Tar River spinymussel populations.

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

Overutilization for commercial, recreational, scientific or educational purposes was not specifically considered to be a limiting factor in 1985 when the species was listed as endangered or in the species' 1992 revised recovery plan. We have no new information to indicate that this has changed.

c. Disease or predation:

At the time of listing, disease and predation were not considered significant threats to the Tar River spinymussel. However, based on available information, all the surviving populations are small in number; most appear to be extremely small with only a few live Tar River spinymussels documented during the most recent surveys (NCRWC database 2014). Several small mammal species are known to feed on mussels including muskrat, otter, raccoon, mink, etc. While predation is not thought to be a significant threat to a healthy mussel population, it could, as suggested by Neves and Odum (1989), limit the recovery of endangered mussel species or contribute to the local extirpation of mussel populations already depleted by other factors. Also, while we do not have any new information indicating that disease has been a contributing factor in the decline of the Tar River spinymussel, extensive mussel kills or die-offs have been reported at various times in streams throughout the United States. The cause(s) of many of these die-offs is unknown, but disease has been suggested as a possible factor.

d. Inadequacy of existing regulatory mechanisms:

The overwhelming majority of statutory or regulatory mechanisms capable of affording protection to the Tar River spinymussel derive from the species' Federal status under the Endangered Species Act (Act) of 1973, as amended. This statute provides various protections to this species that would not otherwise occur under any other Federal, state, or local statute. In particular, federally funded activities with the potential to affect this species that are authorized, funded or otherwise carried out by Federal agencies are subject to section 7 consultation with the Service to ensure that such actions do not jeopardize the continued existence of the species. Section 7(a)(1) of this statute also directs Federal agencies to utilize their

authorities to assist the Service in the recovery of species (such as Tar River spinymussel) listed under this statute.

Many of the activities that pose a significant threat to the surviving populations of the Tar River spinymussel and its habitat are not subject to the regulations of section 7 of the Act because they do not have any federal involvement – no federal permits, federal authorization, or federal funding associated with the activity – and therefore no requirement for consultation with the Service if they may adversely affect federally-listed species. Accordingly, most of these activities occur without any coordination with the Service and are reviewed and regulated, if any review/regulation takes place, only by state and local regulatory agencies/governments for compliance with any applicable state and local regulations/ordinances[1]. Neither the State of North Carolina nor the local governments with jurisdictions within the watersheds of streams supporting populations of the Tar River spinymussel, currently have regulations/ordinances that are adequate to protect the species from many of the adverse effects of agriculture, private forestry, and residential and commercial development activities (e.g., degradation or loss of riparian buffers; impacts to the streams' hydrographs; stormwater runoff of sediments and other non-point source pollutants; wastewater discharges, etc.).

The Tar River spinymussel is listed as endangered by the state of North Carolina. The NC Wildlife Resources Commission administers the NC Endangered Species Act (ESA) (General Statues 113-331 to 113-337; enacted in 1987), which protects animals, and maintains the state's list of "protected animal species." The NC ESA generally prohibits killing, harming, possessing, or trading protected species without a permit (NC NHP 2001; NC Bar Association 2013), and regulates collection and commercial trade of species listed under the statute. This law does not prohibit habitat modification (NC NHP 2001).

Since 2011, several state environmental regulations have been under intense review and scrutiny, dubbed as "regulatory reform". The NC General Assembly has considered regulatory reform legislation that repeals "unnecessary" state agency rules (NC General Assembly HB74, 2013), and those directly affecting the Tar River spinymussel include provisions that repeal stream buffer requirements in the Neuse and Tar-Pamlico River basins, as well as the elimination of a dedicated funding source for parks/conservation programs. Further, the NC General

[1] Unless it can be proven: (1) in a federal court of law that violation of section 9 of the Act, which prohibits the "take" of federally listed species, or other federal regulation, has occurred as a result of the activity; or, (2) that violation of section 9 will occur and a permit pursuant to section 10(a)(1)(B) of the Act is required. However, under the former scenario, impact(s) to the species has (have) already occurred or is(are) occurring, and the latter requires notification of the Service of the impending activity.

Assembly has decided that if a federal environmental standard exists, state and local environmental rules should not go beyond the federal requirement except in extraordinary circumstances (Smith 2013).

One area where this is a concern relates to the Clean Water Act. Recent studies indicate that current federal and state water quality standards for several pollutants commonly found in wastewater discharges and stormwater runoff are either not available (no criteria or standard derived) or likely not protective of freshwater mussels and current regulations controlling the discharge or runoff of these pollutants are not protective. For example, studies show that ammonia is extremely toxic to freshwater mussels at levels well below the current federal standard for this pollutant (Augspurger et al. 2003). Significant sources of ammonia include municipal and package wastewater treatment plants, agricultural runoff (animal wastes and chemical fertilizers), and lawn and turf runoff. In 2013, the U.S. Environmental Protection Agency (EPA) revised the water quality criteria for ammonia (EPA 2013). Acute and chronic criteria were developed to protect organisms from both immediate effects, such as mortality, and longer-term effects on reproduction, growth and survival, respectively. EPA provides several supporting documents to aid states considering adoption of the updated criteria, but North Carolina has not undertaken this effort. Also, recent studies indicate that pharmaceuticals and personal care products are commonly being discharged into surface waters and may be having acute and chronic impacts on aquatic species. For example, Fluoxetine, an often prescribed antidepressant drug, is increasingly being detected in surface waters at high enough levels that can cause female mussels to discharge/abort undeveloped glochidia and has the potential to disrupt numerous other aspects of native mussel reproduction (Bringolf et al., 2007). However, very few if any treatment plants monitor for these pollutants and there are no federal or state standards regulating the discharge of pharmaceuticals or numerous other pollutants commonly found in wastewater discharges.

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

The genetic viability of the surviving populations remains a significant concern. All of the remaining populations of the Tar River spinymussel appear to be effectively isolated from one another by impoundments and long reaches of highly degraded habitat; and, the numbers of all of the surviving populations appear to be well below the level necessary to maintain a reproductively viable population (Courchamp et al. 2008, Kramer et al. 2009).

The multitude of effects of climate change has and will likely continue to impact the Tar River spinymussel. Many species of native freshwater

mussels are especially sensitive to climate change because of their patchy distribution, limited mobility, and dependence on host fish for their larval stage, as well as fragmentation of their ranges by habitat alteration (Newton and Lubeck 2013). Thermal regime change (e.g., higher temperatures) and habitat alteration/degradation (e.g., severe storm events and droughts) are climate change threats that aquatic species will face in the future (Pandolfo 2014). These changes can alter nutrient cycling, decrease habitat availability, decrease water quality, and possibly introduce parasites and pathogens into freshwater ecosystems (Pandolfo 2014 and references therein). Furthermore, climate change can alter species interactions and cause shifts in species distributions (Pandolfo 2014 and references therein).

Streams supporting populations of the Tar River spinymussel have been affected by reoccurring drought conditions, including prolonged severe - exceptional drought conditions which persisted from the fall of 2006 through 2008 (NOAA 2008) – flow in reaches of several of the streams supporting the species was significantly reduced and in places completely dried up. In addition, from 2010-2012, Pandolfo (2014) found that temperatures in streams supporting the Tar River spinymussel reached thresholds that have been shown to cause harm to mussels in laboratory tests. These temperatures are also known to cause harm to several fish species, thus threatening the host-fish interaction with mussels. A recent study in Oklahoma found that mussel assemblages shifted from thermally sensitive to thermally tolerant species, and that these changes corresponded with a period of drought in the river (Galbraith et al. 2010). Thus, droughts and thermal stress, in conjunction with several other factors, could be shifting the mussel communities and thus threatening Tar River spinymussel persistence in the basins.

D. Synthesis

Although there have been discoveries of additional occurrences of the Tar River spinymussel since the species was listed as endangered in 1985, the species continues to have a very fragmented, relict distribution and available trend information indicates that the species is rapidly declining throughout its range. Based on available survey data, all extant populations are extremely small in numbers and three of the populations in the Tar River, Shocco Creek, and Neuse River may possibly be extirpated, though additional surveys are needed to confirm this. Surveys in the Sandy/Swift Creek basin have also shown dramatic declines in numbers, and intensive survey efforts are needed to determine whether the species continues to persist. Although a very low level of successful reproduction may be occurring in the Little Fishing/Fishing Creek and Little River populations, all of the surviving populations appear to be well below self-maintenance levels. Because of these extremely low population levels, the proximity of

males and females may be limiting their reproductive success. All surviving populations are isolated from one another and restricted to short stream reaches. Habitat in the streams were the species exists generally appears to be marginal at best, as evidenced by the extremely low numbers of individuals found, and patchily distributed. All surviving populations are under significant and increasing threat of extirpation from existing and likely future land use activities. Once extirpated, opportunities for populations to reestablish through natural recolonization do not appear to be possible.
Due to the threats from habitat destruction and modification, inadequacy of existing regulatory mechanisms, small population size, and climate change, the Tar River spinymussel continues to meet the definition of endangered under the ESA.

III. RESULTS

A. Recommended Classification:

__X__ No change is needed

IV. RECOMMENDATIONS FOR FUTURE ACTIONS

1. Improve planning, coordination, and efficacy of recovery activities with key partners (e.g., NCWRC, NCDWR, NCNHP, USFWS, NRCS, local governments, local conservation NGOs, researchers, etc.) by meeting at least biennially to share information and review and recommend priority recovery actions.
2. Formalize a detailed population and habitat monitoring plan for all surviving populations.
3. Continue working with state and local governments to implement protective regulations/ordinances for addressing the impacts and threats from forestry, agriculture, development, and other land disturbance activities; wastewater discharges; and other impacts and threats to aquatic habitats within the streams supporting the Tar River spinymussel. One of the highest priorities is to continue working closely with state and local partners to develop, encourage public support for, and effectively implement protective water quality management strategies for the Tar River spinymussel such as protective stream designations and site-specific plans like the those required by *North Carolina Procedures for Assignment of Water Quality Standards* Rule 15A NCAC 02B .0110. In addition to addressing nonpoint source pollution, any strategy/plan should work to eliminate surface wastewater discharges from streams supporting the species. The strategy/plan should also result in implementation of regulations for water withdrawals that are protective of the streams' hydrology, especially during periods of low flow.
4. Continue analyzing threats to the species and measures for off-setting these threats; determine species specific vulnerability to commonly discharged wastes (e.g. ammonia, chlorine) for which present discharge limits may not be protective of mussels.

5. Continue captive propagation efforts. Several of the extant populations are likely to become extirpated in the very near future. These populations represent a significant portion of the species' historic geographic range. Without immediate efforts through captive holding and propagation to maintain the genetic material from these populations for augmentation and reintroduction efforts, we may forever lose the genetic strains necessary for reestablishing these and other already extirpated populations of the species.
6. Work in coordination with federal and state agencies, knowledgeable biologists, and land stewards, using information about current water quality, fish and mussel assemblages, current watershed conditions, and prospective protective mechanisms to identify and evaluate candidate streams for potential reintroduction efforts and reintroduce/establish new populations were feasible. Because of their small size, amount of habitat degradation that has already occurred, existing land uses and degree of future threats, conservation of some of the extant populations in the streams they currently occupy is likely untenable. Immediate efforts should be undertaken to secure individuals from these populations and move them to captivity for propagation or refugia streams and use for reintroduction to suitable habitats. This would maintain the genetic diversity represented in these populations, while allowing for development of wild, viable populations within the species' historic range.
7. Continue habitat, life history, and captive propagation studies aimed at specific conservation applications, including: water temperature tolerances and optimal range; instream flow requirements, DO requirements, and specific impacts from altered flow regimes; support continued controlled propagation experiments with congeneric surrogates and permit work directly with Tar River spinymussel.
8. Continue working with partners to acquire land and establish conservation easements and restore forested buffers and instream habitat. Initially these efforts should be focused primarily on the best of the remaining populations of the Tar River spinymussel and areas targeted for population augmentation and/or reintroduction of the species.

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U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW
Tar River spinymussel (*Elliptio steinstansana*)

Current Classification: Endangered
Recommendation resulting from the 5-Year Review

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist
_X__ No change is needed

Review Conducted By: Initially drafted by John A. Fridell, Asheville Ecological Services Field Office, Asheville, NC; finalized by Sarah McRae, Raleigh Ecological Services Field Office, Raleigh, NC

FIELD OFFICE APPROVAL:

Lead Field Supervisor, U.S. Fish and Wildlife Service

Approve _____ Date 8/25/14

REGIONAL OFFICE APPROVAL:

for

Lead Regional Director, U.S. Fish and Wildlife Service

Approve _____ Date 9-10-14

APPENDIX A: Summary of peer review for the 5-year review of Tar River spinymussel

Peer Reviewers:
John Alderman, Alderman Environmental Services, Pittsboro, North Carolina; Telephone: (919) 542-5331

Dr. Arthur Bogan, Curator of Aquatic Invertebrates, North Carolina Museum of Natural Sciences, Raleigh, North Carolina; Telephone: (919) 707-8863

Chris Eads, North Carolina State University College of Veterinary Medicine, Raleigh, North Carolina; Telephone: (919) 645-8657

Sarah McRae, Aquatic Ecologist, North Carolina Natural Heritage Program; currently working with the USFWS and responsible for completing this review.

Rob Nichols, Aquatic Diversity Research Coordinator, Eastern Region, North Carolina Wildlife Resources Commission; Telephone: (919) 896-6254

Tim Savidge, The Catena Group, Raleigh, North Carolina; Telephone: (919) 417-2314

A. Peer Review Method: A draft 5-year review for the Tar River spinymussel was sent to each of the reviewers requesting their review and any other comments or additions that should be included in the document. All reviewers have extensive knowledge of this species and have worked with the species in field conditions.

B. Peer Review Charge: Reviewers were charged with providing a review of the document including any other comments and/or additions appropriate to include. Reviewers were not asked to comment on the legal status of the species.

C. Summary of Peer Review Comments/Report: Reviewers responded verbally and/or by email with responses placed in the file record. All reviewers thought the information in the draft 5-year review provided to them was accurate. They did provide some additional references and recommendations that were incorporated into the 5-year review as appropriate.

D. Response to Peer Review: Recommendations from the reviewers were included in the document.

5-YEAR REVIEW
Tar River Spinymussel/*Parvaspina (=Elliptio) steinstansana*

Addendum 1. Summary of new information obtained since the 2014 5-year review.

I. GENERAL INFORMATION

A. Methodology used to complete the review:

We provided public notice of this five-year review in the Federal Register on June 20, 2019 (84 FR 28850) and opened a 60-day public comment period. We obtained pertinent information on the status of this species from the recovery plan, peer reviewed scientific literature and published papers, unpublished reports, and experts on this mussel species from State agencies, local universities, etc. Once all known and pertinent data were collected for this species, the status information was compiled and the review was drafted by the Raleigh Ecological Services Office, North Carolina. A draft was peer-reviewed by Service partners and experts familiar with Tar River Spinymussel. Comments that were received were evaluated and incorporated as appropriate (see Appendix A.)

B. Reviewers

Lead Regional or Headquarters Office – South Atlantic-Gulf and Mississippi Basin Regions (Legacy Region 4): Carrie A. Straight, Ph.D., (404) 679-7226

Lead Field Office – Raleigh, North Carolina: Jennifer M. Archambault, Ph.D., (919) 856-4520, extension 30

C. Background

1. **FR Notice citation announcing initiation of this review:** 84 FR 28850; June 20, 2019

2. **Species status:** Decreasing; survey and monitoring efforts indicate that populations of Tar River Spinymussel persist at extremely low densities with no documented wild recruitment, and populations remain isolated.

3. **Recovery achieved:** 1 (0 – 25% recovery objectives completed)

6. **Review History:** The Service finalized a 5-year review for Tar River Spinymussel in 2014. The review recommended that the species remain classified as endangered due to extremely low abundance of mussels and evidence of further decline in remaining populations, fragmented distribution, likely inadequate reproduction and recruitment, and possible extirpation of the species from many known localities (USFWS 2014).

8. **Recovery Plan:**

   Name of plan: Tar Spinymussel Recovery Plan
   Original Date: January 16, 1987

Revision: (Revised) Tar Spinymussel Recovery Plan
Revision Date: May 5, 1992
Amendment: Recovery Plan for Tar River Spinymussel (*Parvaspina (=Elliptio) steinstansana*), Amendment 1
Amendment Date: November 7, 2019

II. REVIEW ANALYSIS

B. Recovery Criteria

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

_X_ ***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?

_X_ ***Yes***

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

_X_ ***Yes***

3. List the recovery criteria as they appear in the recovery plan, and discuss how each criterion has or has not been achieved.

The Recovery Plan Amendment (USFWS 2019) replaced the downlisting criteria from the Revised Tar River Spinymussel Recovery Plan (USFWS 1992) with delisting criteria. The Tar River Spinymussel (*Parvaspina (=Elliptio) steinstansana*) should be considered for delisting when:

1) <u>At least seven (7) sub-populations exhibit a stable or increasing trend, as evidenced by natural recruitment, and multiple age classes (addresses Factors A and E).</u>

This criterion has not been achieved and existing sub-populations remain small and isolated. In establishing these updated criteria, the Recovery Plan Amendment (USFWS 2019) stated that populations refer to river basins (e.g., the Tar or Neuse population) and sub-populations refer to large tributary systems (e.g., Fishing Creek sub-basin; Sandy-Swift Creek tributaries) or isolated stretches of mainstem rivers (e.g., upper Tar River above Louisburg; lower Tar River below Tarboro).

The previous 5-year review (USFWS 2014) reported that, despite discoveries of

previously unknown populations of Tar River Spinymussels since the revised Recovery Plan was published (USFWS 1992), few mussels have been found in modern surveys of known occupied habitats. Since 2014, only 11 wild individuals have been encountered in two sub-populations in 541.5 person-hours of survey efforts conducted by the North Carolina Wildlife Resources Commission (NCWRC). Ten mussels were found in the Fishing Creek sub-population of the Tar River population (eight in Little Fishing Creek and two in Fishing Creek) and one mussel was found in the Little River sub-population of the Neuse River population (NCWRC 2020). The low rate of detection within the recent range of Tar River Spinymussel indicates that the species continues to decline. Most of the survey efforts to date have used qualitative or semi-quantitative techniques (e.g., visual surveys; timed searches). Additional surveys are needed to determine whether wild individuals are extant at other locations, where they have not been detected in 15 or more years (USFWS 2014). Surveys using robust, quantitative methods (e.g., quadrats, excavation) would be particularly helpful in determining occupancy, population size, and recruitment.

Although wild mussels are scarce, captive propagation techniques have improved for Tar River Spinymussel and this criterion is being addressed with active management. The NCWRC and research partners at North Carolina State University have produced and reared several broods of mussels to sufficient length for release into river habitats within the species' extant range. The 11 wild individuals encountered during surveys in the last five years were collected and have been incorporated into the propagation program to increase genetic diversity of the broodstock and progeny. Augmentation efforts began in 2014 with the release of 259 age-3 individuals (i.e., propagated in 2011) in Little Fishing Creek, part of the Fishing Creek sub-population (NCWRC 2020). Augmentation efforts have continued each year, and a total of 35,086 tagged Tar River Spinymussels from eight cohorts (propagated 2010 – 2017) have been released among three sub-population sites between 2014 and 2019. Of those released, 27,164 mussels were stocked into the Fishing and Little Fishing Creeks of the Fishing Creek sub-population, 7,060 were stocked into the Swift and Sandy Creeks of the Swift Creek sub-population, and 862 were stocked into the Tar River sub-population (NCWRC 2020). These recent successes in stocking have been facilitated by especially productive cohorts propagated in 2013 and 2016, and by using a floating basket system in ponds to grow small juvenile mussels (4 – 10 mm (0.16 – 0.39 in)) to a suitable size for stocking (~25 mm (~1 in)) within one season (Eads and Levine 2017). Additional details on the captive propagation and augmentation program are provided below in section II.C.1.g.

The NCWRC conducted surveys of the augmented populations in 2015, 2016, 2018, and 2019 to monitor success of the program, by assessing survival, growth, and reproduction of the captive-reared mussels in the wild (NCWRC 2020). Monitoring included timed search techniques, quadrat sampling (without excavation), and use of a passive integrated transponder (PIT) tag reader. In two reaches where mussels were stocked to a mean density of approximately17

mussels/m^2 (1.6 mussels/ft^2), subsequent quadrat monitoring yielded recapture densities ranging from 0.30 – 0.55 mussels/m^2 (0.03 – 0.05 mussels/ft^2; NCWRC 2020). Compared to stocking rates of mussels, the observed densities equate to recapture rates ranging from approximately 7.5 – 21% (M. Fisk, NCWRC, personal communication). In reaches where timed searches were used, detection of mussels varied among sites and years, from a catch per unit effort of 0.5 mussels/person-hour to more than 88 mussels/person-hour (NCWRC 2020), with a median of 9.7 mussels/person-hour. Recapture rates of released mussels in some of the timed search surveys were 20 – 35% (NCWRC 2018). The NCWRC has recorded 1,457 recaptured mussels, most of which are singular events (i.e., a small proportion of mussels have been recaptured more than once), and they have observed some mortality, with 46 shells recovered (NCWRC 2020).

In addition to monitoring the survival and persistence of stocked mussels, NCWRC biologists have documented growth of mussels since release (median annual growth rates of 0.7 – 1.4 mm/year (0.03 – 0.06 in/year; NCWRC 2020). They have also documented more than 200 gravid females. In addition to observing some gravid females while stocking new mussels at stream sites, specific efforts of monitoring gravidity in 2018 have documented 25 – 68% of mussels gravid in those surveys (NCWRC 2020). Natural recruitment, as would be indicated by detection of juvenile mussels, has not been documented yet. Age class structure in occupied reaches has not been assessed; however the majority of mussels are likely those that have been stocked within the last five years.

Augmentation of populations, along with the evidence of good survival, observed growth, and gravidity offer promise that this recovery objective is attainable if environmental conditions are sufficient to support mussels. To achieve success of this recovery criterion, continued propagation and stocking will be required in these and additional sub-populations to meet the objective of seven sub-populations, habitat and water quality conditions must be maintained or improved to support mussels throughout their life cycle, and continued monitoring is needed to evaluate population trends (stable, increasing, or decreasing), natural recruitment, and age class structure.

2) Spatial distribution of seven (7) sub-populations (as defined in Criterion 1) includes one (1) sub-population in each of the Tar and Neuse river basins, and sub-populations (as defined in Criterion 1) occupy both mainstem and tributary systems (addresses Factors A and E).

This criterion has not been achieved, but it is being addressed through active management – specifically augmentation of wild populations with the release of captive-propagated mussels. As noted above under Criterion 1, individuals have been found in only two subpopulations since the last review – 10 mussels in the Fishing Creek subpopulation of the Tar River population and one mussel in the Little River subpopulation of the Neuse River population. Sub-populations continue to be isolated by unsuitable habitat, and occupied reaches within sub-

populations are similarly isolated from each other (NCWRC 2018, 2020; USFWS 2014, 2019). Augmentation and reintroduction with propagated mussels has been identified by the Service as one of the best available tools for recovering Tar River Spinymussel (USFWS 2014, 2019). Augmentation efforts since 2014 focused in the following three subpopulations (i.e., NCWRC management units; NCWRC 2018), as noted under Criterion 1 above: Fishing Creek, Swift Creek, and Tar River. The NCWRC has identified these subpopulations in the Tar River population, along with the Little River subpopulation of the Neuse River population as high priority for conservation efforts, including promoting habitat protection, improving connectivity and gene flow among existing occupied reaches, and augmentation. Additional management units within the species' known and historic range also have been identified as potential candidates for augmentation efforts if water quality and habitat conditions are sufficient to support mussels (NCWRC 2018).

3) Threats have been addressed and/or managed to the extent that the species will remain viable into the foreseeable future (addresses Factors A, D, and E).

Threats including habitat and water quality degradation from sedimentation, runoff, and point-sources discharges, as identified and detailed in the Recovery Plan, most recent review, and the Recovery Plan Amendment (USFWS 1992, 2014, 2019), remain as pervasive threats to the persistence and recovery of Tar River Spinymussel. Because remaining populations, including mussels released in augmentation efforts, occupy small, isolated stream reaches, stochastic events – such as storms, drought, or isolated chemical spills or sedimentation events that have harmed populations in the past (USFWS 1992, 2014) – will continue to threaten recovery until populations have been augmented with sufficient resilience, redundancy, and representation to withstand or recover from such events. Other important threats include fragmented habitat by dams/reservoirs, which contributes to the isolation of sub-populations; invasive species, such as the Asian Clam (*Corbicula fluminea*), from which threats are poorly understood and merit further investigation (Haag 2019); and urbanization (Terando et al. 2014) and loss of riparian habitats, which contribute to all of the primary threats listed above.

The previous five-year review (USFWS 2014) and the Recovery Plan Amendment (USFWS 2019) summarized how the Service is addressing these threats through partnerships with land trusts, municipalities, landowners, and state agencies to protect remaining habitats and improve and restore habitats within the historic range. Such partnerships have contributed to the protection of forested lands and riparian habitats (USFWS 2014). The Service has continued to pursue these efforts since that last review; our most recent endeavor includes an initiative to partner with the North Carolina Forest Service and consulting foresters to implement a pilot program that incorporates specific best management practices for timber harvests important for protecting in-stream habitats from damage, sedimentation, and runoff. The Service also is pursuing a Programmatic Safe

Harbor Agreement for 21 aquatic species in North Carolina, including Tar River Spinymussel, to encourage habitat restoration and species recovery efforts among non-federal landowners.

C. Updated Information and Current Species Status

1. Biology and Habitat

a. Summary of New Information of Species Biology and Life History: Limited new information on Tar River Spinymussel biology and life history has been reported since the last review; recent findings include information on host fish use and a study of thermal effects on reproduction.

Host fishes: Since the 2014 review (see section II.C.1.f.), the Satinfin Shiner (*Cyprinella analostana*) has been characterized as a marginally effective host (NCWRC 2018); it was listed in the previous review among effective hosts (USFWS 2014). An updated understanding of suitable host fishes is informative for future efforts in monitoring fish assemblages in occupied or candidate reintroduction sites for Tar River Spinymussel, and it provides additional insight for successful propagation of mussels for such augmentation and reintroduction efforts. See also a discussion below (section C.1.g) related to the effectiveness of using hosts multiple times within a breeding season for captive mussel propagation.

Thermal effects on reproduction: Eads et al. (2015) investigated the effects of temperature on conglutinate (i.e., larval sac) release and glochidial (i.e., larval) transformation. Over a range of temperatures in a laboratory experiment (20 – 24°C), they found that the duration of encystment on host fish for metamorphosis was approximately two days shorter for every 1°C increase in temperature (i.e., metamorphosed juveniles dropped off of host fish more quickly under warmer conditions). Those in the warmest treatment (24°C) achieved peak drop off approximately 12 – 14 days after encystment, while those in the coolest treatment (20°C) took approximately 23 – 25 days to achieve peak drop off (Eads et al. 2015). Further, all juvenile drop offs in the warmest treatment occurred over a shorter time period (5 days) than in the coolest treatment (7 days; Eads et al. 2015). The study also included observations of conglutinate release in captive-held females in a range of ambient water temperatures over a seven-year period of propagation efforts (2008 – 2014). Their observational findings included: conglutinate release typically began shortly after water temperature exceeded 15°C (March/April); females released conglutinates multiple times throughout a range of spring and summer temperatures until July/August; there was no apparent thermal optimum for release or transformation; and brood development and release continued after an extreme temperature event (> 30°C) in 2008 (Eads et al. 2015).

These findings contribute to our understanding of Tar River Spinymussel life history, and they may offer important insights for refining propagation techniques,

or appropriately timing population monitoring for evidence of gravidity and host fish encystment in the wild. Research on the thermal ecology and tolerance of native mussels is limited (e.g., Spooner and Vaughn 2008; Lurman et al. 2014), and most studies have focused on thermal limitations. Findings in studies of mussel thermal sensitivity suggest that some species already may be experiencing temperatures near their upper thermal limits (Pandolfo et al. 2010), that considerations of mussel and host fish sensitivities are important (Pandolfo et al. 2012), and that conditions such as increasing water temperature and drought may have lethal and sub-lethal effects on freshwater mussels (Gough et al. 2013; Archambault et al. 2013; 2014; Payton et al. 2016; Khan et al. 2019). As such, this advance by Eads et al. (2015) in understanding the effects of temperature on reproductive ecology of Tar River Spinymussel will help contextualize threats that thermally impact aquatic environments (e.g., industrial thermal effluents, heated stormwater runoff, loss of riparian shading, increasing annual mean temperature, or low flows associated with water extraction or drought).

b. Abundance, population trends, demography:

As noted above in Section B.3 (Recovery Criteria 1 and 2), few individuals have been found since the last review (NCWRC 2020). Wild populations remain very small, with no evidence of natural recruitment. The last review indicated that the Tar River, Shocco Creek, and Little River (Neuse) sub-populations may be extirpated (USFWS 2014); there has been only one Tar River Spinymussel found in the Little River. The lack of consistent detection suggests these sub-populations are at least functionally extirpated. Quantitative surveys in the best remaining habitats would help in making that determination. However, the NCWRC has stocked more than 35,000 propagated mussels into the Fishing Creek, Swift-Sandy Creek, and Tar River subpopulations since 2014. Monitoring surveys since 2015 have documented survival, growth, and gravidity in tagged mussels that were released, and augmentation and monitoring will continue (NCWRC 2020). The Service is working with the NCWRC to formalize an augmentation and reintroduction plan that will include evaluation and success metrics for these activities as they relate to recovery. See section II.B.3 discussion for additional information.

c. Genetics:

Significant advances in genetic research of Tar River Spinymussel have been made since the last review. Perkins et al. (2017) investigated the genetic profiles of the three North American spinymussels (*Elliptio spinosa, Elliptio steinstansana,* and *Pleurobema collina*) – all federally endangered species. Using mitochondrial and nuclear DNA techniques, Perkins et al. (2017) found genetic evidence that Tar River Spinymussel and James Spinymussel (*P. collina*) form a monophyletic clade, and they described the new genus, *Parvaspina*, to reflect that relationship. (Altamaha Spinymussel, *E. spinosa,* was found to be divergent from the others, forming its own monophyletic clade). Perkins et al. (2017) described that the etymology of *Parvaspina* comes from the Latin parva, meaning small, and spina, meaning spine. Perkins et al. (2017) reported that Tar River and James

Spinymussel diverged from other mussels in the Pleurobemini tribe approximately 6.19 million years ago, and diverged from each other, only ~0.69 million years ago. Within the genetic samples available for their study, Perkins et al. (2017) identified four haplotypes for Tar River Spinymussel; they reported that one haplotype represented 73% of the samples and they found no geographic structure represented in the samples. These findings highlight the genetic distinction and biodiversity that the North American spinymussels represent, and the description of, and assignment within, the new genus *Parvaspina* should inform conservation priorities. Perkins et al. (2017) assert that continued management of spinymussels within the previously assigned genera (*Elliptio* for Tar River Spinymussel) would be inappropriate and that conservation priorities and strategies will be more effective in the framework of the updated understanding of *Parvaspina.* Williams et al. (2017) provided a revised list of 298 mussel species of the United States and Canada, including the Tar River Spinymussel, which incorporated changes in nomenclature and systematic taxonomy. This document is accepted by mussel experts as the most current and accepted taxonomic structure of North American unionids.

Another ongoing genetic initiative is a research project of the NCWRC, in partnership with Georgia Southern University, to develop genomic markers and evaluate genetic diversity in eight freshwater mussel species, including Tar River Spinymussel. Results are expected to provide valuable information on the genetic diversity of all known populations of the species and a panel of genetic markers for maximizing conservation of genetic diversity in captive propagation and population augmentation activities (NCWRC 2019, 2020).

d. Taxonomic classification or changes in nomenclature:
As described in the Genetic section above (II.C.1.c), genetic evaluation revealed strong evidence that Tar River Spinymussel (along with James Spinymussel) diverged from other species in Pleurobemini. Perkins et al. (2017) described the new genus, *Parvaspina*, for Tar River and James Spinymussels, which is currently accepted by North American malacologists (Williams et al. 2017). Although the taxonomy has been updated in the current literature, Tar River Spinymussel has not yet been updated from *Elliptio steinstansana* in the Integrated Taxonomy Information System (ITIS 2020).

e. Distribution and trends in spatial distribution:
The previous review (Section II.C.1.d., USFWS 2014) reported on updated knowledge about the extended historic and extant distribution of Tar River Spinymussel; in particular it noted the species' occurrence in the Neuse River Basin and additional locations in the Tar River Basin that were unknown when the Recovery Plan was published (USFWS 1992). The Service updated the recovery criteria in the Recovery Plan Amendment (USFWS 2019) based on this updated understanding of Tar River Spinymussel spatial distribution. As mentioned in the Review Analysis above (Section II.B.3), wild mussels have been found in only two sub-populations since the last review (Fishing Creek (Tar) and

Little River (Neuse). These data support recent findings that trends in spatial distribution of Tar River Spinymussel have not improved (NCWRC 2018; USFWS 2014, 2019).

f. Habitat or ecosystem conditions:

Perpetual threats from land use changes and point- and non-point-source discharges into waterways, as outlined in Criterion 3 (under Section II.B.3), are a concern for maintaining and improving habitat to facilitate recovery of the species. As noted in the previous review (Section II.C.1.e., USFWS 2014), the very low detection of wild mussels and presumed low occupancy within known occupied habitats, along with the isolated, relict nature of such occurrences, indicates that habitat conditions are potentially unsuitable for supporting Tar River Spinymussel population persistence without intervention. Monitoring of augmented populations will improve our understanding of habitat suitability for supporting population persistence, recruitment, and recovery.

In a recent study, Pandolfo et al. (2016) were able to use habitat data in hierarchical modeling techniques to generate occurrence probabilities for several mussel species, including Tar River Spinymussel. They reported that the species "was anecdotally associated with moderately penetrable coarse sand and slow velocity" (Pandolfo et al. 2016, p. 34), which indicates the species has been relegated to degraded habitat conditions compared to the Tar River Spinymussel's preferred habitat outlined in the Recovery Plan (i.e., fast-flowing, well-oxygenated water and silt-free uncompacted substrates; USFWS 1992). Though only a few individuals were detected in the work by Pandolfo et al. (2016), such findings and techniques may be useful in guiding identification of suitable reintroduction sites or metrics for restoring streams to support rare mussels. Habitat models for future use may be improved with detailed records of habitat conditions associated with previous occurrences of Tar River Spinymussel or habitat data from successful reintroduction sites.

g. Other:

The NCWRC Conservation Aquaculture Center in Marion, North Carolina, currently has 18 wild Tar River Spinymussels held in captivity as broodstock for their permitted propagation program (permit no. TE31057A-1). Seventeen mussels (8 females and 9 males) were collected from the Tar River Basin population between 2009 and 2019, one male was collected from the Neuse River Basin population in 2018. All the mussels held have grown while in captivity, and adult survival in captivity has been high. The typical holding time of mussels has averaged 4.2 years before mortality (range 1 – 8 years; mussels currently in holding have been held for 1 – 11 years since collection (average 7.3 years; R. Hoch, NCWRC, personal communication). Four of the mussels from the Tar River Basin population were collected in 2009 and have contributed to the program through 11 breeding seasons (2010 – 2020). This may represent the longest known successful captive holding of federally listed unioinid mussels (R. Hoch, NCWRC, personal communication). Such long and successful holding of

Tar River Spinymussels is significant because they tend to be older on collection (as evidenced by size and eroded shells). Although the life span of this species is unknown, their small size compared to other native species suggests it is among shorter-lived unionids (e.g., < 20 years; Haag 2012).

Other notable results in the last five years of propagation – in addition to successful rearing of juveniles and release into the wild (see Section II.B.3) – include higher fertilization rates (average 66%; range 56 – 73%) than those documented in wild mussels and advancements in host fish use. Low fertilization rates (< 5% to 39%) have been documented in wild-caught mussels (Eads and Levine 2014). One exception was a wild-caught mussel that had 68% of her brood fertilized in 2015 after the first round of population augmentation had been performed in 2014. It is likely that fertilization in wild mussels has been low because of low mussel density and the difficulty for females to encounter sperm; it is possible that the release of mussels was related to increased fertilization and this is one goal of propagation and augmentation activities.

The NCWRC has successfully infested host fish with Tar River Spinymussel glochidia multiple times in one breeding season (two to three infestations of a given host fish, instead of just one use; R. Hoch, NCWRC, personal communication). This is an important advancement in Tar River Spinymussel propagation because fewer fish will need to be collected from the wild to support the program, thus reducing the impact on wild fish populations.

In the host trials and propagation work, transformation success of glochidia from 2014 to 2019 has ranged 10 – 58%, and survival of transformed juveniles has ranged 1.2 – 68% (1.2 – 3.1% most years, except for high survival in 2016; R. Hoch., NCWRC, personal communication and permit reports, including NCWRC 2019). Wide variation in success is common in mussel propagation endeavors, and explanations for the variation observed in Tar River Spinymussel production include a focus on changes to water supplies and culture systems from the construction of a new hatchery facility at the Conservation Aquaculture Center and periodic issues at the hatchery that have compromised juvenile mussels (e.g., fungal infection, NCWRC 2019). The Service and partners could help support more consistent production of Tar River Spinymussel and other listed mussels by investing in a health program to investigate mussel fitness and common pathogens and develop treatments or techniques to improve post-transformation survival of juveniles.

2. Five-Factor Analysis (threats, conservation measures, and regulatory mechanisms):

The purpose of a 5-Year Review is to recommend whether a listed taxon continues to warrant protection under the Endangered Species Act (ESA) and, if so, whether it should be reclassified (from threatened to endangered or from endangered to threatened). This task requires that the analysis of the threats to the species be

performed while assuming that the species is not receiving the regulatory protections, funding, recognition, and other benefits of ESA listing. Summaries of ongoing applications of ESA protections may shed light on some future activities that constitute threats to the species. However, the analysis under Factor D (Inadequacy of Existing Regulatory Mechanisms) focuses on the adequacy of existing alternative (i.e., non-ESA) mechanisms to address the continuing and foreseeable threats.

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

Current and future threats to habitat and range of the Tar River Spinymussel are consistent with those identified in the previous review (USFWS 2014) and in the Recovery Plan Amendment (USFWS 2019). Urban growth and related consequences to water quality and aquatic habitat (e.g., increased runoff of contaminants, heated stormwater, sedimentation, and creation of new water supply reservoirs in the species' range) remain pervasive threats. Urbanization can influence many factors relevant to Tar River Spinymussel, including water demand, local climate variables, and water pollution. The South Atlantic Land Conservation Cooperative has identified many areas within the Tar and Neuse River watersheds as "highest" or "high" priority for conservation based on several indicators, including freshwater aquatic metrics (e.g., imperiled species, impervious surfaces, riparian buffers), and based on existing and projected threats – especially urban growth (SALCC 2017). A study by the US Geological Survey's Southeast Climate Adaptation Science Center and its affiliates projected that urbanization will increase in southeastern US regions by 101 – 192% (Terando et al. 2014). The largest absolute increase in urbanization is expected in the Southeast's Piedmont region (Terando et al. 2014), including watersheds the Tar River Spinymussel occupies. It is especially important for the Service to maintain and improve productive partnerships because current and projected future land uses continue to threaten Tar River Spinymussel and its habitats.

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

The previous review noted that overutilization has not been identified as a specific limiting factor in the Recovery Plan (USFWS 1992, 2014), and we have no new information to indicate that has changed.

c. Disease or predation:

The previous review noted that disease or predation have not been previously identified as specific limiting factors (USFWS 1992), but that these factors could limit recovery or contribute to local extirpation for endangered species, such as Tar River Spinymussel, that have an already contracted range and low abundance (USFWS 2014). Although evidence of predation on recently stocked Tar River Spinymussels has been observed (five shells found in a muskrat midden, NCWRC 2020), predation is a natural occurrence, and there is not sufficient information to consider it a pervasive threat. We have received no new information about disease in wild or stocked Tar River Spinymussels. However, as noted in the Recovery

Plan and the previous review (USFWS 1992, 2014), large-scale mussel die-offs in the United States have been documented to occur with unknown causes, including one in the Tar River in 1986 (USFWS 1992). Such die-offs have continued to be documented in the United States and elsewhere in the last five years, and disease is suspected as a possible causative factor (Haag 2019). The Freshwater Mollusk Conservation Society held a special workshop on mollusk health and disease in 2018 and published the proceedings in a special issue of Freshwater Mollusk Biology and Conservation (Volume 22, Number 2, October 2019). One recent study identified a novel pathogen as a potential causative factor of a mass mortality event in the Southeast (Richard et al. 2020). Such developments in mollusk disease research may help in future assessments of disease risk for Tar River Spinymussel and may help to identify and ameliorate habitat conditions that promote disease risk. Given that infections have been observed in hatchery mussels and have compromised juvenile health (and thus, reduced the number of mussels available for stocking), research on the role of pathogens in propagation may improve rearing and restoration success and also may inform disease threats for wild populations.

d. Inadequacy of existing regulatory mechanisms:

The previous five-year review (USFWS 2014) provided a detailed narrative on the inadequacy of federal and state regulatory mechanisms. Specific concerns arising from this factor are still relevant and include the lack of regulatory mechanisms for protection of habitat and the inadequacy of those that address water quality concerns (e.g., contaminants, runoff, and other discharges), sedimentation, and alteration of riparian habitats.

Efforts in North Carolina to reduce regulation of riparian buffers, as mentioned in the 2014 narrative about regulatory reform (USFWS 2014) have continued. In 2017, the North Carolina General Assembly considered a bill entitled “An Act to Amend Certain Environmental and Natural Resources Laws” (Senate Bill 434) that included provisions to reduce protections of riparian buffers and prohibit local governments from instituting stricter protections than those required by the state. Although that particular bill did not move forward (possibly because of comments provided by conservation groups and professional organizations concerned about water quality), the proposed action highlights the continued fragility of existing regulatory mechanisms at the state level.

In April 2020 the US Army Corps of Engineers and US Environmental Protection Agency (EPA) finalized, a revised definition of “Waters of the United States” (85 FR 22250). The new rule established a narrower definition than previous interpretations and reduces protections for some waterways. The effect of this definition change on water quality and habitat for Tar River Spinymussel is unknown at this time. However, it is plausible that a narrower application of the Clean Water Act based on the new definition may reduce federal authority to regulate contaminant- or habitat-related threats for Tar River Spinymussel that were identified in the previous review (USFWS 2014) and updated herein.

e. Other natural or manmade factors affecting its continued existence:
The previous review (USFWS 2014) discussed concerns about genetic viability of Tar River Spinymussel and the potential for climate-related impacts to affect the species continued existence. Both issues remain a concern.

Concerns about genetic viability are currently being addressed through research to understand the species' current genetic diversity and to learn how captive propagation can be conducted in a manner that will conserve and maximize the genetic diversity remaining in wild populations (noted above in Section II.C.1.c).

The Intergovernmental Panel on Climate Change predicts that many freshwater species face a greater threat of extinction, along with irreparable changes to the structure and function of freshwater ecosystems (IPCC 2014) under projected climate change. Freshwater mollusks are expected to experience greater loss of habitats than any other freshwater group (Markovic et al. 2014). Additionally, fish movements – including species range shifts – will be affected by climate change (Comte et al. 2013; Lynch et al. 2016), which could affect mussel-host relationships. These broad-scale concerns about the effects of climate on freshwater species and habitats are directly relevant to Tar River Spinymussel because the southeastern Piedmont may become 2 – 6°C warmer, and experience synergistic effects from the combined impacts of climate change and urbanization (Terando et al. 2014). Specifically, North Carolina is expected to experience increased summer heat and more intense severe droughts, among other impacts (e.g., flooding/hurricanes), and concurrent with other stressors, such as human population growth (NC DEQ 2020). Such events may be detrimental to Tar River Spinymussel survival, reproduction, and population persistence and recovery. The state of North Carolina has identified protecting endemic and near-endemic species (e.g., Tar River Spinymussel) as a responsibility, and further suggested that protecting ecosystems through creating nature preserves, maintaining habitat connectivity, and preservation/restoration of riparian and wetland areas as important strategies for climate resilience (NC DEQ 2020). These priorities align with those of the Service as strategies for preventing extinction and promoting recovery of Tar River Spinymussel.

D. Synthesis:

Despite substantial time invested in surveying for Tar River Spinymussel in the last five years, only 11 wild individuals have been encountered. Ten were located in the Fishing/Little Fishing Creeks (Fishing Creek sub-population of Tar River Basin) and one was located in the Little River within the Neuse River population. Three of the mussels found were gravid, indicating mussels are attempting to reproduce; however, sparse detection of mussels and no documentation of wild recruitment suggest that the species has limited capability to reproduce, maintain gene flow, and recover without intervention. Mussels were found to be extant in only two sub-populations – a spatially depauperate existence compared to the species' known historic range – and their low numbers indicate continued decline. Such decline suggests that habitat conditions are potentially unsuitable

for continuing to support Tar River Spinymussel and are in need of restoration. Continued land use activities and projected land use changes in the watersheds remain as contributors to primary threats to Tar River Spinymussel, including habitat degradation via sedimentation and effects on water quality. Because of the species' limited abundance and range, the small populations that remain are highly vulnerable to extirpation via singular stochastic events (e.g., drought) or stream-adjacent activities (e.g., sediment influx). Beginning in 2014, propagated Tar River Spinymussels have been released at three sub-population sites. Augmentation and reintroduction through the captive breeding program have potential to assist in the species' recovery. However, monitoring and appropriate metrics are needed to assess success of the program, and additional sites and suitable habitats that can support population stability and recruitment will be required.

Due to extremely low abundance and fragmented populations that signify inadequate representation, resilience, and redundancy, and the persistence of threats, including habitat degradation, inadequacy of existing regulatory mechanisms, and the potential for stochastic land use or climate related events to extirpate remaining populations, the Tar River Spinymussel continues to meet the definition of endangered under the ESA.

III. RESULTS

A. Recommended Classification: No change is needed.

IV. RECOMMENDATIONS FOR FUTURE ACTIONS

Recommendations from the previous review (e.g., continuing propagation, protecting lands, ameliorating causes of habitat and species decline; USFWS 2014) remain relevant and should be referenced along with the recommendations that follow. These recommendations will promote recovery of Tar River Spinymussel over the next five years, and they align with several conservation objectives outlined for the species by the NCWRC (2018). Recommendations here are focused on protecting and restoring habitat, identifying and ameliorating pervasive threats, and promoting recovery through a rigorous propagation and reintroduction program.

Preserve, improve, and restore aquatic and riparian habitats. Progress toward this goal would benefit from identification and conservation of targeted locations (i.e., mussel sanctuaries) in the Tar and Neuse River Basins that could serve as a foundation for recovery of Tar River Spinymussel and co-occurring listed and at-risk species. Such conservation corridors also could benefit neighboring communities by providing opportunities for compatible uses (e.g., scenic "blue trails" and improved water quality for recreation and subsistence). The Service will work with partners, including land trusts, state agencies, municipalities, and private landowners to acquire land, establish conservation easements, and restore riparian forests. Protecting land and restoring riparian habitats will remove, reduce, or mitigate threats. Multiple resources that highlight hotspots for conservation (e.g., Master et al. 1998; Smith et al. 2000; SALCC

2017) may be useful tools for identifying potential sanctuary areas that would promote recovery of Tar River Spinymussel.

Reduce or remove threats to riparian and aquatic habitats on private lands. The vast majority of land is not in conservation holdings, and partnerships that promote responsible land management that protects water quality and aquatic habitats remain critical to the recovery of Tar River Spinymussel. A necessity for progress toward this goal is expanding public engagement to facilitate and improve awareness about Tar River Spinymussel (and co-occurring listed and at-risk species) among communities that live in the Neuse and Tar River watersheds. Collaborative conservation by landowners may help reduce existing threats (e.g., sedimentation and water quality issues); serve to mitigate impending threats (e.g., buffers from urbanization, stream shading to mitigate temperature extremes in a warming climate); and promote improved conditions to support Tar River Spinymussels released as part of population augmentation and reintroduction activities. Finalizing the Programmatic Safe Harbor Agreement currently being drafted between the Service and NCWRC will be important for relieving regulatory burden and promoting partnerships with landowners who are interested in engaging in activities that support aquatic habitat and species recovery.

The Service will work with partners, including land trusts, state agencies, municipalities, and private landowners to reduce land use impacts on stream habitats (e.g., sedimentation) and water quality (e.g., pollution from runoff and discharges), both in the extant and historic ranges of Tar River Spinymussel so that remaining populations persist and augmentation/reintroduction activities will be successful. Examples of activities such partnerships could support include (but are not limited to): adhering to established best management practices (e.g., agricultural pesticide application/erosion control and timber management operations); restoring/maintaining riparian forests; eliminating disturbance in riparian areas and in-stream or streambank habitats; stormwater management to reduce runoff; adherence to existing water quality standards for permitted discharges; and improving wastewater treatment to remove contaminants.

Identify and address factors limiting survival and persistence of wild populations and evaluate sites for reintroduction of Tar River Spinymussel. Progress toward this goal will improve our understanding of population decline, inform reintroduction activities, and support Recovery Criteria 1, 2, and 3. Restoring habitats for augmentation and reintroduction is critical for progress toward recovery. Identifying factors that have limited persistence in the Neuse River watershed would contribute to progress toward spatial recovery, as outlined in Recovery Criterion 2. However, evaluating sites for reintroduction in the Tar River watershed where wild populations more recently persisted also will be important for implementing reintroduction activities over the next five years. Successful reintroduction in many locations will be contingent on engagement and collaboration with local communities, where landowners may provide access to streams and other supportive measures.

Based on existing knowledge of threats reported in this review and in previous assessments (USFWS 1992, 2014, 2019), important factors to investigate and address for site evaluation/restoration include physical habitat suitability, habitat stability, habitat

connectivity, and water quality. Ecological factors that may affect Tar River Spinymussel persistence and merit attention include host fish considerations (e.g., habitat suitability for host fishes, mussel-host overlap) and the influence of invasive species (e.g., competition from Asian Clam, effects of Flathead Catfish on host fish populations). Continued monitoring of mussels that have already been released in augmentation activities will provide valuable data for some of these factors.

Formalize and implement a propagation and reintroduction plan. The Service and the NCWRC are currently working on a draft propagation and reintroduction plan. Because reintroduction has been identified as a promising management strategy for recovery of Tar River Spinymussel, a rigorous plan is important for guiding the work. Formalizing such a plan is imperative for establishing goals, evaluating risks, planning and implementing monitoring to evaluate success and inform/trigger adaptive management, and ensuring continuity of the program (IUCN 2013). The plan should include elements that address captive propagation protocol and procedures to maximize production and improve juvenile survival (e.g., refining techniques; understanding effects of pathogens on production); and it should address wild and augmented/reintroduced population abundance, stability, and spatial distribution (i.e., Recovery Criteria 1 and 2). Implementation should include activities that will inform the species status based on recovery criteria for the next review. Examples include (but are not limited to): monitoring data on survival and population structure, information on genetic diversity of wild and released mussels (this also would address genetic concerns), and evidence of reproduction (e.g., intensive survey techniques that improve detection of juvenile mussels).

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U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW of Tar River Spinymussel (*Parvaspina (=Elliptio) steinstansana*)

Current Classification: Endangered.

Recommendation resulting from the 5-Year Review:

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

Appropriate Listing/Reclassification Priority Number, if applicable:

Review Conducted By: Jennifer M. Archambault, Ph.D., Raleigh Ecological Services Field Office.

FIELD OFFICE APPROVAL:

Lead Field Supervisor, Fish and Wildlife Service

Approve PETER BENJAMIN Digitally signed by PETER BENJAMIN Date: 2020.11.02 08:32:29 -05'00' Date _____

Pete Benjamin

APPENDIX A: Summary of peer review for the 2020 5-year review of Tar River Spinymussel (*Parvaspina (=Elliptio) steinstansana*)

Peer Reviewers

Michael Fisk, Eastern Region Aquatic Wildlife Diversity Coordinator, North Carolina Wildlife Resources Commission, Mebane, North Carolina

Rachael Hoch, Conservation Aquaculture Center Coordinator, North Carolina Wildlife Resources Commission, Marion, North Carolina

A. Peer Review Method: A draft five-year review for Tar River Spinymussel was sent to each of the reviewers requesting comments or other feedback on the document's contents and analysis of the information. Both reviewers have extensive knowledge of the species and have worked with Tar River Spinymussel in the field and/or hatchery conditions.

B. Peer Review Charge: Reviewers were charged with providing a review of the document, including any comments, feedback, or additions they deemed appropriate to include. As the reviewers' agency is our state partner in conservation, reviewers were asked provide feedback (e.g., concurrence, comments) on whether "Recommendations for Future Actions" reflected appropriate priorities for the species over the next five years.

C. Summary of Peer Review Comments/Report: Reviewers responded by email concurring with the contents and findings of the five-year review. They provided several minor editorial corrections and a few comments and suggestions via electronically tracked changes. The only edit of substance resulting from the review was the addition of a statement related to understanding the role of disease in captive propagation.

D. Response to Peer Review: Recommendations from the reviewers were incorporated into the document.