Carolina Heelsplitter
(*Lasmigona decorata*)

5-Year Review:
Summary and Evaluation
2019

Credit: USFWS

U.S. Fish and Wildlife Service
Southeast Region
South Carolina Ecological Services Field Office
Charleston, South Carolina

5-YEAR REVIEW

Carolina heelsplitter (*Lasmigona decorata*)

I. GENERAL INFORMATION.

A. Methodology Used to Complete the Review: This 5-year review was accomplished using pertinent status data obtained from the recovery plan, peer-reviewed scientific publications, unpublished research reports, and experts on this species. Once all known and pertinent data were collected for this species, the status information was compiled and the review was completed by the species' lead recovery biologist Morgan Wolf in the U.S. Fish and Wildlife Service's (Service) Ecological Services Field Office in Charleston, South Carolina. The Service published a notice in the *Federal Register* (83 FR 10737) announcing the 5-year review of the Carolina heelsplitter and requesting new information on the species. A 60-day public comment period was opened. Two general comments were received from the public, none of which provided additional status information or in some cases supporting literature on the species (see Appendix A). The 5-year review was also peer-reviewed by experts familiar with the Carolina heelsplitter. Comments received were evaluated and incorporated as appropriate (see Appendix A).

B. Reviewers.

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

Lead Field Office: Ecological Services Field Office, Charleston, South Carolina – Morgan Wolf, 843/727-4707, Ext. 219.

Cooperating Field Office: Ecological Services Field Office, Asheville, North Carolina – Jason Mays, 828/258-3939, ext. 226.

C. Background.

1. **Federal Register notice citation announcing initiation of this review:** March 12, 2018 (83 FR 10737).

2. **Species' status:** Declining. Not all occupied habitat was thoroughly surveyed since the last 5-year review (2012-2018). However, abundances in newly surveyed reaches were compared to those from previous survey efforts in the same reaches to assess the status trend. Over the last six years, declines have been observed in 4 of the 11 surviving populations (Table 1). This is especially concerning because one of the populations was thought to be a stronghold for the species (Turkey Creek), and two others have nearly been reduced to below detectable levels, while continuing to face pressure from rapid urbanization (Sixmile Creek, Gills Creek). The status of 3 additional populations is unknown, as surveys were not completed during this time period (Table 1). While not surveyed, less than two individuals were found in

each population during past survey efforts. It is expected that these populations have experienced further declines in the past 6 years. Only 4 of 11 populations have been designated as stable (Table 1). Expanded survey efforts and augmentations of individuals have contributed to these designations, although some appear to be naturally viable.

3. **Recovery achieved:** 1 (0 to 25 percent of recovery objectives achieved).

4. **Listing history:**

   Original Listing**:**
   FR notice: 58 FR 34926.
   Date listed: June 30, 1993.
   Entity listed: species.
   Classification: endangered.

5. **Associated rulemakings**: Critical habitat for the Carolina heelsplitter was designated on July 2, 2002 (67 FR 44502).

6. **Review history:**

   Final Recovery Plan, 1997.

   Each year, the Service reviews and updates listed species information for inclusion in the required Recovery Report to Congress. Through 2013, we did a recovery data call that included status recommendations such as "Declining" for this mussel. We continue to show that species status recommendation as part of our 5-year reviews. The most recent evaluation for this species was completed in 2018.
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   5-Year Review, 2012.

7. **Species' Recovery Priority Number at start of review (48 FR 43098):** 5C. This number indicates a high degree of threat and low recovery potential.

8. **Recovery plan:**

   Name of plan: Carolina Heelsplitter Recovery Plan.

   Date issued: January 17, 1997.

II. REVIEW ANALYSIS.

A. Application of the 1996 Distinct Population Segment (DPS) Policy: The Carolina heelsplitter is an invertebrate and therefore is not covered by the DPS policy.

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?** Yes.

   b. **Are all of the five 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)?** 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 Carolina heelsplitter (Service 1996) states that the species will be considered for downlisting to threatened status when the following criteria are met:

   a. Through protection of existing populations, successful establishment of reintroduced populations, or the discovery of additional populations, a total of four distinct viable populations exist. These four populations must be distributed throughout the species' known historic range, with at least one each in the Catawba, Pee Dee, and Savannah River systems. Also, these populations must be extensive enough that it is unlikely that a single event would eliminate or significantly reduce one or more of them.

   There are currently 11 known surviving populations of the Carolina heelsplitter, occurring as listed in the following river systems:

   Pee Dee River System:

   - Goose Creek/Duck Creek population, Union County, North Carolina.
   - Flat Creek /Lynches River (Flat Creek/Lynches River population), Lancaster, Kershaw, and Chesterfield Counties, South Carolina.

   Catawba River System:

   - Waxhaw Creek population, Union County, North Carolina, and Lancaster County, South Carolina.
   - Sixmile Creek population, Union and Mecklenburg Counties, North Carolina, and Lancaster County, South Carolina.
   - Gills Creek/Cane Creek population, Lancaster County, South Carolina.
   - Fishing Creek/South Fork Fishing Creek population, Chester County, South Carolina.
   - Bull Run Creek/unnamed tributary to Bull Run Creek/Beaverdam

Creek/Hooper Branch (Rocky Creek population), Chester County, South Carolina.

Saluda River System:

- Red Bank Creek population, Saluda County, South Carolina.
- Halfway Swamp Creek, Greenwood and Saluda Counties, South Carolina.

Savannah River System:

- Turkey Creek/Mountain Creek/Beaverdam Creek/Sleepy Creek/Little Stevens Creek/Rocky Creek/Log Creek (Turkey Creek population), Edgefield and McCormick Counties, South Carolina.
- Cuffytown Creek population, Greenwood and McCormick Counties, South Carolina.

Although there are currently 11 known surviving populations of the Carolina heelsplitter, all of them are small in size, and their genetic health and viability is questionable (Table 1). Based on the survey data for each of the 11 populations since the last 5-year review, 1 population is based on a single known shell (Halfway Swamp Creek population); 4 are comprised of a total of only 1 to 3 known individuals (Waxhaw Creek, Gills Creek/Cane Creek, Redbank Creek, and Cuffytown Creek populations); 4 are comprised of a total of only 10 to 17 known individuals (Goose Creek/Duck Creek, Sixmile Creek, Rocky Creek, and Fishing Creek/South Fork Fishing Creek populations); 1 is comprised of a total of only 30 known individuals (Turkey Creek population, though only 1 individual was found in each of three of the five streams that support this population); and 1 is comprised of only 64 known individuals (Flat Creek/Lynches River population) (see Table 1 and the survey data presented in the paragraphs following Table 1). During the most recent surveys (2012-2018), a total of only 193 Carolina heelsplitters were found in all of the surviving populations combined.

Table 1

Population	Year of Survey	# Found*	Total #*	Trend
Goose Creek/Duck Creek			**17**	**Stable**
Goose Creek	2013-2018	13		
Duck Creek	2013-2016	4		
Flat Creek/Lynches River			**80**	**Stable**
Flat Creek	2014-2018	48		
Lynches River	2014, 2015	32		
Waxhaw Creek			**43**	**Stable**
NC portion	2016	32~		
SC portion	2016	11~		
Sixmile Creek			**1**	**Declining**
NC portion	No Survey	0		
SC portion	2015	1		
Gills Creek/Cane Creek			**0**	**Declining**
Gills Creek	2014-2016	0		
Cane Creek	No Survey	0		
Fishing Creek/South Fork				
Fishing Creek			**18**	**Stable**
Fishing Creek	2014-2016	0		
S. Fork Fishing Creek	2015	18		
Rocky Creek			**10**	**Declining**
Bull Run Creek	2014	7		
Unnamed tributary	2014	0		
Beaverdam Creek	2015	3		
Hooper Branch	2013	0 (1 Shell)		
Red Bank Creek	No Survey		**0**	**Unknown**
Halfway Swamp Creek	No Survey		**0**	**Unknown**
Turkey Creek			**24**	**Declining**
Turkey Creek	2015-2018	6		
Beaverdam Creek	2015	3		
Mountain Creek	2012, 2018	9		
Sleepy Creek	2018	1		
Little Stevens Creek	2018	0 (1 Shell)		
Rocky Creek	2016	4		
Log Creek	2017	1		
Cuffytown Creek	No survey		**0**	**Unknown**
Total			**193**	

Note: Numbers presented in this table are raw, representing variable survey

effort. In some cases, the surveys conducted were only partial surveys of the occupied streams. However, the surveys included a significant portion of the streams and, in most cases, the reaches of the streams that appear to provide the best habitat for the species. Accordingly, while the total number of individuals recorded would be expected to be slightly higher if more extensive surveys of these streams were conducted, these figures should give a relatively accurate indication of the population levels within these streams. In addition, these numbers do not reflect the total number of augmented animals placed into the wild. Because we are unsure of their survival rate post-augmentation, this table only includes animals that were re-captured during subsequent survey events.

~Survey number includes recaptures of pit-tagged animals that were augmented in October, 2015.

All 11 of the surviving populations remain highly susceptible to extirpation from a single event or chronic conditions (e.g., drought, chemical spills, stormwater runoff, etc.). For a species that occupies small streams, occupying more than one stream within a connected system can reduce the probability of extirpation from a single event. Six of the 11 extant populations (Flat Creek/Lynches River, Fishing Creek/South Fork Fishing Creek, Gills Creek/Cane Creek, Rocky Creek, Turkey Creek, Goose Creek/Duck Creek populations) may still occupy more than one stream. However, within these populations, they are not evenly distributed. The majority of the individuals within each of these populations occur primarily in only one of the streams supporting the populations and in most cases primarily occupy only one short reach of each occupied stream, where a single event or recurring impacts to their habitat could result in their extirpation or reduce their population numbers to a point where extirpation over a short time period would be likely.

While a number of populations were designated “stable” in Table 1, it is important to note that this is simply a reflection of numbers found during semi-quantitative (timed catch per-unit effort) surveys over the last six years. Semi-quantitative survey methodologies involve searching as much suitable habitat as possible during a given period of time, collecting and counting mussels seen by observers. This methodology is not very effective at finding small mussels or those buried below the substrate. Because most of the survey efforts for heelsplitter are semi-quantitative, the population trend designations must be inferred from site conditions, catch rates of other species, and professional judgement, and designations should be viewed as approximate. They should also not be thought of as a direct reflection of the viability of the populations. Demographic and other factors influencing viability are discussed in later sections of this document.

As mentioned previously, recent population augmentations and expanded survey efforts took place in certain occupied stream reaches, both of which have contributed to “stable” population designations. To confidently assign a population an “increasing” designation, we require observation of additional evidence of population health: increased natural recruitment, occupied range

expansion, improved habitat suitability, continued augmentation and survivorship of these individuals, multiple (more than 2) year classes, genetic viability (i.e. diversity), etc.

Based on the available evidence, the Service believes the overall trend of the species since the last review is declining. This opinion is based largely on the difficulty of finding Carolina heelsplitter in the majority of the known occupied streams. However, due to the rarity of this species, unknown life history aspects, and the limited survey information, we cannot draw strong conclusions about individual population trends. Accordingly, the trend designations presented in Table 1 have high uncertainty. Expanded survey efforts, habitat assessment, and demographic studies will be necessary to better understand the species' trend in a comprehensive way.

b. Two distinct naturally reproduced year classes exist within each of the four populations. One of these year classes must have been produced within the 5 years prior to the time the species is reclassified from endangered to threatened. Within the year prior to the downlisting date, gravid females and the mussel's host fish must be present in each populated river/stream reach.

Gravidity-
During the most recent surveys conducted by the Service (2014-2018), gravid individuals were found in both the Flat Creek/Lynches River population and the Turkey Creek population (Mountain and Turkey Creeks). These females were found during brood collection surveys for propagation efforts, conducted in November and February of different years. The maturity of larvae (glochidia) in November were not assessed, but by February the gill contents extracted from each individual contained viable, fully formed glochidia, capable of attaching to host fish.

Gravid heelsplitters found in Mountain Creek and Turkey Creek in the Savannah Basin contained mature glochidia in early February of 2018. This is an important finding since this population is relatively small and spread out, with only 30 animals being found among six streams over five years of survey effort. Only 9 animals were found in Mountain Creek itself during this time period. Although it is possible independent males are fertilizing females in the population, there is also the possibility the species is exhibiting hermaphroditism. We plan to research this topic as part of the Carolina heelsplitter recovery program in the coming years (see Section IV).

Year Classes-
Based on size as an indication of the age of individuals recorded, at least two year classes, with one year class produced within the last 5 years, appear to be present in 7 of the 11 surviving populations (Goose Creek/Duck Creek, Flat Creek/Lynches River, Waxhaw Creek, Sixmile Creek, Fishing Creek/South Fork Fishing Creek, Rocky Creek, Turkey Creek). Four of 11 populations are

represented by only one or a few individuals have been recorded during the most recent surveys (Gills Creek/Cane Creek, Red Bank Creek, Halfway Swamp Creek, and Cuffytown Creek populations). Individuals found in these populations were all relatively large, older individuals (5-15+ year olds). This means that two year classes were not documented in the Saluda Basin, and were found almost exclusively in the western half of the Catawba Basin.

Host Fish-

For the Yadkin Pee-Dee River Basin, of 20 fish species tested, 5 species of Cyprinidae, including satinfin shiner (*Cyprinella analostana*), bluehead chub (*Nocomis leptocephalus*), golden shiner (*Notemigonus crysoleucas*), highfin shiner (*Notropis altipinnis*), and spottail shiner (*Notropis hudsonius*) acted as the best hosts [during lab trials] with the percentage of glochidia transforming ranging from 32.2 to 73.7%. (Eads et al., 2010). In the same study, the most efficient hosts for the Catawba Basin, in addition to the bluehead chub and golden shiner, included rosyside dace (*Clinostomus funduloides*), whitefin shiner (*Cyprinella nivea*), sandbar shiner (*Notropis scepticus*), and creek chub (*Semotilus atromaculatus*).

Based on fish assemblage studies of streams known to support populations of the Carolina heelsplitter conducted by the South Carolina Department of Natural Resources (SCDNR), as well as cooperative host fish collections for propagation efforts, most of the fish species that have been documented in the lab to successfully transform Carolina heelsplitter glochidia to juveniles have also been documented in areas currently occupied by the Carolina heelsplitter. Additionally, most fish species identified as suitable lab hosts for the Carolina heelsplitter are common throughout the range of the Carolina heelsplitter and are relatively tolerant of variable habitat conditions. Also, several of these species were documented to be present in nearby streams with marginal to degraded habitat, such as Little Lynches Creek (K. Kubach, SCDNR, pers. comm, 2015). Accordingly, at least some of these probable host species are assumed to be present in these five streams as well, at least during certain periods of the year, though surveys are needed to further confirm their presence and abundance levels.

c. Biological and ecological studies have been completed and any required recovery measures developed and implemented from these studies are beginning to show signs of success, as evidenced by an increase in population density and/or an increase in the length of the river reach inhabited by each of the four populations.

General information concerning the habitat requirements of the Carolina heelsplitter is becoming better known through survey and monitoring efforts for the species. In addition, the species' life history, biology, and specific habitat preferences are being investigated on a number of fronts, as described

below.

Recovery measures for the species are progressing in a variety of ways, with positive species populations responses expected in the coming years. Most surveys conducted over the last five years have focused on known occupied habitat. These surveys have not clearly documented increases in population density or length of occupied habitat. Survey efforts outside of known occupied habitat have documented a few additional occurrences of the species in the Savannah and Catawba Basins (Tim Savidge, pers. comm, 2016, John Alderman, pers. comm., 2013). These occurrences are very small, and more survey work is needed to fully evaluate the scale of occupied habitat and viability of these locations. A recent large-scale effort to evaluate potential mussel habitat on the Long Cane Ranger District of Sumter National Forest documented little to no mussel fauna in a large part of the Savannah Basin adjacent to known Carolina heelsplitter occurrences (Alderman, 2017).

Propagation/Augmentation-

Propagation and augmentation of Carolina heelsplitter for release in the wild is outlined as a recovery goal in Section C, 4 of the Recovery Plan. For the species to survive, the plan says that it will likely be necessary that existing populations be supplemented to enable them to reach a viable size. The plan points out that there may be areas within the species' historic range that could support reestablished (re-introduced) populations, and directly calls out the need to both augment existing populations and establish new populations within its historic range. Importantly, although additional populations have been discovered since the time of listing, the existing recovery outlook of the species in the wild, absent human intervention, remains unchanged. As stated previously, all 11 surviving populations are extremely small, fragmented, and under threat from a myriad of current and future impacts.

Propagation efforts for the Carolina heelsplitter began about a decade ago in North Carolina. In the fall of 2006, North Carolina State University collected Carolina heelsplitters from Duck Creek. Adults were taken to Table Rock Fish Hatchery for holding. In 2007, two of the animals from Duck Creek were found to be gravid. An additional gravid heelsplitter from Six Mile Creek was brought in to the hatchery by Tim Savidge (Chris Eads and Jason Mays, pers. comm., 2017). These animals were used for host trials.

Propagated animals from host trials went initially to Table Rock Hatchery but did not do well and were subsequently moved to the North Carolina Wildlife Resources Commission's (NCWRC) Marion facility in August 2008, where they grew well and exhibited decent survivorship. From 2008 onward, Marion has been responsible for most Carolina heelsplitter propagation efforts in North Carolina.

Table 2. Transformation results; North Carolina Facilities

North Carolina Hatchery Production Year	Mussel Species	Total Transformation (viable individuals)
2012	*Lasmigona decorata*	2,834 (CAC), 3,314 (NCSU)
2013	*Lasmigona decorata*	706 (NCSU)
2016	*Lasmigona decorata*	4,213 (CAC)

*CAC – Marion Conservation and Aquaculture Center; NCSU – North Carolina State University

Beginning in the spring of 2015, the Service initiated propagation and augmentation efforts for the Carolina heelsplitter in the state of South Carolina, at Orangeburg National Fish Hatchery's Mussel Conservation Center (OMCC). Containing 10 of the species' 11 surviving populations, watersheds in South Carolina play a critical role in maintaining species abundance and genetic viability into the future. As such, it was important to build production capacity in South Carolina.

Table 3. Transformation results; OMCC

Orangeburg Hatchery Production Year	Mussel Species	Total Transformation (viable individuals)
2015	*Lasmigona decorata*	5,687
2016	*Lasmigona decorata*	5,462
2017	*Lasmigona decorata*	697
2018	*Lasmigona decorata*	6,369

To date, juveniles have been produced at OMCC from brood animals collected from three of four Carolina heelsplitter-occupied river basins; the Catawba, Pee Dee, and Savannah. This program relied on the help of partners, including the SCDNR, to get off the ground. Initial efforts in 2015 used glochidia from the Catawba Basin adults being held at the Marion, NC facility. Subsequent propagation efforts in South Carolina have exclusively used glochidia collected from wild gravid females.

Over the last six years, augmentation of existing Carolina heelsplitter populations with hatchery-produced juveniles has taken place in both North and South Carolina. The overall goal of these efforts is to bolster surviving populations, and to reconnect fragmented occupied habitat reaches.

On October 20, 2015, NCWRC, along with SCDNR and the Asheville (AFO)

and South Carolina Field Offices (SCFO) of the USFWS, released 240 propagated Carolina heelsplitters, into Waxhaw Creek, within the Catawba River Basin. Release sites were selected on both the North Carolina (upstream) reach of Waxhaw Creek, as well as downstream in South Carolina. South Carolina waters received 105 animals, North Carolina, 135. These animals were propagated in 2007 from Catawba Basin brood stock. All released individuals were PIT (Passive Integrated Transponder) tagged and will be monitored for five years for growth and survival (T.R. Russ, pers. comm., 2018). Both augmentations occurred on private land, with the consent of the landowners.

At this point, it's important to discuss the expected outcomes of augmentation events. Referring back to Table 1, we see that only 43 animals were found in Waxhaw Creek over the past six years. Thirty-two of these animals were recaptures of augmented individuals. This relatively low recapture rate is typical of mussel augmentation efforts. Even with the best of existing habitat conditions, mussels migrate, wash downstream, and some die off. In the case of Waxhaw Creek, the habitat is very stable and there is a resident population of Carolina heelsplitter. Therefore, the chances of success for augmentation efforts in this stream are at least as good as any other potential stocking site.

Looking to both increase efficiency and diversify augmentation methodologies, OMCC and the Service implemented a "free release" effort in Flat Creek (Pee Dee River Basin) in early 2016, with the assistance of Natchitoches National Fish Hatchery. After infesting and holding wild-caught host fish (bluehead chub) for a week in order to allow glochidia to develop and ensure rapid drop-off after stocking, 250 fish were released into Flat Creek, Lancaster County, South Carolina. Approximately 108 other fish were held back at OMCC for estimating a sample count regarding the number of transformers (juvenile mussels that have just dropped off of host fish) introduced to the stream during the release event. Drop off rates at the OMCC resulted in 25 mussels per fish average, predicting that approximately 6,250 mussel transformers were released into Flat Creek on February 26, 2016 (Jonathan Wardell, pers. comm., 2016). As with other augmentation protocols, Flat Creek will be monitored to assess effectiveness of this protocol once these mussels are assumed to have reached detectible size.

Propagation efforts at OMCC over the last couple of years produced over 600 tag-able size (>20mm) heelsplitter that were used to augment South Carolina populations of the species. Approximately 391 1-2 year old animals were placed in federally-designated Critical Habitat in Flat Creek (Pee Dee River Basin) on September 25, 2017, and another 300 2-3 year old mussels were placed in Critical Habitat in Gills Creek (Catawba River Basin) on October 17, 2017. As in 2015, augmentations occurred on private land in Lancaster County, with the consent, and in some cases the assistance of each landowner.

Monitoring of augmented reaches will take place regularly for at least a 5-year period to assess survivorship and growth. Monitoring was not completed in 2018 due to a combination of major storm events and adjusting habitat conditions connected to road crossing replacements throughout the system.

Pool Refugia Study-
Two major drought periods occurred during the past 2 decades in the Carolinas: 1999-2002 and 2006-2008 (Alderman, 2014). During each, widespread stranding of mussels occurred as flowing streams transitioned to dry creek beds interspersed with the remnant pool habitat. In such events, deeper pools offer crucial protection from desiccation to animals close enough to seek out their protection, or to those lucky enough to already reside within them. Acknowledging the severe impact previous drought events had on Carolina heelsplitter populations, the Service funded a study aimed at identifying and prioritizing protection of stream reaches containing significant refugial pool habitat for the species. Surveys and analysis conducted by Alderman Environmental Services between 2011 and 2013 identified eight priority conservation reaches in the Savannah River Basin. Along with qualitative mussel surveys, bankfull maximum depths (thalweg) were regularly acquired during extreme low flow conditions (pools were full with little flow between pools). Also, dominant substrate near each thalweg point was documented. Adjacent parcel ownership and land use were also assessed. Three of the conservation reaches occurred in Mountain Creek, 5 in Sleepy Creek (Alderman, 2014).

Fish Passage/Catawba Basin Study-
In addition to drought, fish passage impairment in Carolina heelsplitter-occupied streams negatively affects recovery potential for the species because host fishes cannot freely move through non-functioning (i.e. perched or undersized) road crossing structures. In 2014, the Service funded surveys in the Catawba River Basin aimed at both comprehensively assessing current population status in the basin, and identifying sources of habitat degradation.

According to the 2017 survey report, over 397 survey hours were expended by Three Oaks Engineering, Inc. from 2014-2016 (Three Oaks Engineering, 2017). Each of the five distinct Carolina heelsplitter populations in the basin were assessed with regards to water quality conditions, freshwater mussel community composition, relative abundance and distribution (previous and current data), and in-stream habitat conditions. Additionally, quantitative habitat and mussel survey data were collected at six distinct locations within three streams supporting the Carolina heelsplitter (Beaverdam Creek, Waxhaw Creek, and South Fork Fishing Creek). All potential barriers to fish migration and mussel dispersal found during qualitative mussel surveys were evaluated.

Each of the distinct locations were evaluated and ranked in the context of current and future population viability of the Carolina heelsplitter. The rankings considered numerous factors such as length of occupied habitat,

relative abundance, and evidence of reproduction and recruitment, as well as the other associate freshwater mussel species, in-stream habitat conditions, and general watershed land use (Three Oaks Engineering, 2017). During this study, 20 live individuals were found, including a number of young (post drought) animals. The report states that these populations are persisting, and also display evidence of reproduction/recruitment. The Fishing Creek and Rocky Creek populations were highlighted as the most important for sustained Carolina heelsplitter viability in the basin.

Genetic Research-
In an effort to supplement research conducted by Bogan and Raley in 2012, the Service funded a genetic project through Appalachian State University (ASU) in 2015. Genetic material was collected from all wild Carolina heelsplitters encountered during recent survey efforts has been sent to ASU for archiving and DNA evaluation. To date, over 20 samples have been archived, and sequenced for a portion of the mitochondrial Cytochrome Oxidase I (COI) gene.

This study had two objectives. The first was to assess genetic diversity within and among remaining Carolina heelsplitter populations in the Catawba, Pee Dee, and Savannah River Basins in order to infer historical gene flow patterns among populations (Fowler and Gangloff, 2018). Secondly, they aimed to find additional Carolina heelsplitter populations within the Savannah Basin. The stated overall goal of the research was to determine the number of management units (or distinct haplotypes) present among extant Carolina heelsplitter populations and provide agencies with empirical data to inform ex-situ propagation and habitat management strategies (Fowler and Gangloff, 2018).

Although the species identification of some samples are currently under review, preliminary results indicate that at this locus, genetic variation in this species appears to be minimal (i.e., <0.25% pairwise divergence), both within populations and among river basins, with a high rate of haplotype sharing among Carolina heelsplitter populations. These data show that the COI is highly conserved within this species. All detected haplotypes are shared broadly among the three drainages examined. This means that populations are similar enough to consider mixing genes between them during propagation efforts. This is important, as we believe future management decisions aimed at recovering the species may require inter-basin transfer of genetic stock, particularly in situations where populations have been extirpated from a portion of the historical range.

d. <u>Where habitat has been degraded, noticeable improvements in channel stability, water and substrate quality, and associated biota have occurred.</u>

Habitat Restoration and Conservation-

Habitat restoration and conservation are both designated as priority tasks in the Carolina Heelsplitter Recovery Plan (Plan) (USFWS, 1996). The Plan states that if the species is to survive and expand its range, protection of the existing populations and remaining areas of suitable habitat is vital. It goes on to say that [managers must] "consider and, if necessary, use land use acquisition as a means of protecting the species' essential habitat (Section C, 1.5). In addition to protection of habitat, the Plan also points to the importance of actively identifying and alleviating impacts to the species. Section C, 2.4 recommends managers, based on the biological data and threat analyses, investigate the need for management, including habitat improvement. It goes on to say that this management may need to include habitat improvement programs in order to alleviate limiting factors.

In the years immediately following listing, preservation of existing habitat was prioritized, and resulted in the conservation of numerous key parcels of land along both occupied and critical habitat. During this time, the Forest Service, SCDNR, NCWRC, NGOs and others, coordinated with the Service on acquisition strategies that would benefit the Carolina heelsplitter.

Over the past 5 years or so, there has been an active push to restore and enhance existing habitat for the species, across multiple Service programs. The majority of this work has involved restoring fish passage and natural flows at road crossing structures, and has involved the Recovery, Refuges, and Fisheries Programs of the Service, as well as Lancaster County, South Carolina. During these projects, undersized, round culverts were replaced with appropriately sized bottomless arch culverts. To date, 3 projects have been completed (Happy Trail, Langley Road and Gills Creek Drive), re-opening the entire length, approximately 6 miles of Critical Habitat Unit 3 to fish passage. Upon completion, miles of critical habitat for the Carolina heelsplitter will be reopened to fish passage and natural flows.

The Forest Service has also taken strides to retrofit and replace non-functioning culverts on their system of roads. In South Carolina, much of this ongoing work is taking place on the Long Cane Ranger District of the Sumter National Forest, home to several Carolina heelsplitter populations. The SCDNR is also incorporating fish passage restoration into much of their work, including Clean Water Act compensatory mitigation recommendations and state-wide property management plans.

In total, approximately three miles of federally-designated critical habitat for the Carolina heelsplitter has been re-opened to aquatic organism passage through road crossing replacement work in Lancaster County, SC within the

last five years. In addition, hundreds of acres and thousands of linear feet of critical habitat in the Flat Creek watershed have been protected via conservation easements (Carolina heelsplitter Conservation Bank) and fee simple transfer of property to the State of South Carolina. The Forest Service continues its fish passage restoration program on tributaries in the Savannah River Basin. While extremely important to the eventual recovery of the Carolina heelsplitter, habitat conservation and restoration efforts for the species are new and will take years of monitoring and management to document perceptible benefits to the Carolina heelsplitter.

Regulated and Unregulated Discharges –

While significant progress has been made in addressing fish passage issues throughout Carolina heelsplitter-occupied habitat, degradation of these streams from other sources continues to hamper effective recovery implementation. In particular, point (NPDES) and non-point source discharges continually degrade water quality throughout the range. Even though some discharges are permitted by state entities, questions remain regarding the effectiveness of enforceable water quality standards on protecting native freshwater mussel populations in receiving waters.

Point Source Discharges

Throughout much of the range of the Carolina heelsplitter, NPDES permitted discharges are relatively sparse, except for locations in North Carolina near the Charlotte suburbs. For example, in the entire lower Catawba Basin, only 17 NPDES sites were documented by Three Oaks Engineering in their January, 2017 survey report. Of these, only a few are thought to discharge on a regular basis, and must do so under permit limitations imposed by the South Carolina Department of Health and Environmental Control (SCDHEC).

Currently, the most pervasive point source discharge of concern to Carolina heelsplitter populations is sewage effluent from wastewater treatment plants. The exposure of mussels to surface waters contaminated by a municipal effluent has led to many stress responses, depending on both the tissues and the species being examined (Gagné et al., 2002). These discharges create issues for mussel populations on a number of fronts. First, freshwater mussels, and the early life stages in particular, are extremely sensitive to inorganic pollutants such ammonia and copper. Research indicates that significant levels of some metals, including copper, accumulate in mussels downstream of effluent plumes (Gagné et al., 2002).

Responding to the sensitivity of freshwater mussels to ammonia, the U.S. EPA revised the freshwater ammonia aquatic life ambient water quality criteria (acute and chronic) to reflect thresholds protective of freshwater

mussels (USEPA, 2013). While this is a positive development, SCDHEC's most recent triennial review of water classifications and standards did not include these recommendations in the numeric criteria for the protection of aquatic life and human health (SCDHEC, 2016a). The ammonia criteria referenced in the 2016 document are outdated EPA recommendations from 2009 (freshwater) and 1989 (saltwater). These criteria are not considered protective of freshwater mussel species. In addition, the last 5-year review for the Carolina heelsplitter indicated that there were "no water quality standards or monitoring requirements for ammonia, copper, or phosphorus in North Carolina" (USFWS, 2012).

In South Carolina, according to SCDHEC's **Water Pollution Control Permits: R61-9** NPDES and Land Application Permits Regulation, Section 405(d)(4) of the CWA requires the Department (SCDHEC in this case), prior to promulgation of standards for sewage sludge use and disposal, to "impose conditions in permits issued to publicly owned treatment works under section 402 of this Act, or take such other measures as the [Department] deems appropriate to protect public health and the environment from any adverse effects which may occur from toxic pollutants in sewage sludge" (SCDHEC, 2011).

In addition, the Regulation states that Section 405(f) of CWA provides that NPDES permits must include requirements implementing the standards for sludge use and disposal (40 CFR Part 503) "unless such requirements have been included in a permit issued under the appropriate provisions of subtitle C of the Solid Waste Disposal Act, part C of the Safe Drinking Water Act, the Marine Protection, Research, and Sanctuaries Act of 1972, or the Clean Air Act, or under State [NPDES] permit programs approved by the Administrator...." Section 405(f) also authorizes the Department to issue permits with requirements for sludge use or disposal that assure compliance with 40 CFR Part 503 to any treatment works treating domestic sewage that is not subject to NPDES (i.e., has no point source discharge) and has not been issued a permit that includes applicable 40 CFR Part 503 standards under the other permit programs listed in section 405(f)(1) of the CWA.

Sections 402(b), 318(b) and (c), and 405(c) and (f) of CWA authorize EPA approval of State NPDES permit programs for discharges from point sources, discharges to aquaculture projects, and use and disposal of sewage sludge. Section 304(i) of CWA provides that the Administrator shall promulgate guidelines establishing uniform application forms and other minimum requirements for the acquisition of information from dischargers in approved States and establishing minimum procedural and other elements of approved State NPDES programs.

At least for all publicly-owned treatment works (POTWs) in South Carolina

with a flow equal or great then 0.1 MGD, testing is required for ammonia (as N), Chlorine (total residual, TRC), dissolved oxygen, nitrate/nitrite, kjeldahl nitrogen, oil and grease, phosphorus and total dissolved solids. In addition, effluent parameters for selected PTOWs include metals such as copper.

Non-Point Source Discharges

Of greater concern to the viability of Carolina heelsplitter populations range-wide are the pervasive and largely unregulated non-point source discharges occurring at regular intervals across the range. Non-point source discharges occur via overland flow of sediment, fertilizers, and other pollutants into adjacent receiving streams. In places where riparian buffers have been eliminated or greatly reduced, the effects of these discharges are increased, as the filtering capacity of forest stands and other vegetated areas near streams are greatly reduced. In urban areas, this effect is exacerbated even more by the construction of impervious surfaces such as parking lots, roads, sidewalks and houses. When it rains, water is unable to soak into these surfaces and is forced to sheet flow off the landscape and into receiving streams at unnatural volumes and frequencies. This water is usually carrying oils and other pollutants from the urban landscape directly into streams and rivers.

Global climate change has also resulted in periods of extended drought as well as increased flooding frequency in the southeast. Analyzing 75 years of climate and streamflow data in the southeast, Ford et al., 2011, documented significant increases in temperature and the frequency of extreme wet and dry years since the 1980s. In dry years, streams suffer through an accumulation of pollutants, increasing water temperatures, and low dissolved oxygen. In wet years, high sediment loads are pushed through receiving waters, and stream channels are scoured out by the extreme flows, displacing mussels and altering the structure and location of suitable habitat types within a stream. An analysis of ecological responses to stream flow in the South Atlantic Region, indicated that while responses to natural changes in flow magnitude, frequency, and duration were highly variable, in contrast the majority of ecological responses to anthropogenic-induced flow alterations were negative (McManamay et al., 2013).

Population Accounts-

Most surviving Carolina heelsplitter populations occur in rural areas where the majority of the land use in each watershed is either forested (pine plantation or natural forests) or under agricultural use. The exceptions are the upper Catawba Basin populations in South Carolina (Sixmile, Cane and Waxhaw Creeks) and the upper Pee Dee Basin (Goose and Duck Creeks), which are under increasing urban development pressure from the expansion and urban sprawl associated with the City of Charlotte, North Carolina.

Although about half of the occupied watersheds are forested, most of this is planted pine (loblolly), not natural forest cover. A recent publication by the USDA Forest Service (USFS) found that converting deciduous stands to pine altered the streamflow response to extreme annual precipitation the most among all land use conversions; the apparent frequency of observed extreme wet years decreased on average by sevenfold (Ford et al., 2011). The authors go on to say that this increased soil water storage may reduce flood risk in wet years, but create conditions that could exacerbate drought.

The status of Carolina heelsplitter habitat in the Turkey Creek system and Cuffytown Creek appears to have been seriously affected by drought/low water conditions in past years. In 2005, John Alderman also hypothesized that the effects of conversion of the native forest (hardwood and mixed hardwood pine) to pine monoculture and the rapid rotation of pine monoculture stands on private land in the upper Turkey Creek watershed were a contributing cause of habitat degradation in the headwaters of Cuffytown, Mountain, Sleepy, and Little Stevens Creek subbasins. In August of 2011, miles of Sleepy and Mountain Creeks were surveyed by the USFS and the USFWS, revealing long stretches of dry streambed, with large numbers of stranded mussels of all species (pers. obs. 2011).

Portions of Cuffytown Creek and portions of all the streams in the Turkey Creek system harboring occurrences of the Carolina heelsplitter are within the present boundaries of the Sumter National Forest, and much of the remaining land within the watersheds of these streams (not within the national forest boundaries) is currently owned by commercial timber companies; development within the watersheds of these streams is presently very limited.

The USFS continues working with the Service to identify and eliminate threats from their management activities on the Sumter National Forest and to implement conservation measures for the Carolina heelsplitter on all of their land within the watersheds of the stream supporting the species, including establishing and maintaining minimum 200-foot forested buffers along both sides of all perennial streams and minimum 100-foot forested buffers along both sides of all intermittent streams. These specialized conservation measures are formalized in the Land Management Plan and are enforced within a physical area designated Management Area 1(USFS, 2004).

Habitat quality and quantity within Goose and Duck Creeks has declined from the indirect, direct, and cumulative effects of residential and commercial development that has occurred and is occurring within the watersheds of these streams. Surveys by the Service, NCWRC, and others have documented a significant and continuing decline in range and abundance of not only the Carolina heelsplitter but of all native mussel species within these two streams. Stream-channel and streambank stability, critical to freshwater mussels, has

already been seriously degraded in numerous areas throughout the watershed as a result of changes in the stream's hydrology due to loss of forested buffers, increased imperious surface area, and inadequate stormwater control. In many areas of the creek, channel substrate has been scoured down to bedrock, and much of the remaining smaller substrates the Carolina heelsplitter and other native mussels require (e.g., cobble, gravel, sand) are unstable. Also, because of the level of impervious surface area, more rainwater is running off the land rather than infiltrating and recharging groundwater levels. As a result, streams in the Goose Creek watershed appear to be experiencing abnormally low flows during dry periods, adversely affecting aquatic species.

According to the 2012 5-year review of the species, the Waxhaw Creek population of the Carolina heelsplitter was considered extremely small and restricted to a few scattered sites within short reaches of this stream. Suitable habitat in Waxhaw Creek was deemed limited and of marginal quality. This degraded condition was explained as mimicking Goose Creek, where development activities associated with the expansion of the Charlotte metropolitan area are expanding into the watershed, and the long-term survival of this population is doubtful. Water quality in Waxhaw Creek is not currently being monitored by the State of North Carolina; however, in South Carolina, Waxhaw Creek has been added to the state's 303(d) list of impaired waters because of copper standard violations and is considered by the state as impaired for aquatic life.

Surveys conducted since the last review period indicate that, although degraded in some reaches, habitat within Waxhaw Creek is able to support a stable population of Carolina heelsplitter (pers. obs., 2015, 2016). Augmentation and monitoring survey efforts within the past five years have provided some evidence of natural recruitment, with a few sub-five year old individuals found. While the upper portion of the creek in North Carolina is small and shallow in spots, the lower South Carolina portion contains a well-established, stable thalweg (deepest part of the channel), with rock outcroppings. These areas remain underwater during dry periods of the year, which enables mussels to survive in place. In addition, lower Waxhaw Creek is bordered mostly by timber land and native forest. Stream buffers are largely intact all the way down to the confluence with the Catawba River. One year post-augmentation, monitoring surveys revealed about a fifth of animals survived in the same location they were placed. These animals appeared to be in good physical condition. Future survey efforts will analyze the survivorship and health of natural vs. augmented animals in Waxhaw Creek.

The most recent comprehensive survey data for Flat Creek (Alderman, 2011) and the Lynches River (The Catena Group, 2014) indicate that suitable Carolina heelsplitter habitat has remained relatively stable in most of the middle and lower reaches of Flat Creek; however, large reaches of the upper

portion of the creek carry a heavy load of unstable, shifting sand that is unsuitable for native mussel species like the Carolina heelsplitter (pers. obs., 2018). As part of a granite quarry mussel survey, The Catena Group tracked habitat and species population conditions in the Lynches river from 2006-2014. They reported that although the river continues to support the Carolina heelsplitter, as well as a diverse assemblage of up to 13 other mussel species, habitat degradation is continuing to occur in portions of the watershed, as evidenced by severely eroded streambanks, and low numbers and patchy distribution of mussels (The Catena Group, 2014). They go on to say that habitat in many parts of the river is largely depositional, with little flow and large accumulations of silt, detritus, and woody debris, which is poor quality for freshwater mussels.

Land surrounding the Flat Creek/Lynches River population is currently primarily rural, with the primary land uses being timber production and farming. However, Lancaster County, South Carolina, is located just south of Mecklenburg and Union Counties, North Carolina, and growth from the Charlotte area is rapidly spilling across the state line and is beginning to threaten the watersheds of these streams. This is of major concern to the Service, as the Flat Creek/Lynches River Carolina heelsplitter population is considered the largest, most viable remaining.

e. Each of these four populations and their habitats are protected from any present and foreseeable threats that would jeopardize their continued existence.

Some success has been made toward meeting this criterion. Recent land conservation activities along Flat Creek are of particular note, considering the landscape-scale level of protection now in place for the largest surviving population of the species. Over the last 5 years, the resources of a number of public and private entities have focused on this area, with quite a bit of success.

The State of South Carolina currently owns the Forty Acre Rock Heritage Preserve within the Flat Creek watershed. During the recent permitting and mitigation process for the Haile Gold Mine near Kershaw, SC, hundreds of additional acres were transferred to SCDNR, increasing protection along upper Flat Creek by thousands of linear feet. In addition, perpetual non-wasting endowments were put in place to both restore/manage the new habitat, and to fund projects specifically benefitting the Carolina heelsplitter range-wide. SCDNR and the Service jointly administer these funds and will continue to cooperatively plan restoration and recovery activities pursuant to these endowments for the foreseeable future.

The Carolina Heelsplitter Conservation Bank, located along upper Flat Creek near Forty Acre Rock Heritage Preserve, also expanded in 2016. Over 500

acres were added to the property, ensuring that areas within 400 feet of perennial streams, and 200 feet of intermittent streams will remain undisturbed in perpetuity. As mentioned in the 2012 5-year review, the Carolina Heelsplitter Conservation Bank began a novel approach to land conservation in watersheds containing the Carolina heelsplitter. The catalyst for bank implementation included increasing development impacts to water quality in the Charlotte Metro Area, little to no regulatory nexus allowing for implementation of avoidance and minimization measures for the Carolina heelsplitter during project construction. Through the bank, impacts to Carolina heelsplitter habitat (impervious surface creation and buffer encroachment) in rapidly developing areas, may be offset by land protection near prime Carolina heelsplitter habitat elsewhere.

While progress has been made, all surviving populations continue to be threatened by many of the same factors identified at the time of listing as leading to the loss and decline of the species throughout significant portions of its historic range and threats to surviving populations. These include siltation and other pollutants resulting from runoff from poorly implemented development, forestry, and agricultural activities; golf course construction; road construction and maintenance; runoff and discharge of municipal, industrial, and agricultural pollutants; habitat alterations associated with impoundments, channelization, dredging, and sand-mining operations; and other natural and human-related factors that adversely modify the aquatic environment.

Although agriculture, mining, and dams continue to impact and pose significant threats to the continued existence of the Carolina heelsplitter, one of the most significant threats to the majority of the extant populations is currently associated with direct, secondary, and cumulative impacts from residential and commercial development activities. The only known surviving North Carolina populations of the Carolina heelsplitter--the Goose Creek/Duck Creek, Waxhaw Creek, and Sixmile Creek populations--occur in western Mecklenburg County and Union County, North Carolina, on the outskirts of Charlotte. These counties are among the fastest-growing counties in the nation, and development is rapidly spilling over into bordering South Carolina counties, including Lancaster, Chesterfield, and York Counties, where several of the extant South Carolina populations of the Carolina heelsplitter occur.

The same factors associated with development activities (e.g., runoff and discharge of silt, sediments, and organic and chemical pollutants; loss of forested buffers; increased stormwater runoff affecting bank and channel stability; etc.) that have in the past eliminated other populations of the Carolina heelsplitter in Mecklenburg and surrounding counties (e.g., Irwins Creek, Paw Creek, Sugar Creek) are contributing to a significant decline in the health and range of the Goose Creek/Duck Creek and Sixmile Creek populations and pose significant and increasing threats to the Waxhaw

Creek, Fishing Creek/South Fork Fishing Creek, Gills Creek/Cane Creek, and Flat Creek/Lynches River populations of the Carolina heelsplitter (pers. obs., 2012-2018). The majority of the development that is occurring within the watersheds of the streams which support occurrences of the Carolina heelplitter does not have a federal nexus, and current state and local regulations designed to protect water and aquatic habitat quality have proven ineffective at protecting sensitive species like the Carolina heelsplitter.

Also, as indicated above, the effects of recurring, prolonged periods of drought have had significant adverse impacts on all of the Carolina heelsplitter populations. Drought and other factors that affect stream hydrology, such as pine monoculture and water withdrawals for irrigation, continue to pose a very serious threat to the continued existence of this species.

C. Updated Information and Current Status.

1. Biology and habitat.

a. **Abundance, population trends (e.g., increasing, decreasing, stable), demographic features (e.g., age structure, sex ratio, family size, birth rate, age at mortality, mortality rate, etc.), or demographic trends:** Although there have been discoveries of additional occurrences of the Carolina heelsplitter since the species was listed as endangered in 1993, the species continues to have a very fragmented, relict distribution. There are currently 11 known extant populations. Based on available survey data, all extant populations are small in number; only 4 populations appear to be relatively stable; four populations (Sixmile Creek, Gills Creek/Cane Creek), Rocky Creek, Turkey Creek) appear to be in significant decline; and current trend information is not presently available for 3 of these populations because of lack of recent monitoring surveys (see Table 1).

For the purposes of this review, we labeled a population as stable if survey data completed over the past 5 years turned up comparable numbers of individuals as past survey periods. Stable populations also reflected the persistence of relatively comparable amounts of suitable habitat as in previous survey periods. Although survey information is not available for 3 of the 11 known extant populations (Red Bank Creek, Halfway Swamp Creek, and Cuffytown Creek), given their extremely low population levels, these populations are likely in decline and, like the other 8 populations, are under significant threat of becoming extirpated in the near future.

It is important to note that, while this species has remained on the landscape over the past 6 years, all populations remain at such low densities as to make them vulnerable to continuing or increased impacts to each watershed. For instance, the upper Catawba Basin populations (especially Waxhaw Creek,

Sixmile Creek, Gills Creek/Cane Creek), and upper Pee Dee Basin population (Goose/Duck Creek), continue to suffer habitat degradation from ongoing expansion of the Charlotte Mecklenburg Metropolitan Area. Rapid urbanization is leading to increased impervious surface creation in each basin, altering stream hydrology by increasing flow velocity (quicker flow responses to storm events), bank erosion, substrate particle movement (shear stress), water temperatures, and pollutant discharges into waterbodies, among other factors (see Factor A discussion below).

As mentioned previously, at least two year classes, with one year class produced within the last 5 years, appear to be present in 7 of the 11 surviving populations (Goose Creek/Duck Creek, Flat Creek/Lynches River, Waxhaw Creek, Sixmile Creek, Fishing Creek/South Fork Fishing Creek, Rocky Creek, Turkey Creek). In the remaining 4 populations (Gills Creek/Cane Creek, Red Bank Creek, Halfway Swamp Creek, and Cuffytown Creek) only one or a few individuals have been recorded during the most recent surveys. These were all relatively large, older individuals (5-15+ year olds). This means that two year classes were not documented in the Saluda Basin, and were found almost exclusively in the western half of the Catawba Basin.

Not much is known about current sex ratios in surviving populations. Since the species is not sexually dimorphic, only females have been positively identified in the wild during times of year when they are gravid. Without sacrificing the animals, it is impossible to know at any given time if you are looking at a non-gravid female or simply a male. Research is planned to evaluate the ability of the species to self-fertilize in the lab. While this research on suspected hermaphroditism will offer important insights into the reproductive biology of the species, we must be careful when extrapolating results produced in captive situations with those natural experienced in the wild.

The same is true with other demographic features such as age at maturity. This year, we discovered 3 year old mussels at the OMCC hatchery that were holding larvae (although unfertilized or immature) in their gills. While age at sexual maturity is likely to be similar in wild populations, it is important to independently analyze and document that this is in fact the case.

b. **Genetics, genetic variation, or trends in genetic variation (e.g., loss of genetic variation, genetic drift, inbreeding, etc.):** Little information is currently known concerning the genetic health of the surviving populations. However, a study by the North Carolina Museum of Natural Sciences found that haplotypes of the Carolina heelsplitter are restricted to a river basin, in some cases a creek basin (Bogan and Raley 2012). They recommended that when considering population augmentations or reintroductions, the augmentation/reintroduction should only be accomplished by using animals from within the same river or creek basin (Bogan and Raley 2012).

Results of this study were countered by the most recent investigation of population genetics for the species (Fowler and Gangloff, 2018). Their research indicated much lower levels of genetic diversity between occupied river basins, with three haplotypes occurring broadly across all three river basins examined (Fowler and Gangloff, 2018). Because observed overall genetic diversity was so low, the authors suggested that there was minimal concern with combining populations to increase heterozygosity (genetic diversity).

Future research on this topic is outlined in Section IV below.

c. **Taxonomic classification or changes in nomenclature:** There has been no change in the classification or nomenclature of this species.

d. **Spatial distribution, trends in spatial distribution (e.g., increasingly fragmented, increased numbers of corridors, etc.), or historic range:** The species' distribution is highly fragmented, and all surviving populations are small in number and restricted in range. Within each river system, each of the surviving populations is isolated from the other populations in the same river system by impoundments and/or degraded stream reaches that do not appear to be capable of supporting the Carolina heelsplitter. Since the last 5-year review, three additional occurrences have been discovered, one in the Catawba Basin (Hooper Branch), and two in the Savannah Basin (Rocky and Log Creek). Although positive events for the species, these discoveries are represented by only a very few individuals (1 Hooper Branch, 1 Log Creek, 4 Rocky Creek).

e. **Habitat or ecosystem conditions:** Suitable habitat for the Carolina heelsplitter appears to be limited throughout the species' range, as evidenced by the low numbers of individuals within each population. The species has a highly fragmented, relict distribution. Based on historic and recent records for the species, the surviving occurrences exist as small fragments, restricted primarily to short reaches of tributary streams. Based on past and recent records, we believe they were formerly extensive populations inhabiting and connected by the major rivers within these drainages (Catawba River, Pee Dee River, Saluda River, etc.). Suitable aquatic habitat in the majority of the streams that currently support occurrences of the species appears to be extremely limited and presently in decline in quality and threatened with further decline by existing and potential future changes in land-use activities, drought, and other factors.

2. Five-factor analysis.

a. **Present or threatened destruction, modification or curtailment of its habitat or range:** The range of the Carolina heelsplitter has increased since listing through the discovery of previously unknown occurrences of the species. However, all of the surviving populations are small (see Table 1),

highly fragmented, isolated from each other, and restricted to short stream reaches where they are vulnerable to extirpation from stochastic and chronic events (e.g., drought, toxic spills, land-use runoff, etc.). Habitat in most of the streams where the species exists is generally marginal at best, as evidenced by the low numbers of individuals found at each site, their patchy distribution, and their separation by relatively long reaches of highly degraded habitat. All of the surviving populations continue to be threatened by many of the same factors identified at the time of listing, including habitat fragmentation, loss, and alteration resulting from impoundments, the operation of hydroelectric dams, mining, wastewater discharges, and the runoff of silt and other pollutants from ground disturbance activities.

Numerous dams/impoundments exist on all of the major river systems within the range of the species (e.g., the Pee Dee, Catawba, Saluda, and Savannah River systems) and continue to fragment and isolate the surviving populations from one another. Additionally, some of these impoundments are now being used to supply water (several of which involve interbasin water transfers) to support the extensive development within and/or planned within the watersheds of several streams that support occurrences of the Carolina heelsplitter.

Existing and potential future land uses within the watersheds of streams supporting the species threaten the habitat and water quality with increased discharge and runoff of silt, sediments, and organic and chemical pollutants. Past and on-going agriculture and timbering operations threaten several of the populations with continued loss of forest buffers; runoff of silt and other sediments; fertilizer, insecticide, and herbicide drift, runoff, and contamination of groundwater entering the streams; and destabilization of streambanks and substrate (from excessive stormwater runoff, loss of bank vegetation, livestock entering streams, etc.).

Forestry activities on private land in the upper Turkey Creek watershed have previously been hypothesized as a cause of habitat degradation in the headwaters of the Cuffytown, Mountain, Sleepy, and Little Stevens Creek subbasins (Alderman 2007), and it is speculated they continue to do so in adjacent areas of the Savannah Basin (Alderman, 2017). Long reaches of Sixmile Creek, Fishing Creek, South Fork Fishing Creek, Rocky Creek, Bull Run Creek, and Cane Creek (Three Oaks Engineering, 2017) have cut, eroding banks and carry heavy, unstable sediment loads from past and ongoing farming and forestry activities. The loss of woodlands and forested stream buffers and the runoff of pollutants and excessive stormwater from residential and commercial development activities, together with the effects of wastewater discharges from some of these developments, are contributing to a significant decline in the health and range of the Goose/Duck Creek population (USFWS, pers observation 2003 through 2012). Extensive development has and is occurring throughout much of the Sixmile Creek watershed, and the upper Fishing Creek watershed is rapidly urbanizing. The

effects of this development have likely contributed to a significant decline in these populations as well, and these effects pose a significant and increasing threat to the survival of the other populations of the species. Runoff from development activities in the upper Lynches River watershed, municipal wastewater discharge, and pollutants from past gold-mining activities continue to degrade and fragment aquatic habitat within this river.

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 1993, when the species was listed as endangered, or in the species' recovery plan. There is 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 Carolina heelsplitter. However, based on available information, all the surviving populations are small in number; several are extremely small with only 1 to 80 live Carolina heelsplitters documented during the most recent surveys (see Table 1). 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. This is potentially the case for Carolina heelsplitter populations. All are fragmented, with individuals usually spread great distances from each other. Therefore, even predation of a few individuals within a population has the ability to effectively remove reproductive capacity in that stretch of river. Also, while we do not have any new information indicating that disease has been a contributing factor in the decline of the Carolina heelsplitter, 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:** Both North and South Carolina have implemented permitting programs through their state wildlife agencies that require permits be obtained prior to collection of native freshwater mussels species. However, although both states list the species as state endangered, neither state, nor the local governments with jurisdictions within the watersheds of streams supporting populations of the Carolina heelsplitter, 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., loss of riparian buffers, adequate stormwater controls to protect the stream hydrograph and to control the runoff of sediments and other nonpoint-source pollutants, point-source pollutants, etc.).

The majority of the land-use activities in the watersheds of streams that support the Carolina heelsplitter are occurring without any federal nexus. This means that it is not legally required to consult with the Service regarding potential impacts to federally protected species, even though project proponents are still responsible for impacts to these species. Even in cases where a federal nexus has been demonstrated (e.g. impacts to streams or wetlands) for a project, it is difficult to ensure effective avoidance and minimization measures are prescribed and implemented through the regulatory framework allowed. Unfortunately, the probability of implementing successful conservation measures can often be a function of inter-agency relationships, instead of regulatory requirements.

Also, recent studies indicate that current federal and state water-quality standards for many of pollutants commonly found in wastewater discharges and stormwater runoff likely are 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 (ex. Augsperger et al., 2003), and state agencies have not adopted the latest federal guidelines for this pollutant into state regulations for water quality protection. Significant sources of ammonia include municipal and package wastewater treatment plants, agricultural runoff (animal waste and chemical fertilizer), and lawn and turf runoff.

As mentioned previously, the U.S. Environmental Protection Agency has revised the current federal standards (acute and chronic standards) for ammonia to a level protective of freshwater mussels; however, elevated levels of this toxicant continue to affect native mussel populations, including occurrences of the Carolina heelsplitter, mostly due to lack of state-level implementation and oversight in the Carolinas.

Because of the inadequacy of existing federal, state, and local regulations designed to regulate the discharge and runoff of pollutants into surface waters, numerous pollutants threaten the continued survival of all of the extant occurrences of the species. Portions of the majority of the streams currently supporting populations of the Carolina heelsplitter have been listed by North Carolina and/or South Carolina as having impaired water quality, including Goose Creek, Duck Creek, Sixmile Creek, Flat Creek, the Lynches River, Cane Creek, Gills Creek, Beaverdam Creek (Rocky Creek system), Fishing Creek, South Fork Fishing Creek, Cuffytown Creek, and Sleepy Creek (SCDHEC, 2016b). Of the streams monitored for water quality by the states, only Beaverdam Creek (in the Turkey Creek system) and Turkey Creek itself currently meet the state's water-quality standards at all of the sites monitored. Mountain Creek and Little Stevens Creek are not currently being monitored by the state. Stations on the Lynches River, Cuffytown Creek, Beaverdam Creek (Turkey Creek system) and Turkey Creek were recently removed from the 2014 list of impaired waters in South Carolina due to standard attainment.

e. **Other natural or manmade factors affecting its continued existence:** The genetic viability of the surviving populations remains a concern. All of the remaining populations of the Carolina heelsplitter appear to be effectively isolated from one another by impoundments, and several of these populations appear to be below the level required to maintain long-term genetic viability.

In addition, drought and climate change have become a major threat to the continued existence of the Carolina heelsplitter. Stream flow in all of the streams within the range of the Carolina heelsplitter has been severely affected in recent years by reduced base flows and increased water temperatures associated with prolonged periods of drought conditions and higher than average air temperatures. Long reaches of the stream channel, and in many cases nearly the entire stream channel, have dried up or have been reduced to scattered pools with little or no flow. Extensive mussel mortality has been documented in many of these streams. For example, surveys of the Savannah basin in August of 2011 revealed over a mile of dry stream bed in Sleepy Creek, in an area known to have a relatively high number of Carolina heelsplitter (pers. obs., 2011). Deeper pool habitat was the only place live mussels were found. It appeared most others tried to bury in the substrate to avoid drying out.

Carolina heelsplitter population levels, already reduced by other impacts to their numbers, are highly susceptible to becoming extirpated. Higher average temperatures and longer periods between rainfall events, together with increased development and human population levels within the watersheds of the streams supporting the Carolina heelsplitter, will result in an increased demand on freshwater systems for drinking water, irrigation, and other water needs.

D. Synthesis.

Extensive recovery activities for the species have taken place over the past six years, including propagation, augmentation, and habitat restoration of the surviving populations. Partnerships with other agencies as well as private landowners have expanded and have increased the momentum and effectiveness of the recovery program as a whole. Life history, genetic, and habitat research has also increased since the last five year review. The next five years will demonstrate the ability of this new research to translate into attainment of population-level recovery goals.

Based on the most recent information available, four populations appear to be stable (though small in numbers) overall; four of the remaining populations are declining in numbers and are likely to become extirpated in the next few years. And although trend data is not currently available for three of the populations, past survey data combined with habitat information indicates that these populations are likely in decline.

Care has been taken in this document to avoid conflating the recent expansion of

recovery efforts with the species' actual response in the wild. Augmentation has added animals to population counts and increased reproductive potential, but it is important to note that the official recovery criteria stress the importance of documenting natural recruitment and multiple age classes, in combination with some level of protection from threats. Therefore, we must document improvements in natural reproduction, recruitment, and age structure in order to tie augmentation into attainment of recovery goals. Similarly, expanded survey efforts have turned up Carolina heelsplitter in three new tributaries in South Carolina over the past six years. However, these occurrences are very small (less than 5 individuals), and the tributaries are within watersheds already known to contain the species. Most are also located on private (unprotected) property, which leaves them vulnerable to impacts.

Densities of all known populations remain extremely low and highly vulnerable to extirpation from stochastic and chronic events affecting the quality of their habitat. In some of the streams, only a single live individual has been observed; in several, only a few live individuals have been recorded (see Table 1). All surviving populations are isolated from one another and are restricted to short stream reaches. The majority of habitat in the streams where the species exists appears to be marginal at best, patchily distributed, and separated by relatively long reaches of highly degraded habitat.

Also, Carolina heelsplitter populations continue to be threatened by many of the same factors identified during the last five-year review as leading to the loss and decline of the species throughout significant portions of its historic range and threats to surviving populations. These include habitat fragmentation, loss, and alteration resulting from impoundments, mining activities, wastewater discharges, and the runoff of silt and other pollutants from ground-disturbance activities. In addition, drought and other factors affecting water quantity in the streams supporting the Carolina heelsplitter have become a significant threat the species' continued existence. Considering all factors described above and throughout this document, we believe this species still meets the definition of endangered.

III. RESULTS.

A. Recommended Classification:

__X__ No change is needed.

IV. RECOMMENDATIONS FOR FUTURE ACTIONS.

A. Continue planning, coordination, and efficacy of recovery activities with key partners (e.g., SCDNR, NCWRC, NCDWQ, NCNHP, Service, NRCS, local

governments, local conservation NGOs, researchers, etc.) by meeting at least annually to share information and review and recommend priority recovery actions.

B. Continue working with state and local governments to implement protective regulations/ordinances for addressing the impacts and threats from development and other land-disturbance activities. This includes continuing support for the operation and expansion of the Carolina Heelsplitter Conservation Bank, and potentially others of its kind, to provide for the protection of those populations of the species that, in terms of numbers, number of age classes present, range/amount of occupied habitat, availability of suitable habitat, land ownership, and existing land uses, represent the best remaining occurrences of the Carolina heelsplitter and offer the best opportunity for the long-term conservation and recovery of the species. Another priority 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 Carolina heelsplitter, such as protective stream designations and site-specific plans.

C. Formalize a detailed population and habitat monitoring plan for all surviving populations. SCDNR, in coordination with the Service, is currently developing a strategic and long-term state-wide monitoring plan for the species in South Carolina. Special focus will be directed to augmented habitat, degraded habitat, reference reaches, known and anticipated historically occupied habitat, and populations lacking recent assessment.

D. Continue analyzing threats to the species and measures for offsetting these threats and to determine its specific vulnerability to commonly discharged wastes (e.g., ammonia, chlorine) for which present discharge limits may not be protective of mussels.

E. Continue surveys for previously unknown occurrences of the species.

F. Continue and expand 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.

G. 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, the 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 to refugia streams 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.

H. Refine study protocols to effectively investigate intra- and interpopulation genetics. This information is necessary to estimate the relative viability of populations, provide guidance for augmentation and reintroduction efforts, and inform other potential management actions. Research proposals for future genetic studies are currently under development. Working with partners including the state of South Carolina, we aim to identify and strategically analyze the most pertinent research questions applicable to the current and projected status of the species. Such questions include, but are not limited to: effective population sizes, heterozygosity, parentage considerations of propagated animals, etc.

I. Continue habitat, life-history, and captive-propagation studies aimed at specific conservation applications, including: (1) research on potential species hermaphroditism (2)water temperature tolerances and optimal range; (3) in-stream flow requirements, dissolved oxygen requirements, and specific impacts from altered flow regimes; (4) physical habitat requirements/preferences; and (5) the continued support of controlled-propagation (including life-history) experiments.

J. Continue working with partners to establish conservation easements and restore forested buffers and in-stream habitat. Document the effectiveness of these efforts in reducing impacts to the species and improving stream habitat.

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U.S. FISH AND WILDLIFE SERVICE

5-YEAR REVIEW
Carolina Heelsplitter *(Lasmigona decorata)*

Current Classification: **Endangered.**

Recommendation resulting from the 5-Year Review:

_X___ **No change needed.**

Review Conducted By: **Morgan Wolf, South Carolina Ecological Services Field Office, Charleston, SC.**

FIELD OFFICE APPROVAL:

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

Approved: THOMAS MCCOY Digitally signed by THOMAS MCCOY Date: 2019.05.21 12:36:46 -04'00' Date: May 21, 2019

Thomas D. McCoy, Field Supervisor

APPENDIX A

Summary of Peer Review for the 5-Year Review of the Carolina Heelsplitter (*Lasmigona decorata*) and Public Comments received

A. Peer Review Method: The 5-year review of the Carolina heelsplitter was sent to three independent peer reviewers, as an attachment to an email, requesting a critical review and any other changes or additions that should be included in the document. All three reviewers have extensive knowledge of this and similar species. They included Tim Savidge (with Three Oaks Engineering), Thomas Russ (with North Carolina Wildlife Resources Commission), and John Alderman (retired state malacologist). In addition, we sought internal peer review from our Asheville Field Office and with Jonathan Wardell.

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

C. Summary of Peer Review Comments/Report: Reviewers responded by email. Two reviewers responded with recommendations, and one in particular shared additional survey data for one river basin that we were not aware of. One of the reviewers confirmed the accuracy in our tables based on his own data.

D. Response to Peer Review: Recommendations from the reviewers were evaluated and incorporated into the document as appropriate. These consisted primarily of editorial comments, data verification, and additional information concerning available survey data for certain populations.

E. Public Comments Received: We received two comments from the general public during our open comment period.

F. Response to Public Comments: The commenter shared a generic list of reasons or threats that they believed were appropriate to keep the heelsplitter listed as endangered with no supporting information. This response did not provide any new or additional information for the Service.