Carolina Heelsplitter
(*Lasmigona decorata*)

5-Year Review:
Summary and Evaluation
2012

U.S. Fish and Wildlife Service
Southeast Region
Asheville Ecological Services Field Office
Asheville, North 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was accomplished using pertinent status data obtained from the recovery plan, peer-reviewed scientific publications, unpublished research reports, and experts on this species.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 John Fridell in the U.S. Fish and Wildlife Service's (Service) Ecological Services Field Office in Asheville, North Carolina, with assistance from biologist Lora Zimmerman, formerly with the Service's Ecological Services Field Office in Charleston, South Carolina. The Service published a notice in the *Federal Register* (FR [71 FR 42871]) announcing the 5-year review of the Carolina heelsplitter and requesting new information on the species. A 60-day public comment period was opened. No information about this species was received from the public. A draft of the 5-year review was peer-reviewed by six experts familiar with the Carolina heelsplitter. Comments received were evaluated and incorporated as appropriate.

B. Reviewers.

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

Lead Field Office: Ecological Services Field Office, Asheville, North Carolina - John Fridell, 828/258-3939, Ext. 225.

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

C. Background.

1. **FR notice citation announcing initiation of this review:** July 28, 2006 (71 FR 42871).

2. **Species' status:** Declining (2011 Recovery Data Call). Surveys are currently under way to assess the status of the species' populations.

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.

   Recovery Data Call, 1994–2011.

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[1] 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 (Rocky Creek population), Chester County, South Carolina (Note: Bull Run Creek and Beaverdam Creek are tributaries to Rocky Creek).

      Saluda River System:

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

[1]A viable population is defined in the Service's recovery plan for the Carolina heelsplitter 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 viable population is identified in the recovery plan as one of the recovery tasks.

Savannah River System:

- Turkey Creek/Mountain Creek/Beaverdam Creek/Sleepy Creek/Little Stevens 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 to extremely small in size, and their genetic health and viability is, at best, highly questionable. Based on the most recent survey data for each of the 11 populations, 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, a total of only 152 Carolina heelsplitters were found in all of the surviving populations combined. Several of the streams supporting populations or portions of the populations have not been surveyed since these streams were affected by a prolonged period of extreme to exceptional drought that lasted from late 2006 through early 2009,[2] as well as other impacts to their habitat, and several of these streams continue to be affected by recurring, prolonged periods of severe to extreme drought (e.g., the South Carolina portion of Waxhaw Creek, South Carolina portion of Sixmile Creek, the Lynches River portion of the Flat Creek/Lynches River population, Cane Creek, Fishing Creek, Red Bank Creek, Halfway Swamp Creek). Consequently, the Carolina heelsplitter may now be extirpated from some of these streams, or the species' numbers may be significantly lower than indicated in Table 1 and the paragraphs that follow Table 1.

Also, all 11 of the surviving populations remain highly susceptible to extirpation from a single event or chronic events (e.g., drought, chemical spills, stormwater runoff, etc.). Even though 6 of the 11 extant populations--the Flat Creek/Lynches River population, Fishing Creek/South Fork Fishing Creek population, Gills Creek/Cane Creek population, Rocky Creek population, Turkey Creek population, and possibly the Goose

[2]All streams that support populations of the Carolina heelsplitter were significantly affected by "extreme to exceptional" drought conditions (the National Oceanic and Atmospheric Administration's worst drought categories), which persisted from the fall of 2006 through the spring of 2009. Flow in several of the streams that support the species completely dried up, and significant mussel mortality was documented in several of the streams surveyed.

Table 1

Population	Year of Survey	# Found*	Total #*	Trend
Goose Creek/Duck Creek			**12**	**Declining**
Goose Creek	2011	12		
Duck Creek	2011	0		
Flat Creek/Lynches River			**64**	**Stable**
Flat Creek	2010	50		
Lynches River	2006	14		
Waxhaw Creek			**2**	**Declining**
NC portion	2011	0		
SC portion	2004	2		
Sixmile Creek			**10**	**Declining**
NC portion	2011	1		
SC portion	2005	9		
Gills Creek/Cane Creek			**3**	**Declining**
Gills Creek	2011	1		
Cane Creek	2006	2		
Fishing Creek/South Fork Fishing Creek			**13**	**Declining**
Fishing Creek	2007	1		
S. Fork Fishing Creek	2009	12		
Rocky Creek			**17**	**Declining**
Bull Run Creek	2009	11		
Unnamed tributary	2009	0		
Beaverdam Creek	2009	5		
Red Bank Creek	2006		**1**	**Unknown**
Halfway Swamp Creek	2008		**0 (1 shell)**	**Unknown**
Turkey Creek			**30**	**Declining**
Turkey Creek	2010	1		
Beaverdam Creek	2010	1		
Mountain Creek	2010	9		
Sleepy Creek	2011	18		
Little Stevens Creek	2011	1		
Cuffytown Creek	2010		**2**	**Declining**

*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.

Creek/Duck Creek population--currently inhabit more than one stream, 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, 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.

Survey Data for Each of the Populations:

Goose Creek/Duck Creek population (Pee Dee River system): During surveys in 1989 and 1990, Keferl (1991) documented the Carolina heelsplitter in approximately (~) 7.2 kilometers (km) (~4.5 miles [mi]) of the main stem of Goose Creek; and, during surveys in 2000, biologists with the North Carolina Wildlife Resources Commission (NCWRC) documented 13 Carolina heelsplitters scattered within a total of ~8.8 km (~5.5 mi) of the main stem of Duck Creek (NCWRC 2000).

Based on the most recent survey data (Tim Savidge, The Catena Group [TCG], personal communication [pers. comm.], 2011; personal observation [pers. obs.], 2011), the Goose Creek portion of the population is now restricted to less than (<) 4.0 km (<2.5 mi) of the creek, a reduction of more than 3.2 km (~1.99 mi) since Keferl (1991) first discovered the population 1989. In addition, only 12 individuals of the species were found at scattered sites, with generally only 1 or 2 individuals found per site, within the remaining occupied reach of Goose Creek (Savidge, pers. comm., 2011; pers. obs., 2011). The catch per unit effort (CPUE) averaged 0.47 heelsplitters per man-hour for stream segments still supporting the species[3] (Savidge, pers. comm., 2011). Surveys of the Duck Creek portion of the population in 2010 (Chris Eads, North Carolina State University, College of Veterinary Medicine, pers. comm., 2010; pers. obs., 2010) and 2011 (pers. obs., 2010, 2011) failed to locate any individuals of the species in this stream. Since the NCWRC's discovery of the Carolina heelsplitter in Duck Creek in 2000, the species now appears to have declined to the point where it is below detection levels or may possibly be extirpated from the creek. The Goose Creek/Duck Creek population is rapidly declining and, without significant conservation efforts, is likely to become extirpated within the next few years.

Flat Creek/Lynches River population (Pee Dee River system): Alderman (1998a) documented a total of 23 Carolina heelsplitters in a survey of Flat Creek in 1997, which included some individuals less than 60 millimeters

[3]The CPUE was determined for each stream segment within the occupied stream reach by dividing the total number of Carolina heelsplitters found in each stream segment by the number of man-hours taken to survey the stream segment. The stream segments included in this average CPUE varied in length and time necessary to adequately survey each segment and, in this case, included only stream segments containing sites where the Carolina heelsplitter was found. This average CPUE did not include stream segments within the occupied creek reach where no heelsplitters were found.

(mm) in length, indicating relatively recent reproduction (likely within the previous 5 to 6 years or less). In 2007, John Alderman (Alderman Environmental Services [AES], pers. comm., 2007) conducted surveys of two reaches of Flat Creek (one in upper Flat Creek and one in middle lower Flat Creek) and documented 15 live Carolina heelsplitters, including several age classes, some likely less than 5 years of age based on shell measurements. He recorded a CPUE of 4.67 heelsplitters per man-hour. During surveys in 2010, biologists with the Service, AES, and South Carolina Department of Health and Environmental Control (SCDHEC) documented a total of 50 Carolina heelsplitters, including multiple age classes, in Flat Creek (Alderman and Alderman 2011; pers. obs., 2010). Most of the individuals found were in the middle lower reaches of the creek (pers. obs., 2010).

Alderman (1998a) also documented a total of only three live Carolina heelsplitters in a survey of the Lynches River from just below the North Carolina/South Carolina state line, downstream to the vicinity of South Carolina Highway 265 (a short distance below the confluence of Flat Creek and above the confluence of Fork Creek). He found heelsplitters only in the reach of the river between U.S. Highway 601 and South Carolina Highway 265. During surveys of several sites in the main stem of the Lynches River in 2006, between South Carolina Highways 265 and 903, biologists with TCG (2007a) found only four live Carolina heelsplitters (and one shell) between the South Carolina Highway 265 Bridge and the confluence of Fork Creek; their recorded CPUEs were 1.5 and 0.21 in the two reaches where they found heelsplitters. They also recorded a total of ten live heelsplitters, some of which were young individuals, in a reach of the river in vicinity of the South Carolina Highway 903 Bridge that extended both upstream and downstream of the bridge (their report recommended additional surveys downstream of the South Carolina Highway 903). Their recorded CPUEs were 6.0 in a reach of the river upstream of the South Carolina Highway 903 Bridge and 1.49 in a reach of the river downstream of the bridge. They reported that they were unable to find any Carolina heelsplitters, and very few other species of mussels, for several kilometers downstream of the confluence of Fork Creek and that the area in the vicinity of the South Carolina Highway 903 Bridge may be critical for maintaining the species in the Lynches River (TCG 2007a).

Based on available data, the Flat Creek/Lynches River population inhabits ~16 km (~10 mi) of the main stem of middle and lower Flat Creek (Alderman 1998a; Alderman, pers. comm., 2007); a total of ~14 km (~8.7 mi) of the main stem of the Lynches River above the confluence of Fork Creek (Alderman 1998a); and at least ~0.77 km (~0.48 mi) of a reach of the river several kilometers downstream of the confluence of Fork Creek in the vicinity of the South Carolina Highway 903 Bridge (TCG 2007a). Although this population appears to be the largest of the surviving populations, the species appears to exist only in relatively small numbers in both streams (Alderman 1998a;

Alderman, pers. comm., 2007; TCG 2007a); and in the Lynches River, the species' distribution is patchy and highly fragmented (TCG 2007a).

Waxhaw Creek population (Catawba River system): Since the Carolina heelsplitter was first discovered in Waxhaw Creek, North Carolina, this population has always been extremely small and restricted to isolated pockets of suitable habitat (Keferl 1991). Keferl (1991) found only one live Carolina heelsplitter in 1987 and two in 1990. Surveys by biologists with the NCWRC, Service, and others found: no live individuals during surveys in 1994 and 1995 (NCWRC 1995); one weathered shell in 1996 (pers. obs., 1996); one live individual in 1998 (NCWRC 1999); one weathered shell in 2005 (Savidge, pers. comm., 2005); one live individual in 2006 (Steve Fraley, NCWRC, pers. comm., 2006); and no live individuals or shells in 2011 (Fraley, pers. comm., 2011).

Surveys of the South Carolina portion of Waxhaw Creek, conducted in 2004, documented only two live individuals at a single site, one of only a couple of sites in the stream below the North Carolina/South Carolina state line that appeared to provide suitable substrate for the heelsplitter (Alderman, pers. comm., 2004). The population level in Waxhaw Creek is very low, and this population is extremely vulnerable to extirpation.

Sixmile Creek population (Catawba River system): The Carolina heelsplitter was first discovered in Sixmile Creek, Lancaster County, South Carolina, in 2005, during mussel surveys conducted for a proposed major shopping center development in the creek's watershed near the North Carolina/South Carolina state line (TCG 2005). During surveys by TCG and the Service in 2007, the species was found in Sixmile Creek along the Mecklenburg/Union County line in North Carolina (TCG 2007b). This population appears to be limited to scattered sites of suitable habitat in Sixmile Creek from ~3.2 km (~1.99 mi) upstream of the North Carolina/South Carolina state line and downstream ~15.3 km (~9.5 mi) to near its confluence with Twelvemile Creek. However, long reaches of the stream appear to be unsuitable for the species (Savidge, pers. comm., 2006; pers. obs., 2006). This population appears to be extremely small; only three live Carolina heelsplitters (CPUE in the reach of stream surveyed was 0.15 heelsplitters per man-hour) and one shell have been found in the North Carolina portion of Sixmile Creek (TCG 2007b), and only nine live individuals were documented in the South Carolina portion of Sixmile Creek. CPUE was 0.11, 0.42, and 0.06 in the three stream reaches where the Carolina heelsplitter was found (Savidge, pers. comm., 2006). Only a single live individual was found in 2011 during surveys, by the NCWRC and the Service, of the reach of Sixmile Creek in North Carolina, where biologists with TCG and the Service first documented the species in 2007 (pers. obs., 2011). This population appears to be in significant decline and, without significant conservation efforts, is likely to become extirpated in the very near future.

Gills Creek/Cane Creek population (Catawba River system): In 1998, Alderman (1998a) found one live Carolina heelsplitter and one shell of the species in a short reach of Gills Creek (a tributary to Cane Creek) upstream from the town of Lancaster, South Carolina, but was unable to find the species elsewhere in this stream. Until 2010, no surveys had been conducted in Gills Creek since Alderman's discovery of the Carolina heelsplitter in the creek. In 2010, Service and AES biologists surveyed Gills Creek from several hundred meters downstream from South Carolina Highway 9 Bridge and upstream to the Gills Creek Drive crossing. This reach of the creek included the site where Alderman (1998a) had previously found a live Carolina heelsplitter. One Carolina heelsplitter shell was found, but no live heelsplitters were observed (pers. obs., 2010; Alderman and Alderman 2011). This reach of the creek carried a very heavy silt load, which coated the rocks and stream bottom, apparently resulting from a recent blowout of the Gills Creek Drive culvert crossing of the creek and subsequent reconstruction of the crossing. In 2011, AES and Service biologists surveyed Gills Creek from the South Carolina Highway 9 Bridge upstream to the Langley Road crossing and found one live Carolina heelsplitter upstream from the Gills Creek Drive crossing (Alderman and Alderman 2011; pers. obs., 2011).

In 2006, biologists with TCG discovered the species in Cane Creek while conducting surveys for a proposed development project (Savidge, pers. comm., 2006). They surveyed roughly 16 km (~10 mi) of Cane Creek and its tributaries from its headwaters downstream to the town of Lancaster, South Carolina, and recorded two live Carolina heelsplitters (one each at two sites ~1.0 km [~0.6 mi] apart) and one relict, partial shell, found several kilometers upstream from these sites. Their CPUE for the heelsplitter was 0.06 per man-hour. Within the area surveyed for the Carolina heelsplitter, they reported that mussel distribution was patchy, with long reaches of the creek being devoid of a mussel fauna due to the amount of habitat degradation. However, they also canoed an additional 5.15 km (~3.2 mi) of the creek immediately downstream of the area surveyed and reported that areas of suitable habitat may occur in the lower reaches of Cane Creek, downstream from the effects of the city of Lancaster (wastewater treatment plant discharge, urban runoff, etc.). Additional surveys of these lower reaches are needed to determine the overall status of the species in this stream; however, based on available information, the Gills Creek/Cane Creek population appears to be very small (being comprised of only a few individuals) and rapidly trending toward extirpation.

Fishing Creek/South Fork Fishing Creek population (Catawba River system): The Carolina heelsplitter was first discovered in South Fork Fishing Creek, a tributary to Fishing Creek, during surveys by TCG and Service personnel in 2004 (pers. obs., 2004). During 2005 and 2006, biologists with AES surveyed several sites throughout South Fork Fishing Creek and Fishing

Creek and documented a total of 24 live Carolina heelsplitters in an ~7.24-km (~4.5-mi) reach of South Fork Fishing Creek but were unable to document the species at any of the sites surveyed in Fishing Creek (Alderman 2007). Alderman (2007) reported that his CPUE averaged 1.5 to 2.33 at the majority of sites where Carolina heelsplitters were found in South Fork Creek, but he documented a CPUE of 2.30 to 3.00 at one site and 7.20 to 10.00 at another site in the stream. In 2007, biologists with TCG found a single live Carolina heelsplitter in the upper reaches of South Fork Fishing Creek in York County, South Carolina, upstream of the sites surveyed by Alderman (2007), and a single live individual in Fishing Creek (Savidge, pers. comm., 2007). Although present in Fishing Creek, available survey data indicate that this population is restricted primarily to South Fork Fishing Creek. In 2009, surveys of South Fork Fishing Creek by AES biologists documented only 12 live Carolina heelsplitters, indicating that this population is in decline (Alderman and Alderman 2011).

Rocky Creek population (Catawba River system): In 2005, Alderman (2007) discovered a surviving population of the Carolina heelsplitter in the Bull Run Creek system and Beaverdam Creek, tributaries to Rocky Creek. Alderman (2007) recorded 20 live Carolina heelsplitters in a 7.08-km (4.4-mi) reach of Bull Run Creek; 21 live, including several young (40 to 50 mm [1.58 to 1.97 inches] in length), in a 0.32-km (0.20-mi) reach of an unnamed tributary to Bull Run Creek; and 1 live Carolina heelsplitter at a site in the extreme upper reaches of Beaverdam Creek. His recorded CPUE averaged 1.49 to 2.33 at four sites and 4.00 to 7.23 at two sites in Bull Run Creek, where Carolina heelsplitters were found; and 3.00 to 4.00 at sites in the unnamed tributary where heelsplitters were found (Alderman 2007). However, during surveys in 2008 and 2009, AES biologists found only 11 live Carolina heelsplitters in Bull Run Creek and 1 live individual in the unnamed tributary to Bull Creek, though they did find 5 live individuals in Beaverdam Creek (Alderman and Alderman 2011). This population appears to be in significant decline and nearing extirpation.

Red Bank Creek population (Saluda River system): During surveys in 2006, biologists with TCG found one live Carolina heelsplitter and one relict shell in a short reach of Red Bank Creek (Savidge, pers. comm., 2006). Service biologists found a weathered shell of the Carolina heelsplitter roughly 1.61 km (1 mi) upstream from the reach surveyed by TCG (Lora Zimmerman, Service, pers. comm., 2006). This population appears be extremely small, though additional surveys are needed to determine its current status.

Halfway Swamp Creek population (Saluda River system): In 2008, biologists with TCG surveyed two sites in Halfway Swamp Creek and found one shell of the Carolina heelsplitter (TCG 2009). Like Red Bank Creek, this population appears to be extremely small, though additional surveys are needed to determine its status.

Turkey Creek population (Savannah River system): In the Turkey Creek system, the Carolina heelsplitter has been recorded from the main stem of Turkey Creek and its tributaries, Mountain Creek (Alderman 1995), Beaverdam Creek (Alderman 1995), Sleepy Creek (Alderman, pers. comm., 2005), and Little Stevens Creek (Alderman, pers. comm., 2006).

Although portions of the main stem of Turkey Creek support a relatively diverse, healthy mussel fauna, only a few Carolina heelsplitters have ever been recorded from this stream--one in 1995 (pers. obs., 1995); two in 2006 (Alderman, pers. comm., 2007); two in 2007 (Alderman, pers. comm., 2007); and one in 2010 (Alderman and Alderman 2011). This portion of the population appears to be extremely small and highly vulnerable to extirpation.

In 1995, Alderman (1995) recorded a single shell of the Carolina heelsplitter in Beaverdam Creek. Periodic surveys, between 1995 and 2007, failed to locate any other evidence of the species in this stream (Alderman, pers. comm., 2007); however, during extensive surveys of the creek in 2010, AES and Service biologists recorded one live heelsplitter and one shell of the species. This portion of the Turkey Creek population also appears to be extremely small and highly vulnerable to near-term extirpation.

In Mountain Creek, two live Carolina heelsplitters were documented in lower Mountain Creek in 1995 (Alderman 1995) and six in the upper and middle reaches of the stream in 2001 (pers. obs., 2001). During surveys in 2009 and 2010, AES biologists recorded a total of nine live Carolina heelsplitters at sites scattered throughout this stream. Some of those found were <60 mm in length (one was <40 mm in length), indicating the presence of multiple year classes and relatively recent reproduction. Even so, based on available information, the Mountain Creek portion of the Turkey Creek population is very small and highly vulnerable to extirpation.

Alderman (pers. comm., 2005) discovered the Carolina heelsplitter in Sleepy Creek in 2004. During surveys in 2011, AES and Service biologists found a total of 18 live Carolina heelsplitters in an ~6.63-km (~4.12-mi) reach of the creek.

In 2006, Alderman (pers. comm., 2006) recorded seven live individuals and one moribund individual from Little Stevens Creek. However, during surveys in 2011, he was able to find only one live individual. This portion of the Turkey Creek population appears to be in significant decline and rapidly approaching extirpation.

Cuffytown Creek population (Savannah River system): A total of three live Carolina heelsplitters were discovered at two sites in Cuffytown Creek in 1998 (Alderman 1998a). During surveys in 2010, AES biologists found two

live Carolina heelsplitters at two separate sites. This population appears to be extremely small.

Based upon available information, all of the remaining populations of the Carolina heelsplitter are small to extremely small, and their viability is highly questionable (see Table 1). Also, with the exception of the Flat Creek/Lynches population, all of the surviving populations appear to be in decline.

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.

Individuals found during the most recent surveys were either not gravid or were not checked for gravidity. The majority of the most recent surveys have been conducted outside the time of year that the Carolina heelsplitter is gravid (late fall to early spring).[4] However, 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 each of the surviving populations (with the exception of the Waxhaw Creek, Gills Creek/Cane Creek, Red Bank Creek, Halfway Swamp Creek, and Cuffytown Creek populations), where only one or a few individuals have been recorded during the most recent surveys. These were all relatively large, older individuals.

Based on fish assemblage studies of streams known to support populations of the Carolina heelsplitter from 2001 to 2003 (Starnes and Hogue 2005) and limited fish collections in Bull Run Creek by Alderman and Service biologists in 2007, at least some of the fish species documented in the lab to successfully transform Carolina heelsplitter glochidia (larvae) to juveniles (Eads, pers. comm., 2007) (see list of probable fish hosts for Carolina heelsplitter glochidia under discussion in Criterion c below) have been documented in all areas currently occupied by the Carolina heelsplitter, with the exception of Sixmile Creek, Cane Creek, Fishing Creek system, Red Bank Creek, and Halfway Swamp Creek. Fish sampling has not been conducted in these five streams/stream systems. However, many of the fish species identified as suitable lab hosts for the Carolina heelsplitter (see list of fishes under discussion in Criterion c, below) are common throughout the range of the Carolina heelsplitter and are relatively tolerant of habitat conditions. Also, several of these species were documented to be present in nearby streams with marginal to degraded habitat, such as Waxhaw and Gills Creek (Starnes and Hogue 2005). Accordingly, at least some of these probable host species are assumed to be present in these five streams as well, at least during certain

[4]The Carolina heelsplitter is a bradytictic (long-term) brooder; gravid females typically hold the eggs over winter and release them in late winter or early spring.

periods of the year, though surveys are needed to 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. However, we still know very little about the species' life history, biology, and specific habitat preferences and tolerances of the various life stages.

Using surrogate species, limited studies have been conducted to determine potential toxicities of some common pollutants to mussels; however, there are countless numbers of other pollutants present in discharges and stormwater runoff into streams occupied by the species, the acute and chronic effects of which we know very little or nothing about.

Personnel with North Carolina State University, in cooperation with the NCWRC and the Service, have initiated experiments in captive propagation and culture of the Carolina heelsplitter. Several species of fish have been used in the lab to successfully transform Carolina heelsplitter glochidia to juveniles, and offspring produced from these efforts presently range in age from 5 to 6 months (Eads, pers. comm., 2007). Fish species that successfully transformed glochidia to juveniles in the lab include:

Bluehead chub (*Nocomis leptocephalus*)
Creek chubsucker (*Erimyzon oblongus*)
Bluegill (*Lepomis macrochirus*)
Golden shiner (*Notemigonus crysoleucas*)
Rosyside dace (*Clinostomus funduloides*)
Satinfin shiner (*Cyprinella analostana*)
Highfin shiner (*Notropis altipinnis*)
Spottail shiner (*Notropis hudsonius*)
Sandbar shiner (*Notropis scepticus*)
Whitefin shiner (*Cyprinella nivea*)
Warmouth (*Lepomis gulosus*)

These propagation efforts should provide valuable insight into the early life history, growth, food requirements, and microhabitat requirements of juveniles, which could then inform habitat monitoring and conservation. Other goals for this line of investigation include: (1) developing the capability to produce surplus individuals in a hatchery setting in order to augment populations when short-term impacts are experienced (e.g., severe flood impacts, chemical spills); (2) assisting with the establishment of new, or the augmentation of severely depleted, populations when degraded habitats are restored; and (3) providing surplus individuals for toxicity testing and other threat assessment work.

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

Several of the populations of the Carolina heelsplitter (including the Sixmile Creek, Fishing Creek/South Fork Fishing Creek, Rocky Creek, Red Bank Creek, and Halfway Swamp Creek populations and the Cane Creek portion of the Gills Creek/Cane Creek population and South Carolina portion of the Waxhaw Creek population) have only relatively recently been discovered, and adequate monitoring to determine overall current habitat trends in these streams has not yet been conducted. However, based on available information, Carolina heelsplitter habitat in Sixmile Creek (TCG 2005, 2007; pers. obs., 2007, 2011), Red Bank Creek (Savidge, pers. comm., 2006; Zimmerman, pers. comm., 2006), and Cane Creek (Savidge, pers. comm., 2007) appears to be very limited and restricted to scattered sites within short scattered reaches of these creeks. Carolina heelsplitter habitat in long reaches of the streams in the Fishing Creek system (Alderman 2007; Savidge, pers. comm., 2007) and Rocky Creek system (Alderman 2007) is adversely affected by sediment loading and bank and channel scour from stormwater runoff. Alderman (2007) reported that, with the exception of the lower reaches of Bull Run Creek and the unnamed tributary to Bull Run Creek, where most of the watershed is currently in woodland, the Carolina heelsplitter populations in the Fishing Creek and Rocky Creek systems exist within overall degraded habitats. Also, portions of Sixmile Creek, Fishing Creek, Rocky Creek, and Beaverdam Creek have been added by North Carolina (NCDWQ 2010) and/or South Carolina (SCDHEC 2010) to their state's list of impaired streams pursuant to Section 303(d) of the Clean Water Act. Without successful efforts to address the problems associated with existing land uses and protect these streams from the effects of future land-disturbance activities, habitat conditions are expected to continue to decline in these systems.

Although TCG (2009) described the channel and substrate habitat in Halfway Swamp Creek at the sites they surveyed as fairly stable, they reported a general trend of conversion of the surrounding woodlands to yellow pine monoculture as a potential threat to water/habitat quality in the clear and excessive algal growth at the lower two sites as an indication of potential water-quality problems at these sites. Additional monitoring is needed to determine water/habitat-quality trends within this stream.

Despite extensive efforts by biologists with the NCWRC and Service to restore and enhance degraded habitat, establish conservation easements, work with local landowners to carry out voluntary conservation measures,[5] and

[5]Through a grant from the North Carolina Clean Water Management Trust, the NCWRC purchased easements on 23 properties, protecting 156.6 acres of land along Goose and Duck Creeks. Conservation easements now protect ~32,127 linear feet of stream on one or both sides of Goose and Duck Creeks and their tributaries. Enhancement of these easements included the reestablishment of forested riparian buffers through the planting of hardwood tree species and herbaceous plants by the North Carolina Division of Forest Resources and the creation of several

work with the state regulatory agencies and local governments to establish protective regulations in the Goose Creek watershed,[6] habitat quality within Goose and Duck Creeks has declined from the 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 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

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depressional wetlands. Additionally, portions of five tributary stream channels were enhanced, totaling 1,540 linear feet.

[6]The Service and NCWRC have been working, with very limited success, for several years with the NCDWQ and local governments in the Goose and Duck Creek watersheds to establish and implement ordinances designed to protect water and habitat quality from the effects of development activities resulting from numerous past and proposed infrastructure improvement projects (highway improvements, water and sewer line construction, interbasin water transfers, etc.) within the watersheds of these streams.

In 2005, the NCDWQ issued Phase II National Pollutant Discharge Elimination System stormwater permits to three municipalities within the Goose Creek watershed. These permits failed to address/include the recommendations made by the Service and state resources agencies for the protection of the Carolina Heelsplitter. The Southern Environmental Law Center (SELC), on behalf of the Central Piedmont Group of the North Carolina Chapter of the Sierra Club and the North Carolina Wildlife Federation, filed a petition for a contested case hearing challenging the permits. At the request of the SELC, the Service provided expert testimony at an administrative hearing on the case in 2006. The Administrative Law Judge (ALJ) ruled in favor of the plaintiffs. In 2007, the NCDWQ reissued the contested permits, which included some (but not all) of the measures for the protection of the Carolina heelsplitter in the ALJ's ruling; however, in the interim, several development projects within the jurisdictions of the affected municipalities were issued development permits that will not have to comply with the measures included in the NCDWQ's revised Phase II permits.

In addition, the Service, NCWRC, and the North Carolina Natural Heritage Program (NCNHP) worked with the NCDWQ to develop a site–specific management plan (as required by *North Carolina Procedures for Assignment of Water Quality Standards* Rule 15A NCAC 02B.0110) for Goose and Duck Creeks for the protection of the Carolina heelsplitter. This plan and rules for implementing the plan were approved by the North Carolina Environmental Management Commission in 2009. This plan and associated rules included several Service, NCWRC, and NCNHP recommendations for improving water quality and stormwater-control and -treatment measures for new land-clearing and -development activities within the Goose and Duck Creek watersheds and should help lessen the effects of future land-disturbance and -development activities within the watersheds of Goose and Duck Creeks. However, the plan did not include several of the agencies' other recommendations for protecting and enhancing water quality and controlling and treating stormwater. The plan did provide for the issuance of variances, in many instances without required mitigation, and exempted several types of activities, including forestry activities and agricultural activities, from the requirements in the plan.

affecting aquatic species. In addition to the effects to the stability and quality of aquatic habitats associated with the development in the watershed, water quality has been significantly impaired. Water-quality monitoring in Goose Creek (conducted by the NCDWQ, the Service, and a private consultant) has documented levels of several pollutants harmful to freshwater mussels (e.g., ammonia, chlorine, heavy metals, sediment, nutrients), that exceed the state's action/concern levels; therefore, the NCDWQ has placed this stream on the 303d list of the state's impaired waters (NCDWQ 2000, 2006, 2010). Although point-source discharges that occur as a result of development are a major source of this impairment, stormwater runoff has been implicated as a significant factor contributing to elevated levels of many of these pollutants (Chen et al. 2001; NCDWQ 2003; Allan 2005).

The Waxhaw Creek population of the Carolina heelsplitter is extremely small and restricted to a few scattered sites within short reaches of this stream. Suitable habitat in Waxhaw Creek is limited and of marginal quality (Eugene Keferl, Brunswick Community College, pers. comm., 1992; Alderman, pers. comm., 2004; pers. obs., 1996, 1998, 2004, 2007). Like Goose Creek, development activities associated with the expansion of the Charlotte metropolitan area are expanding into this 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.

The most recent survey data for Flat Creek (Alderman, pers. comm., 2007) and the Lynches River (TCG 2007a) 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 (Alderman, pers. comm., 2011; pers. obs., 2011). Habitat in the Lynches River appears to be declining in quality and is patchy and fragmented (TCG 2007a). TCG (2007a) reported that mussels "are extremely rare to absent in long stretches of the river, a reflection of actively degrading habitat conditions, or even a lack of suitable habitat" and that "unsuitable habitat conditions dominate in most of the long survey segments . . . which are characterized by shifting substrates and eroded banks. . . ." In addition, the Carolina heelsplitter's distribution in the Lynches River has been fragmented by past and possibly continuing water-quality impacts associated with wastewater discharges in the Fork Creek watershed and the failure of an overflow pond at the Brewer Gold Mine Company's mine site in 1990 that resulted in the release of cyanide, copper, and mercury into Little Fork Creek (causing a fish kill in ~78.9 km [~49 mi] of the Lynches River) (TCG 2007a). Within the occupied reach of the Lynches River, the Carolina heelsplitter is found above the confluence of Fork Creek, appears to

be absent from the river for several kilometers downstream of the confluence, and is found again downstream in the vicinity of South Carolina Highway 601 (TCG 2007a).

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. The State of South Carolina currently owns the Forty Acre Rock Heritage Preserve within the Flat Creek watershed and is currently working in partnership with the Service, The Nature Conservancy (TNC), and a local land trust to acquire additional land within the watershed for the protection of the Carolina heelsplitter and other significant aquatic resources within this stream. In addition, the Service is working with Lancaster County and a private consulting firm (Environmental Banking Exchange) to establish a "conservation bank"[7] for the Carolina heelsplitter for the protection and, where necessary, restoration of land within the Flat Creek watershed and the eventual expansion of this conservation bank into some of the other best-remaining drainages that support the Carolina heelsplitter (e.g., Lynches River, Bull Run Creek and its unnamed tributary, portions of the Turkey Creek system, and South Fork Fishing Creek).

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 recent years (Alderman, pers. comm., 2007). Alderman (2005) also identified 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 as a contributing cause of habitat degradation in the headwaters of Cuffytown, Mountain, Sleepy, and Little Stevens Creek subbasins. The portion of the population in Mountain Creek, which once supported one of the highest-known concentrations of the heelsplitter in the Turkey Creek system, appears to have declined significantly (pers. obs., 2002; Alderman, pers. comm., 2007).

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.

[7]A conservation bank is a parcel of land containing natural resource values that are conserved and managed in perpetuity (through a conservation easement that is held by an entity responsible for enforcing the terms of the easement for specified listed species and is used to offset impacts occurring elsewhere to the same resource values on non-bank land).

The U.S. Forest Service (USFS) has been 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. In addition, the Service is working with the USFS and TNC to establish agreements with the timber companies that own land within the watersheds of these streams to acquire or establish conservation easements for the conservation of the heelsplitter.

All of the streams that support populations of the Carolina heelsplitter were significantly affected by severe to exceptional drought conditions which persisted from the fall of 2006 through the spring of 2009; flow in several of the streams that support the species completely dried up, and significant mussel mortality was documented in several streams surveyed (Alderman, pers. comm., 2008, 2009; pers. obs., 2008). In addition to stranding and desiccation, mussels in these streams have been exposed to increased predation and concentrated pollutants from wastewater discharges into streams with unprecedented low stream flows. Reproduction and fish host availability may also have been significantly reduced. Although flow conditions have improved somewhat in many of the streams, the base flows of all the streams that support the Carolina heelsplitter appear to be significantly reduced, and all of the streams continue to be affected by recurring and prolonged periods of drought.

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

There has been limited success in meeting this criterion. 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 eastern 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 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., 2004, 2007, 2008, 2010, 2011). In addition, the Turkey Creek system and Cuffytown Creek populations are sandwiched between the cities Aiken and North Augusta, South Carolina, where they are threatened by development associated with the expansion of these cities (Alderman 1998b). 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 in Criterion d, 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 one population appears to be relatively stable; eight populations appear to be in significant decline; and current trend information is not presently available for two of these populations because of either their recent discovery or lack of recent monitoring surveys (see Table 1). Although trend information is not available for 2 of the 11 known extant populations, given their extremely low population levels, these 2 populations are likely in decline and, like the other 9 populations, are under significant threat of becoming extirpated in the near future.

b. Genetics, genetic variation, or trends in genetic variation (e.g., loss of genetic variation, genetic drift, inbreeding, etc.): No information is currently known concerning the genetic health of the surviving populations. However, a recent 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).

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 extensive stream reaches that, based on the most recent survey data, do not appear to be capable of supporting the Carolina heelsplitter.

e. Habitat or ecosystem conditions: Suitable habitat for the Carolina heelsplitter appears to be extremely 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, of what were once, based on past and recent records, likely 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 to extremely 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 been identified as a cause of habitat degradation in the headwaters of the Cuffytown, Mountain, Sleepy, and Little Stevens Creek subbasins (Alderman 2007). Long reaches of Fishing Creek, South Fishing Creek (Alderman 2007; Savidge, pers. comm., 2007), Rocky Creek, Bull Run Creek (Alderman 2007), Cane Creek, and Red Bank Creek (Savidge, pers. comm., 2006) 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 (pers. obs., 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:** The 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 12 live 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. 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:** Neither the states of North Carolina or South Carolina, 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. In cases where a federal nexus has existed, many of the measures necessary for the protection of the heelsplitter and its habitat are not within the authority of the federal permitting or funding agencies.

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 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 waste and chemical fertilizer), and lawn and turf runoff. The U.S. Environmental Protection Agency has been evaluating the potential revision of the current federal standards (acute and chronic standards) for ammonia but has yet to revise them to a protective level; meanwhile, elevated levels of this toxicant continue to affect native mussel populations, including occurrences of the Carolina heelsplitter. Goose Creek is a prime example; water-quality monitoring by the North Carolina Division of Water Quality (NCDWQ 2002) identified average and maximum concentrations of ammonia in Goose Creek as being among the highest of any monitored sites in the Yadkin/Pee Dee River basin. In addition to ammonia, several other pollutants of concern for freshwater mussels have been identified as exceeding concern levels in Goose Creek, including, but not limited to, sediment/suspended solids (NCDWQ 2000, Chen et al. 2001, Allan 2005), copper (NCDWQ 2002), chlorine (NCDWQ 1998), and phosphorus (Chen et al. 2001; NCDWQ 2002, 2003; Allan 2005). North Carolina does not have water-quality standards for ammonia or these other pollutants, and there has been no requirement for the state to address them. Concentrations of several of these pollutants in Goose Creek, including ammonia, appear to be on an increasing trend (Chen et al. 2001, Service et al. 2005). Goose and Duck Creeks have been rated by the state as having poor water quality, the lowest ranking in their system. This poor water-quality rating has been recognized for over 9 years (NCDWQ 1998, 2000, 2003), yet little progress has been made in addressing this problem.

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 the Goose Creek/Duck population of the Carolina heelsplitter as well as 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, Waxhaw Creek, Sixmile Creek, Flat Creek, the Lynches River, Cane Creek, Gills Creek, Beaverdam Creek (Rocky Creek system), Fishing Creek, and South Fork Fishing Creek. Of the streams monitored for

water quality by the states, only Beaverdam Creek (in the Turkey Creek system) and Cuffytown Creek currently meet the state's water-quality standards at all of the sites monitored. Mountain Creek, Sleepy Creek, and Little Stevens Creek are not currently being monitored by the state.

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. 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.

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. Densities of all known populations are 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. 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. All surviving populations are under significant and increasing threat of extirpation from existing land-use activities and rapidly increasing urbanization.

Based on the most recent available information, only the Flat Creek/Lynches River population appears to be stable overall, but even this population is small in numbers; eight of the remaining populations are declining in range and numbers and are likely to become extirpated in the next few years. Although trend data is not currently

available for two of the populations, available information indicates that these populations are likely in decline.

All of the surviving populations of the Carolina heelsplitter 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, including 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. Therefore, we believe this mussel still meets the definition of endangered.

III. RESULTS.

A. Recommended Classification:

__X__ No change is needed.

IV. RECOMMENDATIONS FOR FUTURE ACTIONS.

A. Improve planning, coordination, and efficacy of recovery activities with key partners (e.g., NCWRC, NCDWQ, NCNHP, Service, NRCS, local governments, local conservation NGOs, researchers, etc.) by meeting at least biennially 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. One of the highest priorities is to continue pursuing the development of a conservation bank for the Carolina heelsplitter 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 like those required by *North Carolina Procedures for Assignment of Water Quality Standards* Rule 15A NCAC 02B.0110.

C. Formalize a detailed population and habitat monitoring plan for all surviving populations.

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. Determine 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.

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

J. Continue working with partners to establish conservation easements and restore forested buffers and in-stream habitat. Initially, these efforts should be focused primarily on the best of the remaining populations of the Carolina heelsplitter and areas targeted for reintroduction of the species.

V. REFERENCES.

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APPENDIX A

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

Reviewers: A list of peer reviewers is provided in the "References" section of this document.

A. Peer Review Method: A draft 5-year review of the Carolina heelsplitter was sent to each of the 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 six reviewers have extensive knowledge of this and similar species.

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. All reviewers agreed that the information in the document provided to them was accurate. They did provide some additional references and recommendations that were incorporated into the 5-year review as deemed appropriate.

D. Response to Peer Review: Recommendations from the reviewers were incorporated into the document. These consisted primarily of editorial changes and additional information concerning the status of certain populations.