Appalachian Elktoe
(Alasmidonta raveneliana)

5-Year Review:
Summary and Evaluation

Credit: USFWS

U.S. Fish and Wildlife Service
Southeast Region
Asheville Ecological Services Field Office
Asheville, North Carolina

5-YEAR REVIEW

Appalachian Elktoe (*Alasmidonta raveneliana*)

I. GENERAL INFORMATION

A. Methodology Used to Complete the Review: Public notice of this review was given in the *Federal Register* and a 60-day comment period was opened (79 FR 16366). Pertinent status data were obtained from the Recovery Plan for the Appalachian Elktoe (*Alasmidonta raveneliana*) Lea, published papers, unpublished reports, and species experts. Once all known and pertinent data were collected for this species, the status information was compiled and the review was completed by the species' recovery lead biologist in the U.S. Fish and Wildlife Service's (Service) Asheville Ecological Services Field Office, Asheville, North Carolina, with assistance from Steve Fraley, Aquatic Wildlife Diversity Coordinator, Western Region, North Carolina Wildlife Resources Commission (NCWRC). A draft of this document was internally reviewed by Stephanie Chance, in the Service's Cookeville Ecological Services Field Office, Cookeville, Tennessee, and was peer reviewed by experts familiar with the Appalachian elktoe and other mollusks (see Appendix A). Comments received were evaluated and incorporated as appropriate.

B. Service Reviewers

Lead Region – Southeast Region; Kelly Bibb, 404/679-7132.

Lead Field Office – Ecological Services, Asheville, North Carolina; Jason Mays, 828/258-3939, Ext. 226.

Cooperating Field Office – Ecological Services, Cookeville, Tennessee; Stephanie Chance, 931/528-6481.

C. Background

1. ***Federal Register* Notice Citation Announcing Initiation of This Review:** March 25, 2014, 79 FR 16366.

2. **Species' Status:** The 2012 International Union for Conservation of Nature (IUCN) Red List of Threatened Species lists the Appalachian elktoe as Critically Endangered with a decreasing current population trend (IUCN 2012). Since the last 5-year review in 2009, Appalachian elktoe has experienced declines in two populations. A sudden die-off in the Little Tennessee River, once considered the largest and most secure population, began in 2005 and continued through 2015, when periodic monitoring efforts failed to find any live individuals. In February 2017, one individual Appalachian elktoe was found in the Little Tennessee River, indicating a remnant population, but the population remains at or below detectable levels. The cause of this sudden decline remains unknown despite efforts to reveal a cause. Appalachian

elktoe also declined in the lower portion of the South Toe River, a tributary of the Nolichucky River. The cause of this decline appears to be related to sediment pollution deriving from the construction of a large highway project, a wastewater treatment plan, and other non-point sources of sediment in the South Toe River watershed. Appalachian elktoe are still present in the South Toe River, but at reduced density in the affected reach. Despite this reduction in density in the South Toe River, the Nolichucky population as a whole remains widespread. The other populations of Appalachian elktoe appear to be stable (Tuckasegee, Cheoah, and Pigeon Rivers) or expanding (French Broad River). A remnant population known in the Cheoah River since the early 2000's is presently being augmented by the NCWRC with hatchery-propagated individuals sourced from the Tuckasegee River. This effort appears to be successful in bringing this population back to a viable state. Prior to 2004, the French Broad River population appeared to be confined to two tributary streams (Little River, Mills River), but over the last few years the known range of Appalachian elktoe in the main stem of the French Broad River has expanded and now appears to be well established, albeit at low density, over a broad area.

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

4. **Listing History:**
   Original Listing
   FR notice: 59 FR 60334
   Date listed: November 23, 1994
   Entity listed: Species
   Classification: Endangered

5. **Associated Rulemakings:**
   Critical Habitat; 67 FR 61016, September 27, 2002.

6. **Review History**:
   Final Recovery Plan – August 26, 1996.
   Latest 5-Year Review – approved on March 3, 2009. In that review, no changes were recommended for the listing status of this mussel (i.e., remain endangered). The species recovery priority number was changed to a 5c to reflect increasing development activities, which lead to increased wastewater discharges, loss of upland forest and riparian forest buffers, soil erosion, runoff of pollutants, etc.

   Each year, the Service reviews and updates listed species information to benefit the required Recovery Report to Congress. Through 2013, we did a recovery data call that including showing status recommendations, such as "Declining" for this mussel. We continue to show that species status recommendation part in our 5-year reviews. The most recent evaluation for this mussel was completed in 2016.

7. **Species' Recovery Priority Number at Start of Review (48 FR 43098)**: 5c. This number indicates a high degree of threat and a low recovery potential. It also reflects

a species that may be in conflict with development activities or other forms of economic activity.

8. **Recovery Plan:**
Name of plan: Recovery Plan for the Appalachian Elktoe (*Alasmidonta raveneliana*) Lea.
Date issued: August 26, 1996.

II. REVIEW ANALYSIS

A. Application of the 1996 Distinct Population Segment (DPS) Policy: The Appalachian elktoe is an invertebrate and therefore is not covered by the DPS policy. Other DPS questions will not be addressed in this review.

B. Recovery Criteria

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

2. **Adequacy of recovery criteria.**

   a. **Do the recovery criteria reflect the best available and most up-to-date information on the biology of the species and its habitat?** 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 Appalachian elktoe will be considered for downlisting to threatened status when the likelihood of the species' becoming extinct in the foreseeable future has been eliminated by achievement of the following criteria:

   a. **Through protection of existing populations and successful establishment of reintroduced populations or the discovery of additional populations, a total of four distinct viable populations exist. (A viable population is defined as a naturally reproducing population that is large enough to maintain sufficient genetic variation to enable it to evolve and respond to natural environmental changes.) These four populations shall be distributed throughout the species' historic range, with at least one each in the Little Tennessee, French Broad, or Nolichucky 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 these populations.**

At the time of listing, only two populations of the Appalachian elktoe were known to exist--one in the main stem of the Little Tennessee River in Swain and Macon Counties, North Carolina; and one in the Nolichucky River system, including the main stem of the North Toe River in Yancey and Mitchell Counties, North Carolina; the main stem of the Cane River in Yancey County, North Carolina; and the main stem of the Nolichucky River in Yancey and Mitchell Counties, North Carolina, and Unicoi County, Tennessee. Since listing, five additional populations have been discovered--(1) in 1996, a population was discovered in the Tuckasegee River in Jackson and Swain Counties, North Carolina; (2) in 1999, a population was discovered in the West Fork Pigeon River and the Pigeon River in Haywood County, North Carolina; (3) in 2000, a small population was discovered in the Cheoah River in Graham County, North Carolina; (4) also in 2000, a population was discovered in the Little River in Transylvania County, North Carolina (USFWS 2002), and in 2005, that population was found to extend into the French Broad River, near the mouth of the Little River (S. Fraley, NCWRC, personal communication [pers. comm.], 2005); and (5) in 2003, a population was discovered in the Mills River in Henderson County, North Carolina (T. Savidge, The Catena Group [now Three Oaks Engineering], pers. comm., 2003).

At this time, there insufficient information to determine the genetic viability of the remaining populations. Recovery Task Number 2.5 indicates a need for studies to determine the genetic composition of the populations and the number of individuals necessary to maintain genetic viability and to develop an understanding of the factors that affect viability. Presently, these topics have not been sufficiently investigated, and the current knowledge of Appalachian elktoe population genetics and reproductive success is limited. In 2005, the population of the Appalachian elktoe in the Little Tennessee River began a rapid decline, leading to an inability to find any live individuals in this population in 2015. The recent dramatic decline of this species in the Little Tennessee River (formerly the largest extant population) forces us to reevaluate what we consider to be a viable or secure population.

Of the seven known surviving Appalachian elktoe populations, two--the Nolichucky River population and the Tuckasegee River population--are currently the largest populations and are the most likely to maintain long-term viability. Recent expansion of the species in the upper French Broad River is promising, and this population may be considered viable if the increasing trend continues. Of the remaining populations, only the Nolichucky River and French Broad populations are dendritic (occupying multiple independent watersheds), providing protection from an event that might affect only one of the watersheds. The upper French Broad River population is also dendritic, but most of this population is contained within a short section of the Little River watershed, somewhat reducing its resiliency compared to the Nolichucky population. The other populations are contained within single linear stretches of river, making them vulnerable to

extirpation from a single event, such as a major chemical spill or large-scale development of the watershed.

b. **Three distinct naturally reproduced year classes exist within each of the four populations. One of these year classes must have been produced within the 3 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.**

At this time, we cannot demonstrate reproduction is occurring in the Little Tennessee River. The Cheoah River population is composed of a small number of adult individuals, and only limited reproduction has ever been observed there. Augmentation of this population by the NCWRC is increasing the viability of this population and will continue for the foreseeable future. The population in the Mills River is small and composed of only a few adult individuals; recent reproduction has not been observed. Evidence of at least three year classes, albeit limited in some of the streams, and gravid females have been documented in the remaining populations (Tuckasegee, Pigeon, Little/French Broad, and Nolichucky Rivers). Also, at least some of the fish species documented in the lab to successfully transform Appalachian elktoe glochidia (larvae) into juveniles have been documented in all areas currently occupied by the species (J. Fridell, Service [retired], personal observation [pers. observ.], 2006 through 2008).

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.**

A study conducted at NC State University has identified several common fish that can serve as fish hosts for the Appalachian elktoe. In this study, mottled sculpin (*Cottus bairdi*) had the best transformation rate with an average of 61.8 transformed juveniles per fish. Central stoneroller (*Campostoma anomalum*), gilt darter (*Percina evides*), greenfin darter (*Etheostoma chlorobranchium*), and river chub (*Nocomis micropogon*) also successfully transformed Appalachian elktoe juveniles (Levine 2011)

Biologists with the NCWRC completed a two-year study to determine the periods of spawning, gravidity, and release of glochidia in the Little Tennessee River population. Results indicate that the Little Tennessee population spawns in late August to mid-September, and brood larvae overwinter until they are released in late April to mid-May (Fraley, pers. comm., 2006). The NCWRC is also conducting a study of age and growth using dead shell thin-sections, primarily from the Little Tennessee River with limited material from the Nolichucky, Pigeon, and Little River populations (Fraley, pers. comm., 2006). A study of age

and growth, conducted at Appalachian State University by Mike Gangloff in 2015, showed that the Appalachian elktoe has a typical lifespan of 10 to 12 years. General information on the species' habitat requirements has been gathered through observations made during surveys/monitoring activities. However, numerous aspects of the Appalachian elktoe's life history have yet to be studied and remain unknown, such as the species' food requirements, mirohabitat requirements of its various life stages, etc.

Experiments in captive propagation and culture have been initiated for the Appalachian elktoe and the closely related brook floater (*Alasmidonta varicosa*) and slippershell (*A. viridis*), which may be considered as surrogates for the Appalachian elktoe. Culture techniques have progressed to the point where successful broods of the Appalachian elktoe are being produced yearly for population augmentation into the Cheoah and Nolichucky Rivers (NCWRC 2016). The Appalachian elktoe is still considered to be among the more challenging of the species to maintain in a hatchery setting during its early life history stages, leading to several instances of substantial losses of early juveniles. Anecdotal evidence from feeding trials suggests that the Appalachian elktoe is not clearing algae from the water column, indicating that this species may have different feeding requirements than other mussels (R. Hoch, NCWRC, pers. comm., 2015). Technology necessary to more reliably produce the Appalachian elktoe in a hatchery setting is progressing, and we believe additional augmentations and reintroductions will be necessary to conserve the species.

Survey efforts in the French Broad River since 2005 have consistently shown an increase in the extent of occupied area, with the species appearing to have moved upstream a considerable distance since its initial observation near the mouth of the Little River. Similarly, this species has been observed to have made range expansions in the Cane River, South Toe River, and East Fork Pigeon River (Mays, pers. observ., 2005-2016).

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

To date, there has not been any long-term habitat monitoring or detailed analysis of habitat conditions in any of the streams supporting populations of the Appalachian elktoe other than documenting general habitat conditions present at sites during monitoring surveys of the species. Several populations of the Appalachian elktoe, including populations in the Little River/French Broad River, Mills River, West Fork Pigeon River/Pigeon River, and Cheoah River have not had substantial habitat monitoring to determine overall habitat trends.

At the time of listing, suitable mussel habitat in the Nolichucky River system appeared limited due to large quantities of unstable, shifting sand and other sediments from past land-use activities; however, noticeable improvements in the habitat quality in portions of the upper Nolichucky River system were occurring,

primarily in reaches of the Nolichucky River, Toe, and North Toe Rivers. The Appalachian elktoe's range and numbers in the upper Nolichucky River system were increasing in response to these habitat improvements. Whether due to improvements in habitat quality or previous lack of adequate surveys (likely a combination of both), known population levels in the South Toe River have risen from nonexistent to the highest densities of mussels observed among all sites in the system (Fraley and Simmons 2006). However, flooding associated with the remnants of Hurricanes Frances, Ivan, and Jeanne in September 2004 resulted in the scouring of streambanks and the stream channel in several areas in the Upper Nolichucky River system, temporarily reducing the species' numbers and distribution in portions of this river system (Fraley and Simmons 2006). Subsequent monitoring data indicated that the mussel density quickly rebounded and continues to increase in areas not affected by other stressors. The Cane River portion of the Nolichucky River system population appears to have been eliminated from approximately 30.6 km (19 rm) of the river in 2008, a time frame that corresponds to water quality issues associated with an existing waste water treatment plant (WWTP, Fridell, pers. observ., 2008) in Burnsville, NC. Construction of the US 19E highway through the South Toe River drainage has led to habitat degradation in the river, downstream of the road crossing. The Appalachian elktoe population in the affected section has declined between 60 and 90 percent from preconstruction levels, and during the summer of 2015 large amounts of silt and sand were observed to be affecting habitat quality. High flows during the fall of 2015 resulted in the removal of some of the fine substrates assumed to be associated with the population decline, but the construction is ongoing and its long-term effect on this population is unknown (Mays, pers. observ., 2015).

The amount of suitable habitat in the reach of the Little Tennessee River capable of supporting the Appalachian elktoe appears to be declining. As noted above, this population has suffered severe decline. This population formerly occurred in the reach of the river between the dam at Lake Emory in the city of Franklin, North Carolina and the backwaters of the Fontana reservoir. The river channel above Lake Emory (above the reach of the river supporting the Appalachian elktoe) carries a very high load of unstable sediments and is devoid of mussels. It is believed that Lake Emory has served as a sediment trap that has helped to protect the integrity of river below the dam at Lake Emory. However, the lake has filled in with sediments and there are now sediment accumulations affecting habitat quality in the river below the lake (Mays, pers. observ., 2015). Jarvis (2011) reported elevated levels of copper and zinc in the Little Tennessee River which might have contributed to the decline of the species following mobilization of sediment during the flooding in 2004.

Only limited surveys have been conducted in the Tuckasegee River, and habitat trends are not currently available. In 2009, Duke Power removed a small hydroelectric dam--the Dillsboro Dam--as part of a relicensing agreement, which has provided continuity between the lower part of the river and an additional

14.5 km (9 rm) of river habitat. Monitoring one year after the dam removal showed that Appalachian elktoe had moved in to the restored habitat (John Alderman pers. comm., 2017). Prior to dam removal mussels immediately below the dam were relocated to areas further upstream to avoid any take from construction. Surveys in the relocation reach in 2016 observed that many of the relocated mussels were still alive and that the population was thriving in this area, indicating that removal of the dam has restored population connectivity in the Tuckaseegee River (Mays, pers. observ. 2016).

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, and 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 (see the "Five Factor Analysis" below). We have been and will continue working with state, private, other federal resource agencies, state and federal regulatory agencies, and local governments and landowners to address threats and improve the status of the species in the streams where it occurs.

In 2004, the Nature Conservancy, NCWRC, and other partners acquired approximately 4,500 acres of land bordering part of the reach of the Little Tennessee River that formerly supported the Appalachian elktoe and portions of its tributaries. Since that time, the additional parcels purchased by the NCWRC and non-governmental organizations have increased the total property conserved to almost 5000 acres. The preserved property was designated as a Nature Preserve on December 27, 2010, and is presently managed as a game land by the NCWRC. The property is 83% forested and is being managed to improve the habitat quality for endangered species (NCWRC 2016).

The Service has been involved in ongoing projects with the Natural Resources Conservation Service and other partners to repair and restore streambanks, riparian buffers, and in-stream habitats and establish conservation easements on streams supporting the Appalachian elktoe. In 2013, the NRCS, NCWRC and the Service cooperated on removal of a large debris dam in the upper French Broad River that was potentially affecting the continued expansion of Appalachian elktoe in the river. This project successfully restored the habitat and has resulted in increased cooperation with NRCS and as of 2017, other bank stabilization projects are being considered that will benefit the recovery of this species in the French Broad.

The majority of the surviving populations of the Appalachian elktoe continue to face significant threats associated with development activities, agriculture

operations, wastewater discharges, stormwater runoff, and nonpoint-source pollutants, etc.

f. All four populations remain stable or increase over a period of 10 to 15 years.

As indicated above, while some populations of the Appalachian elktoe meet some of the criteria for downlisting, none of the populations meet all of the above criteria.

C. Updated Information and Species' 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:

Nolichucky River: In the Nolichucky River system, at the time of listing, the Appalachian elktoe was known to survive in only a few scattered areas of suitable habitat in the Nolichucky River in North Carolina, downstream to the vicinity of the city of Erwin, Tennessee, and the Toe River and lower Cane River in North Carolina (USFWS 1994). Since listing, monitoring surveys conducted by the Service, NCWRC, the North Carolina Department of Transportation (NCDOT), Tennessee Valley Authority (TVA), and other researchers have also documented the species in the North Toe River (McGrath 1996, 1999; USFWS 2002), South Toe River (Fridell, pers. observ., 1998 and 2000; Fraley, pers. comm., 1999; USFWS 2002), and further up the Cane River (USFWS 2002) in North Carolina. The Nolichucky River population is scattered throughout roughly 111.1 km (69.03 rm).

In September 2004, flooding associated with the remnants of Hurricanes Frances, Ivan, and Jeanne resulted in streambank erosion and stream-channel scour in several areas in the upper Nolichucky River system, significantly reducing the species' numbers and distribution at several sites throughout this river system (Fraley and Simmons 2006). Fraley and Simmons (2006) reported decreases in numbers of the Appalachian elktoe at nearly all of the sites they surveyed; however, the populations of Appalachian elktoe have subsequently been observed to rebound after the flood.

In April 2008, The Catena Group reported an ongoing fish kill in the Cane River below the Burnsville WWTP (Savidge, pers. comm., 2008). Available evidence indicates that the WWTP had been experiencing problems with their treatment tank and had been discharging untreated wastewater into the river since at least March 2008 (R. Davis, North Carolina Division of Water Quality, pers. comm., 2008). Follow-up surveys by biologists with the Service, NCWRC, and The

Catena Group failed to find any live mussels in the river for approximately 30.6 km (19 rm) below the WWTP discharge; only seven live Appalachian elktoes were found in the river near the confluence of the Cane and Toe Rivers (Fraley, pers. comm., 2008). Since 2013, a small remnant population of approximately 12 live Appalachian elktoes has been found within 1.6 km (1 rm) upstream of the WWTP. Efforts to restore Appalachian elktoe to the affected reach are under way. A preliminary assessment of feasibility was done by release of translocated adults from the South Toe River in 2014 and propagated juveniles placed in enclosures in 2015. Promising survival and growth observed in these preliminary releases led to the stocking of 8,368 propagated juveniles in 2016 (NCWRC 2016 Section 10 Report; Fraley, pers. comm., 2016).

The South Toe River portion of this population also experienced a population decline first observed in the summer of 2015. This decline coincided with a large road construction project. Monitoring efforts conducted by the Service observed that Appalachian elktoe immediately upstream of the effects of the road construction maintained normal density while those downstream have declined compared to previous monitoring records (Mays, pers. observ. 2015). The Service is currently in consultation with the NC Department of Transportation (NCDOT) and the NCWRC to develop a plan to address potential effects of road construction on this population.

Little Tennessee River: The Little Tennessee River population formerly occupied a 39 km (24 rm) mile reach of the river between the dam at Lake Emory, below the city of Franklin, North Carolina, and the backwaters of the Fontana reservoir in North Carolina (USFWS 1994, 1996, 2002; McGrath 1999). Up- and downstream expansion of this population was prevented by these reservoirs. At the time of listing and until just recently, this had been considered the healthiest population of the Appalachian elktoe in terms of overall numbers, number of year classes represented, quality of habitat, etc. In 2005, this population was observed to be in rapid decline (Fraley, pers. comm., 2005). Ongoing monitoring in the Little Tennessee has demonstrated that this population of the Appalachian elktoe has continued to decline; and in 2015, no live Appalachian elktoes were found in the Little Tennessee River during triennial surveys (Fraley, pers. comm., 2015). A survey in February 2017 observed a single live individual immediately below Emory dam. A second survey in June 2017, observed another live individual in the lower portion of the river, confirming that this species is still present in the Little Tennessee River but at very low density (Luke Etchison, NCWRC, pers. comm., 2017). The cause of this decline is being investigated; however, at this time no cause has been positively identified.

Tuckasegee River Population: Prior to listing, surveys in the Tuckasegee River system failed to detect the presence of the Appalachian elktoe; this population was first discovered in 1996 (M. Cantrell, Service, pers. comm., 1996).

This population is distributed over 41.6 km (25.8 rm) in scattered areas of suitable habitat from below the town of Cullowhee, North Carolina, downstream to Bryson City, North Carolina (Fridell, pers. observ., 1996, 1997; McGrath 1998; Savidge, pers. comm., 2001; Fraley 2002, Mays, pers. observ. 2015). Upstream expansion of this population is restricted by cold-water discharges and peaking operations from hydropower facilities in the headwaters of the Tuckasegee River and by the Bryson Dam on the Oconaluftee River, which presents a physical barrier a short distance upriver from the confluence of the Oconaluftee River and the Tuckasegee River (Fraley 2002). The Tuckasegee River supports a population of moderate density (considered high density in some areas) but has never approached the high densities previously seen in the adjacent drainage, the Little Tennessee River. Recent surveys suggest that the Appalachian elktoe population is presently stable in the Tuckasegee River (Mays pers. observ, 2016).

Cheoah River Population: In 2000, a single live individual and one shell of the Appalachian elktoe were discovered in the Cheoah River in North Carolina, below the Santeetlah Dam (W. Pennington, Pennington and Associates, Inc., pers. comm., 2000). Subsequent surveys in 2002, 2003, and 2004 by biologists with the NCDOT, NCWRC, U.S. Forest Service, the Service, and others recorded additional live individuals from the river below the Santeetlah Dam, but less than 20 in each survey (Savidge, pers. comm., 2002; Fridell, pers. observ., 2002; Cantrell, pers. comm., 2005). Steve Fraley, NCWRC, found a single individual in the Summer of 2016 believed to be an individual from the relict native population. Recent surveys indicate that the population is very small and occupies a stretch of river around 5.8 km (3.6 rm, Mays pers. observ. 2015).

The population is confined to an area heavily affected by the operation of hydropower dams. Upstream expansion of this population is blocked by the Santeetlah Dam, and downstream expansion is blocked by a series of impoundments on the Little Tennessee River (including the Calderwood reservoir, at the mouth of the Cheoah River). Between 1929 and 2004, the river was largely dewatered by a penstock that bypassed the Cheoah River, causing the habitat to be starved of suitable substrates (gravel and sand), leaving only small areas of suitable habitat for the Appalachian elktoe.

Since 2005, Tapoco Power Company (now Brookfield Hydropower) has agreed to maintain minimum flows from the dam that closely approximate flows in the river prior to construction of the dam and to add coarse sand and gravel to the river channel below the dam to help improve the quality of the substrate. Since 2011, the relict Appalachian elktoe population in the Cheoah River has been augmented with both translocated adults and captively propagated juveniles from source stock in the Tuckasegee River. The objective is to restore the species following restoration of water flow downstream from the Santeetlah Dam after 70+ years of diversion (NCWRC 2016 Section 10 Report; Fraley, pers. comm., 2016). Due to the long lifespan and slow growth of mussels, it will likely be several years before

it can be determined how successful these measures will be in improving Appalachian elktoe populations in the river.

Pigeon River System Population: In the Pigeon River system in North Carolina, a small population of the Appalachian elktoe occurs at scattered sites in a short reach of the Pigeon River from Canton, North Carolina, upstream to the confluence of the West and East Fork Pigeon Rivers, and upstream in the West Fork Pigeon River to approximately 3.2 km (2 rm), downstream of the confluence of the Little East Fork River (Fridell, pers. observ., 1999; McGrath 1999; USFWS 2002; Fraley and Simmons 2006). This population is distributed over 22.6 km (14.04 rm), but the density of the Appalachian elktoe in this river is patchy and relatively low (Mays pers. observ. 2016). The upper Pigeon River system upstream from Canton, where the presently extant population exists, is relatively cold, higher gradient, and good habitat is more restricted and patchy than in some rivers with higher density populations. This may limit a substantial increase in the population density in the reach. Downstream from Canton, the occupied reach is truncated by a low head dam and waste-water outfall at a paper mill that severely polluted the river for nearly a century. Waste water quality from the mill has been substantially improved and fish and other mussel species have recovered and/or are being reintroduced in the reach downstream; however, intensive agriculture and rural development in the lower watershed and subsequent non-point source impacts may limit or preclude expansion of Appalachian elktoe into the reach. In 2016, a small number of Appalachian elktoe were located in the East Fork Pigeon River, representing an expansion of the known range of this population (Mays pers. observ., 2016). Additional monitoring of this population is needed to determine long-term population trends.

Little River/French Broad River Population: The Little River population was discovered in 2000 (Fridell, pers. observ., 2000) and is restricted to the reach of the river below the powerhouse at Cascade Lake. The population in the Little River appears to be stable and maintaining very high density in an occupied reach approximately 2.7 km (1.68 rm) long (Mays pers. observ. 2015). The upper portion of this watershed is protected (in state ownership) for most of its drainage area. The presence of Cascade Lake, a former hydropower dam, upstream of the occupied reach further improves the habitat, by attenuating sediment and improving productivity. Further downstream in the Little River, the habitat is degraded by agriculture and rural development and the density of the Appalachian elktoe is very low or nonexistent. The Little River population, though small, represents a very important element for the recovery of this species in the French Broad.

The French Broad river population appears to be expanding out of the Little River and into the main stem river. Since 2005, the Appalachian elktoe has been increasingly found throughout a 32-km (20-rm) section of the river (Fraley pers. comm., 2016). Presently they are at relatively low density (Mays pers. observ.

2016), but their continued expansion and the large amount of suitable habitat in this portion of the French Broad River indicate that this population is becoming more secure and may reach long-term viability in the future. Additional monitoring surveys are needed to better define the range in this watershed and to determine long-term population trends.

Mills River Population: The Mills River population was discovered in 2003 (Savidge, pers. comm., 2003). The Appalachian elktoe occurs in a short reach of the Mills River from just above the Highway 280 Bridge to about 1.6 km (1 rm) below the bridge (J. Simmons, NCWRC, pers. comm., 2004). This appears to be a small population, occurring only at scattered locations within this river reach. Several sites within the occupied reach were destabilized by the floods of September 2004, requiring removal of the species from the general areas to allow for in-stream restoration activities that were necessary to repair the storm damage. Recent survey efforts have only been able to demonstrate a small number of individuals in this population. The Mills River supports a large population of a closely related species, slippershell (*Alasmidonta virdis*). The reason for the low density of Appalachian elktoe remains unknown. Stream bank and other erosion have apparently degraded mussel habitat in the lower reach where Appalachian elktoe have not been seen in recent years, and the slippershell population has declined substantially. (S.J. Fraley, pers comm. 2017).

b. Genetics, genetic variation, or trends in genetic variation (e.g., loss of genetic variation, genetic drift, inbreeding, etc.):

In 2010, the North Carolina Museum of Natural Sciences submitted a report (Raley 2010) to the NCWRC documenting their genetic evaluation of the known Appalachian elktoe populations, using microsatellite and mitochondrial gene analysis. The result suggests that the global population of Appalachian elktoe is composed of two metapopulations corresponding to the major drainages where the species occurs (Little Tennessee River and French Broad River). The data also suggested that the Pigeon River population may represent a third grouping, but the results were inconclusive.

c. Taxonomic classification or changes in nomenclature:

There has been no change in the classification or nomenclature of this species (ITIS 2017).

d. Spatial distribution, trends in spatial distribution (e.g., increasingly fragmented, increased numbers of corridors, etc.), or historic range (e.g., corrections to the historical range, change in distribution of the species within its historic range, etc.):

As stated previously in Section II.B.3.a, the Appalachian elktoe has been lost from most of the Little Tennessee population and has declined in portions of the Nolichucky population. The remaining populations, though stable, remain isolated from one another by impoundments, and natural gene flow is not possible between the populations due to these barriers.

e. Habitat or ecosystem conditions (e.g., amount, distribution, and suitability of the habitat or ecosystem):

The Appalachian elktoe has been reported from relatively shallow, medium-sized creeks and rivers with cool, clean, well-oxygenated, moderate- to fast-flowing water. The species is most often found in riffles, runs, and shallow flowing pools with stable, relatively silt-free, coarse sand and gravel substrate associated with cobble, boulders, and/or bedrock (Gordon 1991; USFWS 1994, 1996, 2002; J. Alderman, formerly with NCWRC, pers. comm., 2000; C. McGrath, formerly with NCWRC, pers. comm., 2000; Savidge, pers. comm., 2000; Fridell, pers. observ., 1989 through 2004). Stability of the substrate appears to be critical to the Appalachian elktoe, and the species is seldom found in stream reaches with accumulations of silt or shifting sand, gravel, or cobble (Fridell, pers. observ., 1989 through 2001; Fraley and Simmons 2006). Individual specimens that have been encountered in these areas are believed to have been scoured out of upstream areas during periods of heavy rain and have not been found during subsequent surveys (McGrath, pers. comm., 1996; Fridell, pers. observ., 1995, 1996, 1999).

Suitable habitat in the majority of the streams where the species survives is limited; and the majority of the surviving populations are comprised of scattered occurrences of the species, restricted to pockets or short reaches of suitable habitat. Large reaches of many of the streams that support the species have been degraded by past and/or ongoing land-disturbing activities and alterations to natural flow and temperature regimes. In many instances, habitat for the Appalachian elktoe has been degraded and is marginal or unsuitable. Although there have been noticeable improvements in habitat quality in recent years in some areas that support the species, particularly in portions of the Nolichucky River system, most of the watersheds of the rivers supporting the Appalachian elktoe are threatened by the effects of increased development.

2. Five-Factor Analysis

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

The Service's 1994 listing of the Appalachian elktoe as endangered, 1996 recovery plan for the species, and 2002 rule designating critical habitat for the species identify several factors as leading to the loss and decline of the species throughout a significant portion of its historic range and significant threats to the species' continued existence, including habitat loss and alterations associated with

impoundments, channelization, mining, and dredging operations; pollutants in wastewater discharges (sewage treatment plants and industrial discharges); and the runoff of silt, fertilizers, pesticides, and other pollutants from land-disturbing activities that were implemented without adequate measures to control erosion and stormwater runoff. Many of these same factors continue to threaten the surviving populations of Appalachian elktoe.

Impoundments scattered throughout the upper Tennessee River system continue to fragment and isolate all of the surviving populations from one another. Both upstream and downstream expansion of the Tuckasegee, Little Tennessee, and Cheoah River populations are prohibited by dams and impoundments and, in the case of the Tuckasegee River, by peaking operations and cold-water discharges from the operation of hydroelectric dams in the river's headwaters.

Portions of the headwaters of the Little Tennessee, Tuckasegee, Cheoah, Pigeon, South Toe, and Cane Rivers are in Pisgah National Forest; however, significant portions of the watersheds are in private ownership. These watersheds are experiencing an increase in residential and industrial development. With the exception of a few private inholdings, the reach of the Cheoah River that supports the Appalachian elktoe is surrounded by the Nantahala National Forest. Also, a large tract of land adjacent to a portion of the Little Tennessee River population was recently acquired and is now owned and managed by the NCWRC; however, most tributaries and the river's upper reaches and headwaters are primarily privately owned and unprotected.

Although there have been improvements in protecting and restoring riparian buffers and in-stream habitat in portions of the watersheds of some of these streams (through federal and state programs), private forestry, agriculture, and development activities continue to result in the narrowing and loss of riparian buffers and streambank vegetation and an increase in the runoff of nonpoint-source pollutants in many areas throughout the watersheds of these streams. A reach of the lower Cane River (~5.6 km [~3.5 rm]), including part of the occupied reach of the river; a reach of the North Toe River (~18.2 km [~11.3 rm]), including all of the occupied reach; and the entire length of Jacks Creek (~13.7 km [~8.5 rm]), a tributary to the occupied reach of the Toe River, were both recently added by the North Carolina Division of Water Quality (NCDWQ) to North Carolina's list of impaired streams [303(d) list]. The Cane River was added because of turbidity standard violations, the North Toe River because of violations of the turbidity standard and impaired biological integrity, and Jacks Creek because of impaired biological integrity. The nonpoint-source runoff of silt/sediments is identified as the most likely cause of impairment of the reaches of the Cane and North Toe Rivers; the cause(s) of impairment of Jack's Creek is (was) not yet identified by the NCDWQ.

Also, point-source discharges continue to pose a substantial threat to the several surviving populations. The majority of the streams that support populations of the

Appalachian elktoe do not have adequate designations for protecting occupied reaches from pollutants associated with new or expanded wastewater discharges. In 2008, problems with the effluent from the Burnsville WWTP on the Cane River coincided with the loss of the Appalachian elktoe from approximately 30.6 km (19 rm) of the river (Fridell, pers. observ., 2008). The NCDWQ recently permitted: (1) a new wastewater discharge into occupied habitat on the South Toe River; (2) the expansion of two wastewater discharges into occupied habitat on the Tuckasegee River (one of which is currently operating in violation of their discharge standards); and (3) the expansion of wastewater discharges short distances above occupied habitat on the Little Tennessee and French Broad Rivers. The discharge from the WWTP on the Little Tennessee River discharges into the river at Lake Emory, immediately above occupied habitat; this plant expanded its discharge in 1999 and has recently requested a modification of their permit to more than double their current permitted level of discharge.

Biologists with the NCWRC, NCNHP, and the Service have been, and will continue, to work with the NCDWQ in the development of "Site Specific Management Plans" for the watersheds of streams supporting federally-listed aquatic species, including plans for the streams supporting the Appalachian elktoe that, at some time in the future, hopefully will help protect these streams from additional point and nonpoint sources of pollution; however, it will likely be several years before these plans are drafted and finalized and the regulations necessary for implementation of the plans are adopted by the state. Although the *North Carolina Procedures for Assignment of Water Quality Standards* Rule 15A NCAC 02B .0110 (Rule), which authorized site specific management plans states that ". . . plans shall be developed within the basinwide planning schedule with all plans completed at the end of each watershed's first complete five year cycle following adoption of the Rule," the state has completed no plans for the watersheds supporting Appalachian elktoe.

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 1994 (when the Appalachian elktoe was listed as endangered) or in the recovery plan for the species. We have no new information to indicate any change in the previous assessment.

c. Disease or predation:

Although no specific information was available at the time of listing concerning the degree to which disease and predation posed a threat to the species, both were identified as potential threats. The same is still true. As previously mentioned in Section II.B.3.a, the loss of this species from its most extensive population in the Little Tennessee River is presently unexplained. Disease has been suggested as a

possible cause of this decline though limited preliminary analysis of dead and moribund specimens by researchers at the U.S. Geological Survey's (USGS) National Fish Health Laboratory in Leetown, West Virginia, was unsuccessful in confirming the cause (C. Starlipper, USGS, pers. comm., 2006). The North Carolina State University Veterinary College completed an extensive study to try and identify the cause(s) of the decline but could not determine if disease was a possible cause (Levine et al. 2015). Due to the rapid decline of this population of the Appalachian elktoe and the lack of obvious physical causes, we should consider an unknown disease mechanism as a potential threat to the entire species.

Predation is not thought to be a significant threat to a healthy mussel population; however, on the South Toe River, muskrat middens (with as many as 50 shells) have been observed, indicating that predation could have a localized effect on mussel beds (pers. observ., 2015). Neves and Odum (1989) suggested that predation could contribute to the local extirpation of populations already depleted by other factors. Predation on the Appalachian elktoe could become a problem in populations with declining numbers, but this is not known to be substantially affecting any population presently.

d. Inadequacy of existing regulatory mechanisms:

The Appalachian elktoe is listed as endangered by both the States of North Carolina (NCG.S. 113-337) and Tennessee (Tennessee Annotated Code 70-8-105). Though this designation prohibits the collection of the species without a valid state collecting permit, it does not provide any protection from other forms of take including habitat loss.

Many activities that pose a significant threat to the surviving populations of the Appalachian elktoe and its habitat are not subject to the regulations of section 7 of the Endangered Species Act of 1973, as amended (Act). The activities do not have any federal involvement--no federal permits, authorizations, or funding are associated with the activities--therefore, there is no requirement for consultation with the Service, even though they may adversely affect federally listed species. Accordingly, most of these activities occur without any coordination with the Service and are not reviewed or regulated. Any review/regulation takes place in compliance with applicable state and local regulations/ordinances, unless it can be proven in a federal court of law that a violation of section 9 of the Act (which prohibits the "take" of federally listed species) or other federal regulation has occurred as a result of the activity. Neither North Carolina or Tennessee nor local governments with jurisdictions within the watersheds of streams supporting populations of the Appalachian elktoe currently have regulations/ordinances that are adequate to protect the species from the effects of residential and commercial development activities; private, county, and state road construction, maintenance, and runoff; agriculture and forestry activities, etc. (e.g., loss of riparian buffers, adequate stormwater controls to protect the stream hydrographs and to control nonpoint-source pollution, etc.). Accordingly, many of the activities occurring in

the watersheds of streams that support the Appalachian elktoe continue to impact or contribute to impacts to the species and/or limit the species' recovery or pose a significant threat to the species and its recovery.

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

The genetic viability of the surviving populations remains a concern. All remaining populations of Appalachian elktoe appear to be effectively isolated from one another by impoundments. Even small mill dams have been shown to cause divergence of mussel populations within the same stream (Abernethy et al., 2013). Populations of Appalachian elktoe have always been divided by long stretches of habitat that is not ideal for their adult life stage, but their use of fish hosts and broadcasting of sperm at one time allowed for genetic migration between populations. Presently, each population of Appalachian elktoe has a reservoir blocking the ability of genes to migrate between populations. This lack of genetic migration may become an issue in the future, especially in the populations such as the Pigeon and Cheoah where the total number of individuals is relatively small.

The effects of water temperature on Appalachian elktoe survival and recruitment has not been studied, but experiments with other mussels suggest that decreasing discharge and increasing temperatures associated with climate change pose a significant threat for Appalachian elktoe (Ganser et al. 2013).

D. Synthesis

The unexplained decline of the Appalachian elktoe in the Little Tennessee River between 2005 and 2015 is an unprecedented occurrence. It is difficult to assess the magnitude of this loss with certainty, but the Little Tennessee River formerly represented the majority of all individual Appalachian elktoe throughout the species' range and likely numbered in the tens of thousands, or perhaps even hundreds of thousands. The loss of this population marks a substantial decrease of the global population. As noted in Section II.C.2.c, the physiology of individuals that were experimentally caged in the Little Tennessee River have indicated that the animals declined in health, but no causative agent has been determined. At this time, without knowing the cause of the decline in the Little Tennessee River, we are extremely concerned about the viability of the remaining populations. The surviving populations are small in size compared to the Little Tennessee River population and generally occupy isolated reaches of river, leaving them vulnerable to events that could affect the entire population. All of the surviving populations continue to be threatened by many of the same factors identified at the time of listing throughout significant portions of its historic range, including habitat fragmentation, loss, and alteration resulting from impoundments, the operation of hydroelectric dams, in-stream mining, wastewater discharges, and the runoff of silt and other pollutants from ground-disturbing activities. In view of the above, the Service believes this mussel continues to meet the definition of endangered.

III. RESULTS

A. Recommended Classification:

__X__ **No change is needed.**

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IV. RECOMMENDATIONS FOR FUTURE ACTIONS

A. Continue analyzing threats to the species and measures for offsetting these threats; conduct studies to determine the extent and cause of the recent decline of the Little Tennessee River and South Toe River populations and develop measures necessary for stabilizing and recovering this population; determine species-specific vulnerability to commonly discharged wastes (e.g., ammonia, chlorine) for which present discharge limits may not be protective of mussels.

B. Fund or seek funding to continue the genetic analysis of existing populations in order to 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.

C. Continue habitat, life history, and captive propagation studies aimed at specific conservation applications, including water temperature tolerances and optimal range, in-stream flow requirements and specific impacts from altered flow regimes, and the expansion of propagation efforts. Utilize juveniles produced from propagation efforts for evaluation of water quality limits including for several important parameters. Parameters to be evaluated may include, but are not limited to: ammonia, pH, conductivity, potassium, sodium, chlorine, zinc, and copper. Evaluate specific diet and organic forage requirements for different life history stages of the Appalachian elktoe.

D. Develop a population augmentation/reintroduction plan for each of the occupied watersheds. Incorporate testing of initial release sites with 1-2 year old progeny in a limited release, may be instructional and help discern priority systems for extensive efforts.

E. Continue working with partners to establish conservation easements and restore forested buffers and in-stream habitat.

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U.S. FISH AND WILDLIFE SERVICE

5-YEAR REVIEW OF THE APPALACHIAN ELKTOE

Current Classification: Endangered.

Recommendation resulting from the 5-Year Review:

_____ **Downlist to Threatened**
_____ **Uplist to Endangered**
_____ **Delist**
__X__ **No change is needed**

Review Conducted By: Jason Mays, Ecological Services Field Office, Asheville, NC.

FIELD OFFICE APPROVAL:

Janet Mizzi, Lead Field Supervisor, Ecological Services Field Office, Asheville, NC

Approve _____ Date 8/28/17

The lead field office must ensure that other offices within the range of the species have been provided adequate opportunity to review and comment prior to the review's completion. The lead field office should document this coordination in the agency record.

APPENDIX A

Summary of Peer Review for the 5-Year Review of the Appalachian elktoe (*Alasmidonta ravaneliana*)

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 Appalachian elktoe 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 four 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. One reviewer requested that we include catch per unit effort (cpue) data to show trends in population data. During preparation of this review we considered all available cpue data to draw conclusions about occupancy and stability of populations, but found a lack of data collection standardization and few repeat samples made it impossible to calculate variance and as such, we chose to limit the analysis to qualitative interpretation.