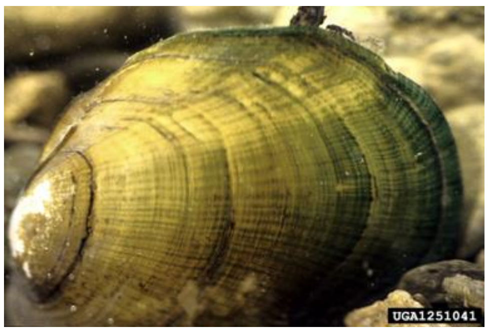
Tan Riffleshell
Epioblasma florentina walkeri

5-Year Review:
Summary and Evaluation



(USFWS photo by G. Peeples)

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

5-YEAR REVIEW
Tan riffleshell (*Epioblasma florentina walkeri*)

I. GENERAL INFORMATION

A. Methodology used to complete the review:

We announced initiation of this review and requested information in a published *Federal Register* notice with a 60-day comment period (72 FR 54057). Pertinent data were obtained from the Recovery Plan, published papers, unpublished reports, and experts on this species. Once all data were collected for this species, the status information was compiled and the review was completed by the species' recovery lead biologist in the Ecological Services Field Office, Asheville, North Carolina. In conducting this 5-year review, we relied on the best available information pertaining to historical and current distribution, life histories, genetics, habitats, and potential threats of this species. A draft of the 5-year review was peer reviewed by three experts familiar with this mussel (see Appendix A). No part of the review was contracted to an outside party. Comments received on this review were evaluated and incorporated as appropriate.

B. Reviewers

Lead Region: Southeast Regional Office, Atlanta, Georgia—Kelly Bibb, 404/679-7132

Lead Field Office: Ecological Services Field Office, Asheville, North Carolina—Bob Butler, 828/258-3939, Ext. 235

Cooperating Field Offices: Ecological Services Field Office, Cookeville, Tennessee—Stephanie Chance, 931/528-6481, Ext. 211; Ecological Services Field Office, Frankfort, Kentucky—Leroy Koch, 502/695-0468, Ext. 106

Cooperating Regions: Northeast Regional Office, Hadley, Massachusetts—Mary Parkin, 617/417-3331

Cooperating Field Offices: Ecological Services Field Office, Abingdon, Virginia—Shane Hanlon, 276/623-1233, Ext. 25, and Brian Evans, 276/623-1233, Ext. 26

C. Background:

1. **Federal Register notice citation announcing initiation of this review:** 72 FR 54057; September 21, 2007

2. **Species status:** Declining (This determination is due to the status of the mussel in the Indian Creek, Virginia, population.).

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

4. **Listing history:**
   Original Listing
   FR notice: 42 FR 42351
   Date listed: August 23, 1977
   Entity listed: subspecies
   Classification: endangered

5. **Associated rulemakings:** None.

6. **Review History:**
   Final Recovery Plan: 1984
   Recovery Data Call: 1998–2012
   5-Year Review: November 6, 1991.
   In this review (56 FR 56882), different species were simultaneously evaluated with no species-specific, in-depth assessment of the five factors as they pertained to the different species' recovery. In particular, no changes were proposed for the status of this mussel in the review.

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

8. **Recovery Plan:**
   Name of plan: Recovery Plan [for the] Tan [Riffleshell] Mussel *Epioblasma* (=*Dysnomia*) *walkeri*
   Date issued: October 22, 1984

II. REVIEW ANALYSIS

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

The Endangered Species Act (ESA) defines species as including any subspecies of fish or wildlife or plants, and any distinct population segment of any species of vertebrate wildlife. This definition limits listing DPS to only vertebrate species of fish and wildlife. Because the species under review is an invertebrate, the DPS policy is not applicable.

B. Recovery Criteria

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

2. **Adequacy of recovery criteria.**

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

The recovery criteria do not reflect the best available and most up-to-date information on the biology of the species and its habitat because all populations considered extant have been discovered since the time of the 1984 Recovery Plan (U.S. Fish and Wildlife Service [Service] 1984) and conversely, previously known populations are likely extirpated. This development essentially renders Recovery Criteria 1 and 4 irrelevant for tan riffleshell recovery.

b. **Are all of the five listing factors that are relevant to the species addressed in the recovery criteria?** No.

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 tan riffleshell mussel shall be considered recovered when the following criteria are met:

> *1. A population of* Epioblasma florentina walkeri*, with evidence of recent recruitment (specimens age 5 or younger), exists in the Middle Fork Holston River, Smyth and Washington Counties, VA. This population is distributed widely enough in the Middle Fork such that it is unlikely a single adverse event would result in the total loss of the population.*
>
> The Recovery Plan contains these definitions:
> *viable population*—a reproducing population that is large enough to maintain sufficient genetic variation to enable it to evolve and respond to natural habitat changes. Determining the number of individuals needed to meet this definition is one of the recovery tasks.
> *population center*—a single shoal or grouping of shoals which contain *Epioblasma florentina walkeri* in such close proximity that they can be considered as belonging to a single breeding unit.

The tan riffleshell was restricted to a single population in Middle Fork Holston River (upper Tennessee River drainage), Virginia, at the time the 1984 Recovery Plan was written. No evidence of its continued existence has been documented since 1997–1998 and the population is likely extirpated (Henley et al. in press).

> *2. Through re-establishments and/or discoveries of new populations, a viable population exists in three additional rivers or*

> *river corridors which historically contained the species. The river (corridors) will contain at least two population centers which are dispersed to the extent that a single adverse event would be unlikely to eliminate* Epioblasma florentina walkeri *from its re-established location. For a re-established population, surveys must show that three year-classes, including one year-class of age 10 or older, have been naturally produced within each of the population centers.*

The 1984 Recovery Plan stated that two Tennessee tan riffleshell populations were potentially extant in the Duck (lower Tennessee River drainage) and Red (lower Cumberland River drainage) Rivers. Live individuals were last collected from the Duck in 1964 and a single fresh dead shell was last found in 1988. As no further evidence of its existence has been recorded since 1988 despite comprehensive sampling efforts, the species is considered extirpated from Duck River (Ahlstedt et al. 2004). The last known records for Red River were made in 1966 and 1969. Although not as thoroughly surveyed as the Duck River, the Red River has not yielded any evidence of tan riffleshell in over 40 years and the population is considered extirpated.

The tan riffleshell was rediscovered in the upper Cumberland River drainage in Big South Fork, Kentucky and Tennessee, in 1985–1986 (Bakaletz 1991). Additional upper Tennessee River drainage populations were discovered since 1984, and include Hiwassee River, Tennessee, in 1992 (Parmalee and Hughes 1994); and Indian Creek/Clinch River, Virginia, in 1995–1996 (Winston and Neves 1997). The Big South Fork population is recruiting and viable but limited to a 12-mile reach of stream (Ahlstedt et al. 2003–2004). It now represents the best population of the species rangewide. In Indian Creek/Clinch River, the Clinch River component of the population was lost due to a catastrophic chemical spill in 1998, resulting to the current restriction of the tan riffleshell to less than two miles of lowermost Indian Creek (Jones et al. 2001, Schmerfeld 2006). The species was recruiting to some degree up to a decade ago, but its current status appears to be in decline. The Indian Creek population is much smaller than its counterpart in Big South Fork (Watson and Neves 1998, Rogers et al. 2001, Jones and Neves 2004, Dinkins 2011). Several surveys over the past decade have failed to detect evidence for an extant population in Hiwassee River leading experts to consider this population to be extirpated (S.A. Ahlstedt, USGS retired, pers. comm., 2008). Big South Fork and Indian Creek appear to be the only streams where tan riffleshell populations are currently extant.

Several streams have been identified by regional mussel managers as possible reintroduction streams for this species (Cumberlandian Region Mollusk Restoration Committee 2010). In the Tennessee River drainage, potential restoration streams by state include: Alabama— Paint Rock River, Hurricane Creek, Estill Fork; Tennessee—Pigeon and Duck Rivers; and Virginia—upper Clinch River, upper North Fork and South Fork Holston Rivers, Copper Creek. Lower French Broad, lower Holston, lower Hiwassee, and Elk Rivers, all in Tennessee, may also be potential reintroduction sites if tailwater conditions (e.g., thermal, oxygen, flow regimes) are improved by Tennessee Valley Authority (TVA) below dams and powerhouses they manage. In the Cumberland River drainage, potential restoration streams by state include: Kentucky—Rockcastle and Red Rivers, Buck Creek; and Tennessee—Clear Fork Cumberland and Red Rivers. The Service is working with Virginia Polytechnic Institute and State University (VPI), Virginia Department of Game and Inland Fisheries (VDGIF), Tennessee Wildlife Resources Agency (TWRA), Kentucky Department of Fish and Wildlife Resources (KDFWR), U.S. Geological Survey (USGS), National Park Service (NPS), Environmental Protection Agency (EPA), TVA, The Nature Conservancy (TNC), and other partners to address this criterion.

> *3. The species and its habitats are protected from present and foreseeable anthropogenic and natural threats that may interfere with the survival of any of the populations.*

We are working with VPI, VDGIF, TWRA, KDFWR, USGS, NPS, EPA, TVA, TNC, and other partners to improve habitat conditions and protect extant populations of the tan riffleshell. In the Clinch River drainage, TNC and partners have ongoing projects intended to repair and restore stream banks, riparian areas, and instream habitats. The species' distribution in Big South Fork is protected to some degree by its location in the Big South Fork National River and Recreation Area managed by NPS. However, private lands in the headwaters are relatively unprotected. Activities that fail to maintain riparian buffers and allow sedimentation and pollutants to enter headwater streams of both Big South Fork and Indian Creek may impact the only two extant tan riffleshell populations known.

The occurrence of mineral resources in the watersheds of the only two populations of the species adds a significant threat to its continued existence but was not pertinent at the time the Recovery Plan was written. The headwaters of both Big South Fork and Indian Creek represent significant areas of coal, oil, and gas resources. Threats particularly from coal mining activities imminently threaten the tan riffleshell's continued existence in both watersheds.

At the present time, noticeable improvements in resource extraction-related problems in Big South Fork and Indian Creek are perhaps negligible or limited in scope, thus water quality and substrate quality in both watersheds may still be affected by mining. In fact, mining activities appear to be increasing in several tributaries to the upper Clinch River watershed. Scores of active and inactive mines are known from Virginia and five mine tailings pond spills were reported from 1995–1999 in the upper Clinch and Powell River drainages (Hampson et al. 2000). Such mines and tailings ponds may continue to be sources of pollutants that negatively affect tan riffleshell populations. Natural gas extraction is anticipated to increase, thus threatening tan riffleshell populations with increased risk of exposure to associated pollutants (e.g., brines, sedimentation). Although the production of coal in Virginia has declined by more than half since 1990 (VDMME 2012), it is anticipated that production of coal and particularly natural gas in the future may reverse that trend based on current energy demands and human population growth. Further, construction on a 585-megawatt hybrid energy power plant has been completed and is now in operation on upper Clinch River in Virginia City, Wise County, Virginia. Dominion, owner and operator of the facility, intends to burn coal from Virginia sources only. This facility alone may drive energy demand in the area for some time to come.

Other deleterious factors have affected the tan riffleshell. A major chemical spill occurred in 1998 at a U.S. Route 460 intersection located adjacent to the Clinch River upstream of Indian Creek (Schmerfeld 2006). At least, 182 tan riffleshells were killed in the Clinch River (Jones et al. 2001). Subsequent survey work determined that the species was eliminated from the river, reducing the population to a linear segment restricted to less than two miles at the lower end of Indian Creek. A significant sedimentation event associated with a gas pipeline crossing Indian Creek occurred in 2006 (Ostby and Neves 2006). The sediment impacted tan riffleshell habitat in the lower reaches of the stream but the level of mortality resulting from this impact is unknown. Conditions in Indian Creek have contributed to the species' decline to the point where it has become increasingly rare since its discovery in the mid-1990s (Rogers et al. 2001, Jones and Neves 2004, Dinkins 2011).

4. Noticeable improvements in water quality have occurred in the Middle Fork Holston River.

Poor water quality continues to plague the Middle Fork Holston River. The river parallels Interstate 81, which has fostered further development of townships, industry, and agriculture within the corridor. Twenty-six reaches of the river and some of its tributaries have been classified as impaired for recreational and/or aquatic life uses by the Virginia Department of Environmental Quality (VDEQ) under the mandate provided by Sections 303(d) and 305(b) of the Clean Water Act (CWA) (Henley et al. in press). Causes of impairment listed in the watershed include sediment, siltation, fecal coliform from unrestricted livestock access to water bodies, animal feeding operations, crop production, grazing in riparian zones, and failing septic tanks. But since the population is likely extirpated (Henley et al. in press), this issue may become moot. At this time, Middle Fork Holston River is not considered of high enough habitat quality to be considered for population reintroduction of this species; native mussel populations appear to be in continued decline in the stream (Henley et al. 1998, in press). Therefore, this recovery criterion has not been met and may no longer be applicable.

C. Updated Information and Current Species Status

1. Biology and Habitat

Since the Recovery Plan was written, significant biological work on the tan riffleshell has been completed. The life history of the species was studied in Indian Creek in the late 1990s (Rogers et al. 2001). This species is a long-term brooder with spawning putatively occurring in August and September. Most females became gravid by late fall or early winter and released glochidia principally in May and June. Host fishes identified through laboratory induced infections include greenside, fantail, redline, and Tennessee darters and sculpins. It lives at least 12 years.

Since this study was conducted, similar species of *Epioblasma* have been shown to be host trappers, actually grasping darters with their valve edges and ejecting glochidia into their buccal cavity, thus infecting gill tissues; It is likely the tan riffleshell is also a "darter snapper" (Jones and Neves 2010). Another study estimated fecundity in both extant populations, summarized as follows: Big South Fork (n = 4), mean length = 42.1 mm, mean fecundity = 7213 (range = 1828–12,822); Indian Creek (n = 7), mean length = 29.6 mm, mean fecundity = 8068 (range = 5818–12,558) (Haag 2013).

a. Abundance, population trends (e.g., increasing, decreasing, stable), demographic features, or demographic trends:

The following tan riffleshell stream populations include those that were considered extant at some time since circa 1970. Only Big South Fork and Indian Creek are thought to currently harbor extant populations.

Big South Fork, Kentucky and Tennessee: This tributary of the upper Cumberland River drainage below Cumberland Falls clearly has the best population of tan riffleshell remaining. The population, not reported since the late 1940s (Neel and Allen 1964), was rediscovered during a 1985–1986 survey (Bakaletz 1991). A total of 26 live individuals and 37 dead specimens were collected at 7 of 14 main stem sites sampled. A survey conducted from 1999–2002 recorded 113 live individuals from 6 of 19 sites (Ahlstedt et al. 2003–2004). Data from these two surveys indicate that the tan riffleshell is distributed over at least 12 river miles (RM 50.3–

62.5). The population—which since 2002 has been augmented by KDFWR with laboratory cultured juveniles—is sizable and recruiting (Jones et al. 2006). It is currently considered to be stable over the past several years, and the species is fairly common at select sites (S.A. Ahlstedt, USGS retired, pers. comm., 2008, 2013).

Indian Creek, Virginia: This tan riffleshell population was discovered in 1995–1996 while surveying under-sampled streams in the upper Tennessee River drainage in Virginia (Winston and Neves 1997). The population extended into a short reach of the parent stream, upper Clinch River, but a 1998 chemical spill eliminated the Clinch portion of the population (Jones et al. 2001, Schmerfeld 2006). Among Tennessee River drainage populations, this one was deemed critically important since the only other populations known at the time were not thought to be recruiting (Watson and Neves 1998). More intensive survey work was conducted during 1996–1997 (Watson and Neves 1998). A total of 130 live individuals was observed, all but one located in the lowermost mile of stream. Total population size was estimated at 2000 individuals in 1999 (Rogers et al. 2001). A 2004 survey indicated the tan riffleshell population had declined significantly since the late 1990s; maximum population size had plummeted to an estimated 366 individuals, an 82% decline in only five years (Jones and Neves 2004). Recurrent sampling throughout the tan riffleshell reach in the spring of 2007, 2009, and 2011 produced only seven live/fresh dead individuals, six of them in 2007 and none in 2011 (Dinkins 2011). Significant effort was employed in the spring of 2013 to find individuals for broodstock, but resulted in only two live individuals. The population has become exceedingly rare since the mid-1990s and is restricted to less than two miles of the lowermost section of stream. The loss of the Clinch River portion of this population in 1998—not to mention potential impacts inherent in Indian Creek—may be a major reason for the rapid decline of the tan riffleshell in the upper Clinch River drainage.

Since, 2002, efforts have been under way to augment the population in Indian Creek as well as reintroduce it into the adjacent Clinch River with minimally invasive streamside infestations and release of host fishes (N. Eckert, VDGIF, pers. comm., 2007). Unfortunately, there is little evidence to suggest that efforts to augment this population have been successful. A recent study at VPI concluded that streamside infestations of small host fishes were not a good recovery tool for mussels (Carey in prep.). Funding has been made available for augmenting this population as mitigation for the effects of the 1998 toxic spill (Schmerfeld 2006), a 2006 sedimentation event from a pipeline crossing, and a 2006 bridge replacement project.

Clinch River, Virginia: This population, which was discovered in the 1960s, was considered one with the Indian Creek population. The rediscovery of the species in the Clinch River in 1994 prompted surveys in smaller, poorly sampled headwater streams in the Clinch and adjacent watersheds (Winston and Neves 1997), which led to its discovery in Indian Creek (S.A. Ahlstedt, USGS retired, pers. comm., 2013). Periodic sampling over the years indicated that the tan riffleshell occupied a short reach downstream from a lowhead dam at Cedar Bluff. The population persisted until a major chemical spill occurred in 1998 (Schmerfeld 2006). A salvage of mussels killed by the spill was conducted shortly after the event. Over 7,000 dead specimens of 16 species were collected from the 5.5 mile kill zone including 182 tan riffleshells, ranking it 7th for relative abundance among species salvaged (Jones et al. 2001). No evidence of this species has been detected during subsequent sampling efforts. Beginning in 2004, partners have been reintroducing laboratory-reared juveniles and infested host fish to reestablish a population. To date, these reintroduction efforts have not yielded any individuals during subsequent monitoring.

Middle Fork Holston River, Virginia: This tan riffleshell population was the only one positively considered extant at the time the 1984 Recovery Plan was published. It was thought to occur in the reach from River Mile (RM) 17.7–29.1. Five live individuals were sampled in 1985 (Ahlstedt and Saylor 1995–1996). Although a single live individual was collected during a 1997–1998 survey of 25 sites (Henley et al. 1998), population viability was questionable due to the recent lack of recruitment (Watson and Neves 1998). The stream was resurveyed in 2010–2011 by Henley et al. (in press) at the same sites as during the 1997–1998 survey. No evidence of the tan riffleshell was found. The species has declined to the point where no live individuals or fresh dead shells have been located since the 1997–1998 survey, though a relic shell was collected in 2006. The population is now likely extirpated (Henley et al. in press).

Hiwassee River, Tennessee: The tan riffleshell was rediscovered in Hiwassee River in 1992 (Parmalee and Hughes 1994). This small population appeared to be rare and limited to a dewatered reach immediately above the Appalachia Powerhouse upstream approximately nine river miles to the vicinity of the TN 68 crossing (RM 53.7–62.6). The population was thought to be small and its viability questionable in the early 1990s (Parmalee and Hughes 1994). A total of 19 live individuals or fresh dead specimens are known since 1992 (S.A. Ahlstedt, USGS retired, pers. comm., 2008). Approximately 7,000 captive propagated juveniles using Indian Creek broodstock cultured at VPI were released into the river in 2000. Subsequent annual sampling from 2002–2007 to assess the restoration effort failed to detect survival of any individuals—not even shell material (S.A. Ahlstedt, USGS retired, pers.

comm., 2008). The cultured individuals released in the river were but a few weeks old and very small, suggesting that they may have succumbed to the host of predators known for very young mussel juveniles (Zimmerman et al. 2003, Klocker and Strayer 2004). A recent study concluded that release of several week old, newly-metamorphosed juveniles was not a good recovery tool for mussels (Carey in prep.). Recent survey and other information suggest that the species is extirpated from the river.

Duck River, Tennessee: Two live individuals sampled in 1964 and a single fresh dead shell in 1988 in the reach above Old Columbia Dam are the last evidence of the tan riffleshell in the river (Ahlstedt 1991). A survey of 112 sites conducted from 2000–2003 failed to record even relic shells of this species (Ahlstedt et al. 2004). Since no evidence for its continued existence has been recorded since 1988 despite comprehensive sampling efforts, the species is now considered extirpated from Duck River (Ahlstedt et al. 2004).

Red River, Tennessee: Records at the Ohio State University Museum of Biological Diversity (OSUM) indicate that several Red River tan riffleshell collections were made in 1966 and 1969. A single 1966 collection had 376 specimens, indicating that the population was at least locally abundant collections have been made in subsequent years without finding specimens. Although not as thoroughly surveyed as other streams of occurrence, the Red River population is nevertheless considered extirpated.

Stones River, Tennessee: A once sizable population existed in the Stones River and a major tributary, East Fork Stones River—the type locality for the species (Wilson and Clark 1914). Several collection lots exist at OSUM with ~40–80 specimens collected in the mid-1960s. A large dam (J. Percy Priest) was constructed on lower Stones River in 1968, essentially flooding or otherwise altering the entire main stem and the lower portion of the East Fork. A 1980–1981 survey failed to detect the species (Schmidt et al. 1989). Single relic specimens (OSUM records) found in 1970, 1976, and late 1981 (shortly after the 1980–1981 survey was completed) represent the last evidence of tan riffleshell in the stream. The Stones River population is currently considered extirpated.

b. Genetics, genetic variation, or trends in genetic variation:

A detailed taxonomic study was completed on the tan riffleshell and the closely related and easily confused oyster mussel (*Epioblasma capsaeformis*) by Jones and Neves (2010). Results of the study determined that the two extant tan riffleshell populations (Big South Fork and Indian Creek) represent distinct taxonomic entities at the subspecific level. Characters used to distinguish the two taxa include: 1) distinctiveness of molecular genetic markers, 2) coloration of mantle pads, 3) size of glochidia, and 4) allopatric ranges within the Cumberlandian Region (upland portions of the Cumberland and Tennessee Rivers) (Jones et al. 2006). Since the type locality of the tan riffleshell is in the Cumberland River drainage (Wilson and Clark 1914), the Big South Fork population is considered the "true" *Epioblasma florentina walkeri*. The Tennessee River population was described as *Epioblasma florentina aureola* (Jones and Neves 2010). However, for the purposes of this 5-year review, both remaining populations are collectively referred to as the tan riffleshell. For biological and conservation purposes—since the species is now known to be comprised of two taxonomically distinct subspecies occurring in different river drainages—remaining populations will require basin-specific management actions to maintain and recover each lineage as separate taxonomic entities.

c. Taxonomic classification or changes in nomenclature:

The tan riffleshell was described as *Truncilla walkeri* by Wilson and Clark (1914) and has been placed in various other genera over time (e.g., *Dysnomia*, *Plagiola*)—most currently *Epioblasma*. In addition, it has variously been considered a full species (*Epioblasma walkeri*) or subspecies (*Epioblasma florentina walkeri*) of the presumed extinct yellow blossom mussel (*Epioblasma florentina florentina*). Taxonomically, the Service currently considers it to be a subspecies, *Epioblasma florentina walkeri* (but see Section II.C.1.b. above).

d. Spatial distribution, trends in spatial distribution, or historical range (corrections to the historical range, change in distribution of the species' within its historical range, etc.):

Tan riffleshell populations were once widespread throughout the Cumberlandian Region, occurring in both the Tennessee and Cumberland Rivers and dozens of their tributary streams. But they have been fragmented for decades as the result of major impoundment construction in the region primarily during the mid-20th century (Haag 2009, 2012). All populations noted since the 1960s were highly disjunct and isolated from each other. At the time the 1984 Recovery Plan was published, the only known (Middle Fork Holston River) and potentially extant (Duck and Red Rivers) populations are now considered extirpated. The Hiwassee River population, rediscovered in 1992, is now likely extirpated. Big South Fork and Indian Creek represent the only extant populations of tan riffleshell remaining.

2. Five-Factor Analysis

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

The Recovery Plan listed impoundment, pollution, and siltation as the "major causes" for the decline of this species. The era of big dam construction appears to be over, and numbers of smaller dams are beginning to be removed (though not so much in the Cumberlandian Region). However, ongoing issues associated with the fragmentation and isolation of tan riffleshell populations from dams continue to threaten the species (see Section II.C.2.e. below).

A major chemical spill adjacent to the Clinch River upstream of Indian Creek occurred in 1998 that resulted in 182 dead tan riffleshell (Jones et al. 2001). The event reduced the range of the tan riffleshell population in the upper Clinch River drainage to Indian Creek. Settlement funds from the responsible party are being used to restore the population to this portion of Clinch River (Schmerfeld 2006).

Coal and natural gas extraction continues to occur in the upper portions of both watersheds that harbor extant tan riffleshell populations. Impacts from various coal mining activities on the aquatic fauna were reviewed by Hull et al. (2006). Mine-related pollutants that may have contributed to the decline of the tan riffleshell (e.g., water column ammonia, arsenic and other metals in sediments) were identified by Price et al. (2011). Although they noted a general decline in these contaminants in the Clinch River drainage over the past several decades, total dissolved solids continue to rise, especially in reaches of these streams where mining is still active. Research indicates that mussel populations were inversely correlated with coal fines in the substrate. When coal fines were present, decreased filtration times and increased movements were noted in laboratory-held mussels (Kitchel et al. 1981).

Although the production of coal in Virginia has declined by more than half since 1990 (VDMME 2012), it is anticipated that production of coal and particularly natural gas in the future may reverse that trend based on current energy demands and human population growth. In fact, a hybrid energy power plant was recently completed and is now operational on upper Clinch River in Virginia. Scores of active and inactive mines are known from Virginia and five mine tailings pond spills were reported from 1995–1999 in the upper Clinch and Powell River drainages (Hampson et al. 2000). Such mines may continue to be sources of pollutants that negatively affect tan riffleshell populations. Natural gas extraction is also anticipated to increase, thus threatening the species with increased risk of exposure to associated pollutants (e.g., brines, sedimentation).

Fecal coliform counts were high during recent sampling prompting VDEQ to put Indian Creek on its CWA Section 303d Total Maximum Daily Load

(TMDL) list in 2004 based on violations of the state fecal coliform water quality criterion. A detailed biological and point/nonpoint source pollutant effects assessment was conducted in 2004 by the Service in Indian Creek (Service 2004a). Biological communities, habitat conditions, and water quality were generally good, but some sites showed patterns of impairment, warranting continued monitoring.

Sedimentation remains a significant threat in Indian Creek, and to a lesser degree in Big South Fork. Any activity that allows eroded soil to enter tan riffleshell streams (several were listed in the Recovery Plan) may threaten the species. Failure of erosion control measures during the 2006 construction of a gas pipeline in the upper Indian Creek watershed resulted in a major sedimentation release during a storm event (Ostby and Neves 2006). Various other activities in the watershed are potential sources of sedimentation (e.g., coal mining activities, gas exploration and well development, unpaved roads, agriculture, silviculture). The Service and its partners, (e.g., VDGIF, TWRA, KDFWR, USGS, NPS, EPA, TVA, TNC) are working on improving stream habitat conditions in Big South Fork and Indian Creek through various funding sources that serve to improve instream, stream bank, and riparian habitats.

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 the Recovery Plan. An attempt to establish an ark population by VDGIF proved futile after a high percentage of individuals died in captivity. Due to the apparent sensitivity of this species to captive holding, VDGIF limits the number of gravid females used for propagation efforts. The increasing rarity of the species has made this limitation a non-issue. If we cannot find broodstock for propagation activities and raise adequate numbers for translocations soon, we risk losing the population outright.

c. Disease or predation:

The Recovery Plan did not specifically discuss disease or predation as limiting factors for this species. Muskrat predation has been an issue with the tan riffleshell population in Indian Creek and with mussel populations in other portions of the upper Tennessee River drainage (Neves and Odom 1989). A muskrat trapping program has been implemented over the past decade to control this threat and monitoring seems to indicate that predation has decreased (S. Hanlon, Service, pers. comm., 2008). We have no new information on disease that would indicate that it is a limiting factor, though diseases in mussels are poorly known (Grizzle and Brunner 2009).

d. Inadequacy of existing regulatory mechanisms:

The inadequacy of existing regulatory mechanisms was not specifically considered to be a limiting factor in the Recovery Plan. We have new information regarding inadequacy of existing regulatory mechanisms for protecting this species. VDEQ has determined that Indian Creek exhibited CWA Section 303d TMDL impairment in 2004 for both recreational and aquatic life use.

According to a 1996 non-jeopardy biological opinion and conference report issued to the U.S. Office of Surface Mining Reclamation and Enforcement regarding surface coal mining and reclamation operations under Surface Mining Control and Reclamation Act, Species Specific Protective Measures (SSPMs) were to be developed with the objective of minimizing potential take of federally listed species during lawful mining activity (Service 1996). Although draft SSPMs were developed in Virginia, they have not been finalized or implemented. The tan riffleshell population in Indian Creek remains especially vulnerable to the impacts of coal mining (not to mention the Big South Fork population).

Point source discharges within the range of the tan riffleshell have been reduced since the inception of the CWA, but this may not provide adequate protection for filter-feeding organisms that can be impacted by extremely low levels of contaminants. There is no specific information on the sensitivity of the tan riffleshell to common industrial and municipal pollutants and little information on other mussels. Mussels are sensitive to a variety of water contaminants, especially during early life stages. Toxicological studies on freshwater mussels have demonstrated that current EPA water quality criteria for ammonia and copper—to mention but two pollutants—are not protective of all life stages of many freshwater mussel species (Augspurger et al. 2003, Wang et al. 2007). Although not finalized, the EPA is currently considering inclusion of mussels in the toxicity database that is used to set water quality criteria for primary pollutants (e.g., chlorine, copper) and non-priority pollutants (e.g., ammonia). A lack of adequate research and data may prevent existing regulations, such as the CWA, from being fully and effectively utilized.

Section 7 of the ESA requires Federal agencies to consult with the Service when actions they fund, authorize, or carry out may affect the tan riffleshell. However, there is no Federal regulation of many actions likely impacting tan riffleshell habitat. Many of the threats involve activities that likely do not have a Federal nexus (e.g., water quality changes resulting from development, water withdrawals, or indiscriminate logging) and, thus, likely require a Section 10 permit under the ESA. The Service is frequently not informed or aware when many of these activities are being considered, planned, or implemented; therefore, there is no opportunity to provide input into the design of the project or to inform project proponents of the need for a Section 10 permit. Although the take prohibitions of Section 9 of the ESA apply to these activities, enforcement of Section 9 prohibitions is difficult.

Sources of nonpoint source pollution include timber clearcutting, clearing of riparian vegetation, urbanization, road construction, and other practices that allow eroded earth to enter streams. Current laws do not adequately protect tan riffleshell habitat from nonpoint source pollution, as the laws to prevent sediment entering waterways are poorly enforced. Best management practices (BMPs) for sediment and erosion control are often recommended or required by local ordinances for construction projects; however, compliance, monitoring, and enforcement of these recommendations are often poorly implemented. Despite the introduction of BMP cost-share programs, there is a lack of evidence suggesting that agricultural perturbations are being curtailed significantly. Currently, there are no regulatory mechanisms to maintain stream buffers to adequately protect stream habitat from livestock access and loss of functional riparian vegetation.

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

The Recovery Plan did not mention any other natural or manmade factors contributing to the demise of the tan riffleshell. Our knowledge has increased enough over the past three decades to expand on the threats that climate change, population fragmentation and isolation, stochastic events, and the extinction debt principle pose to the species.

Climate change will potentially have significant effects on tan riffleshell, its host fishes, and their habitats. Effects on freshwaters is already manifest in some impacts (e.g., higher temperatures, altered species ranges and phenology of aquatic organisms) (Ashizawa and Cole 1994, Parmesan 2006, Heino et al. 2009). Species have evolved within a matrix of environmental conditions and some will perish if they are unable to adapt to altered conditions wrought by climate change (Larsen et al. 2005, Galbraith et al. 2010). Specific factors associated with climate change potentially affecting aquatic organisms include changes in stream temperature regimes, timing and levels of precipitation, and severity and frequency of floods and droughts (International Panel on Climate Change 2007, Galbraith et al. 2010). Higher temperatures, reduced precipitation, and prolonged droughts should result in lowered dissolved oxygen levels and a potential reduction of suitable habitats for some aquatic organisms. Many riverine mussel and fish species may be unable to compensate for environmental changes due to their inability to migrate to more suitable waters due to morphological or man-made constraints (Strayer and

Dudgeon 2010). Organisms like tan riffleshell—that have adapted highly specialized reproductive strategies—may be particularly vulnerable to environmental changes (Kay 1995).

Deleterious effects of population fragmentation and isolation are major concerns to imperiled mussels (reviewed in Haag 2012). Limited geographic range and rarity make tan riffleshell populations extremely vulnerable to localized extirpations due to decreased fitness from reduced genetic diversity. Further, the potential for populations to drop below the minimum viable population size threshold is a major concern for highly isolated and imperiled species. Species that are restricted in range and population size are more likely to suffer loss of genetic diversity due to genetic drift, potentially increasing their susceptibility to inbreeding depression and decreasing their ability to adapt to environmental changes (Allendorf and Luikart 2007). Impoundments, pollution, and other human-induced changes are a significant threat to aquatic organisms due to the genetic concerns associated with small, geographically isolated populations.

Stochasticity becomes an increasing threat to small, declining populations of rare organisms (Lande et al. 2003). Stochastic factors come under two categories: environmental and demographic. Environmental stochasticity includes factors such as chemical spills or extremely prolonged droughts. This threat is a constant concern for most rare populations of isolated aquatic organisms, especially when linearly distributed. The prevalence of transportation arteries adjacent (railroads and highways paralleling streams) and over (railroad and highway bridges) their habitat further increases the probability that such events will affect their populations. The accidental or intentional release of chemicals associated with fossil fuel extraction activities, agricultural practices, or residential applications is another potential event that may threaten tan riffleshell populations. The prevalence of multiple tailings ponds upstream of the Big South Fork population is especially threatening, given the history of pond blowouts in recent decades (e.g., Hampson et al. 2000). Demographic stochasticity pertains to variation in reproduction, survival, and similar factors that may negatively impact population growth to the point of pushing populations past the threshold level for viability. Species with low fecundity like the tan riffleshell (see Section 2.C.1.) are more susceptible to demographic stochasticity than more fecund species. Even in high quality habitats (e.g., Big South Fork), stochastic events can decimate populations and directly cause extinction (Lande et al. 2003, Haag and Williams 2013).

The mid-20th century construction of scores of dams destroyed thousands of miles of large river shoal habitat, fragmenting and reducing the remaining riverine fauna to isolated stream reaches. This era of impoundments (and to a lesser extent, pollution events) directly resulted in the extinction of about 30 mussel species in eastern U.S. rivers (Haag 2009). Models predict that in populations isolated due to habitat destruction even good competitors and abundant species are susceptible to eventual extirpation (Tilman et al. 1994). Further, additional habitat destruction threatens more species in patches that are already fragmented. Extinctions due to population fragmentation have a time lag during which species must pay an extinction debt sometime in the future (Tilman et al. 1994, Hanski and Ovaskainen 2002). While the first major extinction wave was clearly attributable to habitat loss mostly from impoundments, a second extinction wave appears inevitable due to small populations of mussels slowly dying out in isolated stream reaches due to demographic stochasticity, attrition, and other factors (Haag 2012). More startlingly, the second extinction wave may affect a broader suite of species than the first wave (Haag and Williams 2013). Without directly addressing the factors that cause fragmentation and isolation, more mussel species will be lost to extinction.

D. Synthesis

The tan riffleshell was once widely distributed in nearly 30 streams in upland portions of the Cumberlandian Region. Only a few small populations were known to exist in 1976, prompting the listing of the species as endangered under the ESA. At the time the 1984 Recovery Plan was written, the tan riffleshell was known to occur with certainty only in Middle Fork Holston River, while populations were suspected in Duck and Red Rivers. Three decades later, two populations are known—both discovered since 1984: Big South Fork and Indian Creek. In Big South Fork, it occurs in a 12-RM reach straddling the Kentucky and Tennessee border. The Indian Creek population is restricted to about 2 RMs in the lowermost portion of the creek in Virginia. The Indian Creek population was contiguous with the species in the Clinch River, its parent stream, until a 1998 chemical spill eliminated it from the Clinch. All other populations where the species was known historically—including the three populations potentially extant in 1984—are now considered extirpated. Most general threats to the tan riffleshell remain similar to what they were in 1976 when listed and 1984 when the Recovery Plan was written. In addition to fossil fuel extraction activities and the potential effects of climate change, the myriad effects resulting from small population size, population fragmentation and isolation, and stochasticity are the primary factors that threaten the continued existence of the tan riffleshell. We do have considerably more information since 1984 on its life history, population estimates, development of propagation technology, and a clearer understanding of stressors, but there have been no significant improvements regarding these threats. Population size has been in decline for the past 15 years due to the decrease in the upper Clinch River/Indian Creek population. Reduction of global distribution to a total of 14 RMs, coupled with the heightened possibility for stochastic events to decimate its two small populations, makes the tan riffleshell arguably one of the most highly imperiled species listed under the ESA. The species clearly warrants continued listing as endangered.

III. RESULTS

A. Recommended Classification:

__X__ No change is needed

IV. RECOMMENDATIONS FOR FUTURE ACTIONS

- Continue to refine propagation technology and especially growout to raise juveniles in captivity to a size that vastly reduces natural mortality and readily allows tagging before release to the wild.
- The distinct populations in the Tennessee (Indian Creek) and Cumberland (Big South Fork) River drainages should be maintained separately when considering and conducting management actions. Reintroduction efforts should utilize only stock from the same respective stream drainage.
- Reintroduce populations in streams within its historical range (e.g., Tennessee River drainage—upper Clinch River, Virginia; Copper Creek, Virginia; upper North Fork Holston River, Virginia; South Fork Holston River, Virginia; Pigeon River, Tennessee; Paint Rock River, Alabama; Hurricane Creek, Alabama; Estill Fork, Alabama; Duck River, Tennessee; and lower French Broad, lower Holston, and Elk Rivers, all in Tennessee, if tailwater conditions (e.g., thermal, oxygen, flow regimes) are improved by TVA; Cumberland River drainage—Rockcastle River, Kentucky; Buck Creek, Kentucky; Clear Fork, Tennessee; Red River, Kentucky and Tennessee) that have suitable habitat and water quality conditions through the propagation of juveniles and/or release of infected host fishes. Reintroductions might be accomplished through agreements with respective states or non-essential experimental population designations, whichever method is most expedient.
- Continue to augment and expand extant populations, where warranted, through the propagation and release of cultured juveniles.
- Determine the conservation status, population demographics, and minimum viable population through periodic monitoring and research projects. Monitoring programs should be conducted in the least invasive manner practicable, to include assessing the feasibility of monitoring primarily or solely by the mark-recapture method in conjunction with collection of gravid females for propagation and restoration purposes.
- Assess the degree of threats (e.g., coal mining, urbanization, agriculture, silviculture) to extant populations.
- Assess the effects of toxicants on all life stages from threats (e.g., coal mining, urbanization, agriculture, silviculture).
- Assess population genetics of extant populations and introduced individuals in an attempt to ward off genetic bottlenecks and improve fitness.
- Continue monitoring water and biological parameters in Indian Creek to assess trends in its biological communities, habitat conditions, and water quality.
- Update the Tan Riffleshell Action Plan (Mollusk Recovery Group 2007) as needed and expand the scope to include its entire historical range.
- Update the Indian Creek stress analysis (TNC 2008) as needed.

- Survey Red River.
- If warranted, continue muskrat trapping in Indian Creek to reduce predation.
- Identify and implement habitat restoration projects in the Big South Fork and Indian Creek watersheds to improve instream conditions.
- Identify other streams in the species' historical range to conduct large-scale habitat restoration efforts and restore populations there (e.g., Haag and Williams 2013).

V. REFERENCES

Ahlstedt, S.A. 1991. Cumberlandian Mollusk Conservation Program: mussel surveys in six Tennessee Valley streams. Walkerana 5(13):123–160.

Ahlstedt, S.A., S. Bakaletz, M.T. Fagg, D. Hubbs, M.W. Treece, and R.S. Butler. 2003–2004. Current Status of freshwater mussels (Bivalvia: Unionidae) in the Big South Fork National River and Recreation Area of the Cumberland River, Tennessee and Kentucky (1999–2002). Evidence of faunal recovery. Walkerana 14(31):33–77.

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

Ahlstedt, S.A., and C.F. Saylor. 1995–1996. Status survey of the little-wing pearlymussel, *Pegias fabula* (Lea, 1838). Walkerana 8(19):81–105.

Allendorf, F.W., and G. Luikart. 2007. Conserving Global Biodiversity? Conservation and the Genetics of Populations. Blackwell Publishing, Oxford, United Kingdom. 642 pp.

Ashizawa, D., and J.J. Cole. 1994. Long-term temperature trends of the Hudson River—a study of the historical data. Estuaries 17:166–171.

Augspurger, T., A.E. Keller, M.C. Black, W.G. Cope, and F.J. Dwyer. 2003. Water quality guidance for protection of freshwater mussels (Unionidae) from ammonia exposure. Environmental Toxicology and Chemistry 22(11):2569–2575.

Bakaletz, S. 1991. Mussel survey of the Big South Fork National River and Recreation Area. M.S. thesis, Tennessee Technological University, Cookeville. 61 pp.

Carey, C.S. In prep. Restoring the endangered oyster mussel (*Epioblasma capsaeformis*) to the upper Clinch River, Virginia: an evaluation of population reintroduction techniques. [chapter 1 of M.S. thesis, written for publication]

Cumberlandian Region Mollusk Restoration Committee. 2010. Plan for the population restoration and conservation of imperiled freshwater mollusks of the Cumberlandian Region. Working draft, Asheville, North Carolina. 152 pp.

Dinkins, G.R. 2011. Assessment of native mussels in Indian Creek and North Fork Holston River. Report for Virginia Chapter of The Nature Conservancy, Abingdon. 21 pp.

Galbraith, H.S., D.E. Spooner, and C.C. Vaughn. 2010. Synergistic effects of regional climate patterns and local water management on freshwater mussel communities. Biological Conservation 143:1175–1183.

Grizzle, J.M., and C.J. Brunner. 2009. Infectious diseases of freshwater mussels and other freshwater bivalve mollusks. Reviews in Fisheries Science 17:425–467.

Haag, W.R. 2009. Past and future patterns of freshwater mussel extinctions in North America during the Holocene, pp. 107–128. *In*: Holocene extinctions. S.T. Turvey (ed.). Oxford University Press, Oxford, United Kingdom.

Haag, W.R. 2012. North American freshwater mussels: ecology, natural history, and conservation. Cambridge University Press, Cambridge, United Kingdom.

Haag, W.R. 2013. The role of fecundity and reproductive effort in defining life-history strategies of North American freshwater mussels. Biological Reviews 88:745–766.

Haag, W.R., and J.D. Williams. 2013. Biodiversity on the brink: An assessment of conservation strategies for North American freshwater mussels. Hydrobiologia DOI 10.1007/s10750-013-1524-7 [advance on-line publication]

Hampson, P.S., M.W. Treece, Jr., G.C. Johnson, S.A. Ahlstedt, and J.F. Connell. 2000. Water quality in the upper Tennessee River basin, Tennessee, North Carolina, Virginia, and Georgia 1994–98. U.S. Geological Survey Circular 1205. 32 pp.

Hanski, I., and O. Ovaskainen. 2002. Extinction debt at extinction threshold. Conservation Biology 16:666–673.

Heino, J., R. Virkkala, and H. Toivonen. 2009. Climate change and freshwater biodiversity: detected patterns, future trends and adaptations in northern regions. Biological Review of the Cambridge Philosophical Society 84(1):39–54.

Henley, W.F., R.J. Neves, L.L. Zimmermann, and R. Winterringer. 1998. Status of freshwater mussels in the Middle Fork Holston River, Virginia. Virginia Polytechnic Institute and State University, Blacksburg. 71 pp.

Henley, W.F., M.J. Pinder, B.T. Watson, and R.J. Neves. In press. Status of freshwater mussels in the Middle Fork Holston River, Virginia. Walkerana.

Hull, M.S., D.S. Cherry, and R.J. Neves. 2006. Use of bivalve metrics to quantify influences of coal-related activities in the Clinch River watershed, Virginia. Hydrobiologia 556:341–355.

International Panel on Climate Change. 2007. Climate change 2007: synthesis report. Intergovernmental Panel on Climate Change, Geneva, Switzerland. 73 pp. Accessed 11 May 2010 from: http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf

Jones, J.W., and R.J. Neves. 2004. Survey of freshwater mussel populations in Indian Creek, Tazewell County, Virginia. Report for U.S. Fish and Wildlife Service, Abingdon, Virginia. 33 pp.

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

Jones, J.W., R.J. Neves, S.A. Ahlstedt, and E.M. Hallerman. 2006. A holistic approach to taxonomic evaluation of two closely related endangered freshwater mussel species, the oyster mussel *Epioblasma capsaeformis* and tan riffleshell *Epioblasma florentina walkeri* (Bivalvia: Unionidae). Journal of Molluscan Studies 72:267–283.

Jones, J.W., R.J. Neves, M.A. Patterson, C.R. Good, and A. DiVittoria. 2001. A status survey of freshwater mussel populations in the upper Clinch River, Tazewell, County, Virginia. Banisteria 17:20–30.

Kay, E.A. 1995. The conservation biology of molluscs. International Union for Conservation of Nature, Gland, Switzerland. 81 pp.

Kitchel, H.E., J.C. Widlak, and R.J. Neves. 1981. The impact of coal-mining waste on endangered mussel populations in the Powell River, Lee County, Virginia. Report to Virginia State Water Control Board, Richmond. 26 pp.

Klocker, C.A., and D.L. Strayer. 2004. Interactions among an invasive crayfish (*Orconectes rusticus*), a native crayfish (*Orconectes limosus*), and native bivalves (Sphaeriidae and Unionidae). Northeastern Naturalist 11(2):167–178.

Lande, R., S. Engen, and B.-E. Sæther. 2003. Stochastic population dynamics in ecology and conservation. Oxford University Press, Oxford, United Kingdom.

Larsen, T.H., N.M. Williams, and C. Kremen. 2005. Extinction order and altered community structure rapidly disrupt ecosystem functioning. Ecology Letters 8:358–547.

Mollusk Recovery Group. 2007. Action plan for the Tan Riffleshell (*Epioblasma florentina walkeri*) in the upper Tennessee River system in Virginia. Abingdon, Virginia.

Neel, J. K., and W. R. Allen. 1964. The mussel fauna of the upper Cumberland Basin before its impoundment. Malacologia 1(3):427–459.

Neves, R.J., and M.C. Odom. 1989. Muskrat predation on endangered freshwater mussels in Virginia. Journal of Wildlife Management 53(4):934–941.

Ostby, B. J. K and R. J. Neves. 2006. Assessment of a sedimentation event on mussel habitat in Indian Creek, Tazewell County, Virginia. Report to U.S. Fish and Wildlife Service, Gloucester, Virginia and Virginia Department of Game and Inland Fisheries, Richmond. 21 pp.

Parmalee, P.W., and M.H. Hughes. 1994. Freshwater mussels (Bivalvia: Unionidae) of the Hiwassee River in east Tennessee. American Malacological Bulletin 11(1):21–27.

Parmesan, C. 2006. Ecological and evolutionary responses to recent climate change. Annual Review of Ecology, Evolution, and Systematics 37:637–669.

Price, J.E., C.E. Zipper, J.W. Jones, and C. Franck. 2011. Water and sediment quality in the Clinch and Powell Rivers of Virginia and Tennessee, 1964–2010. Virginia Polytechnical Institute and State University, Blacksburg. 146 pp.

Rogers, S.O., B.T. Watson, and R.J. Neves. 2001. Life history and population biology of the endangered tan riffleshell (*Epioblasma florentina walkeri*) (Bivalvia: Unionidae). Journal of the North American Benthological Society 20(4):582–594.

Schmerfeld, J. 2006. Reversing a textbook tragedy. Endangered Species Bulletin 31:12–13.

Schmidt, R.E., R.D. Estes, and M.E. Gordon. 1989. Historical changes in the mussel fauna (Bivalvia: Unionoidea) of the Stones River, Tennessee. Malacological Review 22:55–60.

Strayer, D.L., and D. Dudgeon. 2010. Freshwater biodiversity conservation: recent progress and future challenges. Journal of the North American Benthological Society 29(1):344–358.

The Nature Conservancy. 2008. Indian Creek watershed initial stressor analysis: working document (2008 draft). Virginia Chapter, Abingdon.

Tilman, D., R.M. May, C.L. Lehman, and M.A. Nowak. 1994. Habitat destruction and the extinction debt. Nature 371:65–66.

U.S. Fish and Wildlife Service. 1984. Recovery Plan [for the] Tan [Riffleshell] Mussel *Epioblasma* (=*Dysnomia*) *walkeri*. 59 pp.

U.S. Fish and Wildlife Service. 1996. Formal Section 7 biological opinion and conference report on surface coal mining and reclamation operations under the Surface Mining Control and Reclamation Act of 1977. U.S. Fish and Wildlife Service, Washington, D.C. 15 pp.

U.S. Fish and Wildlife Service. 2004a. Multi-agency analysis of periphyton, fish, and benthic macroinvertebrate communities and the effects of point and non-point sources in the Indian Creek watershed, Tazewell County, Virginia. Virginia Field Office, Gloucester. 109 pp.

U.S. Fish and Wildlife Service. 2004b. Recovery plan for Cumberland Elktoe (*Alasmidonta atropurpurea*), Oyster Mussel (*Epioblasma capsaeformis*), Cumberlandian Combshell (*Epioblasma brevidens*), Purple Bean (*Villosa perpurpurea*), and Rough Rabbitsfoot (*Quadrula cylindrica strigillata*). Atlanta, Georgia. 174 pp.

Virginia Department of Mines, Minerals, and Energy. 2012. http://www.dmme.virginia.gov/DMR3/coal.shtml [and] http://205.254.135.7/coal/annual/

Wang, N., C.G. Ingersoll, D.K. Hardesty, C.D. Ivey, J.L. Kunz, T.W. May, F.J. Dwyer, A.D. Roberts, T. Augspurger, C.M. Kane, R.J. Neves, and M.C. Barnhart. 2007. Acute toxicity of ammonia, copper, and chlorine to glochidia and juveniles of freshwater mussels (Unionidae). Environmental Toxicology and Chemistry 26:2036–2047.

Watson, B.T., and R.J. Neves. 1998. A survey of the freshwater mussel fauna of Indian Creek, Tazewell County, Virginia. Virginia Polytechnic Institute and State University, Blacksburg. 18 pp.

Wilson, C.B., and H.W. Clark. 1914. The mussels of the Cumberland River and its tributaries. Report to the U.S. Commission of Fisheries for 1912, Special Papers. 63 pp.

Winston, M.R., and R.J. Neves. 1997. Survey of the freshwater mussel fauna of unsurveyed streams of the Tennessee River drainage, Virginia. Banisteria 10:3–8.

Zimmerman, L.L., R.J. Neves, and D.G. Smith. 2003. Control of predaceous flatworms *Macrostomum* sp. in culturing juvenile freshwater mussels. North American Journal of Aquaculture 65:28–32.

Reviewers: Steve Ahlstedt, USGS, retired (865/776-9510); Megan Bradley, VDGIF (276/783-2138), and Don Hubbs, TWRA (731/441-1941)

U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW of Tan Riffleshell (*Epioblasma florentina walkeri*)

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: Bob Butler, Asheville Ecological Services Field Office

FIELD OFFICE APPROVAL:

Lead Field Supervisor, Fish and Wildlife Service

Approve Anita Goetz, Acting Date 9/6/2013

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.

REGIONAL OFFICE APPROVAL:

The Regional Director or the Assistant Regional Director, if authority has been delegated to the Assistant Regional Director, must sign all 5-year reviews.

For
Lead Regional Director, Fish and Wildlife Service

Approve Aaron L Valenta Date 9-11-13

for
Cooperating Regional Director, Fish and Wildlife Service

X Concur ____ Do Not Concur

Signature Paul R. P Date 9/26/13

APPENDIX A: Summary of peer review for the 5-year review of tan riffleshell (*Epioblasma florentina walkeri*)

Reviewers: *A list of peer reviewers is provided above on page 25.*

A. Peer Review Method: A draft 5-year review of the tan riffleshell was sent to each of three reviewers, as an attachment to an email or via mail, requesting their review and any other changes or additions that should be included in the document. All three reviewers have extensive knowledge of this and similar species.

B. Peer Review Charge: Reviewers were charged with providing a review of the document including any other comments or additions they felt were appropriate to include. Reviewers were not asked to comment on the legal status of the species but were asked if they concurred with the documents' assessment.

C. Summary of Peer Review Comments/Report: Reviewers responded by email or by mail. All reviewers did not suggest that the status of the species needed to be changed and generally thought the information in the provided document was accurate. Some did provide additional data, references, and recommendations for future actions that were incorporated into the 5-year review as appropriate, as well as shared minor editorial corrections.

D. Response to Peer Review: Recommendations from the reviewers were incorporated into the document as appropriate. These consisted primarily of additional information concerning the status of certain populations, threats to the species, additional references, and recommendations for future actions.