Appendix H: Description of Cumulative Effects and Environmental Baseline of the Assessed Mussels

1. CUMULATIVE EFFECTS

Cumulative effects include the effects of future state, tribal, local, private, or other non-federal entity activities on endangered and threatened species and their critical habitat that are reasonably certain to occur in the action area. Future federal actions unrelated to the proposed action are not considered in this section because they are subject to consultation pursuant to section 7 of the ESA. Numerous non-federal actions that could affect listed species are reasonably certain to occur within the action area. These will typically include silviculture, mining, forestry, agriculture, grazing activities, dredging, construction activities such as bridge construction, and urban development. Each of these future activities could contribute to cumulative effects on listed species or their habitat in the action area.

2. ENVIRONMENTAL BASELINE

The environmental baseline is defined as the effects of past and ongoing human induced and natural factors leading to the status of the species, its habitat, and ecosystem, within the action area. The environmental baseline is a snapshot of the assessed mussel's status at this time. However, baseline condition of each of the assessed mussel's habitat varies across locations and even within each stream/river. Details of the mussels' habitat description and known locations are included in Appendix C. Given the large number of habitats and extent of the action area included of this assessment, the discussion of environmental baseline is limited to a general discussion of factors that may affect freshwater mussels within the action area and was provided by U.S. FWS (2007). In addition, some recent biological opinions have been prepared by the U.S. FWS that provide information on environmental baseline of the assessed mussels. These are summarized in Attachment 1 and 2 of this appendix.

2.1. Factors affecting species environment within the action area

The decline, extirpation, and extinction of mussel species is overwhelmingly attributed to habitat alteration and destruction (Neves 1993). Dredging and channelization activities have profoundly altered riverine habitats nationwide. Channelization impacts a stream's physical (e.g., accelerated erosion, increased bedload, reduced depth, decreased habitat diversity, geomorphic instability, riparian canopy loss) and biological (e.g., decreased fish and mussel diversity, changed species composition and abundance, decreased biomass, and reduced growth rates) characteristics (Hartfield 1993; Hubbard *et al*. 1993). Channel construction for navigation has been shown to increase flood heights (Belt 1975). This is partially attributed to a decrease in stream length and increase in gradient (Hubbard et al. 1993). Flood events may thus be exacerbated, conveying into streams large quantities of sediment, potentially with adsorbed contaminants. Channel maintenance may result in profound impacts downstream (Stansbery 1970).

Channel maintenance operations for barge navigation likely has impacted habitat for the pink mucket in the Ouachita River. Impacts include increases in turbidity that may impede sight-feeding host fishes and potentially disrupt mussel attractant mechanisms to lure fish hosts (Hartfield and Hartfield 1996) and sedimentation that may smother juvenile mussels (Ellis 1936). Periodic navigation maintenance activities may continue to adversely affect this species in the Ouachita River downstream of Camden, Arkansas.

Contaminants in point and non-point discharges can degrade water and substrate quality, and adversely impact or destroy mussel populations. The effects of heavy metals, ammonia, and other contaminants on freshwater mussels were reviewed by Mellinger (1972), Fuller (1974), Havlik and Marking (1987), Naimo (1995), Keller and Lydy (1997), Neves *et al*. (1997), and Newton (2003). Although chemical spills and other point sources (e.g., ditch, swale, artificial channel, drainage pipe) of contaminants may directly result in mussel mortality, widespread decreases in density and diversity result in part from the subtle, pervasive effects of chronic, low-level contamination (Naimo 1995).

Among pollutants, ammonia warrants priority attention for its effects on mussels (Augspurger *et al*. 2003), and has been shown to be lethal at concentrations of 5.0 parts per million (ppm) (Havlik and Marking 1987). The un-ionized form of ammonia (NH_3) is usually attributed as being the most toxic to aquatic organisms (Mummert *et al*. 2003), although the ammonium ion form (NH_4^+) may contribute to toxicity under certain conditions (Newton 2003). Sources of ammonia are agricultural (e.g., animal feedlots, nitrogenous fertilizers), municipal (e.g., waste water treatment plant effluents), and industrial (e.g., chemical companies) as well as from precipitation and natural processes (e.g., decomposition of organic nitrogen) (Augspurger *et al.* 2003; Newton 2003). Atmospheric deposition is one of the most rapidly growing sources of anthropogenic nitrogen entering aquatic ecosystems (Newton 2003). Agricultural sources of ammonia may be highly variable over time, compounding the determination of accurate concentration readings.

Agricultural sources of chemical contaminants are considerable and include two broad categories: nutrients and pesticides (Frick *et al.* 1998). Nutrient enrichment generally results from runoff from livestock farms and feedlots, and fertilizers from row crops. Nitrate concentrations are particularly high in surface waters downstream of agricultural areas (Mueller *et al.* 1995). Stream ecosystems are impacted when nutrients are added at concentrations that cannot be assimilated, resulting in over-enrichment, a condition exacerbated by low-flow conditions. Juvenile mussels utilizing interstitial habitats are particularly affected by depleted dissolved oxygen (DO) levels resulting from over-enrichment (Sparks and Strayer 1998). Increased risks from bacterial and protozoan infections to eggs and glochidia (Fuller 1974) and to host fishes may also pose a threat. Pesticide runoff commonly ends up in streams where the effects (based on studies with laboratory-tested mussels) may be particularly profound (Fuller 1974; Havlik and Marking 1987). Fertilizers and pesticides are also commonly used in developed areas.

Various mining activities take place in the lower Ouachita River system that have potentially affected or potentially continue to impact pink mucket populations. Oil and gas production is common in the southern portion of the action area. Pollutants from these activities include brines and organics. Bauxite mining also takes place in portions of the Saline River system.

Excessive sedimentation is a pervasive problem with an estimated 46 percent of all U.S. streams affected (Judy *et al.* 1984). Sedimentation, including siltation, has been implicated in the decline of stream mussel populations (Ellis 1936; Marking and Bills 1979; Vannote and Minshall 1982; Dennis 1985; Brim Box and Mossa 1999; Fraley and Ahlstedt 2000). Specific biological impacts on mussels from excessive sediment include reduced feeding and respiratory efficiency from clogged gills, disrupted metabolic processes, reduced growth rates, increased substrate instability, limited burrowing activity, and physical smothering (Ellis 1936; Stansbery 1971; Marking and Bills 1979; Vannote and Minshall 1982; Waters 1995). Primary productivity reduction is an indirect impact that affects mussel food supplies (Henley *et al.* 2000). Studies tend to indicate that the primary impacts of excess sediment levels on mussels are sublethal, with detrimental effects not immediately apparent (Brim Box and Mossa 1999). The physical effects of sediment on mussels appear to be multifold, and include:

1. changes in suspended and bed material load;
2. bed sediment composition associated with increased sediment production and run-off in the watershed;
3. channel changes in form, position, and degree of stability;
4. changes in depth or the width/depth ratio that affects light penetration and flow regime;
5. actively aggrading (filling) or degrading (scouring) channels; and
6. changes in channel position that may leave mussels high and dry (Vannote and Minshall 1982; Kanehl and Lyons 1992; Brim Box and Mossa 1999).

Interstitial spaces in the substrate provide crucial habitat for juvenile mussels. When clogged, interstitial flow rates and spaces become reduced (Brim Box and Mossa 1999), thus reducing juvenile habitat. Sediment acts as a vector for delivering contaminants such as nutrients and pesticides to streams. Juveniles can readily ingest contaminants adsorbed to silt particles or in interstitial pore water during normal feeding activities (Yeager *et al.* 1994; Newton 2003). These factors may help explain, in part, why so many mussel populations, potentially including certain pink mucket populations, are experiencing recruitment failure.

Agricultural activities produce the most significant amount of sediment that enters streams (Waters 1995; Henley *et al.* 2000). Neves *et al.* (1997) stated that agriculture (including both sediment and chemical run-off) affects 72 percent of the impaired river miles in the country. Croplands located on river banks and unrestricted stream access by livestock is not common in the lower Ouachita River basin, but is a significant threat to many streams. Grazing may reduce infiltration rates, decrease filtering capacity of pollutants (thereby increasing sedimentation run-off), and trampling and eventual elimination of woody vegetation reduces bank resistance to erosion and contributes to increased water temperatures (Armour *et al.* 1991; Trimble and Mendel 1995; Brim Box and Mossa 1999; Henley *et al.* 2000).

Erosion from silvicultural activities accounts for 6 percent of national sediment pollution (Henley *et al*. 2000). Sedimentation impacts are more the result of logging roads than from the actual harvesting of timber (Waters 1995; Brim Box and Mossa 1999). Annual run-off and/or peak flow volumes increase with timber harvests, particularly during the wet season (Allan

1995). This is partially due to the construction of logging roads, and vegetation removal tends to compact soils, reduce infiltration rates, and increase soil erosion. Increased flows and improper harvesting within streamside management zones may result in stream channel changes (Brim Box and Mossa 1999) that may ultimately affect mussel beds.

Water withdrawals for agricultural irrigation, municipal, and industrial water supplies are an increasing concern for all aquatic resources and are directly correlated with expanding human populations. Impacts include decreased flow velocities and DO levels (Johnson *et al.* 2001). Such stochastic events may be exacerbated by global climate change and water withdrawals. These primarily anthropogenic activities act insidiously to lower water tables, thus making mussel populations susceptible to depressed stream levels.

Attachment 1. Summary of Biological Opinions prepared by the U.S. FWS on the Assessed Freshwater Mussels

Description of Federal Action	**Citation**	**Location**	**Mussel Species**	**Magnitude of Take**	**Jeopardy Call**
Luxapallila Creek Segment Flood Control Project	U.S. FWS, 1996.	Tombigbee Rivers and Tribs, Luxapallila Creek Segment, Lowndes County, MS and Lamar County, AL	Ovate clubshell, southern clubshell mussel, and Alabama moccasinshell orange-nacre mucket	The Service believes that incidental take of the four listed mussel species resulting from Project construction actions (i.e., channelization, installation of the GCS's, and reexcavation of the lower 2.1-mile reach) would be minimized, limited to the 5-mile reach of Luxapallila Creek upstream from the Waterworks Road bridge, and continue for no more than 5 years after the issuance of this opinion.	Not likely to result in jeopardy Jeopardy call based on the limited nature of the Project and the existence of other populations of these species that are unaffected by the Project.
Maintenance dredging	U.S. FWS, 1999.	Tennessee River, Hardin County, TN	Cracking pearly, Fanshell, Orange-footed pearly, Pink mucket, Ring pink, Rough pigtoe, White wartyback	The Service believes that no more than 25 percent of individuals of the listed mussel species present in the dredge sites will be incidentally taken.	Not likely to result in jeopardy
Bridge replacement	U.S. FWS, 2000	Tennessee River in Madison and Morgan Counties, AL	Pink mucket pearly mussel, Rough pigtoe	Incidental take during existing bridge demolition and removal is limited to one *Pleurobema plenum* and 17 *Lampsilis abrupta*.	Not likely to result in jeopardy Jeopardy call based on the limited and localized extent of the activity
Chickamauga lock project	U.S. FWS, 2002a	Tennessee River, Hamilton county, TN	Pink mucket pearly mussel, orange-foot pimpleback	No incidental take is expected to occur	No jeopardy call per se, but no take is anticipated
mussel relocation experiment	U.S. FWS, 2002b	Tennessee River, Hardin County, TN	White wartyback pearly mussel, Rough pigtoe pearly mussel, Ring pink, Fanshell, Cracking pearly mussel	One individual of each species may exist there and could possibly be incidentally taken during implementation of the proposed experiment	Not likely to result in jeopardy
Bridge construction	U.S. FWS, 2003a	Ouachita River; Hot Springs County, Arkansas	Pink mucket	Indeterminate number may be harmed due to sedimentation	Not likely to result in jeopardy Pink mussels will be artificially propagated to compensate for any loss in reproductive success or incidental take
Enhancement of Survival Permit	U.S. FWS, 2003b	Chewacla creek, Lee county, AL	Ovate clubshell, southern clubshell, fine-lined pocketbook	No take anticipated	Not likely to result in jeopardy

Description of Federal Action	Citation	Location	Mussel Species	Magnitude of Take	Jeopardy Call
Mussel relocation experiment	U.S. FWS, 2003c	TN River, Hardin County, TN	Pink mucket, fanshell, orangefoot pimpleback, white wartyback, rough pigtoe, ring pink, and cracking pearlymussel	Level of take was estimated to be one individual of each species.	Not likely to result in jeopardy
Bridge construction	U.S. FWS, 2004	Saline river, Grant County, Arkansas	Pink mucket	Level of take was estimated to be 1 mussel or 5% of the mussels re-located from the site, whichever is greater.	Not likely to result in jeopardy
Bridge construction	U.S. FWS, 2005	Cahaba River, Shelby County, AL	Southern acornshell, ovate clubshell, southern clubshell, upland combshell, triangular kidneyshell, Alabama moccasinshell, orange-nacre mucket, and the fine-lined pocketbook	No take anticipated	Species is outside of the action area; destruction or adverse modification of criticial habitat is not anticipated
Bridge construction	U.S. FWS, 2006a	Saline River, Grant County, Arkansas	Pink mucket	Level of take was estimated to be no more than two individuals.	Not likely to result in jeopardy
Healthy Forest Reserve Program	U.S. FWS, 2006b	Arkansas	Pink mucket, winged mapleleaf, and Ouachita rock-pocketbook	Magnitude of potential take unable to be determined.	Not likely to result in jeopardy
River Enhancement Project	U.S. FWS, 2006c	Clinch River, Hancock County, TN	Slender chub, Pygmy madtom, Birdwing pearly mussel, Dromedary pearly mussel, Shiny pigtoe, Fine-rayed pigtoe, Fanshell, Cumberlandian combshell, Cumberlandian combshell, Cracking pearly mussel, Oyster mussel, Rough rabbitsfoot, Little-wing pearly mussel, pink mucket pearly mussel,rough pigtoe	Anticipated level of take varied for each species and ranged from 5 to 4,753 individuals.	Not likely to result in jeopardy
Water control project	U.S. FWS, 2006d	Tennessee River/AL, GA, KY, NC, TN, VA	Fanshell, Dromedary pearly mussel, Cumberlandian combshell, Oyster mussel, Shiny pigtoe, Fine-rayed pigtoe, Cracking pearly mussel, Pink mucket pearly mussel, Birdwing pearly mussel, Ring pink, White wartyback, Orangefoot pimpleback, Rough pigtoe, Cumberland monkeyface pearly mussel	Not likely to adversely affect determination was made for several species not included in this table. Take is expected for several 2-mile stretches of habitat in the TN river for each of the species included in this table except the oyster mussel.	Not likely to result in jeopardy

Attachment 1 References.

U.S. FWS. 1996. Biological Opinion. Letter to District Engineer, U. S. Army Corps of Engineers from U.S. FWS (C4-3-96-071C). September 12, 2006.

U.S. FWS. 1999. Biological Opinion. Biological Opinion For Proposed Maintenance Dredging In The Tennessee River At Diamond Island Hardin County, Tennessee. Ecological Services Field Office, Cookeville, Tennessee. July, 1999.

U.S. FWS. 2000. Biological Opinion. Letter to Mr. Joe D. Wilkerson, Division Administrator, Federal Highway Administration from Fish and Wildlife Service. February 18, 2000.

U.S. FWS. 2002a. Biological Opinion For The Proposed Chickamauga Lock Project Hamilton County, Tennessee. Ecological Services Field Office, Cookeville, TN. February, 2002.

U.S. FWS. 2002b. Biological Opinion. Letter to Colonel Steven W. Gay, U.S. Army Corps of Engineers from Fish and Wildlife Service (FWS #02-1906). September 9, 2002.

U.S. FWS. 2003a. Biological Opinion. Letter to Mr. Randal Looney, Federal Highway Administration, Arkansas Division from Fish and Wildlife Service. July 29, 2003.

U.S. FWS. 2003b. Biological Opinion. Letter to Regional Director, FWS, Atlanta, GA from Field Supervisor, FWS, Daphne, AL. Subject: Biological opinion for intra-agency consultation on the proposed Chewacla Creek Safe Harbor Agreement for the conservation of the endangered ovate clubshell mussel (*Pleurobema perovatum*) and southern clubshell mussel (*Pleurobema decisum*), and the threatened fine-lined pocketbook (*Lampsilis altilis*) in Chewacla Creek, Lee County, Alabama. August 6, 2003.

U.S. FWS. 2003c. Biological Opinion. Letter to Lieutenant Colonel Byron G. Jorns District Engineer, U.S. Army Corps of Engineers from U.S. Fish and Wildlife Service 9 FWS #03-1578). November 13, 2003.

U.S. FWS. 2004. Biological Opinion. Letter to Mr. Randal Looney, Federal Highway Administration, Arkansas Division from U.S. FWS. July 7, 2004.

U.S. FWS. 2005. Biological Opinion. Letter to Mr. Joe D. Wilkerson, Division Administrator, Federal Highway Administration from U.S. FWS. January 18, 2005.

U.S. FWS. 2006a. Biological Opinion. Letter to Mr. Randal Looney, Federal Highway Administration, Arkansas Division from U.S. FWS. January 30, 2006.

U.S. FWS. 2006b. Biological Opinion. Programmatic Biological Assessment And Programmtic Biological Opinion For The Natural Resources Conservation Service's

Arkansas Healthy Forest Reserve Program. September 25, 2006.

U.S. FWS. 2006c. Biological Opinion. Letter to Lieutenant Colonel Steven J. Roemhildt from Fish and Wildlife Service (FWS Log No. 06-FC-1028; 06-I-0231). October 10, 2006.

U.S. FWS. 2006d. Biological Opinion. Letter to Ms. Kathryn Jackson Executive Vice President of River Operations and Environment, Tennessee Valley Authority. October 16, 2006.

U.S. FWS. 2007. Personal email communication between Marjorie Nelson and Anita Pease on 01/18/2007. Data from file entitled Status and baseline for mussels in the AR HFRP BO.doc.

Attachment 2. Exerpts from Biological Opinions listed in Attachment 1 that describe environmental baseline of the assessed species.

U.S. FWS, 2006a
Species: Pink Mucket
Location: Saline river, Grant County, AR

Status of the species within the action area
The Saline River system is inhabited by several federally protected mussels including the pink mucket (*Lampsilis abrupta*), Arkansas fatmucket (*L. powellii*), and the winged mapleleaf (*Quadrula fragosa*) (Harris *et al.* 1997, Davidson and Clem 2002, 2004). Pink mucket was the only potential inhabitant near the project vicinity (Davidson and Clem 2002). The Arkansas fatmucket generally occurs in streams flowing through uplands with its distribution upstream of Arkansas Highway 270 (Davidson and Clem 2002). The winged mapleleaf appears to have an affinity for larger river habitat than that found in the project area (Harris 2000) and occurs approximately 50 river kilometers downstream of the proposed site (Davidson and Clem 2002, 2004). The general habitat type within the survey reach was deemed suitable to support pink mucket; however, previous surveys conducted within the project area did not encounter any of the three species (Davidson and Clem 2002). Davidson and Clem (2002) noted that mussel Bed #27, located 1.8 miles upstream of the project location, was estimated at 190 m^2 with average mussel density of 20 mussels/m^2 and contained one pink mucket. Mussel Concentration #36, located 2.5 miles downstream of the project area, was estimated at 200 m^2 with average mussel density of eight mussels/m^2 and contained one pink mucket. Results suggest that occurrence of the pink mucket within this stretch of the Saline River is rare.

Factors affecting species environment within the action area
To adequately evaluate the effects of permit activities covered in this biological opinion, the Service must not only consider the impacts from the activities addressed in the biological opinion, but also must consider other, separate effects currently ongoing and likely to occur in the foreseeable future that also could have adverse impacts to pink mucket. To accomplish this the Service considers other incidental take statements, incidental take permits issued, recovery permits issued, other section 7 consultations, and cumulative impacts.

Currently, four individuals or entities retain active Section 10(a)1(A) permits for pink mucket in Arkansas. There has been no report of incidental take in the form of injury or death reported by any of the permittees.

A March 2002 biological opinion for pink mucket populations on the White River in Arkansas issues incidental take of five pink muckets per year as a result of dredging operations for navigational purposes. Construction of the Rockport Bridge across the Ouachita River also yielded a July 2003 biological opinion that granted incidental take in the form of harm or harassment. No other biological opinions have been written for the pink mucket in the previous five years.

Currently, sedimentation from forest practices likely has the largest impact on pink mucket populations occurring within the Saline River. Timber harvest along the Saline is prevalent on private lands (Davidson and Clem 2002, 2004). Riparian forests are integral to stream ecosystem function. Loss of riparian habitat can lead to stream bank destabilization, channel alteration, and loss of aquatic habitat diversity (Davidson and Clem 2002, 2004). Improperly maintained riparian habitats may adversely affect species diversity and biological productivity by degrading water quality, energy sources, and altering flow regimes and physical habitat (Roell 1994).

Butler (2005) summarized the effects of sedimentation on freshwater mussels, in part, as follows:

> *Excessive sedimentation is a pervasive problem with an estimated 46% of all U.S. streams affected (Judy et al. 1984). Sedimentation, including siltation, has been implicated in the decline of stream mussel populations (Kunz 1898, Ellis 1936, Marking and Bills 1979, Vannote and Minshall 1982, Dennis 1985, Brim Box 1999, Fraley and Ahlstedt 2000, Poole and Downing 2004). Sources, biological effects, and the control of sediment in streams were thoroughly reviewed by Waters (1995). Brim Box and Mossa (1999) and Henley et al. (2000) reviewed how mussels are specifically affected by sediment, and discussed land-use practices and remediation measures that may affect mussels and stream habitats. Specific biological impacts on mussels from excessive sediment include reduced feeding and respiratory efficiency from clogged gills, disrupted metabolic processes, reduced growth rates, increased substrate instability, limited burrowing activity, and physical smothering (Ellis 1936, Stansbery 1971, Marking and Bills 1979, Vannote and Minshall 1982, Waters 1995). Primary productivity reduction is an indirect impact that affects mussel food supplies (Henley et al. 2000). Studies tend to indicate that the primary impacts of excess sediment levels on mussels are sublethal, with detrimental effects not immediately apparent (Brim Box and Mossa 1999). The physical effects of sediment on mussels appear to be multifold, and include changes in suspended and bed material load; bed sediment composition associated with increased sediment production and run-off in the watershed; channel changes in form, position, and degree of stability; changes in depth or the width/depth ratio that affects light penetration and flow regime; actively aggrading (filling) or degrading (scouring) channels; and changes in channel position that may leave mussels high and dry (Vannote and Minshall 1982, Kanehl and Lyons 1992, Brim Box and Mossa 1999).*
>
> *Interstitial spaces in the substrate provide crucial habitat for juvenile mussels. When clogged, interstitial flow rates and spaces become reduced (Brim Box and Mossa 1999), thus reducing juvenile habitat. Sediment acts as a vector for delivering contaminants such as nutrients and pesticides to streams. Juveniles can readily ingest contaminants adsorbed to silt particles or in interstitial pore water during normal feeding activities (Yeager et al. 1994, Newton 2003). These factors may help explain, in part, why so many mussel populations, potentially including certain rabbitsfoot populations, are experiencing recruitment failure.*
>
> *Turbidity has been considered the most detrimental of water quality parameters affecting a third of all U.S. streams (Judy et al. 1984). Many rabbitsfoot streams in the Midwest and Southeast have increased turbidity levels due to siltation. It produces conglutinates that appear to function in attracting visual-feeding host fishes. Such a reproductive strategy*

depends on clear water when mussels are releasing glochidia (Hartfield and Hartfield 1996). In addition, mussels may be indirectly affected when turbidity levels significantly reduce the amount of light available for photosynthesis and the production of unionid food items (Kanehl and Lyons 1992).

Erosion from silvicultural activities accounts for 6% of national sediment pollution (Henley et al. 2000). Sedimentation impacts are more the result of logging roads than from the actual harvesting of timber (Waters 1995, Brim Box and Mossa 1999). Annual run-off and/or peak flow volumes increase with timber harvests, particularly during the wet season (Allan 1995). This is partially due to the construction of logging roads, and vegetation removal tends to compact soils, reduce infiltration rates, and increase soil erosion. Increased flows and improper harvesting within streamside management zones may result in stream channel changes (Brim Box and Mossa 1999) that may ultimately affect mussel beds.

U.S. FWS, 2006b
Species: Pink Mucket
Location: Saline and Ouachita River

Status of the species within the action area

The Saline and Ouachita River systems are inhabited by the pink mucket (*Lampsilis abrupta*) (Posey, 1997; Harris *et al.* 1997; Davidson and Clem 2002, 2004). Davidson and Clem (2002) reported pink mucket from 13 Saline River sites upstream of the action area in Grant, Dallas, and Cleveland counties. The species is extremely rare upstream of Arkansas Highway 167. While more common downstream of Arkansas Highway 167 to the confluence with the Ouachita River, the species is never locally abundant (Davidson and Clem 2002, 2004). Davidson and Clem (2004) collected pink mucket at six Saline River sites in the action area (Bradley and Ashley counties). Harris (2006) collected pink mucket at four of four sites quantitatively sampled downstream of Longview Landing. Percent total composition per mussel bed was less than 0.5 percent at all four sites. An accurate population estimate for the species is difficult to assess due to the rare occurrence of the pink mucket within the Saline River.

In the Ouachita River, most pink mucket sites are located upstream of Camden, Arkansas (Posey, 1997). Posey (1997) collected three pink mucket from two sites downstream of Camden, Arkansas (within action area). As with the Saline River, comprehensive surveys have been conducted on the entire river within the action area. Surveys since Posey (1997) have generally been focused on threatened and endangered species sites concentrated upstream of the action area. An accurate population estimate for the species is difficult to assess due to the rare occurrence of the pink mucket within the Ouachita River.

Factors affecting species environment within the action area

The decline, extirpation, and extinction of mussel species is overwhelmingly attributed to habitat alteration and destruction (Neves 1993). Dredging and channelization activities have profoundly altered riverine habitats nationwide. Channelization impacts a stream's physical (e.g., accelerated erosion, increased bedload, reduced depth, decreased habitat diversity, geomorphic instability, riparian canopy loss) and biological (e.g., decreased fish and mussel diversity, changed species composition and abundance, decreased biomass, and reduced growth rates) characteristics (Hartfield 1993; Hubbard *et al*. 1993). Channel construction for navigation has been shown to increase flood heights (Belt 1975). This is partially attributed to a decrease in stream length and increase in gradient (Hubbard et al. 1993). Flood events may thus be exacerbated, conveying into streams large quantities of sediment, potentially with adsorbed contaminants. Channel maintenance may result in profound impacts downstream (Stansbery 1970).

Channel maintenance operations for barge navigation likely has impacted habitat for the pink mucket in the Ouachita River. Impacts include increases in turbidity that may impede sight-feeding host fishes and potentially disrupt mussel attractant mechanisms to lure fish hosts (Hartfield and Hartfield 1996) and sedimentation that may smother juvenile mussels (Ellis 1936). Periodic navigation maintenance activities may continue to adversely affect this species in the Ouachita River downstream of Camden, Arkansas.

Contaminants in point and non-point discharges can degrade water and substrate quality, and adversely impact or destroy mussel populations. The effects of heavy metals, ammonia, and other contaminants on freshwater mussels were reviewed by Mellinger (1972), Fuller (1974), Havlik and Marking (1987), Naimo (1995), Keller and Lydy (1997), Neves *et al*. (1997), and Newton (2003). Although chemical spills and other point sources (e.g., ditch, swale, artificial channel, drainage pipe) of contaminants may directly result in mussel mortality, widespread decreases in density and diversity result in part from the subtle, pervasive effects of chronic, low-level contamination (Naimo 1995).

Among pollutants, ammonia warrants priority attention for its effects on mussels (Augspurger *et al*. 2003), and has been shown to be lethal at concentrations of 5.0 parts per million (ppm) (Havlik and Marking 1987). The un-ionized form of ammonia (NH_3) is usually attributed as being the most toxic to aquatic organisms (Mummert *et al*. 2003), although the ammonium ion form (NH_4^+) may contribute to toxicity under certain conditions (Newton 2003). Sources of ammonia are agricultural (e.g., animal feedlots, nitrogenous fertilizers), municipal (e.g., waste water treatment plant effluents), and industrial (e.g., chemical companies) as well as from precipitation and natural processes (e.g., decomposition of organic nitrogen) (Augspurger *et al.* 2003; Newton 2003). Atmospheric deposition is one of the most rapidly growing sources of anthropogenic nitrogen entering aquatic ecosystems (Newton 2003). Agricultural sources of ammonia may be highly variable over time, compounding the determination of accurate concentration readings.

Agricultural sources of chemical contaminants are considerable and include two broad categories: nutrients and pesticides (Frick *et al.* 1998). Nutrient enrichment generally results from runoff from livestock farms and feedlots, and fertilizers from row crops. Nitrate concentrations are particularly high in surface waters downstream of agricultural areas (Mueller *et al.* 1995). Stream ecosystems are impacted when nutrients are added at concentrations that cannot be assimilated, resulting in over-enrichment, a condition exacerbated by low-flow conditions. Juvenile mussels utilizing interstitial habitats are particularly affected by depleted dissolved oxygen (DO) levels resulting from over-enrichment (Sparks and Strayer 1998). Increased risks from bacterial and protozoan infections to eggs and glochidia (Fuller 1974) and to host fishes may also pose a threat. Pesticide runoff commonly ends up in streams where the effects (based on studies with laboratory-tested mussels) may be particularly profound (Fuller 1974; Havlik and Marking 1987). Fertilizers and pesticides are also commonly used in developed areas.

Various mining activities take place in the lower Ouachita River system that have potentially affected or potentially continue to impact pink mucket populations. Oil and gas production is common in the southern portion of the action area. Pollutants from these activities include brines and organics. Bauxite mining also takes place in portions of the Saline River system.

Excessive sedimentation is a pervasive problem with an estimated 46 percent of all U.S. streams affected (Judy *et al.* 1984). Sedimentation, including siltation, has been implicated in the decline of stream mussel populations (Ellis 1936; Marking and Bills 1979; Vannote and Minshall 1982; Dennis 1985; Brim Box and Mossa 1999; Fraley and Ahlstedt 2000). Specific biological impacts on mussels from excessive sediment include reduced feeding and respiratory efficiency from clogged gills, disrupted metabolic processes, reduced growth rates, increased substrate instability, limited burrowing activity, and physical smothering (Ellis 1936; Stansbery 1971; Marking and Bills 1979; Vannote and Minshall 1982; Waters 1995). Primary productivity reduction is an indirect impact that affects mussel food supplies (Henley *et al.* 2000). Studies tend to indicate that the primary impacts of excess sediment levels on mussels are sublethal, with detrimental effects not immediately apparent (Brim Box and Mossa 1999). The physical effects of sediment on mussels appear to be multifold, and include:

7. changes in suspended and bed material load;

8. bed sediment composition associated with increased sediment production and run-off in the watershed;

9. channel changes in form, position, and degree of stability;

10. changes in depth or the width/depth ratio that affects light penetration and flow regime;

11. actively aggrading (filling) or degrading (scouring) channels; and

12. changes in channel position that may leave mussels high and dry (Vannote and Minshall 1982; Kanehl and Lyons 1992; Brim Box and Mossa 1999).

Interstitial spaces in the substrate provide crucial habitat for juvenile mussels. When clogged, interstitial flow rates and spaces become reduced (Brim Box and Mossa 1999), thus reducing juvenile habitat. Sediment acts as a vector for delivering contaminants such as nutrients and pesticides to streams. Juveniles can readily ingest contaminants adsorbed to silt particles or in interstitial pore water during normal feeding activities (Yeager *et al.* 1994; Newton 2003). These factors may help explain, in part, why so many mussel populations, potentially including certain pink mucket populations, are experiencing recruitment failure.

Agricultural activities produce the most significant amount of sediment that enters streams (Waters 1995; Henley *et al.* 2000). Neves *et al.* (1997) stated that agriculture (including both sediment and chemical run-off) affects 72 percent of the impaired river miles in the country. Croplands located on river banks and unrestricted stream access by livestock is not common in the lower Ouachita River basin, but is a significant threat to many streams. Grazing may reduce infiltration rates, decrease filtering capacity of pollutants (thereby increasing sedimentation run-off), and trampling and eventual elimination of woody vegetation reduces bank resistance to erosion and contributes to increased water temperatures (Armour *et al.* 1991; Trimble and Mendel 1995; Brim Box and Mossa 1999; Henley *et al.* 2000).

Erosion from silvicultural activities accounts for 6 percent of national sediment pollution (Henley *et al*. 2000). Sedimentation impacts are more the result of logging roads than from the actual harvesting of timber (Waters 1995; Brim Box and Mossa 1999). Annual run-off and/or peak flow volumes increase with timber harvests, particularly during the wet season (Allan 1995). This is partially due to the construction of logging roads, and vegetation removal tends to compact soils, reduce infiltration rates, and increase soil erosion. Increased flows and improper harvesting within streamside management zones may result in stream channel changes (Brim Box and Mossa 1999) that may ultimately affect mussel beds.

Water withdrawals for agricultural irrigation, municipal, and industrial water supplies are an increasing concern for all aquatic resources and are directly correlated with expanding human populations. Impacts include decreased flow velocities and DO levels (Johnson *et al.* 2001). Such stochastic events may be exacerbated by global climate change and water withdrawals. These primarily anthropogenic activities act insidiously to lower water tables, thus making mussel populations susceptible to depressed stream levels.

U.S. FWS. 2006c.
Species: Shiny pigtoe, Fine-rayed pigtoe, pink mucket pearly mussel,rough pigtoe
Location: Clinch River, Hancock County, TN

The Clinch River is one of three major tributaries of the upper Tennessee River Basin. It originates in western Virginia, flows southwesterly for approximately 145 miles into Tennessee, then continues for an additional 203 miles, joining the Tennessee River at River Mile 567.8. It has a drainage area of more than 4,400 square miles and it flows through two physiographic regions (i.e., Ridge and Valley, Cumberland Plateau). The majority of the Clinch River watershed is rural in nature; forest covers almost 50 percent and row-cropping is the predominant land use. Other land uses include surface coal mining and rock quarrying.

As have many of the rivers in the Tennessee River Basin, the Clinch River has been physically altered. Three dams constructed by the Tennessee Valley Authority have converted free-flowing riverine habitat to lake-like conditions. Watts Bar Dam on the Tennessee River, completed in 1942, impounds the lowermost reach of the Clinch River to River Mile 10. Melton Hill Dam, located at Clinch River Mile 23.1, was completed in 1963 and impounds the river to River Mile 60. Norris Dam is located at Clinch River Mile 79.8. It was completed in 1936 and impounds the river to approximately River Mile 148. (Ahlstedt 1991)

Compared with other streams in the upper Tennessee River Basin and despite past perturbations, water quality in the Clinch River is generally good. The only major municipalities adjacent to the river are the cities of Clinton and Oak Ridge, located on Melton Hill Lake in Tennessee. Discharges from those cities and from the Oak Ridge National Laboratory have likely affected water quality in the lower reach of the river. Despite its rural setting, significant adverse impacts to the upper reaches of the river have also occurred. Spills of fly ash in 1967 and sulfuric acid in 1971 from a steam-generated electric plant in Carbo, Virginia (Clinch River Mile 267.0), resulted in major kills of fish and mussels for fifteen or more miles downriver (Ahlstedt 2005). More recently, a vehicle accident resulted in a spill of Octocure-554, a rubber accelerant, near Cedar Bluff, Virginia, causing a kill of hundreds of fish and mussels, including several endangered species, for more than six miles downriver (Ahlstedt 2005). In addition, the upper portion of the Clinch River drainage contains numerous abandoned surface coal mines which may be contributing coal fines, sediment, and possibly acidic discharges and other contaminants into the river. Coal mining activities have recently begun again in the upper Clinch River drainage and could result in further adverse impacts to the river habitat and the aquatic fauna (Ahlstedt 2005).

Historical and current activities have adversely impacted the habitat and aquatic fauna in the Clinch River. Extensive logging in the late 1800's and early 1900's likely introduced substantial amounts of sediment into the river; and use of the river to float logs to markets downstream likely destroyed or significantly altered some of the shoal habitat. Prior to and during this period there was also a substantial amount of deep mining for coal in the Clinch River drainage, and in the early 1950's surface coal mining activity began. Numerous "blackwater" releases of coal fines and sediment have been noted in the Clinch River since then. Chemicals used at facilities to wash and process raw coal have also likely contributed to water quality problems in the Clinch River. (Ahlstedt 2005)

The action area is located between Clinch River miles 189.0 and 190.0. The nearest municipality is the town of Sneedville, located at River Mile 177.5. Adjacent land use consists of forest, scattered residences, and pastureland. Two highway bridges cross the river in the vicinity of the action area: State Route 33 at Sneedville (CRM 177.4) and State Route 70 at Kyles Ford (CRM 189.8). Recently, timber harvest activities at Testerman Hollow, adjacent to the action area, resulted in sedimentation of the river. Also, biologists conducting surveys in and around the action area have reported substantial amounts of coal fines on the river bottom, likely the result of coal mining upriver in Virginia.

Status of the species within the action area

The shiny pigtoe is currently very rare in the action area. Biologists conducting mussel surveys over the past 30 years have reported the species in low numbers in the river reach from Sneedville to the Tennessee/Virginia border.

The fine-rayed pigtoe is currently very rare in the action area. The species has been collected only in low numbers in the river reach from Sneedville to the Tennessee/Virginia border during recent surveys.

The pink mucket pearly mussel is currently rare in the action area. Fresh dead shells have been recently collected in the Clinch River downstream from the action area at river miles 158.0 and 179.7. If the species exists in the action area, it occurs in low numbers.

The rough pigtoe is currently rare in the action area. Live individuals have been collected downstream from the action area at river miles 178.7, 179.7, and 183.4 (Brooks Island). It is likely that the rough pigtoe exists in the action area in low numbers.

Factors affecting species environment within the action area

The left descending riverbank in the action area continues to erode. High-flow events continue to cut into the riverbank, resulting in sedimentation of the river. Observational evidence indicates that riverbank erosion is progressing downriver. As the riverbank sloughs off, the river channel widens, altering the flow pattern in the action area and potentially disrupting mussel habitat. Sediment moves downriver, adversely affecting aquatic resources.

Over the past ten years, biologists conducting surveys at Kyles Ford have reported increasing amounts of coal fines in the river (Ahlstedt pers. comm. 2006). Some reports are of substantial amounts of fines in areas where coal fines were not observed in previous years (Hubbs pers. comm. 2006). This is likely the result of increased mining activity in the upper Clinch River drainage.

Inspection of a recent logging operation in Testerman Hollow, adjacent to Kyles Ford, revealed sedimentation in the Clinch River originating from an eroding access road to the logging site. The operator subsequently instituted Best Management Practices to eliminate runoff of sediment from the logging site.

U.S. FWS. 2006d.

Species: Shiny pigtoe, Fine-rayed pigtoe, Pink mucket pearly mussel, Rough pigtoe
Location: Tennessee River (entire reach)

The Tennessee Valley Authority is a multipurpose federal corporation responsible for managing a range of programs in the Tennessee River Valley for the use, conservation, and development of the water resources related to the Tennessee River. In carrying out this mission, TVA operates a system of dams and reservoirs with associated facilities - i.e., its water control system - to manage the storage and flow of water within the system. This system is used to manage the water resources of the Tennessee River for the purposes of navigation, flood control, power production, and a wide range of other public benefits. (TVA 2004)

The water control system provides the cooling water supply for TVA=s fossil and nuclear power plants located adjacent to TVA reservoirs. Additionally, TVA owns and manages approximately 293,000 acres of land in the Tennessee River Valley, much of which is along the shorelines of the reservoirs. Policies have been established for the development of reservoir shorelines and adjacent TVA lands, and reservoir levels influence development and management of these lands, activities, and river flows. Reservoir operations policy for TVA's water control system--i.e., the dams, reservoirs, and regulated river segments--guides the day-to-day operation of the Tennessee River system. (TVA 2004)

The Tennessee River drainage covers approximately 41,000 square miles. This area includes 125 counties within much of Tennessee and parts of Alabama, Kentucky, Georgia, Mississippi, North Carolina, and Virginia. The larger TVA Power Service Area covers 80,000 square miles and includes 201 counties in the same seven states. The TVA watershed includes 42,000 miles of streams that drain to the Tennessee River, 480,000 acres of reservoirs, and 300,000 acres of TVA-managed land. (TVA 2004)

The Tennessee River drainage begins with headwaters in the mountains of western Virginia and North Carolina, eastern Tennessee, and northern Georgia. At Knoxville, Tennessee, the Holston River and French Broad River join to form the Tennessee River, which then flows southwest through Tennessee, gaining water from three other large tributaries: the Little Tennessee River, Clinch River, and Hiwassee River. The Tennessee River eventually flows into Alabama, where it picks up another large tributary, the Elk River. At the northeast corner of Mississippi, the river turns north, re-enters Tennessee, picking up the Duck River, and continues flowing north to Paducah, Kentucky, where it enters the Ohio River at Ohio River Mile 932. (TVA 2004)

The total river elevation change from the maximum reservoir surface elevation at Watauga Dam (highest elevation on the system) to the minimum tailwater surface elevation at Kentucky Dam (lowest elevation on the system) is 1,675 feet in 828.6 river miles. The mainstem of the Tennessee River has a fall of 515 feet in 579.9 river miles from the top of the Fort Loudoun Dam gates to the minimum tailwater elevation at Kentucky Dam. The mainstem fall is gradual except in the Muscle Shoals area of Alabama, where a drop of 100 feet is found in a stretch of less than 20 miles. (TVA 2004)

The eastern half of the Tennessee Valley includes the slopes of the Blue Ridge and Great Smoky Mountains, where an abundant growth of timber covers the ground. The western half of the Valley is less rugged, with substantial areas of flat or rolling land occurring in middle Tennessee and along the western edge. Reservoirs and the associated tailwaters of the Tennessee River Valley span six physiographic regions, including the Highland Rim, Coastal Plain, Cumberland Plateau, Blue Ridge, Central Basin, and Valley and Ridge. Thirty-nine percent of the TVA region is in the Highland Rim and 40 percent in the Coastal Plain. (TVA 2004)

The eastern portion of the Tennessee River watershed is located in the Blue Ridge Physiographic Region (Unaka Mountains) and the Valley and Ridge Physiographic Region. The headwaters of the Tennessee River originate in the rugged Unaka Mountains in North Carolina and eastern Tennessee. This region has undergone multiple mountain-building events and is underlain by folded and faulted complexes of igneous, metamorphic or sedimentary rocks dating from the Precambrian and Paleozoic Eras. The soils of the Blue Ridge Physiographic Region consist of highly weatherable material. The depth of soil varies from 1 to 3 feet at higher elevations and from to 3 to 7 feet on the lower side slopes. The valleys contain a variety of soils and are generally productive. Soil depths of the Valley and Ridge Physiographic Region range from shallow over shales and sandstones to very deep over the dolomitic limestone. The upland soils are primarily highly leached, and strongly acidic with low fertility. Because of the variable landscape, soils properties vary over short distances, resulting in small patches of productive land intermixed with average land or large tracts of rough land. (TVA 2004)

The Tennessee River flows southwest from the Valley and Ridge Physiographic Region into the Cumberland Plateau Physiographic Region. This region consists of a high tableland that is underlain by nearly flat-lying sedimentary rocks of Paleozoic age. The Plateau is highly dissected by streams and rivers, forming valleys with moderate to high relief. Because limestone underlies portions of this region, karst (an irregular limestone region with sinks, underground streams, and caverns) landscapes and extensive cave systems have developed. The Cumberland Plateau is bounded on the west and east by escarpments. The terrain is gently rolling to hilly highland with deeply cut gorges. (TVA 2004)

From the Cumberland Plateau, the Tennessee River flows northwest through the Highland Rim Physiographic Region. This region consists of a highly dissected flat-lying tableland that is underlain by nearly flat-lying Paleozoic age limestone. Due to the presence of limestone, an extensive karst plain has developed, with numerous sinkholes, disappearing streams, and cave systems. The hill slope soils were formed from limestone and have clayey and cherty subsoils. The more level areas and hill caps have soils formed from thin loess (windblown material) and limestone residuum. The soils are highly leached and strongly acid with low fertility, except near the Kentucky/Tennessee border. (TVA 2004)

The Central Basin Physiographic Region is within the Highland Rim. The Central Basin is one of the smaller physiographic regions of the Tennessee Valley watershed and includes parts of the Duck River and Cumberland River drainages. The Basin is underlain by up-warped Paleozoic age limestone that has been eroded to form a basin surrounded by the Highland Rim. The inner portion of the Basin is relatively flat lying with low relief, and is bordered by large hills and ridges along its outer edge. Due to the weathering and erosion of the underlying limestone, karst topography is present in this region. (TVA 2004)

From the Highland Rim, the Tennessee River flows north through the Coastal Plain Physiographic Region. The portion of this region that lies within the Tennessee Valley is almost entirely west or southwest of the Tennessee River and includes the drainages of the Beech River and Bear Creek. The relief within this area is generally low; consequently, stream gradients are very low. Their valleys are broad and flat and filled with thick accumulations of alluvium. The rocks exposed in the Gulf Coastal Plain are all unconsolidated sediments, with Paleozoic rocks underlying the whole area at great depth. The soils of the Coastal Plain Physiographic Region are highly leached, low in fertility, and highly acidic. Control of erosion is of major concern, as evidenced by deep gullies that are common on some hillsides. (TVA 2004)

Aquatic resources occurring in the Tennessee Valley region are important from local, national, and global perspectives. Tennessee has approximately 319 fish species, including native and introduced species, and 129 species of freshwater mussels. The Tennessee-Cumberland River eco-regions have the highest number of fish, mussels, crayfish, and endemic species in North America, making them the most diverse temperate freshwater ecosystems in the world. (TVA 2004)

Prior to construction of the TVA reservoir system, aquatic communities were structured by water quality and physical habitat condition, which were driven by physiographic region and climate. Stream flow was proportional to rainfall, and flow regime (pattern) followed the same trends as the annual rainfall pattern. Flow established physical habitat conditions (e.g., depth, velocity) within a stream and maintained stream shape and other habitat conditions (substrate). Relatively infrequent high-flow events (i.e., flows that only occur every 1 to 2 years) were responsible for maintaining large-scale habitat patterns such as the number of riffles or pools. High flow cleans the substrate by flushing out fine sediments, which may suffocate fish eggs or mussels and fill in the spaces between rocks needed by aquatic insects. Because historical flow was proportional to rainfall, over short time intervals, such as days, flow was relatively predictable with little daily or hourly change, except during storm events. (TVA 2004)

Floods were common during spring, and flows decreased throughout the year with the lowest flows typically occurring August through October, the warmest part of the year. Spring flooding was an important component in the life cycles of some fish species that use flooded overbank areas for spawning or nursery areas. The Tennessee River was shallow, with expansive areas of rocky or gravel shoals; critical features contributing to the great diversity of aquatic life. Two of the purposes of TVA-system dams and reservoirs were to provide year-round navigation on the river and control flooding. Achieving these objectives required modifying the river environment described above to which the pre-impoundment aquatic community was adapted. For example, most of the shoal habitat was eliminated by impoundments, and seasonal flow patterns were greatly modified by capturing high spring flows in upstream impoundments and increased late summer/fall flows with drawdown releases from those reservoirs. (TVA 2004)

The construction of the TVA reservoir system significantly altered both the water quality and physical environment of the Tennessee River. Protection of aquatic resources was generally not a consideration for many types of river projects at that time because flood control, navigation, and low-cost hydroelectric power for economic stimulation were more highly valued. (TVA 2004)

The primary impact of the reservoir system was to convert free-flowing river habitat into reservoir pools. Virtually all of the mainstem Tennessee River was impounded to maintain navigation channel depth. The dams became obstacles to migratory species. Differences in goals and, consequently, operation of reservoirs became important factors in determining water quality and associated impacts on resident aquatic communities in tributary and mainstem reservoirs and downstream tailwaters. Low levels of dissolved oxygen in summer and fall virtually eliminated aquatic communities from the pool area in the lowest layer of the reservoir that is characterized by relatively cool water. Before the Reservoir Release Improvement Program, similar impacts occurred in downstream tailwaters because water was released from the lower layer of the upstream reservoir. (TVA 2004)

The large differences between summer and winter pool levels of some tributary reservoirs also created environmental hardships for aquatic resources in these reservoirs. Benthic organisms requiring re-colonization each summer cannot survive in bottom areas exposed to drying during winter. This exposure, in association with dissolved oxygen stratification impacts, severely limits benthic communities in many tributary reservoirs. Aquatic communities in and downstream of mainstem reservoirs are also affected by poor water quality conditions. Taking advantage of modified habitat conditions (i.e., reservoir pools and dam tailwaters), state agencies have introduced numerous non-native sport and some prey fishes, including rainbow trout, brown trout, lake trout, cutthroat trout, kokanee, striped bass, striped bass hybrids, muskellunge, northern pike, cisco, rainbow smelt, alewife, yellow perch, and walleye (northern strains). Not all introductions have led to self-sustaining populations and state agencies continue stocking many popular fishes. Stocking has in itself led to changes to aquatic communities or created new community types in areas in which they did not historically exist (e.g., trout in cold tailwater river reaches). (TVA 2004)

Completion of TVA=s water control system resulted in the following impacts to the aquatic system: (1) conversion of riverine habitat to reservoir pool habitat; (2) loss of riverine habitat and associated species; (3) conversion of floodplain to reservoir pool; (4) loss of seasonal floodplain habitat and associated species; (5) fragmentation of riverine sections; (6) disruption of fish migrations; (7) seasonal fluctuations of pool levels; seasonal drying of habitat which reduces abundance and diversity of species; (8) strong stratification (layering) of temperature for certain dam types; (9) stress or mortality of organisms or sensitive life stages; (10) seasonal dissolved oxygen depletion in temperature stratified water; (11) ammonia release created by presence of dissolved oxygen-depleted water; (12) disruption of stream transport of sediment; (13) trapping of sediment; (14) capture of toxic substances associated with substrate; (15) toxic substances release created by presence of dissolved oxygen-depleted water; and (16) enrichment of nutrients (eutrophication) with consequent increases in productivity, plant and algae growth, and changes in habitat quality and associated species. (TVA 2004)

U.S. FWS. 2005

Location: Cahaba River, Shelby County, AL

Species: Ovate clubshell, southern clubshell

Status of the species within the action area

The shiny pigtoe occurs in the Clinch River, Powell River, North Fork Holston River, and Paint Rock River. Its overall status is uncertain (Service 2002).

The fine-rayed pigtoe occurs in the Elk River and the Clinch River below Norris Dam; individuals have been collected in the Sequatchie River (Tennessee) and the North Fork of the Holston River. This species also occurs in several other rivers in the Tennessee River Basin, but its overall status is uncertain (Service 2002).

The pink mucket pearly mussel occurs in the tailwater reaches of Kentucky, Pickwick Landing, Wilson, Guntersville, Nickajack, Chickamauga, Watts Bar, and Fort Loudoun dams; it also exists in the upper reaches of Kentucky Lake and Wheeler Lake; and in the tailwater reaches of Bear Creek, Norris, Cherokee, and Douglas dams. Populations of this species also exist in two rivers in Missouri, but the species has never been reported to be common in areas in which it is found. The overall status of the species is uncertain (Service 2002).

The rough pigtoe occurs in the mainstem of the Tennessee River below Pickwick Landing Dam, Wilson Dam, Guntersville Dam, and Watts Bar Dam; and in Pickwick and Wheeler reservoirs. The species' overall status is uncertain (Service 2002).

Factors affecting species environment within the action area

Because all of the mussel species addressed in this biological opinion are riffle/shoal species that inhabit moderate-to-swift-flowing areas of the rivers with clean-swept sand/gravel/cobble substrate, effects are assumed to be similar. All of the mussel species will, therefore, be considered together in this section. The stream environments of the 14 mussels addressed in this biological opinion have been affected by various factors. Construction of the dams resulted in significant changes in the aquatic environment. Free-flowing stream habitat was changed to a non-flowing environment with deeper water, altered temperature, and lower dissolved oxygen levels near the bottoms of the reservoirs. Operation of the dams has resulted in fluctuations in water levels in the downstream reaches, seasonal deficits of dissolved oxygen, and changes in water temperature. Runoff into some of the reservoirs may contain contaminants such as heavy metals. These materials settle to the bottom and some attach to the sediment. Releases of water from the bottom of the reservoir may result in elevated levels of those contaminants downriver. Releases from the dams also act to dilute pollutants that enter the river from discharges located downstream from the dam, or from discharges located on tributary streams. Reduced releases or total lack of release from dams at times prevents dilution and assimilation of those pollutants, allowing for potential accumulation of contaminants to levels that may be acutely or chronically toxic to aquatic fauna in the tailwater.

Activities such as mining, dredging, agriculture, logging, and highway construction conducted without regard for protection of aquatic habitats typically contributes significant amounts of sediment to adjacent streams. Sediment increases turbidity, decreases light penetration, and blankets the stream bottom. As sediment accumulates, it can smother eggs and larval fish, and juvenile mussels. Unless it is flushed downstream by flood events, the sediment fills the interstitial spaces in the sand, gravel, and cobble over time, compacting and “cementing” the substrate and eliminating habitat for species that burrow into the stream bottom.

Discharges from various industrial, municipal, and agricultural sources have also affected the environment of the 14 mussel species addressed in this biological opinion. Effects to the environment and the organisms involved depend on the type of contaminant, the magnitude (i.e., the concentration of the contaminant) introduced into the stream, duration (i.e., how long the contaminant remains in the water column), and the frequency of input of the contaminant. Some contaminants or pollutants cause immediate effects; for example, a large spill of sulfuric acid into the upper Clinch River killed aquatic organisms for approximately 15 miles downriver. Others, such as heavy metals, accumulate in the tissues of fish, mussels, and other aquatic species, and result in long-term chronic effects.

U.S. FWS. 2004.
Species: Pink Mucket
Location: Saline river, Grant County, Arkansas

The Saline River system is inhabited by several federally protected endangered mussels including the pink mucket (*Lampsilis abrupta*), Arkansas fatmucket (*L. powellii*), and the winged mapleleaf (*Quadrula fragosa*) (Harris *et al.* 1997, Davidson and Clem 2002). Only the pink mucket was a suspected potential inhabitant of the project vicinity (Harris *et al.* 1997, Davidson and Clem 2002). The Arkansas fatmucket is more of an upland species with its center of distribution above Arkansas Highway 270 (Davidson and Clem 2002). The winged mapleleaf appears to have an affinity for bigger river habitat than that found in the project area (Harris 2000) and occurs approximately 50 river kilometers downstream of the proposed site (Davidson and Clem 2002). The general habitat type within the survey reach was deemed suitable to support the pink mucket. An accurate population estimate for the species is difficult to assess due to the rare occurrence of the pink mucket within the Saline River.

Currently, sedimentation from forest practices likely have the largest impacts on pink mucket populations occurring within the Saline River. Detrimental effects of fine sediment from runoff and erosion on freshwater mussels have been documented. Heavy sediment loads in the water column can interfere with feeding activity (Kat 1982, Brim Box and Mossa 1999). Various mussel species have demonstrated a slower growth rate in turbid waters (Stansbery 1970), which may be related to reduced feeding under high sedimentation levels.

U.S. FWS. 2003a.
Species: Pink Mucket
Location: Ouachita River; Hot Springs County, Arkansas

The Ouachita River system is inhabited by several federally protected endangered mussels including the Ouachita rock pocketbook (*Arkansia wheeleri*), pink mucket (*Lampsilis abrupta*), Arkansas fatmucket (*L. powellii*), scaleshell (*Letptodea leptodon*), and the winged mapleleaf (*Quadrula fragosa*) (Harris *et al.* 1997, Harris 1999). Only the Ouachita rock pocketbook, pink mucket, and Arkansas fatmucket were suspected potential inhabitants of the project vicinity (Harris *et al.* 1997, Harris 1999). Harris (1999) found relict shells of the Ouachita rock pocketbook and the pink mucket in the vicinity of the Interstate 30 bridge that is approximately 450 m upstream of the Rockport Bridge. No specimens of the Ouachita rock pocketbook or Arkansas fatmucket were found during the October 8, 2002 survey of two stream reaches below the proposed site by the AHTD; however, a single male pink mucket specimen (>100 mm in length) was located approximately 1.4 rkm downstream of the proposed bridge crossing. The general habitat type within the two survey reaches was deemed suitable to support the pink mucket. An accurate population estimate for the species is difficult to assess due to the rare occurrence of the pink mucket within the Ouachita River.

U.S. FWS. 2003b
Species: Ovate clubshell, Southern clubshell
Location: Chewacla creek, Lee county, AL

Status of the species within the action area

Baseline conditions for the SHA, and associated ESP, are described with reference to each SHA property. Included in each property, for the purposes of the baseline descriptions in this section, is the bed and banks of Chewacla Creek adjacent to that property. The baseline is described in terms of locations and numbers of covered species. The aquatic habitat within the SHA properties is described in Webber and Blevins (2000) and Richardson (2001).

The following is the baseline description for each property in terms of locations and numbers of the covered species:

Water Board property

Garner (2002) conducted a survey for freshwater mussels at the Water Board property downstream from Lake Ogletree Dam. Garner located and identified ten live fine-lined pocketbook individuals, but located no southern clubshell or ovate clubshell individuals. However, based on the description of where these mussels were located it was unclear whether they were actually on Water Board property or on adjacent property, outside of the creek area covered by the SHA. Gangloff and Feminella (2003) conducted a new survey of the Water Board property to correctly determine the baseline population for this property. They found one live fine-lined pocketbook and no ovate or southern clubshell mussels within the Water Board property. Gangloff and Feminella (2003) describe the habitat within the Water Board property as suboptimal, except for the last 50 meters of stream reach closest to their downstream property boundary, due to a lack of sufficient flow for mussel reproduction. Thus, the baseline for the Water Board property downstream from Lake Ogletree Dam is one for the fine-lined pocketbook and zero for the southern clubshell and ovate clubshell.

Between the Water Board upstream property and the Harris property, Chewacla Creek flows adjacent to multiple properties, the landowners of which are not parties to the SHA. Populations of fine-lined pocketbook in Chewacla Creek in this area are described in Gangloff (2001).

The downstream parcel of the Water Board property is adjacent to Chewacla Creek near the Wright=s Mill Road bridge. Gangloff (2001) reported none of the covered species or any other member of the Unionidae family at the Wrights Mill Road bridge. Richardson (2001) also reported none of the covered species at a site just upstream of the Wrights Mill Road bridge. Thus, the baseline for all three mussel species for this downstream parcel of the Water Board property is zero.

Harris property

Garner (2002) conducted a survey for freshwater mussels at the Harris property, but located no live specimens of any of the covered species. Sampling performed by Richardson (2001) in Chewacla Creek adjacent to the Harris property also revealed none of the covered species. Moreover, as noted by Garner (2002), much of Chewacla Creek adjacent to the Harris property (from Pretty Hole downstream to outfall 2) is of an ephemeral nature and currently can not maintain a baseline population for any of the covered species. Thus, the baseline for the Harris property is zero for all three mussel species.

Pace property

Recent sampling performed in Chewacla Creek adjacent to the Pace property revealed none of the covered species. Gangloff (2001) reported none of the covered species or any other member of the Unionidae family at the Wrights Mill Road bridge (near the western boundary of the enrolled property). Richardson (2001) sampled for mussels in Chewacla Creek adjacent to the Pace property near its eastern boundary and just upstream of the Moore=s Mill Creek confluence and reported none of the covered species. Weber and Blevins (2000) conducted sampling for invertebrates, including mussels, over a 300 foot stretch of Chewacla Creek adjacent to the Pace property and counted none of the covered species. Thus, the baseline for the three mussels for this property is zero.

Phillips property

Sampling in Chewacla Creek adjacent to the Phillips property also revealed none of the covered species. Gangloff (2001) reported none of the covered species or any other member of the Unionidae family at the Wrights Mill Road bridge (near the eastern boundary of enrolled property). Richardson (2001) sampled for mussels in Chewacla Creek adjacent to the Phillips property near its eastern boundary and reported none of the covered species. Weber and Blevins (2000) conducted sampling for invertebrates, including mussels, over a 300 foot stretch of Chewacla Creek adjacent to the Phillips property and counted none of the covered species. Thus, the baseline for the mussel species for this property is zero.

ADNCR property

The ADCNR property is located on the north side of Chewacla Creek directly across from the Harris, Pace, downstream Water Board, and Phillips properties. Thus, the baseline for the ADCNR property is zero for all three mussel species, the same as the baseline for the Harris, Pace, downstream Water Board, and Phillips properties as described above. Chewacla Creek runs for about 252,300 feet and averages about 25 feet wide through these properties, totaling 5.79 acres.

Factors affecting the species environment within the action area

These riverine mussels are intolerant of impoundments and are generally limited to high quality, stable gravel or gravel and sand substrates in flowing water (Hartfield and Jones, 1989; and Pierson, 1991). Impoundments adversely affect riverine mussels by: killing them during construction; suffocation by accumulation of sediments; lower food and oxygen availability by the reduction of water flow; and local extirpation of the fish host. The Lake Ogletree Dam was constructed by the City of Auburn on Chewacla Creek in the 1940s. Increased water usage by the residents of Auburn, compounded by drought conditions during recent years, has restricted the amount of water flowing into Chewacla Creek downstream of the dam. This has resulted in habitat degradation to Chewacla Creek, as described above, within the action area.

U.S. FWS. 2003c
Species: Pink mucket, rough pigtoe
Location: TN River, Hardin County, TN

ENVIRONMENTAL BASELINE

The Tennessee River in the action area has been subjected to numerous anthropogenic impacts (Tennessee River from River Mile 194.0 to River Mile 195.0). The river is heavily used by navigation traffic; a minimum depth navigation channel of nine feet is maintained in this un-impounded reach of the river. Periodic dredging has been needed to maintain the channel and keep it free of depositional materials; actions have also been taken in the past to remove rock outcroppings that extended into the channel and posed navigational hazards. Sand and gravel dredged from the channel are disposed of in the back chute of Diamond Island, approximately one mile to the south. Additionally, commercial sand and gravel dredging operations have occurred downriver at Wolf Island and, to a limited degree, upriver in the vicinity of Diamond Island.

The watershed adjacent to the action area is primarily rural and agricultural land. Cleared areas have likely contributed sediment to the river and affected the aquatic fauna. However, no urban, industrial, or residential developments exist along this reach of the river. Pickwick Reservoir likely acts as a catchment for discharges from the urban areas of Florence, Sheffield, and Muscle Shoals, Alabama; and the nearest urban area, Savannah, Tennessee, lies approximately five miles downriver. The action area is, therefore, somewhat protected from pollutants discharged from upriver urban areas.

Subsidence features in, and adjacent, to the stream bed allow creek water to flow into the ground. This has resulted in a section of the creek to become seasonally dewatered. This dewatered portion directly eliminates habitat from being available to the mussels. It also restricts host fish from being able to transport the mussel glochidia to other portions of the creek.

Sedimentation may cause direct mortality by deposition and suffocation (Ellis, 1936) and eliminate or reduce recruitment of juvenile mussels (Negus, 1966). Suspended sediments can also interfere with feeding (Dennis, 1984). Due to a lack of consistent stream flow between the dam and dewatered section, excess sedimentation accumulates between storm flushing events reducing habitat quality. Downstream of the dewatered section, several streams, which flow through the City of Auburn, enter Chewacla Creek. These streams include large amounts of sediment run-off from residential and commercial growth in Auburn and the surrounding area. This excess sedimentation also reduces habitat quality within the action area.

Other types of water quality degradation from both point and non-point sources affect these mussel species within the action area. Point sources of water quality degradation include runoff from agricultural fields, pastures, wastewater effluents, active and abandoned mine sites, and highway and road drainage (Service, 1993). Martin Marietta currently has two NPDES discharge points in Chewacla Creek within the action area.

Stream discharge from these point and non-point sources result in decreased oxygen concentration, increased acidity and conductivity, and other changes in water chemistry which may impact mussels and/or their host fishes.

Exotic mussel species are also a problem in this area. The Asiatic clam (*Corbicula fluminea*), which is locally abundant in Chewacla Creek within the action area, reproduces rapidly, does not need a fish host for reproduction, and can reach high densities that out compete native mussels for food and physical space (Dillon, 2000).

Currently, artificial impoundment and sedimentation from forest/agricultural practices likely have the largest impacts on pink mucket populations occurring within the Ouachita River. Habitat and flow regime in the river were altered by the construction of Remmel Dam in 1923 and Carpenter Dam nine years later. As stated earlier, dams act as barriers to fish movement and prevent dispersion of potential fish hosts. Stream reaches that become impounded are usually unsuitable mussel habitat and hypolimnetic discharges negatively alter temperature regimes below impoundments. Siltation has long been associated with reductions in freshwater mussel assemblages (Brim Box and Mossa 1999). Detrimental effects of fine sediment from runoff and erosion on freshwater mussels have been documented. Heavy sediment loads in the water column can interfere with feeding activity (Kat 1982, Brim Box and Mossa 1999). Various mussel species have demonstrated a slower growth rate in turbid waters (Stansbery 1970), which may be related to reduced feeding under high sedimentation levels.

U.S. FWS. 2002a.
Species: Pink mucket pearly mussel
Location: Tennessee River, Hamilton county, TN

The aquatic habitats in the Tennessee River Basin have been significantly altered and impacted since European settlement of the area. The main stem of the Tennessee River has been impounded from near its mouth in Kentucky upstream to Knoxville for flood control, navigation, and other purposes. These impoundments have effectively altered the riverine habitat into a series of lake-like pools. At times, discharges from some of these dams contain low levels of dissolved oxygen (i.e., less than 5 parts per million), which can have significant adverse impacts on downstream aquatic communities. Portions of the remaining riverine habitat below the dams have been dredged to maintain a navigable channel for commercial vessels. Urban development in Florence and Decatur, Alabama; Chattanooga and Knoxville, Tennessee; and smaller communities along the river has continued to increase and has consequently affected aquatic habitats. Removal of sand and gravel from the river for commercial purposes has significantly altered aquatic habitat. And, other land uses such as agriculture, mining, and timber harvest have affected aquatic habitats in the Tennessee River and the species that utilize them.

The exotic zebra mussel was introduced into the Great Lakes from Europe in 1988, and has rapidly spread throughout the eastern United States. It is presently known to exist in the Ohio, Tennessee, Mississippi, and Cumberland Rivers. This species does not require a fish host to complete its life cycle and it can produce one or more generations per year. Consequently, this species can quickly reach densities of thousands of individuals per square meter. At these densities, the zebra mussel has the ability to filter tremendous quantities of water, reducing the availability of food for native mussels. In addition, zebra mussels attach to any hard surface, including the shells of living mussels and snails, reducing the ability of the mussel or snail to feed and respire. Although densities of zebra mussels in the Tennessee River have not exhibited dramatic increases as in other waters, and although populations of native mussels appear to have survived high infestations of zebra mussels in some areas, the long-term impacts to native freshwater mussel species associated with zebra mussel infestations are presently unknown.

The Tennessee River in the project area is approximately 1,050 feet in width and 8 to 35 feet deep. It is in a transition zone between the riverine habitat in the tailwater of Fort Loudon Dam and the headwaters of Watts Bar Lake. The aquatic fauna in this reach of the river is likely being adversely affected as a result of water quality degradation from a number of sources. Fort Loudon Dam frequently discharges water with two to three parts per million dissolved oxygen (TVA 1990). Release of water with low oxygen content coupled with discharges from large commercial facilities located immediately upstream from the project site may result in degradation of water quality in the river and stress to aquatic species. Furthermore, the project area is subject to commercial barge traffic which likely affects aquatic habitats. Recently, the Tennessee Valley Authority has made efforts to improve the quality of water discharged from some of its facilities on the

Tennessee River. Aeration of the water used for hydropower generation prior to discharge has reduced the degree of adverse impacts to downriver aquatic species.

An attempt was recently made by TVA to improve habitat conditions for juvenile mussels in the Tennessee River below Watts Bar Dam. Large boulders were placed in the tailwater area below the dam. It is anticipated that fine gravel and sand will settle immediately downstream from the boulders, providing suitable habitat for newly transformed juvenile mussels to settle and grow. Long-term monitoring of this boulder field will reveal if the effort has succeeded.

Over the past five years, there have been a number of actions conducted in the project impact area, primarily on Tennessee River tributaries. Housing developments have been constructed in the City of Loudon and along the Little Tennessee River, and an industrial park was constructed in Loudon. A new wastewater treatment plant was constructed in Loudon on Sweetwater Creek and a recreational impoundment was constructed on Town Creek in the town of Lenoir City. A bank stabilization project was completed on Tellico Lake and several private boat docks, boathouses, and boat launching ramps were constructed on Tellico Lake and the Little Tennessee River. On the main stem of the Tennessee River, additions were made to an existing barge terminal, a sewer line crossing and water intake structure were constructed, and a bank stabilization project consisting of placement of riprap on the riverbank was completed. Some of these projects likely have had minimal impacts on the aquatic habitats in the Tennessee River and the species that inhabit them, including the orange-foot pimpleback and pink mucket pearly mussel. Others, such as the housing and industrial developments, boat ramps, and barge terminal, may have had more significant direct effects and could potentially continue to adversely effect aquatic species in the Tennessee River.

0 <u>Direct/Indirect Effects</u>

Implementation of the preferred alternative could adversely impact aquatic resources downstream. The new lock and approach wall would be constructed on the riverward side of the existing lock and would require removal of four spillway gates. Construction of the downstream cofferdam will cause some level of sedimentation. Project-related construction on the riverbanks at and downstream from the dam will also be sources of sedimentation. Bank excavation and dredging downstream to align the navigation channel will cause sedimentation, and will disturb the river bottom. Increased number of tows and horsepower of towboats using the new lock will result in new areas of scour on the river bottom, which will likely eliminate benthic organisms from the scoured areas. Runoff from spoil disposal areas could also be a source of sediment in the river. Additionally, discharges from those areas and from settling basins could introduce various pollutants.

Dredging to provide access to the new lock and to improve the navigation channel downstream from the dam could have adverse impacts on mussel resources in the river. Portions of the mussel beds adjacent to the riverbank and navigation channel could be destroyed by dredging activities; substrate could be destabilized on areas adjacent to those dredged. Individual mussels could suffer direct mortality from dredging and others could be dislodged from the substrate and moved downstream by river currents.

U.S. FWS. 2002b.
Species: Rough pigtoe pearly mussel,
Location: Tennessee River, Hardin County, TN

The Tennessee River in the action area has been subjected to numerous anthropogenic impacts. Construction of Pickwick Dam, approximately 12 miles upriver, created an impoundment that likely has affected natural downriver flows. The river is heavily used by navigation traffic; a minimum depth navigation channel is maintained in this un-impounded reach. Periodic dredging has been needed to maintain the channel and to remove rock outcroppings that extend into the channel. Sand and gravel dredged from the channel are disposed of in the back chute of Diamond Island, approximately one mile to the south. Additionally, commercial sand and gravel dredging operations have occurred downriver at Wolf Island and, to a limited degree, upriver in the vicinity of Diamond Island.

The area through which the action area flows is primarily rural and agricultural land. Cleared areas have likely contributed sediment to the river and affected the aquatic fauna. However, no urban, industrial, or residential developments exist along this reach of the river. Pickwick Lake likely acts as a catchment for discharges from the urban areas of Florence, Sheffield, and Muscle Shoals, Alabama; and the nearest urban area, Savannah, Tennessee, lies approximately five miles downriver. The action area is, therefore, somewhat protected from pollutants discharged from urban areas.

! <u>Direct/Indirect Effects</u>

Effects to listed species resulting from the proposed action will be limited to the one-half acre dredging and disposal sites. Direct mortality to individual mussels could occur from crushing, cracking, or other damage to the shell as the dredge scoops up substrate. Mussels suffering immediately non-lethal damage to the shells would be indirectly affected; adverse effects could occur subsequent to dredging.

Indirect effects also could occur at the disposal site. Mussels will be dumped from the barge with the dredged substrate. It will take an undetermined amount of time for each mussel to reposition itself in the substrate, and some may be unable to do so, perishing by suffocation.. River currents could move some of these relocated mussels downriver into areas of unsuitable habitat.
Indirect effects to mussels could also result from handling. Mussels collected for data recording will be out of the water for some time while data are collected. This will cause stress to individual mussels that may or may not result in more serious effects or mortality at a later time.

U.S. FWS. 1999.
Species: Pink mucket, Rough pigtoe
Location: Tennessee River, Hardin County, TN

Over the past 70 years, the Tennessee River has undergone significant changes. The Tennessee Valley Authority has constructed a series of impoundments along the entire length of the mainstem to alleviate flooding and to promote commercial navigation from the mouth of the river to the City of Knoxville. Although the proposed action is located in the headwaters of Kentucky Lake, the area retains riverine habitat conditions which are influenced by releases from Pickwick Dam located approximately 10 miles upriver. The Corps of Engineers is responsible for maintaining a navigable channel; periodic dredging is conducted as sand and gravel is deposited in the channel, reducing the depth below acceptable levels. Initial dredging of the navigation channel probably affected mussel resources, however, subsequent maintenance dredging in areas of the existing channel that are frequently dredged likely has minimal effects; those areas that are dredged at a frequency of every six years or more may be re-colonized by mussels in the interim. The Corps also issues permits for other activities that affect the river such as commercial sand and gravel dredging, pipeline crossings, and riverbank stabilization. Gas pipelines have been constructed across the river at Mile 202, and Federal mooring cells are located at Mile 201 and Mile 206. Sand and gravel from the river is considered the best material for road beds, consequently, sand and gravel dredging has been a major activity. Until recently, sand and gravel companies have had unlimited access to all areas in the river and have likely been responsible for significant changes in habitat conditions for benthic organisms, including mussels. However, the Service has worked with the Corps to restrict dredging activity, and the river reach in the project area is now closed to commercial sand and gravel dredging.

In 1990, in response to an increase in the numbers of barges grounding on rock ledges in a bend in the river, the Tennessee Valley Authority widened the navigation channel below Pickwick Dam between Mile 204 and Mile 206. Prior to beginning this project, mussels were removed from the impact area and relocated to a mussel bed along the right descending bank, and a study was conducted to determine effects to mussels from blasting which was required to widen the channel. The rock removed from the project area was used to stabilize an eroding riverbank on the right descending side of the river.

0 <u>Direct/Indirect Effects</u>

Dredging can have significant adverse effects on the species addressed in this biological opinion and their habitats. Removal of sand and gravel substrate destroys the habitat preferred by these species. Individual mussels can also be physically removed from the substrate or crushed during the dredging operation. Mussels placed into a dump scow with dredged material for transport to a disposal site are likely to be severely stressed and are not likely to survive when placed back into the river. Direct effects of the proposed action to listed mussels may be less at one site since the site was disturbed approximately seven years ago by past dredging activities. However, one of the two remaining areas proposed for dredging has not previously been subjected to maintenance dredging and another has not been dredged for over seven years. The pink mucket pearly mussel has been found within at least one of the areas proposed for dredging, therefore, direct effects described above will occur as a result of the proposed action.

U.S. FWS. 1996.
Species: Ovate clubshell, southern clubshell mussel
Location: Tombigbee Rivers and Tributaries, Luxapallila Creek Segment, Lowndes County, MS and Lamar County, AL

Channelization of Luxapallila Creek for flood control purposes between its confluence with the Tennessee-Tombigbee Waterway and Waterworks Road bridge (RM 6.2) in Columbus, which is bordered by commercial and residential development, is nearing completion. The reach between Waterworks Road bridge (RM 6.2) and Steens, Mississippi (RM 16.3) is unchannelized and bordered by a relatively continuous riparian forest. Private land use in this reach is primarily agriculture and silviculture.

There are few historic records of unionid mussels in Luxapallila Creek. Shultz (1981) reported 13 mussel species from Luxapallila Creek, including P. decisum and P. perovatum. The Mississippi Museum of Natural Science collection also contains specimens of L. perovalis from Luxapallila Creek. Hartfield collected M. acutissimus from the creek near Steens in 1984 and reported a total of 16 mussel species known from Luxapallila Creek at that time (USFWS 1992).

On May 11-12, 1992, a mussel survey was conducted by Hartfield and Bowker in Luxapallila Creek near Millport, Alabama, and between RM 16.3 (Steens, Mississippi) and the Luxapallila Creek mouth. They collected live specimens of two (L. perovalis and P. decisum) of the listed four mussel species in Luxapallila Creek between RM 13.0 and 6.2 in Mississippi, and concluded that it was likely the other two mussel species (P. perovatum and M. acutissimus) also occurred in this reach because habitat conditions were suitable. None of these proposed endangered/threatened mussel species and few other mussel species were found downstream from RM 6.2. Hartfield and Bowker concluded that it was unlikely the listed mussels continue to inhabit Luxapallila Creek downstream of RM 6.2 in Columbus because of the effects of pollution, siltation, and the slack water influence of Aliceville Pool (USFWS 1992 and 1992(A)). This survey increased the known unionid fauna of Luxapallila Creek to 21 species.

References

Allan, J.D. 1995. Stream ecology: structure and function of running waters. Chapman and Hall, London, JK. xii + 388 p.

Armour, C.L., D.A. Duff, and W. Elmore. 1991. The effects of livestock grazing on riparian and stream ecosystems. Fisheries 16(1):7-11.

Augspurger, T., A.E. Keller, M.C. Black, W.G. Cope, and F.J. Dwyer. 2003. Derivation of water quality guidance for protection of freshwater mussels (Unionidae) from ammonia exposure. Environmental Toxicology and Chemistry.

Baker, F.C. 1928. The fresh water Mollusca of Wisconsin, Part 2: Pelecypoda. Bull. Univ. Wisconsin 1527 (1301): vi + 495 p. + 77 pl.

Baker, J.B.and Broadfoot, W.M. 1979. Site evaluation for commercially important southern hardwoods. Gen. Tech. Rep. SO–26. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 51 p.

Baker, J. C. and Hunter, C. 2002. Terra-4: Effects of forest management on terrestrial ecosystems. Southern forest resource assessment. Gen. Tech. Rep. SRS-53. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station.

Baker, W.W. 1983. Decline and extirpation of a population of red-cockaded woodpeckers in northwest Florida. Pp. 44-45 *In* D.A. Wood (ed.). Red-cockaded Woodpecker Symposium II Proceedings. Florida Game and Fresh Water Fish Commission. Tallahassee, FL.

Barnhart, M.C., F.A. Riusech, and A.D. Roberts. 1997. Fish hosts of the federally endangered pink mucket, *Lampsilis abrupta*. Triannual Unionid Report 13:35. Available from: U.S. Fish and Wildlife Service, Asheville, North Carolina.

Beal, F.W.L. 1911. Food of the woodpeckers of the United States. U.S. Department of Agriculture Biological Survey Bulletin 37.

Beckett, T. 1971. A summary of red-cockaded woodpecker observations in South Carolina. Pp. 87-95 *In* R.L. Thompson (ed.). Proc. Symp. The Ecology and Management of the Red-cockaded Woodpecker. Bureau of Sport Fisheries and Wildlife, U.S. Dept. Int. and Tall Timbers Res. Sta., Tallahassee, FL.

Beyer, D.E., Jr., R. Costa, R.G. Hooper, and C.A. Hess. 1996. Habitat quality, group size, and reproduction of red-cockaded woodpecker groups in Florida. J. Wildl. Manage. 60:826-835. Carter, J.H. III, R.T. Stamps and P.D. Doerr. 1983. Status of the red-cockaded woodpecker in the North Caroline Sandhills. Pp. 24-29 *In* D.A. Wood (ed.). Proc. Red-cockaded Woodpecker Symp. II. Florida Game and Freshwater Fish Comm., Tallahassee, FL.

Brim Box, J. and J. Mossa. 1999. Sediment, land use, and freshwater mussels: prospects and problems. J.N. Amer. Benthol. Soc. 18(1):99-117.

Broley, C.L. 1947. Migration and nesting of Florida bald eagles. Wilson Bulletin 59:3-20.

Broley, C.L. 1950. The plight of the Florida bald eagle. Audubon Magazine 52:43-49.

Buchanan, A. C. 1980. Mussels (Naiades) of the Meramec River basin. Missouri Dept. of Conservation Aquatic Series, No. 17. 68pp.

Carter, J.H. III, R.T. Stamps, and P.D. Doerr. 1983. Status of the red-cockaded woodpecker in the North Carolina Sandhills. Pages 24-29 *in* D.A. Wood, editor. Red-cockaded woodpecker symposium II proceedings. Florida Game and Fresh Water Fish Commission, Tallahassee, Florida, USA.

Carter, J.H. III, J.R. Walters and P.D. Doerr. 1995. Red-cockaded woodpeckers in the North Carolina Sandhills: A 12-year population study. Pp. 248-258. *In* D.A. Wood (ed.). Proc. Red-cockaded Woodpecker Symp. II. Florida Game and Freshwater Fish Comm., Tallahassee, FL.

CBSG. 1998 Population and Habitat Viability Assessment for the winger maple leaf. 92pp.

Chaplin, S.J. 1986. Letter to D. B. Jordan, Field Supervisor, U.S. Fish and Wildlife Service, Jackson, Mississippi, on the Proposal to List *Geocarpon minimum* as a threatened species.

Christian, A.D. and J L. Harris. 2004. Status survey for the pink mucket (*Lampsilis abrupta* (Say, 1831)), winged mapleleaf (*Quadrula fragosa* (Conrad, 1835)), and Ouachita rock pocketbook (*Arkansia wheeleri* Ortmann and Walker, 1912) in the Little Missouri River, Arkansas. Final report submitted to Arkansas Game and Fish Commission, Little Rock. 19 p. + appendices I-II.

Churchill, E. P., Jr., and S. I. Lewis. 1924. Food and feeding in freshwater mussels. Bull. U.S. Bur. Fish. 39: 439-471.

Clark, A. 1992. Influence of tree factors and site on formation of heartwood in loblolly and longleaf pine for red-cockaded woodpecker colonization in the southeast. Proc. Ann. Conf. Southeastern Assoc. Of Fish and Wildl. Agencies 46:79-87.

Clark, A. 1993 Characteristics of timber stands containing sufficient hardwood for cavity excavation by red-cockaded woodpecker clans. Pp. 621-626. *In* J.C. Brissette (ed.). Proceedings of the 7th Biennial Southern Silvicultural Research Conference, Southern Forest Experiment Station, New Orleans, LA.

Clarke, A.H. 1981. The Tribe Alasmidontini (unionidae: Anodontinae), Park I: *Pegias*, *Alasmidonta*, and *Arcidens*. Smithsonian contributions to Zoology. No. 326, Smithsonian Institution Press, Washington. D.C. iv + 101 p.

Clarke, A. H. 1982. Survey of the freshwater mussels of the upper Kanawha River (RM 91-95), Fayette County, West Virginia, with special reference to *Epioblasma torulosa* (Rafinesque) and *Lampsilis abrupta* (Say) (= *Lampsilis orbiculata* (Hildreth), of authors). Final Report. USFWS, Newton Corner, MA. 45pp.

Clarke, A.H. 1987. Status survey of *Lampsilis streckeri* Frierson (1927) and *Arcidens wheeleri* (Ortmann & Walker, 1912). Ecosearch, Inc., final report to the U.S. Fish and Wildlife Service, Jackson, MS. Contract No. 14-16-0004-86-057. i(ii) + 24 p. + 66 P. appendix.

Clendenin, M, and W.G. Ross. 2001. Effects of cool season prescribed fire on understory vegetation in a mixed pine hardwood forest of east Texas. Texas J.Sci. 53 (1):65-78

Conner, R.N. and K.A. O'Halloran. 1987. Cavity tree selection by red-cockaded woodpeckers as related to growth dynamics of southern pines. Wilson Bull. 99:398-412.

Conner, R.N. and D.C. Rudolph. 1991a. Effects of midstory reduction and thinning in red-cockaded woodpecker cavity tree clusters. Wildl. Soc. Bull. 19:63-66.

Conner, R.N. and D.C. Rudolph. 1991b. forest habitat loss, fragmentation and red-cockaded woodpecker populations. Wilson Bull. 103:446-457.

Conner, R.N., D.C. Rudolph, and J.R. Walters. 2001. The red cockaded woodpecker: surviving in a fire maintained ecosystem. University of Texas Press, Austin, TX.

Copeyon, C.K., J.R. Walters and J.H. Carter. 1991. Induction of red-cockaded woodpecker group formation by artificial cavity construction. J. Wildl. Manage. 55:549-556.

Costa, R. 1995. Red-cockaded woodpecker recovery and private lands: a conservation strategy responsive to the issues. pp. 67-74. In D.L. Kulhavey, R.G. Hooper and R. Costa (eds.). Red-cockaded Woodpecker: Recovery, Ecology and Management. Center for Applied Studies, College of Forestry, Stephen F. Austin State Univ., Nacogdoches.

Costa, R. and R.E.F. Escano. 1989. Red-cockaded woodpecker: status and management in the southern region in 1986. U.S. Dept. Agr., For. Serv., Tech. Pub. R8-TP 12, Southern Region, Atlanta, GA.

Costa, R. and J.W. Walker. 1995. Red-cockaded woodpecker. *In* E.T. Laroe, G.S. Farris, C.E. Puckett, and P.D. Doran (eds.). Our Living Resources: A report to the National of the Distribution, Abundance, and Health of U.S. Plants, Animals and Ecosystems. U.S. Department of the Interior, National Biological Service, Washington, D.C.

Crowder, L.B., J.A. Priddy, and J.R. Walters. 1998. Demographic isolation of red-cockaded woodpecker groups: a model analysis. Project final report to U.S. Fish and Wildlife Service. Duke University, Nicholas School of the Environment, Beaufort, NC. 17 pp.

Davidson, C. L. 1997. Analysis of mussel beds in the Little Missouri and Saline rivers, Blue Mountain, Ozark, and Dardanelle lakes, Arkansas. M. S. Thesis, Dept. of Biological Sciences, Arkansas State University, Jonesboro. 156 pp.

Davidson, C.L. and S.A. Clem. 2002. The freshwater mussel (Bivalvia: Unionacea) resources in a selected segment of the Saline River: location, species composition and status of mussel beds. Report to the Nature Conservancy-Arkansas Field Office and the Arkansas Game and Fish Commission. Submitted by the Department of Biological Sciences, Fisheries and Wildlife Program, Arkansas Tech University, Russellville, AR. 23 p.

Davidson, C.L. and S.A. Clem. 2004. The freshwater mussel resources in a selected segment of the Saline River: location, species composition, and status of mussel beds. Addendum 2: Arkansas Highway 15 to the Felsenthal National Wildlife Refuge. Report submitted to the Arkansas Game and Fish Commission, Little Rock. Submitted by the Department of Biological Sciences, Fisheries and Wildlife Program, Arkansas Tech University, Russellville, AR. 23 pp.

DeLotelle, R.S. and R.J. Epting. 1988. Selection of old trees for cavity excavation by red-cockaded woodpeckers. Wildl. Soc. Bull. 16:48-52.

DeLotelle, R.S., R.J. Epting and J.R. Newman. 1987. Habitat use and territory characteristics of red-cockaded woodpeckers in central Florida. Wilson Bull. 99:202-217.

DeLotelle, R.S., R.J. Epting and G. DeMuth. 1995. A 12-year study of red-cockaded woodpeckers in central Florida. pp. 259-269. In D.L. Kulhavey, R.G. Hooper and R. Costa (eds.). Red-cockaded Woodpecker: Recovery, Ecology and Management. Center for Applied Studies, College of Forestry, Stephen F. Austin State Univ., Nacogdoches, TX.

Dennis, S.D. 1985. Distributional analysis of the freshwater mussel fauna of the Tennessee River system, with special reference to possible limiting effects of siltation. Tennessee Wildlife Resources Agency Report No. 85-2, Nashville. 171 pp.

Deval, M., N. Schiff, and D. Boyette. 2001. Ecology and Reproductive Biology of the Endangered Pondberry, *Lindera melissifolia* (Walt) Blume. Natural Areas Journal. Vol. 21:250-258.

Ellis, M.M. 1936. Erosion silt as a factor in aquatic environments. Ecology 17(1):29-42.

Epting, R.J., R.S. DeLotelle and T. Beaty. 1995. Red-cockaded woodpecker territory and habitat use in Georgia and Florida. pp 270-282. *In* D.L. Kulhavey, R.G. Hooper and R. Costa (eds). Red-cockaded Woodpecker: Recovery, Ecology and Management. Center for Applied Studies, College of Forestry, Stephen F. Austin State Univ. Nacogdoches, TX.

Escano, R.E. 1995. Red-cockaded woodpecker extinction or recovery: Summary of status and management on our National Forests. pp. 28-35. *In* D.L. Kulhavey, R.G. Hooper and R. Costa (eds.). Red-cockaded Woodpecker: Recovery, Ecology and Management. Center for Applied Studies, College of Forestry, Stephen F. Austin State Univ., Nacogdoches, TX.

Farris, J. L., J. H. Seagraves and J. L. Harris. 2003. Reproductive biology and habitat characterization of the federally endangered freshwater mussel, Arkansia wheeleri in the Little and Ouachita Rivers, Arkansas. Unpubl. Report submitted to the U. S. Fish and Wildlife Service, Conway, AR.

Fraley, S.J., and S.A. Ahlstedt. 2000. The recent decline of the native mussels (Unionidae) of Copper Creek, Scott County, Virginia. Pp. 189-195 *in*: P.D. Johnson and R.S. Butler, eds. Freshwater Mollusk Symposium Proceedings--Part II: Proceedings of the First Symposium of the Freshwater Mollusk Conservation Society, March 1999, Chattanooga, Tennessee. Ohio Biological Survey, Columbus.

Frick, E.A., D.J. Hippe, G.R. Buell, C.A. Couch, E.H. Hopkins, D.J. Wangsness, and J.W. Garrett. 1998. Water quality in the Apalachicola-Chattahoochee-Flint River basin, Georgia, Alabama, and Florida, 1992-95. U.S. Geological Survey Circular 1164. 38 pp.

Greis, J. G.and Wear, D. N., eds. 2002. Southern forest resource assessment. Gen. Tech. Rep. SRS-53. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 635 p.

Haig, S.M., J.R. Belthhoff and D.H. Allen. 1993. Population viability analysis for a small population red-cockaded woodpeckers and an evaluation of enhancement strategies. Conservation Biology. 7:289-301.

Harris, J. L. 2006. *Quadrula fragosa* population estimates at 10 sites in the Ouachita River Drainage, Arkansas. Unpubl. Report submitted to U. S. Fish and Wildlife Service, Conway, AR. 14 pp. + appendix.

Harris, J.L. and M.E. Gordon. 1987. Distribution and status or rare and endangered mussels (Mollusca: Margaritiferidae, Unionidae) in Arkansas. Proc. Arkansas Acad. Sci. 41:49-56.

Harris, J.L., P.J. Rust, A.D. Christian, W.R. Posey II, C.L. Davidson, and G.L. Harp. 1997. Revised status of rare and endangered Unionacea (Mollusca: Margaritiferidae, Unionidae) in Arkansas. Journal of the Arkansas Academy of Science 51:66-89.

Havlik, M.E. and L.L. Marking. 1987. Effects of contaminants on naiad mollusks (Unionidae): a review. U.S. Dept. Interior, Fish and Wildlife Service, Resource Publication 164. Washington, D.C. ii + 20 p.

Heath, D.J. and P.W. Rasmussen. 1990. Results of base-line sampling of freshwater mussel communities for long-term monitoring and the Saint Croix National Scenic Riverway, Minnesota and Wisconsin. Wisconsin Department of Natural Resources, Madison. Unpublished.

Heinzman, G. 1961. The American bald eagle. Natural History 70 (6): 18-21.

Heinzman, G. 1962. American bald eagle-a last stand in Florida? Florida Wildlife 15(8):14-17.

Henley, W.F., M.A. Patterson, R.J. Neves, and A.D. Lemly. 2000. Effects of sedimentation and turbidity on lotic food webs: a concise review for natural resource managers. Reviews in Fishery Science 8(2):125-139.

Hess, C.A. and R. Costa 1995. Augmentation from the Appalachicola National Forest: the development of a new management technique. *In* Red-cockaded Woodpecker Symposium III: Species Recovery, Ecology, and Management. Center for Applied Studies, School of Forestry, Stephen F. Austin State University, Nacogdoches, TX.

Hess, C.A. and F.C. James 1998. Diet of the red-cockaded woodpecker in the Appalachicola National Forest. Journal of Wildlife Management 62:509-517.

Hickman, M.E. 1937. A contribution to the Mollusca of east Tennessee. Unpublished M.S. Thesis, University of Tennessee, Knoxville. 165 pp.

Hildreth, S. 1828. Observations on, and descriptions of the shells found in the waters of the Muskingum River, Little Muskingum and Duck Creek, in the vicinity of Marietta, Ohio. Am. J. Sci. and Arts. 14:276-291.

Hooper, R. G. 1988. Longleaf pines used for cavities by red-cockaded woodpeckers. Jounal of Wildlife Management 52:392-398

Hooper, R. G., L. J. Niles, R. F. Harlow and G. W. Wood. 1982. Home ranges of red-cockaded woodpeckers in coastal South Carolina. Auk 99:675-682.

Hooper, R.G. and R.F. Harlow. 1986. Forest stands selected by foraging red-cockaded woodpeckers. U.S. Dept. Agr. For. Serv., Southeastern For. Exp. Sta., Res. Paper SE-259, Asheville, NC.

Hooper, R. G. and M. R. Lennartz. 1981. Foraging behavior of the red-cockaded woodpeckers. Southeastern Forest Experimental Station Research paper: SE-259, USDA Forest Service.

Hooper, R.G. and M.R. Lennartz. 1983. Roosting behavior of red-cockaded woodpeckers with insufficient cavities. J. Field Ornithology 54:72-76.

Hooper, R.G. and C.J. McAdie. 1995. Hurricanes and the long-term management of the red-cockaded woodpecker, pp. 148-166. In D.L. Kulhavey, R.G. Hooper and R. Costa (eds.). Red-cockaded Woodpecker: Recovery, Ecology and Management. Center for Applied Studies, College of Forestry, Stephen F. Austin State Univ., Nacogdoches, TX.

Hooper, R.G., J.C. Watson and R.E.F. Escano. 1990. Hurricane Hugo's initial effects on red-cockaded woodpeckers in the Francis Marion National Forest. Trnas. 55th No. Amer. Wildl. Nat. Resour. Conf. 55:220-224.

Hornbach, D.J., J.G. March, T. Deneka, N.H. Troelstrup, and J.A. Perry. 1996. Factors influencing the distribution and abundance of the endangered winged mapleleaf mussel, *Quadrula fragosa* in the St. Croix River, Minnesota and Wisconsin. American Midland Naturalist 136:278-286.

Hove, M., Heath, D., Benjamin, R., Endris, M., Karns, B., Kenyon, R., Whaley, B, Woods, J, and A. Kapuscinski. 2000. Winged mapleleaf glochidia metamorphose on channel catfish. Triannual Unionid Report 19. Available http://ellipse.inhs.uiuc.edu/FMCS/TUR/TUR19.html. (Accessed: December 4, 2003)

Hove, M. 2004. Recovery information needed to prevent extinction of the federally endangered winged mapleleaf: early life history of select upper Mississippi River mussel species. Report submitted to U.S. Fish and Wildlife Service, Onalaska, WI. Prepared by Department of Fisheries, Wildlife, and Conservation Biology, University of Minnesota, Saint Paul, MN. 28 p.

Isley, F.B. 1925. The freshwater mussel fauna of eastern Oklahoma. Proceedings of the Oklahoma Academy of Science (1924) 4:43-118 + 2 tables

Jackson, J.A. and B.J.S. Jackson. 1986. Why do red-cockaded woodpeckers need old trees. Wildl. Soc. Bull. 145:318-322.

James, F.C. 1991. Signs of trouble in the largest remaining population of red-cockaded woodpeckers. Auk 108:419-423.

James, F.C. 1994. The status of the red-cockaded woodpecker in 1990 and the prospect for recovery. A report by the American Ornithologist Union. 22pp.

James, F.C. 1995. The status of the red-cockaded woodpecker in 1990 and the prospect for recovery. Pp. 439-451. *In* D.L. Kulhavey, R.G. Hooper and R. Costa (eds.). Red-cockaded Woodpecker: Recovery, Ecology and Management. Center for Applied Studies, College of Forestry, Stephen F. Austin State Univ., Nacogdoches, TX.

James, F.C., C. Hess, G. Hagan and B. Kotrla. 1995. Population structure and annual turnover rates of cavities of the red-cockaded woodpecker in the Appalchicola National Forest. pp. 353-360. I*n* D.L. Kulhavey, R.G. Hooper and R. Costa (eds.). Red-cockaded Woodpecker: Recovery, Ecology and Management. Center for Applied Studies, College of Forestry, Stephen F. Austin State Univ., Nacogdoches, TX.

Johnsgard, P.A. 1990. Hawks, eagles, and falcons of North America. Smithsonian Institution Press; Washington, D.C.

Johnson, R.K. 1980. Zoogeography of North American Unionacea (Mollusca: Bivalvia) north of the maximum Pleistocene glaciation. Bulletin of the Museum of Comparative Zoology 149(2):77-189. Harvard University, Cambridge, Massachusetts.

Johnson, P.M., A.E. Liner, S.W. Golladay, and W.K. Michener. 2001. Effects of drought on freshwater mussels and instream habitat in Coastal Plain tributaries of the Flint River, southwest Georgia (July-October, 2000). Unpublished report, by the Jones Ecological Research Center for The Nature Conservancy, Tallahassee, Florida. 45 pp.

Johnson, R.I. 1980. Zoogeography of North American Unionacea (Mollusca: Bivalvia) north of the maximum Pleistocene glaciation. Bull. Mus. Comp. Zool. 149(2):77-189.

Judy, R.D., Jr., P.N. Seeley, T.M. Murray, S.C. Svirsky, M.R. Whitworth, and L.S. Ischinger. 1982. National fisheries survey. Volume I. Technical report: initial findings. Unpublished report, U.S. Fish and Wildlife Service Report No. FWS/OBS-84/06, Washington DC.

Kanehl, P., and J. Lyons. 1992. Impacts of in-stream sand and gravel mining on stream habitat and fish communities, including a survey on the Big Rib River, Marathon County, Wisconsin. Wisconsin Department of Natural Resources Research Report 155. 32 pp.

Keller, A.E., and M. Lydy. 1997. Biomonitoring and the hazards of contaminants to freshwater mollusks. Unpublished report *in*: Freshwater mollusks as indicators of water quality: a workshop. U.S. Geological Survey Biological Resources Division and National Water Quality Assessment Program. 55 pp.

Keith, E.L., Singhurst, and S. Cook. 2004. *Geocarpon minimum* (Caryophyllaceae), new to Texas. SIDA 21(2):1165-1169.

Kral, R. 1983. A Report on Some Rare, Threatened, or Endangered Forest-related Vascular plants of the South. USDA, Forest Service, Technical Publication R8-TP2. pp. 409-412.

Lennartz, M.R., R.G. Hooper and R.F. Harlow. 1987. Sociality and cooperative breeding in red-cockaded woodpeckers (*Picoides borealis*). Behav. Ecol. Sociobiol. 20:77-88.

Letcher, B.H., J.A. Priddy, J.R. Walters, and L.B. Crowder. 1998. An individual-based, spatially explicit simulation model of the population dynamics of the endangered red-cockaded woodpecker, *Picoides borealis*. Biological Conservation 86:1-14.

Ligon, J.D. 1970. Behavior and breeding biology of the red-cockaded woodpecker. Auk 87:255-278.

Loeb, S.C. and E.E. Stevens. 1995. Turnover of red-cockaded woodpecker nest cavities on the Piedmont plateau. pp. 361-366. *In* D>L. Kulhavey, R.G. Hooper and R. Costa (eds.). Red-cockaded Woodpecker: Recovery, Ecology and Management. Center for Applied Studies, College of Forestry, Stephen F. Austin State Univ., Nacogdoches, TX.

Marking, L.L., and T.D. Bills. 1979. Acute effects of silt and sand sedimentation on freshwater mussels. Pp. 204-211 *in*: J.R. Rasmussen, ed. Proceedings of the UMRCC symposium on Upper Mississippi River bivalve mollusks. Upper Mississippi River Conservation Committee, Rock Island, Illinois.

McEwan, L.C. 1977. Nest site selection and productivity of the southern bald eagle. Unpublished Masters Thesis, University of Florida, Gainesville, Florida.

McNab, W.H. and Avers, P.E. 1994. Ecological subregions of the United States: section descriptions. WO-WSA-5. Washington DC: U.S. Department of Agriculture, Forest Service. 267 p.

Mehhop-Cifelli. P. and B. K. Miller. 1989. Status and distribution of *Arkansia wheeleri* Ortmann & Walker, 1912 (Syn. *Arcidens wheeleri*) in the Kiamichi River. Oklahoma. Oklahoma Natural Heritage Inventory, report to the U.S. Fish and Wildlife Service, Tulsa, OK. iv + 19 p. + appendix.

Montana Bald Eagle Working Group. 1991. Habitat management guide for bald eagles in northwestern Montana. Bureau of Land Management; Billings, Montana.

Morgan, S.W. 1980. status report on *Geocarpon minimum* in Missouri. Missouri Department of Conservation, Jefferson City, Missouri. 16 pp.

Mueller, D.K., P.A. Hamilton, D.R. Helsel, K.J. Hitt, and B.C. Ruddy. 1995. Nutrients in ground water and surface water of the United States--an analysis of data through 1992. Unpublished report, U.S. Geological Survey, Water-Resources Investigations Report 95-4031. 74 pp.

Naimo, T.J. 1995. A review of the effects of heavy metals on freshwater mussels. Ecotoxicology 4:341-362.

NatureServe. 2003. NatureServe Explorer: An online encyclopedia of life [web application]. Version 1.8. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. (Accessed: December 10, 2003).

Nesbitt, S.A., M.J. Folk, and D.A. Wood. 1993. Effectiveness of bald eagle habitat protection guidelines in Florida. Proceedings of the 47th Annual Conference of the Southeastern Association of Fish and Wildlife Agencies. 47:333-338.

Neves, R.J. 1993. A state-of-the unionid address. Pp. 1-10 *in*: K.S. Cummings, A.C. Buchanan, and L.M. Koch, eds. Conservation and management of freshwater mussels. Proceedings of a UMRCC symposium, October 1992, St. Louis, Missouri. Upper Mississippi River Conservation Committee, Rock Island, Illinois.

Neves, R.J. A.E. Goban, J.D. Williams, S.A. Ahlstedt, and P.W. Hartfield. 1997. Status of aquatic mollusks in the southern United States: a downward spiral of diversity. pp. 43-86 *In:* G.W. Benz and D.E. Collins (eds.) Aquatic fauna in peril: the southeastern perspective. Southeast Aquatic Research Institute, Spec. Publ. 1, Lens Design & Communications, Decatur, GA. xviii + 553 p.

Newton, T., J. O'Donnell, M. Bartsch, L.A. Thorson, and B. Richardson. 2003. Effects of un-ionized ammonia on juvenile unionids in sediment toxicity tests. Unpublished report, Ellipsaria 5(1):17.

Ortego, B. and D. Lay. 1988. Status of red-cockaded woodpecker colonies on private lands in east Texas. Wildlife Soc. Bull. 16:402-405.

Ortmann, A.E. 1918. The nayades (freshwater mussels) of the upper Tennessee drainage with notes on synonymy and distribution. Proceedings of the American Philosophical Society 77:521-626.

Ortmann, A.E. 1921. A new locality for *Arkansia wheeleri* Ortmann & Walker. Nautilus 34(4):141.

Ortmann, A.E. 1924. The naiad fauna of Duck River in Tennessee. American Midland Naturalist 9(2):18-62.

Ortmann, A.E. 1925. The naiad-fauna of Tennessee River system below Waldon Gorge. American Midland Naturalist 9(8):321-372.

Ortmann, W.E. and B. Walker. 1912. a new North American naiad. Nautilus 25(9):97-100 + 1 pl.

Pardue, W.J. 1981. A survey of the mussels (Unionidae) of the upper Tennessee River. Sterkiana 71:42-51.

Peterson, D.W. and W.B. Robertson, Jr. 1978. Threatened southern bald eagle. Pages 27-30 *in*: H.W. Kale II, ed. Rare and endangered biota of Florida: Volume II, birds. University Presses Florida; Gainesville, Florida.

Porter, M.L. and R.F. Labisky. 1986. Home range and foraging habitat of red-cockaded woodpeckers in northern Florida. J. Wildl. Manag. 50:239-247.

Porter, M.L., M.W. Collopy, R.F. Labisky and R.C. Littell. 1985. Foraging behavior or red-cockaded woodpeckers: an evaluation of research methodologies. Journal of Wilflie Management 49:505-507.

Posey, W.R. II. 1996. Location, species composition, and community estimates for mussel beds in the St. Francis and Ouachita rivers in Arkansas. M. S. Thesis, Dept. of Biological Sciences, Arkansas State University, Jonesboro. 178 p.

Posey, W.R. II, J.L. Harris, G.L. Harp. 1996. New distributional records for freshwater mussels in the Ouachita River, Arkansas. Proceedings of the Arkansas Academy of Science 50:96-98.

Provencher, L., A.R. Litt, K.E.M. Galley, D.R. Gordon, G.W. Tanner, L.A. Brennan, N.M. Gobris, S.J.McAdoo, J.P. McAdoo, and B.J. Herring. 2001a. Restoration of fire-suppressed longleaf pine sandhills at Eglin Airforce Base, Florida. Final report to the Natural Resources Management Division, Eglin Airforce Base, Niceville, Florida. Science Division, The Nature Conservancy, Gainsville, FL

Radford, A.E., H.E. Ahles, and C. R. Bell. 1968. Manual of the Vascular Flora of the Carolinas. University of N.C., Chapel Hill.

Rosenburg, K.V. and R.J. Cooper. 1990. Approaches to avian diet analysis. Studies in Avian Biology 13:80-90.

Rudolph, D.C. and R.N. Conner. 1991.Cavity tree selection by red-cockaded woodpeckers in relation to tree age. Wilson Bull. 103:458-467.

Service. 1985a. Red-cockaded Woodpecker Recovery Plan. Atlanta, GA.

Service. 1985b. Recovery plan for the pink mucket pearly mussel *Lampsilis abrupta* (Say 1831). U.S. Fish and Wildlife Service. Atlanta, Georgia. 47pp.

Service. 1987. Endangered and Threatened Wildlife and Plants; Threatened Status for *Geocarpon minimum. Federal Register,* 52(115):22930-22933.

Service. 1990 Pondberry Technical Draft Recovery Plan. Atlanta, Georgia. 52 pp.

Service. 1991a. Endangered and threatened wildlife and plants; determination of endangered status for the winged mapleleaf freshwater mussel (*Quadrula fragosa*). Federal Register 56.

Service. 1991b. Endangered and threatened wildlife plants; final rule to list the Ouachita Rock-Pocketbook (Mussel) as an endangered species. Federal Register 56(205): 54950-54957.

Service. 1991c. Endangered and threatened wildlife and plants; final rule to list the Ouachita rock-pocketbook (mussel) as an endangered species. Federal Register 56(205:54950-54957.

Service. 1993. Recovery Plan: *Geocarpon minimum.* 34 pp.

Service. 1997a. Winged mapleleaf recovery plan (*Quadrula fragosa*). Winged Mapleleaf Recovery Team, Ft. Snelling, MN. 359 pp.

Service. 1997b. Pink Mucket Fact Sheet, http://www.fws.gov/midwest/Endangered/clams/pinkm_fc.html

Service. 1999a. South Florida Multi-species recovery plan (MSRP) for south Florida. U.S. Fish and Wildlife Service; Vero Beach, Florida.

Service. 2003. Recovery plan for the red-cockaded woodpecker. 2nd revision. Atlanta, GA.

Service. 2004 Recovery plan for the Ouchita rock-pocketbook (*Arkansia wheeleri* Ortmann and Walker, 1912) 86 pp.

Service. 2006. Draft national Bald Eagle management guidelines. U.S. Fish and Wildlife Service.

Simpson, C.T. 1914. A descriptive catalogue of the naiads of pearly freshwater mussels. B. Walker, Detroit, Michigan.

Smith, G. 1969. American bald eagle. Florida Wildlife 23(2):12-17.

Sparks, B.L. and D.L. Strayer. 1998. Effects of low dissolved oxygen on juvenile *Ellipitio complanata* (Bivalvia: Unionidae). J.N. Amer.Bentol. Soc. 17(1):129-134.

Stansbery, D.H. 1971. Rare and endangered molluscs in the eastern United States. Pp. 5-18 *in*: S.E. Jorgensen and R.W. Sharpe, eds. Proceedings of a Symposium on Rare and Endangered Mollusks (Naiads) of the United States, April 1971, Columbus, Ohio. U.S. Fish and Wildlife Service, Twin Cities, Minnesota.

Steyermark, J.A. 1949. Lindera melissifolia. Rhondora 51 (608): 153-162.

Trimble, S.W., and A.C. Mendel. 1995. The cow as a geomorphic agent: a critical review. Geomorphology 13:233-253.

Tucker, G.E. 1983. Status report on *Geocarpon minimum* MacKenzie. Provided under contract to the U.S. fish and Wildlife Service, Southeast Region, Atlanta, Georgia. 41 pp.

Tucker, G.E. 1984. Status Report on *Lindera melissifolia* (Walt.) Blume. Provided Under Contract to the U.S. Fish and Wildlife Service, Southeast Region, Atlanta, Georgia. 41 pp.

Tennessee Valley Authority. 1978. Recent mollusk investigations on the Tennessee River. TVA unpublished data. Division of Environmental Planning, Water Quality and Ecology Branch, Mussel Shoals, AL. 126pp.

USDA. 1976. Soil survey of Drew county, Arkansas. Washington DC: U.S. Department of Agriculture. 86 p.

USDA. 1979. Soil survey of Ashley county, Arkansas. Washington DC: U.S. Department of Agriculture. 92 p.

Valentine, B.D., and D.H. Stansberry. 1971. An introduction to the naiads of the Lake Texoma region. Oklahoma. With notes on the Red River fauna (Mollusca: Unionidae). Sterkiana No. 42:1-40.

Vannote, R.L. and G.W. Minshall. 1982. Fluvial processes and local lithology controlling abundance, structure, and composition of mussel beds. Proc. Natl. Acad. Sci. USA 79(13):4103-4107.

Vaughn. C.C. 1991. Habitat use and reproductive biology of *Arkansia wheeler*, (Mollusca: Unionidae) in the Kiamichi River, Oklahoma. Oklahoma Natural Heritage Inventory. Performance report to the Oklahoma Department of Wildlife Conservation. Federal Air Project E-12-1, 16p.

Walters, J.R. 1991. Application of ecological principals to the management of endangered species: the case of the red-cockaded woodpecker. Annu. Rev. Ecol. Syst. 1991:505-523.

Walters, J.R., P.D. Doerr and J.H. Carter, III. 1988. The cooperative breeding system of the red-cockaded woodpecker. Ethology 78:275-305.

Walters, J.R. 1990. Red-cockaded woodpeckers: a "primitive" cooperative breeder. pp. 69-101 *In* P.B. Stacey and W.D. Koenig (eds.). Cooperative Breeding in Birds: Long-term Studies of Ecology and Behavior. Cambridge Univ. Press, Cambridge, England.

Walters, J. R., C. K. Copeyon and J. H. Carter, III. 1992. Test of the ecological basis of cooperative breeding in the red-cockaded woodpecker. Auk 109:90-97.

Watson, J.C., R.G. Hooper, D.L. Carlson, W.E. Taylor and T.C. Milling. 1995. Restoration of the red-cockaded woodpecker population on the Francis Marion National Forest: three years post-Hugo. pp. 172-182. *In* D.L. Kulhavey, R.G. Hooper and R. Costa (eds.). Red-cockaded Woodpecker: Recovery, Ecology and Management. Center for Applied Studies, College of Forestry, Stephen F. Austin State Univ., Nacogdoches, TX.

Waters, T.F. 1995. Sediment in streams: sources, biological effects, and control. American Fisheries Society Monograph 7. 251 pp.

Widdows, J., P. Fieth, and C.M. Worrall. 1979. Relationships between seston, available food, and feeding activity in the common mussel *Mytilus edulis*. Marine Biology 50:195-207.

Williams, J.D., M.L. Warren, Jr., K.S. Cummings, J.L. Harris, and R.J. Neves. 1993. Conservation status of freshwater mussels of the United States and Canada. Fisheries 18:6-22.

Wilson, C.B., and H.W. Clark. 1914. The mussels of the Cumberland River and its tributaries Report of the U.S. Fishery Commission, Washington, D.C. U.S. Bureau of Fisheries Document No. 781.

Wright, Robert D. 1990. Species Biology of Lindera melissifolia (Walt.) Blume. in Northeast Arkansas. University of Central Arkansas. Conway, Arkansas 72203.

Yeager, M.M., D.S. Cherry, and R.J. Neves. 1994. Feeding and burrowing behaviors of juvenile rainbow mussels, *Villosa iris* (Bivalvia: Unionidae). Journal of the North American Benthological Society 13(2):217-222.

Yokley, P. 1972. Freshwater mussel ecology, Kentucky Lake, Tennessee: May 1, 1969 - June 15, 1972. Unpublished report, Tennessee Game and Fish Commission, Nashville. 133 pp.