

# **Mussel Surveys Associated with the Duke Power – Nantahala Area Relicensing Projects in the Little Tennessee and Hiwassee River Systems**

Prepared for

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# **1.0 Introduction**

## **1.1 Background**

Duke Power (Duke), a division of Duke Energy Corporation, is presently in the process of relicensing several of its Nantahala area hydroelectric projects with the Federal Energy Regulatory Commission. As a part of that process, the US Fish and Wildlife Service (USFWS) and the North Carolina Wildlife Resources Commission (NCWRC) requested that surveys for the federally endangered Appalachian elktoe mussel, *Alasmidonta raveneliana* (I. Lea, 1834), and other mussel resources be conducted at localities near Duke Power-Nantahala Area hydropower facilities. Duke agreed to conduct mussel surveys in stream reaches associated with 4 riverine hydropower facilities on the Hiwassee, Little Tennessee, Oconaluftee, and Tuckasegee rivers (Mission, Franklin, Bryson, and Dillsboro); and peaking hydropower projects on the Nantahala River, and the East and West Forks (and other tributaries) of the Tuckasegee River (Nantahala Project, East Fork Project, and West Fork Project).

Within the Nantahala area, viable populations of native mussels are known presently in the Little Tennessee River downstream from Franklin Dam; in the Tuckasegee River (Little TN River system) downstream from Dillsboro Dam to the backwaters of the Tennessee Valley Authority (TVA) Fontana Reservoir and upstream to near Cullowhee; and in the Hiwassee River downstream from Mission Dam (downstream from Brasstown Creek to the backwaters of TVA's Hiwassee Reservoir). These Little Tennessee and Tuckasegee River populations constitute most of the native riverine mussel fauna left in the entire Little Tennessee River system. Throughout most of their lengths, the Little Tennessee River and its larger tributaries have been impounded or otherwise altered such that native mussel habitats are either absent or substantially degraded. The mainstem of the Little Tennessee River is almost entirely impounded from the mouth upstream to the backwaters of TVA's Fontana Reservoir (Little Tennessee River Miles [LTRM] 0-90). In the Hiwassee River system, fewer dams have been built and a bit more riverine habitat survives along the mainstem; however, mussel habitat in most of these remaining riverine reaches is degraded by altered flow regimes and cold water temperatures controlled by releases from upstream dams.

At least 10 mussel species are believed to survive within streams near Duke Power-Nantahala Area hydroelectric facilities in western North Carolina: at least eight of these species likely persist in the Little Tennessee River system and at least 6 species still occur in the Hiwassee River system (Ahlstedt and Fraley 2000; C. McGrath, NCWRC, and J. Fridell, USFWS, personal communication 2001). Two of these mussels are federal endangered species [Appalachian elktoe and littlewing pearlymussel, *Pegias fabula* (I. Lea, 1838) in the Little Tennessee River], two are listed as endangered in North Carolina [slippershell mussel, *Alasmidonta viridis* (Rafinesque, 1820) in the Little Tennessee, and Tennessee pigtoe, *Fusconaia barnesiana* (I. Lea, 1838) in the Little Tennessee and Hiwassee]; and two are listed as special concern in North Carolina [wavy-rayed lampmussel, *Lampsilis fasciola* Rafinesque, 1820, and rainbow, *Villosa* sp. cf. *iris* (I. Lea, 1829) in the Little Tennessee and Hiwassee] (Alderman, et al. 2001, Ahlstedt and Fraley 2000, North Carolina Department of Environment and Natural Resources 2001, Tennessee Valley Authority 2001). Stream reaches near Duke Power-Nantahala Area hydroelectric facilities known to contain Appalachian elktoes are limited to scattered localities on the Tuckasegee River (Little Tennessee River system) from the backwaters of Fontana Reservoir upstream to the vicinity of Webster, NC (approximately 25 river miles) and the Little Tennessee River from the backwaters of Fontana Reservoir upstream to Franklin Dam (approximately 24 river miles) (Fridell 2001, TVA Regional Natural Heritage Database 2001, C. McGrath, NCWRC, personal communication 2001). The littlewing pearlymussel is believed to inhabit this same reach of the Little Tennessee River (Alderman, et al. 2001, D. Biggins, USFWS, personal communication 1996). More detailed distribution and life history information for these protected species is given in section 3.0.

## **1.2 Purpose and Scope**

Surveys were conducted to identify the distribution and abundance of native mussel stocks just upstream and downstream from four riverine hydropower facilities (Dillsboro, Bryson, Franklin, and Mission dams) located on the Tuckasegee, Oconaluftee, Little Tennessee, and Hiwassee rivers. Other surveys were conducted to determine if native mussel populations were present in specific areas influenced by the operation of peaking hydropower facilities located on the Nantahala River, Dicks Creek, and the East

and West forks of the Tuckasegee River. In addition, any hellbenders (*Cryptobranchus alleghaniensis*) (Federal Species of Concern and NC Species of Concern) encountered during any of these surveys were reported. The areas surveyed at some sites included all likely habitats, while others were limited to transects previously established for Instream Flow Incremental Methodology (IFIM) analysis. All of the survey sites were located in Cherokee, Clay, Jackson, Macon, and Swain counties, North Carolina.

## **2.0 Methods**

### **2.1 Survey Techniques**

All in-water work was conducted by mask and snorkel-equipped personnel. At each site, the stream bottom was visually searched for mussel shells and siphons. Tactile searches were also used to augment visual searching when necessary. Larger rocks and other material (particularly macrophytes) at the substrate surface were moved and sediment was fanned away to increase search efficiency. When found, mussels were removed from the substrate and identified to species. Nomenclature follows Turgeon, et al. (1998). Maximum lengths from a representative sample of each species encountered at a site were measured to the nearest 0.1 mm with digital calipers. Mussels were replaced at the approximate location from which they were removed.

Three types of field techniques were employed during these surveys. Each technique was used to achieve specific goals, depending on the location.

***Riverine Facilities*** - The surveys at these facilities began by laying out grids running either 300 or 600 feet (91 or 183 meters) downstream and subdivided into 100 foot (30.5 meter) increments. The width of the river also was measured and divided into four equal segments and delineated with anchored buoys at each 100 foot linear segment. Each 100 foot by  $\frac{1}{4}$  river width segment was surveyed for mussels using a timed, random search approach, with effort concentrated in areas which appeared to be the best mussel habitat. Separate tallies were kept for each 100 foot by  $\frac{1}{4}$  river width segment of the number of mussels encountered, a qualitative assessment of the spatial distribution of mussels, substrate composition, and average water depth.

***Along IFIM Transects*** - At specific locations on the Tuckasegee River, mussels were quantitatively surveyed along previously established IFIM transects. Surveyor's pins marking transect locations across likely Appalachian elktoe habitat (cobble/gravel runs and riffles) were located on both sides of the river. A chain was stretched between these pins (perpendicular to the flow of the river) and was anchored along the river bottom. Five meter increments were marked along the length of the chain. Personnel searched

for mussels along the downstream side of this chain, using a one meter long gauge stick, held parallel to the flow of the river with the upstream end flush with the transect chain, to limit their search area. Mussel presence and habitat data were recorded separately for each one meter long by 5 meter wide transect segment.

**All Other Sites** - Timed, random searches in representative stream reaches were conducted, with effort concentrated in areas with the apparent best mussel habitat. The total number of mussels encountered and catch per unit effort (CPUE = number of mussels/hours of effort) were combined for all personnel searching at each site. A qualitative assessment of substrate composition, and average depth also were recorded for each area surveyed.

## **2.2 Surveyed Areas**

Figure 1 shows the relative locations of the Duke Power-Nantahala Area hydropower facilities and the areas surveyed. Figures 2 through 14 depict the areas specifically surveyed. Table 1 lists the site-specific location information for all areas included in this survey. The following paragraphs summarize this information for each identified river.

**Tuckasegee River** - (9 sites) An area was intensively surveyed in the reach within 300 feet (91 meters) immediately downstream from the Dillsboro Dam (Tuckasegee River Mile [TuRM] 31.7) (Figure 2). Timed, random surveys were made at five other sites: a site immediately upstream from the Dillsboro impoundment (TuRM 32.6) and four sites within the reach immediately downstream from the low-head dam at Cullowhee (not operated by Duke), upstream to the NC 107 crossing (TuRM 41.2-45) (Figure 3). These sites were selected for surveys because they contained the most suitable mussel habitat in stream segments representative of conditions found within the Tuckasegee River. Three other sites between Webster and Bryson City were intensively surveyed across previously established IFIM transect localities (TuRM 14.2, 23.3, and 36.2) (Figures 4 and 5).

**Nantahala River** - (7 sites) Timed, random surveys were made at four sites within the bypass reach between Nantahala Dam and Nantahala Powerhouse (NRM 17.4-22.3) (Figure 6). Sites were selected for surveys because they contained the most suitable mussel habitat in stream segments representative of conditions found within the bypass

reach. Three sites with the most suitable mussel habitat downstream from the powerhouse were also surveyed (NRM 5.3-12.5) (Figures 7 through 9). The uppermost site was at the upstream end of the uppermost fish depletion sampling site.

***Little Tennessee River*** - (2 sites) A site was intensively surveyed in the 300 foot (91 meter) reach immediately downstream from Franklin Dam downstream to the mouth of Watauga Creek (LTRM 113.1) (Figure 10). A timed, random survey was made at one site upstream from the Franklin impoundment (LTRM 118.5) (Figure 11). The upstream site was selected based on presence of most suitable mussel habitat nearest to the upstream end of the Franklin impoundment.

***Oconaluftee River*** - (2 sites) A site was intensively surveyed in the reach within 600 feet (183 meters) immediately downstream from Bryson Dam (ORM 0.5) (Figure 12). The other site immediately upstream from the Bryson impoundment was surveyed in an area with the most suitable mussel habitat within the upstream limit of the Bryson project boundary (ORM 2).

**Table 1. Locality and survey information for all sites associated with Nantahala Power & Light hydroelectric projects, surveyed in August and September, 2001. Latitude and longitude coordinates are to the nearest thousandths of a minute. Effort time was not recorded for quantitative samples at IFIM transects.**

River	River Mile	Latitude N	Longitude W	County	Description	Survey Technique	Overall Effort (phrs)	Date Surveyed
Tuckasegee	14.2	35 25.893	83 25.427	Swain	Approximately 0.6 mi. downstream from the US 19 bridge, adjacent to campground on left descending bank. <b>IFIM transect: SS4-T2</b>	IFIM Transect	-	14-Sep
Tuckasegee	23.3	35 24.516	83 19.614	Jackson	Approx. 0.8 air mile east of US 441-19/74 intersection, behind upstream end of Gateway Flea Market. <b>IFIM transect: SS3-T1</b>	IFIM Transect	-	13-Sep
Tuckasegee	31.7	35 22.031	83 15.065	Jackson	100 yard reach immediately downstream from Dillsboro Dam, upstream from US 441 crossing.	Downstream ROR	9	7-Aug
Tuckasegee	32.6	35 21.393	83 14.962	Jackson	At first shoal upstream from Dillsboro impoundment, approx. 1 mile downstream from Savannah Cr. confluence.	Timed Random Search	4	6-Sep
Tuckasegee	36.2	35 20.464	83 12.670	Jackson	At head of island approx. 0.75 mi. upstream from NC 116 crossing (Webster Bridge). <b>IFIM transect: SS1-T1</b>	IFIM Transect	-	13-Sep
Tuckasegee	41.2	35 18.911	83 10.581	Jackson	Shoal area immediately downstream from lowhead dam at Cullowhee, upstream from old NC 107 crossing.	Timed Random Search	2	8-Aug
Tuckasegee	42.5	35 18.456	83 09.572	Jackson	Off Wayehutta Rd. 0.6 road mile southeast of Edgewater Rd. intersection.	Timed Random Search	2	8-Aug
Tuckasegee	43.6	35 18.205	83 10.360	Jackson	Off Wayehutta Rd., approx. 0.5 road mile north of old NC 107 intersection.	Timed Random Search	2	8-Aug
Tuckasegee	45	35 17.700	83 9.450	Jackson	Shoal at NC 107 crossing, upstream from Cullowhee.	Timed Random Search	2	8-Aug
Nantahala	5.3	35 19.978	83 35.450	Swain	Off US 19/74, just upstream from Wesser Falls, at new bridge.	Timed Random Search	2	18-Sep
Nantahala	7.2	35 20.157	83 37.076	Swain	Off US 19/74, behind Roper's Barbeque, upstream from Miller Cove.	Timed Random Search	2	18-Sep
Nantahala	12.5	35 16.911	83 40.422	Macon/ Swain	Off US 19/74, near mouth of Ledbetter Creek	Timed Random Search	2	18-Sep
Nantahala	13.6	35 16.385	83 40.489	Macon	Bypass reach, just upstream from Queen's Creek Powerhouse discharge.	Timed Random Search	2	12-Sep
Nantahala	17.4	35 15.015	83 38.433	Macon	Bypass reach, just upstream from mouth of Whiteoak Creek.	Timed Random Search	2	11-Sep
Nantahala	18.7	35 14.059	83 38.665	Macon	Bypass reach, 1.5 road miles upstream from mouth of Whiteoak Creek.	Timed Random Search	1.5	12-Sep
Nantahala	22.3	35 12.397	83 39.330	Macon	Bypass reach, 0.4 road mile downstream from Nantahala Dam Rd. ford.	Timed Random Search	1	11-Sep
Little Tennessee	113.1	35 13.236	83 22.296	Macon	100 yard reach immediately downstream from Emory Dam, to the mouth of Watauga Creek.	Downstream ROR	21.4	23-Aug
Little Tennessee	118.5	35 09.708	83 22.516	Macon	First shoal upstream from Emory impoundment, approx. 0.3 mile upstream from US 441/23 (Bypass) crossing.	Timed Random Search	4	6-Sep
Oconaluftee	0.5	35 26.790	83 22.550	Swain	200 yard reach immediately downstream from Ela Dam.	Downstream ROR	8	7-Sep
Oconaluftee	2	35 27.328	83 22.162	Swain	First shoal upstream from Ela impoundment, off US 19.	Timed Random Search	3	12-Sep
Hiwassee	106	35 03.917	83 56.083	Cherokee/ Clay	200 yard reach immediately downstream from Mission Dam.	Downstream ROR	8	6-Aug
Cullasaja	0.3	35 10.229	83 21.923	Macon	Area immediately upstream from Emory impoundment to upstream Emory project boundary, near US 441/23 (Bypass) crossing.	Timed Random Search	2.3	7-Aug
Dicks Creek	(0+)	35 13.285	83 39.662	Macon	Lower 100 yard reach from confluence with Nantahala River to near Cloud Walker Rd.	Timed Random Search	1	11-Sep

**Hiwassee River** - (1 site) This site was intensively surveyed in the reach within 600 feet (183 meters) immediately downstream from Mission Dam (HiRM 106) (Figure 13). Results from a previous survey immediately upstream from the Mission impoundment were also reported (Ahlstedt and Fraley 2000).

**Cullasaja River** - (1 site) This site, immediately upstream from the Franklin impoundment, was surveyed to the upstream limit of the Franklin project boundary (CuRM 0.3) (Figure 11).

**Dicks Creek** - (1 site) The lower 100 yards (91 meters) of Dicks Creek were surveyed, beginning at the confluence with the Nantahala River (Figure 14).

**West Fork Tuckasegee River** - A reconnaissance of the West Fork Tuckasegee River, between Glenville Dam and powerhouse and Tuckasegee Dam and powerhouse, was made to determine if any suitable mussel habitat exists there. No promising habitat or other evidence of mussel occurrence was discovered and no further instream surveys were conducted.

## **3.0 Distribution and Life History of Protected Species**

### **3.1 General Information**

North American freshwater mussels are bivalve mollusks classified in the families Unionidae and Margaritiferidae. These animals spend most of their lives embedded in the bottom of streams, rivers, or lakes, generally moving very little. Mussels have paired calcareous shells (valves) that are secreted by the outer layer of their bodies (mantle). The soft bodies of mussels can be completely enclosed within the valves; however, life functions require that the valves be partially open for most of the time. Feeding, gas exchange, and reproduction all involve taking water in and expelling it out through two tube-like extensions of the mantle called siphons. The beating of cilia moves water over the gills where gas exchange occurs and food items are filtered from the water. Mussels collect and digest small suspended material, including plankton and organic detritus.

Mussels have a complex reproductive cycle. Male mussels release sperm into the water column and eggs are believed to be fertilized when females take in water that contains sperm. Portions of the females' gills are modified into brood pouches where the eggs are held while they develop into larvae. Female mussels carrying larvae are termed "gravid". Native freshwater mussels are broadly separated into two reproductive categories: short- and long-term brooders. Short-term brooders are those species whose larvae are fertilized, grow, and are expelled within the warmer months of a single year. Long-term brooders typically retain the mature larvae over the winter before releasing them. Larvae (glochidia) of almost all mussel species must live as parasites on a fish before they can transform into a juvenile mussel. Some species can transform on a number of fish species, while others are restricted to one or a small group of fish species. Glochidia attach to the gills or fins of their host fishes. Many mussel species have evolved elaborate "lures" that attract fishes, increasing the likelihood of glochidia attachment. Modified parts of the mantle on some mussel species mimic in incredible detail the appearance and movements of minnows, crayfish, hellgrammites, worms, and other fish prey. Others expel the glochidia encased in small packets (conglutinates) that also mimic fish prey (e.g. larval fish, aquatic insects, worms). The glochidia generally

remain attached to the host fish for between one and several weeks before transforming and detaching from the fish. Subsequent survival of the juvenile mussel is presumed to depend largely upon it settling in suitable habitat on the stream bottom.

North American freshwater mussels are one of the most imperiled groups of animals in the world (Bogan 1993; Williams, et al. 1993). Of the 102 recognized species known from the Tennessee River basin, 29 are presently listed as federally endangered or threatened under the Endangered Species Act and 11 species are believed to be extinct. While not formally listed, the continued survival of another 6 species has been identified as threatened or endangered and 31 species are considered species of special concern (Williams, et al. 1993). Only 36 of the 102 species known from the Tennessee River drainage are considered at presently stable population levels.

The following accounts contain specific distribution and life history information for each of the six mussel species with either state or federal protection, that are known to occur in the Nantahala area. This information was compiled from a number of primary (Ortmann 1921, Clarke 1981) and summary (Alderman, et. al., 2001; Fridell 2001; North Carolina Department of Environment and Natural Resources 2001; Parmalee and Bogan 1998; Tennessee Valley Authority 2001; Watters 1994) source materials, as well as personal observations.

### **3.2 Appalachian Elktoe, *Alasmidonta raveneliana* (I. Lea, 1834)**

***Protection Status:*** Federal Endangered Species.

The USFWS has proposed critical habitat for this species (Fridell 2001). The proposed areas include: 24 river miles (38.5 km) of the Little Tennessee River from Franklin Dam downstream to the backwaters of Fontana Reservoir, Swain and Macon Counties, North Carolina; and, 26 river miles (41.6 km) of the Tuckasegee River from the N.C. State Route 1002 Bridge in Cullowhee, downstream to the N.C. Highway 19 Bridge, north of Bryson City, Jackson and Swain counties, North Carolina.

***Distribution:*** The known range of the Appalachian elktoe is restricted to tributaries of the Tennessee River in East Tennessee and western North Carolina. In Tennessee, the

species is known only from a short reach of the Nolichucky River. In North Carolina, it is now known to occur in short reaches of the Nolichucky, North Toe, South Toe, Cane, Pigeon, and Little rivers (French Broad River system); and the Little Tennessee, Tuckasegee, and Cheoah rivers (Little Tennessee River system). Historically, it was also found in Tulula Creek (Little Tennessee River system), the mainstem of the French Broad River, and the Swannanoa River (French Broad River system), but has apparently been eliminated from those streams. The Appalachian elktoe has never been recorded from the Hiwassee River system.

**Habitat Preferences:** Relatively little is known about the micro-habitat requirements of this animal. The Appalachian elktoe is known to inhabit relatively shallow, medium-sized rivers and large creeks with cool, well-oxygenated and moderate to fast-flowing water, generally at depths of less than three feet. It is found in a variety of substrate types including gravel mixed with cobble and boulders; in cracks in bedrock; and in relatively silt-free, coarse sand. Substrate stability appears to be critical to the Appalachian elktoe, and it is seldom found in stream reaches with excessive accumulations of silt or other shifting substrata.

**Life History:** The Appalachian elktoe is generally identified as a long-term brooder. Ortmann (1921) reported that the breeding season ended in May, based on four gravid females collected from the Pigeon River in May, 1914. Gravid Appalachian elktoes have been found in the Little Tennessee River in October through January. Both the banded sculpin (*Cottus carolinae*) and the mottled sculpin (*C. bairdi*) have been identified as fish hosts for this mussel. Based on current sculpin taxonomy and distributions, the mottled sculpin most likely serves as a host in North Carolina streams. The life span and many other aspects of this mussel's life history are presently unknown. Anecdotal observations suggest that it is relatively fast-growing and short-lived (~10 years).

### **3.3 Littlewing Pearlymussel, *Pegias fabula* (I. Lea, 1838)**

**Protection Status:** Federal Endangered Species.

**Distribution:** The littlewing pearlymussel once inhabited tributaries of the Tennessee and Cumberland River systems in Alabama, Tennessee, Kentucky, Virginia and North

Carolina. Historical records are known from 24 stream reaches in these states, but it is presently known from only six stream reaches. In the Nantahala area, it is known from recent collections (1990-1995) from the Little Tennessee River (LTRM 90-95-- within the reach between Franklin Dam and Fontana Reservoir) and an historical collection (date unknown) from "Valley Creek" in the Hiwassee River drainage in Cherokee County (exact locality unknown-- probably Valley River).

**Habitat Preferences:** This small mussel inhabits cool, clear, small creeks to medium-sized rivers. Individuals have been found in the transition zone between pools and riffles, buried under large flat rocks, and in sand and gravel substrata adjacent to waterwillow (*Justicia americana*) beds, generally in water less than 2 feet deep. During spawning, it is often found lying on the substrate surface.

**Life History:** Relatively little is known about the life history requirements of this now extremely rare animal. Ortmann (1914, cited in Parmalee and Bogan 1998) collected a gravid female littlewing pearlymussel in mid-September, suggesting that it is a long-term brooder. The greenside darter (*Etheostoma blennioides*) and emerald darter (*E. baileyi*) [does not occur in the Tennessee River system] have been identified as hosts for this species. The banded sculpin, redline darter (*E. rufilineatum*), and wounded darter (*E. vulneratum*) have been suggested as potential hosts. Many other aspects of this mussel's life history are presently unknown.

### **3.4 Slippershell Mussel, *Alasmidonta viridis* (Rafinesque, 1820)**

**Protection Status:** North Carolina Endangered Species

**Distribution:** This species is widespread and occurs in the Upper Mississippi River, Ohio River (including the Cumberland and Tennessee River drainages), St. Lawrence River, Lake Huron, Lake St. Clair, and Lake Erie basins. In North Carolina, it is known from a short reach of the Mills River (French Broad River system) and the Little Tennessee River, between Franklin Dam and Fontana Reservoir.

**Habitat Preferences:** While the slippershell mussel is found primarily in small creeks and medium-sized rivers today, it once inhabited the shoals and riffles of large rivers

such as the French Broad and Holston before impoundment. It may typically be found in sand and fine gravel substrate, and in mud and sand bottoms among the roots of aquatic vegetation (especially waterwillow) where current is present.

**Life History:** The slippershell is probably a long-term brooder, with gravid females observed from fall through spring. Individuals of this species have been observed spawning in January and February in the Little Tennessee River. Fish hosts identified for the slippershell mussel include banded and mottled sculpins, and the Johnny darter (*E. nigrum*) [does not occur in Tennessee River tributaries in the Nantahala area].

### **3.5 Tennessee Pigtoe, *Fusconaia barnesiana* (I. Lea, 1838)**

**Protection Status:** North Carolina Endangered Species

**Distribution:** The Tennessee pigtoe is restricted to streams in the Tennessee River drainage. It is widespread and often locally common within this drainage and occurs in portions of nearly all Tennessee River tributaries, primarily in headwaters. In North Carolina, this species is very rare and found only in a short reach of the Little Tennessee River, between Franklin Dam and Fontana Reservoir, and in the Hiwassee River, between Mission Dam and Hiwassee Reservoir.

**Habitat Preferences:** This species prefers riffles and runs of cool, clear small streams and medium rivers. It was also found in larger rivers prior to impoundment. Throughout most of its range it is found in clean-swept substrates of sand, gravel, and cobble. In many streams, the Tennessee pigtoe is often the most abundant mussel species in these habitats. It is rare in pools and slack waters.

**Life History:** Surprisingly, very little is known about the life history of this often common mussel. It is probably a short-term brooder, based on data from other closely related species. Host fish are unknown.

### **3.6 Wavyrayed Lampmussel, *Lampsilis fasciola* Rafinesque, 1820**

**Protection Status:** North Carolina Species of Special Concern

***Distribution:*** The wavyrayed lampmussel is widely distributed from the Great Lakes, through the Ohio and Mississippi river basins, as far south as the Tennessee River drainage (Parmalee and Bogan 1998). Similar to the Tennessee pigtoe, it is widespread and often locally common in the Tennessee River drainage and occurs in portions of nearly all of its tributaries, primarily in headwaters. In North Carolina, it occurs in the Nolichucky and Pigeon rivers (French Broad River system); the Little Tennessee and Tuckasegee rivers (Little Tennessee River system); and the Hiwassee River.

***Habitat Preferences:*** This species typically inhabits larger creeks and medium-sized rivers, usually occurring at depths of three feet or less. Wavyrayed lampmussels and Tennessee pigtoes often occur in the same general stream reaches; however, it can tolerate habitats with slower currents and finer substrata, that are often unfavorable to other species. It reaches its greatest abundance in moderate currents with a stable sand and gravel bottom.

***Life History:*** In spite of the extensive range and local abundance of the wavyrayed lampmussel, its reproductive period is poorly understood. In the Little Tennessee River, the abundance of gravid females appears to peak in early to mid-summer (June - July), which suggests it is a long-term brooder; however, some gravid females can be found from early spring through fall. While the primary host fish is apparently smallmouth bass (*Micropterus dolomeiu*), it may utilize other black bass species. This species, like other *Lampsilis*, produces elaborate lure displays from a highly modified mantle flap. Females in the Little Tennessee River show exceptional variability in the types of mimics that they produce.

### **3.7 Rainbow, *Villosa* sp. cf. *iris* (I. Lea, 1829)**

***Protection Status:*** North Carolina Species of Special Concern

***Distribution:*** Rainbows are widely distributed throughout the St. Lawrence, upper Mississippi, and Ohio river basins (including the Cumberland and Tennessee River drainages). Rainbows are also widespread and locally common in the Tennessee River drainage and occur in portions of nearly all of its tributaries, primarily in headwaters. In

North Carolina, this species was collected historically from the Watauga (Holston River system) and French Broad rivers, but is now known only from the Hiwassee and Little Tennessee river systems. It is present both up- and downstream from Mission Dam (Hiwassee River) and downstream from Franklin Dam (Little Tennessee River).

The type locality for this species is on the Ohio River. In the Tennessee and Cumberland drainages, there are several distinct forms that are presently included within the rainbow species concept. Some of these forms may represent closely related, but as of now, unrecognized species. Animals collected from tributaries in western North Carolina may represent one or more of these forms. This problem is presently being studied and more information regarding the taxonomic status of this group may become available in the near future.

**Habitat Preferences:** The rainbow generally occurs at depths of less than three feet in relatively clean, well-oxygenated reaches of small streams to medium-sized rivers. This species is found in a variety of habitats from swift riffles to quiet backwaters. It is most numerous along the edges of streams in moderate to low current and in silt, sand, and gravel substrata, often along the edges of waterwillow beds. In faster flowing reaches, it is often found under large, flat rocks.

**Life History:** This species is a long-term brooder with gravid females observed from July to May. Numerous host fishes have been identified for this species, including: rockbass (*Ambloplites rupestris*), smallmouth bass, largemouth bass (*Micropterus salmoides*), spotted bass (*M. punctulatus*), Suwannee bass (*M. notius*) [does not occur in the Tennessee River system], and the western mosquitofish (*Gambusia affinis*). Rainbows appear to be relatively short-lived (~10 years).

## **4.0 Results**

Tables 2 and 3 present the results from sites where mussels were found. The following paragraphs present summaries of this information and other observations. Hellbender observations are listed under a separate heading at the end of this section.

### **4.1 Riverine Facilities**

***Dillsboro Dam (Tuckasegee River)*** - Two mussel species were found immediately downstream from Dillsboro Dam, including the Appalachian elktoe, which was the most abundant species (see Table 2). A total of 44 individual mussels (41 Appalachian elktoes) were collected and the overall CPUE was 4.9 mussels per person hour of search time (Appalachian elktoe CPUE= 4.4). Greatest relative abundance was at and to the left (descending) side of mid-channel, between 100 and 300 feet (30.5 and 91 meters) downstream from the dam. One Appalachian elktoe was found within 100 feet of the dam (70 feet [21 meters] from the dam face, center left quarter of channel). This 100-foot segment immediately downstream from the dam contained relatively poor mussel habitat, with much of the area dominated by a deep pool and bedrock substrate. The remaining area surveyed contained relatively good mussel habitat, consisting primarily of shallow runs with a mix of gravel, cobble, and sand substrate.

The same two species were found immediately upstream from the Dillsboro impoundment. A total of 15 mussels (14 Appalachian elktoes) was collected at the upstream site and overall CPUE was 3.75 mussels per person hour of search time (Appalachian elktoe CPUE= 3.5). A good distribution of size/age classes (range= 25-76 mm total length) was represented by the Appalachian elktoe specimens collected from both the upstream and downstream sites, indicating recent reproduction and recruitment at both sites.

***Franklin Dam (Little Tennessee River)*** - Four mussel species were found immediately downstream from Franklin Dam, including the Appalachian elktoe, which was the most abundant species (see Table 3). A total of 164 mussels (63 Appalachian elktoes) was

collected and the overall CPUE was 7.7 mussels per person hour of search time (Appalachian elktoe CPUE= 2.9). Greatest relative abundance was to the right (descending) of mid-channel, between 100 and 300 feet (30.5 and 91 meters) downstream from the dam. The distribution of mussels was roughly wedge-shaped, with the powerhouse discharge channel at the narrow end of the wedge. Mussels were present to within 50 feet (15 meters) downstream from the powerhouse, in the right (descending) quarter of the river channel. Very little mussel habitat existed in the left

**Table 2. Mussels collected immediately downstream from Dillsboro Dam, Tuckasegee River mile 31.7 (phrs= person hours, CPUE= catch per unit effort, Appalachian elktoe CPUE in parentheses)**

Distance From Dam (ft)	Species		Channel Quarter				Total
	Common Name	Scientific Name	Right	Center Right	Center Left	Left	
0-100	Appalachian elktoe	<i>Alasmidonta raveneliana</i>	0	0	1	0	1
		Effort (phrs)	0.5	0.5	0.5	0.5	2
		CPUE	0	0	(2)	0	(0.5)
100-200	Appalachian elktoe	<i>Alasmidonta raveneliana</i>	4	1	14	6	25
	Wavyrayed lampmussel	<i>Lampsilis fasciola</i>	0	0	3	0	3
		Total	4	1	17	6	28
		Effort (phrs)	0.75	0.75	0.75	0.75	3
		CPUE	(5.3)	(1.3)	22.7 (18.7)	(8)	9.3 (8.3)
200-300	Appalachian elktoe	<i>Alasmidonta raveneliana</i>	3	3	8	0	14
	Wavyrayed lampmussel	<i>Lampsilis fasciola</i>	1	0	0	0	1
		Total	4	3	8	0	15
		Effort (phrs)	1	1	1	1	4
		CPUE	4 (3)	(3)	(8)	0	3.8 (3.5)
Total	Appalachian elktoe	<i>Alasmidonta raveneliana</i>	7	4	23	6	40
	Wavyrayed lampmussel	<i>Lampsilis fasciola</i>	1	0	3	0	4
		Total	8	4	26	6	44
		Effort (phrs)	2.25	2.25	2.25	2.25	9
		CPUE	3.6 (3.1)	(1.8)	11.6 (10.2)	(2.7)	4.9 (4.4)

(descending) three quarters of the river channel, to approximately 250 feet (76 meters) downstream from the dam. Bedrock and large boulders dominated the substrate in this area. All four species collected were represented by multiple size/age classes (range= 14.1-90.9mm), indicating recent reproduction and recruitment.

No live mussels or any relict shells were found at the Little Tennessee River and Cullasaja River sites, immediately upstream from the Franklin impoundment. The Little Tennessee River site was dominated by slow runs with heavy deposits of sand and fine sediments. Some relatively fair mussel habitat was present in riffles and swift runs;

however, a large proportion of sand and fine sediments was present in these habitats. The area surveyed at the Cullasaja River site was entirely slow run, approximately 2.5 feet (0.8 meters) deep. While a high proportion of sand and fine sediments was present, there was noticeably less than at the Little Tennessee site.

***Mission Dam (Hiwassee River)*** - During this survey, no live mussels nor any relict shells were found immediately downstream from Mission Dam on the Hiwassee River. Substrate and habitat quality appeared to be at least adequate to support native mussels; however, none were found. Previous surveys identified at least four mussel species immediately upstream from the Mission impoundment (HiRM 108.2), no mussels at HiRM 104.6, and at least three species at HiRM 102.2 (Ahlstedt and Fraley 2000).

***Bryson Dam (Oconaluftee River)*** - No live mussels nor any relict shells were found during surveys at both upstream and downstream sites associated with Bryson Dam on the Oconaluftee River. Substrate and habitat quality appeared to be at least adequate to support native mussels; however, no mussels were found.

#### **4.2 IFIM Transects**

In the Tuckasegee River, no mussels were collected during surveys along IFIM transects at the upstream site (TuRM 36.2), nor at the middle site (TuRM 23.3). These results should not be interpreted to mean that mussels are absent from these reaches of the river. Mussels are known to be present in the general reaches where these transects were located; however, their abundance is low and distribution is patchy.

Five Appalachian elktoes were collected at the downstream site (TuRM 14.2). Mussels were collected from three of 21 total transect segments. Segments containing mussels were located between 15 and 20 meters (49 and 66 feet) from the left (descending)

**Table 3. Mussels collected immediately downstream from Franklin Dam, Little Tennessee River (phrs= person hours, CPUE= catch per unit effort, Appalachian elktoe CPUE in parentheses)**

Distance From Dam (ft)	Species		Channel Quarter				Total
	Common Name	Scientific Name	Right	Center Right	Center Left	Left	
0-100	Appalachian elktoe	<i>Alasmidonta raveneliana</i>	2	0	0	0	2
	Wavyrayed lampmussel	<i>Lampsilis fasciola</i>	1	0	0	0	1
	Rainbow	<i>Villosa sp. cf. iris</i>	1	0	0	0	1
		Total	4	0	0	0	4
		Effort (phrs)	2.5	0.5	0.5	0.5	4
	CPUE	1.6 (0.8)*	0	0	0	1 (0.5)	
100-200	Appalachian elktoe	<i>Alasmidonta raveneliana</i>	24	1	0	0	25
	Wavyrayed lampmussel	<i>Lampsilis fasciola</i>	17	0	0	0	17
	Slippershell mussel	<i>Alasmidonta viridis</i>	14	0	0	0	14
	Rainbow	<i>Villosa sp. cf. iris</i>	7	0	0	0	7
		Total	62	1	0	0	63
	Effort (phrs)	3.9	1.3	0.5	0.5	6.2	
	CPUE	15.9 (6.15)	(0.8)	0	0	10 (4)	
200-300	Appalachian elktoe	<i>Alasmidonta raveneliana</i>	18	15	3	0	36
	Wavyrayed lampmussel	<i>Lampsilis fasciola</i>	13	1	6	0	20
	Slippershell mussel	<i>Alasmidonta viridis</i>	3	14	12	2	31
	Rainbow	<i>Villosa sp. cf. iris</i>	2	2	5	1	10
		Total	36	32	26	3	97
	Effort (phrs)	2.8	2.8	2.8	2.8	11.2	
	CPUE	12.9 (6.4)	11.4 (5.4)	9.3 (1.1)	1.1	8.7 (3.2)	
Total	Appalachian elktoe	<i>Alasmidonta raveneliana</i>	44	16	3	0	63
	Wavyrayed lampmussel	<i>Lampsilis fasciola</i>	31	1	6	0	38
	Slippershell mussel	<i>Alasmidonta viridis</i>	17	14	12	2	45
	Rainbow	<i>Villosa sp. cf. iris</i>	10	2	5	1	18
		Total	102	33	26	3	164
	Effort (phrs)	9.2	4.6	3.8	3.8	21.4	
	CPUE	11 (4.8)	7.2 (3.5)	6.8 (0.8)	0.8	7.7 (2.9)	

bank (1 mussel), between 30 and 35 meters (98 and 115 feet) from the right bank (3 mussels), and between 35 and 40 meters (115 and 131 feet) from the right bank (1 mussel). This transect crossed a variety of habitat conditions. Mussels were found in both relatively swift and slow flowing runs with substrates ranging from predominately cobble/gravel to sand/gravel.

### **4.3 All Other Sites**

Mussels were found at only one other site. The second-most upstream site surveyed on the Tuckasegee River (TuRM 43.6, upstream from Cullowhee) produced a single live mussel. The shell of that mussel was severely eroded and almost completely lacking periostracum, making a positive identification very difficult. It could be ruled out as being an Appalachian elktoe, however, because the valves were so eroded that well defined lateral teeth were visible (lateral teeth are vestigial to absent in the Appalachian elktoe). It was tentatively identified as either a rainbow or a spike, *Elliptio dilatata* (Rafinesque,

1820), based on overall shell shape; however, this identification should be regarded as tentative given the condition of the shell and the apparent absence of other known records of either of these species from the Tuckasegee River (C. McGrath, NCWRC, personal communication, 2001). This individual mussel appeared to be a non-reproducing, living relict, and probably does not represent a viable population in this reach of the Tuckasegee River. Other recent surveys in the same general reach have failed to detect any mussels (C. McGrath, NCWRC; and T. Savidge, NC Department of Transportation, personal communication 2001).

No live mussels nor any relict shells were found at any of the sites surveyed on the Nantahala River and Dicks Creek. Some sites on the Nantahala bypass reach, especially the most downstream site (just upstream from the powerhouse discharges), appeared to have habitat at least adequate to support native mussels; however, none were found.

#### **4.4 Hellbender Observations**

Hellbenders were seen at three sites on the Tuckasegee River (TuRM 32.6, 43.6, and 45) and at the downstream site on the Oconaluftee River (ORM 0.5). One hellbender was seen at each of these sites, except at TuRM 32.6, where two animals were observed.

## **5.0 Discussion**

Impacts from impoundment are often cited as a primary cause for the decline of mussel species richness and abundance in the Tennessee River drainage (e.g. Ahlstedt 1983 and 1984; Bates 1962; Bogan 1993; Isom 1969 and 1971a; Parmalee and Bogan 1998; Parmalee and Hughes 1993). The habitat alterations associated with impoundment have played a role in the extinction of at least 11 mussel species from the Tennessee River system during the last century (Williams, et. al. 1993). Most reservoirs are very different from free-flowing rivers and a variety of relatively well understood factors related to impoundment can result in a drastic reduction in mussel species richness and changes in community composition (see Baxter 1977, Ward and Stanford 1979, Watters 2000, and Yeager 1993 for reviews of the effects of impoundment and other aspects of river regulation). Stream reaches downstream from dams (tailwaters) generally experience a different, but related, set of habitat alterations and subsequent changes in mussel resources. While some of the specific mechanisms involved are not yet fully understood, most downstream effects of dams are relatively well known. Some of these effects are clearly detrimental to mussels, some are neutral or insignificant, and other effects may even be beneficial under certain circumstances.

All dams are not identical and these differences can result in different reservoir and tailwater conditions and related impacts to mussels. There is a wide variety of dam designs and functions; however, the Duke Power-Nantahala Area hydroelectric projects can be divided into two general types: riverine facilities and storage-peaking facilities. Each type of facility has a similar design, but different operation characteristics. Thus, mussel populations can be affected differently downstream from some Nantahala area facilities of the same design. In addition, other factors such as past pollution events, can have a greater influence on present mussel community characteristics than some dam-related effects. In the following paragraphs, the common effects of each general dam type, and any unique characteristics of each facility or affected stream reach, are discussed as they relate to the present status of associated mussel resources.

### **5.1 Riverine Facilities**

**Common Effects** - Riverine facilities are generally less ecologically disruptive than storage-peaking facilities. This is due to their smaller overall “footprint” and fewer detrimental effects to tailwaters downstream from these dams. The four Nantahala area riverine projects (Dillsboro, Franklin, Mission, and Bryson) have relatively low head dams that impound small detention pools. Penstocks or flumes are relatively short and water that passes through the turbine(s) re-enters the stream a short distance downstream from the dam. By definition, these dams do not significantly alter water flow in the streams. River flow that exceeds the capacity-- or the desired operation level-- of the turbine(s) passes over the dam. Thus, the natural or background flow regime (hydrograph) is essentially unaltered by these facilities.

The most obvious impacts to mussels occur upstream from these dams. Impoundment causes lower flow velocities, increased depth, and subsequent sedimentation in the relatively small detention pools. These are unfavorable conditions for the protected mussels known from the Nantahala area and for the riffle and run-dwelling fishes that serve as hosts for their larvae. Small dams also can prevent the upstream movement of host fishes. This can effectively isolate upstream mussel populations or potential habitats by impeding gene flow and/or (re)colonization from downstream mussel populations (Watters 1996).

Downstream effects of riverine facilities are generally less detrimental to mussels. Since the detention pools are relatively shallow and retention time is short, the detention pools don't stratify (Duke, unpublished data). Consequently, water temperature and dissolved oxygen in the discharge are essentially the same as upstream of the impounded reach. Similarly, nutrient flow is not likely to be significantly altered by small riverine facilities. While some settling of particulate organic matter (an important source of nutrients for filter feeders) surely occurs in the detention pools, frequent mixing and flushing by higher flows likely prevents any substantial sequestration of nutrients.

In addition, small dams can alter bedload and sediment transport patterns. They can serve as sediment traps, allowing coarser sediments (e.g. sand) and some silt to settle out in the detention pool. Long-term downstream transport of larger bedload constituents (i.e. gravel, cobble) may also be interrupted. The loss of bedload material downstream from these dams can contribute to increased channel degradation (down

cutting) and bank erosion in the tailwater (Simons 1979, Ligon et al. 1995). Assessing the impact of these alterations on mussel resources is complicated and, for the most part, beyond the scope of this study. Nonetheless, some conclusions can be drawn from our observations and they are discussed below.

Excessive sedimentation is detrimental to most mussels (see reviews in Waters 1995 and Parmalee and Bogan 1998); however, a certain amount of sediment is necessary for the growth and survival of juvenile mussels (Yeager et al. 1994, R.J. Neves and J.W. Jones, Virginia Polytechnic Institute, personal communication, 2001). Lack of sediment does not appear to be a significant limiting factor for mussels downstream from Nantahala area riverine facilities. A relatively small stream reach between the downstream dam face and the powerhouse discharge may be sediment limited. These areas receive little or no flow except when water passes over the dam. Sediments and other small bedload particles are apparently scoured away from the area immediately downstream from the dam. These scoured reaches are relatively short downstream from Bryson and Dillsboro dams, but are slightly longer downstream from Franklin and Mission dams. Among the two riverine tailwaters that are presently known to contain mussels, no mussels were found in this reach immediately downstream from Franklin Dam, while one Appalachian elktoe was found immediately downstream from Dillsboro Dam.

***Franklin Dam*** - During these surveys, the greatest species richness and highest relative abundance of mussels (including the Appalachian elktoe) were found downstream from Franklin Dam. This reach of the Little Tennessee River from Franklin Dam to the backwaters of TVA's Fontana Reservoir supports the most abundant and diverse mussel fauna in western North Carolina. In contrast, no mussels were found upstream from the Franklin impoundment in either the Little Tennessee or Cullasaja rivers during these, or any other recent surveys (C. McGrath and J. Alderman, NCWRC, personal communication, 2001). Excessive sedimentation resulting from poor land use practices in the upper Little Tennessee River watershed, is apparently the primary reason for the lack of mussels upstream from Franklin Dam.

As evident by the near filling of Lake Emory (the Franklin detention pool), Franklin Dam has effectively trapped substantial amounts of sediment. Lake Emory contains perhaps

10 million cubic yards (7.6 million cubic meters) of sediments that otherwise would have continued down the Little Tennessee River (Simmons 1993, Kroeger 1994). This sediment trapping function may be the primary reason the relatively rich mussel fauna persists downstream from Franklin Dam. Much of this benefit, however, may have been already realized. Lake Emory no longer has the capacity to trap sediments due to near filling of the detention pool (G. Vaughan, Duke Energy, personal communication, 2002). Presently, most of the suspended sediment and much of the fine bedload sediments transported from upstream pass over the dam during high flow events. Bottom conditions in the immediate tailwater observed during our surveys indicate that a fair amount of sediment is also passed through the Franklin powerhouse.

The survey results suggest that the presence of Franklin Dam and the present operating regime have had no significant detrimental effects on the four mussel species found downstream from Franklin Dam. Moreover, considering the amount of sediment that has been trapped in Lake Emory, the presence of Franklin Dam has been a net benefit for downstream mussel populations.

***Dillsboro Dam*** – The presence and operation of the Dillsboro facility has had relatively little effect on mussel populations in the Tuckasegee River beyond those discussed under *Common Effects*. The present mussel species richness in the Tuckasegee River appears to have been limited primarily by past events that were unrelated to any action associated with Dillsboro Dam. Reproducing populations of the same species occur both upstream and downstream from the dam and detention pool, suggesting that the linear distribution of these species is not significantly affected by the Dillsboro facility.

The Tuckasegee River is now known to support reproducing populations of two mussel species: Appalachian elktoe and wavyrayed lampmussel. Prior to 1996, the presence of mussels in the Tuckasegee River was unknown to resource managers. No historical mussel collections are known from the Tuckasegee River and limited surveys made by TVA in the 1970's found no live mussels at selected sites between Dillsboro and Bryson City (TVA unpublished data; S.A. Ahlstedt, US Geological Survey, personal communication, 2001). Observations at that time suggested that effluent from a paper mill at Sylva produced water and sediment quality conditions that were unsuitable for mussels (Ridenhour 1973). This effluent entered the Tuckasegee River via Scott Creek,

which joins the river approximately 0.25 mile (0.4 km) downstream from Dillsboro Dam. Changes in operation and improved wastewater treatment at the paper mill that occurred during the 1970's and 80's, have apparently improved habitat conditions and helped make the lower Tuckasegee River suitable for natural mussel recolonization.

In 1996, Appalachian elktoes were found near Bryson City and subsequently at other upstream locales to near Dillsboro. In 1997, both Appalachian elktoes and wavyrayed lampmussels were found between the US 441 bridge and the Dillsboro Dam, and just upstream from the Dillsboro impoundment (author's personal observations; C. McGrath, NCWRC, personal communication, 1997; North Carolina Department of Environment and Natural Resources 2001). The results of our surveys add no new species to the known reproducing mussel fauna in the Tuckasegee River. The species now known to occur downstream from the mouth of Scott Creek are the same as those represented by reproducing populations upstream from both the mouth of Scott Creek and Dillsboro Dam. This suggests that the apparent recolonization of the lower Tuckasegee River has likely resulted from surviving mussel populations in the reach upstream from the mouth of Scott Creek.

***Mission Dam*** - Mussel occurrence in the Hiwassee River upstream from TVA's Hiwassee Reservoir was unknown to resource managers prior to 1998. Surveys conducted in 2000 confirmed the presence and linear distribution of at least six species in this reach of the river (Ahlstedt and Fraley 2000). At least four mussel species have been encountered immediately upstream from the Mission impoundment (HiRM 108.2); however, the absence of any evidence of recent recruitment and the apparent old age and poor condition of the remaining adults suggests that these are non-reproducing relicts. No mussels have been found within four miles downstream from Mission Dam, but at least three species are known at HiRM 102.2, where limited recruitment is occurring among wavyrayed lampmussels and rainbows.

In the reach of the upper Hiwassee River affected by Mission Dam, mussel populations appear to be limited primarily by cold water temperature coming from hypolimnetic releases from TVA's Chatuge Dam (HiRM 121). Cold water temperatures appear to play a major role in limiting mussel populations downstream from Mission Dam, at least to the mouth of Brasstown Creek (HiRM 103.1) (TVA, unpublished data). As evident by their

presence upstream from Mission Dam, individual mussels can persist for many decades in river reaches that experience altered temperature and flow regimes; however, reproduction and/or recruitment in these populations may cease. Cold water temperatures alone may not fully explain the apparent absence of at least a few relict adult mussels in the four-mile reach downstream from Mission Dam. Determination of such causal factors is beyond the scope of this study; however, the normal, daily operation of Mission Dam as a riverine facility has likely had little additional effect on downstream mussel populations.

**Bryson Dam** - Since there are no known historical records of mussels from the Oconaluftee River upstream or downstream from Bryson Dam, and none were found during this survey, specific impacts from Bryson Dam on mussel resources are difficult to determine. Habitat in the reach downstream from Bryson Dam to the confluence with the Tuckasegee River appears to be suitable, and water temperature and the fish community present in this reach appear to be sufficient for mussel growth and reproduction. The Appalachian elktoe population in the lower Tuckasegee River extends downstream well past the mouth of the Oconaluftee River. The apparent lack of colonization of the lower Oconaluftee River by the Appalachian elktoe remains unexplained by our limited observations.

## **5.2 Peaking Facilities**

**Common Effects** - Unlike riverine projects, storage-peaking facilities can have drastic and far-reaching effects on aquatic life in general and mussel resources in particular. There are a number of basic construction and operational differences between storage-peaking and riverine facilities that produce these effects. Storage-peaking dams are generally larger and impound longer river reaches, creating larger and deeper reservoirs. This larger pool area is used to store water during high flow periods for controlled release later in the year. Downstream from these dams, floods are substantially reduced (if not eliminated entirely) and maximum flow rarely exceeds bank-full. Releases for hydroelectric generation are planned to meet peak power demands, which may occur one or two times each day. This results in a tailwater hydrograph that may fluctuate from no (or minimum) flow to bank-full on a daily or hourly basis. Seasonal discharge in tailwaters is generally altered from the free-flowing hydrograph. Most of the typical high spring flows are stored in the reservoir and downstream releases

are reduced. In late summer and early autumn when free-flowing streams are generally at their lowest levels, releases from these dams are generally greater and more frequent in order to meet peak power demand.

The Nantahala area storage-peaking projects were constructed on high gradient streams at relatively high elevations (2278 – 3491 feet above sea level). Streams of this kind in the Blue Ridge physiographic province rarely support mussel populations (Parmalee and Bogan 1998). There are no known historical records of mussels from streams within the immediate vicinity of any of these storage-peaking facilities. It is reasonable to conclude that mussels did not occur at or upstream from these dam sites prior to their construction. Therefore, it is assumed that there are no effects on mussel populations upstream from these dams. Accordingly, the following discussion is limited to downstream effects and upstream effects only as they influence downstream conditions.

The potential downstream effects produced by storage-peaking facilities can be divided into three general categories: thermal, physico-chemical, and hydrological. Direct measurement of these variables below Nantahala area dams was beyond the scope of this study; however, a brief review of their known effects on mussel resources elsewhere is provided.

Changes in downstream water temperatures result from thermal stratification within the reservoir and the relative position of the intake to the powerhouse. Dams with hypolimnetic, or bottom intakes can discharge water that is substantially colder than the pre-impoundment condition and can cause some of the most significant effects in tailwaters below dams with hypolimnetic releases (Ward and Stanford 1979a, Watters 2000, Miller, et.al. 1984). These colder conditions can significantly alter ecological processes and aquatic community structure. Changes in fish and macroinvertebrate communities in cold tailwaters are generally drastic and can happen relatively quickly following impoundment (e.g. Pfitzer 1962, Ward and Stanford 1979b). Changes in fish communities in cold tailwaters can indirectly affect mussel reproduction by eliminating warm-water fish hosts (Tarzwell 1939, Dendy and Stroud 1949, Pfitzer 1962). Cold water conditions can also directly curtail reproduction in many mussel species, apparently through physiological changes that can disrupt gamete production (Heinricher and Layzer 1999, McMahon 1991, Yokely 1972). Layzer et al. (1993) concluded that

while a known fish host (banded sculpin) for three species of *Epioblasma* was abundant in the Center Hill Dam tailwater portion of the Caney Fork River, these mussels may have disappeared from that reach due to direct inhibition of reproduction by cold water. Mussel growth, condition, and short term survival can be adversely affected by cold tailwater conditions (Cahn 1936, Isom 1971b); however, some individual adult mussels may persist for many years following impoundment (Layzer et al. 1993, Ahlstedt and Fraley 2000). Eventually, most mussel species are eliminated entirely from cold tailwaters (Ahlstedt 1983, 1984; Layzer et al. 1993, Miller et al. 1984, Yeager et al. 1987).

Physico-chemical effects in storage-peaking tailwaters that can degrade mussel habitat include lowered dissolved oxygen concentrations, metal precipitates, increased hydrogen sulfide concentrations, and disruption of seston/nutrient transport. The biological and chemical processes that occur in the hypolimnion of stratified reservoirs can result in releases that are very low in dissolved oxygen. Dissolved oxygen (DO) levels of 6 mg/l are occasionally cited as the minimum necessary for mussel growth and reproduction in large streams (e.g. TVA 1990); but species-specific information regarding critical DO limits at all life stages is not available, especially for the species of concern in the Nantahala area. Anaerobic conditions in the hypolimnion of storage reservoirs facilitate the mobilization of certain metals (especially manganese and iron) and accumulation of hydrogen sulfides. As these waters are released below the dam and are aerated by turbulence, dissolved metals can precipitate out and are deposited on the stream bed (Hannan and Broz 1976). During this study, deposits believed to be characteristic of manganese and iron were noted in the upper reaches of the Tuckasegee (TRM 46 to 49.5) and Nantahala (NRM 10 to 13.5) rivers. Hydrogen sulfide (H<sub>2</sub>S) concentrations >0.002mg/l are considered to be detrimental to most fish and other aquatic life (Walburg et al. 1981, USEPA 1986). Toxic or harmful concentrations and specific effects of these metals (both dissolved and as deposits) and hydrogen sulfide on mussel species in the Nantahala area are not well known; however, national water quality criteria are established (USEPA 1986). Measurement of metal or hydrogen sulfide concentrations in the Nantahala area tailwaters was beyond the scope of this study.

Disruption of seston transport may have detrimental effects on mussel populations downstream from storage reservoirs. Seston in this context includes all suspended material, but particularly sources of carbon, nitrogen, and phosphorus, both living (plankton) and non-living (particulate organic matter). The effect of storage impoundments on downstream seston transport is complex and variable, depending on several factors, including discharge intake level, reservoir retention times, season, and nutrient inputs from upstream (see review in Yeager 1994). Based on our limited observations, the Nantahala area storage-peaking facilities may limit the availability of nutrients, especially those associated with fine particulate organic matter (FPOM), within the first few miles downstream from the powerhouses. Mussels are filter feeders and once past the juvenile stage, are dependent upon suspended material for food. Recent, unpublished research suggests that a substantial proportion of mussel nutrition (practically all carbon and nitrogen) is derived from bacteria associated with FPOM (Nichols 2002). Juvenile mussels feed on fine organic sediments. Reduced transport of seston and fine bedload may limit food availability for juvenile and adult mussels for some distance downstream from these dams (Mehlop and Vaughn 1994).

One of the most obvious downstream effects produced by storage-peaking hydroelectric facilities is the altered flow regime or hydrology. Flow is altered in two fundamental ways in tailwaters downstream from these dams: daily flow variability is increased and seasonal variability is decreased. These alterations can affect the stream for many miles downstream from the dam, often much farther than any other dam-related effect. The result is a hydrograph that has little in common with natural cycles or historical flow patterns. The effects of these alterations on mussel resources is not fully understood; however, some recent studies indicate that in free-flowing rivers, spatial distribution and species composition of mussel communities are influenced directly and indirectly by characteristics of the flow regime (Di Maio and Corkum 1995; Layzer and Madison 1995; Strayer 1993, 1999; Vannote and Minshall 1982). Alterations to these natural characteristics and patterns of flow typically result in adverse effects on mussel communities in tailwaters.

Daily fluctuations for peaking power production can dewater shallow areas in the tailwater. Benthic life in general and mussels in particular cannot tolerate prolonged periods of dewatering (Blinn et al. 1995, Fisher and LaVoy 1972, Moog 1993, Neck and

Howells 1994). Observations in the Cherokee Dam tailwater of the Holston River in eastern Tennessee indicate that mussels have been eliminated from shallow riffles that were dewatered more or less daily over several decades prior to adoption of minimum flow releases (TVA unpublished data). Mussel reproductive activities may be affected by both daily and seasonal variations in flow. The cycle of low flow periods that allow shallow areas to warm and sudden cold water releases can result in rapid temperature fluctuations that can cause some gravid mussels to abort developing glochidia (Matteson 1948).

Recruitment of juvenile mussels may also be affected by the altered flow regime. Mussels evolved in free-flowing streams with certain seasonal characteristics of discharge. Daily peaking discharge and seasonal storage (late winter-spring) and release (late summer-autumn) result in a hydrograph that rarely, or only inconsistently, resembles the natural, seasonal patterns. Many mussel reproductive strategies appear to be adapted to typical seasonal flow patterns and the resulting host fish behavioral patterns. Studies indicate that higher density mussel beds are often associated with relatively lower bottom velocities (Way et al. 1989, Strayer and Ralley 1993, Layzer and Madison 1995). Moreover, near-bottom shear stresses and other complex hydraulic variables associated with high flows may inhibit settlement and subsequent recruitment of juvenile mussels, when high flows coincide with when early juveniles drop from their fish hosts (Layzer and Madison 1995; Hardison and Layzer 2001). Peaking discharges can result in daily flows that may approximate naturally infrequent flood events in a given season (especially mid-summer through mid-autumn) and may inhibit the settlement of juvenile mussels in suitable habitats.

***Tuckasegee River*** - Nantahala area storage-peaking projects on upper Tuckasegee River tributaries (East and West Fork projects) release cold, hypolimnetic water into the Tuckasegee River. This results in a fish community that is dominated by cold water species downstream to the vicinity of the Dillsboro impoundment (TVA unpublished data). Both Appalachian elktoes and wavyrayed lampmussels are present within this reach; however, their densities were considerably lower immediately upstream from the Dillsboro impoundment than they were downstream from Dillsboro Dam. By all indications, mussels become more scarce as you move upstream from the Dillsboro area toward Webster, where Appalachian elktoes reach their known upstream limit.

While determination of specific limiting factors and their relative importance was beyond the scope of this study, some reasonable conclusions can be drawn from our observations. Cold water releases appear to be the primary factor limiting the present upstream distribution of both Appalachian elktoes and wavyrayed lampmussels. Whatever effects the other potential limiting factors may be having on potential mussel habitat within this reach, they are likely masked by the overriding influence of cold water conditions.

As water temperatures are ameliorated farther downstream, effects from peaking discharge may have some limiting effect on mussel distributions. Some small areas of shallow habitat may be degraded by dewatering. Alterations in seasonal flow patterns may have some effect on mussel recruitment and distribution. Habitat may also be degraded by siltation and water quality resulting from local runoff along this reach of the Tuckasegee River and its tributaries. The relative importance of these various factors in limiting the potential for mussel resources in the lower Tuckasegee River is unclear.

***Nantahala River*** - There are no known historical records of mussels from the Nantahala River system and none were found during this survey; therefore, specific impacts from the Nantahala River system storage-peaking projects on extant mussel resources are difficult to determine. It is difficult to imagine that mussels did not historically exist in at least the lower reaches of the Nantahala River (the area now impounded by TVA's Fontana Reservoir and upstream to near the Nantahala Powerhouse) given the relatively rich mussel fauna known from the Little Tennessee River. Habitat in this area is now very unfavorable for mussels, due to impoundment and cold water releases from the Nantahala and Queens Creek powerhouses. The bypass reach between Nantahala Dam and Powerhouse contains a cool-warm water fish community and some scattered habitat that appears to be at least adequate to support mussels; however none were found during this survey. The reach between the Nantahala Powerhouse and the dam has a relatively higher gradient than the reach downstream, with several waterfalls and steep cascades. Conditions in this reach may never have been favorable for the colonization and long-term survival of mussels. Initial colonization of these areas may have been precluded by waterfalls and cascades that prevented the upstream dispersal of glochidia-infected host fishes. If mussels ever existed upstream from these barriers,

frequent floods and scour may have washed them out and subsequent recolonization may have been prevented by the same barriers.

## **6.0 Summary and Conclusions**

Twenty three sites associated with Duke Power-Nantahala Area hydroelectric projects on seven streams were surveyed for native mussels. Native mussels were found at five of these sites on two streams: at Tuckasegee River miles 14.2, 31.7, 32.6, and 43.6; and Little Tennessee River mile 113.1. The federally endangered Appalachian elktoe was present at four of these sites (not found at Tuckasegee River mile 43.6). Appalachian elktoes were present immediately downstream from the Dillsboro Dam and upstream from the Dillsboro impoundment. They were also present immediately downstream from the Franklin Dam. Based on the size distribution of the mussels collected, these populations have successfully reproduced and recently recruited, indicating viable populations. No mussels were found at sites surveyed on the Cullasaja, Hiwassee, Nantahala, and Oconaluftee rivers; the upper Little Tennessee River (upstream from Franklin Reservoir); and Dicks Creek.

Among the four riverine facilities, each has relatively different situations as they relate to mussel populations, but they presently appear to have few adverse impacts on mussel resources. Franklin Dam appears to be the least detrimental to mussel resources and may have produced considerable benefits in the past. Dillsboro Dam produces unfavorable mussel habitat in its detention pool and isolates upstream mussel populations. Mission Dam likely has no additional effects on mussel resources beyond the predominately unfavorable cold water conditions produced by TVA's Chatuge Dam, located upstream from the Mission facility. Since no mussels are known historically from the Oconaluftee River, and none were found during these surveys, the effects of Bryson Dam on mussel resources are difficult to determine.

Releases from the East and West Fork Tuckasegee River storage-peaking projects produce cold water conditions that appear to inhibit mussel resources in approximately 10 miles of the Tuckasegee River. The altered flow regime resulting from these peaking projects may have some adverse effect on mussel resources in the lower Tuckasegee River. No mussels were found in the Nantahala River and none are known historically; therefore, effects from the Nantahala River system storage-peaking projects are also difficult to determine. Cold water conditions resulting from discharge from Nantahala

and Queens Creek powerhouses presently produce unfavorable conditions in the lower Nantahala River for native mussels.

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## FIGURES