Recovery Plan

Appalachian Monkeyface Pearly Mussel (Quadrula sparsa)

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Recovery Plan for the Appalachian

Monkeyface Pearly Mussel

Quadrula sparsa (Lea, 1841)

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Prepared by

Steven Ahlstedt

For the

United States Fish and Wildlife Service

Southeast Region

Atlanta, Georgia

Approved: Robert E. Gilmore

Associate Director, U.S. Fish and Wildlife Service

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THE RECOVERY PLAN FOR THE MUSSEL AND FISH SPECIES OF THE TENNESSEE RIVER VALLEY HAVE BEEN DEVELOPED ON A SPECIES BY SPECIES BASIS. FOR IMPLEMENTATION PURPOSES, THE PLANS WILL BE CONSOLIDATED ON A WATERSHED BASIS AND THE NEEDS OF ALL LISTED SPECIES IN THAT SYSTEM WILL BE ADDRESSED.

ALTHOUGH THIS PLAN WAS PREPARED BY STEVEN AHLSTEDT, AN EMPLOYEE OF THE TENNESSEE VALLEY AUTHORITY, THE VIEWS, OPINIONS, POLICIES, AND CONCLUSIONS EXPRESSED HEREIN DO NOT NECESSARILY REFLECT THE VIEWS, OPINIONS, POLICIES, AND CONCLUSIONS OF THE TENNESSEE VALLEY AUTHORITY.

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INTRODUCTION

The tributary streams of the Tennessee and Cumberland River basins contain freshwater mussel species that are endemic to the southern Appalachian Mountains and the Cumberland Plateau region. Ortmann referred to these species as "Cumberlandian," and this region became known as one of the chief centers of freshwater mussel speciation. Ortmann (1924) defined the Cumberlandian region to include the drainages of the Tennessee River system from the headwaters to the vicinity of Muscle Shoals, in Colbert and Lauderdale Counties, Alabama; and the Cumberland River system from the headwaters to the vicinity of Clarksville, Montgomery County, Tennessee (Ortmann, 1925). Of the 90 species of unionids found in the Tennessee River 37 are Cumberlandian, as are 27 of the 78 species found in the Cumberland River. These two assemblages contain the largest number of unionid species found in any of the world's rivers (Johnson, 1980). Of the 23 American freshwater mussel species listed as endangered by the U.S. Department of Interior, 13 are members of the Cumberlandian faunal group. The Appalachian monkeyface pearly mussel (Quadrula sparsa) was proposed as an endangered species in September 1975 (Federal Register 40(188):44329-44333) and listed in June 1976 (Federal Register 41(115):24062-24067).

This species was described by Lea in 1841 from the Holston River in eastern Tennessee. Q. sparsa (Lea, 1841) superficially resembles three closely related species, Q. intermedia (Conrad, 1836), Q. metanevra (Rafinesque, 1820), and Q. tuberosa (Lea, 1840). This has led some individuals to conclude that Q. sparsa is a subspecies or synonym of one of these forms. Stansbery (1976) reports that integrating or intermediate specimens are lacking for these species and that Q. tuberosa may be the downstream (big river) form of Q. intermedia or that Q. sparsa is the upper Tennessee River headwaters form of Q. metanevra. However, the necessary evidence for these inferences is lacking, indicating that both Q. intermedia and Q. sparsa are valid species and Q. tuberosa is probably extinct. Both Q. intermedia and Q. sparsa currently exist in the Powell River with no apparent intergrades.

DISTRIBUTION

Historical

Historically, Q. sparsa is a Cumberlandian species reported from both the upper Tennessee and Cumberland River systems. Simpson (1914) describes the distribution of Q. sparsa as simply "Holston and Clinch Rivers, Tennessee." Since Ortmann (1914) considered Q. sparsa a synonym of Q. intermedia and later (Ortmann, 1918) lumped Q. tuberosa, Q. sparsa, and Q. intermedia together under Q. intermedia, there is no means of discerning the distribution of either species from his paper. Stansbery (1976) reports that Q. sparsa is rare and no records have been found outside the upper Tennessee River system or in the Tennessee River proper. Morrison (1942) notes that the type lot used to describe Q. sparsa contained a mixture of Q. intermedia, Q. sparsa, and Q. tuberosa, which confused Ortmann enough to lump them together. Morrison further reports that Q. sparsa is a valid species restricted to the headwaters of the upper Tennessee River drainage. Bogan and Parmalee (1983) report Q. sparsa from archaeological specimens in the lower Clinch River, Tennessee, and Stansbery (1973 and 1976) lists Q. sparsa from the unimpounded reaches of the Clinch River above Norris Reservoir. For the purposes of this report, those historical records for

Q. tuberosa from the Cumberland River are also included with the historical records for Q. sparsa. Records for these species prior to 1970 are summarized in Table 1.

Present

Q. sparsa is presently known only from the free-flowing reaches of the Powell and Clinch Rivers above the backwater impoundment of Norris Reservoir (Figures 1 and 2). The Powell and Clinch Rivers are two of several larger tributary streams to the Tennessee River system.

Recent freshwater mussel surveys of the Powell River conducted by Dennis (1981), Ahlstedt and Brown (1980), Neves et al. (1980), and TVA (1979c) all reported live or freshly dead specimens of Q. sparsa from the Powell. Q. sparsa was reported at three sites on the Powell River, with one live specimen found at Buchanan Ford (PRM 99.2) (Dennis, 1981). Ahlstedt and Brown (1980) reported Q. sparsa at three sites in the Powell between Buchanan Ford (PRM 99.2) and McDowell Ford (PRM 106.6). Although no actual numbers were given in this report, a compilation of records from the Powell River from 1975 to 1978 report three live and four freshly dead specimens of Q. sparsa. Neves et al. (1980) reported one freshly dead specimen of Q. sparsa from the Powell River at Baldwin Ford (PRM 115.4). Two live and eight freshly dead specimens of Q. sparsa were found at eight sampling sites between the Narrows (PRM 89.2) and Flanary Bridge (PRM 130.6) by TVA biologists during a 102-mile dive/float survey of the Powell River in 1979. Recent freshwater mussel sampling in the Powell River by TVA biologists during May and June, 1981, produced six live specimens of Q. sparsa at McDowell Ford (PRM 106.6) and one freshly dead specimen at Fletcher Cliff (PRM 117.9).

Table 1. Historical records for *Quadrula sparsa* and *Quadrula tuberosa* prior to 1970, and subfossil records recorded to 1979.

River	Source
Tennessee River	Lewis (1876) Bogan and Parmalee (1983) archaeological specimens Warren (1975)
Holston River	Lea (1841) Lewis (1871) Call (1885) Simpson (1914)
Powell River	Stansbery 1963 (1970, 1971, and 1976)
Clinch River	Goodrich (1913) Simpson (1914) Stansbery 1963, (1970, 1971, 1973, and 1976) Bogan and Parmalee (1983) archaeological specimens
Cumberland River	Lea (1840) Ortmann (1912) Wilson and Clark (1914)
Big South Fork Cumberland River	Wilson and Clark (1914)
Caney Fork	Lea (1840)

Q. sparsa is considered extremely rare in the Powell River and is probably limited to a 46-mile reach of the upper Powell above Norris Reservoir between Yellow Shoals Ford (PRM 84.8) and Flanary Bridge (PRM 130.6).

One freshly dead specimen of *Q. sparsa* has recently been collected by Richard Neves (personal communication) from the Clinch River at Pendleton Island, Virginia (CRM 226.3). This is the first report of *Q. sparsa* being found in the Clinch River since 1963 (Stansbery, 1976). *Q. sparsa* is extremely rare in the Clinch River and is probably limited to a 53-mile reach between Cleveland, Virginia (CRM 272), and Craft Mill, Virginia (CRM 219.2). TVA's 1979 float survey of this section of the Clinch River was discontinued due to cold weather.

Freshwater mussel surveys by numerous individuals have failed to document populations of *Q. sparsa* in any river other than the Powell and Clinch. This species may be extinct in the Tennessee River since freshwater mussel surveys by Ellis (1931), van der Schalie (1939), Scruggs (1960), Bates (1962, 1975), Stansbery (1964, 1976), Williams (1969), Yokley (1972), Isom (1969, 1971a, 1972), TVA (1978) and Pardue (1981) have failed to produce evidence of *Q. sparsa* in the Tennessee River.

Q. sparsa has been reported as recently as 1963 from the Clinch River by Stansbery (1973, 1976), but the extreme rarity of the species and sampling efforts since that date by Neves et al. (1980), TVA (1979a), and Bates and Dennis (1978) have failed to reveal any specimens in the Clinch; the North, South, and Middle Forks Holston River (Neves et al. 1980; Stansbery, 1972; Stansbery and Clench, 1974, 1975; TVA 1976); Holston River (TVA, 1981a); Big Moccasin Creek (Neves and Zale, 1982); Copper Creek (Ahlstedt, 1981a); Nolichucky River (Mullican et al. 1960; TVA 1980d);

French Broad River (TVA, 1979d); Elk River (Ortmann, 1925; Isom et al. 1973a; TVA, 1980c; Ahlstedt, 1983); Paint Rock River (Isom et al. 1973b; TVA, 1980e); Flint River (Isom et al. 1973b); Duck River (Ortman, 1924; Isom and Yokley, 1968; TVA, 1972, 1979b; van der Schalie, 1973; and Ahlstedt, 1981b); and the Buffalo River (TVA, 1980b; van der Schalie, 1973).

Freshwater mussel surveys in the Cumberland River and tributary streams (Shoup et al. 1941; Neel and Allen, 1964; Stansbery, 1965, 1970; TVA, 1976; Parmalee et al. 1980; Sickle, 1982); Rockcastle River (Blankenship and Crockett, 1972); Stones River (Tucker, 1972; Schmidt, 1982; Stansbery et al. 1983); the Obey River (Shoup et al. 1941), and Little South Fork Cumberland River (Starnes and Bogan, 1982), have failed to find Q. sparsa in these streams.

During TVA's 1976 mussel survey of the middle reaches of the Cumberland River, TVA biologists and consultants mention finding two specimens of Q. sparsa from a commercial mussel clammers cookout camp at CRM 270. The identification of these specimens is questionable, and in actuality may be Q. metanevra lacking pustules (Parmalee et al. 1980).

Thus it can be assumed that only a small portion of the upper Powell and Clinch Rivers (headwater tributary streams to the Tennessee River) contains the only known populations of Q. sparsa.

Since Ortmann (1912) noted that he looked at two specimens of Q. sparsa from the Cumberland River and later lumped Q. tuberosa, Q. sparsa, and Q. intermedia all together under Q. intermedia, the distribution records for each of these species remains uncertain especially in the Cumberland River system. Further, mussel populations in the upper Cumberland River and headwater tributary streams are relatively unknown. Intensive freshwater mussel surveys in the Cumberland River (below Cordell Hull Dam), Big South Fork Cumberland River, Buck Creek, Obed, Obey, and the Caney Fork (below Center Hill Dam) might reveal additional populations of Q. sparsa. Freshwater mussel surveys are also recommended for the Middle and South Forks Holston River, French Broad River (below Douglas Dam), upper Clinch River (between Cleveland, Virginia, and Craft Mill, Virginia), Sequatchie River, and the Emory River (all tributary streams of the Tennessee River).

ECOLOGY AND LIFE HISTORY

Cumberlandian freshwater mussels are most often observed in clean fast-flowing water in areas that contain relatively firm rubble, gravel, and sand substrates, swept free of silt. These mussels are usually found buried in the substrate in shallow riffle and shoal areas. Since freshwater mussels are quite long lived--up to 50 years or more for some species--and rather sedentary by nature, they are especially vulnerable to stream perturbations. Of particular concern are the Cumberlandian species, which have suffered severe population declines. Of the 22 Cumberlandian species recorded from the Tennessee River (Ortmann 1925) in 1924 before the impoundment of Wilson Reservoir, all but 6 were apparently eliminated (Stansbery, 1964; Isom, 1969). TVA's recent mollusk investigations on the Tennessee River in 1978 produced only three Cumberlandian species (TVA, 1978; Pardue, 1981). Neel and Allen's (1964) survey of the upper Cumberland Basin before impoundment documented an almost total elimination of the genus Epioblasma (=Dysnomia) of which six of the eight species reported were Cumberlandian forms. Representatives of the genus Epioblasma are typically found in silt-free riffles and shoals.

Q. sparsa (see photo) is a Cumberlandian species typically found in shallow, fast-flowing water with stable, clean substrate. This medium-sized species has the general form of the *Q. metanevra* complex being sub-quadrate to subtriangulate in outline (Stansbery, 1976). Beaks are elevated and situated in about the middle of the shell. The dorsal slope is obliquely truncated, and the sulcus above the posterior ridge ends in a shallow sinus. The posterior ridge is rounded, slightly elevated and typically lacks pustules, tubercules, or knobs. Tubercules are typically lacking on the anterior third of the shell (Bogan and Parmalee, 1983). The outer covering of the shell (periostracum) is yellowish-green or brownish mixed with small green zig-zags, triangles, or chevrons. Nacre color is generally white, but some specimens may be salmon colored posteriorly (Lea, 1841).

The life history of *Q. sparsa* is presumed similar to that of most unionids and is briefly illustrated in Figure 3. Males produce sperm which are discharged into the surrounding water and dispersed by water currents. Any female *Q. sparsa* downstream from males obtain these sperm during the normal process of siphoning water during feeding and respiration (Stein, 1971). Fertilization of the eggs by sperm occurs within the gills of the female. The fertilized eggs are retained in the posterior section of the outer gills which are modified as brood pouches. The marsupium varies from genus to genus with some genera (*Amblema*, *Quadrula*, and *Fusconaia*) having all water tubes in all four gills of the female carrying developing embryos. These females are gravid for only a few weeks in early summer their gills remaining empty during the remainder of the year. They tend to abort the contents of the gills very readily if placed under stress (Stein, 1971).

The family Unionidae is separated into two groups based on the length of time glochidia remain in the female (Ortmann, 1911). By Ortmann's definitions, bradytictic bivalves (long-term breeders) breed from midsummer through fall or early winter; embryos develop in the female over winter and are released the following spring or summer. Tachytictic bivalves (short-term breeders) breed in spring and release glochidia by mid to late summer of the same year. No life history data exist for Q. sparsa, but seven other members of the genus Quadrula have been described as being tachytictic (Surber, 1912), breeding from May to July (Heard and Guckert, 1970). TVA biologists collecting mussels in the Powell River observed one female Q. intermedia (a closely related species to Q. sparsa) aborting glochidia in May 1981, lending further evidence that Q. intermedia and possibly Q. sparsa are both tachytictic species.

The glochidia of Q. sparsa might be called bean shaped and are of the hookless type. Surber (1912) noted that all members of the genus Quadrula bear hookless glochidia. The hookless type of glochidia has a more delicate shell, the valves of which are shaped like the bowl of a very blunt spoon and are most frequently parasitic on the gill filaments of fish (Coker and Surber, 1911; Lefevre and Curtis, 1910). The fish host(s) for Q. sparsa are unknown.

REASONS FOR DECLINE AND CONTINUED THREATS

Although limited in distribution historically (see previous discussion) Q. sparsa is extremely rare, almost to the point of extinction. The reasons for this decline are not totally understood, but impoundments, siltation, and pollution are speculated by various authors to be the major causes.

Impoundment

Possibly the single greatest factor that has contributed to this species decline, as well as other members of the Cumberlandian faunal group, is the alteration and destruction of stream habitat due to impoundment of the Tennessee and Cumberland Rivers and their headwater tributary streams for flood control, navigation, hydroelectric power production, and recreation. Since the early 1930s and 1940s, the Tennessee Valley Authority, Aluminum Company of America (Alcoa), and the Army Corps of Engineers have constructed numerous dams on the Tennessee and Cumberland River systems. A total of 51 dams is integrated into the TVA water control system. TVA has 36 dams in the Tennessee River basin, of which 9 are located on the main river (Tennessee) and the rest on tributary streams. Five major impoundments are also located on the Cumberland River, with six additional dams located on tributary streams.

Stream impoundment affects species composition by eliminating those species not capable of adapting to reduced flows, and altered temperatures. Tributary dams typically have storage impoundments with hypolimnial discharges and sufficient storage volume to cause the stream below the dam (reservoir tailwater) to differ significantly from both preimpoundment conditions in the same area and from comparable reaches above the reservoir. Possible effects of a hypolimnial discharge include: altered temperature regimes, extreme water level fluctuations, reduced turbidity, seasonal oxygen deficits, and high concentrations of certain heavy metals (TVA, 1980a). Biological responses attributable to these type environmental changes typically include restricted fish and benthic macroinvertebrate communities (Isom, 1971b). Hickman (1937) recorded numerous species of mussels and snails in the vicinity of the Norris Dam construction site prior to the impoundment of that reach of the Clinch River and predicted that the Norris Dam flood control project would have a deteriorating effect on the molluscan fauna. A. R. Cahn (1936) collected mussels extensively in the dewatered riverbed following closure of Norris Dam. Forty-five species of freshwater mussels and nine species of river snails were found in this reach of the Clinch River. In a return visit to the area below the dam 4 months later, not a single live mussel could be found. Isom et al. (1973a) collected 34 species of freshwater mussels in the Elk River directly below the construction site at Tim's Ford Dam prior to the completion of the dam. Ahlstedt (1983) reported no living mussels for almost 8 miles below Tim's Ford Dam.

Siltation

A second factor that has severely affected freshwater mussels, especially Cumberlandian species, is siltation. In rivers and streams, the greatest diversity and abundance of mussels is usually associated with gravel and/or sand substrates. These two types of substrate are most common in running water (Hynes, 1970). Increased silt transport into our waterways due to strip mining, coal washing, dredging, farming, logging, and road construction are some of the more obvious results of human alteration of the landscape. Hynes (1974) states that there are two major effects of inorganic sediments introduced into aquatic ecosystems. The first is an increase in the turbidity of the water with a consequent reduction in the depth of light penetration, and the second is a blanketing effect on the substrate. High turbidity levels due to the presence of suspended solids in the water column have a mechanical or abrasive action which can irritate, damage, or cause clogging of the gills or feeding structures of mollusks (Loar et al. 1980). Additionally, high levels of suspended solids may reduce or inhibit feeding by filter feeding organisms, such as mussels, causing nutritional stress and mortality (Loosanoff, 1961). Freshwater mussels are quite long lived and rather sedentary by nature; many species have been unable to survive in a layer of silt greater than 0.6 cm in depth (Ellis, 1936). Since most freshwater mussels, especially the Cumberlandian forms, are riverine species that require clean, flowing water over stable, silt-free rubble, gravel, and sand shoals, the smothering action by siltation is often severe. Fuller (1977) reported that siltation associated with poor agricultural practices and deforestation of much of North America was probably the most significant factor impacting mussel communities. The reproductive life cycle of the mussel can be affected indirectly by siltation by impacting host-fish populations either by smothering and killing fish eggs and larvae, reducing food availability, or filling of interstitial spaces in a gravel and rubble substratum, thus potentially eliminating both spawning bed and habitat critical to the survival of young fishes (Loar et al., 1980).

Coal production in the Appalachian region, which includes the headwater tributary streams to the Cumberland and Tennessee Rivers, has increased drastically in the last few decades. This change has been brought about largely by the necessity to provide relatively inexpensive coal supplies for the production of more than 80 percent of the electricity consumed in the eastern United States. The majority of this coal has traditionally been mined by auger and deep-mining techniques; however, strip mining is on the increase. By 1985 it is estimated that 67 percent of coal extraction will be accomplished by strip mining (Minear and Tschantz, 1976). Branson (1974) stated that the future of the entire upper Kentucky River Basin as well as that of the Cumberland River looks very bleak because mining operations are being intensified to meet the growing demand for coal. This will result in increased silt runoff and escalate impacts to the freshwater mussel fauna, especially the headwater tributary streams to the Cumberland River and the Powell and Clinch Rivers of the Tennessee River system. Vaughan (1978) reported that so much land has been disturbed by mining in the New River watershed (a Cumberland River tributary in eastern Tennessee) that finding an unaffected stream to study fish and diatoms was extremely difficult. Branson (1974) reported silt (as a by-product of strip mining) is the most widespread pollution in North America. Branson and Batch (1972) found a 90-percent reduction in total benthic population size and number of species as a result of increased siltation. Mussel populations in the upper reaches of the Powell River (including tributary streams such as North Fork Powell, Callahan Creek, and Pigeon Creek) are already heavily impacted by silt and coal fines from coal-washing operations and active and abandoned strip mines (Ahlstedt and Brown, 1980). On numerous occasions since 1975, the Powell River has been observed running black for long periods of time by TVA biologists and concerned fishermen. During the week of March 31, 1979, a biologist with the Tennessee Department of Public Health notified TVA biologists that the Powell River was running black near the head of Norris Reservoir, a distance of over 130 river miles downstream from its point source at a coal preparation plant in Appalachia, Virginia. This was confirmed that same week by a TVA biologist. The Powell River contains the only known reproducing population of _Q. sparsa_ as observed by the author. Continued discharges of silt and coal fines into the Powell River could jeopardize _Q. sparsa_ to the point of extinction. Unless strong corrective measures are taken, the threat posed by coal-related siltation to endangered species in aquatic ecosystems of southwestern Virginia can be expected to grow in the future as coal production increases.

Pollution

A third factor which must be considered, although on a much broader scale, is the impact caused by various forms of pollutants. An increasing number of streams throughout the United States have been subject to municipal, agricultural, and industrial waste discharges. The damage suffered varies according to a complex of interrelated factors, which include the characteristics of the receiving stream and the nature, magnitude, and frequency of the stress or stresses applied. Often the degradation has been so severe and of such duration that the streams are no longer considered valuable in terms of their biological resources (Hill et al. 1974). Usually these areas will not recover if there are residual effects from the pollutant which makes the area unsuitable for aquatic organisms, or if there is an inadequate pool of organisms for recruitment and recolonization (Cairns et al. 1971).

The absence of freshwater mussels can logically be an indication of environmental disruption only when and where their former presence can be demonstrated (Fuller, 1974). It is very rare that the composition and size of the mussel fauna can be quantitatively and/or qualitatively correlated with a specific disruption, be it chemical or physical (Ingram, 1956). However, documentation is available concerning the adverse impacts of some pollutants on freshwater mussels, which also cause a change/decline in fish fauna through environmental alterations. Simpson (1899) mentioned the adverse effect of sawdust upon mussels as a false streambed. Wilson and Danglade (1914) noted that bark dislodged from logs driven downstream coated the bottom substrate of the Prairie River of Minnesota. Neel and Allen (1964) reported that coal mine acids in the major headwater tributaries of the Cumberland River have practically eliminated the most diverse known assemblage of species belonging to the genus Epioblasma (=Dysnomia). This decline in the genus Epioblasma is typical of what has happened to many Cumberlandian species. A combination of toxic wastes, gravel dredging, and increased fertilizer and pesticide use has reduced the freshwater mussel fauna in the Stones River from 45 to 30 species of freshwater mussels (Schmidt, 1982). Ortmann (1918) in his studies of the freshwater mussels of the upper Tennessee drainage reported numerous streams to be already polluted and the mussel fauna gone. These streams included the Powell River, for a certain distance below Big Stone Gap, Virginia (wood extracting plant); the North Fork Holston River, for some distance below Saltville, Virginia (salt and plaster of paris industries); French Broad River at Asheville, North Carolina; Big Pigeon River from Canton, North Carolina, all the way to its mouth (wood pulp and paper mill); and the Tellico River below Tellico Plains, Tennessee (wood pulp and extracting mill).

The North Fork Holston River in southwestern Virginia is one stream that has suffered greatly from chronic pollution. From 1894 to 1972, a chemical plant located along the North Fork Holston River near

Saltville, Virginia, effectively eliminated stream life in much of the lower 80 miles of the river (Hill et al., 1974). Chemicals discharged into the river included sodium hydroxide, sodium carbonate, sodium bicarbonate, hydrozine, chlorine, and dry ice. Additional wastes consisting of sand, limestone particles, and mercury were also discharged into the river and later into settling lagoons located along the banks of the river (TVA, 1968). This plant ceased operation in 1972 because it could not economically comply with water quality standards. Activities are currently underway to correct this problem.

Ortmann (1918) reported 42 species and forms of freshwater mussels from the North Fork Holston River at and below Saltville, Virginia. More recent surveys in the North Fork indicate a good mussel fauna occurring above Saltville; however, the mussel fauna below Saltville has largely been extirpated (Neves et al., 1980; Stansbery and Clench, 1974; TVA, 1976). C. C. Adams (1915) in his study of the pleurocerid river snail Io fluvialis indicated the North Fork Holston River I. fluvialis population had suffered greatly from the outfall of the chemical industry at Saltville since before 1900. No living native populations of I. fluvialis are now known to exist anywhere in the Holston River system (Stansbery, 1972; Stansbery and Clench, 1974).

Mussel surveys in the North Fork near the Virginia-Tennessee State line by TVA biologists in 1981 revealed eight species of mussels naturally occurring in this section of the river, giving an indication of gradual faunal recovery. Several mussel species and the pleurocerid river snail I. fluvialis, transplanted from the Clinch River to the North Fork Holston River from 1975 to 1978 (Ahlstedt, 1980), are still surviving and in some cases may be reproducing. Although some young mussels were found at the transplant site, these mussels could be individuals from the initial transplants, the progeny of the transplanted mussels, or the result of a small but recovering resident population.

Another documented impact to the freshwater mussel fauna in the upper Tennessee River system occurred in the free-flowing reaches of the Clinch River above Norris Reservoir during two separate chemical spills which occurred in 1967 and 1970. In June 1967, a dike surrounding a fly ash settling lagoon collapsed, releasing a highly caustic alkaline slurry (pH 12) into the Clinch River below the Appalachian Power Company (APCo) generating facility at Carbo, Virginia. During this period, an estimated 162,000 fish were killed in the Virginia portion of the Clinch River (66 miles) and an additional 54,000 fish were killed in 24 miles of the Clinch in Tennessee where the polluted mass was diluted (TVA, 1967). The Virginia State Water Control Board conducted a bottom fauna survey to assess the damage to fish food organisms. Their observations indicated that: (1) bottom-dwelling fish food organisms appeared to have been completely eliminated for a distance of approximately 3.0 or 4.0 miles below the spill, (2) a reduction in the number and kinds of bottom-dwelling fish food organisms occurred in the Clinch River for 77.0 miles below the spill, and (3) freshwater mussels and snails were eliminated for 11.5 miles below Carbo, Virginia. In June 1970, a second industrial spill occurred at the plant involving the release of an undetermined amount of sulfuric acid, which killed approximately 5,300 fish. Representatives of the Virginia State Water Control Board indicated that stream damage began approximately 1 mile below the APCo power plant and extended a distance of almost 18 miles downstream to St. Paul, Virginia. Fish populations sampled on the Clinch River near St. Paul, Virginia, following the fish kills by Raleigh et al. (1978) indicated rapid recovery of the fauna. Cairns et al. (1971) reported that recovery was apparently rapid for all faunal groups except mollusks. Recent freshwater mussel surveys of the Clinch River by Neves et al. (1980), TVA (1979a), and Bates and Dennis (1978) all report an almost total elimination of the freshwater mussel fauna from Carbo, Virginia (CRM 264.2), to Miller Yard (CRM 243.0). TVA's 1979 float/survey of the Clinch River produced 12 species of freshwater mussels above the APCo generating facility at Carbo. Only two species of mussels were found in a 20-mile reach below Carbo (TVA, 1979a). One can only speculate as to why the molluscan fauna has failed to recolonize this stretch of the Clinch. This may be, in part, due to the continued discharges of some effluents from the plant. In addition, coal fines have also been observed entering the Clinch River from Lick Creek, a tributary stream located above St. Paul, Virginia. This stream was observed to be running black with coal fines in August 1979 by USFWS and TVA biologists.

II

RECOVERY

A. Recovery Objectives

The ultimate objective of this recovery plan is to maintain and restore viable populations* of Q. sparsa to a significant portion of its historic range and remove the species from the Federal list of endangered and threatened species. This can be accomplished by (1) protecting and enhancing habitats containing Q. sparsa populations and (2) by establishing populations in rivers and river corridors that historically contained Q. sparsa. This species shall be considered recovered, i.e., no longer in need of Federal Endangered Species Act protection, when the following criteria are met:

1. A viable population of Q. sparsa exists in the Powell River from the backwaters of Norris Reservoir upstream to approximately PRM 130, and in the Clinch River from the backwaters of Norris Reservoir upstream to St. Paul, Virginia (CRM 256). These two populations are dispersed throughout each river so that it is unlikely that any one event would cause the total loss of either population.

2. Through reestablishments and/or discoveries of new populations, viable populations* exist in one additional river. This river will contain a viable population that is distributed such

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*Viable population - a reproducing population that is large enough to maintain sufficient genetic variation to enable it to evolve and respond to natural habitat changes. The number of individuals needed to meet this criterion will be determined as one of the recovery tasks.

that a single event would be unlikely to eliminate _Q. sparsa_ from the river system.

3. The species and its habitat are protected from present and foreseeable human-related and natural threats that may interfere with the survival of any of the populations.

4. Noticeable improvements in coal-related problems and substrate quality have occurred in the Powell River, and no increase in coal-related siltation occurs in the Clinch River.

B. Step-down Outline

Prime Objective: Recover the species to the point it no longer requires Federal Endangered Species Act protection.

1. Preserve existing populations and habitat of _Q. sparsa_.
    - 1.1 Continue to utilize existing legislation and regulations (Federal and State endangered species laws, water quality requirements, stream alteration regulations, etc.) to protect the species and its habitat.
    - 1.2 Conduct population and habitat surveys.
        - 1.2.1 Determine species' present distribution and status.
        - 1.2.2 Characterize the habitat, ecological associations, and essential elements (biotic and abiotic factors) for all life history stages.
        - 1.2.3 Determine the extent of the species' preferred habitat.

1.2.4 Present the above information in a manner that identifies essential habitat and specific areas in need of protection.

1.3 Determine present and foreseeable threats to the species and strive to minimize and/or eliminate them.

1.3.1 Determine impacts of coal industry related pollution on nonendangered species.

1.3.2 Investigate and inventory other factors negatively impacting the species and its environment.

1.3.3 Solicit information on proposed and planned projects that may impact the species.

1.3.4 Determine measures that are needed to minimize and/or eliminate any adverse impacts and implement where necessary.

1.4 Solicit help in protecting the species and its essential habitat.

1.4.1 Meet with local government officials and regional and local planners to inform them of our plans to attempt recovery and request their support.

1.4.2 Work with local, State, and Federal agencies to encourage them to utilize their authorities to protect the species and its river habitat.

1.4.3 Meet with local mining and industry interests and solicit their support in implementing protective actions.

1.4.4 Meet with landowners adjacent to _Q. sparsa_ population centers and inform them of the status of the species and get their support in habitat protection measures.

1.4.5 Develop educational program using such items as slide/tape shows and brochures. Present this material to business groups, civic groups, youth groups, church organizations, etc.

1.5 Investigate the use of Scenic River Status, mussel sanctuaries, land acquisitions, and/or other means or combinations for immediate protection of the species.

2. Determine the feasibility of introducing the species back into rivers within its historic range and introduce where feasible.

2.1 Survey rivers within the species' range to determine the availability and location of suitable transplant sites. This can include areas for population expansion within rivers where the species presently exists.

2.2 Identify and select sites for transplants.

2.3 Investigate and determine the best method of establishing new populations, i.e., introduction of adult mussels, juveniles, infected fish, artificially cultured individuals, or other means or combinations.

2.4 Introduce species within historic range where it is likely they will become established.

2.5 Implement the same protective measures for these introduced populations as outlined for established populations in numbers 1.2 through 1.4 above.

3. Conduct life history studies not covered under section 1.2 above; i.e., fish hosts, age and growth, reproductive biology, longevity, natural mortality factors, and population dynamics.

4. Determine the number of individuals required to maintain a viable population.

5. Study the need for habitat improvement in areas where the species exists and where it could be introduced and, if feasible and desirable, identify techniques and sites for improvement.

6. Develop and implement a program to monitor population levels and habitat conditions of presently established populations as well as introduced and expanding populations.

7. Assess overall success of recovery program and recommend action (delist, continued protection, implement new measures, other studies, etc.).

C. Narrative Outline

1. Preserve existing *Q. sparsa* populations and habitat. The only presumed reproducing population of *Q. sparsa* exists in the Powell River. Immediate protection of the Powell River population and habitat is crucial not only for the continued survival of the species but to gain the necessary knowledge needed to save the species from extinction.

1.1 Continue to utilize existing legislation and regulations (Federal and State endangered species laws, water quality requirements, stream alteration regulations, etc.) to protect the species and its habitat. Prior to and during implementation of this recovery plan the species can be protected by the full enforcement of existing laws and regulations.

1.2 Conduct population and habitat surveys. Most of this task has already been completed as part of the Cumberlandian Mollusk Conservation Program (Jenkinson, 1981) and other TVA projects since 1970. However, additional dive/float freshwater mussel surveys are recommended for the upper Clinch River between Cleveland, Virginia (CRM 272.0), and below Craft Mill, Virginia (CRM 219.2). This area has not been intensively searched. A live specimen of *Q. sparsa* was collected by Stansbery (1973, 1976) in the Clinch River at St. Paul, Virginia (CRM 256.0), in 1963. A freshly dead specimen was recently collected at Pendleton Island, Virginia (CRM 226.3). Further intensive dive/float surveys are also recommended for the Middle and South Forks Holston River, French Broad River below Douglas Dam, and the Sequatchie River (all tributaries of the Tennessee River) and the Cumberland River below Cordell Hull Dam, Tennessee. Head-water tributary streams of the Cumberland needed to be surveyed for mussels include the Big South Fork Cumberland River, Obed, Obey, Caney Fork (below Center Hill Dam), and Buck Creek.

1.2.1 Determine species present distribution and status. intensive dive/float surveys will be used where possible.

1.2.2 Characterize the habitat, ecological associations, and essential elements (biotic and abiotic factors) for all life history stages. Some of the work necessary for the characterization of habitat has been accomplished as part of TVA's Cumberlandian Mollusk Conservation Program. The final report on this is expected in 1983. However, it will be necessary to have intimate knowledge of *Q. sparsa* habitat requirements if actions are taken to protect the species.

1.2.3 Determine the extent of the species' preferred habitat. After the types and quality of habitat are defined, it will be necessary to determine the extent of such habitat.

1.2.4 Present the above information in a manner that identifies essential habitat and specific areas in need of protection.

1.3 Determine present and foreseeable threats to the species and strive to minimize and/or eliminate them. Many factors presently adversely affect the species and its habitat, and other problems associated with future development are likely to occur. These negative impacts must be identified and remedied if recovery is to be reached.

1.3.1 <u>Determine impacts of coal industry related pollution on the species</u>. Coal-related pollution (coal washing, strip mining, and orphan mines) appears to be a major problem in the Powell River and to some extent the Clinch River of the Tennessee River system. The present anticipated impacts of the problem need to be assessed in the Powell and in other rivers if they are found to be populated by or are restocked with the species. This could be accomplished with present State and Federal research facilities utilizing both field and laboratory research. Studying impacts on non-endangered mussels as experimental organisms are suggested.

1.3.2 <u>Investigate and inventory factors negatively impacting the species and its environment</u>. Factors such as road construction, dredging, herbicide and pesticide spraying, and chlorinated effluents may be having a substantial impact on the rivers and the species.

1.3.3 <u>Solicit information on proposed and planned projects that may impact the species</u>. Projects that are now planned or proposed could have a serious impact on the recovery of the species. Before delisting could be accomplished, anticipated negative impacts on the species must be addressed.

1.3.4 Determine measures that are needed to minimize and/or eliminate any adverse impacts and implement where necessary. Once the problem areas are identified, measures must be developed and implemented to minimize and/or, where necessary, eliminate those impacts that could likely jeopardize the continued existence of the species.

1.4 Solicit help in protecting the species and its essential habitat. All local, State, and Federal developmental and enforcement agencies and land use groups should be notified of our recovery efforts and the sensitivity of certain areas to prevent any modification or impacts that might prove harmful to Q. sparsa and its habitat. These impacts typically include strip mining, oil and gas drilling, coal slurry pipelines, industrial development, road and bridge construction, installation of sewage treatment plants and their operation, and the use of herbicides along roads and powerline corridors as well as pesticides and fertilizers for farm crops. Some of this work has already been completed for the Clinch and Powell watersheds by USFWS.

1.4.1 Meet with local government officials and regional and local planners to inform them of our plans to attempt recovery and request their support. The support of local government officials and planners will be essential if the river habitat is going to receive sufficient protection to accomplish recovery.

1.4.2 Work with local, State, and Federal agencies to encourage them to utilize their authorities to protect the species and its river habitat. Local, State, and Federal agencies (Soil Conservation Service, Army Corps of Engineers, Office of Surface Mining, etc.) presently have sufficient laws and regulations to effect a measurable change in the quality of these rivers.

1.4.3 Meet with local mining and industry interests and solicit their support in implementing protective actions. Mining and industry along the rivers can have a substantial impact on the river's quality. Cooperation of these groups is essential in meeting the recovery goals.

1.4.4 Meet with landowners adjacent to the species' population centers and inform them of the project and get their support in habitat protection measures. Land use adjacent to the river greatly influences habitat quality. Much of this land is owned privately. Landowner agreements and/or land purchases can be used to protect these sites.

1.4.5 Develop an educational program using such items as slide/tape shows and brochures. Present this material to business groups, civic groups, youth groups, church organizations, etc. In spite of existing perturbations, the Clinch and Powell

Rivers are probably two of the most biologically diverse river systems remaining in the southeastern United States. A brief informative program or pamphlet is needed to point out the basic problems, uniqueness of the river systems, the rarity of the resources at risk, the potential value of undisturbed systems, and the penalties for its abuse. This material could help to eliminate some of the misconceptions about the value of preserving endangered species and their habitat. Educational efforts should also include all local, State, and Federal agencies, wildlife officers and wildlife-oriented clubs. These programs could also be developed for television and local newspaper coverage.

1.5 Investigate the use of Scenic River Status, mussel sanctuaries, land acquisitions, and/or other means or combinations to protect the species. Portions of the Clinch and Powell Rivers appear eligible for Scenic River status under the National Wild and Scenic Rivers Act (USDI, 1976). Such a designation would provide some additional protection for the species and its habitat. The State of Tennessee has designated portions of the Tennessee and Cumberland Rivers and the Clinch and Powell Rivers as mussel sanctuaries, but the headwaters for each of these streams originate in adjoining States such as

Kentucky and Virginia. No protection is offered those mussel populations occurring in Kentucky and Virginia. Such protection is needed to prohibit collecting of mussels and fish for commercial or scientific purposes except with permits granted by State or Federal permitting offices. The Nature Conservancy is actively pursuing land acquisition at one location in the upper Clinch River to protect probably the greatest freshwater mussel diversity found anywhere in the southeastern United States. Protection of the upper Clinch and Powell Rivers from unwarranted collecting and environmental impacts is of the highest priority.

2. <u>Determine the feasibility of introducing the species back into rivers within its historic range and introduce where feasible.</u> Based upon the low number of specimens found in the Powell and Clinch Rivers, the immediate protection and preservation of these populations are crucial for the continued survival of the species. However, it is unlikely that removal from the list of Federal endangered or threatened species would be achieved without the establishment of populations in other rivers and the expansion of the Powell and Clinch River population. The factors that caused extinction or population reductions at potential transplant sites must be remedied prior to attempts at establishing additional populations.

   2.1 <u>Survey rivers within the species' range to determine the availability and location of suitable transplant sites.</u>

This can include areas for population expansion within rivers where the species presently exists. Before the river system can be restocked with the species, the availability of suitable habitat containing all the essential elements for the species' survival and reproduction must be deter-mined. In some cases the physical habitat may be available for adults, but juvenile habitat or the proper fish host might not be present.

2.2 Identify and select sites for transplants. After the suit-ability of a particular river has been determined, specific sites for transplants within that river must be identified. TVA as part of their Cumberlandian Mollusk Conservation Program has studied 15 potential transplant sites for another endangered freshwater mussel *Conradilla caelata*. The current and historical distribution for *C. caelata* overlaps with that of *Q. sparsa* in the Powell and Clinch Rivers. Each of the 15 sites was evaluated as potential transplant sites based on a correlation of stream characteristics with habitats of known populations of *C. caelata*. These sites could also serve as potential transplant sites for *Q. sparsa*. Additional streams that should be screened as potential transplant sites include: (1) lower Holston River near I-40 bridge, (2) North, Middle, and South Forks Holston River, (3) French Broad River, and (4) Sequatchie River of the Tennessee River system. Tributary streams to the Cumberland River system recommended for study include the (1) Big South Fork Cumberland River, (2) Caney Fork, (3) Obed, (4) Obey, and (5) Buck Creek.

2.3 Investigate and determine the best method of establishing new populations, i.e., introduction of adult mussels, juveniles, infected fish, artificially cultured individuals, or other means or combinations. Some of these methods are currently being tested by TVA as part of the Cumberlandian Mollusk Conservation Program. Adult mussels, including gravid female *C. caelata*, were introduced in the fall of 1982 into river systems where they formerly occurred. Laboratory experiments were also conducted to determine specific fish hosts for *C. caelata* and *Q. cylindrica*. Another possible introduction method would be to release host fish infected with *Q. sparsa* glochidia. Isom and Hudson (1982) were successful in artificially culturing some species of freshwater mussels, but the young individuals survived only 60 days. Further investigations and experimentations are required for determining which method(s) should be used.

2.4 Introduce species within historic range where it is likely it will become established. If habitat is available and the introductions are likely to succeed, the introduction of the species to other rivers within its historic range should be initiated.

2.5 Implement the same protective measures for these introduced populations as outlined for established populations in numbers 1.2 through 1.4 above.

3. Conduct life history studies not covered under section 1.2 above; i.e., fish hosts, age and growth, reproductive biology, longevity, natural mortality factors, and populations dynamics. Knowledge of the many varied aspects of the species life history will be needed to understand the species and protect its future. Life history studies for Conradilla have indicated that at least two species of darters, Etheostoma zonale and E. blenniodes, serve as fish host(s) for Conradilla. Data on other potential fish host(s) for all listed mussels is also needed.

4. Determine the number of individuals required to maintain a viable population. Theoretical considerations by Franklin (1980) and Soulê (1980) indicates that 500 individuals represent a minimum population level (effective population size) that would contain sufficient genetic variation to enable that population to evolve and respond to natural habitat changes. The actual population size in a natural ecosystem can be expected to be larger, possibly by as much as 10 times. The factors that will influence actual population size include sex ratio, length of the species reproductive life, fecundity, extent of exchange of genetic material within the population plus other life history aspects of the species. Some of these factors can be addressed under Task 1.2.2., while others will need to be addressed as part of this task on a need to know basis.

5. Study the need for habitat improvement in areas where the species exists and where it could be introduced and, if feasible and desirable, identify techniques and sites for improvement. Low-level check dams should be considered in silt-prone areas in the upper tributary streams of the Cumberland and Powell Rivers and tributary streams to the Powell River, which includes the North Fork Powell, Callahan Creek, and Pigeon Creek. This would help to control silt and coal fines from entering these stream systems from coal preparation plants and silt from active and abandoned strip mines. Routine maintenance dredging would be recommended and spoil could be desposited away from the river or buried in landfills. Although these are temporary measures for controlling silt loads in silt-prone areas such as the upper Cumberland and Powell, these structures are deemed necessary until massive reclamation programs have been established in the watershed basins. Additionally, a green belt corridor at least 40 feet wide is recommended between adjacent farmland and the edge of the streambank or riverbank. This would prevent farming up to the riverbank, construction activities, clearcutting, and other activities that cause erosion, bank slumping, and canopy removal. Other methods of habitat improvement should also be investigated.

6. Develop and implement a program to monitor population levels and habitat conditions of presently established populations as well as introduced and expanding populations. Once recovery actions are implemented, the response of the species to its habitat must be monitored to assess any progress toward recovery.

7. <u>Assess overall success of recovery program and recommend action (delist, continued protection, implement new measures, other studies, etc.)</u>. The recovery plan must be evaluated periodically to determine the progress of the recovery plan and to recommend future actions.

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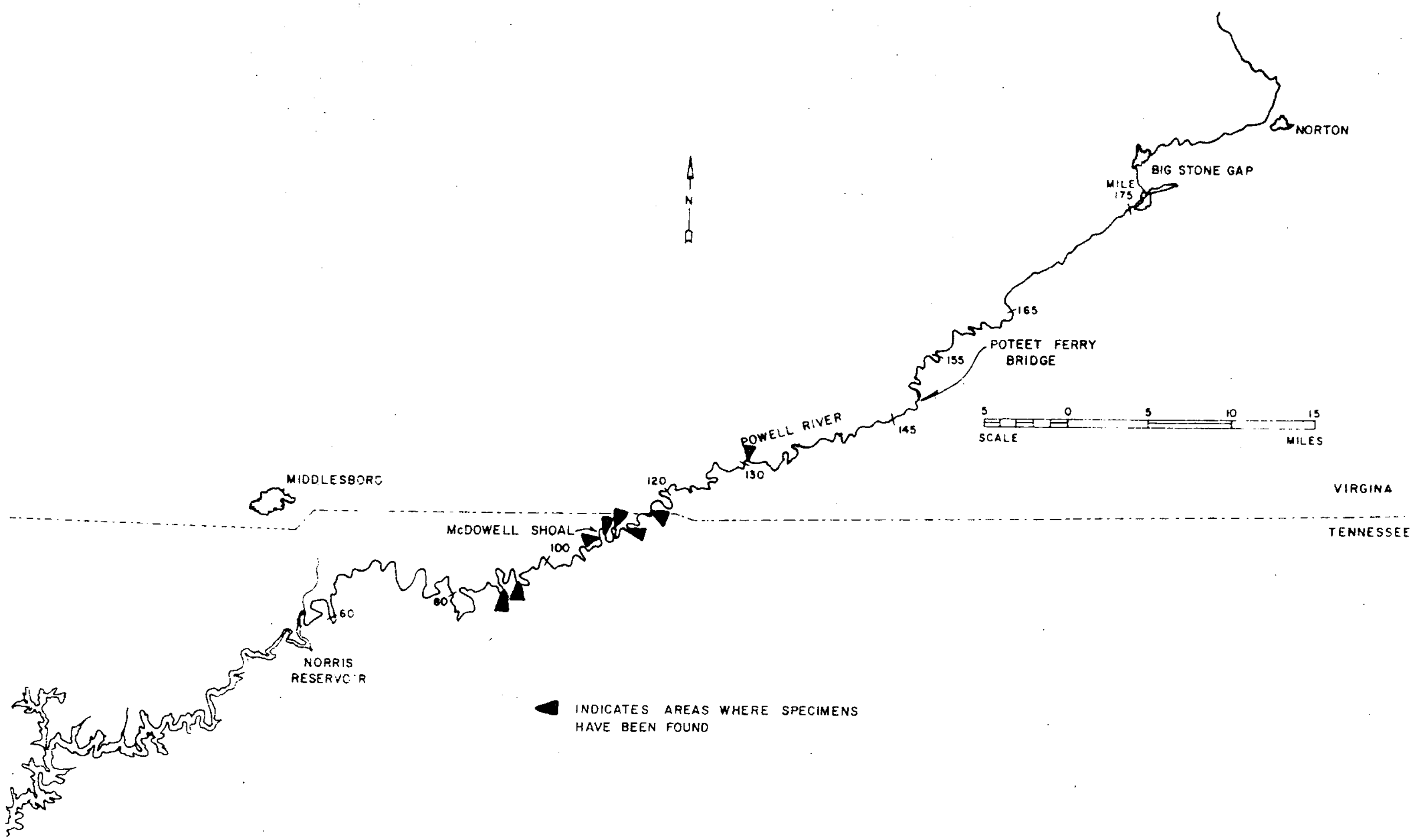

Figure I : Powell River— Recent Locations for QUADRULA SPARSA, (Lea 1841)

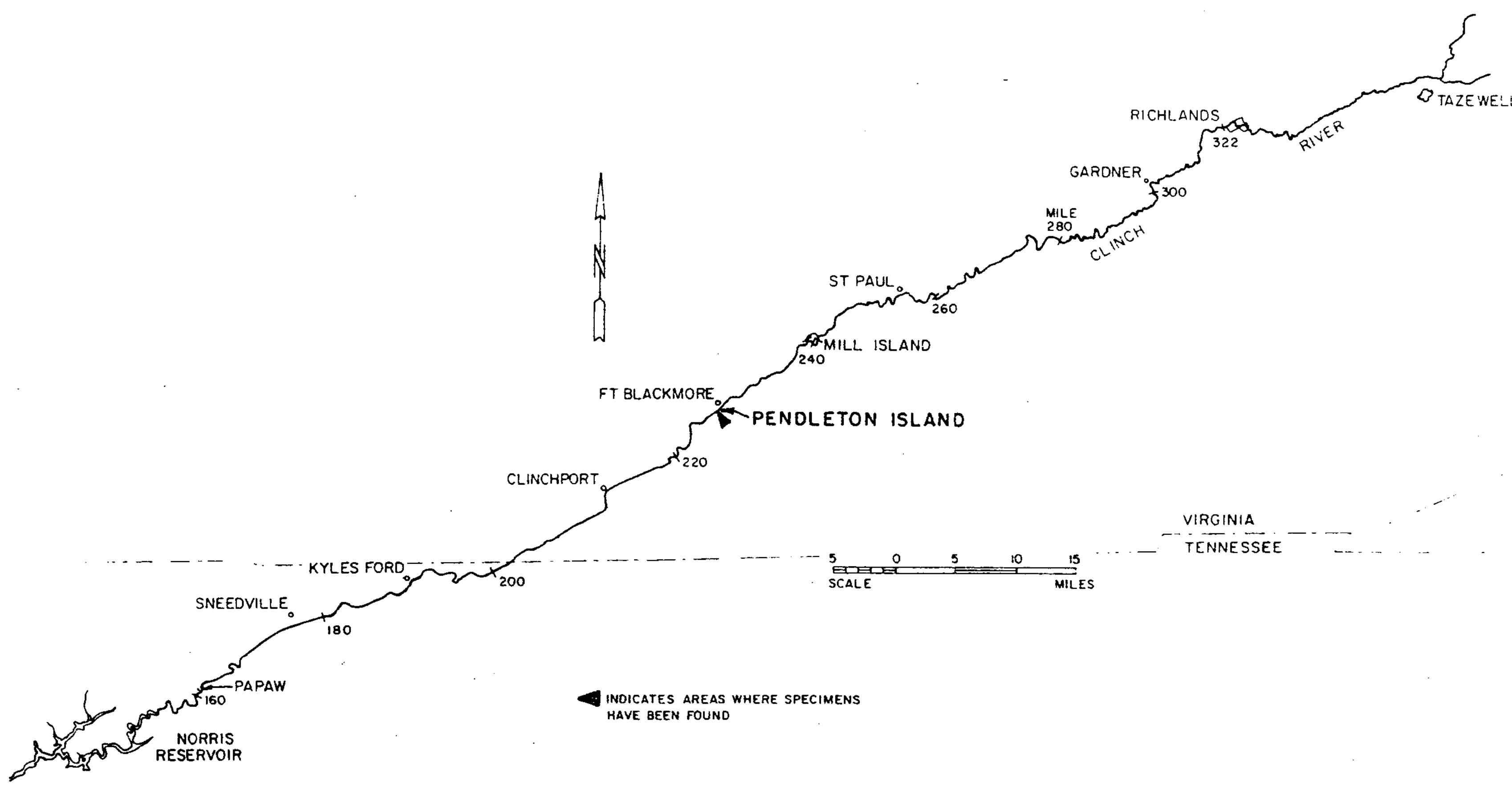

Figure 2. Clinch River - Recent Locations for QUADRULA SPARSA, (Lea 1841)

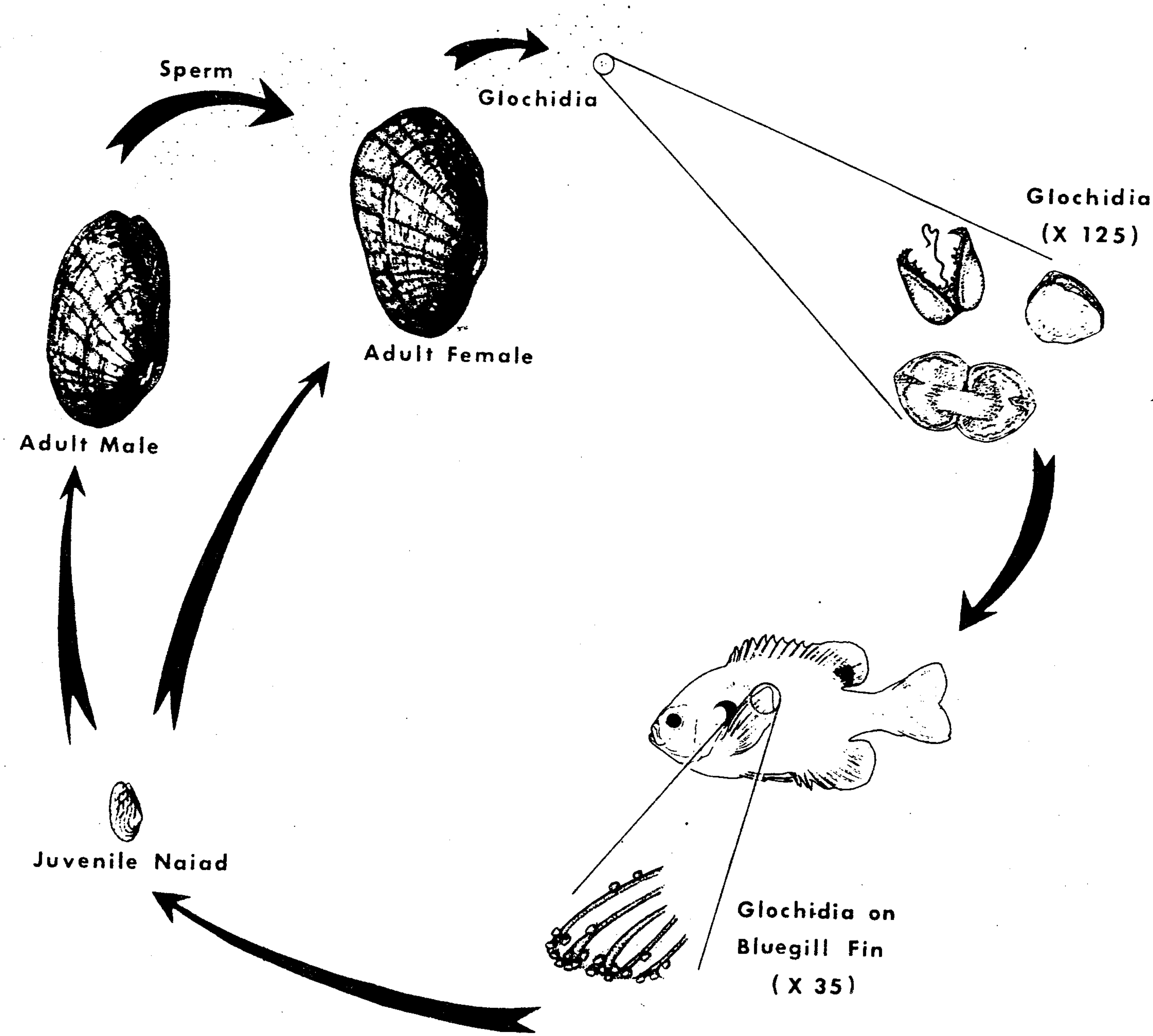

Figure **3.** Typical naiad life cycle depicting the various stages. The life cycle for most species of naiades is very similar to that depicted here (Grace and Buchanan 1981).


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Appalachian Monkeyface Pearly Mussel
(Quadrula sparsa)

Part III Implementation Schedule

*1 General Category	Plan Task	Task Number	Priority	Task Duration	Responsible Agency *2 FWS Region	FWS Program	Other	Estimated Fiscal Year Costs *3 FY 1	FY 2	FY 3	Comments/Notes
01-04	Continue to utilize existing legislation and regulations to protect species and habitat.	1.1	1	Continuous	4&5	SE,ES,LE	Tennessee Valley Authority (TVA), TN Wildlife Resources Agency (TWRA), VA Comm. of Game and Inland Fisheries (VCGIF) and TN Heritage Program (THP)	---	---	---	*1. See general categories for Implementation Schedules. *2. Other agencies' responsibility would be of a cooperative nature or projects funded under a contract or grant program. In some cases contracts could be let to universities or private enterprises.
I1,I2	Determine species' present distribution and status.	1.2.1	3	2 yr.	4&5	SE	TWRA,THP, VCGIF & TVA	---	---	---	*3. Note: Task costs have not been estimated for this plan. This species exists with other listed mussels in the same river systems. Thus, a task aimed at this species will benefit others. Rather than attempting to apportion the costs to each species, recovery tasks will be estimated at a later date when the plans are combined on a watershed basis for implementation.
R3,R8, R9,R10 R11	Characterize habitat and determine essential elements.	1.2.2	2	2 yr.	4&5	SE	TWRA,VCGIF & TVA	---	---	---	
R3,02, M3	Determine the extent of preferred habitat and present information in a manner which identifies areas in need of special attention.	1.2.3 & 1.2.4	2	1 yr.	4&5	SE	TWRA,THP, VCGIF & TVA	---	---	---	
I12,I14	Determine present and foreseeable threats to species.	1.3.1 1.3.2 & 1.3.3	1	3 yr.	4&5	SE&ES	TWRA,VCGIF, TVA & THP	---	---	---	

Appalachian Monkeyface Pearly Mussel
(*Quadrula sparsa*)

Part III Implementation Schedule

*1 General Category	Plan Task	Task Number	Priority	Task Duration	Responsible Agency *2 FWS Region	Responsible Agency *2 FWS Program	Responsible Agency *2 Other	Estimated Fiscal Year Costs *3 FY 1	FY 2	FY3	Comments/Notes
M3,M7	Determine measures needed to minimize threats and implement where needed to meet recovery.	1.3.4	2	Unknown	4&5	SE&ES	TWRA,VCGIF, TVA,THP & TN and VA Nature Conservancy (TNC)	---	---	---	
01,04	Solicit help in protecting species and essential habitat.	1.4.1 1.4.2 1.4.3 & 1.4.4	2	Continuous	4&5	SE&ES	TWRA,VCGIF, TVA,THP & TNC	---	---	---	
01	Develop and utilize information and education program (slide/tape shows, brochures, etc.) for local distribution.	1.4.5	2	1 yr. for devel. continued implementation	4&5	SE&ES	TWRA,VCGIF, TVA,THP & TNC	---	---	---	
M7,A1-A7,03, 04	Investigate the use of Scenic River Status, mussel sanctuaries, land acquisitions, and/or other means to protect the habitat.	1.5	2	Unknown	4&5	SE&ES	TWRA,VCGIF, TVA,THP & TNC	---	---	---	
I13	Survey rivers within species' historic range to determine availability of suitable transplant sites.	2.1 & 2.2	3	1 yr.	4&5	SE	TWRA,VCGIF, TVA & THP	---	---	---	
R13,R7	Determine best method of establishing new populations.	2.3	3	2 yr.	4&5	SE	TWRA,VCGIF, TVA & THP	---	---	---	Task 2.1 - 2.3 may not be required if other populations are found in task 1.2.1.

Part III Implementation Schedule

General Category	Plan Task	Task Number	Priority	Task Duration	Responsible Agency FWS Region	Responsible Agency FWS Program	Responsible Agency Other	Estimated Fiscal Year Costs FY 1	FY 2	FY 3	Comments/Notes
M2	Reestablish populations within historic range as needed to meet recovery.	2.4	3	Unknown	4 & 5	SE	TWRA, THP VCGIF & TVA	---	---	---	
112,114 M3,M7	Implement same protective measures for these reestablished populations as for known populations.	2.5	3	Continuous	4 & 5	SE,ES	TWRA, VCGIF, TVA, THP & TNC	---	---	---	
R3,6,8, 9,10,11 & 14	Conduct life history studies on a need-to-know basis.	3	1	Unknown	4 & 5	SE	TWRA, VCGIF THP & TVA	---	---	---	
R8-R11	Determine the number of individuals required to maintain a viable population.	4	3	Unknown	4 & 5	SE	TWRA, THP VCGIF & TVA	---	---	---	These studies will be developed and carried out where there is a specific need for data necessary to reach recovery.
M3	Investigate the need for habitat improvement and implement only where needed to meet recovery objective.	5	3	Unknown	4 & 5	SE	TWRA, THP VCGIF & TVA	---	---	---	
11,12	Develop and implement a monitoring program.	6	2	Unknown	4 & 5	SE	TWRA, THP VCGIF & TVA	---	---	---	
04	Annual assessment of recovery program and modify where needed.	7	2	Continuous	4 & 5	SE	TWRA, VCGIF TVA, THP & TNC	---	---	---	

KEY TO IMPLEMENTATION SCHEDULE COLUMNS 1 & 4

General Category (Column 1):

Information Gathering - I or R (research)

1. Population status
2. Habitat status
3. Habitat requirements
4. Management techniques
5. Taxonomic studies
6. Demographic studies
7. Propagation
8. Migration
9. Predation
10. Competition
11. Disease
12. Environmental contaminant
13. Reintroduction
14. Other information

Acquisition - A

1. Lease
2. Easement
3. Management agreement
4. Exchange
5. Withdrawal
6. Fee title
7. Other

Other - O

1. Information and education
2. Law enforcement
3. Regulations
4. Administration

Management - M

1. Propagation
2. Reintroduction
3. Habitat maintenance and manipulation
4. Predator and competitor control
5. Depredation control
6. Disease control
7. Other management

Priority (Column 4):

1 - Those actions absolutely necessary to prevent extinction of the species.

2 - Those actions necessary to maintain the species' current population status.

3 - All other actions necessary to provide for full recovery of the species.

APPENDIX

List of Reviewers

Mr. Steven A. Ahlstedt
Field Operations
Division of Water Resources
Forestry Building
Norris, Tennessee 37828

Mr. Herbert D. Athearn
Route 5, Box 376
Cleveland, Tennessee 37311

Mr. John M. Bates
Ecological Consultants, Inc.
1900 Dexter Avenue
Ann Arbor, Michigan 48103

Dr. Arthur E. Bogan
Department of Malacology
Academy of Natural Sciences
Nineteenth and the Parkway
Philadelphia, Pennsylvania 19103

Mr. Alan C. Buchanan
Missouri Department of Conservation
Fish and Wildlife Research Center
1110 College Avenue
Columbia, Missouri 65201

Dr. Arthur H. Clarke
7 Hawthorne Street
Mattapoisett, Mass. 02739

Mr. George M. Davis
Academy of Natural Sciences
19th and the Parkway
Philadelphia, Pennsylvania 19103

Ms. Sally D. Dennis
Center of Environmental Studies
Virginia Polytechnic Institute
and State University
Blacksburg, Virginia 24061

Mr. Samuel L.H. Fuller
Department of Limnology
Academy of Natural Sciences
19th. and the Parkway
Philadelphia, Pennsylvania 19103

Mr. Joseph Bruna, Director
Division of Game Management
Dept. of Fish & Wildlife Resources
592 East Main Street
Frankfort, Kentucky 40601

Mr. Richard Hannan, Coordinator
Kentucky Nature Preserves Commission
407 Broadway
Frankfort, Kentucky 40601

Mr. Charles Gooch
Field Operations
Tennessee Valley Authority
A 251 401 Building
Chattanooga, Tennessee 37401

Dr. William H. Heard
Department of Biology
Florida State University
Tallahassee, Florida 32306

Dr. John C. Hurd
Science Department
La Grange College
La Grange, Georgia 30240

Dr. Marc J. Imlay
Columbia National Fisheries
Research Laboratory
U.S. Fish and Wildlife Service
Route 1,
Columbia, Missouri 65201

Mr. Billy G. Isom
Fisheries and Aquatic Ecology Branch
Division of Water Resources
Tennessee Valley Authority
E & D Building
Muscle Shoals, Alabama 35660

Dr. Eugene P. Keferl
Division of Natural Science
Brunswick Junior College
Brunswick, Georgia 34520

Dr. Paul W. Parmalee
Department of Anthropology
The University of Tennessee
Knoxville, Tennessee 37916

Dr. Hugh J. Porter
Institute of Marine Sciences
University of North Carolina
P.O. Drawer 809
Morehead City, North Carolina 28557

Dr. James B. Sickel
Department of Biology
Murray State University
Murray, Kentucky 40271

Dr. David H. Stansbery
Museum of Zoology
Ohio State University
1813 North High Street
Columbus, Ohio 43210

Dr. Carol B. Stein
Museum of Zoology
Ohio State University
1813 North High Street
Columbus, Ohio 43210

Dr. Edward M. Stern
Department of Biology
University of Wisconsin
at Stevens Point
Stevens Point, Wisconsin 54481

Dr. Fred G. Thompson
Florida State Museum
Museum Road
University of Florida
Gainesville, Florida 32611

Dr. Henry Van der Schalie
15000 Buss Road
Manchester, Michigan 48158

Dr. John D. Williams
Department of Biology
Eastern Kentucky State University
Richmond, Kentucky 23219

Dr. Paul Yokley, Jr.
Department of Biology
University of North Alabama
Florence, Alabama 35630

Virginia Wildlife Federation
Box 1780
Norfolk, Virginia 23501

Dr. R. Don Estes, Leader
Tennessee Cooperative
Fishery Research Unit
Tennessee Technological Universtiy
Box 5063
Cookeville, Tennessee 38501

Mr. John Hardcastle
Chapter Chairman
The Nature Conservancy
Capitol Hill Building 114
301 7th Ave., North
Nashville, Tennessee 37219

Mr. Bob Hatcher, Nongame Biologist
Tennessee Wildlife Resources Agency
Ellington Agriculture Center
P.O. Box 40747
Nashville, Tennessee 37204

Mr. D.W. Yambert
Nongame Biologist
Tennessee Wildlife Resources Agency
Route 3, Box 153-A
Talbott, Tennessee 37877

Mr. Dan Eagars, Zoologist
Tennessee Heritage Program
2611 West End Avenue
Nashville, Tennessee 37203

Dr. Thomas H. Ripley, Manager
Office of Natural Resources
Tennessee Valley Authority
Locust Street Building
Knoxville, Tennessee 37902

Mr. Richard Fitz
Tennessee Valley Authority
Locust Street Building
Knoxville, Tennessee 37902

Mr. John Jenkinson
Tennessee Valley Authority
Evans Building
Knoxville, Tennessee 37902

Jack M. Hoffman, Chief
Fish Division
Commission of Game and Inland Fisheries
4010 West Broad Street
Box 11104
Richmond, Virginia 23230

Robert V. Davis, Executive Director
State Water Control Board
P.O. Box 11143
Richmond, Virginia 23230

Dr. Richard Neves
Virginia Cooperative Fishery Unit
106 Cheatham Hall
Virginia Polytechnic Institute
Blacksburg, Virginia 24061

Dr. and Mr. Wayne C. Starnes
Tennessee Valley Authority
450 Evans Bldg.
Knoxville, Tennessee 37902

Howard Larsen, Regional Director
U.S. Fish and Wildlife Service
One Gateway Center
Newton Corner, Massachusetts 02138

U.S. Fish and Wildlife Service
Ecological Services Field Station
P.O. Box 845
Cookeville, Tennessee 38501

Mr. Anthony J. Campbell
Executive Director
Tennessee Conservation League
1720 West End Avenue
Suite 600
Nashville, Tennessee 37203

Dr. Mohamed T. El-Ashry, Director
Environmental Quality Staff
Tennessee Valley Authority
Knoxville, Tennessee 37902

Mr. Brian Shult, State Director
The Nature Conservancy
619 East High Street
Charlottesville, Virginia 22901

Mr. Gary Myers, Executive Director
Tennessee Wildlife Resources Agency
Ellington Agricultural Center
P.O. Box 40747
Nashville, Tennessee 37204

Mr. Sam Pearsall, Program Coordinator
Tennessee Department of Conservation
Tennessee Heritage Program
701 Broadway
Nashville, Tennessee 37203

Mr. Chuck Cook
The Nature Conservancy
P.O. Box 3017
Nashville, Tennessee 37219

Mr. Ralph Jordan, Jr.
Tennessee Valley Authority
Office of Natural Resources
Forestry Building
Norris, Tennessee 37828