

76-06-14-123

Recovery Plan

Cumberland Monkeyface Pearly Mussel (Quadrula intermedia)

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Recovery Plan for the Cumberland Monkeyface Pearly Mussel

Quadrula intermedia (Conrad, 1836)

November 1983

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For the

United States Fish and Wildlife Service

Southeast Region

Atlanta, Georgia

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Date:

JUL 9 1984



THIS IS THE COMPLETED CUMBERLAND MONKEYFACE PEARLY MUSSEL RECOVERY PLAN. IT HAS BEEN APPROVED BY THE U.S. FISH AND WILDLIFE SERVICE. IT DOES NOT NECESSARILY REPRESENT OFFICIAL POSITIONS OR APPROVALS OF COOPERATING AGENCIES, AND IT DOES NOT NECESSARILY REPRESENT THE VIEWS OF ALL INDIVIDUALS WHO PLAYED A KEY ROLE IN PREPARING THIS PLAN. THIS PLAN IS SUBJECT TO MODIFICATION AS DICTATED BY NEW FINDINGS AND CHANGES IN SPECIES STATUS AND COMPLETION OF TASKS ASSIGNED IN THE PLAN. GOALS AND OBJECTIVES WILL BE ATTAINED AND FUNDS EXPENDED CONTINGENT UPON APPROPRIATIONS, PRIORITIES, AND OTHER BUDGETARY CONSTRAINTS.

THE RECOVERY PLANS 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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U.S. Fish and Wildlife Service. 1982. Cumberland Monkeyface Pearly Mussel Recovery Plan. U.S. Fish and Wildlife Service, Atlanta, Georgia. 59 pp.

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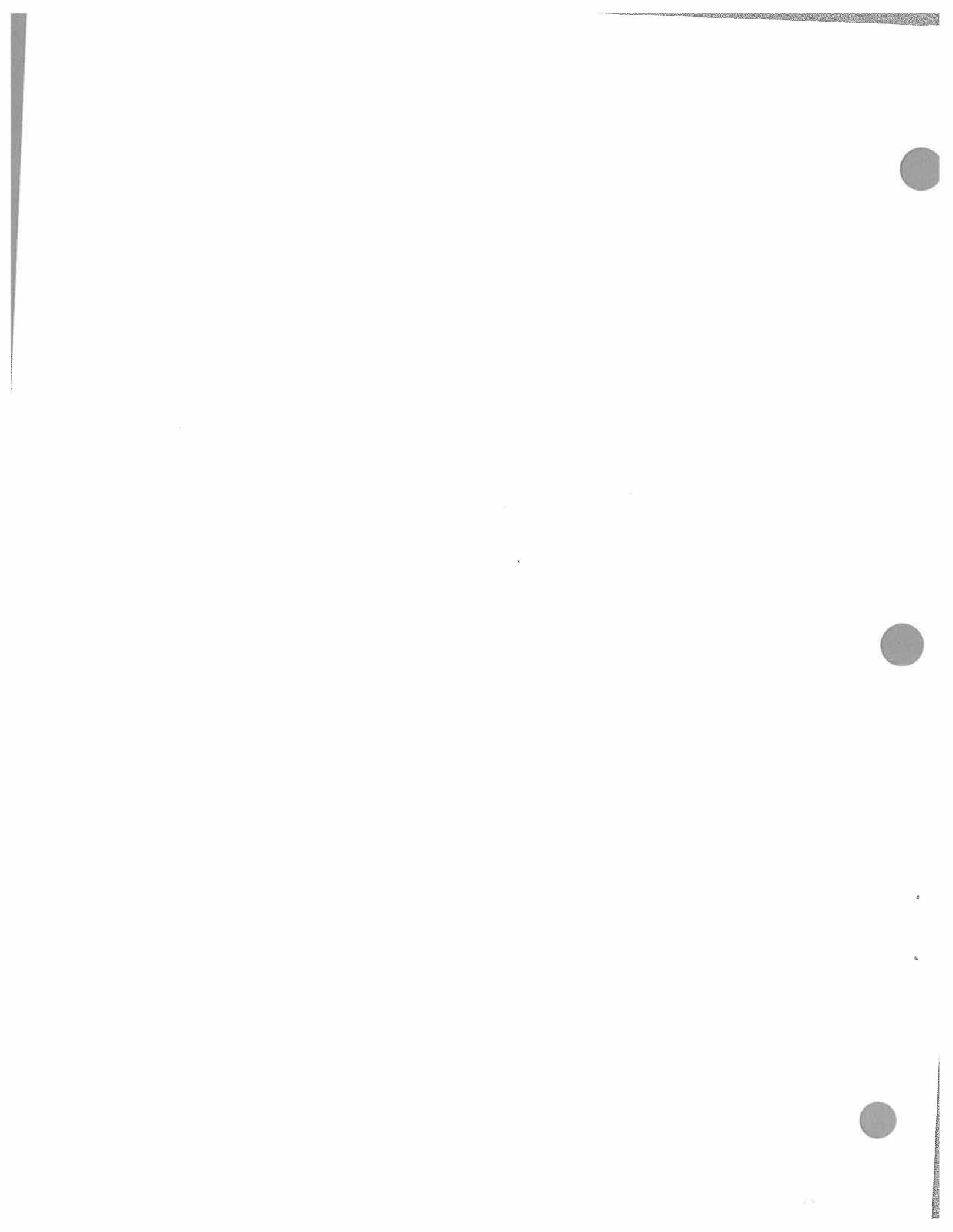
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PART I

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 are 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 Cumberland monkey face pearly mussel (Quadrula intermedia) 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 Conrad in 1836 from the Nolichucky River, Tennessee. Q. intermedia (Lea, 1841) has taxonomically been synonymized with Unio tuberosa (Lea, 1840) and Unio sparsa (Lea, 1841) according to Ortmann (1918). The exact relationship between these species is unknown because both Q. tuberosa and Q. sparsa are or were found within the range of Q. intermedia and resemble it at least superficially (Stansbery, 1976).

The complete absence of intermediate specimens indicates that both these forms are good species. Further, since Q. sparsa is so rare and Q. tuberosa is probably extinct (Stansbery, 1976), it seems unlikely that their taxonomic status will change in the foreseeable future. Both Q. intermedia and Q. sparsa currently exist in the Powell River with no apparent intergrades.

DISTRIBUTION

Historical

The Tennessee and Cumberland River systems are among the world's most ancient. The Tennessee, containing at least 86 species of Unionacea, has the largest assemblage of unionid species found anywhere, followed by the Cumberland River, which has a unionid fauna of at least 78 species (Johnson, 1978).

Ortmann's 1918 monograph on the naiads of the upper Tennessee River is the most significant work on that region's freshwater mussel fauna prior to construction of impoundments and other environmental perturbations on many of these streams. Publications by Wilson and Clark (1912, 1914) and Neel and Allen (1964) on the mussels of the Cumberland River and its tributaries also offer an excellent historical account of that fauna prior to impoundment and extensive coal mining.

Q. intermedia is a Cumberlandian species restricted to the upper Tennessee River (Simpson, 1914), where it was reported by Ortmann (1918) as a rare species. The distribution of Q. intermedia in the upper Cumberland River remains uncertain since a closely related species, Q. tuberosa, was also reported from the Cumberland system. Stansbery (1976) reports that since Q. tuberosa is recognized by Ortmann and another similar species,

Q. sparsa, is rare, it seems probable that most of Ortmann's records for Q. intermedia in 1918, 1924, and 1925 were indeed of that species in the strict sense. For the purposes of this report, the historical distribution for Q. tuberosa will be included with the historical distribution of Q. intermedia. Historical records for both of these species prior to 1970 are summarized in Table 1.

Present

Q. intermedia is presently known only from large tributaries of the Tennessee River including the Duck (Figure 1), Elk (Figure 2), and Powell Rivers (Figure 3).

Recent freshwater mussel surveys of the Duck River were conducted by TVA personnel and consultants in 1972 (TVA, 1972), 1976 and 1978 (Ahlstedt, 1981b), and 1979 (TVA, 1979b). The 1979 survey consisted of a 116-mile dive/float survey from Normandy Dam (DRM 248) to the "old" Columbia Dam (DRM 132). The downstream reaches of the Duck River below Columbia Dam were not searched. A total of five live specimens of Q. intermedia was found during this survey at an unnamed island near Hardison Mill (DRM 173.2), below Hardison Mill (DRM 171.2), and below Hooper Island (DRM 162.8). One additional live specimen was found by TVA biologist Larry Neill (personal communication) below Lillard Mill Dam (DRM 178.6) while sampling for freshwater mussels in 1980. Further, three live specimens were found by TVA biologists at Lillard Mill during fall 1982. Q. intermedia is considered extremely rare in the Duck River and is limited in distribution to a 40-mile reach of the river between Lillard Mill Dam and the "old" Columbia Dam.

Table 1. Historical records for Q. intermedia and Q. tuberosa prior to 1970, and subfossil records recorded to 1979.

River	Source
Tennessee River	Lewis (1871) Call (1885) Hinkley (1906) Ortmann (1918, 1924, 1925) Morrison (1942) Warren (1975) archaeological specimens Bogan and Parmalee (1983) archaeological specimens
Elk River	Ortmann (1924, 1925) Stansbery 1965-1966 (1970, 1976) Isom et al. 1965-1967 (1973)
Duck River	Marsh (1885) Ortmann (1924, 1925) van der Schalie (1973) Isom and Yokley (1968) Stansbery 1964-1965 (1970, 1976) Bogan and Parmalee (1983) relict specimens
Holston River	Lewis (1871) Call (1885) Ortmann (1918)
North Fork Holston River	Ortmann (1918)
South Fork Holston River	Ortmann (1918)
Nolichucky River	Conrad (1836) Jay (1852) Call (1885) Ortmann (1918)
French Broad River	Univ. of Michigan Museum Record
Tellico River	Athearn 1958 (1972)
Clinch River	Lewis (1871) Call (1885) Goodrich (1913) Ortmann (1918) Stansbery 1963 (1970, 1973, 1976) Bogan and Parmalee (1983) archaeological specimens

Table 1. Continued.

River	Source
Powell River	Stansbery 1967-1968 (1970, 1976)
Cumberland River	Lea (1840, 1842) <u>Q. tuberosa</u> Wilson and Clark (1914) <u>Q. tuberosa</u>
Big South Fork Cumberland River	Wilson and Clark (1914) <u>Q. tuberosa</u>
Caney Fork	Lea (1840, 1842) <u>Q. tuberosa</u>

One live and five freshly dead specimens of Q. intermedia were found by TVA biologists while sampling for freshwater mussels in the Elk River during a 120-mile dive/float survey completed in 1980 (TVA, 1980c; Ahlstedt, 1983). These specimens were found at five separate locations from Elk River mile 109.7 downstream to below the island at Pearl City (ERM 70.5). The one live specimen of Q. intermedia was found at ERM 109.7. An additional freshly dead specimen was found by TVA biologists below Dickey Bridge (ERM 105.5) in 1977. Q. intermedia is considered extremely rare in the Elk River and is probably limited in distribution to the lower 48 miles of the Elk River below Shelton Creek (ERM 110.1).

Q. intermedia has also been found in the Powell River by Dennis (1981), Ahlstedt and Brown (1980), Neves et al. (1980), Bogan and Parmalee (1983), and TVA (1979c). Q. intermedia has been reported by Dennis (1981) from the Powell River at five sites between Buchanan Ford (PRM 99.2) and Fletcher Ford (PRM 117.4). In this report, one live specimen was found at Buchanan Ford and two live specimens were found at McDowell Ford (PRM 106.6). Ahlstedt and Brown (1980) reported Q. intermedia at six sites on the Powell River between Buchanan Ford (PRM 99.2) and Flanary Bridge (PRM 130.4). Although no actual numbers were given in this report, a compilation of records from the Powell River from 1975 to 1979 report 3 live and 26 freshly dead specimens of Q. intermedia. Neves et al. (1980) reported one live and an undetermined number of freshly dead specimens of Q. intermedia at Fletcher Ford (PRM 117.4). Bogan and Parmalee (1983) reported an undetermined number of specimens in the upper Powell River from a "well-established population." Four live and thirty-two freshly dead specimens of Q. intermedia were found at 11 sampling sites by TVA biologists during a

102-mile dive/float survey of the Powell River between Olinger (PRM 167.4) and State Highway 25E (PRM 65.1). Recent freshwater mussel sampling in the Powell River by TVA biologists during May and June 1981 produced 12 additional live specimens of Q. intermedia at McDowell Ford (PRM 106.6) and 3 live specimens at Fletcher Cliff (PRM 117.9). Q. intermedia is considered 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). This population of Q. intermedia in the upper Powell River is the largest and healthiest of the three known populations of this species.

Freshwater mussel surveys by numerous individuals have failed to find Q. intermedia living in any streams other than the Duck, Elk, and Powell Rivers. This species may be extinct in the Tennessee River because freshwater mussel surveys by Ellis (1931), van der Schalie (1939), Scruggs (1960), Bates (1962 and 1975), Stansbery (1964 and 1976), Williams (1969), Yokley (1972), Isom (1969, 1971a, and 1972), TVA (1978), and Pardue (1981) have failed to produce evidence of Q. intermedia in the Tennessee River.

Numerous freshwater mussel surveys of the headwater tributary streams in the upper and lower Tennessee River system have also failed to identify Q. intermedia living in the Holston River (Stansbery, 1976; TVA, 1981); the North, South, and Middle Forks of the Holston River (Neves et al., 1980; Stansbery, 1972; Stansbery and Clench, 1974, 1975, and 1978; TVA, 1976); Big Moccasin Creek (Neves and Zale, 1982); Clinch River (Bates and Dennis, 1978; TVA, 1979a; and Neves et al., 1980); Copper Creek (Ahlstedt, 1981a); Nolichucky River (Mullican et al., 1960; Stansbery, 1976; TVA, 1980d); French Broad River (TVA, 1979d); Paint Rock River (Isom

et al., 1973b); TVA, 1980e); Flint River (Isom et al., 1973b); and the Buffalo River (van der Schalie, 1973; TVA, 1980b).

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

Thus, it can be assumed that small portions of the Duck, Elk, and Powell Rivers (all tributary streams to the Tennessee River) contain the only known populations of Q. intermedia. Bogan and Pamalee (1983) report that Q. intermedia is probably restricted to the Tennessee River and its tributaries, but is absent from the Cumberland River system. Stansbery (1976) states "since Ortmann recognized the form called Q. tuberosa and Q. sparsa is so rare, it seems probable that most of Ortmann's records for Quadrula intermedia in 1918, 1924, and 1925 were indeed of that species in the strict sense so the Cumberland River records were added to the distribution of Q. intermedia." Further, 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. intermedia. 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 substrates that contain relatively firm rubble, gravel, and sand substrates swept free from siltation. 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. intermedia is a Cumberlandian species typically found in shallow, fast-flowing water with stable, clean substrate. This species has never been found living in the ponded stretches of rivers, nor is it known from very small streams (Stansbery, 1976).

Q. intermedia (see photo) is a medium-sized species that has the general form of the Q. cylindrica complex (=group of Q. metanevra of Simpson, 1914) and is subquadrate to subtriangulate in outline. Beaks are moderately high but not full and located in the anterior third of the shell. The

posterior-dorsal surface is rounded but interrupted by the sinus formed by the radial depression. The posterior ridge is slightly elevated above the outline of the shell anteriorly, but marked by a deep, wide, radial depression along the posterior-dorsal margin. Valves are typically flat and compressed with a deep beak cavity. The outer surface of the shell has numerous tubercles or knobs except toward the anterior portion of the shell. The outer covering of the shell (periostracum) is greenish-yellow with numerous green spots, chevrons, or zig-zags, sometimes with broken green rays (Bogan and Parmalee, 1983). Nacre color is generally white, straw colored, or salmon in color.

The life history of Q. intermedia is presumed similar to that of most unionids and is briefly illustrated in Figure 4. Males produce sperm which are discharged into the surrounding water and dispersed by water currents. Any female Q. intermedia downstream from the males obtains 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; and in some genera, which include Amblema, Quadrula, and Fusconaia, the water tubes in all four gills of the female carry 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 remains 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. intermedia 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 aborting glochidia May 27, 1981, lending further evidence that Q. intermedia is a tachytictic species.

The glochidia of Q. intermedia 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 more frequently parasitic on the gill filaments of fish (Coker and Surber, 1911; Lefevre and Curtis, 1910). The fish host(s) for Q. intermedia are unknown.

REASONS FOR DECLINE AND CONTINUED THREATS

Historically, Q. intermedia was widespread in the Tennessee River including major tributary streams. An examination of pre-1960 literature by Stansbery (1976) reveals that the range of Q. intermedia was restricted to the upper Tennessee River system (Simpson, 1914; Haas, 1969). However, it was apparently never abundant. Even Ortmann (1918), who lumped forms often considered to be another species (Q. tuberosa) with the records of Q. intermedia reported Q. intermedia to be a "decidedly" rare species. Ortmann's records for Q. intermedia in 1918, 1924, and 1925 were lumped with the species Q. tuberosa.

Q. intermedia has become increasingly rare throughout its range. 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 fauna 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 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.

The second largest known population of Q. intermedia occurs in the Duck River. The most immediate threat to this species is TVA's nearly completed Columbia Dam on the Duck River, which will eliminate Q. intermedia from the Duck. Although TVA has developed a program (known as the Cumberlandian Mollusk Conservation Program) to compensate for this imminent loss, future research will determine how successful the program will be. Life history studies for Q. intermedia were scheduled to commence in spring 1983.

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 are 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 that 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 from 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 form of 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. intermedia. Specimens found in both the Duck and Elk Rivers were found in such low numbers that reproduction may not be possible. Continued discharges of coal fines into the Powell River could jeopardize Q. intermedia 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 that 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 had 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 fluviialis indicated the North Fork Holston River I. fluviialis 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 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 small but recovering resident populations.

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) document 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.

PART II

RECOVERY

A. Recovery Objectives

The ultimate objective of this recovery plan is to maintain and restore viable populations* of Q. intermedia 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. intermedia populations and (2) establishing populations in rivers and river corridors that historically contained Q. intermedia. 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. intermedia exists in the Powell River from the backwaters of Norris Reservoir upstream to approximately PRM 130 and in the Elk River below Fayetteville, Tennessee. 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 by discoveries of new populations, viable populations exists in two additional rivers. Each of these rivers will contain a viable population that is distributed such

*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. intermedia from the river system. (If the Duck River Columbia Dam project is not completed and a viable population of the species exists in the Duck River, only one additional viable population will be needed to meet this criterion.)

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 populations and presently used habitat of Q. intermedia with emphasis on the Duck, Elk, and Powell Rivers.
 - 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 the species' population centers and inform them of the project and get their support in habitat protection measures.
 - 1.4.5 Develop educational programs 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 to protect 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. Investigate the necessity for habitat improvement and, if feasible and desirable, identify techniques and sites for improvement to include implementation.
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 populations and presently used habitat of *O. intermedia* with emphasis on the Powell, Duck, and Elk Rivers. The greatest known concentrations of *O. intermedia* occur in the Powell River. Lesser known populations occur in the Duck and Elk Rivers. If the Columbia Dam project is completed on the Duck River, *O. intermedia* will occur in only two river systems, the Elk and Powell Rivers. Since an undetermined number of *O. intermedia* occur in the Elk and Duck Rivers, these populations may have been reduced

to such low numbers that reproduction may not occur. The immediate protection of the Powell River population and habitat is crucial for the continued survival of the species. TVA will conduct life history studies on Q. intermedia during spring 1983. Preservation of Q. intermedia populations including transplanted populations will be required to meet the recovery objective.

- 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 a number of streams. The lower Elk River below Old Pam Ford (ERM 119.3), Tennessee should be surveyed to determine whether additional populations of Q. intermedia are present. Only one live and six freshly dead specimens were found during freshwater mussel sampling by TVA biologists during 1980 (Ahlstedt, in press). Freshwater mussel surveys are also recommended for the upper Clinch River between Cleveland, Virginia (CRM 272), and Craft Mill, Virginia (CRM 219.2). Freshly

dead specimens of Q. intermedia were reported by Stansbery (1973, 1976) at St. Paul, Virginia (CRM 256.0), as a result of sampling in 1963. However, this species has not been found in the Clinch River since. 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. Headwater tributary streams of the Cumberland in need of surveys 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. intermedia 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 special attention.

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 Determine impacts of coal industry related pollution on the species. 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 nonendangered mussels as experimental organisms are suggested.

- 1.3.2 Investigate and inventory factors negatively impacting the species and its environment. Factors such as road construction, dredging, herbicide and pesticide spraying, and chlorinated effluents may also be having a substantial impact on the species. The effects of toxic spills in the Clinch are well documented, but other less obvious factors may be damaging this and other river systems.
- 1.3.3 Solicit information on proposed and planned projects that may impact the species. 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 the species and its habitat. These impacts typically include strip mining, oil and gas drilling, coal slurry pipeline, 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 the 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 reach 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, U.S. 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. Further, the Cumberland River system contained (at least historically) an extremely rich freshwater mussel fauna. 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. Sections 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. Determine the feasibility of introducing the species back into rivers within its historic range and introduce where feasible.

Based upon the low number of specimens found in the Duck and Elk Rivers, the protection and preservation of the Powell River population and habitat are crucial for the continued survival of the species. However, it is unlikely that removal from the list of Federal endangered or threatened species could be achieved without the establishment of populations in other rivers and the expansion of populations in the Powell, Duck, and Elk Rivers. The factors that caused extinction or population reductions at potential transplant sites must be remedied prior to attempts at establishing additional populations.

- 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. 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 determined. 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 suitability of a particular river has been determined, specific sites for transplants within that river must be

identified. TVA as part of its Cumberlandian Mollusk Conservation Program has studied 15 sites for another endangered freshwater mussel Conradilla caelata. The current distribution for C. caelata overlaps with that of Q. intermedia in the Powell, Duck, and Elk Rivers. Each of the 15 sites was evaluated as a potential transplant site based on a correlation of stream characteristics with habitats of known populations of C. caelata. Upon completion of all data analysis, four sites were chosen to receive C. caelata during the fall of 1982. One thousand specimens of C. caelata were moved to each of the following river systems: North Fork Holston, Nolichucky, Buffalo, and upper Duck Rivers. Three of those sites chosen are within the known historic distribution for Q. intermedia in the Tennessee River system (i.e., North Fork Holston, Nolichucky, and Duck Rivers). These sites could also serve as potential transplant sites for Q. intermedia. Further studies are required in the upper headwater tributary streams of the Tennessee and Cumberland Rivers. Those tributary streams recommended for study include (1) the lower Holston River near I-40 bridge, (2) Middle and South Forks Holston River, (3) French Broad River, (4) upper Clinch River above Norris Reservoir, (5) the Sequatchie River, and (6) the Elk River below Fayetteville, Tennessee (to replenish existing populations in the Elk), of the Tennessee River system. Tributary streams to the Cumberland River system recommended for

study include (1) the 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. intermedia 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 experiments are required for determining which method(s) should be used for Q. intermedia.
- 2.4 Introduce species within historic range where it is likely they 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 population 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 Soulé (1980) indicate that 500 individuals represent a minimum population level (effective population size) which 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. Investigate the necessity for habitat improvement and, if feasible and desirable, identify techniques and sites for improvement to include implementation. 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 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, clear-cutting, and other activities which 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 and its habitat must be monitored to assess any progress toward recovery.

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

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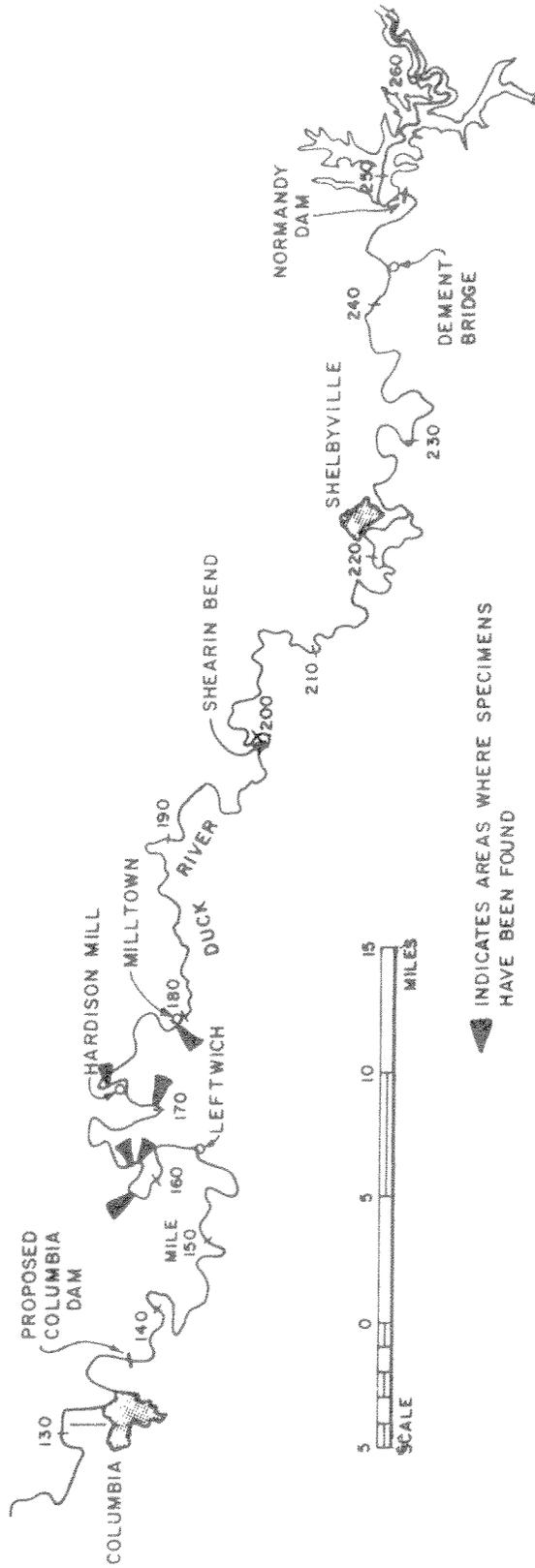


Figure 1 : Duck River - Recent Locations for QUADRULA INTERMEDIA, (Conrad, 1836)

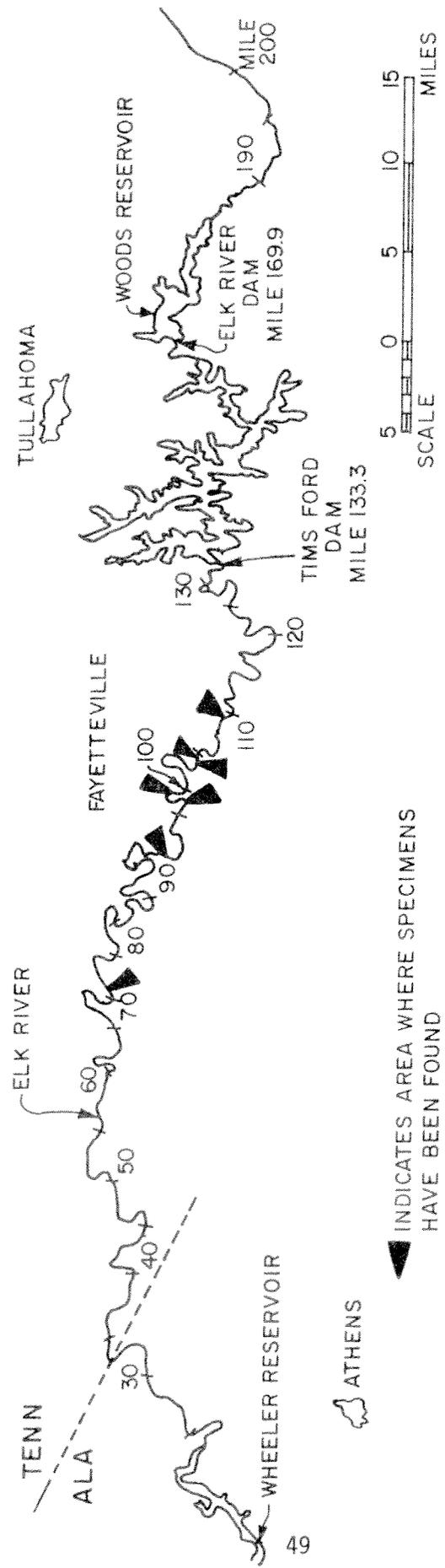


Figure 2 : Elk River -Recent Locations for QUADRULA INTERMEDIA, (Conrad, 1836)

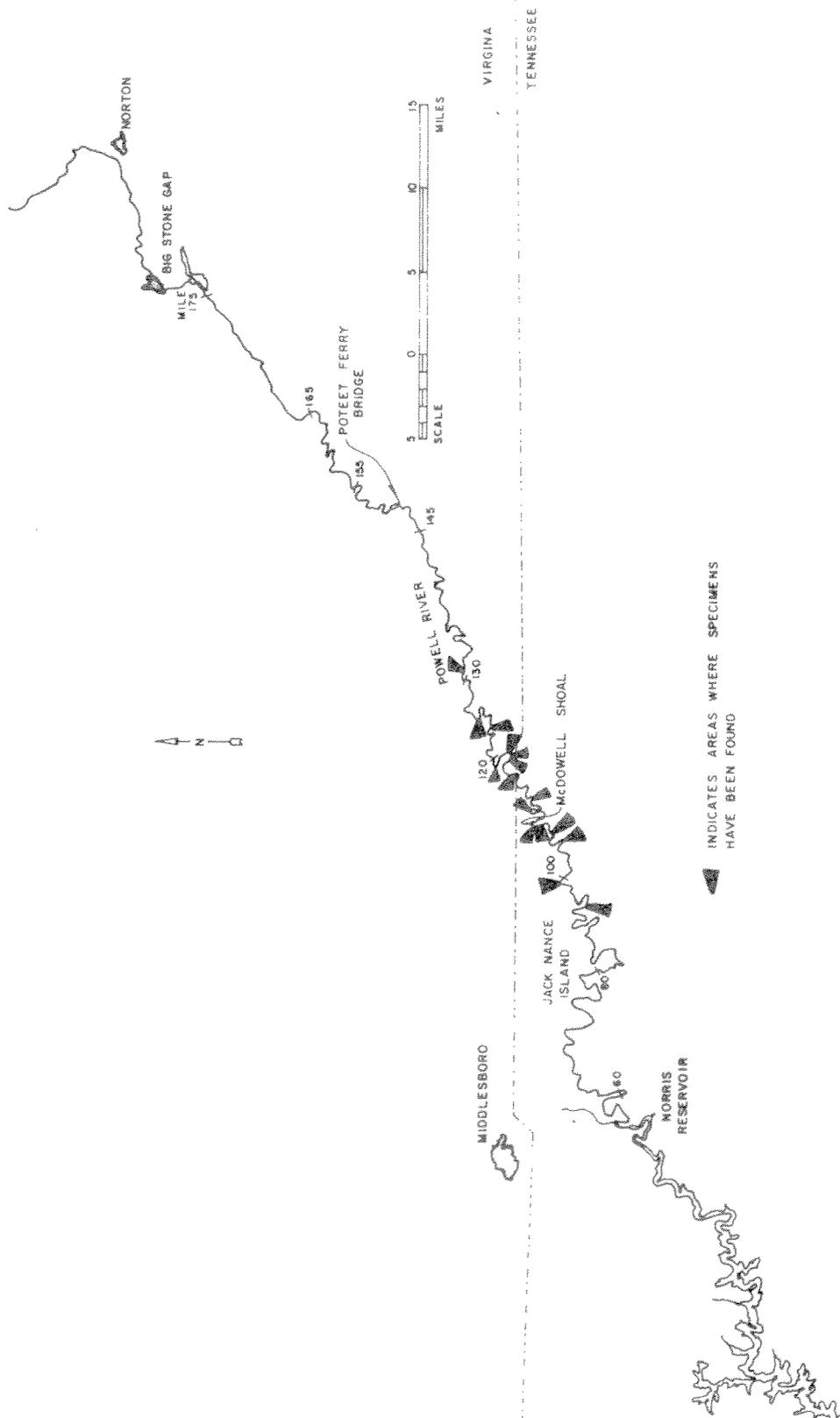


Figure 3 : Powell River —Recent Locations for QUADRULA INTERMEDIA, (Conrad, 1836)

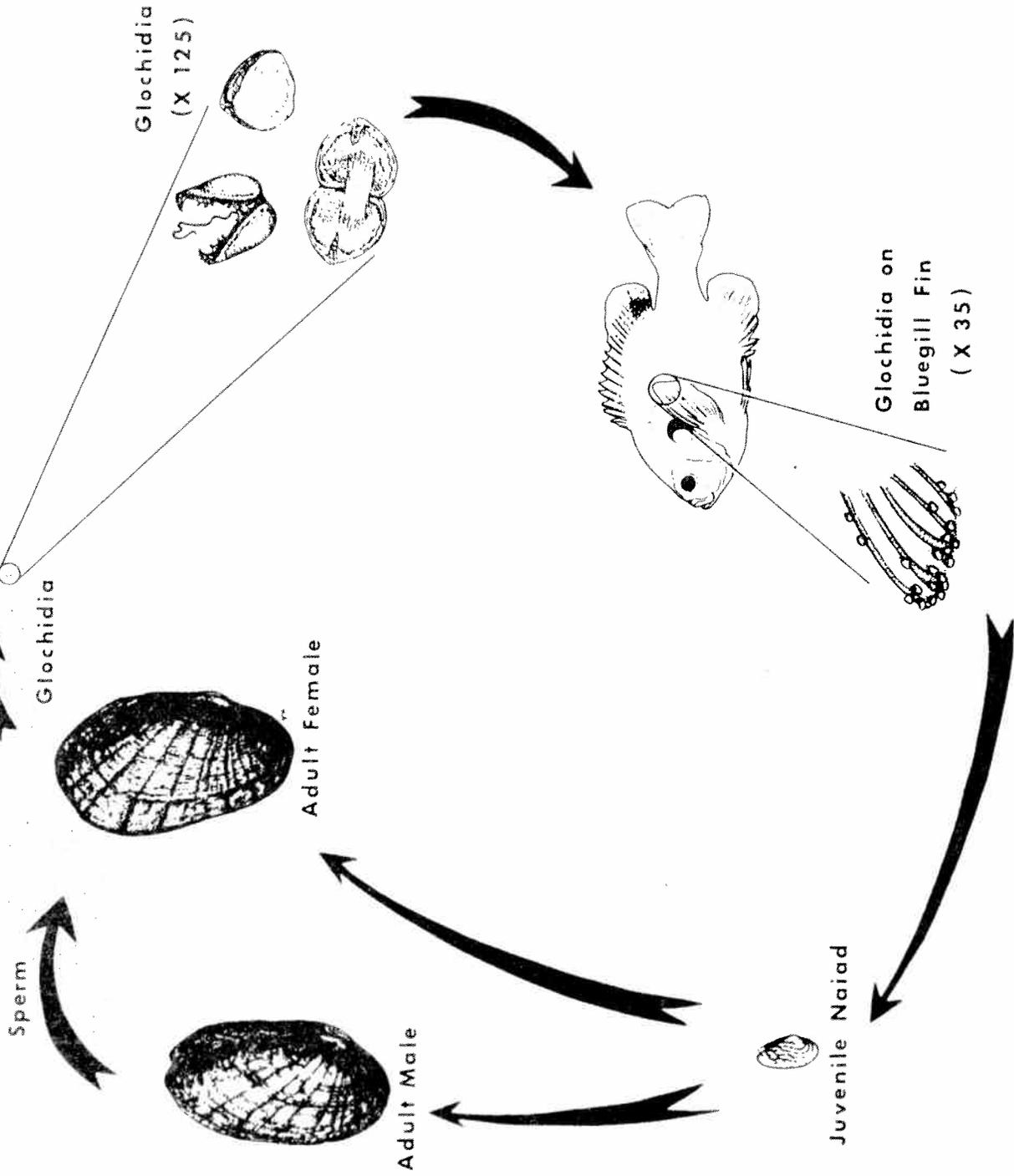


Figure 4. Typical naiad life cycle depicting the various stages. The life cycle for most species of naiades is very similar to that depicted here (Grace and Buchanan 1981).



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Cumberland Monkey Face Pearly Mussel
(Quadrula intermedia)

Part III Implementation Schedule

*1 General Category	Plan Task	Task Number	Priority	Task Duration	Responsible Agency *2		Estimated Fiscal Year Costs *3			Comments/Notes	
					FWS Region	Program	Other	FY 1	FY 2		FY 3
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), WA 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. *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.
I1,I2	Determine species' present distribution and status.	1.2.1	3	2 yr.	4&5	SE	TWRA,THP, VCGIF & TVA	---	---	---	
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	---	---	---	

Cumberland Monkey Face Pearly Mussel
(Quadrula intermedia)

Part III Implementation Schedule

General Category	Plan Task	Task Number	Priority	Task Duration	Responsible Agency *2			Estimated Fiscal Year Costs			Comments/Notes
					FHS Region	Program	Other	FY 1	FY 2	FY 3	
M3,M7	Determine measures needed to minimize threats and implement where needed to meet recovery.	1.3.4	2	Unknown	485	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	485	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	485	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	485	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.	485	SE	TWRA, VCGIF, --- TVA & THP	---	---	---	
P13,R7	Determine best method of establishing new populations.	2.3	3	2 yr.	485	SE	TWRA, VCGIF, --- TVA & THP	---	---	---	Task 2.1 - 2.3 may not be required if other populations are found in task 1.2.1.

Cumberland Monkey Face Pearly Mussel (Quadrula intermedia) Part III Implementation Schedule

*1 General Category	Plan Task	Task Number	Priority	Task Duration	Responsible Agency *2		Estimated Fiscal Year Costs			Comments/Notes
					FWS Region	Program Other	FY 1	FY 2	FY 3	
M2	Reestablish populations within historic range as needed to meet recovery.	2.4	3	Unknown	485	SE TWRA, THP VCGIF & TVA	---	---	---	
I12, I14 M3, M7	Implement same protective measures for these reestablished populations as for known populations.	2.5	3	Continuous	485	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	485	SE TWRA, THP VCGIF & TVA	---	---	---	
R8-R11	Determine the number of individuals required to maintain a viable population.	4.	3	Unknown	485	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 implementation only where needed to meet recovery objective.	5.	3	Unknown	485	SE TWRA, THP VCGIF & TVA	---	---	---	
I1, I2	Develop and implement a monitoring program.	6.	2	Unknown	485	SE TWRA, THP VCGIF & TVA	---	---	---	
O4	Annual assessment of recovery program and modify where needed.	7.	2	Continuous	485	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.

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