Recovery Plan

Birdwing Pearly Mussel (*Conradilla caelata*)

Recovery Plan for the Birdwing Pearly Mussel

Conradilla caelata (Conrad, 1834)

November 1983

Prepared by

Steven Ahlstedt

For the

United States Fish and Wildlife Service

Southeast Region

Atlanta, Georgia

Approved: [signature]

Associate Director, U.S. Fish and Wildlife Service

Date: JUL 9 1984

THIS IS THE COMPLETED BIRDWING 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.

LITERATURE CITATIONS SHOULD READ AS FOLLOWS:

U.S. Fish and Wildlife Service. 1983. Birdwing Pearly Mussel Recovery Plan. U.S. Fish and Wildlife Service, Atlanta, Georgia. 56 pp.

ADDITIONAL COPIES MAY BE OBTAINED FROM:

FISH AND WILDLIFE REFERENCE SERVICE
1776 E. JEFFERSON STREET
4TH FLOOR
ROCKVILLE, MARYLAND 20852

CONTENTS

CONTENTS

(Continued)

TABLE

FIGURES

PHOTOGRAPH

PART 1

INTRODUCTION

The tributary streams of the Tennessee River basin contain freshwater mussel species that are endemic to the southern Appalachian Mountains and the Cumberland Plateau region. Ortmann (1924) referred to these species as "Cumberlandian," and this region became known as one of the chief centers of freshwater mussel speciation. Of the 23 American freshwater mussel species listed as endangered by the U.S. Department of the Interior, 13 are members of the Cumberlandian faunal group. The birdwing pearly mussel (*Conradilla caelata*) was proposed as an endangered species in September 1975 (*Federal Register* 40:44329-44333) and listed in June 1976 (*Federal Register* 41:24062-24067).

This species was described by Conrad in 1834 from the Elk and Flint Rivers, Tennessee, and is sometimes referred to as *Lemiox rimosus*, as described by Rafinesque in 1831 from the Cumberland River. However, *L. rimosus* was never again reported from the Cumberland River (Stansbery, 1979). All later records indicate the species is restricted to the Tennessee River system from the major headwater tributaries downstream as far as Muscle Shoals in northern Alabama (Ortmann, 1925). For the purposes of this recovery plan, the name *C. caelata*, as it appears on the *Federal Register*, will be used.

DISTRIBUTION

Historical

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 the construction of impoundments on many of these streams. At that time, a total of 66 species of mussels occurred in the Tennessee River between Chattanooga and Knoxville, Tennessee. Pardue (1981) reported only 23 species of mussels living in the upper Tennessee River during a survey conducted in 1978.

C. caelata was reported to have a wide distribution, but was never found in large numbers, and was thus considered a rare shell (Ortmann, 1918). Although reported from the Cumberland River as L. rimosus (Rafinesque, 1831), Wilson and Clark's 1914 mussel survey of the Cumberland River and its tributaries failed to produce any evidence of this species. All later records for C. caelata are restricted to the Tennessee River and major tributary streams. All records outside the region are suspected to be errors. A search through several thousand pieces of naiad literature has produced only one record outside the Cumberlandian region compared with 47 records within (Stansbery, 1979). Historical records for C. caelata prior to 1970 are summarized in Table 1.

Present

C. caelata is presently known only from large tributaries of the Tennessee River including the Duck (Figure 1), Elk (Figure 2), Clinch (Figure 3), and Powell Rivers (Figure 4).

Recent freshwater mussel surveys of the Duck River were conducted by TVA personnel and consultants in 1972 (TVA, 1972), in 1976 and 1978 (Ahlstedt, 1981b), and in 1979 (TVA, 1979b). The 1979 survey consisted of a 116-mile 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. Additional recent records for C. caelata from the Duck

Table 1. Historical records for <u>Conradilla caelata</u> prior to 1970, and sub-fossil records recorded to 1981.

River	Source
Cumberland River (Distribution unknown)	Rafinesque (1831)
Tennessee River	Ortmann (1925) Morrison (1942)
Paint Rock River	Isom et al. (1973b)
Flint River	Ortmann (1925) Isom et al. (1973b)
Elk River	Ortmann (1924, 1925)
Duck River	Marsh (1885) Ortmann (1924, 1925) van der Schalie (1973) Isom and Yokley (1968) Stansbery (1979)
Holston River	Ortmann (1916, 1918) Stansbery (1972) sub-fossil specimens TVA (1981) sub-fossil specimens
North Fork Holston River	Ortmann (1916, 1918) TVA (1977) sub-fossil specimens Stansbery (1972) sub-fossil specimens
Nolichucky River	Stansbery (1979) sub-fossil specimens
Clinch River	Call (1885) Goodrich (1913) Bogan and Parmalee (1983) subfossil specimens Ortmann (1916, 1918) Stansbery (1973, 1979)
North Fork Clinch River	Univ. of Mich. Museum Record # 92742
Powell River	Call (1885) Ortmann (1916, 1918) Stansbery (1979)

River are reported by van der Schalie (1973) and Stansbery (1979). C. caelata is considered abundant in the Duck River but is limited in distribution to a 40-mile reach of river between Lillard Mill Dam (DRM 179) and the "old" Columbia Dam, where populations have been estimated at between 20,000 and 30,000 individuals. This represents the largest known population of C. caelata.

In the fall of 1982, TVA as part of their Columbia Dam Conservation Program transplanted 1,000 C. caelata from the Lillard Mill Dam site to each of the following sites: Duck River, River Mile 206.7, Bedford County, Tennessee; Buffalo River, River Mile 79.9, Wayne County, Tennessee; Nolichucky River, River Mile 27.8, Greene County, Tennessee; and North Fork Holston River, River Mile 4.6, Hawkins County, Tennessee. If these transplants prove successful, TVA would be allowed to complete Columbia Dam and flood the present Duck River habitat of the birdwing pearly mussel.

A total of two freshly dead specimens of C. caelata was found by TVA biologists while sampling for freshwater mussels in the Elk River during a 120-mile float survey completed in 1980 (Ahlstedt, 1983). The specimens (evidence of meat still in the shell) were found in muskrat middens at two separate locations (Island at Pearl City ERM 70.5 and Morgan Bend ERM 83.0). This is the first report of C. caelata being found in the Elk River since Ortmann's 1925 survey. Isom et al. (1973a), in reporting the results of a mussel survey of the Elk River from 1965 to 1967, offer an excellent account of that mussel fauna prior to its impoundment in 1970. No C. caelata were found during that survey. Therefore, C. caelata must be considered extremely rare in the Elk River and is probably limited in distribution to the lower 40 miles of the river below the city of Fayetteville, Tennessee (ERM 91.5).

C. caelata has also been reported from the Clinch River by Neves et al. (1980), TVA (1979a), Stansbery (1973, 1979), and Bates and Dennis (1978). Seven live *C. caelata* were found by TVA biologists in 1979 (TVA, 1979a) during a 170-mile float/survey of the Clinch River from Cedar Bluff (CRM 322.6) to State Highway 25E (CRM 153.8). TVA's float survey of the Clinch River was incomplete from Cedar Bluff to Craft Mill (CRM 220) because of cold weather conditions. Stansbery (1979) reported 39 freshly dead specimens taken from muskrat middens at Kyles Ford (CRM 189.6) in 1969. Bates and Dennis (1978) reported one freshly dead shell from Kyles Ford during their survey of the Clinch River. Additional field sampling for mussels by TVA personnel in 1981 (TVA, 1981) report nine freshly dead *C. caelata* found in muskrat middens at Pendleton Island (CRM 226.3). Two live specimens of *C. caelata* were also found at St. Paul, Virginia (CRM 253.5), during a mussel relocation project in December 1981 and May 1982. It is apparent from these records that *C. caelata* is rarely found in the Clinch River and is probably limited to a 106-mile reach of the upper Clinch River above Norris Reservoir between Sneedville Bridge (CRM 173) and Nash Ford (CRM 279.4)

C. caelata has also been found in the Powell River by Dennis (1981), Ahlstedt and Brown (1980), Neves et al. (1980), TVA (1979c), and Stansbery (1979). Eight live *C. caelata* were found by TVA biologists in 1979 during a 102-mile float survey of the upper Powell River between Olinger (PRM 167.4) and State Highway 25E (PRM 65.1). The greatest number of *C. caelata* found in the Powell River were observed by TVA biologists at McDowell Ford (PRM 106.9) where 18 live specimens were found while sampling in June 1981. *C. caelata* is considered rare in the Powell River and is probably limited to a 52-mile reach of the upper Powell River above Norris Reservoir between Cosby Bridge (PRM 78.7) and Flanary Bridge (PRM 130.6).

Additional freshwater mussel surveys by numerous individuals have failed to find C. caelata living in any streams other than the Duck, Elk, Clinch, and Powell Rivers. Freshwater mussel surveys conducted on the Tennessee River by Ortmann (1918, 1925), Ellis (1931), van der Schalie (1939), Scruggs (1960), Bates (1962, 1975), Stansbery (1964), Williams (1969), Yokley (1972), Isom (1969, 1971a, 1972), TVA (1978), and Pardue (1981) failed to find C. caelata in the Tennessee River. Mussel surveys of the Cumberland River by Wilson and Clark (1914), Neel and Allen (1964), TVA (1976), Stansbery (1965), Parmalee et al. (1980), and Sickle (1982) also revealed no evidence of C. caelata in the Cumberland River.

Numerous freshwater mussel surveys of the tributary streams in the Tennessee River system have also failed to identify C. caelata living in the Holston River (TVA, 1981); the North, South, and Middle Forks of the Holston River (Neves et al., 1980; Stansbery, 1972; Stansbery and Clench, 1974, 1975, 1978; and TVA, 1976); Big Moccasin Creek (Neves and Zale, 1982); Copper Creek (Ahlstedt, 1981a); Nolichucky River (TVA, 1980c); French Broad River (TVA, 1979d); Paint Rock River (Isom et al., 1973b; TVA, 1980d); Elk River (Isom et al., 1973a); Flint River (Isom et al., 1973b); and the Buffalo River (van der Schalie, 1973; TVA, 1980b). Stansbery (1979) reports visiting perhaps a thousand or more stream sites across the length and breadth of the former range of L. rimosus (=Conradilla caelata) since 1960. Although the deep water impoundments created by high dams were not sampled, he observed and identified tons of commercial shells harvested from those sites where the inundated channel of the original Tennessee

River still has marketable shell. None of these deep water sites has yielded a single specimen of _C. caelata_. Thus, it can be reliably assumed that only the unimpounded, free-flowing portions of larger rivers above the impoundment pools have extant populations of _C. caelata_. These streams include the Duck River (Tennessee) above Columbia Dam, Elk River (Tennessee) above Wheeler Reservoir, the Clinch River (Tennessee, Virginia) above Norris Reservoir, and the Powell River (Tennessee) above Norris Reservoir.

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 reported from the Tennessee River (Ortmann, 1925) in 1924 before the impoundment of Wilson Reservoir, all but 6 were apparently eliminated (Stansbery, 1964; Isom, 1969).

C. caelata is categorized as a riffle species because it is typically found in shallow, fast-flowing water with stable, clean sub-strate. However, this species has been found alive in approximately 6 to 7 feet of water. In this case, although a shallow riffle or shoal was not present, fast-flowing water over stable, relatively silt-free rubble, gravel, and sand substrates enabled _C. caelata_ to colonize, indicating depth need not be a limiting factor for survival.

C. caelata (see photo) is a relatively small Cumberlandian species, seldom over 50 mm in length, 40 mm in height, and 25 mm in width (Stansbery, 1979). The valves are generally solid, slightly inflated (especially the females), and subtriangular to subovate in outline. Beak sculpturing on young specimens is present on the umbo and typically consists of three or four double-looped bars. The posterior ridge is well developed, being somewhat rounded and distinct. The surface of the shell is marked by strong, irregular growth lines, and the posterior half or two-thirds of the shell is marked by a strong, corrugated (rimose), subradial sculpture (Bogan and Parmalee, 1983). The outer covering of the shell (periostracum) is generally olivaceous green or dark green to black (in older specimens), with faint rays often present on younger individuals. Inside coloration of the shell (nacre) is always white and irridescent posteriorly. The species is sexually dimorphic (see photo), the females being smaller, more ovate, and usually inflated due to marsupial swelling along the posterior ventral margins (Ortmann, 1916).

The life history of *C. caelata* is presumed similar to that of most unionids and is briefly illustrated in Figure 5. Males produce sperm which are discharged into the surrounding water and dispersed by water currents. Any female *C. caelata* downstream from the 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 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. Ortmann (1916) collected gravid specimens of C. caelata in mid-September, implying that it was a bradytictic species. Further observations made during life history studies conducted by Charles Gooch (personal communication) in 1980 have confirmed that C. caelata hold their offspring over winter.

The glochidia of C. caelata are subovate, being higher than long and of the hookless type. The hookless type of glochidia has a more delicate shell, the valves of which are shaped like a 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).

Potential fish hosts for C. caelata are mentioned in an unpublished report by Yokley (1975) as Notropis galacturus, N. spilopterus, and N. sp. cf. spectrunculus. Further life history work on C. caelata by Charles Gooch (personal communication) during spring 1980 indicates that Etheostoma zonale successfully maintained C. caelata glochidia throughout the parasitic stage, suggesting that at least one darter species serves as fish host for this mussel species. Gooch was not able to repeat Yokley's results with the above-listed Notropis species.

REASONS FOR DECLINE AND CONTINUED THREATS

Although the literature indicates that historically *C. caelata* was widespread in the Tennessee River and some of its major tributary streams, it was rarely encountered and always in low numbers (Ortmann, 1918). *C. caelata* has become increasingly rare throughout its range. The reason for this decline is 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 River and its tributaries 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.

Stream impoundment affects species compositions by eliminating those species not capable of adapting to reduced flows and altered temperatures. Tributary dams typically have storage impoundments with hypolimnial discharges with 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.

The most immediate threat to this species is TVA's nearly completed Columbia Dam on the Duck River, which will eliminate the largest known population of this species. Although TVA has developed a program (known as the Cumberland Mollusk Conservation Program) to compensate for this imminent loss, future research will determine how successful the program will be.

Siltation

A second factor that has severely affected freshwater mussels especially Cumberlandian species is siltation. In rivers and streams the greatest diversity and number 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, relatively 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 Powell and Clinch River watersheds) 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). This will result in increased silt runoff and escalate impacts to the freshwater mussel fauna, especially streams such as the Powell and Clinch Rivers. Mussel populations in the upper reaches of the Powell River (including tributary streams such as the 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. 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 that 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. 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. Ortmann (1918) in his studies of the freshwater mussels of the upper Tennessee River 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 Folk 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 have been completed to correct this problem, which includes the digging of a trench around the settling lagoons, dredging the contaminated sediment from the river, and pouring concrete into cracks in the stream bedrock to prevent mercury leakage.

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 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 by TVA biologists in the North Fork near the Virginia-Tennessee State line 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 spiny river snail (_I. fluvialis_) transplanted from the Clinch River into 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 occurrred 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 the 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.

The Duck River and its major tributary, the Buffalo River, contained such a great concentration of freshwater mussels and snails that they were the most significant elements in the benthic fauna of those rivers (van der Schalie, 1973). Over the last 50 years, a rich molluscan fauna has been reported from the Duck River. At least 63 species, subspecies, and forms of freshwater mussels (Ortmann, 1924) and 9 species of river snails (Goodrich, 1940; 1941) once occurred in the Duck River. The freshwater mussel fauna was relatively diverse as recently as 1965, with 47 species reported by Isom and Yokley (1968). A mollusk survey conducted in 1972 by TVA and consultants (TVA, 1972) yielded only 30 species of freshwater mussels and 7 species of river snails. This decline was noted by van der Schalie (1973), who reported that "where once shoals were literally paved with mussels not even fragments of dead shells are now in evidence." Additional freshwater mussel surveys of the Duck River by TVA in 1976, 1978 (Ahlstedt, 1981b), and 1979 report an almost total elimination of the freshwater mussel fauna in the Duck River from Lillard's Mill Dam (DRM 179) upstream to Normandy Dam (DRM 248), a distance of almost 70 river miles. Isom and Yokley (1968) also indicated that the change in the fauna of the Duck River can be explained in terms of water use. Pollution below cities and industries has affected some areas. Phosphate ore mining is as extensive in the Duck River basin as it was in Ortmann's time. Ore washings have contributed to the siltation of habitat. The construction and operation of Normandy Dam and industrial and domestic pollution originating from the city of Shelbyville, Tennessee, have probably added to the decline of the mussel fauna in this reach of the Duck. As late as July 1979, gravel dredging was observed by TVA biologists in the Duck River, and an outfall below the city of Shelbyville was seen polluting the river with an oily, white substance.

The Buffalo River also had a tremendous freshwater mussel fauna similar to that which occurred in the Duck (Ortmann, 1924). More recent collections made by TVA biologists and consultants in 1972 reported an almost total elimination of the freshwater mussel fauna in the Buffalo. During a TVA float survey in 1980 covering 75 miles of the Buffalo only 21 live mussels representing seven species were found (TVA, 1980b). The perturbations that caused this faunal decline remains unknown.

PART II

RECOVERY

A. Recovery Objective

The ultimate objective of this recovery plan is to maintain and restore viable populations* of C. caelata 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 habitat containing C. caelata populations and (2) establishing populations in rivers and river corridors which historically contained C. caelata. 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 C. caelata exists in the Clinch River from the backwaters of Norris Reservoir upstream to approximately CRM 280 and in the Powell River from the backwaters of Norris Reservoir upstream to approximately PRM 130. 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 three additional rivers. Each of

*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.

these rivers will contain a viable population that is distributed such that a single event would be unlikely to eliminate C. caelata from the river system. (If the Duck River Columbia Dam project is not completed and a viable population of the species continues to exist in the Duck River, only two additional viable populations will be needed to meet this criterion.)

3. The species and its habitat are protected from present and foreseeable humanrelated 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 has occurred 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 C. caelata with emphasis on the Clinch 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 and ecological association and determine essential elements (biotic and abiotic factors) of its habitat 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 encourage their support in habitat protection measures.

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.

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 exits.

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 the species within its 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 C. caelata with emphasis on the Clinch and Powell Rivers. If the Columbia Dam project is completed on the Duck River, the greatest known population of *C. caelata* will be lost. In the event that TVA's Cumberlandian Mollusk Conservation Program is not successful (transplant failure), then the protection of the Clinch and Powell Rivers populations and their habitats are essential for the continued survival of the species. Preservation of these mussel populations including transplanted populations of *C. caelata* 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 the work has already been completed by TVA as part of the Cumberlandian Conservation Program (Jenkinson, 1981) and other TVA projects since 1970. However, additional freshwater mussel surveys are recommended for the upper Clinch River between Cleveland, Virginia (CRM 272), to below Craft Mill, Virginia (CRM 219.2), and the Elk River below Fayetteville, Tennessee, to determine if any additional populations of *C. caelata* are present. Only two freshly dead specimens were found in the Elk during freshwater mussel sampling by TVA biologists during 1980 (Ahlstedt, in press). Freshwater mussel surveys are also recommended for the Flint River, which historically contained _C. caelata_, and the Sequatchie and French Broad Rivers. _C. caelata_ has never been reported from the Sequatchie or the French Broad Rivers; however, both rivers have never been investigated intensively for freshwater mussels. Each river does contain mussel populations as observed by the author, and a single subfossil specimen of _C. caelata_ was found in the Nolichucky River (Stansbery, 1979), a tributary to the French Broad River.

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

1.2.2 Characterize the habitat and ecological association and determine essential elements (biotic and abiotic factors) of its habitat 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 the species' 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 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 in the Clinch. The present and anticipated impacts of this problem need to be assessed. 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 be having a substantial impact on the species. The effect 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 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 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, 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 <u>Meet with landowners adjacent to the species' population centers and inform them of the project and encourage their support in habitat protection measures</u>. 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 <u>Develop an educational program using such items as slide/tape shows and brochures. Present this material to business groups, civic groups, youth groups, civic groups, youth groups, church organizations</u>. 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 <u>Investigate the use of Scenic River Status, mussel sanctuaries, land acquisitions and/or other means or combinations to protect the species</u>. Both 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 the Tennessee portions of the Clinch and Powell Rivers as mussel sanctuaries, but the headwaters of each of these streams originates in southwestern Virginia, and no protection in the form of sanctuaries is offered these mussel populations. 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>. The protection and preservation of the Clinch and Powell River populations would be a significant step toward recovery. 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 Clinch and Powell Rivers. The factors that caused extinction or population reductions at potential transplant sites must be identified and 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 exist. 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 system 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 C. caelata. As part of that program, each of these sites was evaluated as potential transplant locations based on a correlation of stream characteristics with habitats of known populations of the species. 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 River. Additional transplant sites not studied by TVA's Cumberlandian Mollusk Conservation Program are recommended for study as potential transplant sites. Those sites recommended are: (1) Holston River below I-40 bridge near Knoxville, Tennessee; (2) French Broad River at Seven Island, Tennessee; (3) Sequatchie River below Mount Airy bridge, Tennessee; (4) Middle Fork Holston River near Chillhowee, Virginia; and (5) Elk River below Fayetteville, Tennessee (to replenish apparent existing C. caelata populations in the Elk).

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 Quadrula cylindrica. Another possible introduction method would be to release host fish infected with C. caelata 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 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) is also needed.

4. Determine the number of individuals required to maintain a viable population. Theoretical considerations by Franklin (1980) and Soulè (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. 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 Powell and tributary streams to include the North Fork Powell, Callahan Creek, and Pigeon Creek. This would help to control silt and coal fines from entering into the Powell River from coal preparation plants and silt from active and abandoned strip mines. Routine maintenance dredging would be recommended and spoil could be deposited away from the river or buried in landfills. Although these are temporary measures for controlling silt loads in siltprone areas such as the 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.

BIBLIOGRAPHY

Adams, C. C. 1915. The variations and ecological distribution of the snails of the genus Io. Mem. Nat. Acad. Sci. 12(2):1-184.

Ahlstedt, S. A. and S. R. Brown. 1980. The naiad fauna of the Powell River in Virginia and Tennessee (Bivalvia: Unionacea). IN: Bull. Amer. Malacol. Union 1979:40-43.

Ahlstedt, S. A. 1980. Recent mollusk transplants into the North Fork Holston River in southwestern Virginia. IN: Bull. Amer. Malacol. Union 1979:21-23.

Ahlstedt, S. A. 1981a. The molluscan fauna of Copper Creek (Clinch River system) in southwestern Virginia. IN: Bull. Amer. Malacol. Union 1980:4-6.

Ahlstedt, S. A. 1981b. The molluscan fauna of the Duck River between Normandy and Columbia Dams in central Tennessee. IN: Bull. Amer. Malacol. Union 1980.

Ahlstedt, S. A. 1983. The molluscan fauna of the Elk River in Tennessee and Alabama. American Malacological Bull. Vol. 1 (1983): 43-50.

Bates, J. M. 1962. The impact of impoundment on the mussel fauna of Kentucky Reservoir, Tennessee River. Am. Midl. Nat. 68(1): 232-236.

Bates, J. M. 1975. Overbank and tailwater studies. TVA contract TV-38606A, Final report.

Bates, J. M. and S. D. Dennis. 1978. The mussel fauna of the Clinch River, Tennessee and Virginia. Sterkiana 69-70:3-23.

Bogan, A. and P. Parmalee. 1983. Tennessee's Rare Mollusks, IN: Tennessee's Rare Wildlife, Final Report: TWRA, Tennessee Department of Conservation and Tennessee Heritage Prg. June 1979. Univ. of Tenn., Knoxville. 360 pp.

Cahn, A. R. 1936. The molluscan fauna of the Clinch River below Norris Dam upon completion of that structure. Unpublished TVA report, Norris, TN.

Cairns, J., Jr., and J. S. Crossman, K. L. Dickson, and E. E. Herricks. 1971. The recovery of damaged streams. ASB (Assoc. Southeast. Biol.) Bull., 18:79-106.

Call, E. R. 1885. Unionidae of the Mississippi Valley, Bull. Des Moines Acad. of Sci. 1(1):5-57.

Coker, R. E. and T. Surber. 1911. A note on the metamorphosis of the mussel (Lampsilis laevissimus). Biol. Bull. 20:179-182.

Conrad, T. A. 1834. Description of some new species of freshwater shells from Alabama, Tennessee, etc. Am. J. Sci. and Arts 25(2):338-343.

Dennis, S. D. 1981. Mussel fauna of the Powell River, Tennessee and Virginia. Sterkiana 71:1-7.

Ellis, M. M. 1931. Some factors affecting the replacement of the commercial freshwater mussels. U.S. Bur. Fish. Circ. 7:1-10.

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

Franklin, R. I. 1980. Evolutionary change in small populations. IN: Conservation biology: an evolutionary-ecological perspective. Michael E. Soule and Bruce A. Wilcox (ed). Published by Sinauer Assoc., Inc., Sunderland, MA. pp. 135-149.

Fuller, S. 1974. Clams and mussels (Mollusca: Bivalvia), pp. 215-273. IN: C. W. Hart and S.L.H. Fuller (eds.) Pollution ecology of freshwater invertebrates. Academic Press. New York. 389 pp.

Fuller, S. 1977. Freshwater and terrestrial mollusks. pp. 143-194. IN: J. E. Cooper, S. S. Robinson, and J. B. Funderburg (eds.) Endangered and threatened plants and animals of North Carolina. North Carolina State Museum of Natural History, Raleigh.

Goodrich, C. 1913. Spring collecting in southwest Virginia. Nautilus 27(7):81-85.

Goodrich, C. 1940. The Pleuroceridae of the Ohio River drainage system. Occ. Papers, Mus. of Zool., Univ. of Mich. No. 417:21 pp.

Goodrich, C. 1941. Studies of the gastropod family Pleuroceridae-VIII. Occ. Papers Mus. Zool., Univ. of Mich. No. 447:13 pp.

Grace, T. B. and A. C. Buchanan. 1981. Naiades of the lower Osage River, Tavern Creek, and Maries River, Missouri. U.S. Army Corps of Eng., Kansas City Dist., MO. 147 pp.

Hickman, M. E. 1937. A contribution to mollusca of east Tennessee. Unpublished master's thesis, Dept. of Zool., The Univ. of Tenn., Knoxville. 165 pp. 104 pl.

Hill, D. M., E. A. Taylor, and C. F. Saylor. 1974. Status of faunal recovery in the North Fork Holston River, Tennessee and Virginia. Proc. of the Twenty-eighth Annual Conference, Southeastern Assoc. of Game and Fish Comm., Nov. 17-20, 1974, White Sulfur Springs, WV. pp. 398-414.

Hynes, H.B.N. 1970. The ecology of running waters. Toronto: University of Toronto Press.

Hynes, H.B.N. 1974. The biology of polluted waters. Toronto: University of Toronto Press.

Ingram, W. M. 1956. The use and value of biological indicators of pollution: Fresh Water Clams and Snails. IN: Biological Problems in Water Pollution. C. M. Tarzwell (ed.), pp. 94-135. Robert A. Taft Sanitary Eng. Center, Cincinnati, OH.

Isom, B. G. and P. Yokley, Jr. 1968. The mussel fauna of Duck River in Tennessee, 1965. Am. Midl. Nat. 80(1):34-42.

Isom, B. G. 1969. The mussel resources of the Tennessee River, Malacologia 7(2-3):397-425.

Isom, B. G. 1971a. Mussel fauna found in Fort Loudoun Reservoir, Tennessee River, Knox County, Tennessee. Malacol. Rev. 4:127-130.

Isom, B. G. 1971b. Effects of storage and main streams reservoirs on benthic macroinvertebrates in the Tennessee Valley. Res. Fish. and Limn. Sp. Publ. No. 8, Am. Fish. Soc. pp. 179-191.

Isom, B. G. 1972. Mussels in the unique Nickajack Dam construction site, Tennessee, 1965. Malacol. Rev. 5:4-6.

Isom, B. G. and R. G. Hudson. 1982. In-vitro culture of parasitic freshwater mussel glochidia. Nautilus 96(4):147-151.

Isom, B. G., P. Yokley, Jr., and C. H. Gooch. 1973a. Mussels of the Elk River Basin in Alabama and Tennessee, 1965-1967. Am. Midl. Nat. 89(2):437-442.

Isom, B. G., P. Yokley, Jr., and C. H. Gooch. 1973b. The mussels of the Flint and Paint Rock River systems of the southwest slope of the Cumberland Plateau in North America, 1965-1967. Am. Midl. Nat. 89(2):442-446.

Jenkinson, J. J. 1981. The Tennessee Valley Authority Cumberlandian Mollusk Conservation Program. Bull. Amer. Malacol. Union 1980:62-63.

Lefevre, G. and W. C. Curtis. 1910. Experiments in the artificial propagation of freshwater mussels. Bull. U.S. Bur. Fish. 20:615-626.

Loar, J. M., L. L. Dye, R. R. Turner, and S. G. Hildebrand. 1980. Analysis fo environmental issues related to small scale hydroelectric development 1. Dredging. ORNL, Env. Science Div. Publ. No. 1565, Oak Ridge, TN. 134 pp.

Loosanoff, V. L. 1961. Effects of turbidity on some larval and adult bivalves. Gulf Caribb. Fish. Inst. Univ. Miami Proc. 14:80-95.

Marsh, P. 1885. List of shells collected in central Tennessee by A. A. Hinkley and P. Marsh with notes on species. Published by the author. Aledo, IL. 10 pp.

Minear, R. A. and B. A. Tschantz. 1976. The effect of coal surface mining on the water quality of mountain drainage basin systems. Jour. Wat. Poll. Control Fed. 48(11):2549-2569.

Morrison, J.P.E. 1942. Preliminary report on molluscan fauna found in the shell mounds of the Pickwick basin in the Tennessee River valley. IN: William S. Webb and David L. DeJarnette, an archaeological survey of Pickwick Basin in the adjacent portions of the States of Alabama, Mississippi, and Tennessee. Bur. Am. Ethnol. Bull. 129:337-392.

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

Neves, R. J., G. B. Pardue, E. F. Benfield, and S. D. Dennis. 1980. An evaluation of endangered mollusks in Virginia. Final Report. Vir. Comm. of Game and Inland Fisheries, Project No. E-F-1. Richmond, VA. 140 pp.

Neves, R. J. and A. Zale. 1982. Freshwater mussels (Unionidae) of Big Moccasin Creek, southwestern Virginia. Nautilus 96(2): 52-54.

Ortmann, A. E. 1911. Monograph of the naiades of Pennsylvania. Mem. Carnegie Mus. 4:279-347.

Ortmann, A. E. 1916. The anatomy of Lemiox rimosus (Raf.). Nautilus, 30(4):39-41.

Ortmann, A. E. 1918. The nayades (freshwater mussels) of the upper Tennessee drainage with notes on synonymy and distribution. Proc. Am. Philos. Soc. Phila. 57:521-626.

Ortmann, A. E. 1924. The naiad fauna of Duck River in Tennessee. Amer. Midl. Nat. 9(1)18-62.

Ortmann, A. E. 1925. The naiad fauna of the Tennessee River system below Walden Gorge. Am. Midl. Nat. 9(7):321-372.

Pardue, J. W. 1981. A survey of the mussels (Unionidae) of the upper Tennessee River - 1978. Sterkiana 71:41-51.

Parmalee P. W., W. E. Klippel, and A. E. Bogan. 1980. Notes on the prehistoric and present status of the naiad fauna of the middle Cumberland River, Smith County, Tennessee. Nautilus 94(3):93-105.

Rafinesque, C. S. 1931. Continuation of a monograph of the bivalve shells of the River Ohio and other rivers of the western states. Privately published, Philadelphia. 8 pp.

Raleigh, R. F., D. H. Bernett, and L. O. Mohn. 1978. Changes in fish stocks after major fish kills in the Clinch River near St. Paul, VA. Amer. Midl. Nat. 99:1-9.

Scruggs, G. D., Jr. 1960. Status of freshwater mussel stocks in the Tennessee River. U.S. Fish and Wildlife Service Special Report Fisheries No. 37:1-41.

Simpson, C. T. 1899. The pearly freshwater mussels of the United States; their habits, enemies, and diseases; with suggestions for their protection. Bull. U.S. Fish Comm. 18:279-288.

Soule, M. E. 1980. Thresholds for survival: Maintaining fitness and evolutionary potential. IN: Conservation biology an evoluntionary-ecological perspective. Michael E. Soule, and Bruce A. Wilcox (eds.). Published by Sinauer Assoc., Inc., Sunderland, MA. Chap. pp. 151-169.

Stansbery, D. H. 1964. The Mussel (Muscle) Shoals of the Tennessee River revisited. Am. Malacol. Union Ann. Rept. pp. 25-28.

Stansbery, D. H. 1965. Changes in naiad fauna of the Cumberland River at Cumberland Falls in eastern Kentucky. Am. Malacol. Union Ann. Rept. pp. 16-17.

Stansbery, D. H. 1972. The mollusk fauna of the North Fork Holston River at Saltville, Virginia. Am. Malacol. Union Bull. 1972:45-46.

Stansbery, D. H. 1973. A preliminary report on the naiad fauna of the Clinch River in the southern Appalachian mountains of Virginia and Tennessee (Mollusca: Bivalvia: Unionidae). Am. Malacol. Union Bull. 1972:20-22.

Stansbery, D. H. and W. J. Clench. 1974. The Pleuroceridae and Unionidae of the North Fork Holston River above Saltville, Virginia. Am. Malacol. Union Bull. 1973:33-36. 1 map, 1 table.

Stansbery, D. H. and W. J. Clench. 1975. The Pleuroceridae and Unionidae of the Middle Fork Holston Rver in Virginia. Am. Malacol. Union Bull. 1974:51-54. 1 map, 1 table.

Stansbery, D. H. and W. J. Clench. 1978. The Pleuroceridae and Unionidae of the Upper South Fork Holston River in Virginia. Am. Malacol. Union Bull. 1977:75-78.

Stansbery, D. H. 1979. The status of Lemiox rimosus (Rafinesque, 1831). Mollusca: Bivalvia: Unionidae. Ohio State Univ. Mus. of Zool., Report to Dept. of Int., Fish and Wildlife Serv., Bur. Sport Fish and Wildlife. 9 pp.

Starnes L. and A. Bogan. (in press). Unionid Mollusca (Bivalvia) from Little South Fork Cumberland River, with ecological and nomenclatorial notes. Brimleyana, N.C. State Mus. Nat. Hist. at Raleigh.

Stein, C. B. 1971. Naiad life cycles: Their significance in the conservation of the fauna. IN: Rare and endangered mollusks (Naiads) of the U.S., USDOI (Fish and Wildlife Service), Region 3, Federal Building, Fort Snelling, Twin Cities, MO. pp. 19-25.

Tennessee Valley Authority. Unpublished field records collected by Steven Ahlstedt (North Fork Holston River, Clinch River, Powell River), Office of Natural Resources, Eastern Area Field Operations Group, Norris, TN.

Tennessee Valley Authority. 1967. Fish kill in Clinch River below steam-electric power plant of App. Power Co., Carbo, VA. June 10-14, 1967. pp. 1-29.

Tennessee Valley Authority. 1968. Stream pollution resulting from mineral wastes originating at Saltville, Virginia, and appraisal by control possibilities. TVA, Knoxville, TN.

Tennessee Valley Authority. 1972. TVA unpublished data, Duck and Buffalo Rivers.

Tennessee Valley Authority. 1976. Mussel fauna of the Cumberland River in Tennessee. September 1976. TVA unpublished data. Division of Environmental Planning, Water Quality and Ecology Branch, Muscle Shoals, Alabama; and the Division of Forestry, Fisheries, and Wildlife Development, Norris, TN.

Tennessee Valley Authority. 1977. Freshwater mussels of the North Fork Holston River. TVA unpublished data. Office of Natural Resources, Eastern Area Field Operations Group, Norris, TN.

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

Tennessee Valley Authority. 1979a. An evaluation of mussel populations in the Clinch River, Tennessee and Virginia. August 1979. TVA unpublished data. Division of Wat. Res. Fish, and Aquatic Ecol. Branch, Norris, TN. 14 pp.

Tennessee Valley Authority. 1979b. An evaluation of mussel populations in the Duck River, Tennessee. May-June 1979. TVA unpublished data. Div. of Wat. Res., Fish and Aquatic Ecol. Branch, Norris, TN. 11 pp.

Tennessee Valley Authority. 1979c. An evaluation of mussel populations in the Powell River, Tennessee and Virginia. June 1979. TVA unpublished data. Division of Water Resources, Fisheries and Aquatic Ecology Branch, Norris, TN. 15 pp.

Tennessee Valley Authority. 1979d. A qualitative survey of fish and macroinvertebrates of the French Broad River and selected tributaries. June-August 1977. TVA unpublished data. Office of Natural Resources, Eastern Area Field Operations Group, Norris, TN.

Tennessee Valley Authority. 1980a. The fisheries resource of the Tennessee Valley Tailwaters - Tims Ford. TVA unpublished data. Division of Water Resources, Norris, TN. 17 pp.

Tennessee Valley Authority. 1980b. Freshwater mussels of the Buffalo River. TVA unpublished data. Office of Natural Resources, Eastern Area Field Operations Group, Norris, TN.

Tennessee Valley Authority. 1980c. Freshwater mussels of the Nolichucky River. TVA unpublished data. Office of Natural Resources, Eastern Area Field Operations Group, Norris, TN.

Tennessee Valley Authority. 1980d. Freshwater mussels of the Paint Rock River. TVA unpublished data. Office of Natural Resources, Eastern Area Field Operations Group, Norris, TN.

Tennessee Valley Authority. 1981. Freshwater mussels of the Holston River. TVA unpublished data. Office of Natural Resources, Eastern Area Field Operation Group, Norris, TN.

U.S. Department of the Interior. 1975. Endangered and threatened wildlife and plants. U.S. Fish and Wildlife Service. Federal Register 40(188):44329-44333.

U.S. Department of the Interior. 1976. Endangered and threatened wildlife and plants. U.S. Fish and Wildlife Service. Federal Register 41(115):24062-24067.

U.S. Department of the Interior. 1976. Proposed South Fork New River national wild and scenic river (North Carolina). U.S. Department of the Interior, Bur. of Outdoor Rec. March 1976. 541 pp.

University of Michigan, Museum of Zoology, Mollusk Division (Mussel records for Conradilla caelata). Ann Arbor.

van der Schalie, H. 1939. Additional notes on the naiades (freshwater mussels) of the lower Tennesssee River. Am. Midl. Nat. 22(2): 452-457.

van der Schalie, H. 1973. The mollusks of the Duck River drainage in central Tennessee. Sterkiana, No. 52:45-55 pp.

Williams, J. C. 1969. Mussel fishery investigation Tennessee, Ohio, and Green Rivers. Final report. Kentucky Dept. of Fish and Wildlife Res. Proj. Number 4-19-R. 107 pp.

Wilson, C. B. and H. W. Clark. 1914. The mussels of the Cumberland River and its tributaries. U.S. Bureau of Fisheries Document, No. 781:63 pp.

Wilson, C. B. and E. Danglade. 1914. The mussel fauna of central and northern Minnesota. Rep. U.S. Comm. Fish for 1913, Appendix V, pp. 1-29. Separately issued as Bur. Fish. Doc. No. 803.

Yokley, P., Jr. 1972. Freshwater mussel ecology, Kentucky Lake, Tennessee. Tennessee Game and Fish Comm. Proj. 4-42-R. 133 pp.

Yokley, P., Jr. 1975. (Unpublished TVA report.)

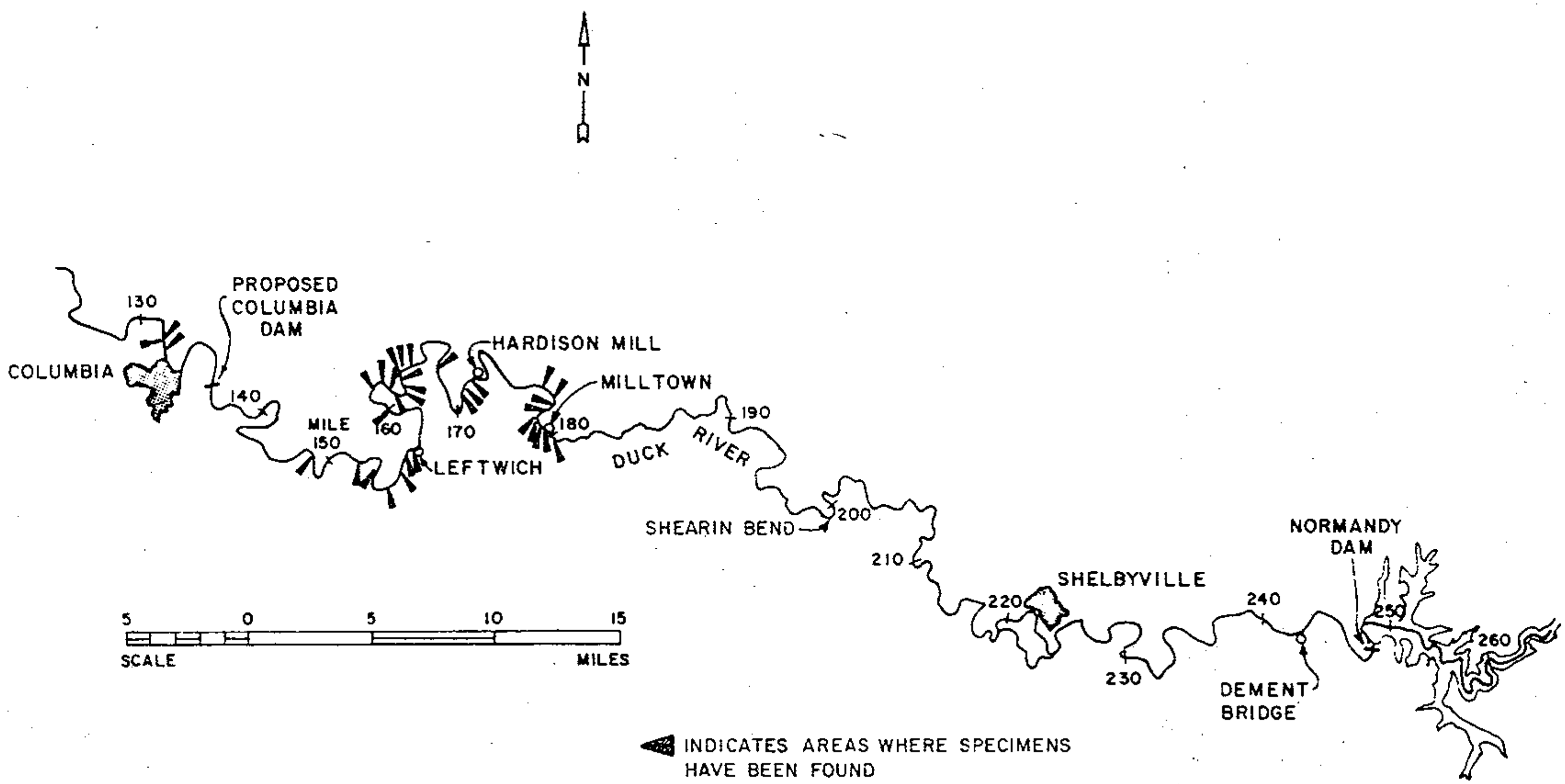

Figure 1: Duck River -Recent Locations for CONRADILLA CAELATA, (Conrad 1834)

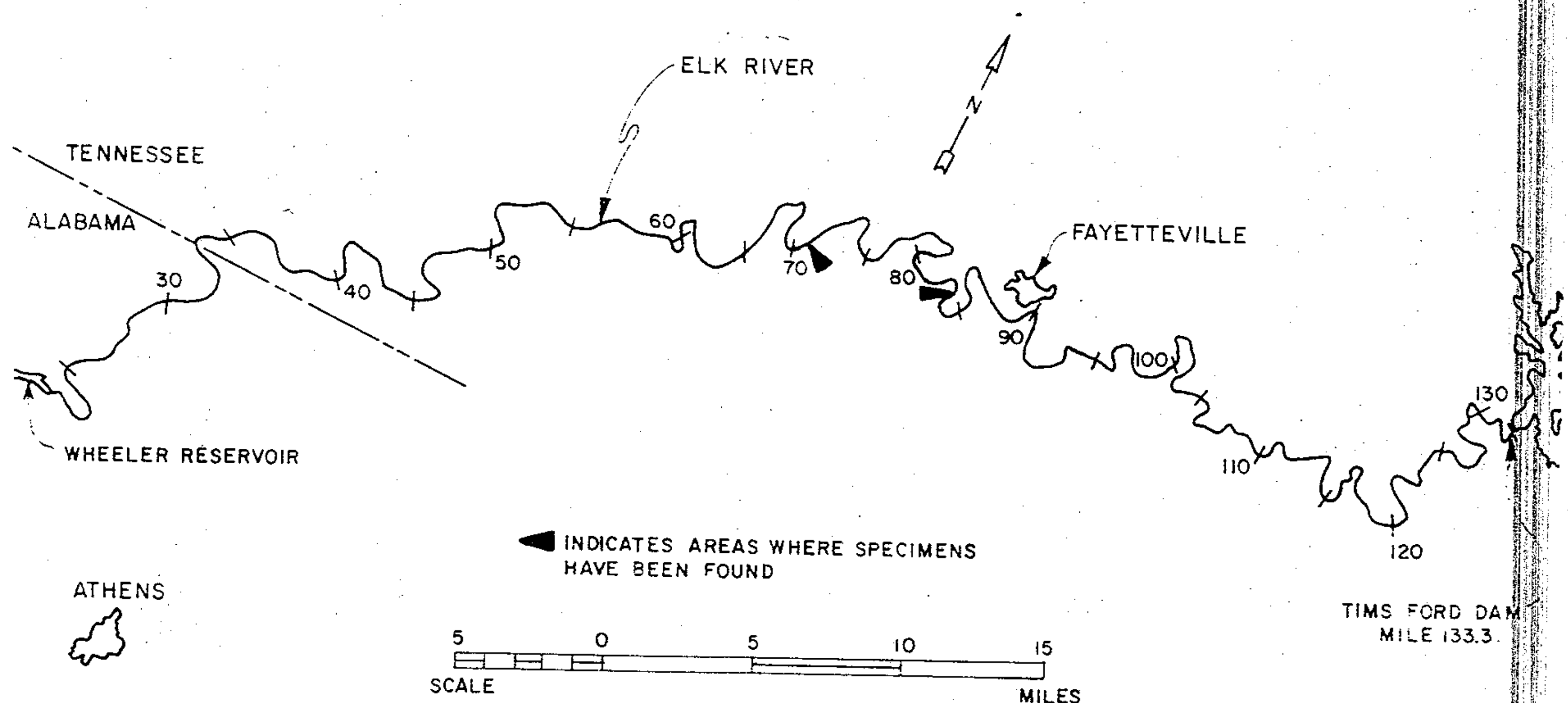

Figure 2: Elk River- Recent Locations for CONRADILLA CAELATA (Conrad 1834)

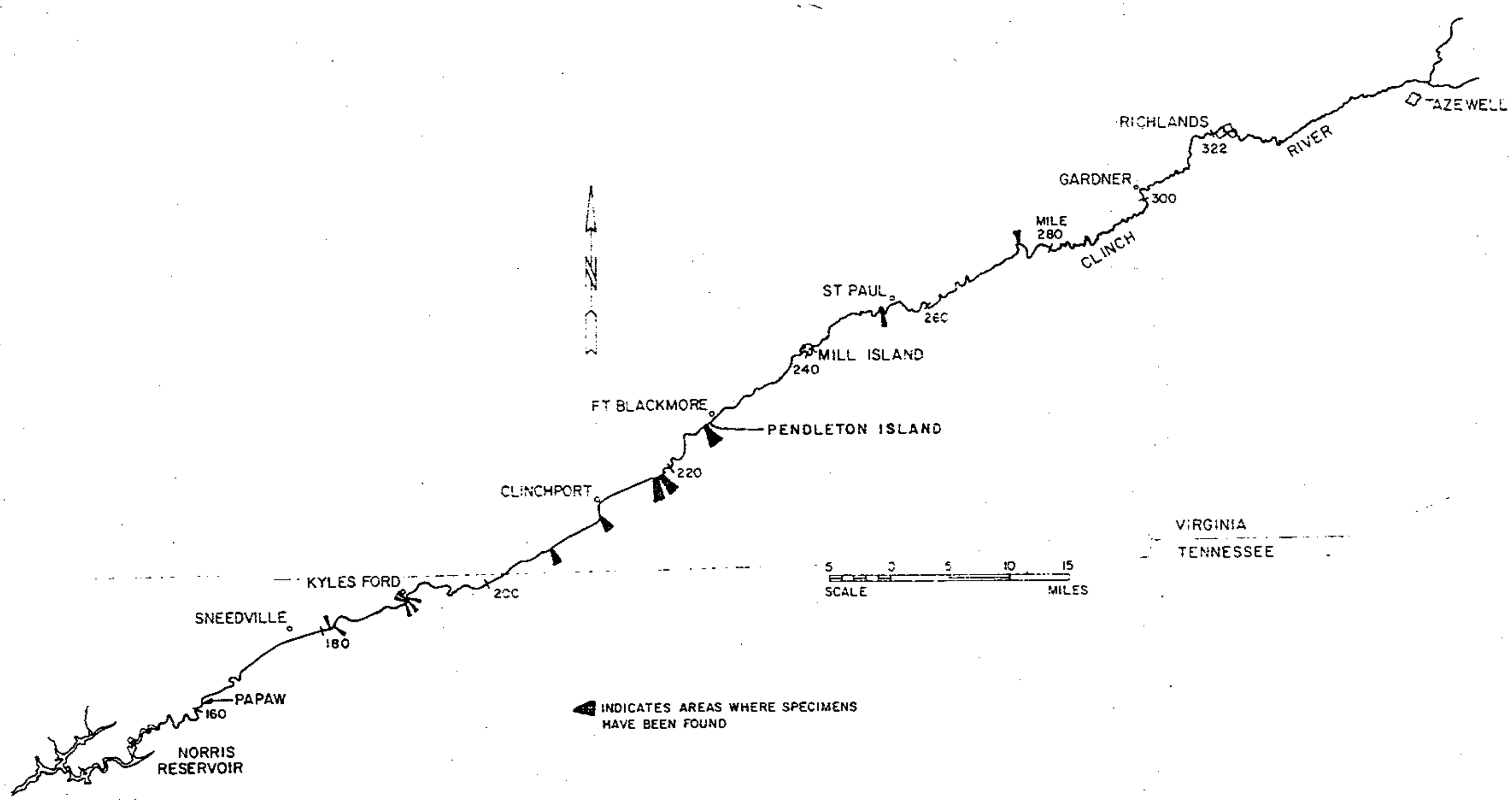

Figure 3: Clinch River - Recent Locations for CONRADILLA CAELATA, (Conrad 1834)

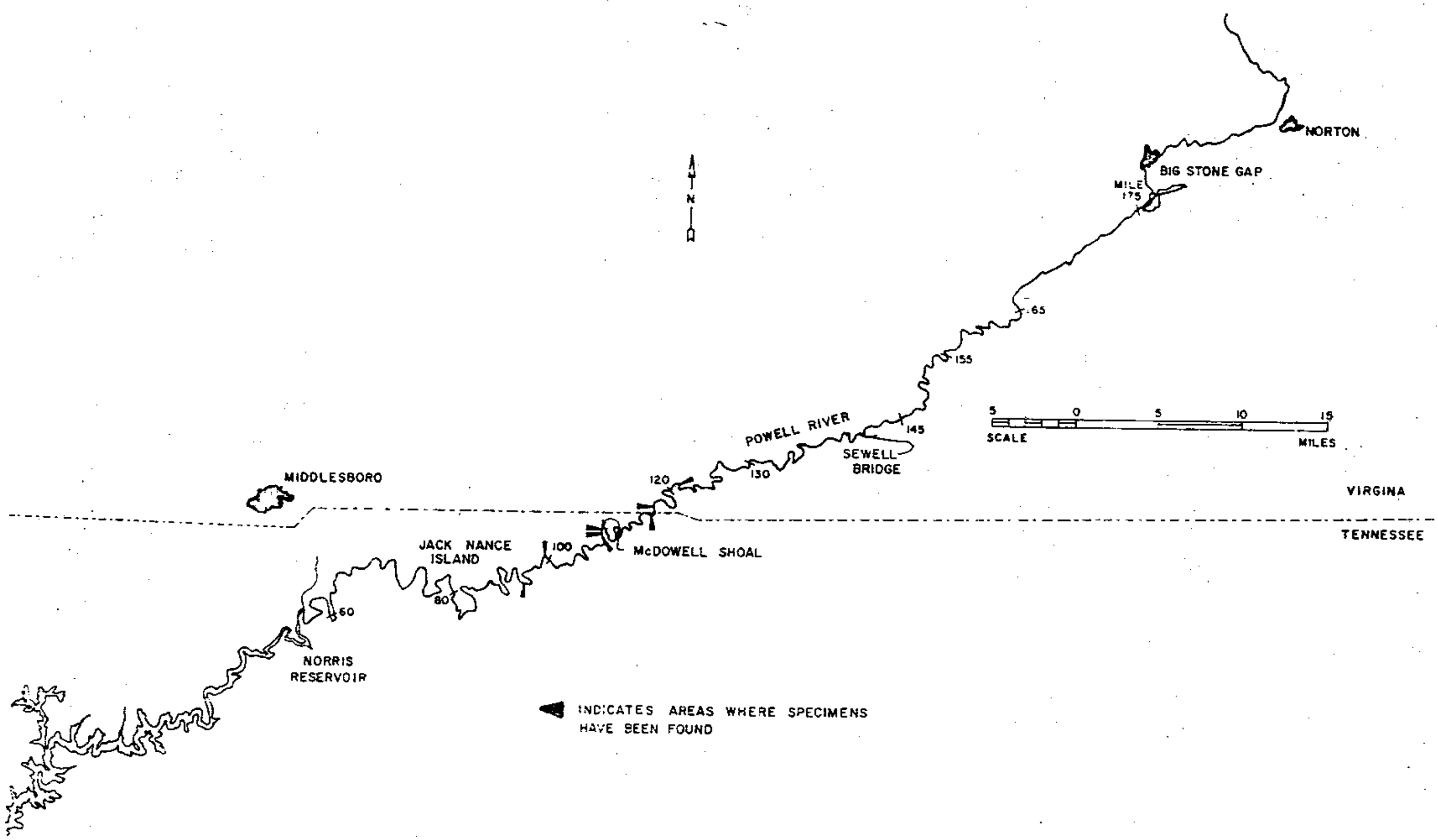

Figure 4: Powell River – Recent Locations for CONRADILLA CAELATA, (Conrad 1834)

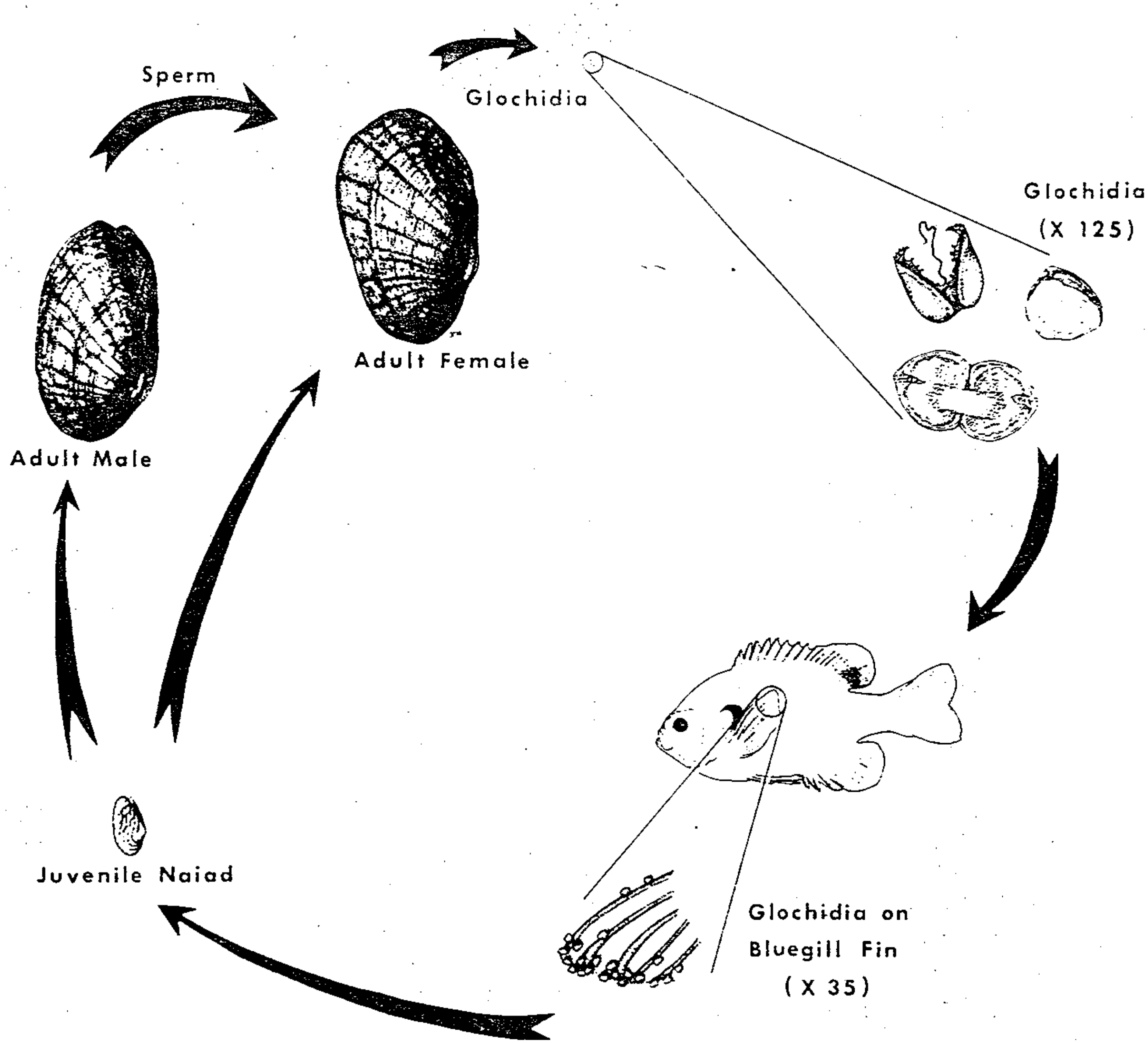

Figure **5.** Typical naiad life cycle depicting the various stages. The life cycle for most species of naiades is very similar to that depicted here (Grace and Buchanan 1981).


0 1
cm

Birdwing Pearly Mussel (*Conradilla caelata*)

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)	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	---	---	---	

Birdwing Pearly Mussel (*Conradilla caelata*)

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

Birdwing Pearly Mussel (Conradilla caelata)

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, Massachusetts 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. 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. 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. Carl 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 University
Box 5063
Cookeville, Tennessee 38501

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

Mr. Bob Hatcher, Nongame Biologist
Tennessee Wildlife Resources Agency
Ellington Agricultural 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

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

Mr. 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 Starnes
Tennessee Valley Authority
450 Evans Building
Knoxville, Tennessee 37902

Mr. 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

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

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. 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