RECOVERY PLAN

PALE LILLIPUT PEARLY MUSSEL

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Recovery Plan for the Pale Lilliput Pearly Mussel

Toxolasma (=Carunculina) cylindrellus (Lea, 1868)

Prepared by
Steven Ahlstedt

for

United States Fish and Wildlife Service
Endangered Species Field Office
100 Otis Street, Room 224
Asheville, North Carolina 28801

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Approved: Roman H Koenings
Acting Associate Director, U.S. Fish and Wildlife Service

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THIS IS THE COMPLETED PALE LILLIPUT 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 ROLE IN PREPARING THIS PLAN. THIS PLAN IS SUBJECT TO MODIFICATION AS DICTATED BY NEW FINDINGS, CHANGES IN SPECIES STATUS, AND COMPLETION OF TASKS DESCRIBED IN THE PLAN. GOALS AND OBJECTIVES WILL BE ATTAINED AND FUNDS EXPENDED CONTINGENT UPON APPROPRIATIONS, PRIORITIES, AND OTHER 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.

Literature citations should read as follows:

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PART I

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 mussels listed as endangered by the U.S. Department of the Interior, 13 are members of the Cumberlandian faunal group. The pale lilliput pearly mussel (*Toxolasma* (=*Carunculina*) *cylindrellus*) was proposed as an endangered species as (*Toxolasma* (=*Carunculina*) *cylindrella*) in September 1975 (*Federal Register* 40:44329-44333) and listed in June 1976 (*Federal Register* 41:24062-24067). This lack of agreement of gender between the masculine form *Toxolasma* and the feminine *cylindrella* was the result of an incorrect transfer of *cylindrella* from the feminine *Carunculina* without the necessary change in gender to the masculine form *cylindrellus*, which would then agree with the gender of *Toxolasma*. The Fish and Wildlife Service is taking steps to correct the spelling of the specific epithet in its listing of the species. Therefore, the correct spelling, *cylindrellus*, will be used throughout this plan.

This species was described by Lea in 1868 from "Duck Creek, Tennessee; Swamp Creek, Whitfield County, Georgia; and northern Alabama." A review of the literature indicates that *Toxolasma cylindrellus* is a small Cumberlandian species restricted to small tributary streams of the Tennessee River (Stansbery, 1976; Bogan and Parmalee, 1983). The only exception to its Cumberlandian distribution is a single record from "Swamp Creek, Whitfield County, Georgia," which is in the Mobile River system (Lea, 1868).

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. Additional freshwater mussel surveys by Marsh (1885), Hinkley (1906), Ortmann (1924, 1925), and van der Schalie (1939, 1973) also provide excellent distributional information on various stream mussel faunas at that time.

Toxolasma cylindrellus is a small stream species restricted to the Tennessee River system. Stansbery (1976) reports that it is a headwater species of the lower Tennessee system in south central Tennessee and northern Alabama. This species has not been found in the Tennessee River proper (Ortmann, 1925; van der Schalie, 1939) and is absent from the upper Tennessee River system (Ortmann, 1918). The Duck River population(s) marks the known downstream extent of this Cumberlandian form, which, incidentally, has yet to be found in the Cumberland River system (Stansbery, 1976; Bogan and Parmalee, 1983). The historical information concerning this rare species is generally lacking. However, its presence in streams as large as the Duck River at Columbia (Marsh, 1885) may have been marginal for this species (Stansbery, 1976). Marsh further notes that *T. cylindrellus* was "not abundant" at this site. Historical records for *T. cylindrellus* prior to 1970 are summarized in table 1.

Present

Toxolasma cylindrellus is presently known only from the Paint Rock River and its upper headwater tributary streams, which includes Hurricane Creek and Estill Fork (figure 1).

Table 1. Historical records for *Toxolasma cylindrellus* prior to 1970.

River	Source
Swamp Creek (Whitfield County, Georgia)	Lea (1868)
Paint Rock River	Stansbery (1976)
Hurricane Creek (tributary to Paint Rock)	Athearn (personal communication) - Collected specimens in 1966
Larkin Fork (tributary to Paint Rock)	Stansbery (1976, 1971) Athearn (personal communication) - Collected specimens in 1966
Flint River	Ortmann (1925)
Elk River	Ortmann (1925) Athearn (personal communication) - Collected specimens in 1954 and 1963
Duck River	Marsh (1885) Ortmann (1924, 1925) Athearn (personal communication) - Collected specimens in 1956 van der Schalie (1973) Stansbery (1976)
Buffalo River	Ortmann (1924) van der Schalie (1973)
Sequatchie River	Bogan and Parmalee (1983) - Specimens collected by Athearn in 1955
Little Sequatchie River	Bogan and Parmalee (1983) - Specimens collected by Athearn in 1955

Recent freshwater mussel surveys of the Paint Rock River including the lower reaches (3 miles) of Hurricane Creek by TVA biologists from May through November 1980 produced both live and freshly dead specimens of T. cylindrellus (TVA, 1980c). Two live specimens were found in the Paint Rock River just below the confluence of Hurricane Creek (PRRM 59.9), and some freshly dead specimens were found in Hurricane Creek. Six freshly dead specimens of T. cylindrellus were found in 1978 by TVA biologists Charles Gooch and Don Wade (personal communication) at Estill Fork near Freedom Bridge (EFM 1.1). Toxolasma cylindrellus is considered extremely rare in the Paint Rock River and is probably limited in distribution to only the upper headwaters of the Paint Rock including tributary streams.

Freshwater mussel surveys by numerous individuals have failed to find T. cylindrellus living in any streams other than the Paint Rock River, Hurricane Creek, and Estill Fork. 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 (1979a), and Pardue (1981) failed to find T. cylindrellus in the Tennessee River. This information further suggests that T. cylindrellus is a small stream species restricted to tributary streams of the lower Tennessee River. Freshwater mussel surveys of the Cumberland River by Wilson and Clark (1914), Ortmann (1925), Neel and Allen (1964), TVA (1976), Stansbery (1969), Parmalee et al. (1980), and Sickel (1982) found no evidence of T. cylindrellus in this river system.

Numerous recent freshwater mussel surveys of the upper reaches of tributary streams to the lower Tennessee River system have also failed to find living T. cylindrellus in the Duck River (Isom and Yokley, 1968a; TVA

1972, 1979b; Ahlstedt, 1981a); Elk River (Isom et al. 1973a; Ahlstedt, 1983); Flint River (Isom et al. 1973b); Bear Creek (Isom and Yokley, 1968b); and the Buffalo River (TVA, 1980b). Based on this information, it appears that the Paint Rock River and its upper headwater tributary streams contain the only known extant populations of T. cylindrellus.

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 sedentary, they are especially vulnerable to stream perturbations. Of particular concern are the Cumberlandian species, which appear to have suffered severe population declines.

Toxolasma cylindrellus (see photo) may be categorized as a riffle species because it is typically found in small rivers and streams in shallow, fast-flowing water with stable, clean substrate. This species is a relatively small Cumberlandian species, with a maximum size of 44 mm in length, 25 mm in height, and 16 mm in width (Stansbery, 1976). Valves are solid, elongate, and described by Lea (1869) as being "somewhat cylindrical." Valves are also subinflated with a full beak and no beak sculpturing. The posterior ridge is low, with the surface of the shell being smooth. The outer covering of the shell (periostracum) is clothlike with, yellowish-green coloration and no rays present.

The left valve has a narrow interdentum with two short lateral and pseudocardinal teeth. The right valve has both a single lateral and pseudocardinal tooth. The muscle scars are impressed with the beak cavities being shallow (Bogan and Parmalee, 1983). Nacre color remains white outside the pallial line, with the inside coloration varying from white to light yellow to coppery tints of blue and purple (Stansbery, 1976; Bogan and Parmalee, 1983). This species is sexually dimorphic with the females being only slightly distinct from the males by having a faint marsupial swelling near the posterior part of the base of the shell (Simpson, 1914).

The life history of T. cylindrellus is unknown (Heard and Guckert, 1970) but is probably similar to that of most unionids and is briefly illustrated in figure 1. Males produce sperm which are discharged into the surrounding water and dispersed by water currents. Females downstream from the males obtain these sperm during the normal process of siphoning water during feeding and respiration (Stein, 1971). Fertilization of the eggs 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 are 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. Heard and Guckert (1970) report this genus as bradytictic.

The glochidia of T. cylindrellus might be called bean-shaped and hookless. Hookless glochidia typically have a more spoon-shaped, delicate shell and are most frequently parasitic on the gill filaments of fish (Coker and Surber, 1911; Lefevre and Curtis, 1910). The fish host(s) for T. cylindrellus are unknown (Heard and Guckert, 1970). However, experimental life history studies by TVA biologists on another closely related species T. moesta (=lividus) report successfully transformed juveniles from infected sunfish, Lepomis cyanellus and Lepomis megalotis (Larry Neill, personal communication). To date, these specimens are 2 years of age and are still surviving.

REASONS FOR DECLINE

Historically, T. cylindrellus had a restricted distribution, found only in the headwaters of the lower Tennessee River system in south central Tennessee and northern Alabama (Stansbery, 1976). An additional population was also reported from Swamp Creek in northwestern Georgia (Lea, 1868). The scarcity of information concerning this rare species' former and present distribution has been recognized by Stansbery (1976). Stansbery (1976) reports there is little information to support what habitat changes may have occurred that resulted in the rarity of T. cylindrellus. However, freshwater mussels as a group have suffered extensively from industrial and agricultural development of the Tennessee Valley since the early 1900s. Three major factors are speculated by various authors to have had a significant impact upon the freshwater mussel fauna: impoundment, siltation, and pollution.

Impoundment

Possibly, the single greatest factor contributing to the decline of freshwater mussels, especially members of the Cumberlandian faunal group, is the alteration and destruction of stream habitat due to impoundment of the Tennessee and Cumberland Rivers including 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 51 impoundments throughout the Tennessee and Cumberland River systems. Stream impoundments affect species compositions by eliminating those species not capable of adapting to reduced flows, altered temperature regimes, and anoxic conditions. Tributary dams typically have hypolimnial discharges that cause the stream below the dam (reservoir tailwater) to differ significantly from preimpoundment conditions and from upstream river reaches. Hypolimnial discharge include: altered temperature regimes, extreme water level fluctuations, reduced turbidity, seasonal oxygen deficits, and high concentrations of certain heavy metals. Biological responses attributable to these type environmental changes typically include reductions in the 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 45 mussel species and 9 river snail species in the dewatered riverbed following closure of Norris Dam. In a return visit to the area 4 months later, he could not find a single live mussel.

Stansbery (1976) was concerned that the upper Duck River *T. cylindrellus* population was threatened by impoundment with the completion of Normandy Dam in 1976. Since that time, not a single specimen of *T. cylindrellus* has been found in the upper Duck River. Further, freshwater mussel surveys conducted in 1980 on the Elk River (Ahlstedt, 1983) have also failed to find *T. cylindrellus* since the completion of Wood's (1952) and Tim's Ford Dams (1970). The freshwater mussel fauna below Wood's Dam has been virtually eliminated, and no live freshwater mussels were found below Tim's Ford Dam for a distance of 8 miles.

Siltation

Siltation is another factor that has severely affected freshwater mussels, especially Cumberlandian species. In rivers and streams the greatest diversity and number of mussels are usually associated with rubble, gravel, and/or sand substrates. These substrates 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 are unable to survive in a layer of silt greater than 0.6 centimeter (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. Mussel life cycles can be affected indirectly by siltation by impacting host-fish populations by smothering fish eggs or larvae, reducing food availability, or filling of interstitial spaces in gravel and rubble substrate, thus eliminating spawning beds and habitat critical to the survival of young fishes (Loar et al. 1980).

Stansbery (1976) reported that *T. cylindrellus* populations in the Paint Rock River are threatened by stream channelization. Eager (1982) reported that the U.S. Army Corps of Engineers completed a snagging and clearing flood control project on the Paint Rock River in 1966. This project resulted in the removal of trees, log jams, sand, gravel bars, and debris from the river and stream banks.

Recent conversations with H. D. Athearn (personal communication) indicates the Sequatchie River *T. cylindrellus* population may have been eliminated by silt and coal fines originating from strip mines in the Sequatchie watershed. Specimens of *T. cylindrellus* were also found in the Little Sequatchie River by Athearn, both collected in 1955.

Pollution

A third factor that must be considered is the impact caused by various forms of pollutants. An increasing number of streams throughout the United States receive municipal, agricultural, and industrial waste discharges. The damage suffered varies according to a complex of inter-related factors, which include the characteristics of the receiving stream and the nature, magnitude, and frequency of the stresses being applied. The degradation can be so severe and of such duration that the streams are no longer considered valuable in terms of their biological resources

(Hill et al. 1974). These areas will not recover if there are residual effects from the pollutants, or if there is an inadequate pool of organisms for recruitment or recolonization (Cairns et al. 1971).

The absence of freshwater mussels can 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, some data are available concerning the adverse impacts of some pollutants on freshwater mussels along with other components of the ecosystem. Ortmann (1918) in his studies of the freshwater mussels in 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 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 (1968b). A mollusk survey conducted in 1972 by TVA and consultants (TVA, 1972) yielded only 30 species of freshwater mussels and seven 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 and 1978 (Ahlstedt, 1981a), and in 1979 (TVA, 1979b) 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 (1968a) 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 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 and possibly the elimination of T. cylindrellus. 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, including T. cylindrellus. 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 stress that caused this faunal decline remains unknown.

Populations of *T. cylindrellus* were reported from Larkin Fork, a tributary to the Paint Rock River, as late as 1966 (Stansbery, 1976). However, a spray rig for herbicides or pesticides was observed in Larkin Fork and Hurricane Creek in early summer 1980 (Don Wade, personal communication). Cotton and bean spraying is common throughout agricultural farmland in the Paint Rock River watershed, which also includes Larkin and Estill Forks and Hurricane Creek. *T. cylindrellus* was found freshly dead in the lower reaches of Hurricane Creek in 1980. This creek enters the Paint Rock River at PRRM 60. During the freshwater mussel survey conducted by TVA in 1980, two live specimens of *T. cylindrellus* were found in the Paint Rock River 0.1 mile below the mouth of Hurricane Creek. If farmers using herbicides or insecticides have been washing out their sprayings in these tributary streams, *T. cylindrellus* may have already been eliminated.

PART II

RECOVERY

A. Recovery Objective

The ultimate objective of this recovery plan is to maintain and restore viable populations* of T. cylindrellus 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 T. cylindrellus populations and (2) by establishing populations in rivers and river corridors that historically contained T. cylindrellus. 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 T. cylindrellus exists in the Paint Rock River, Estill Fork, and Hurricane Creek. These three 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 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 _T. cylindrellus_ from the river system.

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

4. Noticeable improvements are made in substrate quality with regard to siltation generated from agricultural land use practices in the Paint Rock River watershed.

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 _T. cylindrellus_ with emphasis on the Paint Rock River, Estill Fork, and Hurricane Creek.

   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 its host fish and strive to minimize and/or eliminate them.

1.3.1 Investigate and inventory factors negatively impacting the species and its environment.

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

1.3.3 Determine measures that are needed to minimize and/or eliminate 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 industry officials 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 an educational program using such items as slide/tape shows and brochures. Present this material to business groups, civic groups, Boy and Girl Scouts, 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, and/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 1.2.2 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 T. cylindrellus with emphasis on the Paint Rock River, Estill Fork, and Hurricane Creek. The greatest known concentrations of *T. cylindrellus* occur in the Paint Rock River, Estill Fork, and Hurricane Creek. The protection of these populations and their habitat is essential for the continued survival of the species. Preservation of these mussel populations and their habitats, including transplanted populations of *T. cylindrellus*, 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 encouraging States to enforce existing laws and regulations.

1.2 Conduct population and habitat surveys. Some of this work has already been completed by TVA as part of the Cumberland Mollusk Conservation Program (Jenkinson, 1981) and other TVA projects since 1970. A survey of the upper 40 miles of the Paint Rock River above Walker Mill Ford is needed to determine the extent of the population discovered by TVA biologists in 1980. Only two live specimens of *T. cylindrellus* were found. Intensive freshwater mussel surveys are recommended for Hurricane Creek and Estill Fork where freshly dead specimens were found in 1978 (TVA, 1980c). Additional freshwater mussel surveys are recommended for Larkin Fork (a headwater tributary to the Paint Rock River) where 26 freshly dead specimens of *T. cylindrellus* were collected from a muskrat midden in 1966 by Stansbery (1976). Freshwater mussel surveys are also recommended for Swamp Creek in Whitfield County, Georgia, and the Flint River in northern Alabama. Both of these streams historically contained *T. cylindrellus*. The Sequatchie and Little Sequatchie Rivers are also recommended for freshwater mussel surveys. Recent conversations with H. D. Athearn (personal communication) report *T. cylindrellus* collected in 1955 from each of these streams.

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 association, 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 1984. However, it will be necessary to have specific, 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 its host fish and strive to minimize and/or eliminate them. Many factors presently adversely affect the species, host fish, and its habitat. Additional 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 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. This could be accomplished with present State and Federal research facilities utilizing both field and laoratory research. Studying impacts on nonendangered mussels as experimental organisms is suggested.

1.3.2 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 survival and recovery of the species. Before delisting could be accomplished, anticipated negative impacts on the species must be addressed.

1.3.3 Determine measures that are needed to minimize and/or eliminate 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, 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.

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 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, Boy and Girl Scouts, church organizations, etc. 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. The Paint Rock River may be eligible for Scenic River Status under the National Wild and Scenic Rivers Act (USDOI, 1976). Further, the upper headwater tributary streams to the Paint Rock (Hurricane Creek, Larkin, and Estill Forks) may also qualify. Such a designation would provide some additional protection for the species and its habitat. The State of Alabama has designated portions of the Tennessee River as mussel sanctuaries, and the State of Tennessee has designated portions of the Tennessee, Cumberland, Clinch, and Powell Rivers as mussel sanctuaries. 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.

2. Determine the feasibility of introducing the species back into rivers within its historic range and introduce where feasible. The protection and preservation of the Paint Rock River, Estill Fork, and Hurricane Creek populations would be a significant step towards 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 Paint Rock, Estill Fork, and Hurricane Creek. Further, 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 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 another endangered freshwater mussel Conradilla caelata. Seven of the fifteen potential transplant sites studied, including the Duck, Elk, Paint Rock, and Buffalo Rivers, are within the known historic distribution for T. cylindrellus. As part of that program, each of the 15 sites was evaluated as potential transplant sites based on a correlation of stream characteristics with known populations of the species. Upon completion of all data analysis, four sites were chosen as transplant sites that received C. caelata during the fall of 1982. Two of these sites chosen (one in the upper Duck River and one in the Buffalo River) are within the known historic distribution for T. cylindrellus. Those same sites could also serve as potential transplant sites for T. cylindrellus. Further studies of additional streams are required for possible transplant sites. Those streams suggested for study include: (1) Swamp Creek, (2) Flint River, (3) Sequatchie River, and (4) Little Sequatchie River.

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 *T. cylindrellus* glochidia; and 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 for *T. cylindrellus*.

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 1.2.2 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.

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 theoretical 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 corresponding to this theoretical population size can be expected to be larger,

possibly by as much as 10 times. The factors that will influence the required 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.

5. Investigate the necessity for habitat improvement and, if feasible and desirable, identify techniques and sites for improvement to include implementation. A green belt corridor at least 40 feet wide is recommended between adjacent farmland and the edge of the streambank or riverbank. This would prevent farming up to the riverbank, construction activities, clearcutting, and other activities that cause erosion, bank slumping, and canopy removal. Other methods of habitat improvement should also be investigated.

6. Develop and implement a program to monitor population levels and habitat conditions of presently established populations as well as introduced and expanding populations. Once recovery actions are implemented, the response of the species 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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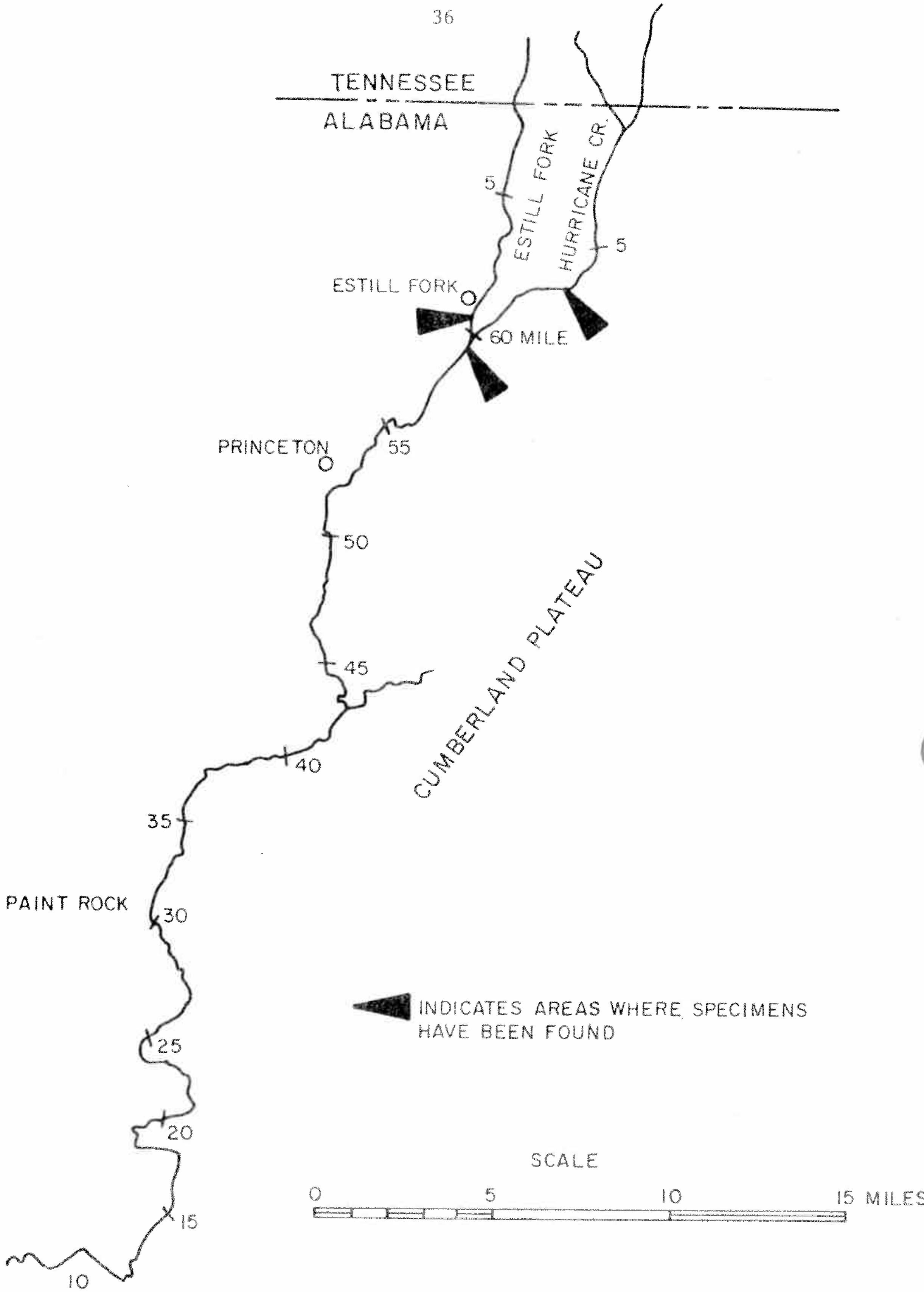

Figure 1: Paint Rock River, Estill Fork, and Hurricane Creek-Recent Locations for Toxolasma (=Carunculina) cylindrellus (Lea, 1868)

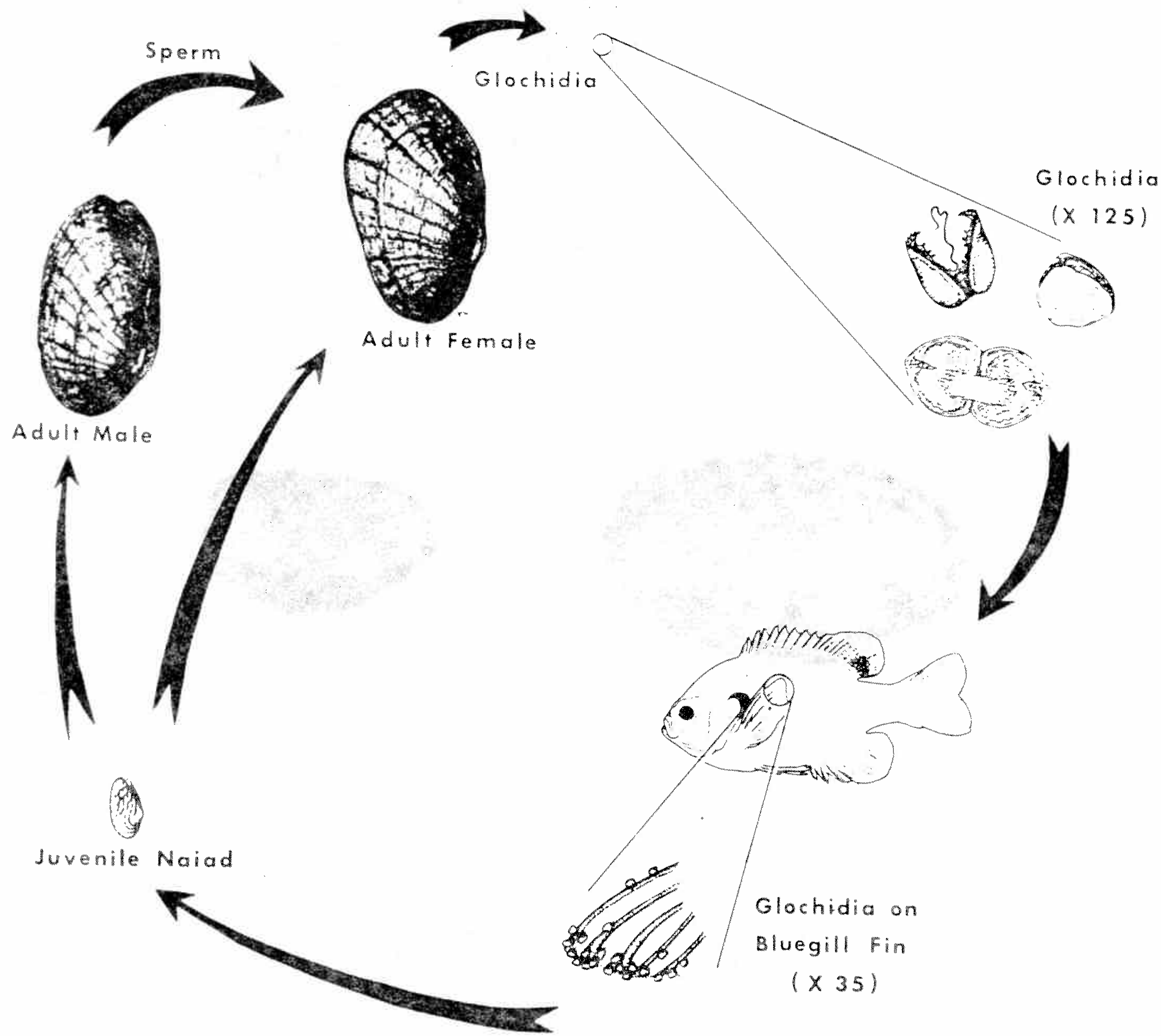

Figure 2. Typical naiad life cycle depicting the various stages. The life cycle for most species of naiades is very similar to that depicted here (Grace and Buchanan 1981).

KEY TO IMPLEMENTATION SCHEDULE COLUMNS 1 AND 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. Depradation 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.

Pale Lilliput Pearly Mussel
Toxolasma (=Carunculina) cylindrella

Part III Implementation Schedule

*1 General Category	Plan Task	Task Number	Priority	Task Duration	Responsible Agency FWS Region	FWS Program	*2 Other	Estimated Fiscal Year Costs FY 1	FY 2	FY 3	*3 Comments/Notes
01-04	Continue to utilize existing legislation and regulations to protect species and habitat.	1.1	1	Continuous	4	SE,ES,LE	Tennessee Valley Authority (TVA), Tennessee Wildlife Resources Agency (TWRA), Tennessee Heritage Program (THP), and Alabama Department of Conservation and Natural Resources (ADCNR)	---	---	---	*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' present/historic distribution coincides with that of other listed species. 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	SE	TVA, TWRA, THP, and ADCNR	---	---	---	
R3,R8 R9,R10 R11	Characterize habitat and determine essential elements.	1.2.2	2	2 yr.	4	SE	TVA, TWRA, THP, and ADCNR	---	---	---	
R3,O2, 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	SE	TVA, TWRA THP, and ADCNR	---	---	---	
I12,I14	Determine present and foreseeable threats to species.	1.3.1 & 1.3.2	1	3 yr.	4	SE&ES	TVA, TWRA, THP, and ADCNR	---	---	---	
M3,M7	Determine measures needed to minimize threats and implement where needed to meet recovery.	1.3.3	2	Unknown	4	SE&ES	TVA, TWRA, THP, ADCNR, and Tennessee and Alabama Nature Conservancy (TNC)	---	---	---	

Pale Lilliput Pearly Mussel
Toxolasma (=Carunculina) cylindrella

Part III Implementation Schedule

General Category	Plan Task	Task Number	Priority	Task Duration	Responsible Agency: FWS Region	FWS Program	Other	Estimated Fiscal Year Costs: FY 1	FY 2	FY 3	Comments/Notes
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	SE&ES	TVA, TWRA, THP, ADCNR, and TNC	---	---	---	
01	Develop and utilize information and education program (slide/tape shows, brochures, etc.) for local distribution.	1.4.5	2	1 yr. for developing continued implementation	4	SE&ES	TVA, TWRA, THP, ADCNR, and TNC	---	---	---	
M7,A1-A7,03, 04	Investigate the use of Scenic River Status, mussel sanctuaries, land acquisitions, and/or other means to protect the species.	1.5	2	Unknown	4	SE&ES	TVA, TWRA, THP, ADCNR, and TNC	---	---	---	
I13	Survey rivers within species' historic range to determine availability of suitable transplant sites.	2.1 & 2.2	3	1 yr.	4	SE	TVA, TWRA, THP, and ADCNR	---	---	---	Task 2.1-2.3 may not be required if other populations are found in task 1.2.1.
R13,R7	Determine best method of establishing new populations.	2.3	3	2 yr.	4	SE	TVA, TWRA, THP, and ADCNR	---	---	---	
M2	Reestablish populations within historic range as needed to meet recovery.	2.4	3	Unknown	4	SE	TVA, TWRA, THP, and ADCNR	---	---	---	

Part III Implementation Schedule

General Category	Plan Task	Task Number	Priority	Task Duration	Responsible Agency: FWS Region	Responsible Agency: FWS Program	Responsible Agency: Other	Estimated Fiscal Year Costs: FY 1	FY 2	FY 3	Comments/Notes
I12,I14 M3,M7	Implement same protective measures for these reestablished populations as for known populations.	2.5	3	Continuous	4	SE,ES	TVA, TWRA, THP, ADCNR, and TNC	---	---	---	
R3,R6, R8,R9-R11, R14	Conduct life history studies on a need-to-know basis.	3.	2	Unknown	4	SE	TVA, TWRA, THP, and ADCNR	---	---	---	
R8-R11	Determine the number of individuals required to maintain a viable population.	4.	3	Unknown	4	SE	TVA, TWRA, THP, and ADCNR	---	---	---	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.	2	Unknown	4	SE	TVA, TWRA, THP, and ADCNR	---	---	---	
I1,I2	Develop and implement a monitoring program.	6.	2	Unknown	4	SE	TVA, TWRA, THP, and ADCNR	---	---	---	
O4	Annual assessment of recovery program and modify where needed.	7.	2	Continuous	4	SE	TVA, TWRA, THP, ADCNR, and TNC	---	---	---	

APPENDIX

LIST OF REVIEWERS FOR THE PALE LILLIPUT PEARLY MUSSEL RECOVERY PLAN TECHNICAL/AGENCY DRAFT

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

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

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

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

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

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

Mr. Martin E. Rivers, Director
Environmental Quality Staff
Tennessee Valley Authority
Room 201, Summer Place Building
Knoxville, Tennessee 37902

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

Dr. and Mrs. Wayne C. Starnes
450 Evans Building
Knoxville, Tennessee 37902

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

Dr. Arthur E. Bogan
Department of Malacology
Academy of Natural Sciences
19th 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

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

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

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

Field Supervisor
FWS, Ecological Services
Cookeville, Tennessee

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

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

Mr. Carl E. Kays, Commissioner
Kentucky Department of Fish and
Wildlife Resources
Arnold L. Mitchell Building
#1 Game Farm Road
Frankfort, Kentucky 40601

Dr. William Bryant
The Nature Conservancy
71 Dudley Road
Edgewood, Kentucky 41017

Regional Director
U.S. Fish and Wildlife Service
Federal Buliding, Fort Snelling
Twin Cities, Minnesota 55111

Field Supervisor
FWS, Endangered Species
Jackson, Mississippi

Dr. John S. Ramsey
Alabama Cooperative Fishery
Research Unit
Fisheries Building
Auburn University
Auburn, Alabama 36849

Mr. Charles D. Kelley, Director
Division of Game and Fish
Department of Conservation and
Natural Resources
64 North Union Street
Montgomery, Alabama 36130

Mr. James W. Warr, Director
Water Improvement Commission
State Office Building
Montgomery, Alabama 36130