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Recovery Plan

Orange-footed Pearly Mussel (*Plethobasus cooperianus*)

Recovery Plan for the Orange-footed Pearly Mussel

Plethobasus cooperianus (Lea, 1834)

Prepared by

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for

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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.

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PART I

INTRODUCTION

Freshwater mussels (naiades) are known to occur in every temperate and tropical climate. Approximately one-half of the extant species of freshwater mussels occur in North America. Eastern North America had, and still contains, the richest freshwater molluscan fauna known in the world. Stansbery (1970) reports this fauna numbers over a thousand species of bivalves and gastropods combined.

The richest freshwater mussel fauna known occurs in the Tennessee River (90 species), followed by the Cumberland (78 species), and Ohio River systems (72 species). These three assemblages contain the largest number of unionid species found in any of the world's rivers (Johnson, 1980).

Twenty-three American freshwater mussels are listed as endangered by the U.S. Department of the Interior. Almost all species listed were known from the Tennessee, Cumberland, and Ohio River systems. The orange-footed pearly mussel (Plethobasus cooperianus) was proposed as an endangered species in September 1975 (Federal Register 40(188):44329-44333) and listed in June 1976 (Federal Register 41(115):24062-24067).

DISTRIBUTION

Historical

Plethobasus cooperianus was described by Lea in 1834. The type locality is the Ohio River. Historical records for P. cooperianus indicate this species is strictly an Ohioan or Interior Basin species (Ohio, Cumberland, and Tennessee River drainage) (Ortmann, 1919). Bogan and Parmalee (1983) reported that P. cooperianus was erroneously reported from the

Mississippi River at Muscatine, Iowa, by Call (1885) and Simpson (1914). Utterback (1915) also reported P. cooperianus from Missouri but noted that the specimens he observed had a close resemblance to Cyclonias tuberculata, varying only in nacre coloration. Haas (1969) later reported these specimens as C. tuberculata, not P. cooperianus.

Plethobasus cooperianus apparently was quite common in the Ohio River between St. Mary's and Marietta (Ortmann, 1919). Call (1900) reported this species to be common in the Wabash River, and Wilson and Clark (1914) reported P. cooperianus second in abundance from a commercial mussel camp located on the Cumberland River. A subsequent survey of the Cumberland River by Neel and Allen (1964) reported P. cooperianus as rare. Sickel (1982) in his survey of the lower Cumberland River reported finding only relict valves of P. cooperianus. Further, Ortmann (1918) reported P. cooperianus to be a rare species in the Tennessee River and tributaries above Knoxville. Historical records for P. cooperianus prior to 1970 are summarized in table 1.

Present

Plethobasus cooperianus is presently known only from the Tennessee, Cumberland, and lower Ohio Rivers (figure 1). Leroy Koch (personal communication) collected and had verified by David Stansbery 148 freshly dead specimens of P. cooperianus between 1979 and 1982 from a shell buyer's cookout camp located along the Tennessee River below Pickwick Dam (TRM 206.7). Of these, 15 specimens were from 3 to 7 years old, indicating a reproducing population of P. cooperianus in this reach of the Tennessee River. Bogan and Parmalee (1983) also reported collecting two juvenile P. cooperianus in November 1980 from a muskrat midden along the Tennessee River in Hardin County, Tennessee.

Table 1. Historical records for P. cooperianus prior to 1970.

River	Source
Ohio River	Lea (1834) Call (1895) Rhoads (1899) Ortmann (1909, 1912, 1919) Simpson (1914) Goodrich and van der Schalie (1944) Stansbery (1962)
Kanawha River, West Virginia	Stansbery (1972) archaeological specimens
Wabash River	Call (1896, 1897, 1900) Goodrich and van der Schalie (1944)
Rough River, Kentucky	Clench and van der Schalie (1944)
Tennessee River	Call (1885) Ortmann (1918, 1919, 1925) Simpson (1914) van der Schalie (1939) Scruggs (1960) Isom (1969) Stansbery (1964, 1970) Warren (1975)
Duck River	Isom and Yokley (1968)
French Broad River	Ortmann (1918, 1919)
Holston River	Lewis (1871)
Clinch River	Pilsbry and Rhoads (1897) Ortmann (1918, 1919)
Cumberland River	Marsh (1885) Wilson and Clark (1914) Simpson (1914) Ortmann (1919) Neel and Allen (1964)

The portion of the Tennessee River below Pickwick Dam (TRM 206.7) downstream to TRM 160.0 is also in Hardin County, Tennessee. Additional freshwater mussel sampling in the Tennessee River by TVA biologists revealed live specimens of P. cooperianus at seven sampling sites on the Tennessee River. Live specimens were reported by TVA in 1978 (1979c) at the following locations: (1) one live specimen below Guntersville Dam (TRM 345.8), (2) one live specimen below Pickwick Dam (TRM 205.2), (3) one live specimen at Diamond Island (TRM 197), (4) one live specimen at Edmonds Branch (TRM 183), (5) four live specimens at Dickey Towhead (TRM 170.4), and (6) one live specimen at Jeter Towhead (TRM 153.5). Pardue (1981) reports one live specimen found below Fort Loudoun Dam (TRM 595.0), and Yokley (1972) collected two live specimens of P. cooperianus from below Pickwick Dam (TRM 200.0-205.2). These are the only known recent records for P. cooperianus from the Tennessee River system.

Plethobasus cooperianus has also been reported from the middle reaches of the Cumberland River (now Old Hickory Reservoir) in Smith County, Tennessee. Three live, old specimens (>20 years) were observed in the Cumberland River from Bartlett's Bar (CRM 296.8) in September 1979 (Parmalee et al. 1980). A fresh half valve of P. cooperianus was also observed in a cull pile near Rome Landing, Tennessee (CRM 292.2), in June 1979. These records represent the only recent records of living P. cooperianus from the Cumberland River since Neel and Allen (1964).

Freshwater mussel collections in the lower Ohio River in August 1982 revealed specimens of P. cooperianus at mile 944 near Metropolis, Illinois (Glenn Fallo, personal communication and Kentucky Nature Preserves Commission record). One live specimen of P. cooperianus was also collected in July 1982 between Ohio River miles 966.4 and 969.3 (John Williams, personal communication), and one freshly dead specimen of P. cooperianus was found in

September 1981 approximately 2 miles below Ohio River Lock and Dam No. 53 (Sam Call, personal communication). Call reports his specimen being harvested by commercial mussel fishermen working that stretch of the lower Ohio River. Three live specimens of P. cooperianus were also observed in June 1980 by TVA biologist Leroy Koch (personal communication) from a commercial mussel fisherman's boat on the lower Ohio River, McCracken County, Kentucky, below Lock and Dam No. 52 (ORM 940). These records are the only recent records known for P. cooperianus from the Ohio River.

Plethobasus cooperianus is considered extremely rare in the Tennessee, Cumberland, and Ohio Rivers. The largest concentrations probably occur in the Tennessee River for an undetermined number of miles below Pickwick Dam (TRM 206.2).

Freshwater mussel surveys by numerous individuals have failed to find P. cooperianus living in any streams other than the Tennessee, Cumberland, and lower Ohio Rivers. Surveys conducted on the Tennessee River by Ellis (1931), Bates (1962, 1975), Williams (1969), and Isom (1971a, 1972) failed to document P. cooperianus living in the Tennessee River at the time of these surveys. Freshwater mussel sampling in some of the larger tributary streams to the Tennessee including the lower Clinch River by Cahn (1936), Hickman (1937) and TVA (1982); French Broad River (TVA, 1979b); Holston River (TVA, 1981); Nolichucky River (TVA, 1980); Elk River (Isom et al. 1973; Ahlstedt, 1983); and the Duck River (Isom and Yokley, 1968; van der Schalie, 1973; TVA, 1972, 1979a; Ahlstedt, 1981) all failed to find any evidence of P. cooperianus. Specimens previously reported as P. cooperianus from the Duck River by Isom and Yokley (1968) were reidentified as Quadrula pustulosa by David Stansbery.

Freshwater mussel surveys of the Cumberland River by Stansbery (1969), TVA (1976), and Sickel (1982) report finding no live specimens of

P. cooperianus. Only relict valves of P. cooperianus were reported by Sickel. Freshwater mussel sampling in the Ohio River by Williams (1969), Taylor (1980), Clarke (1981), Taylor and Spurlock (1982), and tributary streams including the Green River (Clench and van der Schalie, 1944; Stansbery, 1965; Isom, 1974; Clarke, 1981); Wabash River (Parmalee, 1967; Krumholz et al. 1970; Meyer, 1974; Clark, 1976); Illinois River (Parmalee, 1967; Starrett, 1971); and the Kanawha River by Clarke (1982) all report no P. cooperianus.

ECOLOGY AND LIFE HISTORY

Freshwater mussels (naiades) are benthic animals that typically remain buried in the substrate with only the most posterior margin of the shell and siphons exposed to the water. Freshwater mussels are found in a variety of habitats ranging from mud and sand between bedrock ledges and boulders, to rubble and gravel substrates. The majority of freshwater mussel species are typically found in riverine conditions in relatively firm rubble, gravel, and sand substrates swept free from siltation. These mussels are usually found buried in the substrate in shallow riffles and shoal areas.

P. cooperianus (see photograph) is an Ohioan or Interior Basin species found in medium to large rivers in sand and gravel substrates. Yokley (1972) reports P. cooperianus from clean gravel, free of silt, in the Tennessee River; and John Williams (personal communication) has collected this species in sand and gravel habitats in the lower Ohio River in approximately 15 to 29 feet of water. Ortmann (1919) also reported P. cooperianus typically found in deep water. However, Bogan and Parmalee (1983) state that P. cooperianus apparently lived in the shallower riffle and shoal sections of the main Tennessee, Cumberland, and Ohio Rivers in sand and gravel substrate.

Plethobasus cooperianus attains a size up to about 95 mm long, 78 mm high, and 46 mm wide (Ortmann, 1919). The shell is large and heavy and nearly circular or subround in outline. Valves are solid and moderately swollen. Beaks are high and inclined somewhat forward with little or no sculpturing. The posterior ridge is low and rounded with younger specimens, sometimes with an indication of a wing. The surface of the shell is marked by dark, concentric, irregular growth rests; and the posterior two-thirds of the shell is covered with numerous raised tubercles variable in size, shape, and arrangement. Tubercles may be rather crowded and numerous, or scarce, often disappearing entirely toward the lower margin of the shell. The epidermis or periostracum is yellowish brown to rusty or chestnut-brown, becoming rather dark in older specimens. Faint, greenish rays are found only in younger specimens.

Hinge-teeth are well developed, with the left valve having two divergent, ragged teeth. Interdentum is wide and lateral teeth are moderately long. The right valve has a large triangular pseudocardinal tooth and a short lateral tooth. Beak cavity is deep, compressed, with dorsal muscle scars on the hinge-plate. Nacre color varies from white to pink inside the pallial line, being more intense toward the hinge-teeth (Simpson, 1914; Ortmann, 1919; Parmalee, 1967; Bogan and Parmalee, 1983).

The life history for P. cooperianus is unknown but probably similar to that of most naiades and is briefly illustrated in figure 2. Males produce sperm which is 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 while feeding and during respiration. 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 (marsupia)

for larval development to mature glochidia. An interesting characteristic of P. cooperianus is that it has orange or pinkish soft parts as observed by Ortmann (1912, 1919).

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. Wilson and Clark (1914) collected two gravid female P. cooperianus in early June. Utterback (1915) reports P. cooperianus to be a summer breeder and Yokley (1972) observed one specimen with gills charged in August. Based on these observations P. cooperianus is probably a tachytictic species.

The glochidia of P. cooperianus has not been described but the sexual glands and soft parts are usually pinkish in color and also grayish or brown. It is probable that the eggs (glochidia) are also pink, rather small, semioval, and hookless similar to those in a closely related species P. cyphyus (Ortmann 1912, 1919). Hookless glochidia are most frequently parasitic on the gill filaments of fish (Coker and Surber, 1911; Lefevre and Curtis, 1910).

Potential fish host(s) for P. cooperianus are unknown but the sauger (Stizostedion canadense) is reported by Surber (1913) and Wilson (1916) to be the fish host for P. cyphyus. No other life history information is known for P. cooperianus.

REASONS FOR DECLINE AND CONTINUED THREATS

Plethobasus cooperianus had a relatively restricted distribution being reported from the Tennessee, Cumberland, and Ohio Rivers and their

larger tributary streams. This species has become increasingly rare throughout its range. The reasons for its decline is not totally understood, but due to the longevity of most mussel species--up to 50 years--and their sedentary nature, they are especially vulnerable to stream perturbations such as impoundments, siltation, and pollution.

Impoundment

Possibly, the single greatest factor contributing to the decline of freshwater mussels, not only in the Tennessee Valley but other regions as well, is the alteration and destruction of stream habitat due to impoundments 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 U.S. Army Corps of Engineers have constructed 51 impoundments throughout the Tennessee and Cumberland River systems alone. 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 discharges 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 enviromental 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. Ortmann (1925) in his study of the mussels of the Tennessee River below Walden Gorge witnessed the destruction of the most famous and unique freshwater mussel fauna at Muscle Shoals, destroyed by completion of Wilson Dam. Further, Isom (1971a) reported only four species of freshwater mussels from Fort Loudoun Reservoir on the Tennessee River where Ortmann (1918) had previously reported 64 species prior to impoundment.

Siltation

Siltation is another factor that has severely affected freshwater mussels. In rivers and streams the greatest diversity and number of mussels are usually associated with 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, coalwashing, 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

long-lived and sedentary by nature. Many species have been unable to survive in a layer of silt greater than 0.6 cm (Ellis, 1936). Since most freshwater mussels are typically 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. Erosion silt is a common element of the impounded Tennessee River (Scruggs, 1960; Bates, 1962; Williams 1969). Following heavy rains, tributary streams of the Tennessee River become quite turbid and much of this turbidity is a result of runoff from surrounding agricultural land. 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).

Pollution

A third factor which 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 interrelated 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).

PART II

RECOVERY

A. Recovery Objectives

The ultimate objective of this recovery plan is to maintain and restore viable populations* of P. cooperianus to a significant portion of its historic range and remove the species from the Federal list of endangered and threatened species. This can be accomplished by (1) protecting and enhancing habitats containing P. cooperianus and (2) by establishing populations in rivers and river corridors which historically contained P. cooperianus. 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 P. cooperianus exists in the Tennessee, Cumberland, and Ohio Rivers. 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 by discoveries of new populations, viable populations exist in two additional rivers. Each of these rivers will contain a viable population that is distributed such that a single event would be unlikely to eliminate P. cooperianus from the river system. For reestablished populations, surveys

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

must show that three year-classes including one year-class 10 years old or older have been naturally produced within the river system.

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

4. Noticeable improvements in siltation problems and substrate quality have occurred.

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 habitats of P. cooperianus with emphasis on the Tennessee, Cumberland, and Ohio Rivers.

1.1 Continue to utilize existing legislation and regulations (Federal and State endangered species laws, water quality requirements, stream alteration regulations, etc.) to protect the species and its habitat.

1.2 Conduct population and habitat surveys.

1.2.1 Determine species' present distribution and status.

1.2.2 Characterize the habitat, ecological associations, and essential elements (biotic and abiotic factors) for all life history stages.

1.2.3 Determine the extent of the species' preferred habitat.

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

1.3 Determine present and foreseeable threats to the species and 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 and 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 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, and/or other means or combinations.

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

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

3. Conduct life history studies not covered under section 1.2.2 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 P. cooperianus with emphasis on the Tennessee, Cumberland, and Ohio Rivers. The largest known reproducing population of P. cooperianus occurs in the Tennessee River. Small, lesser known populations are also reported from the Cumberland and lower Ohio Rivers. The protection of these populations and their habitats is essential for the continued survival of the species. Preservation of P. cooperianus including transplanted populations will be required to meet the recovery objective.

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

1.2 Conduct population and habitat surveys. Intensive dive/float surveys for freshwater mussels, including the use of a commercial mussel fisherman, are recommended for all State protected mussel sanctuaries on the Tennessee and Cumberland Rivers. Since these areas are State protected, it would seem likely that additional populations of P. cooperianus may be present in these areas for life history and habitat studies. Those areas recommended for surveys are:

A. The Tennessee River from Guntersville Dam (TRM 349) downstream to the mouth of Shoal Creek, Alabama (TRM 347).

B. The Tennessee River from the upstream end of the Hobbs Island (TRM 337) downstream to Whitesburg Bridge (TRM 333).

C. The Tennessee River from Wilson Dam (TRM 259.4) downstream to the upper end of Seven-Mile Island (TRM 253).

D. The Tennessee River (Kentucky Reservoir) bounded on the north by TRM 140 (mouth of Elkins Branch, Decatur County) and on the south by TRM 141.5 (mouth of Cedar Creek, Perry County, Tennessee).

E. The Tennessee River (Kentucky Reservoir) between Pickwick Dam (TRM 106.7) and TRM 201.9.

F. The Tennessee River from Nickajack Dam (TRM 424.7) downstream to the Tennessee-Alabama State line (TRM 416.5).

G. The Tennessee River (Nickajack Reservoir) between TRM 465.9 and TRM 471.0 (Chickamauga Dam).

H. The Tennessee River (Chickamauga Reservoir) between TRM 520.0 and Watts Bar Dam (TRM 529.9).

Intensive dive/float freshwater mussel surveys are also recommended for the lower 20 miles of the Holston River downstream to its mouth, the French Broad River below Douglas Dam downstream to its mouth, Cumberland River below Cordell Hull Dam (CRM 313.5) downstream to Lock and Dam No. 2 near Madison, Tennessee (CRM 201.0), lower Ohio River below Owensboro Dam downstream to its mouth, and the Wabash River, Ohio. These areas have not been intensively searched for freshwater mussels.

1.2.1 Determine species' present distribution and status. See section 1.2.

1.2.2 Characterize the habitat, ecological associations, and essential elements (biotic and abiotic factors) for all life history stages. Some of the work necessary for characterization of freshwater mussel habitat has been accomplished for another endangered freshwater mussel (Conradilla caelata) as part of TVA's Cumberlandian Mollusk Conservation Program (Jenkinson, 1981). Similar studies for P. cooperianus are needed to gain intimate knowledge of the species' habitat requirements, enabling protection of 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 laboratory 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 dredging, strip mining, oil and gas drilling, channelizing, 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 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 water 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, wildlife-oriented clubs, and commercial mussel fishermen. These programs could also be developed for television and local newspaper coverage.

1.5 Investigate the use of mussel sanctuaries, land acquisitions, and/or other means or combinations to protect the species. The States of Tennessee and Alabama have designated portions of the Tennessee and Cumberland Rivers as mussel sanctuaries. However, the headwaters for each of these streams originate in adjoining States such as Kentucky and Virginia. Water quality can be grossly affected from adjoining States, and no protection is offered those mussel populations. Further, 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. Another viable option for protecting mussel habitat is through land purchases (islands). The Nature Conservacy is actively pursuing land acquisition at one particularly sensitive area in the Clinch River. Immediate protection of P. cooperianus populations in the Tennessee, Cumberland, and Ohio Rivers from unwarranted collecting and environmental impacts is of the highest priority.

2. Determine the feasibility of introducing the species back into rivers within its historic range and introduce where feasible. The protection and preservation of the Tennessee, Cumberland, and Ohio River P. cooperianus 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 rivers where it now occurs. Further, 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 stream or river system has been determined, specific sites to receive transplants within that river must be identified. Each potential site must be evaluated based on a correlation of stream characteristics with known populations of the species. Possible streams or sites suggested for study include (1) islands, bypass channels, or mussel sanctuaries on the Tennessee and Cumberland Rivers, (2) lower 20 miles of the Holston River, (3) French Broad River below Douglas Dam at Seven Islands, and (4) the lower Ohio 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, and/or other means or combinations. Some of these methods are currently being tested by TVA as part of the Cumberlandian Mollusk Conservation Program (Jenkinson, 1981). 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 P. cooperianus 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 for P. cooperianus.

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 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 requiredactual 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.

BIBLIOGRAPHY

Ahlstedt, S. A. 1981. The molluscan fauna of the Duck River between Normandy and Columbia Dams in central Tennessee. Bull. Amer. Malacol. Union for 1980:60-62.

Ahlstedt, S. A. 1983. The molluscan fauna of the Elk River in Tennessee and Alabama. Bull. Amer. Malacol. Union for 1983(1):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.

Bogan, A. and P. Parmalee. 1983. Tennessee's Rare Mollusks, IN: Tennessee's Rare Wildlife, Final Report: Tennessee Heritage Program of the Department of Conservation. 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., J. S. Crossman, K. L. Dickson, and E. E. Herricks. 1971. The recovery of damaged streams. Assoc. Southeast. Biol. Bull. 18:79-106.

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

Call, R. E. 1896. Second contribution to the knowledge of Indiana mollusca. Proc. Ind. Acad. Sci. 1895:135-146.

Call, R. E. 1897. The hydrographic basins of Indiana and their molluscan fauna. Proc. Ind. Acad. Sci. 1896:247-258.

Call, R. E. 1900. A descriptive, illustrated catalogue of the mollusca of Indiana. Indiana Dept. of Geo. and Nat. Res. Ann. Rept., 24:335-535, 78 pl.

Clark, C. F. 1976. The freshwater naiads of the lower end of the Wabash River, Mt. Carmal, Illinois, to the south. Sterkiana 61:1-14.

Clarke, A. H. 1981. Determination of the precise geographical areas occupied by four endangered species of freshwater mollusks. Final report. USFWS, Fed. Bldg., Room 668, Fort Snelling, Twin Cities, MN 55111.

Clarke, A. H. 1982. Survey of the freshwater mussels of the upper Kanawha River (RM91-95), Fayette County, West Virginia, with special reference to Epioblasma torulosa torulosa (Rafinesque) and Lampsilis abrupta (Say) (=Lampsilis orbiculata (Hildreth), of authors). Final Rept. USFWS, One Gateway Center, Room 611, Newton Corner, MA. 102 pp.

Clench, W. J. and H. van der Schalie. 1944. Notes on naiades from the Green, Salt, and Tradewater Rivers in Kentucky. Mich. Acad. Sci., Arts, Lett., pp. 223-228.

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

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. Soulę and Bruce A. Wilcox (eds.) Pub. 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, New York.

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. and H. van der Schalie. 1944. A revision of the mollusca of Indiana. Am. Midl. Nat. 32(2):257-326.

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 District., Missouri. 147 pp.

Haas, F. 1969. Superfamily Unionacea. IN: Das Tierreich Berlin Lief (pt.) 88:I-X, 1-663.

Hickman, M. E. 1937. A contribution to mollusca of east Tennessee. Unpublished master's thesis, Dept. of Zoology, 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, Toronto, Ontario.

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

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, etc.), pp. 94-135. Robert A. Taft Sanitary Eng. Center, Cincinnati, Ohio.

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, in Dec. 1970. Malacol. Rev. 4:127-130.

Isom B. G. 1971b. Effects of storage and mainstream 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. 1974. Mussels of the Green River, Kentucky. Trans. Ky. Acad. Sci. 35(1-2):55-57.

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. and L. 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. 1973. Mussels of the Elk River Basin in Alabama and Tennessee. 1965-1967. Am. Midl. Nat. 89(2)437-442.

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

Johnson, R. I. 1980. Zoogeography of North American Unionacea (Mollusca: Bivalvia) north of the maximum Pleistocene glaciation. Bull. Mus. Comp. Zool. 149(2):189 pp.

Krumholz, L. A., R. L. Bingham, and E. R. Meyer. 1970. A survey of the commercially valuable mussels of the Wabash and White Rivers of Indiana. Proc. Indiana Acad. Sci. 79:205-226.

Lea, I. 1834. Observations on the naiades; and descriptions of new species of that and other families. Trans. Am. Philos. Soc. 5:23-119.

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

Lewis, J. 1871. On the shells of the Holston River. Am. J. Conch. 6(3):216-228.

Loar, J. M., L. L. Dye, R. R. Turner, and S. G. Hildebrand. 1980. Analysis of 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.

Meyer, E. R. 1974. Unionid mussels of the Wabash, White and East Fork White Rivers, Indiana. Va. J. Sci. 25(1):20-25.

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

Morris, J. S. and R. W. Taylor. 1978. A survey of the freshwater mussels (Bivalvia: Unionidae) of the Kanawha River of West Virginia. Nautilus 92(4):153-155.

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

Ortmann, A. E. 1909. A preliminary list of the Unionidae of western Pennsylvania, with new localities for species from eastern Pennsylvania. Ann. Carnegie Mus. 5(7):178-210.

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

Ortmann, A. E. 1912. Notes upon the families and genera of the nayades. Annals Carnegie Mus. 8:222-365.

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. 1919. A monograph of the naiades of Pennsylvania, pt. 3, Systematic account of the genera and species. Mem. Carnegie Mus. 8(1):1-389, 1-21 pl.

Ortmann, A. E. 1924. The naiad fauna of Duck River in Tennessee. Am. 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. 1967. The freshwater mussels of Illinois. Ill. St. Mus. Pop. Sci. Series, Vol. 8, 108 pp.

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.

Pilsbry, H. and S. N. Rhoads. 1897. Contributions to the zoology of Tennessee. No. 4, Mollusks. Proc. Acad. Nat. Sci., Phila. pp. 487-506.

Rhoads, S. N. 1899. On a recent collection of Pennsylvanian mollusks from the Ohio River system below Pittsburg. Nautilus 12(12):133-138.

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.

Sickel, J. B. 1982. A survey of the freshwater mussels of the lower Cumberland River from Barkley Dam tailwater downstream to the Ohio River. Nashville Dist., U.S. Army Corps of Engineers. 24 pp.

Simpson, C. T. 1914. A descriptive catalogue of the naiades, or pearly freshwater mussels, Bryant Walker, Detroit, MI. 1540 pp.

Soulé, M. E. 1980. Thresholds for survivial: maintaining fitness and evolutionary potential. IN: Conservation biology an evolutionary-ecological perspective. Michael E. Soulé and Bruce A. Wilcox (eds.). Pub. by Sinauer Assoc., Inc., Sunderland, MA. Chapt. 8, pp. 151-169.

Stansbery, D. H. 1962. The naiades recorded from the Ohio River system of North America (Mollusca: Pelecypoda: Unionacea). A checklist compiled from literature and museum records. Ohio State Univ., Mus. of Zool. at Columbus. 6 pp.

Stansbery, D. H. 1964. The Mussel (Muscle) Shoals of the Tennessee River revisited. Amer. Malacol. Union Ann. Rep. 1964:15-28.

Stansbery, D. H. 1965. The naiad fauna of the Green River at Munfordville, Kentucky. Amer. Malacol. Union Ann Rep. for 1965:13-14.

Stansbery, D. H. 1969. Changes in naiad fauna of the Cumberland River at Cumberland Falls in eastern Kentucky. Amer. Malacol. Union Ann. Rep. for 1969:16-17.

Stansbery, D. H. 1970. Eastern freshwater mollusks. (1) The Mississippi and St. Lawrence River systems. IN: A. H. Clark (ed.). Rare and endangered mollusks of North America. Malacologia 13:9-12.

Stansbery, D. H. 1972. IN: Bettye J. Broyles, A late 17th century Indian village site (46 Pu 31) in Putman Co., West Virginia. Rep. of Arch. Inv. No. 5, West Virginia Geol. and Economic Survey, Morgantown, WV.

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

Starrett, W. C. 1971. A survey of the mussels (Unionacea) of the Illinois River: a polluted stream. Ill. Nat. Hist. Surv. Bull. 30 (art. 5): 268-403.

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.

Surber, T. 1913. Notes on the natural hosts of freshwater mussels. Bull. U.S. Bur. Fish. 32, 110-116. Separately issued as Bur. Fish. Doc. No. 778.

Taylor, R. W. 1980. A survey of the freshwater mussels of the Ohio River from Greenup locks and dam to Pittsburg, PA. A report submitted to the U.S. Army Corps of Eng., Huntington, WV. pp. 1-71, 20 pls.

Taylor, R. W. and B. D. Spurlock. 1982. The changing Ohio River naiad fauna: A comparison of early Indian middens with today. Nautilus 96(2):49-51.

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

Tennessee Valley Authority. 1972. Mussel survey of the Duck River. TVA unpublished data. Division of Environmental Planning, Water Quality and Ecology Branch, Muscle Shoals, AL.

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, AL; and the Division of Forestry, Fisheries, and Wildlife Development, Norris, TN.

Tennessee Valley Authority. 1979a. An evaluation of mussel populations in the Duck River, Tennessee. May-June 1979. TVA unpublished data. Division of Water Resources, Fisheries and Aquatic Ecology Branch, Norris, TN. 11 pp.

Tennessee Valley Authority. 1979b. 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. 1979c. 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. 1980. Freshwater mussels of the Nolichucky 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 Operations Group, Norris, TN.

Tennessee Valley Authority. 1982. Freshwater mussel survey of the lower Clinch River Breeder site (CRBRP). TVA unpublished data. Office of Natural Resources, Eastern Area Field Operations Group, Norris, TN.

Utterback, W. I. 1915-1916. The naiades of Missouri. Am. Midl. Nat. 4(3):41-53; 4(4):97-152; 4(4):181-204; 4(6):224-273; 4(7):311-327; 4(8):339-354; 4(9):387-400; 4(10):432-464.

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

van der Schalie, H. 1973. The mollusks of the Duck River drainage in central Tennessee. Sterkiana 52:45-55.

Warren, R. E. 1975. Prehistoric Unionacean (freshwater mussel) utilization at the Widow's Creek site (1Ja305), northeast Alabama. Unpublished master's thesis, anthropology, Univ. of Neb., Lincoln.

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

Wilson, C. B. 1916. Copepod parasites of freshwater fishes and their economic relations to mussel glochidia. Bull. U.S. Bur. Fish. 34:331-374. Separately issued as Bur. Fish. Doc. 824.

Wilson, C. B. and H. W. Clark. 1912. The mussel fauna of the Kankahee Basin. Dept. of Comm. and Labor, U.S. Bur. of Fish Doc. No. 758. 52 pp.

Wilson, C. B. and H. W. Clark. 1914. The mussels of the Cumberland River and its tributaries. U.S. Bur. of Fish Doc. No. 781. 63 pp.

Yokley, P., Jr. 1972. Freshwater mussel ecology, Kentucky Lake, Tennessee. Tennessee Game and Fish Comm. Proj. 4-46R. 133 pp.

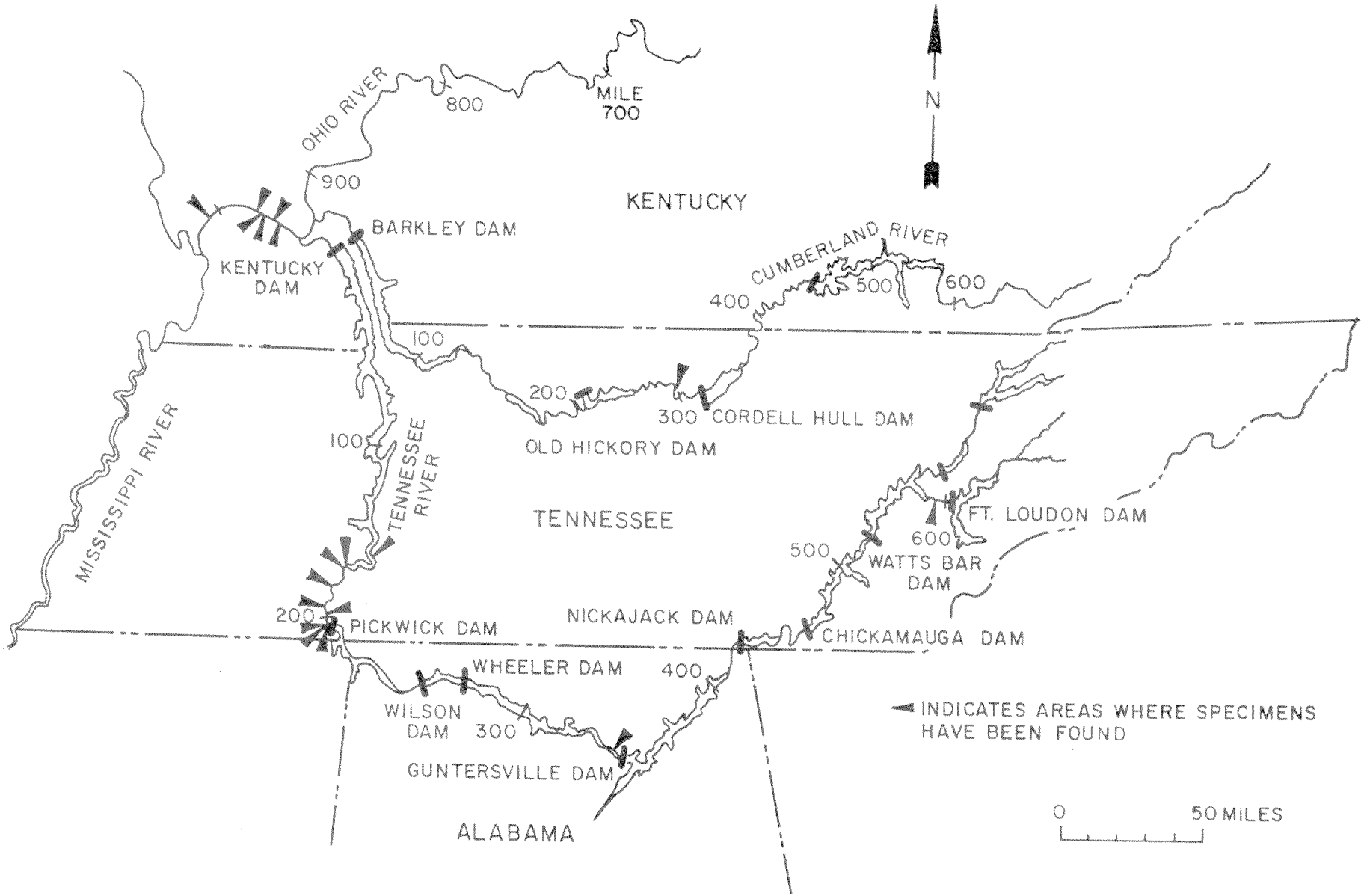


Figure 1: Tennessee, Cumberland and Lower Ohio Rivers – Recent Locations for PLETHOBASUS COOPERIANUS (Lea, 1834)

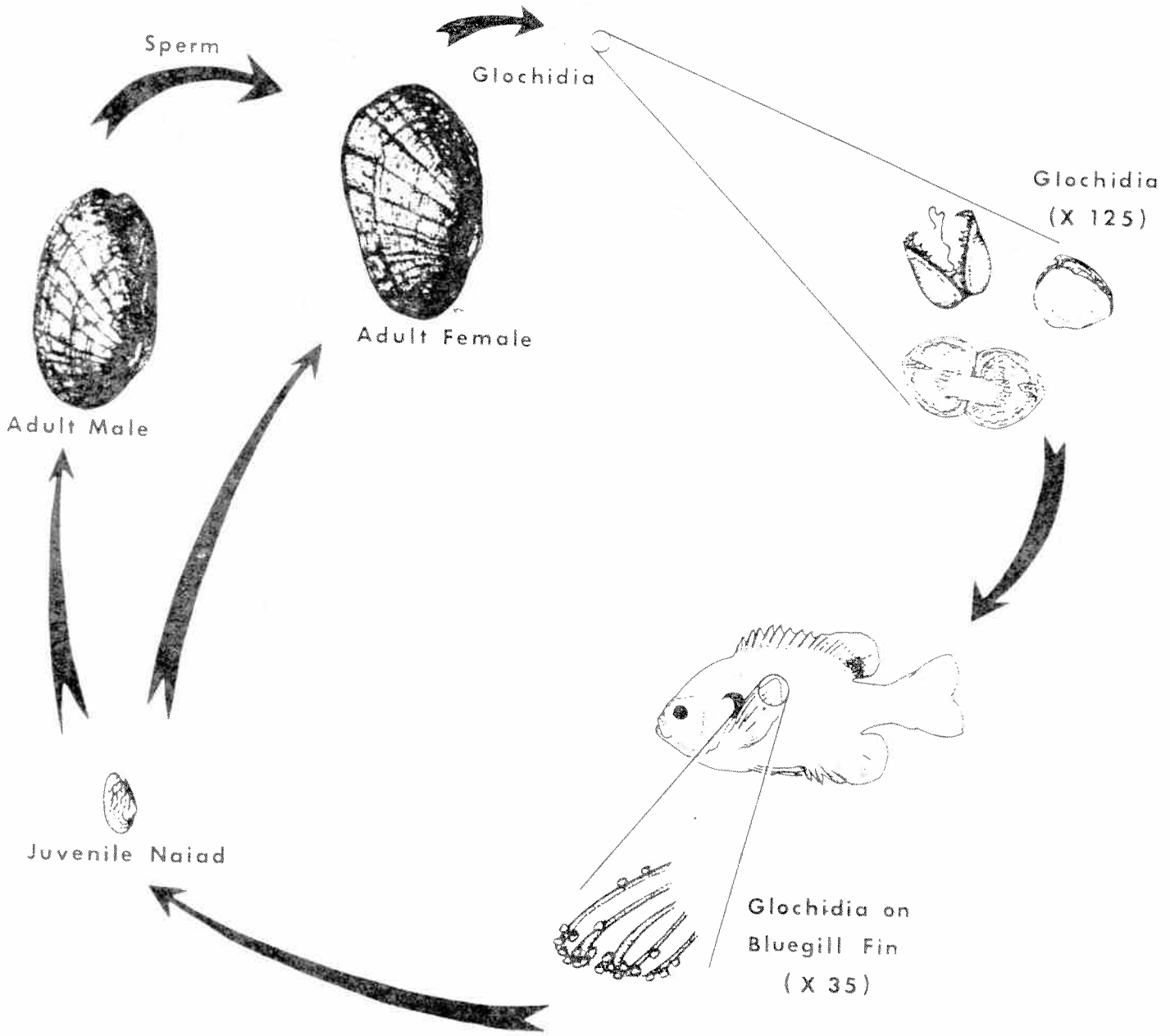
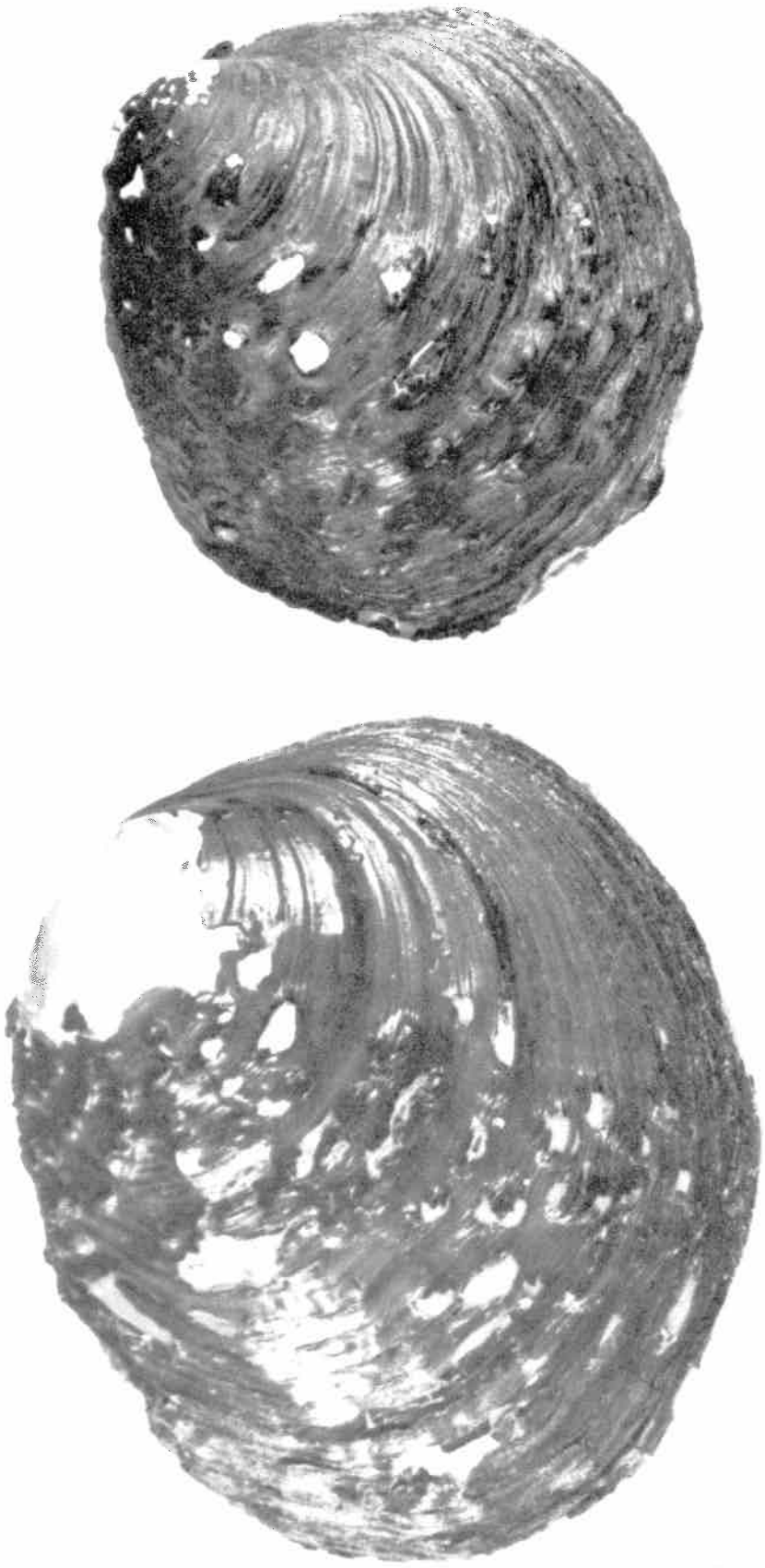


Figure 2. Typical naiad life cycle depicting the various stages. The life cycle for most species of naiades is very similar to that depicted here (Grace and Buchanan 1981).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KEY TO IMPLEMENTATION SCHEDULE COLUMNS 1 AND 4

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.

Orange-footed Pearly Mussel
Plethobasus cooperianus

Part III Implementation Schedule

*1 General Category	Plan Task	Task Number	Priority	Task Duration	Responsible Agency			Estimated Fiscal Year Costs			*3 Comments/Notes
					FWS Region	FWS Program	*2 Other	FY 1	FY 2	FY 3	
01-04	Continue to utilize existing legislation and regulations to protect species and habitat.	1.1	1	Continuous	3,4,5	SE,ES,LE	Tennessee Valley Authority (TVA), Tennessee Wildlife Resources Agency (TWRA), Illinois Department of Conservation (IDOC), Kentucky Kentucky Department of Fish and Wildlife Resources (KDFWR), Kentucky Nature Preserves Commission (KNPC), 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.	3,4,5	SE	TWRA, THP, IDOC, TVA, KDFWR, KNPC, and ADCNR	---	---	---	
R3,R8 R9,R10 R11	Characterize habitat and determine essential elements.	1.2.2	2	2 yr.	3,4,5	SE	TWRA, THP, IDOC, TVA, KDFWR, KNPC, and ADCNR	---	---	---	
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.	3,4,5	SE	TWRA, THP IDOC, TVA, KDFWR, KNPC, and ADCNR	---	---	---	
I12,I14	Determine present and foreseeable threats to species.	1.3.1 & 1.3.2	1	3 yr.	3,4,5	SE&ES	TWRA, THP, IDOC, TVA, KDFWR, KNPC, and ADCNR	---	---	---	

Orange-footed Pearly Mussel
Plethobasus cooperianus

Part III Implementation Schedule

General Category	Plan Task	Task Number	Priority	Task Duration	Responsible Agency			Estimated Fiscal Year Costs			Comments/Notes
					FWS						
					Region	Program	Other	FY 1	FY 2	FY 3	
M3,M7	Determine measures needed to minimize threats and implement where needed to meet recovery.	1.3.3	2	Unknown	3,4,5	SE&ES	TWRA, THP, IDOC, TVA, Tennessee, Illinois	---	---	---	KDFWR, KNPC, ADCNR, and Kentucky, Alabama, and 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	3,4,5	SE&ES	TWRA, THP, IDOC, TVA,	---	---	---	KDFWR, KNPC, 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	3,4,5	SE&ES	TWRA, THP, IDOC, TVA,	---	---	---	KDFWR, KNPC, 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	3,4,5	SE&ES	TWRA, THP, IDOC, TVA,	---	---	---	KDFWR, KNPC, ADCNR, and TNC
I13	Survey rivers within species' historic range to determine availability of suitable transplant sites.	2.1 & 2.2	3	1 yr.	3,4,5	SE	TWRA, THP, IDOC, TVA,	---	---	---	KDFWR, KNPC, and ADCNR
R13,R7	Determine best method of establishing new populations.	2.3	3	2 yr.	3,4,5	SE	TWRA, THP, IDOC, TVA,	---	---	---	KDFWR, KNPC, and ADCNR

Task 2.1-2.3 may not be required if other populations are found in task 1.2.1.

Orange-footed Pearly Mussel
Plethobasus cooperianus

Part III Implementation Schedule

General Category	Plan Task	Task Number	Priority	Task Duration	Responsible Agency FWS Region	Responsible Agency FWS Program	Responsible Agency Other	Estimated Fiscal Year Costs FY 1	FY 2	FY 3	Comments/Notes
M2	Reestablish populations within historic range as needed to meet recovery.	2.4	3	Unknown	3,4,5	SE	TWRA, THP, IDOC, TVA, KDFWR, KNPC, and ADCNR	---	---	---	
I12,I14 M3,M7	Implement same protective measures for these reestablished populations as for known populations.	2.5	3	Continuous	3,4,5	SE,ES	TWRA, THP, IDOC, TVA, KDFWR, KNPC, ADCNR, and TNC	---	---	---	
R3,R6, R8,R9-R11, R14	Conduct life history studies on a need-to-know basis.	3.	2	Unknown	3,4,5	SE	TWRA, THP, IDOC, TVA, KDFWR, KNPC, and ADCNR	---	---	---	
R8-R11	Determine the number of individuals required to maintain a viable population.	4.	3	Unknown	3,4,5	SE	TWRA, THP, IDOC, TVA, KDFWR, KNPC, 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	3,4,5	SE	TWRA, THP, IDOC, TVA, KDFWR, KNPC, and ADCNR	---	---	---	
I1,I2	Develop and implement a monitoring program.	6.	2	Unknown	3,4,5	SE	TWRA, THP, IDOC, TVA, KDFWR, KNPC, and ADCNR	---	---	---	
O4	Annual assessment of recovery program and modify where needed.	7.	2	Continuous	3,4,5	SE	TWRA, THP, IDOC, TVA, KDFWR, KNPC, ADCNR, and TNC	---	---	---	

APPENDIX

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