Recovery Plan

Rough Pigtoe Pearly Mussel (*Pleurobema plenum*)

Recovery Plan for the Rough Pigtoe Pearly Mussel

Pleurobema plenum (Lea, 1840)

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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.

Literature citations should read as follows:

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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. These species occur in what has been recognized as six faunal zones, or regions, which include: (1) North Atlantic Slope, (2) Pacific Coastal, (3) Mississippian, (4) Ozarkian, (5) Cumberlandian, and (6) Ohioan Regions (Johnson, 1980). Eastern North America had, and still contains, the richest freshwater molluscan fauna known in the world. Stansbery (1970) reports that this fauna numbers over a thousand species of bivalves and gastropods combined.

Pleurobema plenum historically had a widespread distribution in eastern North America where it was reported from four faunal regions: (1) Ozarkian, (2) Cumberlandian, (3), Mississippian, and (4) Ohioan. Of these four regions, the Cumberlandian Region, which includes the Tennessee and Cumberland Rivers, contains the largest number of freshwater mussel 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 of these species listed were known from the Tennessee and Cumberland River systems. The rough pigtoe pearly mussel (P. plenum) 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).

Pleurobema plenum was described by Lea in 1840 with its type locality listed as the Ohio River in Hamilton County, Ohio, near Cincinnati.

All records for this species indicate its presence only in the larger rivers of eastern North America.

The systematic status of P. plenum has led to confusions in the Pleurobema complex. The Pleurobema cordatum group is believed to contain four closely related and highly variable species. They include (1) P. cordatum (Rafinesque, 1820), (2) P. coccineum (Conrad, 1836) =Obliquaria sintoxia (Rafinesque, 1820?), (3) P. pyramidatum (Lea, 1834) =Obliquaria rubra (Rafinesque, 1820?) and (4) P. plenum (Lea, 1840). All four species have overlapping distributions and have been reported to occur together at some localities (Clarke, 1981; Stansbery, 1965). Ortmann (1919) reported P. plenum to be a variation of P. cordatum that was found very rarely and later, Ortmann and Walker (1922) clarified the taxonomic status of P. plenum by stating that P. plenum occurs in the same localities as the two or three other forms or species of the P. cordatum group. The author has collected three of these species (P. cordatum, P. rubrum, and P. plenum) from one sampling location in the Clinch River at Brooks Island (CRM 184.5) and has observed all four species taken from a commercial mussel fishermans cull piles from the Tennessee River.

DISTRIBUTION

Historical

Pleurobema plenum historically had a widespread distribution, being reported from various rivers throughout four major geographic regions. Lea (1840) first reported P. plenum from the Ohio River near Cincinnati, Ohio. Simpson (1914) also reported this species from the Ohio, Cumberland, and Tennessee River systems and further reported it southwest to Kansas and Arkansas. Ortmann (1919, 1926), Stansbery (1965), and Williams (1969) also

reported P. plenum from the Ohio and Tennessee River systems, while Wilson and Clark (1914), and Neel and Allen (1964) reported P. plenum from the Cumberland River.

Clarke (1981) reports that the sparsity of locality data on this species is mainly due to taxonomic difficulties with the Pleurobema group, and the lack of voucher specimens in museum collections. Table 1 is a listing of P. plenum collections prior to 1970. Additionally, Warren (1975) and Bogan and Parmalee (1983) reported archaeological specimens of P. plenum from the Tennessee River. Bogan and Parmalee (1983) also reported relict shells of P. plenum from the lower Clinch River.

Present

Pleurobema plenum is presently known only from the Tennessee and Cumberland Rivers (figure 1), Clinch (figure 2), and Green and Barren Rivers (figure 3).

It is apparent that P. plenum are currently being harvested by commercial mussel fishermen from the Tennessee River below three of the lower mainstream dams: Pickwick, Wilson, and Guntersville (Leroy Koch - personal communication). A total of 70 freshly dead specimens of P. plenum were observed between 1979 and 1982 from a shell buyers' cookout camp. Of the specimens reportably harvested, 10 were below Pickwick Dam, 27 from below Wilson Dam, and 33 specimens from below Guntersville Dam. Although these locations are not site specific, Mr. Koch feels that P. plenum is present for an undetermined number of miles below each of these dams and based upon two young specimens observed up to 8 years of age, may be reproducing below Pickwick Dam.

Stansbery (1973) collected P. plenum from the Clinch River in the mid-1960s. A 170-mile dive/float survey of the Clinch River from Cedar Bluff, Virginia (CRM 322.6), to Tennessee State Highway 25E bridge (CRM 153.8)

Table 1. Historical records for Pleurobema plenum prior to 1970 and subfossil records recorded to 1979.

River	Source
Tombigbee River	Hinkley (1906) van der Schalie (1939a)
Alabama River	Lewis (1876)
Tennessee River	Lewis (1876) Hinkley (1904, 1906) Simpson (1914) Ortmann (1918, 1919b, 1925) van der Schalie (1939) Morrison (1942) Warren (1975) archaeological specimens Bogan and Paramalee (1983) archaeological specimens
Holston River	Pilsbry and Rhoads (1897) Ortmann (1919)
French Broad River	Ortmann (1918, 1919)
Clinch River	Pilsbry and Rhoads (1897) Ortmann (1918, 1919) Cahn (1936) Bogan and Parmalee (1983) archaeological specimens
Cumberland River	Marsh (1885) Call (1895) Wilson and Clark (1914) Simpson (1914) Neel and Allen (1964) Stansbery (1969)
Ohio River	Lea (1840) Call (1885) Sterki (1907) Ortmann (1912, 1913, 1919) Simpson (1914) Ortmann and Walker (1922) La Rocque (1966-70)
Allegheny River	Ortmann (1911, 1912, 1919)
Monogahela River	La Rocque (1966-70)
Kanawha River, West Virginia	Stansbery (1972)

Table 1. Continued

River	Source
Green River, Kentucky	Ortmann (1926) Williams (1969) Stansbery (1965, 1971)
Wabash River, Indiana	Hinkley (1887) Call (1896) Daniels (1903) Baker (1906)
Tippecanoe River, Indiana	Call (1896) Daniels (1903) Baker (1906)
White River, Indiana	Call (1896) Daniels (1903) Baker (1906)
Mississippi River	Call (1885) Baker (1905)
Illinois River	Calkins (1874) Baker (1906) Danglade (1914) Coker (1921)
Neosho River, Kansas	Call (1895)
Ouachita River, Arkansas	Call (1895)
St. Francis River, Arkansas	Call (1895)
Meramec River, Missouri	Grier (1915)
James River, Missouri	Utterback (1915)

during 1979 resulted in the collection of six live and seven freshly dead specimens of P. plenum (TVA, 1979a). TVA's float survey of the Clinch River was incomplete from Cedar Bluff, Virginia, to Craft Mill, Virginia (CRM 220), because of adverse sampling conditions. Further, the author collected four additional freshly dead specimens of P. plenum from the Clinch River at Brooks Island (CRM 185.0) in October 1980. Pleurobema plenum is extremely rare and reproducing in limited numbers in the upper Clinch River between Kyles Ford (CRM 189.6) and State Highway 25 E bridge (CRM 153.8).

Parmalee et al. (1980) reported an undetermined number of freshly dead specimens of P. plenum from the middle reaches of the Cumberland River (Smith County, Tennessee) between 1977 and 1979. Parmalee (personal communication) considers P. plenum to be uncommon to rare in the Cumberland River. Recent sampling in the Cumberland River by TVA (1976) and Sickel (1982) failed to locate P. plenum in the Cumberland.

Freshwater mussel sampling in the Green River by Clarke (1981) produced one live specimen of P. plenum below Lock and Dam No. 5 near Glenmore, Warren County, Kentucky. Relict shells of P. plenum were also reported by Clarke (1981) at six additional sites on the Green river and two sites on the Barren River (a tributary to the Green). Sam Call (personal communication) collected "relatively fresh" dead specimens of P. plenum in October 1980, from the Barren River below Lock and Dam No. 1 near Bowling Green, Kentucky. Unpublished field records obtained through the Kentucky Nature Preserves Commission at Frankfort report additional records for P. plenum in the Green River (Appendix A). Clarke (1981) suggested the range of P. plenum in the Green River extends from Lock 5 (near Glenmore, Kentucky) to Lock 4 (near Woodbury, Kentucky), and in the Barren River from Lock 1 (near Greencastle, Kentucky) to the mouth of the river. Isom (1974) did not report P. plenum in his study of freshwater mussels of the Green River.

Freshwater mussel surveys by numerous individuals have failed to find P. plenum living in any streams other than the Tennessee, Cumberland, Clinch, Green, and Barren Rivers. Freshwater mussel surveys conducted on the Tennessee River by Ellis (1931), Scruggs (1960), Bates (1962, 1975), Stansbery (1964), Williams (1969), Isom (1969, 1971a, 1972), Yokley (1972a), and TVA (1979d; Pardue, 1981) failed to find P. plenum in the Tennessee River. Freshwater mussel sampling in some of the larger tributary streams to the Tennessee River including the Clinch River by Hickman (1937), Bates and Dennis (1978), and Neves et al. (1980); French Broad River (TVA, 1979c); Holston River (TVA, 1981); Nolichucky River (TVA, 1980); Elk River (Isom et al. 1973; Ahlstedt, 1983); and Duck Rivers (TVA, 1979b; Ahlstedt, 1981; van der Schalie, 1973; Isom and Yokley, 1968) all failed to find P. plenum.

Freshwater mussel sampling in 664 miles of the Ohio River by Williams (1969), and a resurvey of the Ohio River in 1981 by Williams (personal communication) did not find P. plenum in the Ohio River. Tributary streams to the Ohio River including the Wabash (Goodrich and van der Schalie, 1944; Parmalee, 1967; Krumholz et al. 1970; Meyer, 1974; Clark, 1976); White (Goodrich and van der Schalie, 1944; Krumholz et al. 1970; Meyer, 1974), and the East Fork White River by Meyer (1974) all failed to find P. plenum.

Pleurobema plenum has also not been recently found in the Mississippi River (van der Schalie and van der Schalie, 1950); Tombigbee River (Yokley, 1975); Illinois River (Parmalee, 1967; Starrett, 1971), or the Meramec River basin (Buchanan, 1980).

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, 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 riffle and shoal areas.

Pleurobema plenum (see photo) is found in medium to large rivers (20 m wide or greater) in sand and gravel substrates. It has been collected from the Clinch River in the transition zone between a pool and riffle by the author. Clarke (1981) reports finding P. plenum in muddy sand below a spillway on the Green River and in sand substrate on the Clinch River. Bogan and Parmalee (1983) reports P. plenum as probably a big river shoal species living in sand and gravel substrates. Pleurobema plenum attains a size up to about 65 mm long, 71 mm high, and 43 mm wide (Clarke, 1981). The shell is subtriangular in outline and inflated. The valves are heavy and solid with high, full beaks which are centrally located and turned forward. The anterior portion of the shell is truncated with the dorsal margin being slightly curved. The posterior margin is almost straight with a slight sulcus apparent in most older specimens. The posterior ridge is very prominent, rounded, and curves away from the hingeline. The median ridge is high, wide, and rounded, being separated from the posterior ridge by a radial depression. The surface of the shell is marked by irregular, concentric growth rests. Beak sculpturing is composed of a few coarse bars, which are usually worn away in older specimens. The periostracum is cloth-like, slightly glossy, and yellowish brown to reddish brown in color. In young specimens the periostracum can be rayed with small green rays near the umbos. The umbos project well above the hingeline and are rounded and inflated.

Hinge teeth are solid, heavy, and thick with the left valve consisting of two blunt, ragged, pyramidal teeth separated by a broad interdentum. The right valve has one pseudocardinal tooth. Lateral teeth are relatively heavy, short, and straight consisting of two in the left valve and one in the right. The beak cavity is deep and compressed. Nacre coloration varies from white to pinkish, reddish, or orange often iridescent posteriorly (Simpson, 1914; Scammon, 1906; Clarke, 1981; Bogan and Parmalee, 1983).

The life history for P. plenum is unknown but probably is similar to that of most naiades and is briefly illustrated in figure 4. 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 while feeding and during respiration (Stein, 1971). Fertilization 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. Pleurobema plenum is considered a tachytictic species based on gravid females found in May (Ortmann, 1919).

The glochidia of P. plenum have not been observed; however, glochidia of another species of the Pleurobema complex P. cordatum are semicircular and hookless (Surber, 1915; Yokley, 1972b). 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 P. plenum are unknown but fish host studies for P. cordatum by Yokley (1972) indicate the rosefin shiner (Notropis ardens) as a fish host. Coker et al. (1921) and Surber (1913) also report the bluegill (Lepomis macrochirus) as a fish host for P. cordatum. However, Clarke (1981) states that "rarer mussel species such as P. plenum probably utilize only a single fish host."

REASONS FOR DECLINE AND CONTINUED THREATS

Pleurobema plenum historically had a widespread distribution, being reported from four major geographic regions. 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 rather 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 effects species composition 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 (TVA, 1980). Biological responses attributable to these 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. Clarke (1981) warns that P. plenum will survive in the Green River, Kentucky, only if its natural habitat is restored. The completion of the Green River Dam in 1969 may eliminate this species from that river system.

Siltation

Siltation is another factor that has severely affected freshwater mussels. In rivers and streams, the greatest diversity and abundance 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, 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 long lived and sedentary by nature; many species are unable to survive in a layer of silt greater than 0.6 centimeters (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. Mussel life cycles can be affected indirectly from 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 received 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 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). Williams (1969) in his study of the mussel fauna of the Green River reports an almost total elimination of the freshwater mussel fauna below Greensburg, Kentucky, due to oil brine pollution.

PART II

RECOVERY

A. Recovery Objectives

The ultimate objective of this recovery plan is to maintain and restore viable populations* of P. plenum 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 P. plenum populations and (2) establishing populations in rivers and river corridors that historically contained P. plenum. 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. plenum exists in the Tennessee, Clinch, Cumberland, and Green Rivers. These four 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 that a single event would be unlikely to eliminate P. plenum from the river system. For reestablished populations, surveys must

*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. Stepdown 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 *P. plenum* with major emphasis on the Tennessee, Clinch, Cumberland, and Green 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 mining and industry interests and solicit their support in implementing protective actions.

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

1.4.5 Develop educational programs using such items as slide/tape shows and brochures. Present this

material to business groups, civic groups, youth groups, church organizations, etc.

1.5 Investigate the use of Scenic River status, mussel sanctuaries, 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 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, lonegvity, 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. plenum with emphasis on the the Tennessee, Clinch, Cumberland, and Green Rivers. The largest known concentrations of P. plenum occur in the Tennessee, Clinch, Cumberland, and Green Rivers. Small populations of P. plenum are also reported from the Barren River (tributary to the Green). The protection of these populations and their habitats is essential for the continued survival of the species. Preservation of P. plenum 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. Some of this work has been completed by TVA in the Tennessee River system as part of the Cumberlandian Mollusk Conservation Program (Jenkinson, 1981) and other TVA projects since 1970. During these surveys,

P. plenum was found to occur only in the Clinch River and was possibly not found or incorrectly lumped with P. cordatum specimens found during the Tennessee and Cumberland River surveys (TVA, 1976, 1979d; Pardue, 1981). 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. These areas have remained relatively free from human disturbances (commercial harvest) since they were designated as sanctuaries. Some of these areas may provide specimens for life history studies and possible transplants. Those areas recommended for surveys are:

1. The Tennessee River from Guntersville Dam (TRM 349) downstream to the mouth of Shoal Creek, Alabama (TRM 347).
2. The Tennessee River from the upstream end of Hobbs Island (TRM 337) downstream to Whitesburg (TRM 333).
3. The Tennessee River from Wilson Dam (TRM 259.4) downstream to the upper end of Seven-Mile Island (TRM 253).
4. The Tennessee River (Kentucky Reservoir) bordered on the north by TRM 140 (North of Elkins Branch, Decatur County) and on the south by TRM 141.5 (north of Cedar Creek, Perry County, Tennessee).
5. The Tennessee River (Kentucky Reservoir) between Pickwick Dam (TRM 206.7) and TRM 201.9.
6. The Tennessee River from Nickajack Dam (TRM 424.7) downstream to the Tennessee-Alabama State line (TRM 416.5).

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

8. The Tennessee River (Chickamauga Reservoir) between TRM 520 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; lower Ohio River below Owensboro, Kentucky, downstream to its mouth; Green River from Mumfordville, Kentucky, downstream to Lock and Dam No.4 (near Woodbury, Kentucky); and the Barren River from Lock and Dam No. 1 (near Greencastle, Kentucky) to the mouth of the river.

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 the characterization of freshwater mussel habitat has been accomplished for another endangered freshwater mussel (Conradilla caelata) as part of TVA's Cumberlandian Mollusk Conservation Program. Similar studies for P. plenum 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 if known 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 Determine impacts of coal industry related pollution on nonendangered species.

1.3.2 Investigate and inventory factors negatively impacting the species and its environment. Factors such as road construction, dredging, herbicide and pesticide spraying, and chlorinated effluents may be having a substantial impact on the species. This could be accomplished with present State and Federal research facilities utilizing both field and laboratory research. Studying impacts on nonendangered mussels as experimental organisms are suggested.

1.3.3 Solicit information on proposed and planned projects that may impact the species. Projects that are now planned or proposed could have a serious impact on the 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, 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 to receive sufficient protection to accomplish recovery.

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

Service, U.S. Army Corps of Engineers, Office of Surface Mining, etc.) presently have sufficient laws and regulations to effect a measurable change in the quality of these rivers.

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

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

1.4.5 Develop an educational program using such items as slide/tape shows and brochures. Present this material to business groups, civic groups, 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 Scenic River status, mussel sanctuaries, land acquisitions, and/or other means or combinations to protect the species.

The Clinch River appears eligible for Scenic River status under the National Wild and Scenic Rivers Act (USDOI, 1976). This would offer additional protection for P. plenum and its habitat in the Clinch. The State of Tennessee has designated portions of the Tennessee, Cumberland, Clinch, and Powell Rivers as mussel sanctuaries, and the State of Albama has designated some portions of the Tennessee River in Alabama 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 Federal Nature Conservancy is actively pursuing land acquisition at one particularly sensitive area on the Clinch River. Immediate protection of P. plenum populations in the Tennessee,

Clinch, Cumberland, Green, and Barren 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, Clinch, Cumberland, Green, and Barren Rivers P. plenum 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, 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 to receive transplants within that river must

be identified. Each potential site must be evaluated based on a correlation of stream characteristics with habitats of known populations of the species. These streams or sites suggested for study may include the (1) lower 20 miles of the Holston River, (2) French Broad River below Douglas Dam at Seven Islands, (3) Tennessee River at islands, by-pass channels, or sanctuaries, (4) Clinch River at Brooks Island, (5) lower Ohio River, and (6) Green and Barren Rivers.

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. 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. plenum 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. plenum.

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) which would contain sufficient genetic variation to enable that population to evolve and respond to natural habitat changes. The actual population size in a natural ecosystem 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 stream 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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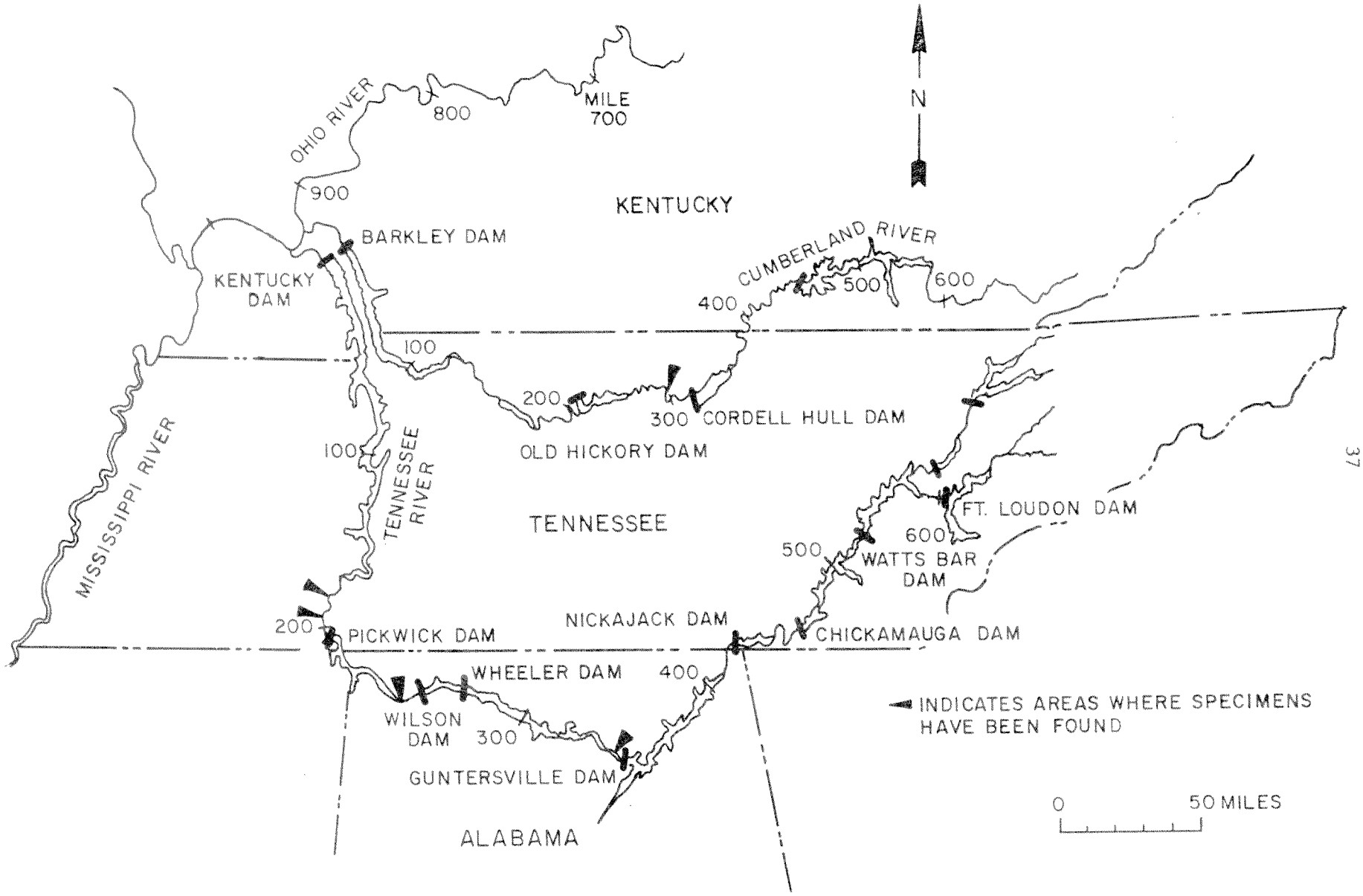


Figure 1: TENNESSEE AND CUMBERLAND RIVERS - RECENT LOCATIONS FOR PLEUROBEMA PLENUM (LEA, 1840)

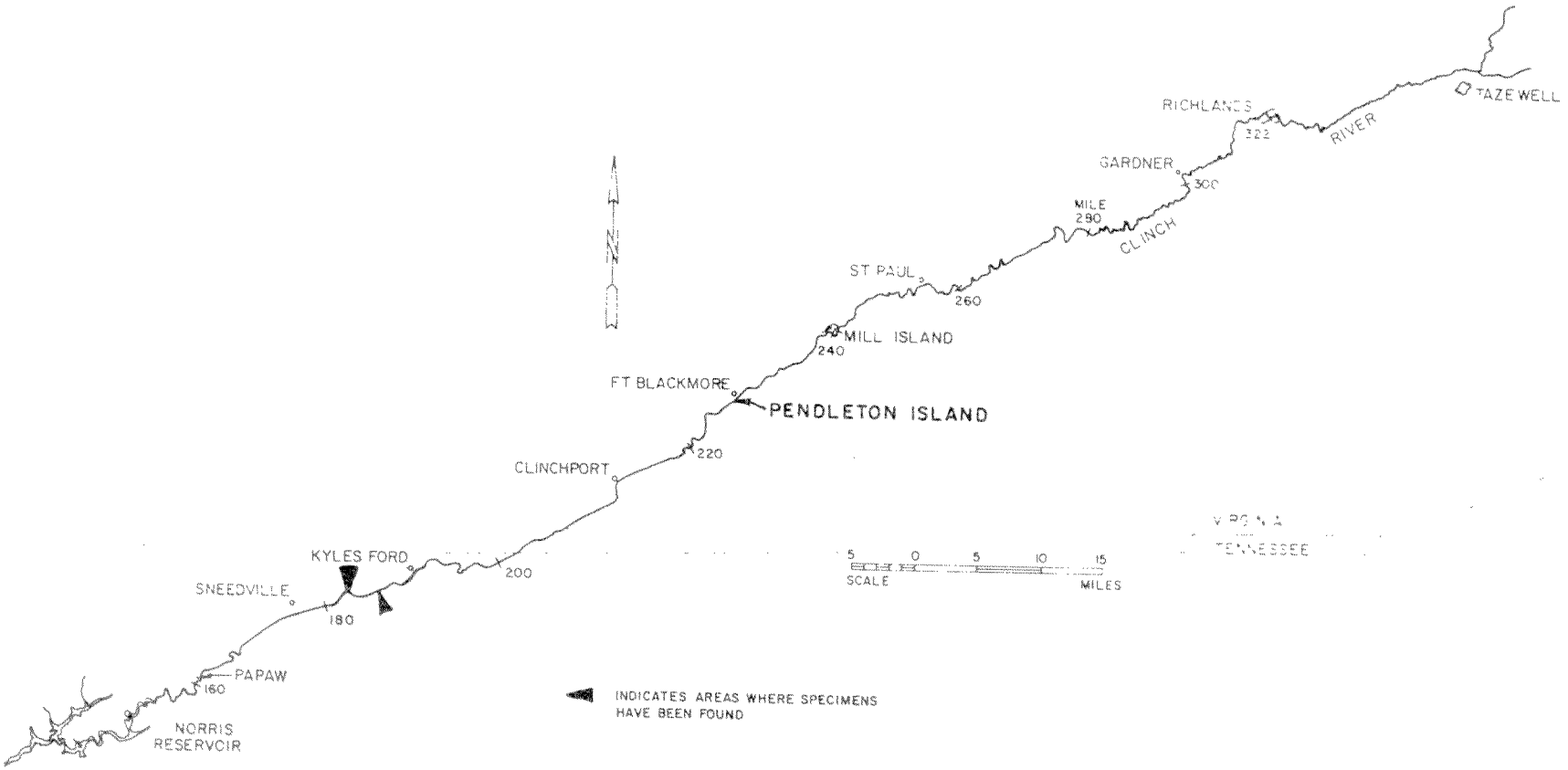


Figure 2: Clinch River - Recent Locations for PLEUROBEMA PLENUM (Lea, 1840)

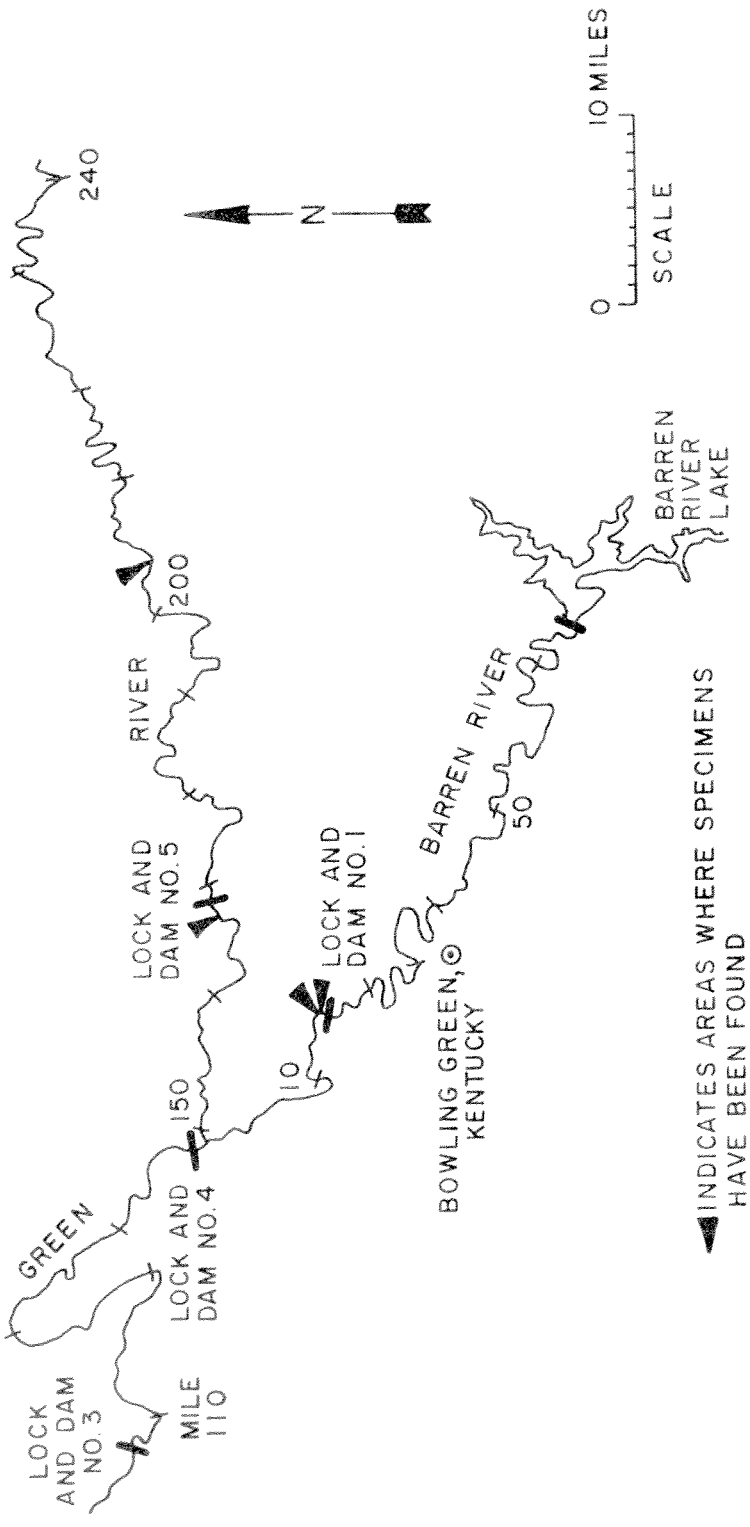


Figure 3: Green and Barren Rivers – Recent Locations for PLEUROBEMA PLENUM (LEA, 1840)

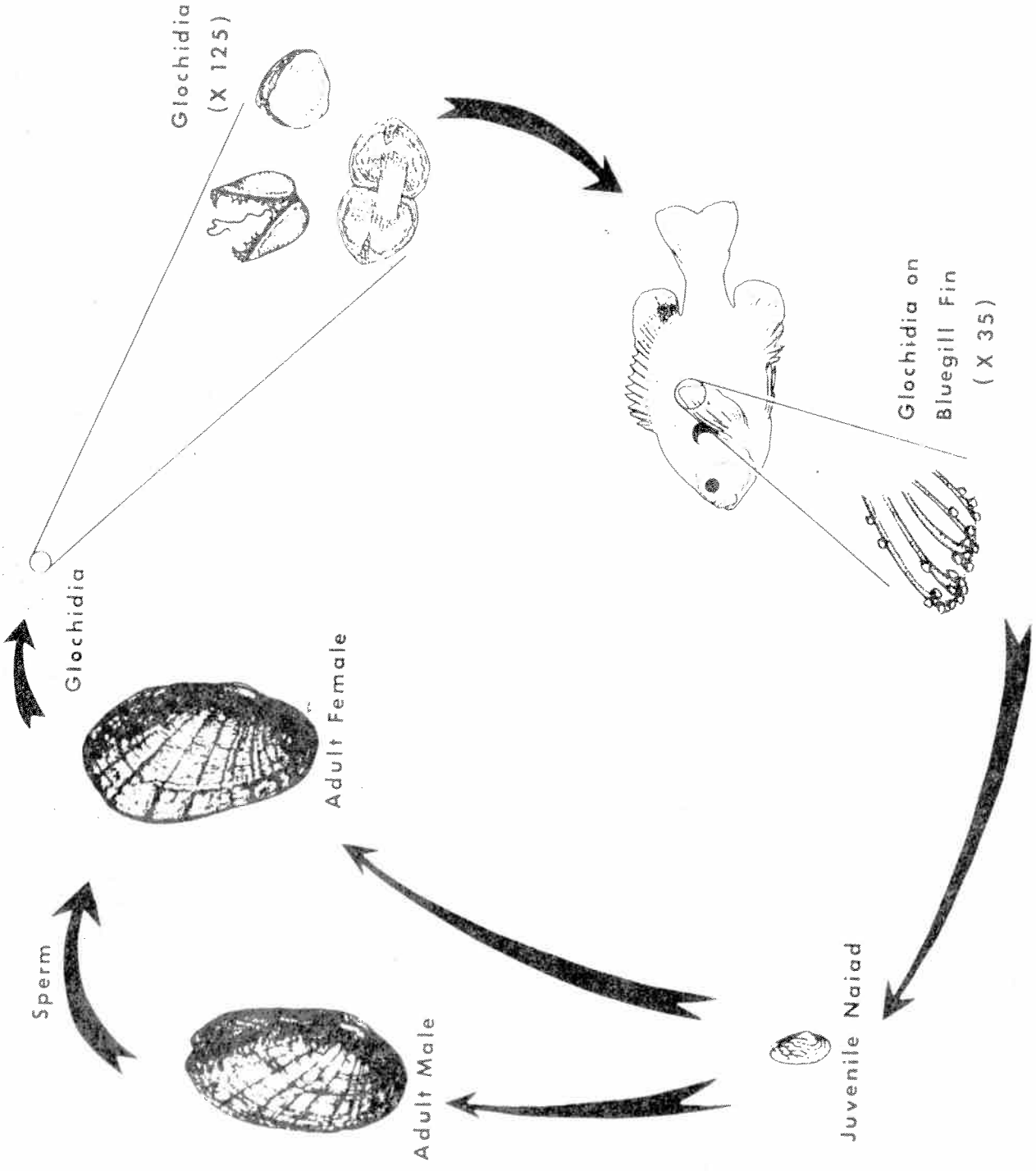
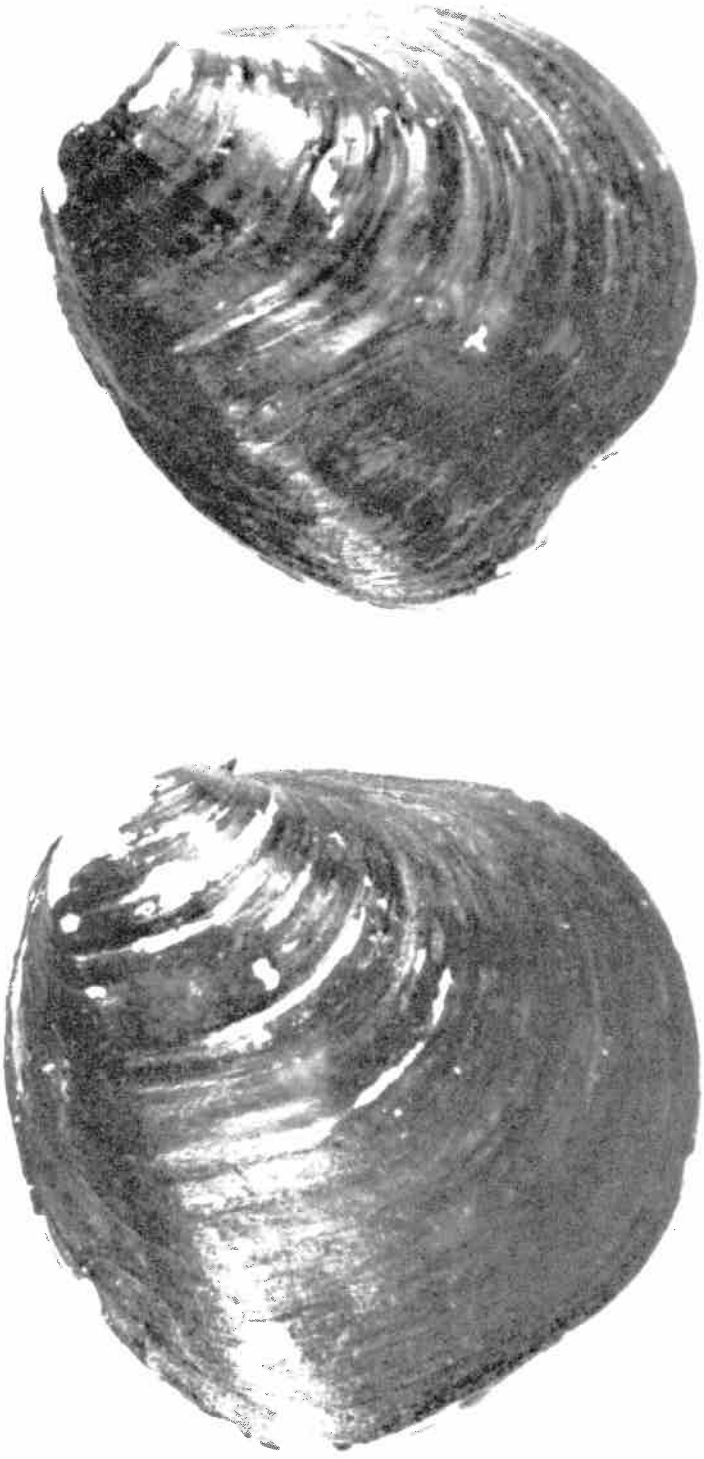


Figure 4. Typical naiad life cycle depicting various stages. The life cycle for most species of naiades is very similar to that depicted here (Grace and Buchanan 1981).



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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.

Rough Pigtoe Pearly Mussel
Pleurobema plenum

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	4&5	SE,ES,LE	Tennessee Valley Authority (TVA), Tennessee Wildlife Resources Agency (TWRA), Virginia Commission of Game and Inland Fisheries (VCGIF), 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.	4&5	SE	TWRA, THP, VCGIF, TVA, KDFWR, KNPC, and ADCNR	---	---	---	
R3,R8 R9,R10 R11	Characterize habitat and determine essential elements.	1.2.2	2	2 yr.	4&5	SE	TWRA, THP, VCGIF, 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.	4&5	SE	TWRA, THP VCGIF, TVA, KDFWR, KNPC, and ADCNR	---	---	---	
I12,I14	Determine present and foreseeable threats to species.	1.3.1 1.3.2	1	3 yr.	4&5	SE&ES	TWRA, THP, VCGIF, TVA, KDFWR, KNPC, and ADCNR	---	---	---	

Rough Pigtoe Pearly Mussel
Pleurobema plenum

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	4&5	SE&ES	TWRA, THP, VCGIF, TVA, KDFWR, KNPC, ADCNR, and Tennessee, Kentucky, Alabama, and Virginia Nature Conservancy (TNC)	---	---	---	
01,04	Solicit help in protecting species and essential habitat.	1.4.1 1.4.2 1.4.3 & 1.4.4	2	Continuous	4&5	SE&ES	TWRA, THP, VCGIF, 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	4&5	SE&ES	TWRA, THP, VCGIF, 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	4&5	SE&ES	TWRA, THP, VCGIF, 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.	4&5	SE	TWRA, THP, VCGIF, TVA, KDFWR, KNPC, 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&5	SE	TWRA, THP, VCGIF, TVA, KDFWR, KNPC, and ADCNR	---	---	---	

Rough Pigtoe Pearly Mussel
Pleurobema plenum

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	
M2	Reestablish populations within historic range as needed to meet recovery.	2.4	3	Unknown	4&5	SE	TWRA, THP, VCGIF, 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	4&5	SE,ES	TWRA, THP, VCGIF, 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	4&5	SE	TWRA, THP, VCGIF, TVA, KDFWR, KNPC, and ADCNR	---	---	---	
R8-R11	Determine the number of individuals required to maintain a viable population.	4.	3	Unknown	4&5	SE	TWRA, THP, VCGIF, 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	4&5	SE	TWRA, THP, VCGIF, TVA, KDFWR, KNPC, and ADCNR	---	---	---	
I1,I2	Develop and implement a monitoring program.	6.	2	Unknown	4&5	SE	TWRA, THP, VCGIF, TVA, KDFWR, KNPC, and ADCNR	---	---	---	
O4	Annual assessment of recovery program and modify where needed.	7.	2	Continuous	4&5	SE	TWRA, THP, VCGIF, TVA, KDFWR, KNPC, ADCNR, and TNC	---	---	---	

Appendix A

GREEN RIVER - KENTUCKY NATURE PRESERVES COMMISSION RECORDS

Date	Location	Number of Specimens
07/03/81	At Mumfordville, below U.S. Route 31 W bridge	2-2 subfossil
07/04/81	At Three Sisters Island, 5.0 km northeast of Mammoth Cave	2-2 weathered dead
07/03/81	At Rush Island, 1.5 miles west-southwest of Mumfordville	1-2 subfossil
09/30/80	Below Kentucky Route 185 bridge, 0.6 mile 55 W of Glenmore	1 weathered dead
07/05/82	At Dennison Ferry, 4.4 miles west of Northtown	

APPENDIX B

LIST OF REVIEWERS FOR THE ROUGH PIGTOE PEARLY MUSSEL RECOVERY PLAN
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