RECOVERY PLAN

WHITE WARTY-BACK PEARLY MUSSEL

(Plethobasus cicatricosus)

Recovery Plan for the White Warty-back Pearly Mussel

Plethobasus cicatricosus (Say, 1829)

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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 on every temperate and tropical climate, with approximately one-half of the extant species occurring 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. River systems with the most diverse freshwater mussel fauna known to occur are the Tennessee River with 90 species, the Cumberland River with 78 species, and the Ohio River with 72 species (Johnson, 1980).

Twenty-three American freshwater mussels are listed as endangered by the U.S. Department of the Interior. Almost all of these species were known from the Tennessee, Cumberland, and Ohio River systems. The white warty-back pearly mussel (*Plethobasus cicatricosus*) 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).

Plethobasus cicatricosus was described by Say in 1829 with its type locality listed as the Wabash River. Based on the small number of records for this species, *P. cicatricosus* was apparently rare or often confused with another closely related species, *P. cyphyus*. *Plethobasus cicatricosus* was reported by Hinkley and Marsh from the Cumberland River (Marsh, 1885); however, Wilson and Clark (1914) did not report any *P. cicatricosus* in their survey.

Distribution

Historical

Historical records for *P. cicatricosus* indicate this species is an Ohioan or Interior Basin species, where it is restricted to the Ohio,

Cumberland, and Tennessee River systems. This species has been reported from the Cumberland River by Marsh (1885) and the Holston River (Lewis, 1871). Plethobasus cicatricosus has also been reported from lower Wabash River in Indiana (Baker, 1906; Goodrich and van der Schalie, 1944; Parmalee, 1969) and the Ohio River (Call, 1885; Daniels, 1903; Sterki, 1907; Parmalee, 1960). Further, Stansbery (1972) reports archaeological specimens of P. cicatricosus from the Kanawha River in West Virginia; and Bogan and Parmalee (1983), Parmalee (1966), Morrison (1942), and Warren (1975) identified specimens from archaeological sites along the Tennessee and Cumberland Rivers. Stansbery (1964) also reported P. cicatricosus from the Tennessee River below Wilson Dam in northern Alabama. Historical records for P. cicatricosus prior to 1970 are summarized in table 1.

Table 1. Historical records for *Plethobasus cicatricosus* prior to 1970, and relict specimens recorded to 1982.

River	Source
Tennessee River	Bogan and Parmalee (1983) archaeological specimens Johnson (1980) Morrison (1942) Parmalee (1966) Simpson (1900, 1914) Stansbery (1964, 1971, 1976) Warren (1975)
Holston River	Lewis (1871)
Cumberland River	Bogan and Parmalee (1983) archaeological specimens Johnson (1980) Marsh (1885)
Ohio River	Call (1885, 1896, 1900) Daniels (1903) Goodrich and van der Schalie (1944) Johnson (1980) Lea (1829) Parmalee (1960) Simpson (1900, 1914) Stansbery (1962) Sterki (1907)
Wabash River	Baker (1906) Frierson (1911) Goodrich and van der Schalie (1944) Johnson (1980) Parmalee (1969) Say (1829) Simpson (1914)
Kanawha River, West Virginia	Stansbery (1972)

Present

Stansbery (1971) reported that all known recent records for P. cicatricosus over the past several decades were from the original Tennessee River channel. The age of individuals collected indicates these specimens were living there before impoundment. Stansbery further reported that no young specimens had been taken in recent years and that extinction was not far away unless conditions necessary for their reproduction were restored.

A few old specimens of P. cicatricosus are still occasionally taken by commercial mussel fishermen from the Tennessee River. One fresh dead specimen of P. cicatricosus was recently collected from a commercial mussel fisherman's cull pile in June 1979 (Leroy Koch, personal communication). This specimen was reported to have been harvested from the Tennessee River below Pickwick Dam (TRM 206.7) near Savannah, Tennessee. In January 1982 one additional fresh dead specimen of P. cicatricosus was found in the same commercial cull pile by the author and Koch. In each case both specimens were old individuals. These two specimens represent the only known recent records for P. cicatricosus found anywhere since last being reported from the Tennessee River in the mid-1960s (Stansbery, 1964). This species must be considered extremely rare and possibly on the verge of extinction. Numerous freshwater mussel surveys of the Tennessee River by Scruggs (1960), Bates (1962, 1975), Williams (1969), Isom (1969, 1971a, 1972), Yokley (1972), TVA (1979); and Pardue (1981) have all failed to find P. cicatricosus in the Tennessee River.

No live specimens of P. cicatricosus have been found in the Cumberland River since being reported by Marsh (1885). Freshwater mussel surveys of the Cumberland River by Neel and Allen (1964), Stansbery (1969), TVA (1976), Parmalee et al. (1980), and Sickel (1982) report no living

P. cicatricosus. Sickel (1982) reports finding one relic single-valve of P. cicatricosus, and Bogan and Parmalee (1983) report only archaeological specimens from the Cumberland River. Freshwater mussel surveys of the Ohio River by Williams (1969), Taylor (1980), Clarke (1981), and Taylor and Spurlock (1982) and a resurvey of the Ohio River in 1981 by John Williams (personal communication) report no evidence of P. cicatricosus. Parmalee (1960) reported only archaeological specimens of P. cicatricosus from the Ohio River. No living specimens of P. cicatricosus have been found in the Kanawha River (Clarke, 1981; Morris and Taylor, 1978) or the Wabash River (Krumholz et al. 1970; Meyer, 1974; Clark, 1976), both tributary streams to the Ohio River. Archaeological specimens of P. cicatricosus were reported from the Kanawha and Wabash Rivers by Stansbery (1972) and Parmalee (1969).

Based on the scarcity of recent information, P. cicatricosus may face extinction unless gravid females can be found for immediate life history studies and artificial propagation.

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. However, the majority of freshwater mussel species are 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.

Plethobasus cicatricosus (see photograph) was probably a big river shoal species living in sand and gravel substrates of larger rivers such as

the Ohio, Cumberland, and Tennessee. The valves of the shell are subovate in outline, thick, solid, and moderately inflated. Beaks are very high, full, and turned slightly forward over a well-developed lunule. The dorsal margin of the shell is almost straight, with the posterior and ventral margins evenly rounded. The posterior ridge is low, narrowly rounded where it ends in a blunt point at or below the median line. The surface of the shell is marked with low, uneven, concentric growth lines and a row of irregular knobs or tubercles restricted to the middle disc of the shell, leaving the anterior and posterior slopes of the shell free of sculpture. The outer covering of the shell (periostracum) is a rayless, greenish-yellow or yellowish-brown.

The left valve has two small sculptured, triangular pseudocardinal teeth and two short, thick, lateral teeth. The right valve can have one to three sculptured, pseudocardinal teeth and double lateral teeth. Beak cavities are broad, shallow, with anterior muscle scars deep and sculptured. Nacre color is white and iridescent posteriorly (Simpson, 1914; Ortmann, 1919; Parmalee, 1967; Bogan and Parmalee, 1983).

The life history for P. cicatricosus is unknown but probably is similar to that of most unionids and is briefly illustrated in figure 2. 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 midsummmer

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. The breeding season for P. cicatricosus is unknown, but this species may be tachytictic based on Wilson and Clark's (1914) observations for a closely related species, P. cooperianus.

The glochidia of P. cicatricosus have not been observed; however, many tachytictic bivalves' glochidia are hookless. Hookless glochidia typically have more a 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. cicatricosus are unknown, but the sauger (Stizostedion canadense) is reported to be the host fish for a closely related species, P. cyphyus (Surber, 1913; Wilson, 1916).

REASONS FOR DECLINE AND CONTINUED THREATS

Plethobasus cicatricosus was historically found only in large rivers and was never a common species. This Ohioan or Interior Basin species has become increasingly rare almost to the point of extinction throughout its known historic range. The reasons for the decline are 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 Engineeers 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 discharge include: altered temperature regimes, extreme water level fluctuations, reduced turbidity, seasonal oxygen deficits, and high concentrations of certain heavy metals. Biological responses attributable to these type environmental changes typically include reductions in the fish and benthic macroinvertebrate communities (Isom, 1971b). Ortmann (1925) witnessed the most famous location for freshwater mussels on the Tennessee River at Muscle Shoals, destroyed by the construction of Wilson Dam. 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. Stansbery (1971) reported that species typically found in riffles or shoals with sand and/or gravel substrates and rapid currents are becomming eliminated due to the conversion of rivers into barge canals and impoundments. Stansbery warns that P. cicatricosus occupies such a precarious position that extinction is inevitable unless conditions necessary for its reproduction are somehow restored.

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 substrate are most common in running water (Hynes, 1970). Increased silt transport into 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, unable to move away from silted conditions. Many species have been unable to survive in a layer of silt greater than 0.6 cm (Ellis, 1931). 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 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 survial of young fishes (Loar et al. 1980).

The tributary streams to the Tennessee River become very turbid with silt following heavy rains. Erosion silt is a common element of the impounded Tennessee River (Scruggs, 1960; Bates, 1962; Williams, 1969).

Pollution

A third factor that must be considered is the impact caused by various forms of pollutants. An increasing number of streams throughout the United States receive municipal, agricultural, and industrial waste discharges. The damage suffered varies according to a complex of 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); the French Broad River at Asheville, North Carolina; the Big Pigeon River, from Canton, North Carolina, all the way to its mouth (wood pulp and papermill); and the Tellico River below Tellico Plains, Tennessee (wood pulp and extracting mill). Yokley (1972), in his study of the mussel fauna of the Tennessee River in Kentucky Lake, reported that the mussel fauna had been damaged by industrial pollution.

PART II

RECOVERY

A. Recovery Objectives

The ultimate objective of this recovery plan is to maintain and restore viable populations* of P. cicatricosus 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. cicatricosus populations and (2) establishing populations in rivers and river corridors that historically contained P. cicatricosus. The remaining portions of this recovery plan are totally dependent on our ability to find extant populations of P. cicatricosus with gravid females for life history studies and/or artificial propagation. If intensive sampling efforts fail, the remaining pertinent portions of this recovery plan will remain in effect until specimens are found or the species is ruled to be extinct. 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. cicatricosus exists in the Tennessee River. This population is dispersed to an extent that it is unlikely that any one event would cause the loss of the entire population.

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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.

2. Through reestablishments and/or by discoveries of new populations, viable populations exist in two additional rivers. Each river will contain a viable population that is distributed such that a single event would be unlikely to eliminate P. cicatricosus from the river system. For reestablished populations, surveys 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.

B. Step-down Outline

Prime Objective: Locate viable populations of P. cicatricosus and recover the species to the point it no longer requires Federal Endangered Species Act protection.

1. Preserve any known population and presently used habitat of P. cicatricosus in any river system.
   - 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 Determine species' present distribution and status.
     - 1.2.1 Conduct population and habitat surveys.
     - 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 industries and solicit their support in implementing protective actions.

1.4.4 Meet with landowners adjacent to P. cicatricosus 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 additional mussel sanctuaries, Scenic River Status, and/or other means or combinations to protect the species.

2. Determine the feasibility of introducing the species back into rivers within its historic range and introduce where feasible.

   2.1 Survey rivers within the species' range to determine the availability and location of suitable transplant sites. This can include areas for population expansion within rivers where the species presently exists.

   2.2 Identify and select sites for transplants.

   2.3 Investigate and determine the best method of establishing new populations, i.e., introduction of adult mussels, juveniles, infected fish, artificially cultured individuals, or other means or combinations.

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

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

3. Conduct life history studies not covered under section 1.2.2 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 established populations, if found, 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 any known population and presently used habitat of *P. cicatricosus*. Stansbery (1971) reported that *P. cicatricosus* was occasionally taken over the last several decades from the impounded Tennessee River's original river channel. These specimens were believed to have been living there prior to impoundment. Two recent freshly dead specimens of *P. cicatricosus* were found in commercial mussel cull piles. The exact location(s) where these individuals were taken is unknown, but it is speculated that *P. cicatricosus* occurs in extremely low numbers below Pickwick (TRM 206.7) and possibly Wilson Dams (TRM 259.4) (Leroy Koch, personal communication). To date, successful reproduction is unknown for this species. If populations of *P. cicatricosus* are located, the immediate protection of these populations and habitat is crucial not only for the continued survival of the species but to gain the necessary knowledge needed to save the species from extinction.

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 Determine species' present distribution and status. Intensive dive/float surveys will be used where possible and the use of a commercial mussel fisherman.

1.2.1 Conduct population and habitat surveys. Commercial mussel fishing boats will be closely monitored on the Tennessee, Cumberland, and lower Ohio Rivers to help determine the presence of *P. cicatricosus* and to pin-point specific locations where additional specimens may be found for intensive study. Further, intensive dive/float surveys are recommended for the lower Ohio River from Owensboro, Kentucky, downstream to its mouth, and all State-protected mussel sanctuaries on the Tennessee and Cumberland Rivers. State-protected mussel sanctuaries are protected by law and should have remained relatively free from human disturbances (commercial harvest) since they were established. Some of these areas may provide specimens for life history studies and artificial propagation.

Areas recommended for surveys include:

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 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 253.0).

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 206.7) 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).

I. The Cumberland River upstream of CRM 264.0 at the mouth of Cedar Creek to CRM 265.5.

J. The Cumberland River between Bartletts Bar (CRM 296.0) and Cordell Hull Dam (CRM 313.5).

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. If gravid females are found for artificial propagation, additional studies are needed for *P. cicatricosus* to gain intimate knowledge of the species' habitat

requirements, enabling protection and propagation 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 modifications or impacts that might prove harmful to the species and its habitat. These impacts typically include dredging, channelizing, erosion, 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 sufficent 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, U.S. Fish and Wildlife Service, 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 industries and solicit their support in implementing protective actions. Industries along the river can have a substantial impact on the river's quality. Cooperation of these groups is essential in meeting the recovery goals.

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

1.4.5 Develop an educational program using such items as slide/tape shows and brochures. Present this material to business groups, civic groups, youth groups, church organizations, etc. A brief informative program or pamphlet is needed to point out basic problems, uniqueness of river systems, rarity of resources at risk, potential value of undisturbed systems, and

penalties for its abuse. This material could help to eliminate some 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 additional mussel sanctuaries, Scenic River Status, and other means or combinations to protect the species. The State of Tennessee has designated portions of the Tennessee and Cumberland Rivers as mussel sanctuaries, and the State of Alabama has designated some portions of the Tennessee River in Alabama as mussel sanctuaries. However, if *P. cicatricosus* is found in the lower Ohio River, no State protection is afforded these populations or habitat. Of course, Federal prohibitions against take apply wherever the species exists in the wild. Additional mussel sanctuaries may need to be established to protect any sites where *P. cicatricosus* occurs. Another viable option for protecting mussel habitat is through land purchases (islands). Immediate protection of any *P. cicatricosus* populations found is of 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 any *P. cicatricosus* populations found would be a significant step toward saving the species. However, life history studies and artificial culture must be accomplished before this species can recover to where it can be transplanted.

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. Transplants should first be considered in those river(s) with known populations. Before additional river systems can be restocked with the species, the availability of suitable habitat containing all the essential elements for the species' survival and possible 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 evaluated based on a correlation of stream characteristics with known populations of the species. Those streams or sites suggested for study include (1) Tennessee River at islands or sanctuaries, (2) Cumberland River at islands and sanctuaries, and (3) 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 combinations. If enough specimens are found during intensive dive/float surveys, immediate life history studies will be initiated. 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. Isom and Hudson (1982) were successful in artificially culturing some species of freshwater mussels, but the young individuals survived only 60 days. This method holds the most promise for species on the verge of extinction such as P. cicatricosus. Further studies will be conducted this summer to improve the in-vitro culture of mussel glochidia. Another possible method of establishing populations if additional gravid female P. cicatricosus are found would be to release host fish infected with glochidia. Further investigations and experimentations are required for determining which method(s) should be used for P. cicatricosus.

2.4 Introduce species within historic range where it is likely they will become established. If habitat is available and the introductions are likely to succeed, the introduction of the species to other rivers within its historic range should be initiated.

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

3. Conduct life history studies not covered under section 1.2.2 above, i.e., fish hosts, age and growth, reproductive biology, longevity, natural mortality factors, and population dynamics. Knowledge of the many varied aspects of the species life history will be needed to understand the species and protect its future.

4. Determine the number of individuals required to maintain a viable population. Theoretical considerations by Franklin (1980) and Soulé (1980) indicate that 500 individuals represent a minimum, theoretical population level (effective population size) that would contain sufficient genetic variation to enable that population to evolve and respond to natural habitat changes. The actual population size in a natural ecosystem corresponding to this theroetical population size can be expected to be larger, possibly by as much as 10 times. The factors that will influence the required actual population size include sex ratio, length of the species' reproductive life, fecundity, extent of exchange of genetic material within the population, plus other life history aspects of the species. Some of these factors can be addressed under Task 1.2.2.

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

6. Develop and implement a program to monitor population levels and habitat conditions of presently established populations as well as introduced and expanding populations. Once recovery actions are implemented, the response of the species and its habitat must be monitored to assess any progress toward recovery.

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

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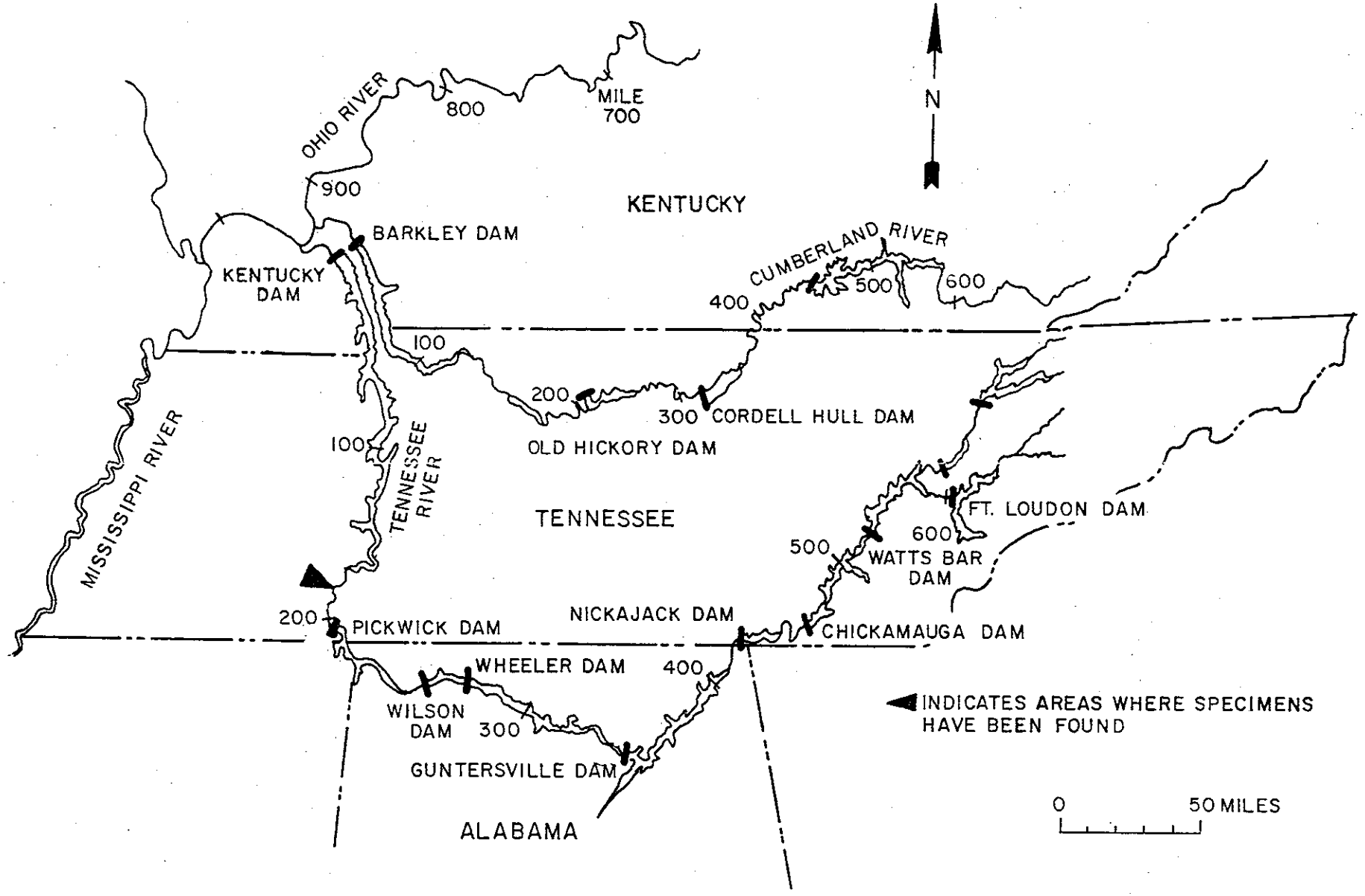


Figure 1: TENNESSEE RIVER - RECENT LOCATION FOR PLETHOBASUS CICATRICOSUS (SAY, 1829)

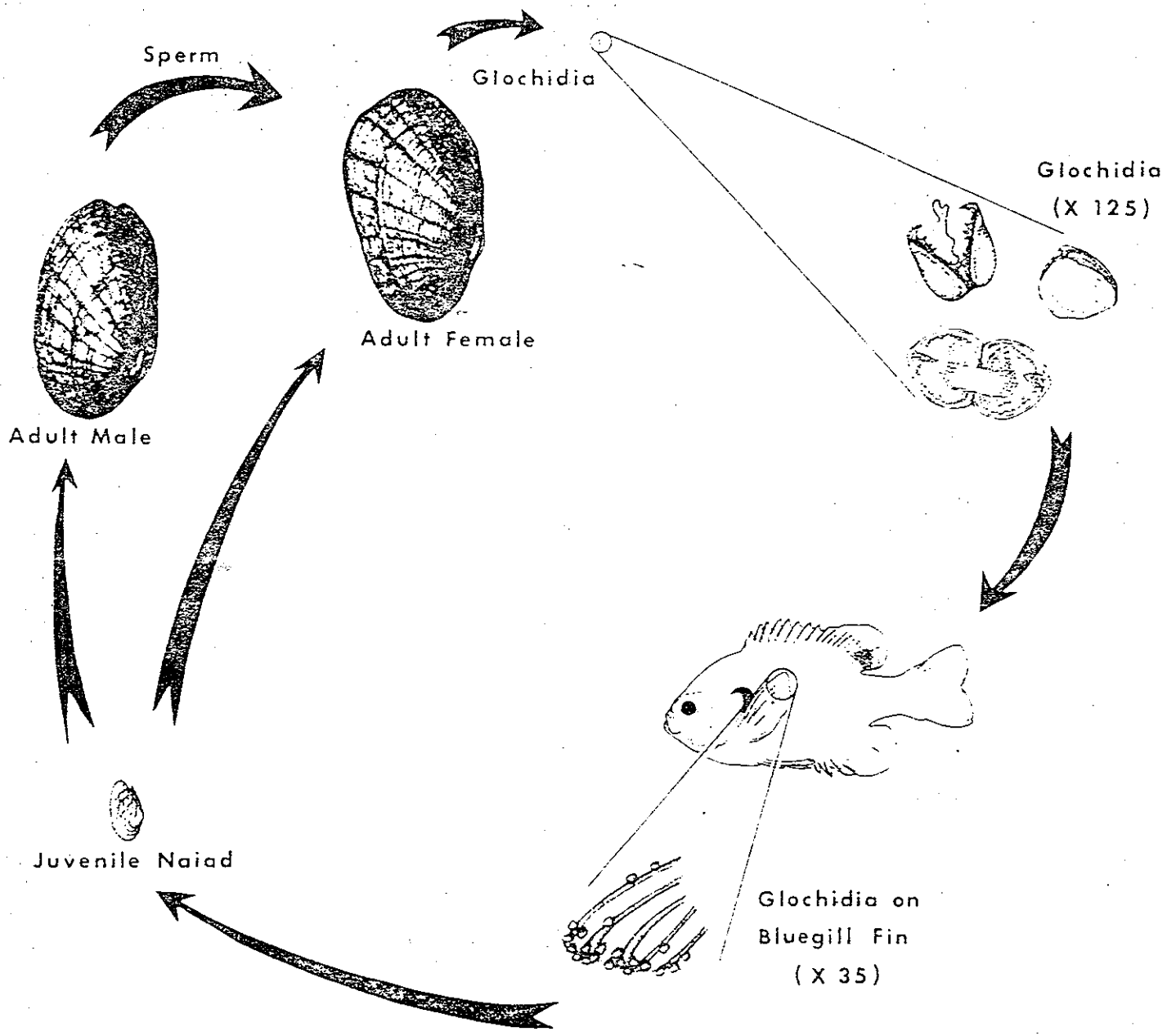
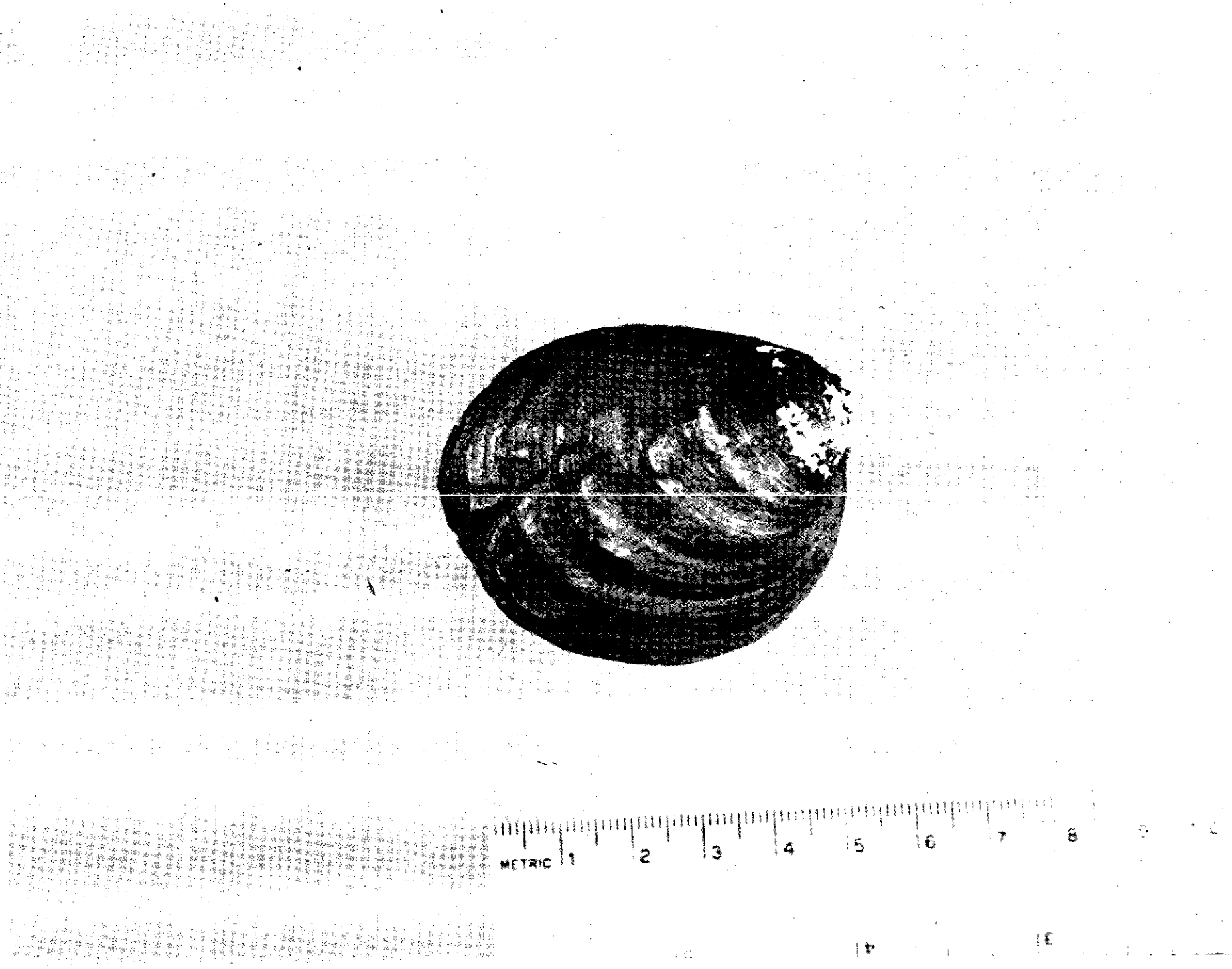


Figure 2. Typical naiad life cycle depicting the various stages. The life cycle for most species of naiades is very similar to that depicted here (Grace and Buchanan 1981).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KEY TO IMPLEMENTATION SCHEDULE COLUMNS 1 AND 4

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

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

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

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.

White Warty-back Pearly Mussel
Plethobasus cicatricosus

Part III Implementation Schedule

*1 General Category	Plan Task	Task Number	Priority	Task Duration	Responsible Agency FWS Region	Responsible Agency FWS Program	Responsible Agency *2 Other	Estimated Fiscal Year Costs FY 1	FY 2	FY 3	*3 Comments/Notes
✓ O1-04	Continue to utilize existing legislation and regulations to protect species and habitat.	1.1	1	Continuous	4	SE,ES,LE	Tennessee Valley Authority (TVA), Tennessee Wildlife Resources Agency (TWRA), Tennessee Heritage Program (THP), and Alabama Department of Conservation and Natural Resources (ADCNR)	---	---	---	*1. See general categories for Implementation Schedules. *2. Other agencies' responsibility would be of a cooperative nature or projects funded under a contract or grant program. In some cases contracts could be let to universities or private enterprises. *3. Note: Task costs have not been estimated for this plan. This species' present/historic distribution coincides with that of other listed species. Thus, a task aimed at this species will benefit others. Rather than attempting to apportion the costs to each species, recovery tasks will be estimated at a later date when the plans are combined on a watershed basis for implementation.
✓ I1,I2	Determine species' present distribution and status.	1.2.1	1	2 yr.	4	SE	TVA, TWRA, THP, and ADCNR	---	---	---	
✓ R3,R8 R9,R10 R11	Characterize habitat and determine essential elements.	1.2.2	2 (1)	2 yr.	4	SE	TVA, TWRA, THP, and ADCNR	---	---	---	
✓ R3,O2, M3	Determine the extent of preferred habitat and present information in a manner which identifies areas in need of special attention.	1.2.3 & 1.2.4	2	1 yr.	4	SE	TVA, TWRA, THP, and ADCNR	---	---	---	
✓ I12,I14	Determine present and foreseeable threats to species.	1.3.1 & 1.3.2	1	3 yr.	4	SE&ES	TVA, TWRA, THP, and ADCNR	---	---	---	
✓ M3,M7	Determine measures needed to minimize threats and implement where needed to meet recovery.	1.3.3	2	Unknown	4	SE&ES	TVA, TWRA, THP, ADCNR, and Tennessee and Alabama Nature Conservancy (TNC)	---	---	---	

White Warty-back Pearly Mussel
Plethobasus cicatricosus

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	Estimated Fiscal Year Costs: FY 2	Estimated Fiscal Year Costs: FY 3	Comments/Notes
✓	01,04	Solicit help in protecting species and essential habitat.	1.4.1 1.4.2 1.4.3. & 1.4.4	2	Continuous	4	SE&ES	TVA, TWRA, THP, ADCNR, and TNC	---	---	---	
✓	01	Develop and utilize information and education program (slide/tape shows, brochures, etc.) for local distribution.	1.4.5	2	1 yr. for developing continued implementation	4	SE&ES	TVA, TWRA, THP, ADCNR, and TNC	---	---	---	
✓	M7,A1-A7,03, 04	Investigate the use of Scenic River Status, mussel sanctuaries, land acquisitions, and/or other means to protect the species.	1.5	2	Unknown	4	SE&ES	TVA, TWRA, THP, ADCNR, and TNC	---	---	---	
✓	I13	Survey rivers within species' historic range to determine availability of suitable transplant sites.	2.1 & 2.2	3	1 yr.	4	SE	TVA, TWRA, THP, and ADCNR	---	---	---	Task 2.1-2.3 may not be required if other populations are found in task 1.2.1.
✓	R13,R7	Determine best method of establishing new populations.	2.3	3 (1)	2 yr.	4	SE	TVA, TWRA, THP, and ADCNR	---	---	---	
✓	M2	Reestablish populations within historic range as needed to meet recovery.	2.4	3	Unknown	4	SE	TVA, TWRA, THP, and ADCNR	---	---	---	

White Warty-back Pearly Mussel
Plethobasus cicatricosus

Part III Implementation Schedule

General Category	Plan Task	Task Number	Priority	Task Duration	Responsible Agency: FWS Region	Responsible Agency: Program	Responsible Agency: Other	Estimated Fiscal Year Costs: FY 1	Estimated Fiscal Year Costs: FY 2	Estimated Fiscal Year Costs: FY 3	Comments/Notes
✓ I12,I14 M3,M7	Implement same protective measures for these reestablished populations as for known populations.	2.5	3	Continuous	4	SE,ES	TVA, TWRA, THP, ADCNR, and TNC	---	---	---	
✓ R3,R6, R8,R9-R11, R14	Conduct life history studies on a need-to-know basis.	3.	2 (1)	Unknown	4	SE	TVA, TWRA, THP, and ADCNR	---	---	---	
✓ R8-R11	Determine the number of individuals required to maintain a viable population.	4.	3	Unknown	4	SE	TVA, TWRA, THP, and ADCNR	---	---	---	These studies will be developed and carried out where there is a specific need for data necessary to reach recovery.
✓ M3	Investigate the need for habitat improvement and implementation only where needed to meet recovery objective.	5.	2	Unknown	4	SE	TVA, TWRA, THP, and ADCNR	---	---	---	
✓ I1,I2	Develop and implement a monitoring program.	6.	2	Unknown	4	SE	TVA, TWRA, THP, and ADCNR	---	---	---	
✓ O4	Annual assessment of recovery program and modify where needed.	7.	2	Continuous	4	SE	TVA, TWRA, THP, ADCNR, and TNC	---	---	---	

APPENDIX

LIST OF REVIEWERS FOR THE WHITE WARTY-BACK PEARLY MUSSEL RECOVERY PLAN TECHNICAL/AGENCY DRAFT

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