Recovery Plan

Green-blossom Pearly Mussel
Epioblasma (=Dysnomia) torulosa gubernaculum

Recovery Plan for the Green-Blossom Pearly Mussel

Epioblasma (=*Dysnomia*) *torulosa gubernaculum* (Reeve, 1865)

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Atlanta, Georgia

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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

The tributary streams of the Tennessee and Cumberland River basins contain freshwater mussel species that are endemic to the southern Appalachian Mountains and the Cumberland Plateau region. Ortmann referred to these species as "Cumberlandian," and this region became known as one of the chief centers of freshwater mussel speciation. Ortmann (1924) defined the Cumberlandian region to include the drainages of the Tennessee River system from the headwaters to the vicinity of Muscle Shoals, in Colbert and Lauderdale Counties, Alabama; and the Cumberland River system from the headwaters to the vicinity of Clarksville, Montgomery County, Tennessee (Ortmann, 1925). Of the 90 species of unionids found in the Tennessee River 37 are Cumberlandian, as are 27 of the 78 found in the Cumberland River. These two assemblages contain the largest number of unionid species found in any of the world's rivers (Johnson, 1980). Of the 23 American freshwater mussel species listed as endangered by the U.S. Department of the Interior, 13 are members of the Cumberlandian faunal group. The green-blossom pearly mussel (*Epioblasma* (=*Dysnomia*) *torulosa gubernaculum*) was proposed as an endangered species in September 1975 (*Federal Register* 40(188):44329-44333) and was listed in June 1976 (*Federal Register* 41(115):14062-24067).

The green-blossom pearly mussel *E. t. gubernaculum* was described by Reeve in 1865 with no type locality given for the species. All records indicate this species is restricted to the upper headwater tributary streams of the Tennessee River above Knoxville. Additional records for E. t. gubernaculum also include the Green River in Kentucky (a tributary to the Ohio River) as reported by Ortmann (1926). This represents the only known record for E. t. gubernaculum outside the upper Tennessee River drainage. Recent conversations with David Stansbery (personal communication) report this record to be an error, and it is, in actuality, E. t. rangiana, that occurs throughout the Green River.

The distribution of E. t. gubernaculum in the upper Tennessee River drainage reflects the clinal variation of big river E. t. torulosa as discussed by Ortmann (1918) and Ball (1922). Ortmann (1918) separated these two species on the basis of poorly developed knobs and the compressed shell typical in the headwaters form E. t. gubernaculum, with the downstream or big river form E. t. torulosa being more inflated with well-developed knobs and turbercles. The headwaters form E. t. gubernaculum apparently graded into the downriver form of E. t. torulosa in the Tennessee River near Knoxville (Ortmann, 1920 and 1925).

DISTRIBUTION

Historical

Historically, E. t. gubernaculum is reported only from the upper headwater tributary streams to the Tennessee River above Knoxville. Ortmann's 1918 monograph on the naiads of the upper Tennessee River is the most significant work on that region's freshwater mussel fauna prior to the construction of impoundments on many of these streams. Most of the known historical distribution records for E. t. gubernaculum are found in Ortmann's monograph. Further, similar freshwater mussel surveys by Wilson and Clark

(1912 and 1914), and Neel and Allen (1964) have documented the mussel fauna in the Cumberland River and its tributaries prior to impoundment and extensive coal mining. However, of interesting note, _E. t. gubernaculum_ has never been reported from the Cumberland River or tributary streams. This seems unusual because of the occurrence of _E. t. gubernaculum_ in the upper headwaters of the Tennessee River system. On numerous occasions since 1975, relict specimens of _E. t. gubernaculum_ have been observed by TVA biologists in old muskrat middens on the Clinch, Holston, and North Fork Holston Rivers. Historical records for _E. t. gubernaculum_ prior to 1970 are summarized in Table 1.

Present

E. t. gubernaculum is presently known only from the free-flowing reaches of the upper Clinch River above the backwater impoundment of Norris Reservoir (Figure 1). The Clinch River is one of several larger tributary streams to the Tennessee River system.

One live specimen of _E. t. gubernaculum_ was recently found in the Clinch River by Richard Neves (personal communication) in July 1982 while freshwater mussel sampling at Pendleton Island, Scott County, Virginia (CRM 226.3). This is the first time _E. t. gubernaculum_ has been collected alive in the Clinch River since Stansbery (1973) collected it in 1965. Bates and Dennis (1978) in their survey of the Clinch River found one freshly dead specimen at Kyles Ford, Hancock County, Tennessee (CRM 189.5), in 1975. Additional freshwater mussel sampling in the Virginia portion of the Clinch River by Neves et al. (1980) produced no specimens of _E. t. gubernaculum_. TVA biologists conducted a 170-mile dive/float survey for mussels in the Clinch River from Cedar Bluff, Virginia (CRM 322.6), to State Highway 25E, Tennessee (CRM 153.8) (TVA, 1979a). Only relict, dead shells of _E. t. gubernaculum_ were found.

Table 1. Historical records for _Epioblasma_ (=_Dysnomia_) _torulosa gubernaculum_ prior to 1970, and relict specimens recorded to 1979.

River	Source
Tennessee River	Ortmann (1918) Johnson (1978)
Holston River	Ortmann (1918) Johnson (1978)
North Fork Holston River	Ortmann (1918) Johnson (1978)
South Fork Holston River	Ortmann (1918)
Nolichucky River	Ortmann (1918) Johnson (1978) Bogan and Parmalee (1983) relict specimen
Clinch River	Ortmann (1918) Stansbery 1965 (1970, 1971, 1973)
Powell River	Ortmann (1918) Johnson (1978)

Freshwater mussel surveys by numerous individuals have failed to document living population(s) of E. t. gubernaculum in any Tennessee tributary other than the Clinch River. Surveys in the Powell River by Dennis (1981), Ahlstedt and Brown (1980), Neves et al. (1980), and a 102-mile dive/float survey of the Powell by TVA biologists from Olinger, Virginia (PRM 167.4), to State Highway 25E, Tennessee (PRM 65.1), failed to find E. t. gubernaculum in the Powell (TVA, 1979b). Additional freshwater mussel surveys in the North, South, and Middle Forks Holston River by Neves et al. (1980), Stansbery (1972), Stansbery and Clench (1974, 1975, and 1978), and TVA (1976); Holston River (TVA, 1981); Big Moccasin Creek (Neves and Zale, 1982); Copper Creek (Ahlstedt, 1981); Nolichucky River (Mullican et al., 1960; TVA, 1980b); and the French Broad River (TVA, 1979c) all have failed to find living or freshly dead E. t. gubernaculum in these streams. E. t. gubernaculum currently exists only in the free-flowing reaches of the upper Clinch River above the backwater impoundment of Norris Reservoir.

ECOLOGY AND LIFE HISTORY

Cumberlandian freshwater mussels are most often observed in clean, fast-flowing water in substrates that contain relatively firm rubble, gravel, and sand substrates swept free from siltation. These mussels are usually found buried in the substrate in shallow riffle and shoal areas. E. t. gubernaculum is a Cumberlandian species (Bates and Dennis, 1978) that was restricted to the high gradient rivers of the Appalachian Mountains and the Cumberland Plateau. Since freshwater mussels are quite long lived--up to 50 years or more for some species--and rather sedentary by nature, they are especially vulnerable to stream perturbations. Of particular concern are the Cumberlandian species, which appear to have suffered severe population declines. Of the 22 Cumberlandian species recorded from the Tennessee River (Ortmann, 1925) in 1924 before the impoundment of Wilson Reservoir, all but 6 were apparently eliminated (Stansbery, 1964; Isom, 1969). TVA's recent mollusk investigations on the Tennessee River in 1978 produced only three Cumberlandian species (TVA, 1978; Pardue, 1981). Of particular concern are freshwater mussels of the genus Dysnomia Agassiz, 1852, (=Epioblasma Rafinesque 1831?) which includes E. t. gubernaculum and other Cumberlandian species.

Stansbery (1971) reports that all species of recent North American naiads believed to be extinct are members of the genus Epioblasma (=Dysnomia). Further, all the species in this genus are characteristic riffle or shoal species inhabiting those parts of streams which are shallow with sandy-gravel substrate and rapid currents. The eight species presumed extinct as reported by Stansbery (1971) were, with few exceptions, recorded from riffles of our largest rivers. This type of habitat has nearly been eliminated by impoundment of the large rivers. Neel and Allen's (1964) survey of the upper Cumberland Basin documented an almost total elimination of the genus Epioblasma (=Dysnomia) due to mine wastes. Six of the eight species reported were Cumberlandian forms.

E. t. gubernaculum is a compressed headwaters form of E. t. torulosa which occurred in the larger rivers. E. t. torulosa exhibits considerable ecophenotypic variation as to sculpture, or the lack of it, and to obesity. Ball (1922) showed the relationship in this species between strong tubercle development and large streamflow and between the lack of tubercles and small streamflow, as well as E. t. torulosa's tendency to be more compressed in smaller streams. Ortmann (1918) noted that typical big river E. t. torulosa from the Tennessee River has a row of prominent knobs across the middle of the shell. But these knobs vary greatly, and in the upstream direction, they have the tendency to become reduced, finally disappearing, thus passing into the condition seen in the next form (E. t. gubernaculum, Reeve). This form, E. t. gubernaculum, differs by the poorly developed or wanting knobs, and by the rather more compressed shell. Like other members of this genus, E. t. gubernaculum is categorized as a riffle or shoal species (Stansbery, 1971).

E. t. gubernaculum (see photo) is a medium-sized species which is sexually dimorphic as are other members of this genus. Shell outline is irregularly ovate, elliptical, or obovate. The valves are inequilateral, subinflated, and solid. The anterior end of the shell is rounded, and the posterior margin in the females is broadly rounded. The hinge ligament is short. The umbos are full, somewhat turned forward, and located in the anterior third of the shell, with beak sculpture being weak and corrugated. The posterior ridge in the males is rather low, narrowly rounded, and separated from the medial ridge by a broad furrow which ends ventrally in an emargination between the two ridges. Both the ridges and the furrow vary from smooth to having elevated knobs. The females are generally larger than the males and possess a large, flattened, rounded marsupial swelling or expansion which extends from the middle of the base to the upper part of the posterior end. The marsupial swelling is thin, usually dark green in color (Ortmann, 1918), and marked usually with small radial furrows. The surface of the shell has many distinct growth lines, and the outer covering of the shell (periostracum) is smooth and shiny, tawny, yellowish green, or straw colored, usually with numerous fine green rays.

The left valve has two triangular pseudocardinal teeth with slight interdentum and long, almost straight, lateral teeth. The right valve has three triangular pseudocardinals, a large tooth with a smaller tooth before and behind, and one large lateral tooth, sometimes with a vestigal tooth below. The umbonal cavity is typically shallow. The pallial line and muscle scars are well impressed. Nacre color varies from white to salmon-red (Bogan and Parmalee, 1983; Johnson, 1978; Simpson, 1914).

The life history of E. t. gubernaculum is presumed 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. Any female E. t. gubernaculum downstream from the males obtain these sperm during the normal process of siphoning water during feeding and respiration (Stein, 1971). Fertilization of the eggs by sperm occurs within the gills of the female. The fertilized eggs are retained in the posterior section of the outer gills, which are modified as brood pouches. Based on the position of the genus Dysnomia (=Epioblasma) in the subfamily Lampsilinae, it is assumed that the outer two demibranches are used for ovisacs (Heard and Guckert, 1970).

The family Unionidae is separated into two groups based on the length of time glochidia remain in the female (Ortmann, 1919). 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. This species appears to be a winter breeder based on

Ortmann's collection records. Breeding season probably begins in early August, glochidia being observed in September (Ortmann, 1919), implying that it is a bradytictic species.

The glochidia of *E. t. gubernaculum* might be called bean-shaped and are of the hookless type. The hookless type of glochidia has a more delicate shell, the valves of which are shaped like the bowl of a very blunt spoon and are most frequently parasitic on gill filaments of fish (Coker and Surber, 1911; Lefevre and Curtis, 1910). The fish host(s) for *E. t. gubernaculum* are unknown.

REASONS FOR DECLINE AND CONTINUED THREATS

E. t. gubernaculum is extremely rare, almost to the point of extinction. This species has apparently never had a wide distribution, being found only in the Tennessee River at or near Knoxville, where it grades into the big river form *E. t. torulosa*, a species now possibly extinct. The genus *Epioblasma* (=*Dysnomia*) as a whole has suffered extensively because members of this genus are riverine, typically found only in streams that are shallow with sandy-gravel substrate and rapid currents (Stansbery, 1971). Eight species of *Epioblasma* are presumed extinct and were, with few exceptions, recorded from riffles of our largest rivers, a greatly diminished type of habitat. Since the remaining specimens of this subspecies (if any) occur in the river containing the most abundant and possibly the most diverse extant freshwater mussel communities (Clinch River), it is likely that *E. t. gubernaculum* is being eliminated by levels or types of impacts that appear not to be killing other species occupying similar habitat(s). The reasons for this species' decline are not totally understood, but in general, impoundments, siltation, and pollution are speculated by various authors to be the major causes.

<u>Impoundment</u>

Possibly the single greatest factor which has contributed to this species' decline, as well as other members of the Cumberlandian fauna group, is the alteration and destruction of stream habitat due to impoundment of the Tennessee and Cumberland Rivers and their headwater tributary streams for flood control, navigation, hydroelectric power production, and recreation. Since the early 1930s and 1940s, the Tennessee Valley Authority, Aluminum Company of America (Alcoa), and the U.S. Army Corps of Engineers have constructed numerous dams on the Tennessee and Cumberland River systems. A total of 51 dams is integrated into the TVA water control system. TVA has 36 dams in the Tennessee River basin, of which 9 are located on the main river (Tennessee) and the rest on tributary streams. Five major impoundments are also located on the Cumberland River, with six additional dams located on tributary streams.

Stream impoundment affects species composition by eliminating those species not capable of adapting to reduced flows and altered temperatures. Tributary dams typically have storage impoundments with hypolimnial discharges and sufficient storage volume to cause the stream below the dam (reservoir tailwater) to differ significantly from both preimpoundment conditions in the same area and from comparable reaches above the reservoir. Possible effects of a hypolimnial discharge include: altered temperature regimes, extreme water level fluctuations, reduced turbidity, seasonal oxygen deficits, and high concentrations of certain heavy metals (TVA, 1980a). Biological responses attributable to these environmental changes typically include restricted fish and benthic macroinvertebrate communities (Isom, 1971). Hickman (1937) recorded numerous species of mussels and snails in the vicinity of the Norris Dam construction site prior to the impoundment of that reach of the Clinch River and predicted that the Norris Dam flood control project would have a deteriorating effect on the molluscan fauna. A. R. Cahn (1936) collected mussels extensively in the dewatered riverbed following closure of Norris Dam. Forty-five species of freshwater mussels and nine species of river snails were found in this reach of the Clinch River. In a return visit to the area below the dam 4 months later, not a single live mussel could be found.

Siltation

A second factor that has severely affected freshwater mussels, especially Cumberlandian species, is siltation. In rivers and streams, the greatest diversity and abundance of mussels are usually associated with gravel and/or sand substrates. These two types of substrate are most common in running water (Hynes, 1970). Increased silt transport into our waterways due to strip mining, coal washing, dredging, farming, logging, and road construction are some of the more obvious results of human alteration of the landscape. Hynes (1974) states that there are two major effects of inorganic sediments introduced into aquatic ecosystems. The first is an increase in the turbidity of the water with a consequent reduction in the depth of light penetration, and the second is a blanketing effect on the substrate. High turbidity levels due to the presence of suspended solids in the water column have a mechanical or abrasive action which can irritate, damage, or cause clogging of the gills or feeding structures of mollusks (Loar et al., 1980). Additionally, high levels of suspended solids may reduce or inhibit feeding by filter feeding organisms, such as mussels, causing nutritional stress and mortality (Loosanoff, 1961). Fresh-water mussels are quite long lived and rather sedentary by nature; many species have been unable to survive in a layer of silt greater than 0.6 cm in depth (Ellis, 1936). Since most freshwater mussels, especially the Cumberlandian forms, and the genus Epioblasma (=Dysnomia) are riverine species that require clean, flowing water over stable, silt-free rubble, gravel, and sand shoals, the smothering action by siltation is often severe. Fuller (1977) reported that siltation associated with poor agricultural practices and deforestation of much of North America was probably the most significant factor impacting mussel communities. The reproductive life cycle of the mussel can be affected indirectly from siltation by impacting host-fish populations either by smothering and killing fish eggs and larvae, reducing food availability, or filling of interstitial spaces in a gravel and rubble substratum, thus potentially eliminating both spawning bed and habitat critical to the survival of young fishes (Loar et al., 1980).

Coal production in the Appalachian region, which includes the headwater tributary streams to the Cumberland and Tennessee Rivers, has increased drastically in the last few decades. This change has been brought about largely by the necessity to provide relatively inexpensive coal supplies for the production of more than 80 percent of the electricity consumed in the eastern United States. The majority of this coal has traditionally been mined by auger and deep-mining techniques; however, strip mining is on the increase. By 1985, it is estimated that 67 percent of coal extraction will be accomplished by strip mining (Minear and Tschantz, 1976). Branson (1974) stated that the future of the entire upper Kentucky

River basin as well as that of the Cumberland River looks very bleak because mining operations are being intensified to meet the growing demand for coal. Neves et al. (1980) report that there are nine coal processing plants in the Clinch River sub-basin. This will result in increased silt runoff and escalate impacts to the freshwater mussel fauna, especially the Powell and Clinch Rivers of the Tennessee River system. Vaughan (1978) reported that so much land has been disturbed by mining in the New River watershed (a Cumberland River tributary in eastern Tennessee) that finding an unaffected stream to study fish and diatoms was extremely difficult. Branson (1974) reported silt (as a by-product of strip mining) is the most widespread pollution in North America. Branson and Batch (1972) found a 90-percent reduction in total benthic population size and number of species as a result of increased siltation. Mussel populations in the upper reaches of the Powell River (including tributary streams such as North Fork Powell, Callahan Creek, and Pigeon Creek) are already heavily impacted by silt and coal fines from coal-washing operations, and active and abandoned strip mines (Ahlstedt and Brown, 1980; Neves et al., 1980). On numerous occasions since 1975 the Powell River has been observed running black for long periods of time by TVA biologists and concerned fishermen. During the week of March 31, 1979, a biologist with the Tennessee Department of Public Health notified TVA biologists that the Powell River was running black near the head of Norris Reservoir, a distance of over 130 river miles downstream from its point source at a coal preparation plant in Appalachia, Virginia. This was confirmed that same week by a TVA biologist. Unless strong corrective measures are taken, the threat posed by coal-related siltation to endangered species in aquatic ecosystems of southwestern Virginia can be expected to grow in the future as coal production increases.

Pollution

A third factor which must be considered, although on a much broader scale, is the impact caused by various forms of pollutants. An increasing number of streams throughout the United States have been subject to municipal, agricultural, and industrial waste discharges. The damage suffered varies according to a complex of interrelated factors, which include the characteristics of the receiving stream and the nature, magnitude, and frequency of the stress or stresses applied. Often the degradation has been so severe and of such duration that the streams are no longer considered valuable in terms of their biological resources (Hill et al., 1974). Usually, these areas will not recover if there are residual effects from the pollutant, which makes the area unsuitable for aquatic organisms, or if there is an inadequate pool of organisms for recruitment and recolonization (Cairns et al., 1971).

The absence of freshwater mussels can logically be an indication of environmental disruption only when and where their former presence can be demonstrated (Fuller, 1974). It is very rare that the composition and size of the mussel fauna can be quantitatively and/or qualitatively correlated with a specific disruption, be it chemical or physical (Ingram, 1956). However, documentation is available concerning the adverse impacts of some pollutants on freshwater mussels, which also cause a change/decline in fish fauna through environmental alteration. Simpson (1899) mentioned the adverse effect of sawdust upon mussels as a false streambed. Wilson and Danglade (1914) noted that bark dislodged from logs driven downstream coated the bottom substrate of the Prairie River of Minnesota. Neel and Allen (1964) reported that coal mine acids in the major headwater tributaries of the Cumberland River have practically eliminated the most diverse known assemblage of mussel species belonging to the genus Epioblasma (=Dysnomia). This decline in the genus Epioblasma is typical of what has happened to many Cumberlandian species. A combination of toxic wastes, gravel dredging, and increased fertilizer and pesticide use has reduced the fresh-water mussel fauna in the Stones River from 45 to 30 species of freshwater mussels (Schmidt, 1982). Ortmann (1918) in his studies of the freshwater mussels of 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).

The North Fork Holston River in southwestern Virginia is one stream that has suffered greatly from chronic pollution. From 1894 to 1972, a chemical plant located along the North Fork Holston River near Saltville, Virginia, effectively eliminated stream life in much of the lower 80 miles of the river (Hill et al., 1974). Chemicals discharged into the river included sodium hydroxide, sodium carbonate, sodium bicarbonate, hydrozine, chlorine, and dry ice. Additional wastes consisting of sand, limestone particles, and mercury were also discharged into the river and later into settling lagoons located along the banks of the river (TVA, 1968). This plant ceased operation in 1972 because it could not economically comply with water quality standards. Activities are currently underway to correct this problem.

Ortmann (1918) reported 42 species and forms of freshwater mussels from the North Fork Holston River at and below Saltville, Virginia. More recent surveys in the North Fork indicate a good mussel fauna occurring above Saltville; however, the mussel fauna below Saltville had largely been extirpated (Neves et al., 1980; Stansbery and Clench, 1974; and TVA, 1976). C. C. Adams (1915) in his study of the pleurocerid river snail Io fluvialis indicated the North Fork Holston River I. fluvialis population had suffered greatly from the outfall of the chemical industry at Saltville since before 1900. No living native populations of I. fluvialis are now known to exist anywhere in the Holston River system (Stansbery, 1972; Stansbery and Clench, 1974).

Mussel surveys in the North Fork near the Virginia-Tennessee State line by TVA biologists in 1981 revealed eight species of mussels naturally occurring in this section of the river, giving an indication of gradual faunal recovery. Several mussel species and the pleurocerid river snail I. fluvialis were transplanted from the Clinch River to the North Fork Holston River from 1975 to 1978 (Ahlstedt, 1980) are still surviving and in some cases may be reproducing. Although young mussels were found at the transplant site, these mussels could be individuals from the initial transplants, the progeny of the transplanted mussels, or the result of a small but recovering resident population.

Another documented impact to the freshwater mussel fauna in the upper Tennessee River system occurred in the free-flowing reaches of the Clinch River above Norris Reservoir during two separate chemical spills which occurred in 1967 and 1970. In June 1967, a dike surrounding a fly ash settling lagoon collapsed, releasing a highly caustic alkaline slurry (pH 12) into the Clinch River below the Appalachian Power Company (APCo) generating facility at Carbo, Virginia. During this period, an estimated 162,000 fish were killed in the Virginia portion of the Clinch River (66 miles), and an additional 54,000 fish were killed in 24 miles of the Clinch in Tennessee, where the polluted mass was diluted (TVA, 1967). The Virginia State Water Control Board conducted a bottom fauna survey to assess the damage to fish food organisms. Their observations indicated that: (1) bottom-dwelling fish food organisms appeared to have been completely eliminated for a distance of approximately 3.0 or 4.0 miles below the spill, (2) a reduction in the number and kinds of bottom-dwelling fish food organisms occurred in the Clinch River for 77.0 miles below the spill, and (3) freshwater mussels and snails were eliminated for 11.5 miles below Carbo, Virginia. In June 1970, a second industrial spill occurred at the plant involving the release of an undetermined amount of sulfuric acid, which killed approximately 5,300 fish. Representatives of the Virginia State Water Control Board indicated that stream damage began approximately 1 mile below the APCo power plant and extended a distance of almost 18 miles downstream to St. Paul, Virginia. Fish populations sampled on the Clinch River near St. Paul, Virginia, following the fish kills by Raleigh et al. (1978) indicated rapid recovery of the fauna. Cairns et al. (1971) reported that recovery was apparently rapid for all faunal groups except mollusks. Recent freshwater mussel surveys of the Clinch River by Neves et al. (1980), TVA (1979a), and Bates and Dennis (1978) all report an almost total elimination of the freshwater mussel fauna from Carbo, Virginia (CRM 264.2) to Miller Yard (CRM 243.0). TVA's 1979 float survey of the Clinch River produced 12 species of freshwater mussels above the APCo generating facility at Carbo.

Only two species of mussels were found in a 20-mile reach below Carbo (TVA, 1979a). One can only speculate as to why the molluscan fauna has failed to recolonize this stretch of the Clinch. This may be due, in part, to the continued discharges of some effluents from the plant. In addition, coal fines have also been observed entering the Clinch River from Lick Creek, a tributary stream located above St. Paul, Virginia. This stream was observed to be running black with coal fines in August 1979 by USFWS and TVA biologists.

PART II

RECOVERY

A. Recovery Objectives

The ultimate objective of this recovery plan is to maintain and restore viable populations* of E. t. gubernaculum 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 E. t. gubernaculum populations and (2) establishing populations in rivers and river corridors that historically contained E. t. gubernaculum. 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 E. t. gubernaculum exists in the Clinch River from the backwaters of Norris Reservoir upstream to approximately CRM 280 and in the Powell River from the backwaters of Norris Reservoir upstream to approximately PRM 130. These two populations are dispersed throughout each river so that it is unlikely that any one event would cause the total loss of either population.
2. Through reestablishments and/or by discoveries of new populations, viable populations exist in two additional rivers. Each of these

*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.

rivers will contain a viable population that is distributed such that a single event would be unlikely to eliminate _E. t. gubernaculum_ from 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 coal-related problems and substrate quality have occurred in the Powell River, and no increase in coal-related siltation occurs in the Clinch River.

B. Step-down Outline

Prime Objective: Recover the species to the point it no longer requires Federal Endangered Species Act protection.

1. Preserve populations and presently used habitat of _E. t. gubernaculum_ with major emphasis on the Clinch River.

   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 strive to minimize and/or eliminate them.

1.3.1 Determine impacts of coal industry related pollution on nonendangered species.

1.3.2 Investigate and inventory other factors negatively impacting the species and its environment.

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

1.3.4 Determine measures that are needed to minimize and/or eliminate any adverse impacts and implement where necessary.

1.4 Solicit help in protecting the species and its essential habitat.

1.4.1 Meet with local government officials and regional and local planners to inform them of our plans to attempt recovery and request their support.

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

1.4.3 Meet with local mining and industry interests and solicit their support in implementing protective actions.

1.4.4 Meet with landowners adjacent to *E. t. gubernaculum* 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, land acquisitions, and/or other means or combinations to protect the species.

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

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

2.2 Identify and select sites for transplants.

2.3 Investigate and determine the best method of establishing new populations; i.e., introduction of adult mussels, juveniles, infected fish, artificially cultured individuals, 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. above; i.e., fish hosts, age and growth, reproductive biology, longevity, natural mortality factors, and population dynamics.

4. Determine the number of individuals required to maintain a viable population.

5. Investigate the necessity for habitat improvement and, if feasible and desirable, identify techniques and sites for improvement to include implementation.

6. Develop and implement a program to monitor population levels and habitat conditions of presently established populations as well as introduced and expanding populations.

7. Assess overall success of recovery program and recommend action (delist, continued protection, implement new measures, other studies, etc.).

C. Narrative Outline

1. Preserve the only known population and presently used habitat of *E. t. gubernaculum* in the Clinch River. The only known population of *E. t. gubernaculum* occurs in the upper Clinch River at Pendleton Island (CRM 226.3), Virginia. The immediate protection of this population 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 the full enforcement of existing laws and regulations.

1.2 Conduct population and habitat surveys. Most of this task has already been completed as part of the Cumberlandian Mollusk Conservation Program (Jenkinson, 1981) and other TVA projects since 1970. However, additional dive/float freshwater mussel surveys are recommended for the upper Clinch River between Cleveland, Virginia (CRM 272.0), to below Craft Mill, Virginia (CRM 219.2). This portion of the Clinch River was not adequately surveyed by TVA (1979a) due to cold weather conditions. Stansbery (1973) collected specimens of E. t. gubernaculum in the Clinch River at Dungannon, Virginia, in 1965. This reach of the Clinch River may be the only hope for finding gravid female E. t. gubernaculum. Urgent studies are necessary to prevent the extinction of E. t. gubernaculum. Further, intensive dive/float surveys are also recommended for the Middle and South Forks Holston River, French Broad River below Douglas Dam, and the Emory River (all tributaries to the upper Tennessee River).

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

1.2.2 Characterize the habitat, ecological associations, and essential elements (biotic and abiotic factors) for all life history stages. Some of the work necessary for the characterization of habitat has been accomplished as part of TVA's Cumberlandian Mollusk Conservation Program. The final report on this is expected in 1983. However, it will be necessary to have specific knowledge of the species' habitat requirements if the species is to survive. Ortmann (1918) considered E. t. gubernaculum to be the headwaters form of E. t. torulosa in the upper Tennessee system and to be analogous to E. t. rangiana in the upper Ohio River system. If these are indeed forms and not subspecies, the possibility of introducing E. t. rangiana into various parts or former ranges of E. t. torulosa and E. t. gubernaculum may be suggested.

1.2.3 Determine the extent of the species' preferred habitat where it occurs. After the types and quality of habitat are defined, it will be necessary to determine the extent of such habitat or availability in other rivers.

powerline corridors as well as pesticides and fertilizers for farm crops. Some of this work has already been completed for the Clinch and Powell watersheds by USFWS.

1.4.1 Meet with local government officials and regional and local planners to inform them of our plans to attempt recovery and request their support. The support of local government officials and planners will be essential if the river habitat is 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 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, Scouts, church organizations, etc. In spite of existing perturbations, the Clinch and Powell Rivers are probably two of the most biologically diverse river systems remaining in the southeastern United States. A brief informative program or pamphlet is needed to point out the basic problems, uniqueness of the river systems, the rarity of the resources at risk, the potential value of undisturbed systems, and the penalties for abuse. This material could help to eliminate some of the misconceptions about the value of preserving endangered species and their habitat. Educational efforts should also include all local, State, and Federal agencies, wildlife officers, and wildlife-oriented clubs. These programs could also be developed for television and local newspaper coverage.

1.5 Investigate the use of Scenic River Status, mussel sanctuaries, land acquisitions, and/or other designations to protect the species. The Clinch River appears eligible for

Scenic River status under the National Wild and Scenic Rivers Act (USDI, 1976). Such a designation would provide some additional protection for the species and its habitat. The State of Tennessee has designated all of the Clinch River in Tennessee as a mussel sanctuary, but the headwaters for the Clinch originate in Virginia. No protection is offered those mussel populations occurring in Virginia. The Nature Conservancy is actively pursuing land acquisition in the upper Clinch River to protect probably the greatest freshwater mussel diversity found anywhere in the southeastern United States. Protection of the upper Clinch River 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 immediate protection and preservation of the Clinch River population and habitat is crucial for the continued survival of the species. 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 the Clinch River population. The factors that caused extinction or population reductions at potential transplant sites must be remedied prior to attempts at established additional populations.

2.1 Survey rivers within the species' range to determine the availability and location of suitable transplant sites.

This can include areas for population expansion within rivers where the species presently exists. Before the river system can be restocked with the species, the availability of suitable habitat containing all the essential elements for the species' survival and reproduction must be determined. In some cases the physical habitat may be available for adults, but juvenile habitat or the proper fish host might not be present.

2.2 Identify and select sites for transplants. After the suitability of a particular river system has been determined, specific sites for transplants within that river must be identified. TVA as part of its Cumberlandian Mollusk Conservation Program has studied 15 potential transplant sites for another endangered freshwater mussel, *Conradilla caelata*. The current distribution for *C. caelata* overlaps with that of *E. t. gubernaculum* in the Clinch. As part of that program, each of these 15 sites was evaluated as potential transplant sites based on a correlation of stream characteristics with habitats of known populations of the species. Upon completion of all data analysis, four sites were chosen to receive *C. caelata* during the fall of 1982. One of these sites chosen is within the known historic distribution for *E. t. gubernaculum* in the upper Tennessee River system (i.e., North Fork Holston River). This site could also serve as a potential transplant site for *E. t. gubernaculum*. Further studies are required in the upper headwater tributary streams. Those tributary streams suggested for study include the (1) Holston River, (2) Middle and South Forks Holston River, (3) French Broad River below Douglas Dam, and (4) the Emory River all of the upper Tennessee River system.

2.3 Investigate and determine the best method of establishing new populations; i.e., introduction of adult mussels, juveniles, infected fish, artificially cultured individuals, or other means or combinations. Some of these methods are currently being tested by TVA as part of the Cumberland 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 *E. t. gubernaculum* 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 *E. t. gubernaculum*.

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

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

3. Conduct life history studies not covered under section 1.2 above; i.e., fish hosts, age and growth, reproductive biology, longevity natural mortality factors, and population dynamics. Knowledge of the many varied aspects of the species' life history will be needed to understand the species and protect its future. Life history studies for *Conradilla* have indicated that at least two species of darters, *Etheostoma zonale* and *E. blenniodes*, serve as fish host(s) for *Conradilla*. Data on other potential fish host(s) for all listed mussels is also needed.

4. Determine the number of individuals required to maintain a viable population. Theoretical considerations by Franklin (1980) and Soulè (1980) indicate that 500 individuals represent a minimum 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 can be expected to be larger, possibly by as much as 10 times. The factors that will influence actual population size include sex ratio, length of the species' reproductive life, fecundity, extent of exchange of genetic material within the population, plus other life history aspects of the species. Some of these factors can be addressed under Task 1.2.2, while others will need to be addressed as part of this task on a need-to-know basis.

5. Investigate the necessity for habitat improvement and, if feasible and desirable, identify techniques and sites for improvement to include implementation. 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 which cause erosion, bank slumping, and canopy removal. Other methods of habitat improvement should also be investigated.

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

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

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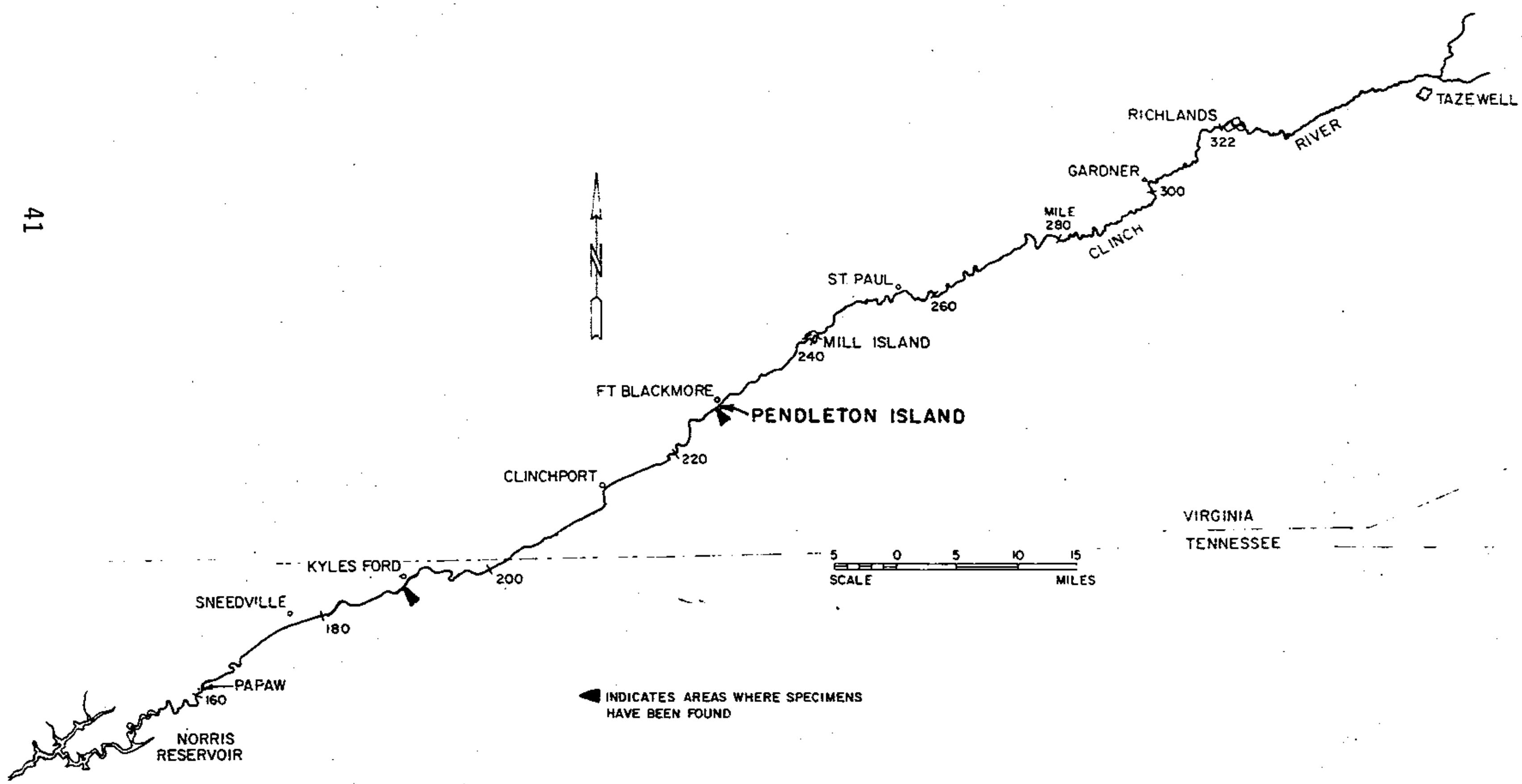

Figure 1 : Clinch River - *Recent Locations* EPIOBLASMA (= DYSNOMIA) TORULOSA GUBERNACULUM (Reeve 1865)

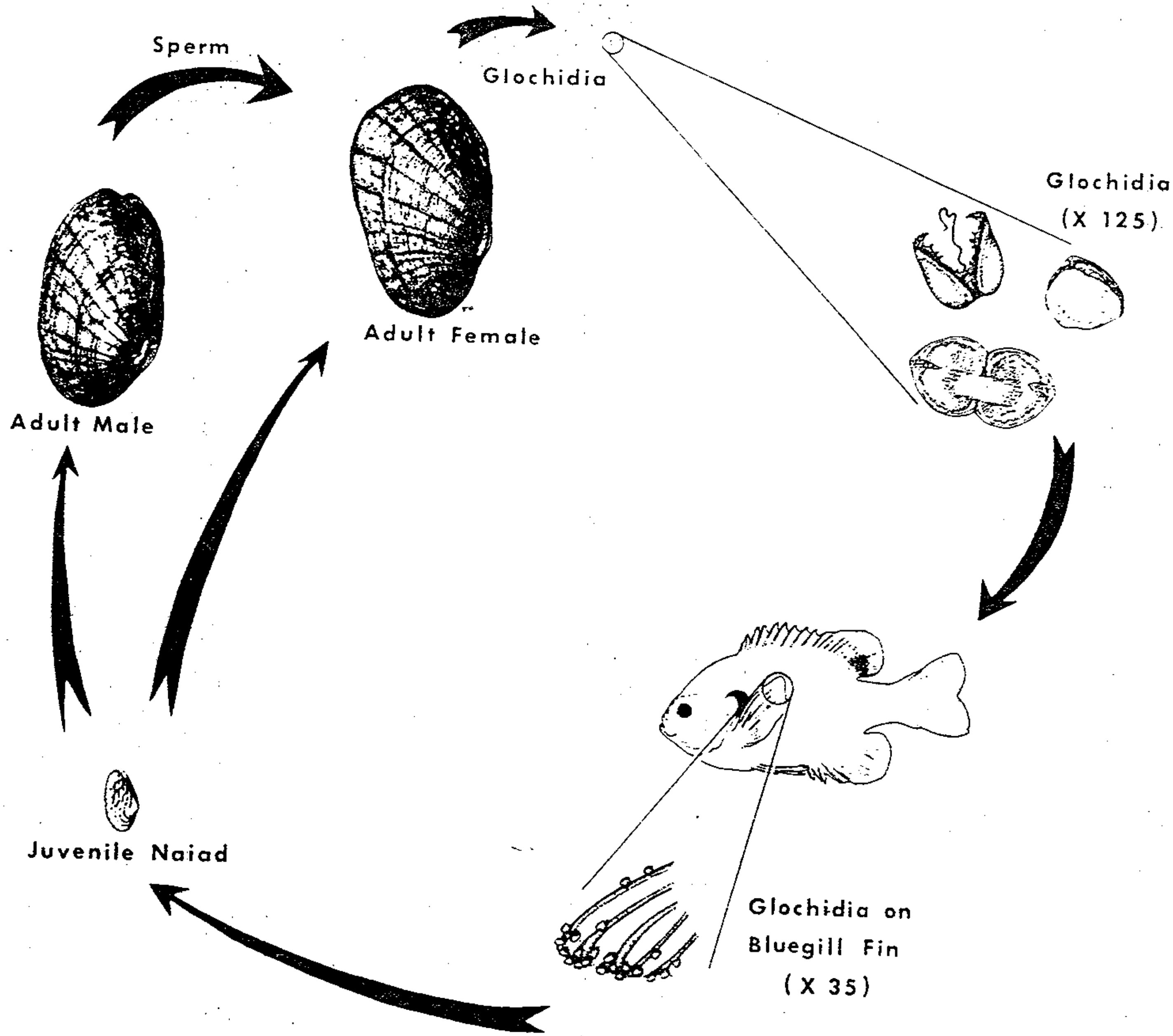

Figure **2.** Typical naiad life cycle depicting the various stages. The life cycle for most species of naiades is very similar t at depicted here (Grace and Buchanan 1981).


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Green Blossom Pearly Mussel
(*Epioblasma torulosa gubernaculum*)

Part III Implementation Schedule

*1 General Category	Plan Task	Task Number	Priority	Task Duration	Responsible Agency *2 FWS Region	FWS Program	Other	Estimated Fiscal Year Costs *3 FY 1	FY 2	FY 3	Comments/Notes
01-04	Continue to utilize existing legislation and regulations to protect species and habitat.	1.1	1	Continuous	4&5	SE&ES	Tennessee Valley Authority (TVA), TN Wildlife Resources Agency (TWRA), VA Comm. of Game and Inland Fisheries (VCGIF) and TN Heritage Program (THP)	---	---	---	*1. See general categories for Implementation Schedules. *2. Other agencies' responsibility would be of a cooperative nature or projects funded under a contract or grant program. In some cases contracts could be let to universities or private enterprises. *3. Note: Task costs have not been estimated for this plan. This species exists with other listed mussels in the same river systems. Thus, a task aimed at this species will benefit others. Rather than attempting to apportion the costs to each species, recovery tasks will be estimated at a later date when the plans are combined on a watershed basis for implementation.
I1,I2	Determine species' present distribution and status.	1.2.1	3 (1)	2 yr.	4&5	SE	TWRA, THP, VCGIF & TVA	---	---	---	
R3,R8, R9,R10 R11	Characterize habitat and determine essential elements.	1.2.2	2 (1)	2 yr.	4&5	SE	TWRA, VCGIF & TVA	---	---	---	
R3,02, M3	Determine the extent of preferred habitat and present information in a manner which identifies areas in need of special attention.	1.2.3 & 1.2.4	2	1 yr.	4&5	SE	TWRA, THP, VCGIF & TVA	---	---	---	
I12,I14	Determine present and foreseeable threats to species.	1.3.1 1.3.2 & 1.3.3	1	3 yr.	4&5	SE&ES	TWRA, VCGIF, TVA & THP	---	---	---	

Green Blossom Pearly Mussel
(Epioblasma torulosa gubernaculum)

Part III Implementation Schedule

*1 General Category	Plan Task	Task Number	Priority	Task Duration	Responsible Agency *2 FWS Region	Responsible Agency *2 FWS Program	Responsible Agency *2 Other	Estimated Fiscal Year Costs *3 FY 1	FY 2	FY 3	Comments/Notes
M3,M7	Determine measures needed to minimize threats and implement where needed to meet recovery.	1.3.4	2	Unknown	4&5	SE&ES	TWRA,VCGIF, TVA,THP & TN and VA Nature Conservancy (TNC)	---	---	---	
01,04	Solicit help in protecting species and essential habitat.	1.4.1 1.4.2 1.4.3 & 1.4.4	2	Continuous	4&5	SE&ES	TWRA,VCGIF, TVA,THP & TNC	---	---	---	
01	Develop and utilize information and education program (slide/tape shows, brochures, etc.) for local distribution.	1.4.5	2	1 yr. for devel. continued implementation	4&5	SE&ES	TWRA,VCGIF, TVA,THP & TNC	---	---	---	
M7,A1-A7,03,04	Investigate the use of Scenic River Status, mussel sanctuaries, land acquisitions, and/or other means to protect the habitat.	1.5	2	Unknown	4&5	SE&ES	TWRA,VCGIF, TVA,THP & TNC	---	---	---	
I13	Survey rivers within species' historic range to determine availability of suitable transplant sites.	2.1 & 2.2	3	1 yr.	4&5	SE	TWRA,VCGIF, TVA & THP	---	---	---	
R13,R7	Determine best method of establishing new populations.	2.3	3 (1)	2 yr.	4&5	SE	TWRA,VCGIF, TVA & THP	---	---	---	Task 2.1 - 2.3 may not be required if other populations are found in task 1.2.1.

Green Blossom Pearly Mussel
(*Epioblasma torulosa gubernaculum*)

Part III Implementation Schedule

General Category	Plan Task	Task Number	Priority	Task Duration	Responsible Agency FWS Region	Responsible Agency FWS Program	Responsible Agency Other	Estimated Fiscal Year Costs FY 1	FY 2	FY 3	Comments/Notes
M2	Reestablish populations within historic range as needed to meet recovery.	2.4	3	Unknown	4 & 5	SE	TWRA, THP VCGIF & TVA	---	---	---	
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, VCGIF, TVA, THP & TNC	---	---	---	
R3, 6, 8, 9, 10, 11 & 14	Conduct life history studies on a need-to-know basis.	3	1	Unknown	4 & 5	SE	TWRA, VCGIF THP & TVA	---	---	---	
R8-R11	Determine the number of individuals required to maintain a viable population.	4	3 (1)	Unknown	4 & 5	SE	TWRA, THP VCGIF & TVA	---	---	---	These studies will be developed and carried out where there is a specific need for data necessary to reach recovery.
M3	Investigate the need for habitat improvement and implement only where needed to meet recovery objective.	5	3 (2)	Unknown	4 & 5	SE	TWRA, THP VCGIF & TVA	---	---	---	
I1, I2	Develop and implement a monitoring program.	6	2	Unknown	4 & 5	SE	TWRA, THP VCGIF & TVA	---	---	---	
O4	Annual assessment of recovery program and modify where needed.	7	2	Continuous	4 & 5	SE	TWRA, VCGIF TVA, THP & TNC	---	---	---	

KEY TO IMPLEMENTATION SCHEDULE COLUMNS 1 & 4

General Category (Column 1):

Information Gathering - I or R (research)

1. Population status
2. Habitat status
3. Habitat requirements
4. Management techniques
5. Taxonomic studies
6. Demographic studies
7. Propagation
8. Migration
9. Predation
10. Competition
11. Disease
12. Environmental contaminant
13. Reintroduction
14. Other information

Acquisition - A

1. Lease
2. Easement
3. Management agreement
4. Exchange
5. Withdrawal
6. Fee title
7. Other

Other - O

1. Information and education
2. Law enforcement
3. Regulations
4. Administration

Management - M

1. Propagation
2. Reintroduction
3. Habitat maintenance and manipulation
4. Predator and competitor control
5. Depredation control
6. Disease control
7. Other management

Priority (Column 4):

1 - Those actions absolutely necessary to prevent extinction of the species.

2 - Those actions necessary to maintain the species' current population status.

3 - All other actions necessary to provide for full recovery of the species.

APPENDIX

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