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Recovery Plan

Shiny Pigtoe Pearly Mussel (*Fusconaia edgariana*)

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Fusconaia edgariana

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For

U.S. Fish and Wildlife Service

Region 4, Atlanta, GA

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Approved: Robert E. Gilmore

Associate Director, U.S. Fish and Wildlife Service

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THIS IS THE COMPLETED SHINY PIGTOE PEARLY MUSSEL RECOVERY PLAN. IT HAS BEEN APPROVED BY THE U.S. FISH AND WILDLIFE SERVICE. IT DOES NOT NECESSARILY REPRESENT OFFICIAL POSITIONS OR APPROVALS OF COOPERATING AGENCIES, AND IT DOES NOT NECESSARILY REPRESENT THE VIEWS OF ALL INDIVIDUALS WHO PLAYED A KEY ROLE IN PREPARING THIS PLAN. THIS PLAN IS SUBJECT TO MODIFICATION AS DICTATED BY NEW FINDINGS AND CHANGES IN SPECIES STATUS AND COMPLETION OF TASKS ASSIGNED IN THE PLAN. GOALS AND OBJECTIVES WILL BE ATTAINED AND FUNDS EXPENDED CONTINGENT UPON APPROPRIATIONS, PRIORITIES, AND OTHER BUDGETARY CONSTRAINTS.

THE RECOVERY PLANS FOR THE MUSSEL AND FISH SPECIES OF THE TENNESSEE RIVER VALLEY HAVE BEEN DEVELOPED ON A SPECIES BY SPECIES BASIS. THE FISH AND WILDLIFE SERVICE REALIZES THAT THIS METHOD HAS RESULTED IN SOME REDUNDANCY, BUT IT HAS ALLOWED US TO ADDRESS THE SPECIFIC RECOVERY NEEDS OF EACH SPECIES AS REQUIRED BY THE ENDANGERED SPECIES ACT. FOR IMPLEMENTATION PURPOSES, THE PLANS WILL BE CONSOLIDATED ON A WATERSHED BASIS AND THE NEEDS OF ALL LISTED SPECIES IN THAT SYSTEM WILL BE ADDRESSED.

LITERATURE CITATIONS SHOULD READ AS FOLLOWS:

U.S. Fish and Wildlife Service. 1983. Shiny Pigtoe Pearly Mussel Recovery Plan. U.S. Fish and Wildlife Service, Atlanta, Georgia. 67 pp.

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Part I

INTRODUCTION

The most diverse freshwater mussel (naiad) fauna in the world occurs in North America and consists of approximately 227 species, described since the late 18th century (Burch 1975). One of the major centers of mussel speciation in North America is located in the Cumberland Plateau Region of the southeastern United States, where headwater tributaries of the Tennessee and Cumberland Rivers are inhabited by 45 endemic or 'Cumberlandian' species (Ortmann 1924). Of the 23 species of mussels in the United States listed as endangered by the United States Department of the Interior, 13 belong to this Cumberlandian group. *Fusconaia edgariana*, the shiny pigtoe pearly mussel, is one of these Cumberlandian species that was listed as endangered on June 14, 1976 (*Federal Register* 41:24062-24067).

The shiny pigtoe was described as *Unio edgarianus* by Lea (1840) from the Holston River, Tennessee (TN) and the Tennessee River, Alabama (AL). A species was described as *Unio cor* by Conrad in 1834 from the Elk and Flint Rivers, AL which some taxonomists believe is the same species now known as *Fusconaia edgariana* (Lea). Since there is disagreement on the identity of *Unio cor*, the well known name *Fusconaia edgariana* will be used. A compressed headwater form, Fusconaia edgariana analoga, was described by Ortmann (1918) from the Clinch River, Virginia (VA). The federal listing of Fusconaia edgariana as endangered includes both forms.

F. edgariana is a medium-sized species distinguished by very smooth and shiny periostracum with prominent dark green to blackish rays on a yellow to brown background (Ortmann 1918) (see photo). Young specimens generally have bold black or green ray patterns whereas older specimens are dull brown in color with indistinct rays fading toward the valve margin. Valves are subtriangular, with surfaces marked by concentric growth checks and a median sulcus. Beaks are turned forward and anterior to the midline with rather deep beak cavities (Bogan and Parmalee 1983). The left valve contains two irregular pseudocardinal and two nearly straight lateral teeth, whereas the right valve has three pseudocardinals and one lateral tooth (occasional vestigial tooth ventrad). The pallial line is well-defined anteriorly and nacre color is white. Valves of male and female specimens exhibit no known dimorphism.

DISTRIBUTION

Historical

Although Fusconaia edgariana was first collected in 1834 from the Elk River, AL, Ortmann (1925) did not report this species during his survey of the river. However, a subsequent naiad survey (1965-1967) by Isom et al. (1973) in the Elk River collected the shiny pigtoe at three sites.

The Flint and Paint Rock Rivers in Alabama also contained populations of the shiny pigtoe (Ortmann 1918, 1925). Isom and Yokley (1973) noted its presence during their 1965-1967 surveys in the Paint Rock River, but they did not find it in the Flint River.

Ortmann (1918) reported F. edgariana from the Clinch River in Anderson County, TN and an abundance of the headwater form (F. e. analoga) up to Cleveland in Russell County, VA. Goodrich (1913) had previously collected F. edgariana from Cleveland, St. Paul, and Fink, VA. Stansbery (1973) sampled the Clinch River extensively from above Norris Reservoir to Tazewell, VA from 1963 to 1971 and reported F. edgariana from several unspecified sites.

In the Powell River, Ortmann (1918) noted the shiny pigtoe from Lytton Mill, Lee County, VA downstream to Claiborne County, TN. Stansbery (1970) reported that the only sizable population of F. edgariana occurred in the Powell but gave no specific localities. No other historical collection records for the Powell River were found in the literature.

Ortmann (1918) did not report F. edgariana from the Holston River proper, but he did observe the compressed form (F. e. analoga) in the North Fork Holston from Hawkins County, TN upstream to Holston, Washington County, VA. The mussel fauna below Saltville, VA was eliminated by toxic wastes (see Reasons for Decline).

In the Tennessee River, Lewis (1871) found *F. edgariana* from Knoxville, TN to 20 miles downstream. Hinkley (1906) collected the shiny pigtoe at Florence, AL (Muscle Shoals), and Ortmann (1918, 1925) noted its presence in the Tennessee River as far downstream as Cypress Creek near Florence, AL.

The known historic range of the shiny pigtoe therefore included sections of the Elk, Flint, Paint Rock, Clinch, Powell, North Fork Holston, and Tennessee Rivers. Apparently, *F. edgariana* was once common throughout much of the Tennessee River, but it was never recorded from the Duck or Cumberland Rivers. A synopsis of historical records for *Fusconaia edgariana* is presented in Table 1.

Present

Fusconaia edgariana has recently been taken (since 1970) from several tributaries of the Tennessee River. Present range of the species is summarized for the North Fork Holston River (Figure 1), Clinch River (Figure 2), Powell River (Figure 3), Elk River (Figure 4), and Paint Rock River (Figure 5).

Stansbery (1972) and Stansbery and Clench (1974) found *F. edgariana* in the North Fork from Saltville upstream to Broadford, VA. A density of one shiny pigtoe per 2 square meters was found in a 350 m section of river at North

Table 1. Historical records of *Fusconaia edgariana* collected prior to 1970.

River	Reference
Elk River	Conrad (1834) Frierson (1916) Isom et al. (1973)
Clinch River	Pilsbry and Rhoads (1896) Goodrich (1913) Ortmann (1918) Hickman (1937) Stansbery (1973)
Powell River	Ortmann (1918) Stansbery (1970)
Holston River	Lea (1840)
North Fork Holston River	Ortmann (1918) Stansbery (1972) Stansbery and Clench (1974)
Flint River	Conrad (1834) Frierson (1916) Ortmann (1918, 1925)
Paint Rock River	Ortmann (1918, 1925) Isom and Yokley (1973)
Tennessee River	Lea (1840) Lewis (1871) Hinckley (1906) Ortmann (1918, 1925) Stansbery (1964)
Poplar Creek, TN	Ortmann (1918)
Cypress Creek, AL	Ortmann (1925)

Holston Ford (NFHRM 86.9) (Kitchel 1983). Quadrat sampling at the USGS gauging station above Saltville (NFHRM 85.0) indicated a density of one shiny pigtoe per 5 square meters (Neves et al. 1980). TVA estimated a density of one shiny pigtoe per 10 square meters at this site (Parr et al. 1982). F. edgariana was also collected from the North Fork Holston River at Watson Gap Branch (NFHRM 87.8) and at the Route 633 bridge (NFHRM 88.6). This species does not occur in the Middle or South Forks of the Holston River (Stansbery and Clench 1975, 1978; Neves et al. 1980).

Fusconaia edgariana has been recently recorded in the Powell River by TVA (1979a), Neves et al. (1980), and Dennis (1981). TVA reported the shiny pigtoe from 14 sites on the Powell River between PRM 65.2 and PRM 136.1. Neves et al. (1980) collected F. edgariana at four sites between Fletcher Ford (PRM 117.4) and Hall Ford (PRM 128.4) in Virginia. Dennis (1981) found four additional sites inhabited by this species between Buchanan Ford, TN (PRM 99.2) and the Route 833 bridge in Virginia (PRM 120.4). Ahlstedt and Brown (1980) found that the most populated reaches of river were between Buchanan Ford, TN and Poteet Ford, VA (PRM 141.0). Silt and coal fines have drastically reduced the mussel fauna above Poteet Ford.

In the Clinch River, a 170-mile float survey (CRM 322.6-153.8) by TVA (1979b,c) located 20 sites with F. edgariana between Brooks Island, TN (CRM 184.5) and Artrip, VA (CRM 274.5). Neves et al. (1980) located the shiny pigtoe at six sites on the Clinch River in Virginia between the Scott County gauging station (CRM 211.1) and Nash Ford (CRM 279.5). Bates and Dennis (1978) found F. edgariana at four sites between Horton Ford, TN (CRM 199.0) and Nash Ford, VA. A scarcity of mussels for 15 river miles below Carbo, VA is attributed to toxic spills in 1967 and 1970 from the Appalachian Power Company (APCO) steam electric plant (see Reasons for Decline). Several live specimens of F. edgariana were found at St. Paul, VA (CRM 253.5) during a mussel salvage effort by TVA in December 1981 and May 1982. Two sites with F. edgariana were found on Copper Creek, a tributary to the Clinch River at Speer's Ferry, VA. These sites, CCRM 1.8 and CCRM 2.1, had a relatively diverse mussel fauna and included specimens of both the shiny and fine-rayed pigtoe, F. cuneolus (Ahlstedt 1981). Quadrat sampling by TVA at CCRM 1.9 indicated a density of three F. edgariana per 100 square meters (Barr et al. 1982).

TVA surveys on the Elk River in Tennessee and Alabama during 1980 reported nine sites with F. edgariana (Ahlstedt in press). These sites, ERM 70.5 to ERM 118.3, were all below Tims Ford Dam (ERM 133.3); no mussels were collected immediately below the impoundment (within 10 km).

Seven sites with F. edgariana were located on the Paint Rock River during a TVA survey in 1980 (TVA unpublished). The shiny pigtoe was found between the bridge at Little

Nashville, AL (PRRM 44.8) and PRRM 58.5. The Paint Rock tributaries, Estill Fork and lower Hurricane Creek in Alabama, were surveyed by TVA but no shiny pigtoes were found.

Mussel surveys in the following upper Tennessee River tributaries failed to collect live or relic valves of the shiny pigtoe: Nolichucky River (TVA 1980a), French Broad River (Harned 1979), Flint River (Isom et al. 1973), Buffalo River (TVA 1980b), and Holston River (TVA 1981).

ECOLOGY AND LIFE HISTORY

Fusconaia edgariana is typically a riffle species, found along fords and shoals of clear, moderate to fast-flowing streams and rivers with stable substrate (Bogan and Parmalee 1983). It does not inhabit deep pools or impounded areas as evidenced, for example, by its disappearance from the Clinch and Powell Rivers in the vicinity of Norris Reservoir and from the main stem of the Tennessee River. The species is usually found well-buried in the substrate during most of the year and is more readily visible in early summer (Kitchel 1983).

Fusconaia edgariana is sedentary and apparently susceptible to stream degradation. The importance of good water quality to this species is well illustrated in the North Fork Holston River above Saltville where a healthy population of shiny pigtoes still exists. More young shiny pigtoes (< age 4) were found in this river section than in any other tributary of the Tennessee River in Virginia (Neves et al. 1980).

The reproductive cycle of freshwater mussels appears to be similar among all species (Figure 6). During the spawning period, males discharge sperm into the water column, and the sperm are taken in by females during siphoning. Eggs are fertilized in the suprabranchial cavity or gills, which also serve as marsupia for larval development to mature glochidia. Members of the Unionidae exhibit two reproductive modes based on the length of time glochidia are retained in the gills of females (Ortmann 1911). Fertilization occurs in the spring in tachytictic mussels (short-term breeders) and glochidia are released during spring and summer. In bradytictic species (long-term breeders), fertilization occurs in mid-summer and fall, and glochidia are released the following spring and summer. Glochidial release for some bradytictic species also has been observed during fall and winter (Zale 1980). Upon release into the water column, mature glochidia attach to the gills and fins of appropriate host fishes to encyst and eventually metamorphose to the juvenile stage.

Fusconaia edgariana is a short-term breeder with all four gills serving as marsupia in females. Ortmann (1921) reported gravid *F. edgariana* from May 13 to July 13. In a recent life history study of the shiny pigtoe, Kitchel

(1983) first observed gravid females from the upper North Fork Holston River in early June. Shiny pigtoe glochidia were collected from the water column in the North Fork during late June and July. The glochidia are hookless and horse shoe-shaped, measuring approximately 0.14 mm in length and 0.17 mm in height. Kitchel (1983) found the gill lamellae of several cyprinid species infected with shiny pigtoe glochidia in the upper North Fork, Holston River. These species included Notropis galacturus (whitetail shiner), N. cornutus (common shiner), N. coccogenis (warpaint shiner) and N. telescopus (telescope shiner). Based on laboratory-induced infections, the common shiner and the whitetail shiner were tentatively identified as fish hosts for the shiny pigtoe (Kitchel 1983).

REASONS FOR DECLINE

Intensive industrial and agricultural development of the Tennessee Valley since the early 1900's has had a significant impact upon the mussel fauna inhabiting the Tennessee River basin. Dams were constructed to impound water for industrial and municipal needs, coal mining was increased to meet energy needs, and herbicides and pesticides were more heavily applied so that higher yields could sustain an ever-expanding population. This increase in development has resulted in a significant decline in mussel populations of the Tennessee River and its tributaries. The naiad fauna was severely reduced in some streams because habitat was destroyed by siltation, channelization, and pollution which directly affected all mussel species. Habitat destruction or change (i.e. from lotic to lentic) also reduced the number of native fish species inhabiting a river section and thus jeopardized the reproductive potential of mussels by removing fish hosts essential for glochidial metamorphosis.

Some streams and rivers in the Tennessee River system have been altered extensively, and it is unlikely that they will ever again sustain a diverse mussel fauna. In order for Fusconaia edgariana to recover, the effects of man's activities must be identified and efforts made to curb further destruction of habitat and water quality degradation. The following sections review environmental alterations in the Tennessee River system and how these changes are thought to have contributed to depletion of the naiad fauna, including the shiny pigtoe.

Impoundment

Dam construction in the upper Tennessee River system may have been the most significant factor contributing to the decline of the shiny pigtoe and other Cumberlandian species in this drainage. There are 48 hydroelectric dams within the Tennessee River basin, 29 owned and operated by TVA and 19 run by privately-owned utilities (F.E.R.C. 1981).

TVA owns a total of 36 dams; operates 9 multi-purpose reservoirs on the main-stem Tennessee River proper primarily for flood control and navigation, and 27 on its headwater tributaries for flood control, hydro-power, or recreation. A total of 51 impoundments constructed by the Army Corps of Engineers, TVA, or the Aluminum Company of America (Alcoa) on the Tennessee and Cumberland Rivers have eliminated large sections of riverine habitat within the historic range of many naiad species (Ahlstedt 1982). Ortmann (1925) published his study of the mussels of the Tennessee River below Walden Gorge because he witnessed the most famous and unique locality for naiads, Muscle Shoals, AL, destroyed by the construction of Wilson Dam.

The effects of impoundment on some mussel species inhabiting lotic systems have been well-documented. Scruggs (1960) speculated that natural replacement of *Pleurobema cordatum*, the pigtoe, was hampered in Wheeler and Chickamauga Reservoirs due to poor survival of glochidia in the environment and the elimination of fish hosts from the system. The accumulation of silt over favorable habitat was also suggested to be detrimental to all age classes of *P. cordatum*. Juveniles of most species were rarely taken, with only *Truncilla donaciformis* juveniles (silt-tolerant species) being found in any abundance. In Kentucky Reservoir, conversion from a lotic to lentic environment apparently altered the mussel fauna by eliminating those species which prefer firm gravel substrate (Bates 1962). Post-impoundment surveys have indicated that only species of the Anodontinae and Lampsilinae, which regularly inhabit muck and sand substrates, have survived and increased in abundance.

Fuller (1974) felt that siltation was the most significant adverse effect of impoundment. Other factors detrimental to mussel survival because of reservoirs include lowered temperatures, changes in pH, oxygen depletion in the hypolimnion, and dewatering of mussel beds below dams. Hypolimnial discharges from reservoirs produce cold tailwater conditions which alter the typical fish and benthic assemblages. Fuller stressed that these changes associated with inundation adversely affect both juvenile and adult mussels and also alter the native fish fauna, eliminating possible fish hosts for glochidia.

Isom (1971a) reported only four unionid species from Fort Loudoun Reservoir on the Tennessee River where Ortmann (1918) had previously reported 64 species prior to impoundment, including Fusconaia edgariana. Ortmann (1918) also reported F. edgariana from sites on the Clinch River above and below Norris Reservoir. Cahn (1936) collected 45 bivalve species prior to closure of Norris Dam. Four months post-impoundment, no mussels were found below the dam (Isom 1971b). In all likelihood, shiny pigtoes inhabiting the lower reaches of the Powell River were also eliminated after closure of this dam.

Isom et al. (1973) reported 48 mussel species collected from the Elk River from 1965 to 1967, including *F. edgariana*. With closure of Tims Ford Dam, they predicted a significant decline in those species requiring fast-flowing water. More recently, Ahlstedt (in press) found no live mussels for approximately 6 miles (10 km) below Tims Ford Dam.

Siltation

Silt derived from erosion in the Tennessee Valley originates from poorly implemented land use practices involving strip mining, road construction, forestry and agricultural operations. Coal mining wastes also contribute to the silt load in the upper Tennessee River and its tributaries. Freshwater mussels are long-lived and sedentary, unable to move to more favorable habitats when silt is deposited over mussel beds. Ellis (1936) found that mussels could not survive in substrate on which silt (0.6 - 2.5 cm) was allowed to accumulate; death was attributed to interference with feeding and suffocation. In this same study, Ellis determined that siltation from soil erosion reduced light penetration, altered heat exchange in the water, and allowed organic and toxic substances to be carried to the bottom where they were retained for long periods of time. This resulted in further oxygen depletion and possible absorption of these toxicants by mussels (Harman 1974).

Erosion silt is now a common element of the impounded Tennessee River (Scruggs 1960, Bates 1962, Williams 1969). Following heavy rains, tributary streams of the Tennessee become quite turbid and much of this turbidity has been observed as direct run-off from surrounding agricultural land. Sediment loads during high discharge may be abrasive to mollusk shells. Erosion of the periostracum allows carbonic and other acids to reach and corrode underlying shell layers (Harman 1974). Feeding mollusks respond to heavy siltation by instinctive closure of their valves, since irritation and clogging of the gills and other feeding structures occurs when suspended sediments are siphoned from the water column (Loar et al. 1980). Although mussels possess the ability to secrete mucus to remove silt from body tissues, Ellis (1936) observed dying mussels with large quantities of silt in their gills and mantle cavities.

Coal fines entering the Powell River and tributary streams of the Clinch River are contributing to the natural sediment loads already present in these streams. The upper Powell River and its tributaries are being heavily impacted by coal wastes from washing operations and strip mining activities (Ahlstedt and Brown 1980). However, very little is known about the effects of coal wastes on the mussel fauna. Branson and Batch (1972) noted that siltation levels in Kentucky streams affected by coal mining were 15 to 30 times higher than those found in streams outside mining areas, and this higher siltation decreased the abundance of benthic organisms by 90 percent in one year. Three substances associated with mining - pyrites, marcasites, and black amorphous pyrite - react with water and air, producing ferrous sulfate and hydrosulfuric acid which lower pH. Kitchel et al. (1981) observed in laboratory experiments that mussels in substrates with varying amounts of coal wastes moved more often than mussels in natural substrate. Mussels placed in tanks with coal fines in suspension did not siphon as frequently as mussels in reference tanks, indicating that coal fines can apparently interfere with normal feeding processes and may eventually produce chronic effects (Kitchel et al. 1981).

Twelve sites in the Powell River with endangered mussels were qualitatively examined for the occurrence of coal wastes, and an inverse correlation between mussel abundance and the quantity of coal wastes was noted (Kitchel et al. 1981). Biologists with TVA have observed on several occasions water with a high concentration of coal fines (black water) in the Powell River at the head of Norris Reservoir (Ahlstedt 1982). Deposits of coal washings measuring one meter in depth have been found at McDowell Ford on the Powell River (PRM 107.4) (Burkhead and Jenkins 1982). Jones (1982) researched the treatability of coal contaminated wastewaters and suggested that recovery of some of these wastes is cost-beneficial. Reclamation of this material by the coal companies would improve substrate and water quality in several streams and rivers of southwest Virginia.

Pollution

Several studies have investigated the effects of specific chemicals and heavy metals on mussels. Fuller (1974) reviewed the effects of arsenic, cadmium, chlorine, copper, iron, mercury, nitrogen, phosphorus, potassium, and zinc on naiads. Of the heavy metals, zinc was noted as the most toxic, whereas copper, mercury, and silver were less harmful. Nitrogen and phosphorus, entering streams through agricultural run-off, tend to organically enrich streams and affect both mussels and their fish hosts. Imlay (1973) studied the effects of different levels of potassium, an industrial pollutant associated with paper mills, irrigation return water, and petroleum brine. The maximum level of potassium which most mussel species could tolerate was 4 to 10 mg/l.

Recent studies on contaminants have focused primarily on heavy metal effects on mussels. Mathis and Cummings (1973) investigated concentrations of certain heavy metals (copper, nickel, lead, chromium, zinc, cobalt, cadmium) in the sediments, water, mussels, fishes and tubificids in the Illinois River. Mussels analyzed (*Fusconaia flava*, *Amblema plicata*, *Quadrula quadrula*) contained higher concentrations of all metals than the water and lower concentrations than sediments. Mussels concentrated zinc to a greater degree than fishes or tubificids; all other metals were accumulated to intermediate concentrations. Salanki and Varanka (1976) found that the rhythmic activity (siphoning) of *Anodonta cygnea* was reduced by 10 percent when exposed to 10-8 g/l of copper sulfate; the chemical was lethal at 10-3 g/l (1 ppm). Salanki (1979) investigated the behavior of *Anodonta cygnea* subjected to certain heavy metals (mercury and cadmium), herbicides, and pesticides (paraquat, lindane, phosphamidon, and phorate). The siphoning period of this species was reduced at some concentrations and the metabolic rate decreased. Manly and George (1977) collected *Anodonta anatina* from the River Thames and determined the distribution of zinc, nickel, lead, cadmium, copper and mercury in body tissues. Zinc and copper were most highly concentrated in the mantle, ctenidia, and kidneys; nickel levels were highest in the kidneys; lead in the digestive gland and kidneys; cadmium in the ctenidia, digestive gland and gonads; and mercury in the kidneys. Imlay (1982) reviewed most studies of heavy metal accumulation in mussel shells and noted that cadmium, copper, mercury, lead, manganese, and strontium are highly concentrated in shells. Because of this ability to accumulate heavy metals, mussels have been suggested as possible biomonitors of stream contamination (Foster and Bates 1978, Adams et al. 1981, Imlay 1982).

During his early surveys, Ortmann (1918) had already observed minor effects of pollution on the mussel fauna in the North Fork Holston River below Saltville, VA and the Powell River below Big Stone Gap, VA. Since that time, the decline in mussel populations has been steady with complete eradication of the mussel fauna in some stretches of streams once inhabited by large populations.

Fusconaia edgariana is presently found in the Holston River system only in the North Fork above Saltville. Historically, the shiny pigtoe inhabited the North Fork Holston downstream to Hawkins County in Tennessee (Ortmann 1918). From 1894 to 1972, the Olin plant in Saltville released various sodium and chloride wastes into the North Fork Holston River. From 1950 to 1972, mercury was used in the plant and up to 100 pounds per day was lost as spillage and vapor (Carter 1977). Although the plant ceased operations in 1972, leachate from the plant site and from 'muck ponds' bordering the river continued to contaminate the river for approximately 80 river miles (128 km) downstream (Turner 1982). Olin Mathieson finally began cleanup activities in August 1982, to include the digging of a trench around the 'muck ponds', dredging contaminated sediment from the river, and pouring concrete into cracks in the stream bedrock to prevent mercury leakage (VWRRC 1982).

The Holston River above Cherokee Reservoir in Tennessee receives discharges from major industrial and municipal sources, including Holston Army Ammunition Plant, Mead Corporation, Tennessee Eastman, and the city of Kingsport, TN. TVA (1978) studied water quality trends in this section of the Holston River and found significant decreases in waste discharges and improved BOD, dissolved solids and total nitrogen condition since 1968.

No problems with water quality in the North Fork Holston above Saltville were apparent from October 1972 through September 1981 (VSWCB 1981), and a healthy mussel population inhabits the river section above NFHRM 85.0 (RKM 136.0) (Neves et al. 1980). In 1981, TVA (unpublished) found eight mussel species in the North Fork Holston River (NFHRM 6.4) near the Virginia - Tennessee border, indicating that gradual recovery of the mussel fauna in the contaminated stretch of this river may be underway (Ahlstedt 1982).

In the Clinch River, Fusconaia edgariana is found above Norris Reservoir, TN. Its historic distribution in the Clinch River, VA was severely reduced by two chemical spills. In June 1967, a storage lagoon wall broke at the APCO generating plant at Carbo, VA releasing 198 million m3 of fly ash slurry (pH 12) into the river (Raleigh et al. 1978). The mussel fauna was eliminated for roughly 18 river miles (28 km) below Carbo (CRM 274.3) (Cairns et al. 1971). In June 1970, sulfuric acid was spilled from the same generating plant, killing most biota for 11 river miles (18 km) downstream (Cairns et al. 1971). Recent mussel surveys indicate that the lower river section specified by Cairns et al. (1971) apparently suffered only a partial kill. The fish fauna has recolonized the river section below Carbo (Raleigh et al. 1978), but there is no evidence of recovery by the mussel fauna (Bates and Dennis 1978, TVA 1979b, Neves et al. 1980).

Several towns on the Clinch and Powell Rivers in Virginia have been in violation of standards for fecal coliforms, as have Saltville and Gate City - Weber City on the North Fork Holston River (Neves et al. 1980, VSWCB 1981). Upper reaches and some creeks flowing into the Powell and Clinch Rivers have been designated as heavy metal and pH contaminated areas due to mining operations (Neves et al. 1980). One component of TVA's Cumberlandian Mollusk Conservation Program (Jenkinson 1981) was water quality analysis at several sites on the Clinch, Powell, Duck, Buffalo, Elk, Nolichucky, Paint Rock Rivers and Copper Creek (Clinch River). The Clinch and Powell River sites exhibited the highest values for total residue (suspended solids > 0.45 mm), and the Powell River sites did not fall within acceptable limits for fecal coliforms (Poppe 1982).

The Federal Water Pollution Control Act specifies that "an interim goal of water quality which provides for the protection of fish, shellfish, and wildlife and provides for recreation in and on the water be achieved by July 1, 1983."

In Virginia, the headwater streams of the Tennessee River total 498 river miles (797 km). The number of miles expected to meet the fishable, swimmable criteria by 1983 is 238 (381 km) (VSWCB 1981). Therefore, 260 river miles (416 km) in southwestern Virginia will not meet federal water quality standards in 1983. The Virginia State Water Control Board has designated the North Fork Holston River below Saltville as a major problem area because of harmful substances. The Powell River is also a major source of problems, with coal mine wastes and elevated coliform levels affecting 71 miles (113 km) of this river (VSWCB 1981). The upgrading of water quality through better wastewater treatment facilities, improved land use practices, coal waste removal, and monitoring of industrial effluents are essential elements for reversing the decline of the shiny pigtoe.

Part II

RECOVERY

A. Recovery Objectives

The ultimate goal of this recovery plan is to maintain and restore viable populations of *Fusconaia edgariana* 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 *F. edgariana* populations and (2) establishing or expanding populations within rivers and river corridors which historically contained this species. The shiny pigtoe pearly mussel shall be considered recovered, i.e., no longer in need of federal Endangered Species Act protection, when the following criteria are met:

1. A population of *Fusconaia edgariana*, with evidence of recent recruitment (specimens age 5 or younger), exists in (a) the North Fork Holston River above Saltville (NFHRM 85.0), Smyth County, VA, (b) the Clinch River from the backwaters of Norris Reservoir, TN, upstream to Nash Ford (CRM 280), Russell County, VA, (c) the Powell River from the backwaters of Norris Reservoir, TN, upstream to

Flanary Bridge, (PRM 130), Lee County, VA, (d) the Elk River in Lincoln County, TN, (e) the Paint Rock River in Jackson County, AL, and (f) Copper Creek in Scott County, VA. These populations are distributed widely enough within their rivers such that it is unlikely a single adverse event in a river would result in the total loss of that population.

2. Through re-establishment and/or discoveries of new populations, a viable population* exists in one additional river or two river corridors which historically contained the species. The river (corridors) will contain at least two population centers** which are dispersed to the extent that a single adverse event would be unlikely to eliminate Fusconaia edgariana from its re-established location. For a re-established population, surveys must show that three year-classes, including one year-class of age 10 or older, have been naturally produced within each of the population centers.

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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. Determining the number of individuals needed to meet this definition is one of the recovery tasks.

**population center - a single shoal or grouping of shoals which contain Fusconaia edgariana in such close proximity that they can be considered as belonging to a single breeding unit.

3. The species and its habitats are protected from present and foreseeable anthropogenic 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 or other energy-related impacts exists in the Clinch River.

B. Step-down Outline

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

1. Preserve populations and habitats of *Fusconaia edgariana* in the North Fork Holston, Clinch, Powell, Elk, and Paint Rock Rivers and in Copper Creek.

   1.1 Conduct population surveys and essential habitat analyses.

      1.1.1 Determine species' current distribution and range.

      1.1.2 Describe species' habitat (relevant physical, chemical, biological elements) for all life history stages.

1.1.3 Disseminate above information in a form for general use by appropriate public and private agencies.

1.2 Identify current and future anthropogenic threats to the species.

1.2.1 Work with municipal, state, and federal agencies to inventory possible negative impacts on the species and its habitat.

1.2.2 Solicit the cooperation of these governmental agencies to identify proposed and future projects that may affect the species and its habitat.

1.2.3 Document the effect of apparent threats to the species such as coal wastes and other environmental contaminants, and recommend corrective measures to appropriate agencies.

1.3 Solicit support for the mitigation or elimination of threats and for the protection and recovery of the species.

1.3.1 Keep state and federal agencies informed of recovery efforts and emphasize the need for enforcement of environmental laws and regulations.

1.3.2 Meet with municipal government officials to promote and collaborate on species protection; seek their assistance in zoning riparian land against overdevelopment.

1.3.3 Meet with appropriate mining, industry, and power company representatives and solicit their support in identifying and mitigating any negative impacts of their activities on the species and its habitat.

1.3.4 Meet with owners of riparian land adjacent to prime habitat for the species and solicit their support for habitat protection.

1.3.5 Investigate the feasibility of protecting the species and its essential habitat through special sanctuaries, state refuges, collecting permit restrictions for mussels, or other means.

1.3.6 Develop a grass roots educational program for civic, church, and school groups; define their role in endangered species and habitat protection.

2. Conduct life history research on the species, to include gametogenesis, fish host identification, age class structure, growth rate, life tables, and mortality factors.

3. Determine the feasibility of introducing the species into one additional river or establishing new population centers in two rivers where it currently resides; implement such activities where feasible.

   3.1 Locate suitable sites for habitation within these rivers which meet the environmental requirements for survival and reproduction of the species.

   3.2 Develop a successful method for establishing new population centers such as adult transplants, glochidia-infected fish hosts, juvenile introductions, or through artificially cultured individuals or other means.

3.3 Implement introductions based on results of 3.1 and 3.2.

3.4 The use of an experimental population designation as described in 10(j) of the Endangered Species Act, as amended, will be considered as an alternative for reestablishing populations on a case-by-case basis.

4. Outline and implement a schedule to monitor population levels and trends in extant and introduced populations and population centers.

5. Evaluate the success of individual activities and overall success of the recovery program; recommend revisions or additional actions as necessary to recover the species.

C. Narrative Outline

1. Preserve populations and habitats of *Fusconaia edgariana* in the North Fork Holston River, Clinch River, Powell River, Elk River, Paint Rock River, and Copper Creek. Based on recent survey data, *F. edgariana* occurs in greatest abundance in the North

Fork Holston, Powell, and Clinch Rivers, with lesser populations in the Elk River, Paint Rock River, and Copper Creek. Protection of these populations and their habitats is imperative for continued survival of the species and to create conditions conducive to natural population expansion.

1.1 Conduct population surveys and essential habitat analyses. The entire range of this species should be delineated prior to (low priority) or concurrently with (high priority) recovery activities.

1.1.1 Determine species' current distribution and range. Mussel population surveys were recently completed by several agencies, especially TVA as part of their Cumberlandian Mollusk Conservation Program (CMCP), and most historic locations have been surveyed. To complete these survey data for present distribution of the species, an intensive survey is required in the upper Clinch River between CRM 220 and 270. Additional mussel surveys are recommended for major, unsurveyed tributaries of the Tennessee River, to include the French Broad River, Emory River, and Sequatchie River.

1.1.2 Describe species' habitat (relevant physical, chemical, and biological elements) for all life history stages. Habitat characterization for this species at selected sites was conducted by Kitchel (1983) and by TVA in their CMCP (Jenkinson 1981). Comparable efforts are required for populations in other rivers so that environmental data from multiple sites can be statistically analyzed to define habitat requirements. Habitat protection will not be very effective until environmental requirements and preferred habitats of the species are identified. A habitat description for juveniles must await life history research (B.2.).

1.1.3 Disseminate above information in a form for general use by appropriate public and private agencies. The results of these scientific studies are to be transcribed and presented in a format, such as distribution maps and brief habitat characterizations, that will foster use by planning officials. A greater awareness of species presence by the staffs of federal and state regulatory agencies would minimize the wanton destruction or damage to species habitat.

1.2 Identify current and future anthropogenic threats to the species and take actions that will lead to their mitigation or elimination. The preservation of extant populations is dependent on meeting this objective. Available evidence indicates that environmental degradation and alteration have accounted for much of the reduction in the species' range. Each river inhabited by the species has and will be affected by environmental perturbations both unique to that system and common to all tributaries in the upper Tennessee River drainage.

1.2.1 Work with municipal, state, and federal agencies to inventory negative impacts on the species and its habitat. High visibility problems and events such as coal mining (Powell River) and toxic spills (Clinch River) have been easily identified, but more subtle deleterious effects associated with road and bridge construction, channelization, gravel dredging, flood control, and pesticide use must be identified and brought to the attention of regulatory agencies. Water pollution associated with coal mining appears to be the major problem affecting the shiny pigtoe population in the Powell River. A meeting with the state of Virginia and appropriate coal companies is recommended to determine whether habitat improvement (water quality, substrate) can be achieved for the Powell River population and how an improvement program can be implemented. Major threats to the populations in other rivers need to be identified.

1.2.2 Solicit the cooperation of these governmental agencies to identify proposed and future projects that may affect the species and its habitat. A working relationship must be established with agencies responsible for planning and evaluating proposed activities in and along these rivers. Designate a contact person to be notified when such proposals (e.g. discharge or project permits) are received for assessment, so that information on the species is provided for consideration in the approval process. For example, a coal slurry pipeline is being proposed for Virginia, one possible route using water from the Powell and Clinch Rivers to transport coal from southwest Virginia to Portsmouth, VA (Yucel 1982). Proposed construction of an offstream reservoir or route of the pipeline could potentially impact endangered mussel populations. Environmental concerns on projects such as this should be addressed at the feasibility stage to protect endangered mussels and their habitats.

1.2.3 Document the effects of apparent threats to the species such as coal wastes and other environmental contaminants, and recommend corrective measures to appropriate agencies. The expertise of research scientists should be sought to assess the potentially acute and chronic effects of suspected environmental pollutants and to recommend corrective measures. Financial support for such research should be sought from governmental agencies or from coal companies and private industries contributing those contaminants.

1.3 Solicit support for the mitigation and elimination of threats and for the protection and recovery of the species. Without the support of local residents to maintain and improve environmental quality in and around their towns, the recovery effort is less likely to succeed. A public information program through state and local news media should be initiated to inform all residents of recovery efforts and the importance of those local habitats for species survival.

1.3.1 Keep state and federal agencies informed of recovery efforts and emphasize the need for enforcement of environmental laws and regulations. There are adequate water quality and project permit laws and regulations currently to prevent further degradation of riverine ecosystems. These agencies must enforce existing regulations for this plan to meet recovery objectives (Part A). It is imperative that Section 7 of the Endangered Species Act be enforced as a protective measure. Effective law enforcement by water pollution control personnel, mining inspectors, fish and game wardens, and other field representatives of monitoring and enforcement agencies will undoubtedly aid in the recovery effort.

1.3.2 Meet with municipal government officials to promote and collaborate on species protection; seek their assistance in zoning riparian land against overdevelopment. Local officials responsible for enforcing laws and regulations pertaining to aquatic environments should be briefed on activities likely to impact the species. If non-point pollution problems such as poor land-use practices and agricultural run-off are identified, aid local officials and landowners in receiving appropriate assistance. A riparian zone to buffer urban and agricultural development may be essential in populated areas. Review the performance reports of sewage treatment plants in and above species' habitats and flag violations for remedial attention. The cooperation of local officials in protecting riverine habitat from illegal or illicit activities is essential.

1.3.3 Meet with appropriate mining, industry, and power company representatives and solicit their support in identifying and mitigating any negative impacts of their activities on the species and its habitat. Coal mining wastes, industrial effluents, and accidental toxic spills are known to be detrimental to mussels. Encourage these individuals to abide by their no-discharge certificate or approved point discharge levels and to implement additional precautions so that these levels are not exceeded.

1.3.4 Meet with owners of riparian land adjacent to prime habitat for the

<u>species and solicit their support for habitat protection.</u> This is probably the most important local group that can recognize and report new environmental problems as they occur. Consult with local officials and landowners to determine whether easements, cooperative agreements, or other means of riparian protection are feasible. Riparian land for sale near prime species' habitat should be brought to the attention of private conservation groups such as The Nature Conservancy.

1.3.5 <u>Investigate the feasibility of protecting the species and its essential habitat through special sanctuaries, state refuges, collecting permit restrictions for mussels, or other means.</u> Meet with representatives of the appropriate state fish and game agencies to determine if special status can be assigned to particularly prime habitat for the species. For example, Tennessee has designated its sections of the Clinch and Powell Rivers as mussel sanctuaries and prohibits the commercial or recreational collecting of any mussels. Such arrangements may be possible in Virginia, Alabama, and other locations in Tennessee where the shiny pigtoe occurs. The incidental taking of endangered specimens by commerical musselmen needs corrective action.

State programs on flood plain regulation and scenic, wild, or recreational rivers have been adopted in at least 24 states (Kusler 1978) and may be appropriate for states with essential habitats amenable to protection via these means.

Determine whether any of the major river sections with the species qualifies for protection under the federal Wild and Scenic Rivers Act (Pub. L. 90-542) and explore other existing legislative means of habitat protection. Consultation services are to be provided to the state agencies and Federal Wildlife Permit Office to prevent the overcollection of mussels or fishes for scientific or other purposes in essential habitat areas.

1.3.6 <u>Develop a grass roots educational program for civic, church, and school groups; define their role in endangered species protection and recovery.</u> A public education campaign is needed to muster support for endangered species recovery. Public awareness of (1) these unique ecosystems and their biota, (2) endangered species legislation, and (3) species protection and recovery should be summarized in an educational format (e.g. slide-tape series, brochures, etc.). Publicity for endangered species issues and projects via the popular magazines of state fish and wildlife agencies is an effective means of presenting endangered mussel protection and recovery to residents. Encourage the information and education sections of these state agencies to use this medium to obtain support for this and other recovery efforts.

2. <u>Conduct life history research on the species, to include gametogenesis, fish host identification, age class structure, growth rate, life tables, and</u>

mortality factors. Unless the species' life cycle and environmental requirements are defined, all recovery efforts may be inconsequential or misdirected. If recovery is to be expedited biologically (e.g. artificial propagation), research on life history aspects is needed. It is recommended that species research be initiated on a need-to-know basis through Section 6, contracts, or other means and that malacologists and other biological scientists are assisted in procuring funds for basic and applied research of value to recovery of the species. Financial support for endangered mussel research will be contingent upon appropriations, species priorities, and other budgetary constraints within the Fish and Wildlife Service (FWS). Because of this, it would be beneficial to develop a research package, to include the shiny pigtoe and other endangered mussels in the upper Tennessee River, that will address common data needs for all these species. This would optimize the utility of research results for the recovery efforts of several species. Virginia has initiated an endangered mollusk study financed by monies donated in a state income tax check-off program for non-game conservation. The use of monies from these check-off programs in Virginia and Alabama for endangered mussel studies should be encouraged. There is ample expertise available within the scientific community to address biological and environmental issues critical to survival and recovery of this and other endangered mussels. Because of limited fiscal support within FWS, encourage these professionals to seek outside funding sources for conducting basic and applied research on the Unionacea.

3. Determine the feasibility of introducing the species into one additional river or establishing new population centers in two rivers where it currently resides; implement such activities where feasible. There are sections of river within the species' historic range which appear suitable for re-establishing populations and expediting recovery.

   3.1 Locate suitable sites for habitation within these rivers which meet the environmental requirements for survival and reproduction of the species. Habitat suitability of likely transplant sites should be determined, to include substrate, water quality, fish host presence, and any other critical factors identified in 2. An initial screening of potentially suitable transplant sites for the endangered birdwing pearly mussel (*Conradilla caelata*) was conducted by TVA as part of their CMCP. Since the distribution of the birdwing overlaps that of the shiny pigtoe in the Clinch, Powell, and Elk Rivers, several of these sites may be suitable for transplants of either species. Based on these data for several rivers and additional habitat studies within the historic range of the shiny pigtoe (e.g. North Fork Holston River below Saltville, Clinch River below Carbo, upper Tennessee River and Flint River), a list of apparently suitable transplant sites can be developed.

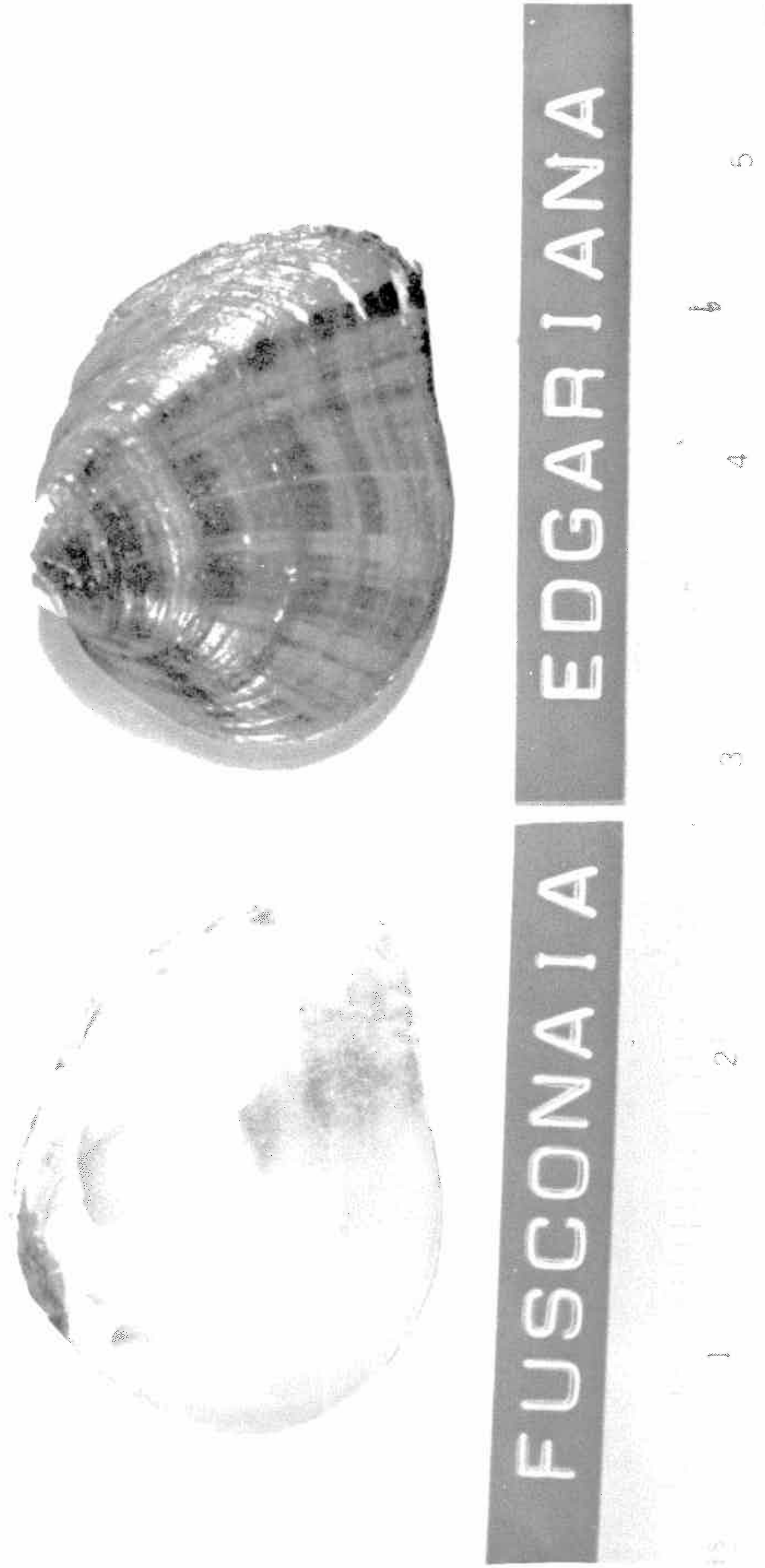
3.2 Develop a successful method for establishing new population centers, such as adult transplants, glochidia-infected fish hosts, juvenile introductions, or through artificially cultured individuals or other means. At least two ongoing projects, one by TVA and the other by the Virginia Cooperative Fishery Research Unit (VCFRU), are (1) evaluating adult transplants to establish populations, and (2) attempting to re-establish mussel populations via glochidia-infected fish hosts (VCFRU) in two tributaries of the upper Tennessee River drainage. An artificial medium for the in vitro metamorphosis of glochidia to juveniles has been developed (Isom and Hudson 1982) and offers potential for the production of juveniles to supplement or establish populations. Experimental trials comparing each of these methods under similar field conditions using common mussel species are required to evaluate the success of each and their practicality for the shiny pigtoe. Results of these initial field studies with common mussel species can then be used to recommend a method or methods likely to establish population centers specified in A.2.

3.3 Implement introductions based on results of 3.1 and 3.2. The number of individuals (adults or juveniles) available for transplanting and the number needed to maintain genetic variability in a viable population on a long term basis are issues that must be resolved before any transplant effort is implemented. Individuals used for the purpose of establishing new populations or population centers are to be obtained from healthy populations with an apparent surplus or from laboratory-produced specimens. All of the factors affecting genetic constitution in a population are influenced by the environment (Berry 1974). Of primary concern in establishing a small population is genetic drift, random genetic change and the fixation of deleterious genes, which reduces the pool of genetic variablilty upon which natural selection operates. Based on available but limited data from animal husbandry and population genetics, consideration of inbreeding alone dictates a minimum effective population size of 50 individuals, assuming random mating (Franklin 1980). To maintain genetic variability and evolutionary potential of a population on a long term basis, roughly 500 individuals are recommended (Soule 1980). Since the number of founders in a population is of lesser importance than effective population size over time, viable populations may be re-established by (1) starting with a relatively small initial transplant, and (2) increasing genetic diversity by the periodic introduction and/or exchange of individuals from other populations until an effective population size is achieved. Consultation with population geneticists and field malacologists is essential to determine available numbers and needed numbers for transplant efforts to achieve likely, long-term success. At this stage of the recovery effort, discussions must be held with the appropriate biologists to resolve the numbers issue and mode of population establishment.

3.4 The use of an experimental population designation as described in 10(j) of the Endangered Species Act, as amended, will be considered as an alternative for reestablishing populations on a case-by-case basis. As experimental populations, these individuals are to receive the protection specified in the 1982 amendments (section 10, subsection J).

4. Outline and implement a schedule to monitor population levels and trends in extant and introduced populations or population centers. Progress toward species recovery and eventual delisting should be continually monitored once recovery activities are underway. A sampling design and time table (biennial) should be proposed to assess survival, recruitment, and population expansion in each of the rivers. Interagency cooperation in identifying new or proposed environmental threats to these populations would prevent habitat or specimen losses during recovery.

5. Evaluate the success of individual activities and overall success of the recovery program; recommend revisions or additional actions as necessary to recover the species. This recovery plan is a working document, based on best available data in 1983. As environmental conditions change and the data base on mussels improves, proposed activities to achieve recovery will be updated.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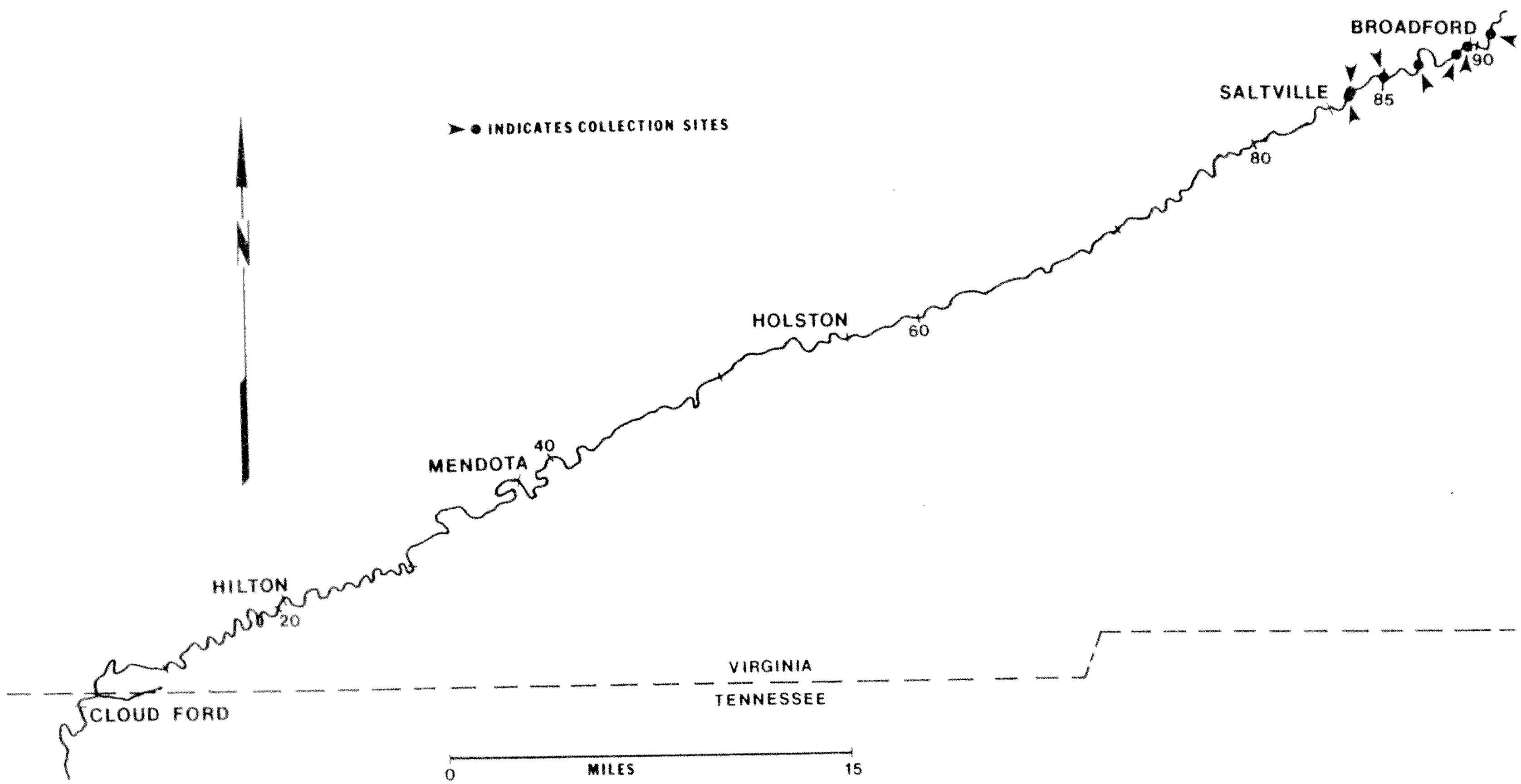

FIG. 1. NORTH FORK HOLSTON RIVER

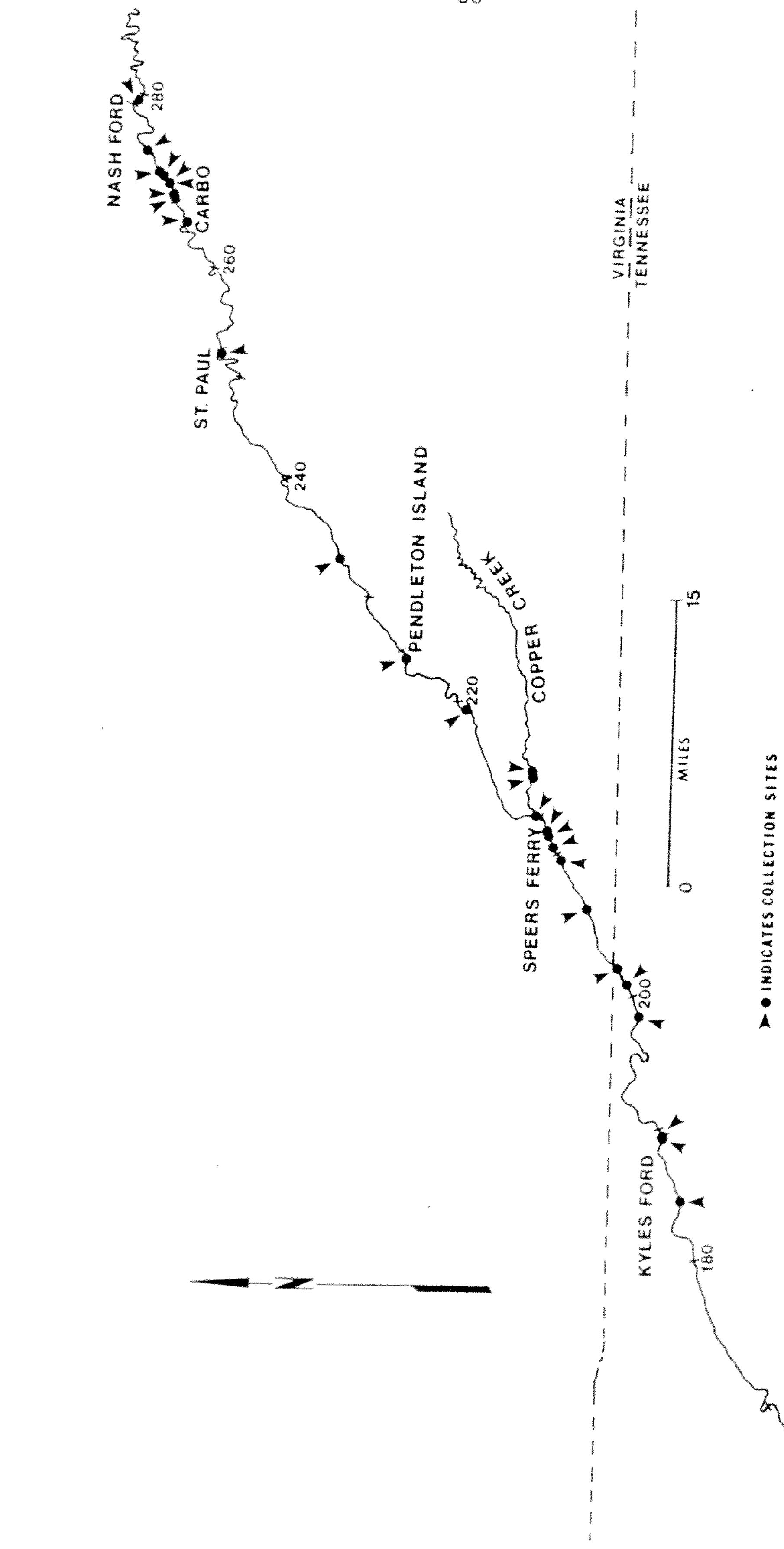

FIG. 2. CLINCH RIVER

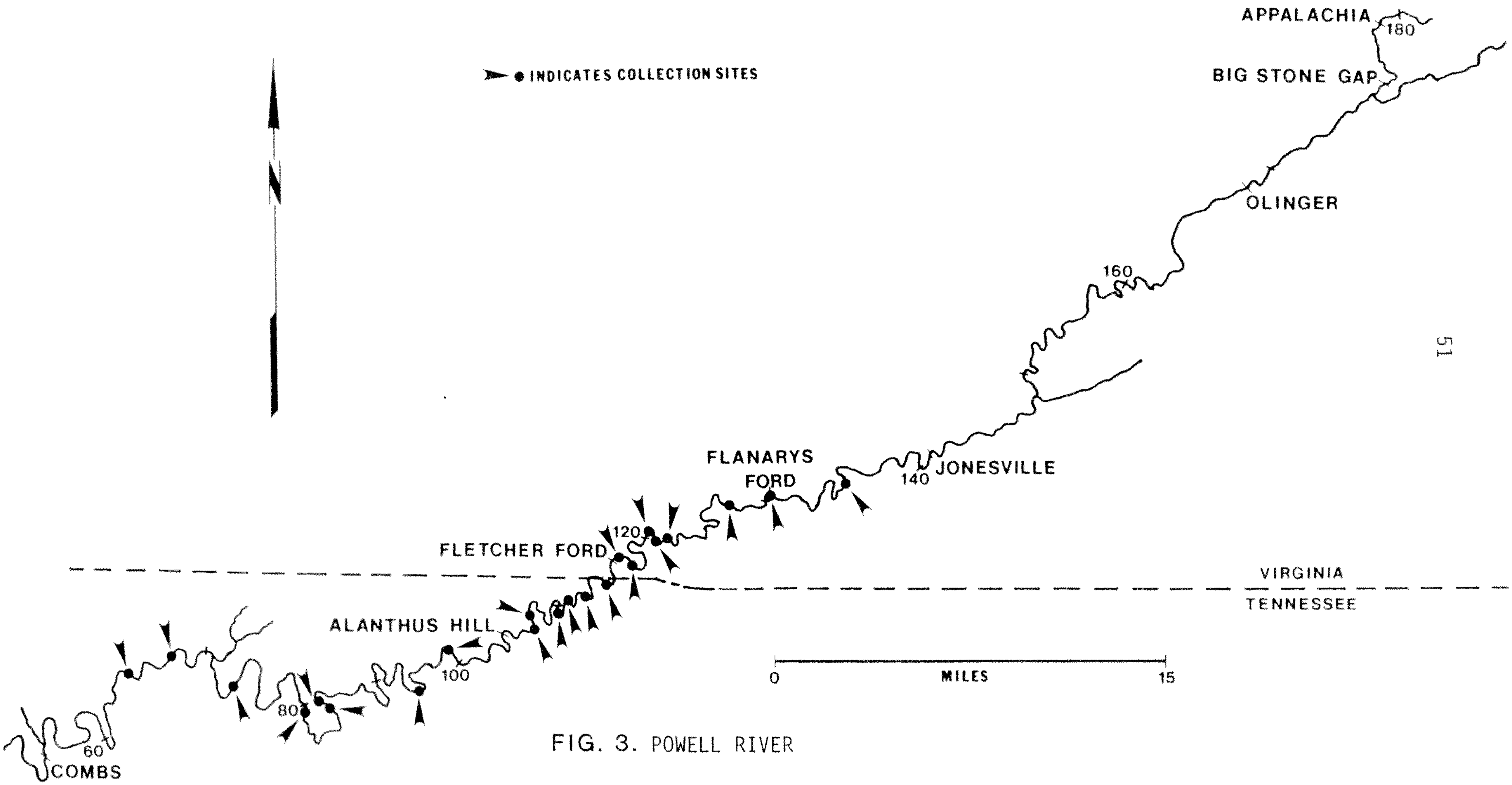

FIG. 3. POWELL RIVER

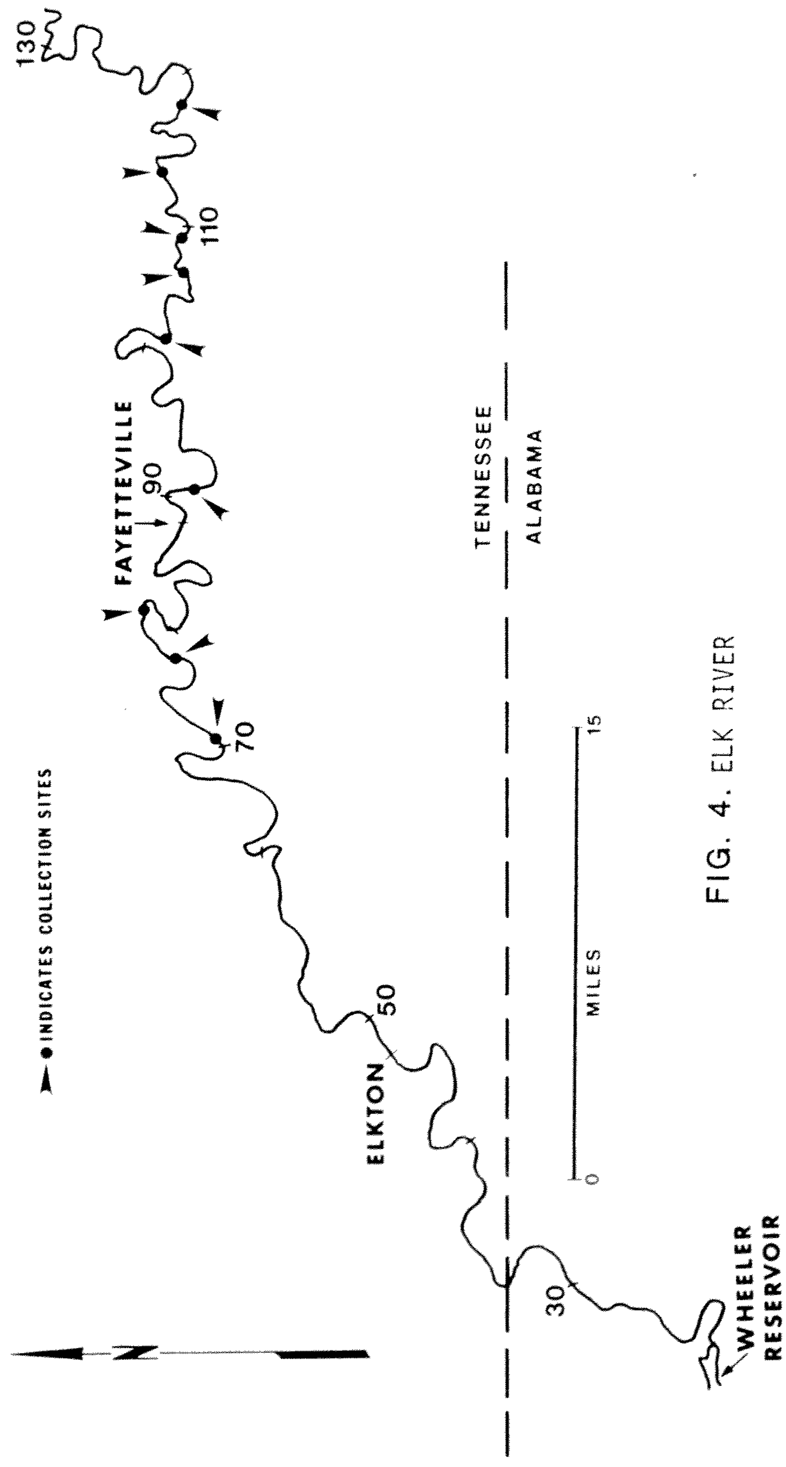

FIG. 4. ELK RIVER

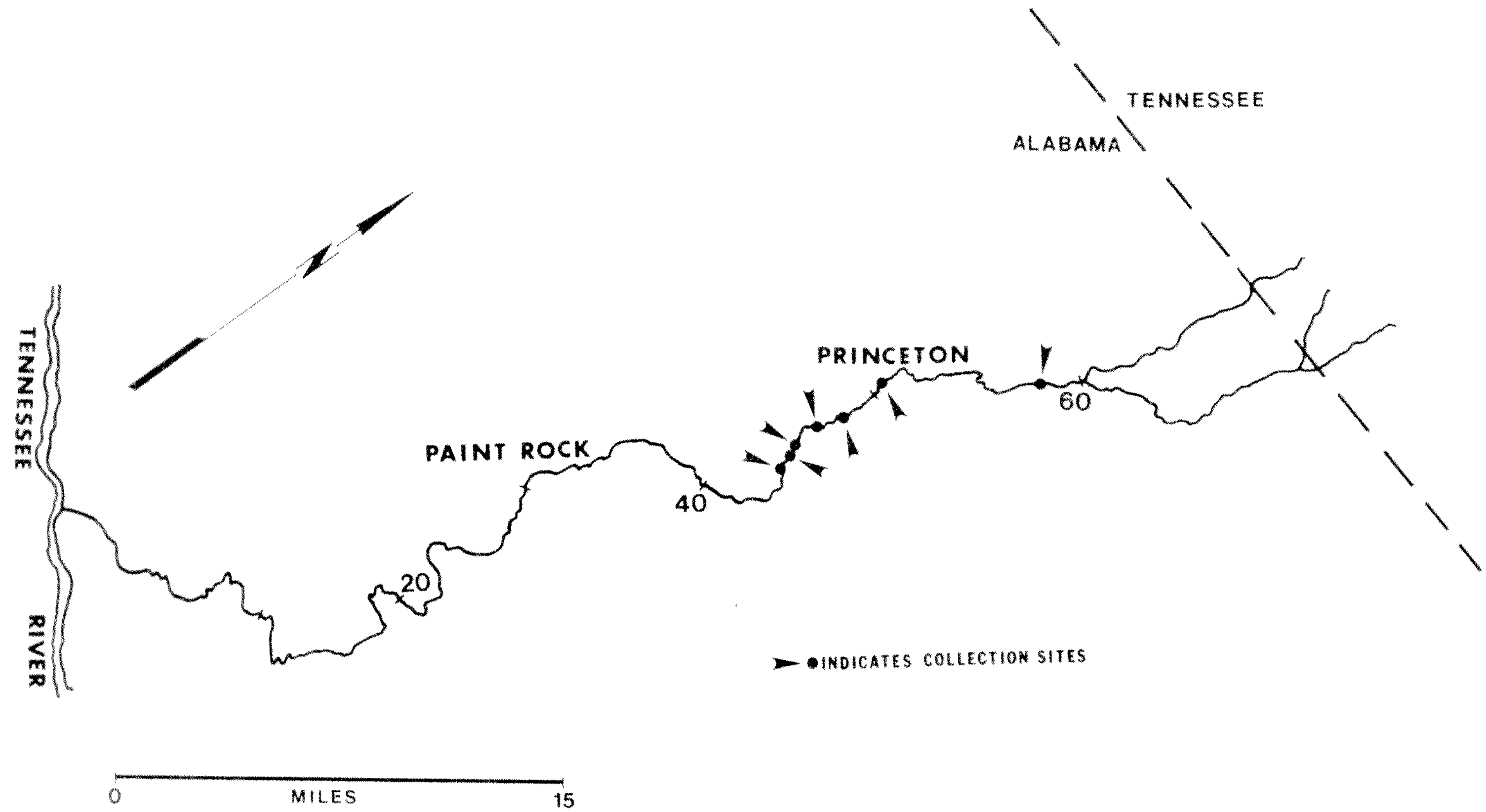

FIG. 5 . PAINT ROCK RIVER

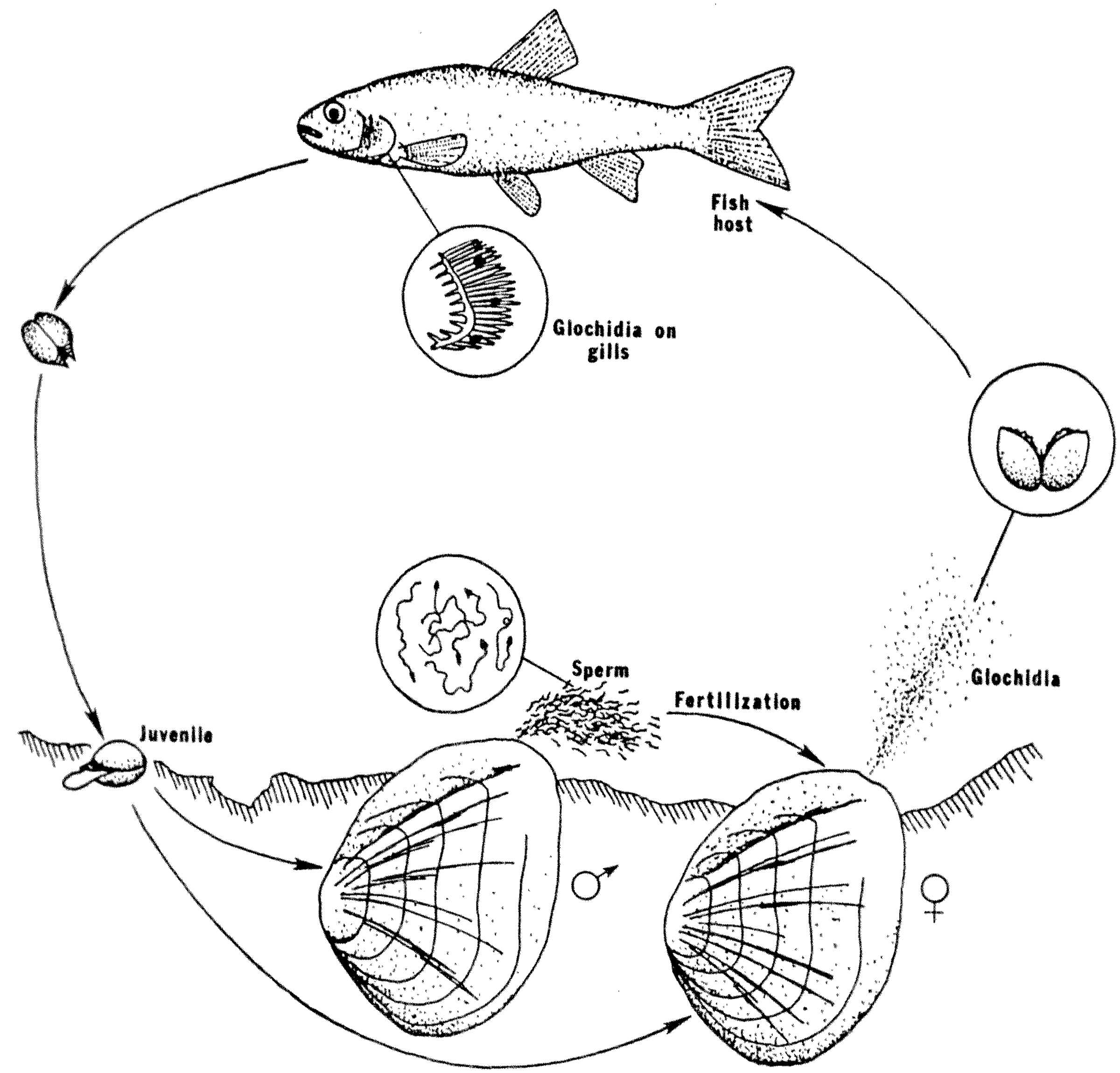

FIG. 6. TYPICAL LIFE CYCLE OF A FRESHWATER MUSSEL.

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Part III Implementation Schedule

1* General Category	Plan Task	Task Number	Priority	Task Duration	Responsible Agency: FWS Region	Responsible Agency: FWS Program	Responsible Agency: Other 2*	Estimated Fiscal Year Costs: FY 1	FY 2	FY 3	3* Comments/Notes
01-04	Preserve presently known populations and habitat	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) and Alabama Dept. 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 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 range	1.1.1	3	2 yr.	4&5	SE	TWRA, THP, VCGIF, TVA, & ADCNR	----	----	----	
R3,R8 R9, R10 R11	Discribe species habitat	1.1.2	2	2 yr.	4&5	SE	TWRA, THP, TVA, & ADCNR	----	----	----	
01	Disseminate distribution and habitat data to appropriate public and private agencies	1.1.3	2	1 yr.	4&5	SE	TWRA, THP, VCGIF, TVA, and ADCNR	----	----	----	
I22,I24	Identify current and future anthropogenic threats and take action to mitigate or eliminate	1.2	1	3 yr.	4&5	SE&ES	TWRA, VCGIF, TVA, THP, and ADCNR	----	----	----	
01,04	Solicit support for protection and recovery of species.	1.3	2	continuous	4&5	SE&ES	TWRA,VCGIF TVA,THP,ADCNR TN & VA Nature Conservancy (TNC)	----	----	----	

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
R3,R6 R8,R9 R10,R11 &R14	Conduct life history research	2	1	3	4&5	SE	TWRA, THP, VCGIF, ADCNR & TVA	----	----	----	
I13	Locate suitable sites for potential introductions	3.1	3	1 yr.	4&5	SE	TWRA, THP, VCGIF, ADCNR, & TVA	----	----	----	
I13,R7	Develop a successful method for introductions	3.2	3	1 yr.	4&5	SE	TWRA, THP, VCGIF, ADCNR, & TVA	----	----	----	
I	Introduce mussels, use of experimental populations will be considered on a case-by-case basis.	3.3 & 3.4	3	2 yr.	4&5	SE	TWRA, THP, VCGIF, ADCNR, & TVA				
I1, I2	Outline and implement a schedule to monitor population levels and trends	4.	2	Unknown	4&5	SE	TWRA, THP, VCGIF, ADCNR, & TVA	----	----	----	
O4	Evaluate success of individual activities and overall recovery program.	5.	2	continuous	4&5	SE	TWRA, THP, VCGIF, ADCNR, TVA, & 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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