# Recovery Plan

# Tan Riffle Shell Mussel
# Epioblasma (=Dysnomia) walkeri

Recovery Plan for the

Tan Riffle Shell Mussel

*Epioblasma walkeri*

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For

U.S. Fish and Wildlife Service

Southeast Region, 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.

Literature citations should read as follows:

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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. *Epioblasma walkeri*, the tan riffle shell mussel, is one of these Cumberlandian species that was listed as endangered on August 23, 1977 (*Federal Register* 42:42351-42353).

The tan riffle shell mussel was first described under the binomial *Truncilla walkeri* by Wilson and Clark (1914) from the East Fork of the Stones River, Tennessee (TN). Since then, its taxonomic validity has been questioned by several malacologists. The confusing history of nomenclatorial changes for *Epioblasma* (=*Dysnomia*=*Plagiola*) was summarized by Bogan and Parmalee (1983), and a complete synonymy for the species is provided in Stansbery (1976).

*Epioblasma walkeri* is a medium-sized species characterized by dull brownish-green or yellowish-green periostracum with numerous faint green rays evenly distributed over the valve surface (Bogan and Parmalee 1983). Valves are inequilateral and subinflated, with uneven growth checks (see photo). Both valves contain two small triangular pseudocardinal teeth. Lateral teeth are short and curved, double in the left valve and single (sometimes double) in the right valve. The pallial line is distinct anteriorly, and nacre color is bluish-white. Sexual dimorphism is readily apparent in this species. The posterior ridge of the male shell appears faintly doubled, ending in a slight biangulation posteriorly; umbo is full, elevated, and slightly anterior of the middle. The female shell has a pronounced marsupial swelling posteriorly, defined by anterior and posterior sulci and often serrated along the ventral margin. Umbo location is in the anterior third of the shell, and the posterior ridge is scarcely visible. The posterior swelling of female *E. walkeri* is very thin and typically has one or more constrictions which give the shell a multilobed appearance (Stansbery 1976). A discussion of the taxonomic characters and facies of this species and their similarity to *E. florentina* is presented in Ortmann (1918, 1924), Stansbery (1976), and Johnson (1978).

# DISTRIBUTION

## Historical

*Epioblasma walkeri* apparently had a restricted distribution in the Cumberland and Tennessee River systems. The type locality is the East Fork Stones River at Walterhill in Rutherford County, TN. Stansbery (1976) reported specimens collected in 1964-1966 from the Stones River and East Fork Stones River, but stated that the Stones River population may have been extirpated since then.

Neel and Allen (1964) collected *E. walkeri* in Beaver Creek, a tributary of the Cumberland River, Kentucky (KY). They reported that this species once occurred in the Big South Fork but collected no specimens during their survey. Illustrations of *Epioblasma florentina* in Neel and Allen (1964) are thought to be *E. walkeri* (Stansbery 1976). If so, the tan riffle shell apparently resided in the Cumberland River downstream to Neeley's Ford, Cumberland County, KY. Ortmann (1924) collected a male specimen from the Cumberland River near Burnside, Pulaski County, KY. A valve of *E. walkeri* was also collected by Ortmann (1924) from the Harpeth River, a tributary of the Cumberland, at Belleview in Davidson County, TN. An additional record for the tan riffle shell in the Cumberland drainage includes the lower Red River, Montgomery County, TN (Stansbery 1976).

A specimen collected by Marsh and Hinckley in 1884 from the Duck River may have been E. walkeri (Ortmann 1924, Stansbery 1976). Ortmann (1924) collected this species from two sites on the Duck River; Lillard's Mills and Wilhoite, Marshall County, TN. In 1931, Goodrich and van der Schalie surveyed the Duck River drainage and collected specimens of E. walkeri at Wilhoite and Hardinson's Mill, Marshall County and Columbia, Maury County, TN (van der Schalie 1973). They also collected specimens in the Buffalo River above Linden and north of Gobelsville, Perry County, TN. Stansbery (1976) reported one specimen from the Duck River in 1964, but a survey of Ortmann's collection sites in 1965 by Isom and Yokley (1968) did not record this species.

In the upper Tennessee River drainage, a single valve of the tan riffle shell was collected in 1965 from the Clinch River (Stansbery 1976), but no previous or subsequent records are known. Three collection records are available for the Middle Fork Holston River, Virginia (VA); Ortmann (1918) recorded it at Chilhowie in Smyth County, Stansbery (1976) included a 1968 collection record, and Johnson (1978) reported a collection record 3.7 miles south of Glade Spring. In the South Fork Holston River, Ortmann (1918) collected specimens at Barron, Washington County, VA and Emmett, Sullivan County, TN. Stansbery and Clench (1978) reported a record of E. walkeri by C. C. Adams in 1901 also at Barron, but they did not collect it during their survey.

Specimens collected by Ortmann (1918) from the mainstem Holston River above Knoxville (Grainger and Knox Counties, TN) and reported as E. florentina were later reidentified as E. walkeri (Ortmann 1924). Since this species resided in the South Fork, Middle Fork, and main stem of the Holston River drainage, it probably occurred in the North Fork as well. The tan riffle shell has not been recorded from the Powell River.

Additional records of E. walkeri include locations in the Flint River at Gurley and in Hurricane Creek at Maysville in Madison County, Alabama (AL), and in Limestone Creek, Mooresville in Limestone County, AL (Ortmann 1924). Johnson (1978) considers the tan riffle shell to be a compressed tributary form of Plagiola (=Epioblasma) florentina. Designation of his MCZ (Museum of Comparative Zoology-Harvard) records for the Tennessee and Cumberland River systems to E. walkeri or E. florentina therefore is not possible at this time. Except for a record (probably E. walkeri) from the Obey River at Duncan Ford, Pickett County, TN, MCZ records appear to corroborate the historical distribution of this species as summarized. A synopsis of historical records for Epioblasma walkeri is presented in Table 1.

Table 1. Historical records of *Epioblasma walkeri* collected prior to 1970.

| River | Reference |
|---|---|
| South Fork Holston River | Adams (1901)*<br>Ortmann (1918) |
| Middle Fork Holston River | Ortmann (1918)<br>Stansbery (1976) |
| Holston River | Ortmann (1924) |
| Clinch River | Stansbery (1976) |
| Cumberland River | Ortmann (1925)<br>Neel and Allen (1964) |
| Big South Fork | Neel and Allen (1964) |
| Beaver Creek | Neel and Allen (1964) |
| East Fork Stones River | Wilson and Clark (1914)<br>Stansbery (1976) |
| Stones River | Stansbery (1976) |
| Red River | Stansbery (1976) |
| Harpeth River | Ortmann (1924) |
| Buffalo River | van der Schalie (1973) |
| Obey River ? | Johnson (1978) |
| Duck River | Marsh (1885)**<br>Ortmann (1924)<br>van der Schalie (1973)<br>Stansbery (1976) |
| Flint River | Ortmann (1924) |
| Hurricane Creek | Ortmann (1924) |
| Limestone Creek | Ortmann (1924) |

*Cited in Stansbery and Clench (1978)
**Cited in Stansbery (1976)

Present

Extant populations were thought to occur in the Duck River, Red River, and Middle Fork Holston River (Stansbery 1976). However, a survey of the Red River in 1977 by Bogan and Parmalee (1983) did not report E. walkeri. Similarly, Ahlstedt (1980) conducted a survey of the Duck River from Columbia, Maury County (DRM 131.0) to Normandy Dam in Bedford County, TN (DRM 248.6) and found no evidence of the tan riffle shell. The only recent collection records (since 1970) for E. walkeri are from the Middle Fork Holston River, VA (Figure 1). Specimens were collected at Middle Fork Church (MFHRM 29.1) in Smyth County and at Craig Bridge (MFHRM 18.4) in Washington County from 1970 to 1974 by Stansbery and Clench (1975). Neves et al. (1980) also recorded a live female and several valves of E. walkeri at Craig Bridge in 1979. These collections in the Middle Fork are apparently the only recent records of the species, although an intensive survey of the Duck River and Red River is needed to confirm the loss of those populations.

## ECOLOGY AND LIFE HISTORY

The life history and ecological requirements of the tan riffle shell are unknown. The type locality was described as shallow and turbid with numerous riffles; substrate consisted of loose rocks and gravel bars with an abundance of water willow (Wilson and Clark 1914). Ortmann (1924) collected it in areas of the Duck River with swift current and sand and gravel substrate, among dense weed patches. Neves et al. (1980) found the species in riffle habitat below a rock outcropping. Since E. walkeri is considered a headwater form, it appears to inhabit coarse substrate in riffle areas of small to moderate-sized rivers.

The reproductive cycle of freshwater mussels appears to be similar among all species (Figure 2). 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.

*Epioblasma walkeri* is assumed to be a long-term breeder, based on biological data for other *Epioblasma* species (Ortmann 1919, Bogan and Parmalee 1983). The posterior halves of the female's outer gills are probably filled with glochidia by fall, and these glochidia are released in spring and early summer. Fish hosts for this species are unknown.

## REASONS FOR DECLINE

Intensive industrial and agricultural development of the Tennessee and Cumberland Valleys since the early 1900's has had a significant impact upon the mussel fauna inhabiting these river basins. 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 and Cumberland Rivers and their 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 and Cumberland River drainages have been altered extensively, and it is unlikely that they will ever again sustain a diverse mussel fauna. In order for *Epioblasma walkeri* 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 and Cumberland River systems and how these changes are thought to have contributed to depletion of the naiad fauna, including the tan riffle shell.

## Impoundment

Dam construction in the upper Tennessee River may have been the most significant factor contributing to the decline of the tan riffle shell 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, 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. The Army Corps of Engineers has constructed five dams on the Cumberland River and five on headwater tributaries (TVA 1980). TVA currently manages one impoundment on the Cumberland River.

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). The uppermost dam on the South Fork Holston River was closed in 1950 and impounded the river in Sullivan County, TN and Washington County, VA. Appalachian Power Company owns and operates Edmonson Dam on the Middle Fork Holston River (MFHRM 14.1), Washington County, VA. Both of these impoundments eliminated historical habitat of the tan riffle shell in Virginia. Two impoundments in the Cumberland drainage have apparently impacted populations of *E. walkeri*. Closure of Wolf Creek Dam in August 1950 inundated the Cumberland River and the lower reaches of most of its tributaries from Roweena Ferry, Russell County, KY to Cumberland Falls. *E. walkeri* occurred in Beaver Creek, one of these tributaries (Neel and Allen 1964). The population of the tan riffle shell in the Stones River system was apparently inundated by J. Percy Priest Reservoir (Stansbery 1976). Stansbery's pre-impoundment survey (1965-1968) listed 45 species, including *E. walkeri*. A recent survey in this river reported 30 mussel species, but not *E. walkeri* (Schmidt 1982).

The effects of impoundment on some mussel species inhabiting lotic systems have been well-documented. 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. 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.

## Siltation

Silt derived from erosion in the Tennessee and Cumberland Valleys 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 these rivers and their 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). Schmidt (1982) felt that silt loads from unauthorized gravel dredging coupled with low flow during summer months may have contributed to the decline of naiads in the Stones River.

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 erode 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 Tennessee and Cumberland River tributaries are contributing to the natural sediment loads already present in these streams. 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. An increase in demand for coal may result in higher silt loads in the Cumberland River system (Branson 1974). 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). 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.

## 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. Chlorination from sewage treatment plants is suspected of eliminating mollusks downstream (Stansbery and Stein 1976), although no corroborative studies are available.

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, England 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).

The Big South Fork was reported to be the focal area for development of the rich Epioblasma fauna in the Cumberland drainage; however, acid mine drainage reduced the abundance of naiad populations (Neel and Allen 1964). Water pollution has also had a substantial impact on the fauna of the Stones River and its tributaries (Schmidt 1982).

Organic wastes and toxic substances have overloaded or bypassed sewage treatment plants at Woodbury and Murfreesboro, TN, resulting in high BOD effluent entering receiving streams. Murfreesboro has since (1978) installed a tertiary treatment plant. In addition to these pollutants, fertilizer and pesticide use in the drainage has increased by up to 50%, adding new non-point pollutants (Schmidt 1982). Dissolved oxygen levels as low as 2.9 mg/l and pH's of 5.9 were also reported in the Stones drainage by Schmidt (1982). These pH levels are within the range of values (pH 4.4-6.1) that result in a cessation of siphoning and weight loss in naiads (Matteson 1955).

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. This section of Virginia presents particular problems in meeting water quality criteria because many older dwellings have direct waste inputs into streams. Soils are generally unsuitable for septic tanks and centralized sewage treatment facilities are too costly (VSWCB 1982). In addition, drought flow (7 day, 10 year) constitutes a small percentage of average flow; water quality problems therefore are most severe during summer months. The upgrading of water quality through better wastewater treatment facilities, improved land use practices, and monitoring of industrial effluents are essential elements for reversing the decline of the tan riffle shell mussel.

Epioblasma walkeri was apparently rare in the Clinch River, and the small population in this river was probably affected by two chemical spills. In June 1967, a storage lagoon wall broke at the APCO generating plant at Carbo, VA releasing 198 million $m^3$ 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 1979, Neves et al. 1980).

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.

Historically, the tan riffle shell inhabited the main stem, South Fork, Middle Fork, and probably North Fork of the Holston River drainage. 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).

Pollution from industrial sources is of particular concern in the Holston River drainage. As a result of high background levels of manganese, the river may be particularly susceptible to anthropogenic pollutants (Young and Blevins 1981). Manganese levels in the South Fork

Holston River at Boone Dam and in the North Fork near Saltville and Gate City exceed the limits for contaminants in drinking water. Concentrations of toxic metals (mercury, cadmium, lead) approach or exceed minimal risk concentrations throughout most of the drainage (Young and Blevins 1981). Minimal risk concentration is defined by EPA as levels considered to pose minimal risk of deleterious effect from water quality criteria.

Fecal coliform levels are also degrading water quality in the upper Holston drainage. The relatively recent sewage treatment plant at Damascus, VA has reduced this problem in the South Fork, and the entire river (54 miles) was expected to meet class B fishable-swimmable standards in 1983 (VSWCB 1981). The Middle Fork above Marion, VA now meets class B criteria. However, the remaining 42 miles were not expected to meet class B standards in 1983 due to raw sewage discharges from treatment plants in Marion and Chilhowie, VA (VSWCB 1981). River miles 17 to 42 in the Middle Fork have been designated as water quality limiting; i.e., requiring more stringent waste treatment to meet standards (VSWCB 1982). Since the current range of _E. walkeri_ is centered in this section of the Middle Fork, domestic pollution may pose the most serious, identifiable threat to the survival of the tan riffle shell.

## Part II

## RECOVERY

### A. Recovery Objectives

The interim goal of this recovery plan is to maintain and enhance the only known population of *Epioblasma walkeri*, which occurs in the Middle Fork Holston River, VA, and protect its habitat from present and foreseeable threats that may interfere with the survival of this population. The *Epioblasma* spp. have been considered the most highly developed and recently evolved species of naiads, and all 8 species of naiads that have recently become extinct in North America belong to this genus. The decline of *E. walkeri* therefore appears to be symptomatic of a general synecological problem that exists between *Epioblasma* and chronic environmental changes that have occurred and apparently are continuing in major river systems. As judged by the dramatic decline of the tan riffle shell, the single, known, remaining population, and the recent extinctions of conspecifics, it appears improbable at this time that (1) viable populations can be restored to other rivers within its historic range, or (2) the species can ever recover to the point of delisting.

Although *Epioblasma walkeri* appears to be approaching extinction, the ultimate goal of this recovery plan is to maintain and restore viable populations of E. walkeri to a significant portion of its historic range and remove the species from the federal list of endangered and threatened species. The interim and ultimate goals of this recovery plan can be accomplished by (1) protecting and expanding the population of E. walkeri in the Middle Fork Holston River and (2) establishing new populations within rivers or river corridors that historically contained this species. The tan riffle shell 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 Epioblasma walkeri, with evidence of recent recruitment (specimens age 5 or younger), exists in the Middle Fork Holston River, Smyth and Washington Counties, VA. This population is distributed widely enough in the Middle Fork such that it is unlikely a single adverse event would result in the total loss of the population.
2. Through re-establishment and/or discoveries of new populations, excluding the Middle Fork Holston River, a viable population* exists in three

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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 additional rivers or river corridors that historically contained the species. Each river (corridor) will contain at least two population centers** which are dispersed to the extent that a single adverse event would be unlikely to eliminate Epioblasma walkeri 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.

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 water quality have occurred in the Middle Fork Holston River.

B. Step-down Outline

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

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

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

1. Preserve the population and habitat of *Epioblasma walkeri* in the Middle Fork Holston River.

    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 potential 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 effects of apparent threats to the species such as siltation, municipal sewage effluents, 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 representatives of companies along the Middle Fork 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 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 three additional rivers and establishing new population centers in the Middle Fork Holston River; implement such activities where feasible.

3.1 Locate suitable sites for habitation within these rivers that 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.

4. Outline and implement a schedule to monitor the population in the Middle Fork Holston River and all 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 maintain the species.

C. Narrative Outline

1. Preserve the population and habitat of *Epioblasma walkeri* in the Middle Fork Holston River. Based on the most recent survey data, *E. walkeri* is restricted to the Middle Fork in Virginia. Protection of this population and its habitat is imperative for continued survival of the species and

to create conditions conducive to population increase and range expansion.

1.1 Conduct a population survey 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. An intensive mussel survey is needed for the entire Middle Fork Holston River upstream of South Holston Reservoir to define the range and abundance of this species. Additional surveys are recommended for sections of the Duck River, Red River, Obey River, Big South Fork, and any other rivers identified in Table 1 that have not been intensively sampled for naiads.

1.1.2 Describe species' habitat (relevant physical, chemical, and biological elements) for all life history stages. Habitat characterization for this species is needed at multiple sites so that these environmental data can be used to identify preferred habitat.

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 (task 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 a distribution map 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. Preservation of the tan riffle shell is dependent on meeting this objective. Available evidence indicates that environmental alteration and degradation have probably accounted for the loss of populations in other rivers and may be posing a threat to the Middle Fork population. A review of current conditions and future plans within the drainage is needed to identify potential threats to species survival.

1.2.1 <u>Work with municipal, state, and federal agencies to inventory negative impacts on the species and its habitat.</u> Virginia's surface waters have improved significantly in quality since implementation of 305(b) standards (VSWCB 1982). Water quality problems such as high coliform levels from raw sewage inputs have been identified, but more localized, deleterious effects associated with road and bridge construction, urban development, channelization, flood control, and pesticide use must be identified and brought to the attention of regulatory agencies. The water quality inventory (305b report) for Virginia in 1982 reported no problems with temperature, dissolved oxygen, pH, heavy metals, pesticides, or organics. Minor localized problems exist with total suspended solids and nutrients, and widespread excesses of fecal coliforms are frequent. Raw sewage discharges and effluents from the Marion (MFHRM 41.4) and Chilhowie (MFHRM 29.1) sewage treatment plants are the major source of violations (VSWCB 1982). A meeting with the Virginia State Water Control Board and appropriate municipalities is recommended to determine whether additional water quality improvement is feasible or needed in the Middle Fork.

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 the Middle Fork. Designate a contact person (Endangered Species Staff, Annapolis Field Office) to be notified when such proposals (e.g. discharge or project permits) are received for assessment so that information on the species can be provided for consideration in the approval process. For example, construction of three new sewage treatment facilities for Marion, Chilhowie, and the Glade Spring-Emory-Meadowview area has been proposed. Environmental concerns and benefits of projects such as this should be addressed at an early stage.

1.2.3 Document the effects of apparent threats to the species such as siltation, municipal sewage effluents, and other environmental contaminants, and recommend corrective measures to appropriate agencies. The expertise of research scientists should be sought to assess the potentially acute or chronic effects of suspected environmental pollutants and to recommend corrective measures. Financial support for such research should be sought from governmental agencies or 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, 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. In the Middle Fork drainage, over 51% of the land in Washington County and 43% in Smyth County is in agricultural, commercial, industrial, and residential classification. 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 representatives of companies along the Middle Fork and solicit their support in identifying and mitigating any negative impacts of their activities on the species and its habitat. Companies should be encouraged 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 habitat for the species and solicit their support for habitat protection. 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 Investigate the feasibility of protecting the species and its essential habitat through special sanctuaries, state refuges, collecting permit restrictions for mussels, or other means. Meet with representatives of the Virginia Commission of Game and Inland Fisheries to inquire whether special status or protection 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. 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 to protect essential habitat in the Middle Fork. Comprehensive development plans adopted by Washington and Smyth County officials have already defined the Middle and South Forks of the Holston River as "critical environmental areas" in need of immediate protection (Washington County Planning Commission 1978, Smyth County Planning Commission 1979). In addition, consultation services should be provided to state agencies and the Federal Wildlife Permit Office to prevent the overcollection of mussels or fishes for scientific or other purposes in essential habitat areas.

1.3.6 Develop a grass roots educational program for civic, church, and school groups; define their role in endangered species protection and recovery. 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. Conduct life history research on the species, to include gametogenesis, fish host identification, age class structure, growth rate, life tables, and mortality factors. Unless the species' life cycle and environmental requirements are defined, all population enhancement 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 tan riffle shell and other endangered mussels in the upper Tennessee River drainage, 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 elsewhere 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 research on the Unionacea.

3. <u>Determine the feasibility of introducing the species into three additional rivers and establishing new population centers in the Middle Fork Holston River;</u>

implement such activities where feasible. There are sections of the Middle Fork and other rivers within the species' historic range, particularly in the Holston River drainage, that appear suitable for sustaining populations of the tan riffle shell.

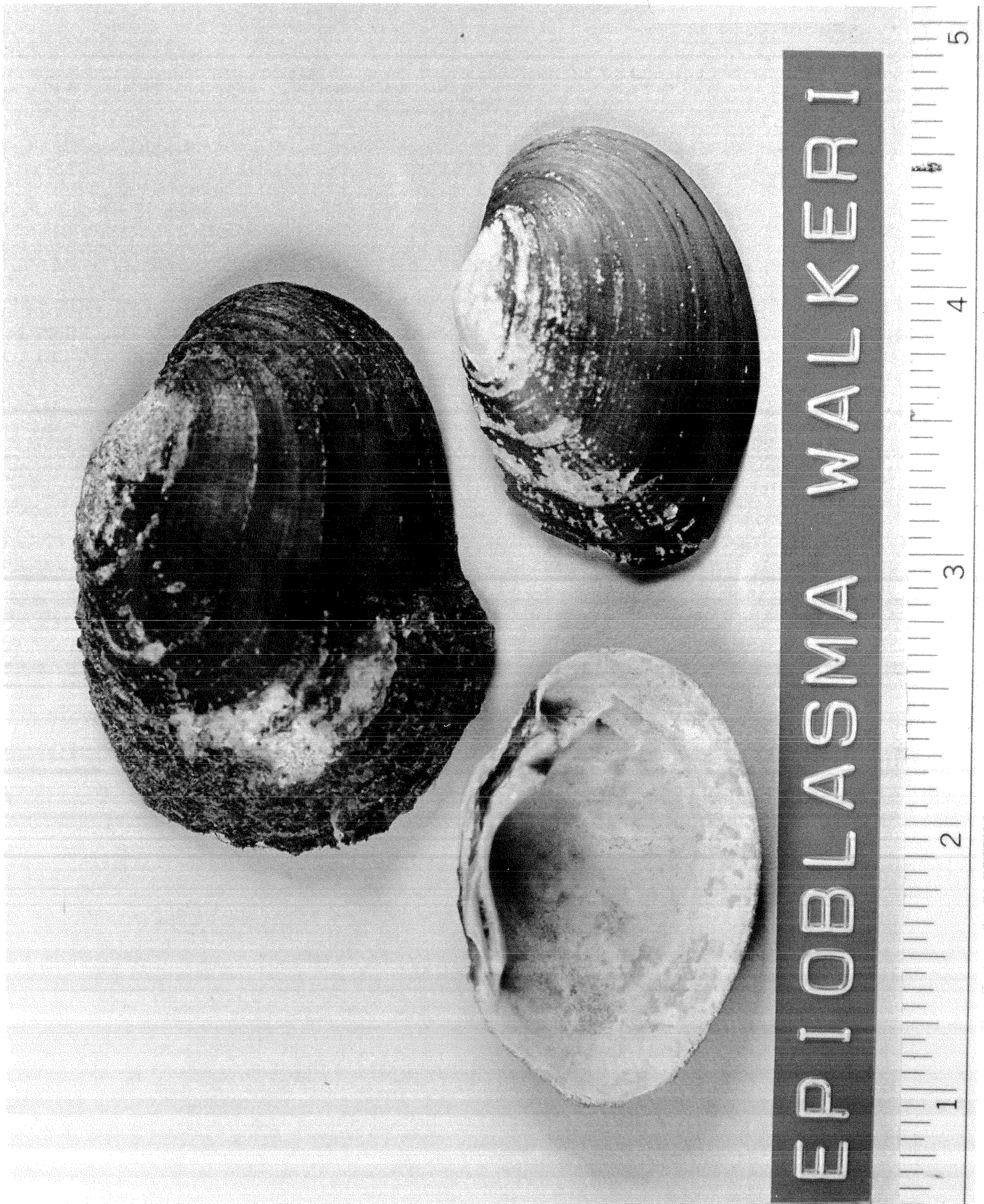
3.1 Locate suitable sites for habitation within these rivers that meet the environmental requirements for survival and reproduction of the species. Habitat suitability of likely transplant sites should be determined, to include substrate, water quality, fish host presence, and any other critical factors indentified 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. Based on these data for several rivers and additional habitat studies within the historic range of the tan riffle shell, 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 tan riffle shell. 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 variability 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.

4. Outline and implement a schedule to monitor the population of *E. walkeri* in the Middle Fork Holston River and all introduced populations and 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 the Middle Fork and other rivers. Interagency cooperation in identifying new or proposed environmental threats to these populations would prevent habitat or specimen losses during recovery.

5. <u>Evaluate the success of individual activities and overall success of the recovery program; recommend revisions or additional actions as necessary to maintain the species.</u> 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 objectives will be updated.


EPIOBLASMA WALKERI

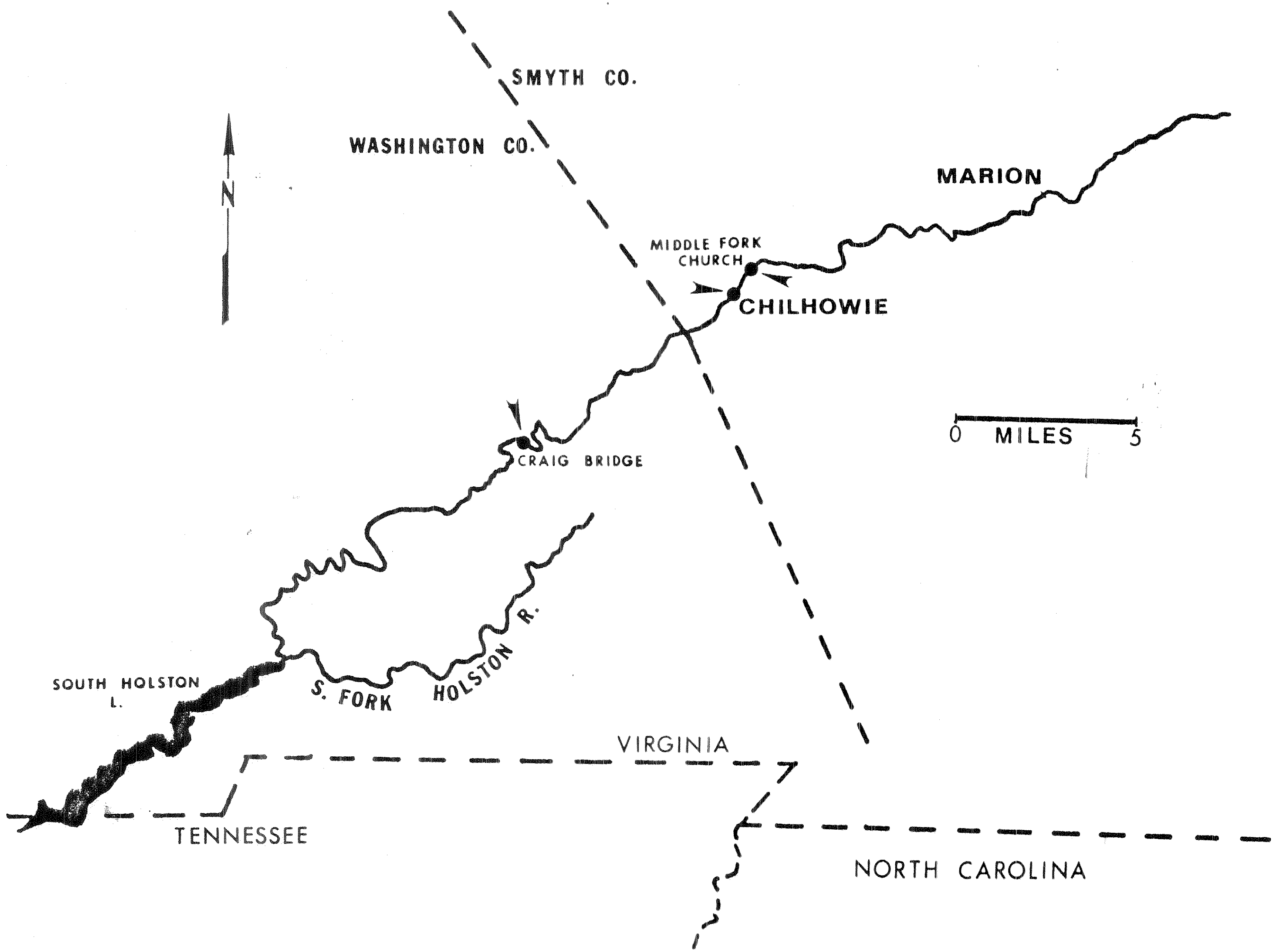



FIGURE 1 RECENT COLLECTION RECORDS

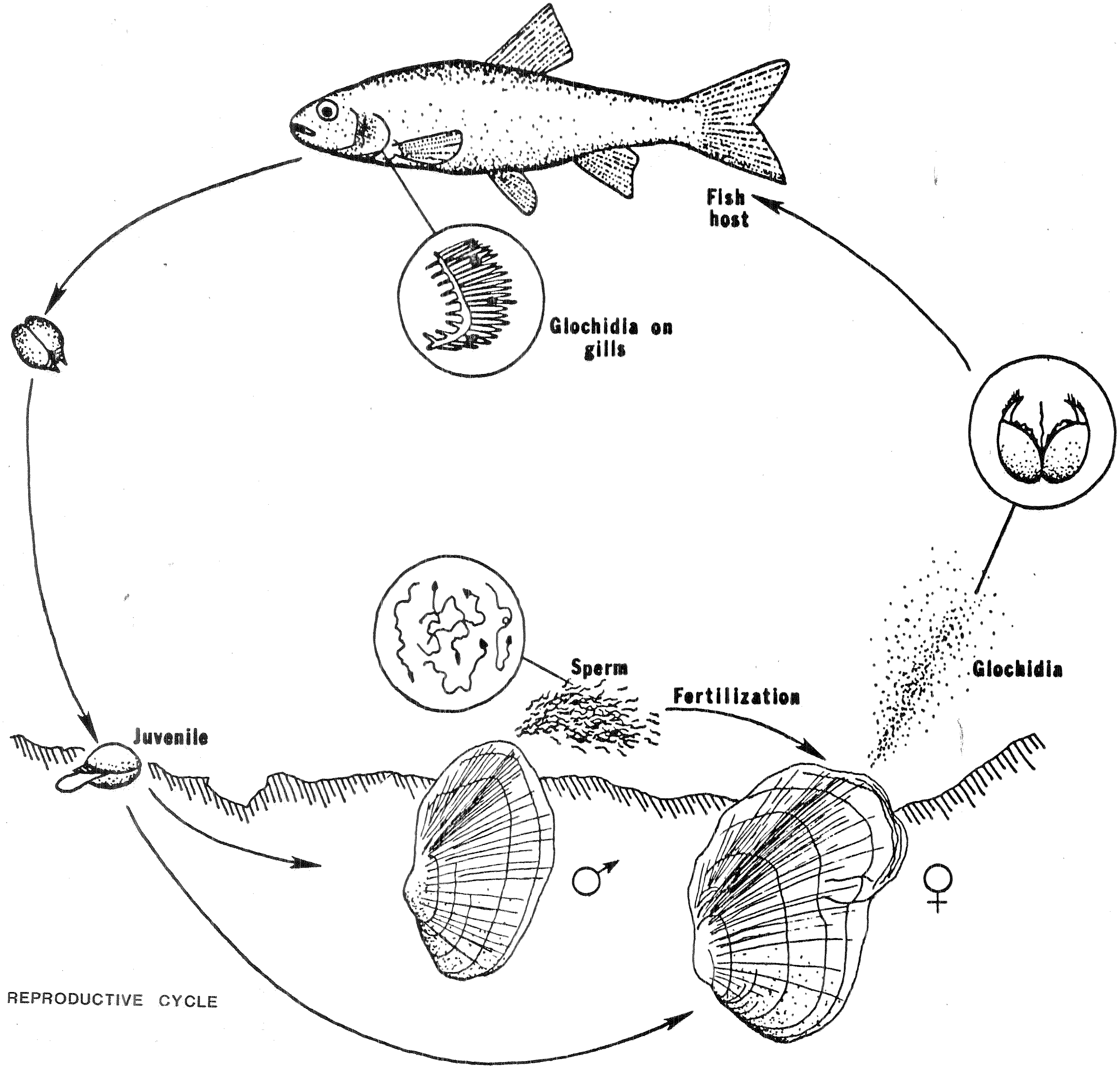



FIGURE 2 REPRODUCTIVE CYCLE

# LITERATURE CITED


Adams, T.G., G.J. Atchison and R.J. Vetter. 1981. The use of the three-ridge clam (Amblema perplicata) to monitor trace metal contamination. Hydrobiologia 83:67-72.

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

Ahlstedt, S.A. 1982. Draft preliminary recovery plan for the birdwing pearly mussel (Conradilla caelata) (Conrad 1834). U.S. Fish Wildl. Serv., Region 4, Atlanta, GA. 54 pp.

Bates, J.M. 1962. The impact of impoundment on the mussel fauna of Kentucky Reservoir, Tennessee River. Am. Midl. Nat. 68:232-236.

Bates, J.M. and S.D. Dennis. 1978. The mussel fauna of the Clinch River, Tennessee and Virginia. Sterkiana 69-70:3-23.

Berry, R.J. 1974. Conserving geuetical variety. Pages 99-115 IN: A. Warren and F. B. Goldsmith (eds.), Conservation in practice. Wiley and Sons, NY.

Bogan, A.E. and P.W. Parmalee. 1983. Tennessee's rare wildlife. Volume II: the mollusks. Tenn. Wildl. Resour. Agency, Tenn. Heritage Prog., Tenn. Dep. Conserv., Univ. Tenn., Knoxville, TN. 123 pp.

Branson, B.A. 1974. Stripping the Appalachians. Nat. Hist. 83:53-60.

Branson, B.A. and D.L. Batch. 1972. Effects of strip mining on small stream fishes in east-central Kentucky. Proc. Biol. Soc. Wash. 84:507-518.

Burch, J.B. 1975. Freshwater unionacean clams (Mollusca:Pelecypoda) of North America. Malacological Publications, Hamburg, MI. 204 pp.

Cairns, J., J.S. Crossman, K.L. Dickson and E.E. Herricks. 1971. The recovery of damaged streams. Assoc. Southeast. Biol. Bull. 18:79-106.

Carter, L.J. 1977. Chemical plants leave unexpected legacy in two Virginia rivers. Science 198:1015-1020.

Ellis, M.M. 1936. Erosion silt as a factor in aquatic environments. Ecology 17:29-42.

Federal Energy Regulatory Commission (F.E.R.C.). 1981. Water resources appraisals for hydroelectric licensing. Tennessee River Basin. Planning Status Rep. FERC-0074. 14 pp.

Foster, R.B. and J.M. Bates. 1978. Use of freshwater mussels to monitor point source industrial discharges. Environ. Sci. Tech. 12:958-962.

Franklin, I.R. 1980. Evolutionary change in small populations. Pages 135-149 IN: M.E. Soule and B.A. Wilcox (eds.), Conservation biology. Sinauer Assoc., Inc., Sunderland, MA.

Fuller, S.L.H. 1974. Clams and mussels (Mollusca: Bivalvia). Pages 215-273 IN: C.W. Hart, Jr. and S.L.H. Fuller (eds.) Pollution ecology of freshwater invertebrates. Academic Press, NY.

Harman, W.N. 1974. The effects of reservoir construction and canalization on the mollusks of the upper Delaware watershed. Bull. Am. Malac. Union 1973:12-14.

Imlay, M.J. 1973. Effects of potassium on survival and distribution of freshwater mussels. Malacologia 12:97-113.

Imlay, M.J. 1982. Use of shells of freshwater mussels in monitoring heavy metals and environmental stresses: a review. Malac. Rev. 15:1-14.

Isom, B.G. and P. Yokley, Jr. 1968. The mussel fauna of Duck River in Tennessee, 1965. Am. Midl. Nat. 80:34-42.

Isom, B.G. and R.G. Hudson. 1982. In vitro culture of parasitic freshwater mussel glochidia. Nautilus 96:147-151.

Johnson, R.I. 1978. Systematics and zoogeography of Plagiola (=Dysnomia=Epioblasma) an almost extinct genus of freshwater mussels (Bivalvia: Unionidae) from middle North America. Bull. Mus. Comp. Zool. 148:239-321.

Jones, L.P. 1982. The effects of rapid mixing on the coagulation and sedimentation of ultra-fine coal and clay particles. M.S. thesis. Virg. Polytech. Inst. State Univ., Blacksburg, VA. 99 pp.

Kitchel, H.E., J.C. Widlak and R.J. Neves. 1981. The impact of coal-mining wastes on endangered mussel populations in the Powell River, Lee County, Virginia. Final Rep. State Water Control Board, Richmond, VA. 26 pp.

Kusler, J.A. 1978. Regulating critical riparian lands: a challenge in intergovernmental cooperation. Pages 332-335 IN: R.R. Johnson and J.F. McCormick (tech. coord.). Strategies for protection and management of floodplain wetlands and other riparian ecosystems: proceedings of the symposium. USDA For. Serv. Gen. Tech. Rep. WO-12.

Loar, J.M., L.L. Dye, R.R. Turner and S.G. Hildebrand. 1980. Analysis of environmental issues related to small-scale hydroelectric development 1. Dredging. ORNL, Environ. Sci. Div. Publ. No. 1565, Oak Ridge, TN. 134 pp.

Manly, R. and W.O. George. 1977. The occurrence of some heavy metals in populations of the freshwater mussel _Anodonta anatina_ (L.) from the River Thames. Environ. Pollut. 14:139-154.

Mathis, B.J. and T.F. Cummings. 1973. Selected metals in sediments, water, and biota in the Illinois River. Water Pollut. Control Fed. 45:1573-1583.

Matteson, M.R. 1955. Studies on the natural history of the Unionidae. Am. Midl. Nat. 40:690-723.

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

Neves, R.J., G.B. Pardue, E.F. Benfield and S.D. Dennis. 1980. An evaluation of endangered mollusks in Virginia. Final Rep. Virg. Comm. Game Inland Fish., Proj. No. E-F-1. Richmond, VA. 140 pp.

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

Ortmann, A.E. 1918. The nayades (freshwater mussels) of the upper Tennessee drainage with notes on synonymy and distribution. Proc. Am. Phil. Soc., Phila. 57:521-626.

Ortmann, A.E. 1919. A monograph of the naiades of Pennsylvania: part III, systematic account of the genera and species. Mem. Carnegie Mus. 8:1-389.

Ortmann, A.E. 1924. The naiad-fauna of Duck River in Tennessee. Am. Midl. Nat. 9:18-62.

Ortmann, A.E. 1925. The naiad-fauna of the Tennessee River system below Walden Gorge. Am. Midl. Nat. 9:321-372.

Raleigh, R.F., D.H. Bennett, and L.O. Mohn. 1978. Changes in fish stocks after major kills in the Clinch River near St. Paul, Virginia. Am. Midl. Nat. 99:1-9.

Salanki, J. 1979. Behavioural studies in mussels under changing environmental conditions. Symp. Biol. Hung. 19:169-176.

Salanki, J. and I. Varanka. 1976. Effect of copper and lead compounds on the activity of the fresh-water mussel. Ann. Biol. Tihany 43:21-27.

Scruggs, G.D., Jr. 1960. Status of freshwater mussel stocks in the Tennessee River. U.S. Fish Wildl. Serv. Spec. Rep. Fish. No. 37:1-41.

Schmidt, J.E. 1982. The freshwater mussels of the Stones River above J. Percy Priest Reservoir, Tennessee. M.S. Thesis, Tenn. Tech. Univ., Cookeville. 65 pp.

Smyth County Planning Commission. 1979. Comprehensive Development Plan Smyth County, Virginia. Vol. I and II. 176 pp.

Soule, M.E. 1980. Thresholds for survival: maintaining fitness and evolutionary potential. Pages 151-169. IN: M.E. Soule and B.A. Wilcox (eds.), Conservation biology. Sinauer Assoc., Inc., Sunderland, MA.

Stansbery, D.H. 1976. Status of endangered fluviatile mollusks in central North America: Epioblasma walkeri (Wilson and Clark 1914). Ohio St. Univ. Res. Found. Rep., Dep. Interior, Fish Wildl. Serv., Bur. Sport Fish. Wildl. 7 pp.

Stansbery, D.H. and W.J. Clench. 1975. The Pleuroceridae and Unionidae of the Midddle Fork Holston River in Virginia. Bull. Am. Malac. Union 1974:51-54.

Stansbery, D.H. and C.B. Stein. 1976. Changes in the distribution of Io fluvialis (Say, 1825) in the Upper Tennessee River system (Mollusca: Gastropoda: Pleuroceridae). Bull. Am. Malac. Union 1976:28-33.

Stansbery, D.H. and W.J. Clench. 1978. The Pleuroceridae and Unionidae of the upper South Fork Holston River in Virginia. Bull. Am. Malac. Union 1977:75-78.

Tennessee Valley Authority (TVA). 1978. Water quality progress in the Holston River basin. Tenn. Valley Authority Rep. TVA/EP-78/08. 43 pp.

Tennessee Valley Authority (TVA). 1979. An evaluation of mussel popula tions in the Clinch River, Tennessee and Virginia. August 1979. Unpublished report. Div. Water Resour., Fish. Aquat. Ecol. Branch, Norris, TN. 14 pp.

Tennessee Valley Authority (TVA). 1980. TVA water control projects and other major hydro developments in the Tennessee and Cumberland valleys. TVA Tech. Monogr. No. 55.

Turner, C.S. 1982. Mercury in the fish and sediment of the North Fork Holston River (1981). Virg. State Water Control Board Rep. B75-028. 21 pp.

van der Schalie, H. 1973. The mollusks of the Duck River drainage in central Tennessee. Sterkiana 52:45-56.

Virginia State Water Control Board (VSWCB). 1981. Tennessee - Big Sandy River basins. IN: Water quality inventory 305(b) report - Virginia. Report to EPA administrator and Congress for January 1, 1979 to December 31, 1980. Info. Bull. 545. 102 pp.

Virginia State Water Control Board (VSWCB). 1982. Water quality inventory. Rep. EPA and Congress, Bull. No. 548. 154 pp.

Virginia Water Resources Research Center (VWRRC). 1982. Mercury cleanup begins in the North Fork of Holston. Water News 13:3.

Washington County Planning Commission. 1978. Comprehensive Development Plan Washington County, Virginia. Vol. I and II. 123 pp.

Williams, J.C. 1969. Mussel fishery investigation Tennessee, Ohio and Green Rivers. Final Rep., Kentucky Proj. No. 4-19-R 107 pp.

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

Young, G.J. and R.D. Blevins. 1981. Heavy metal concentrations in the Holston River basin (Tennessee). Arch. Environ. Contam. Toxicol. 10:541-560.

Zale, A.V. 1980. The life histories of four freshwater lampsiline mussels (Mollusca:Unionidae) in Big Moccasin Creek, Russell County, Virginia. M.S. thesis. Virg. Polytech. Inst. State Univ., Blacksburg, VA. 256 pp.

Tan riffle shell mussel (Epioblasma walkeri) 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 FY 1 | FY 2 | FY 3 | *3 Comments/Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| M1-7 | Preserve the population and habitat of the species in the Middle Fork Holston River. | 1 | 1 | Continuous | 4, 5 | ES, SE | Virginia Commission of Game and Inland Fisheries (VCGIF), Virginia State Water Control Board (VSWCB), The Nature Conservancy (TNC), and Tennessee Valley Authority (TVA) | --- | --- | --- | *1. See general categories for Implementation Schedules. |
| I1-2 | Determine species' current distribution and range. | 1.1.1 | 1 | 1 year | 4, 5 | SE | VCGIF, VSWCB, and TVA | --- | --- | --- | *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. |
| R3, R8-11 | Describe species' habitat for all life history stages. | 1.1.2 | 1 | 2 years | 4, 5 | SE | VCGIF, VSWCB, and TVA | --- | --- | --- | *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. |
| O1 | Disseminate above information in a form for general use by appropriate public and private agencies. | 1.1.3 | 1 | Continuous | 4, 5 | SE, ES | VCGIF, VSWCB, TNC, and TVA | --- | --- | --- | |
| I2, I12, I14 | Work with municipal, state, and Federal agencies to inventory on-going and proposed projects and evaluate their potential negative impacts on species and its habitat. | 1.2.1 and 1.2.2 | 1 | 1 year | 4, 5 | SE, ES | VCGIF, VSWCB, and TVA | --- | --- | --- | |
| I12, I14, M3, M7, O1-4 | Document the effects of apparent threats to the species and recommend corrective measures to appropriate agencies. | 1.2.3 | 1 | 3 years | 4, 5 | SE, ES | VCGIF, VSWCB, and TVA | --- | --- | --- | |

Tan riffle shell mussel (*Epioblasma walkeri*) 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 01 | Solicit support for the mitigation or elimination of threats and for protection and recovery efforts. | 1.3.1, 1.3.2, 1.3.3, 1.3.4, 1.3.5, and 1.3.6 | 2 | Continuous | 4, 5 | SE, ES | VCGIF, VSWCB, and TVA | --- | --- | --- | |
| R6,R8-10,R13-14 | Conduct life history research on the species. | 2 | 1 | 3 years | 4, 5 | SE, ES | VCGIF, VSWCB, and TVA | --- | --- | --- | |
| I13 | Locate sites for possible introduction which meet the species' survival and reproduction needs. | 3.1 | 2 | 1 year | 4, 5 | SE | VCGIF, VSWCB, and TVA | --- | --- | --- | |
| R7,R13, M1-2 | Develop successful methods for establishing new populations and implement. | 3.2 and 3.3 | 2 | 2 years | 4, 5 | SE | VCGIF, VSWCB, and TVA | --- | --- | --- | |
| I1-2 | Monitor Middle Fork Holston River and introduced populations. | 4 | 2 | Continuous | 4, 5 | SE | VCGIF, VSWCB, and TVA | --- | --- | --- | |
| 04 | Evaluate success of individual activities and recommend changes in strategies. | 5 | 3 | Continuous | 4, 5 | SE | VCGIF, VSWCB, and TVA | --- | --- | --- | |

# KEY TO IMPLEMENTATION SCHEDULE COLUMNS 1 AND 4

General Category (Column 1):

Information Gathering - I or R (research)

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

Acquisition - A

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

Other - O

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

Management - M

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

Priority (Column 4):

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

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

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

## Part IV - Appendix

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