Recovery Plan
for
Four Freshwater Mussels in Southeast Kansas:

NEOSHO MUCKET—*Lampsilis rafinesqueana*
OUACHITA KIDNEYSHELL—*Ptychobranchus occidentalis*
RABBITSFOOT—*Quadrula cylindrica cylindrica*
WESTERN FANSHELL—*Cyprogenia aberti*

Upper left to right: Neosho mucket, Ouachita kidneyshell, and western fanshell mussels collected from the Verdigris River, KS.

Prepared by

Brian K. Obermeyer
Stream & Prairie Research

for

Kansas Department of Wildlife & Parks

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Approved: ______________________ **Date: 11/6/2000**

Steve Williams,
Secretary of the Kansas Department of Wildlife & Parks

PREFACE

The Kansas Department of Wildlife and Parks (KDWP) is required to develop recovery plans for all state-listed threatened and endangered species under the authority of K.S.A. 32-960(a). The concept of developing state recovery plans for Kansas' endangered, threatened, and SINC species (species in need of conservation) was conceived by the Kansas Nongame and Endangered Species Task Force, which was created by passage of substitute Senate bill No. 473 during the 1996 Legislative Session. The Task Force, which consisted of 17 members[1], met six times during the summer and fall of 1996. Issues and concerns addressed by the Task Force included listing procedures for endangered, threatened, and SINC species, incentives for affected property owners, recovery and conservation plans, and funding. After receiving the Task Force's report, the 1997 legislature enacted into law the Task Force's recommendations by amending existing state laws and by enacting new laws (H.B. No. 2361). As part of that legislation, KDWP was required to implement several of the measures through regulation. Regulatory language addressing these measures was drafted by Department staff and presented to the KDWP Commission and the public. These recommendations were approved by the Commission in the fall of 1997. A new regulation, K.A.R. 115-15-4, outlined procedures to establish recovery plans[2]. These procedures included the appointment of an advisory group to evaluate recovery plan development priority. The advisory group determined that the highest priority was the immediate development of a joint recovery plan for four threatened and endangered mussel species that occur in southeast Kansas.

The Legislature also amended K.S.A. 32-962 to create conservation and recovery plan agreements with landowners. This amendment was based on recommendations made by the Task Force to create incentives for public participation, encourage sound management practices, and encourage communication between state agencies and affected landowners. A recovery plan agreement must meet the following criteria: i.) participant must carry out

[1] Members of the Taskforce included the Chairperson of the Kansas Nongame Wildlife Advisory Council, Kansas Farm Bureau, Kansas Association for Conservation and Environmental Education, Kansas Chapter of the American Fisheries Society, Kansas Herpetological Society, Kansas Chapter of the Wildlife Society, Kansas Ornithological Society, Kansas Livestock Association, Kansas Audubon Council, Kansas Association of Conservation Districts, Kansas Natural Resource Council, Secretary of the Kansas Department of Wildlife and Parks, President of the Kansas Building Industry Association, Inc., State Association of Kansas Watersheds, one private landowner appointed by the State Executive Director of the USDA Farm Service Agency, one member of the Kansas Department of Wildlife and Parks Commission, and one landowner appointed by the other members of the task force.

[2] "a designated strategy or methodology that, if fully funded and implemented, is reasonably expected to lead to the eventual restoration, maintenance, or delisting of listed species", K.A.R. 115-15-4.

management activities specified in a recovery plan; ii.) property must pass critical habitat designation guidelines for the targeted T&E species; iii.) duration of agreement shall be five years; and iv.) KDWP and other essential personnel will have access privileges to the property for the duration of the agreement for monitoring purposes.

A landowner who meets the recovery criteria will be eligible for state income tax credit equal to the amount of property taxes paid on enrolled property during each year of the agreement. A landowner may also be eligible for state income tax credit equal to the cost incurred for compliance of the recovery plan. This cost may include expenses from maintaining easement roads, planting riparian habitat, building fences for excluding livestock from accessing streams, and constructing alternative watering sources for livestock. KDWP will outline the procedure for applying for state income tax credit before an agreement is signed. However, it is the responsibility of the landowner to acquire the proper tax form (Schedule K-63) created for this purpose from the Kansas Department of Revenue (KDR). The landowner will also be responsible for supplying a copy of the signed recovery plan agreement with KDWP, a completed Real Estate Tax Computation Worksheet, and an itemized list of costs specified in the agreement, with copies of invoices to KDR. If for any reason an agreement is terminated before its end date, KDWP will notify the KDR.

DISCLAIMER

This recovery plan outlines actions believed reasonable to maintain and/or restore self-sustaining populations of state-listed freshwater mussels that occur in southeast Kansas. However, budgetary restraints and social obstacles may hamper or postpone recovery objectives. Moreover, it may take years to reverse a trend of species decline and habitat degradation that has occurred during the past 100 years or so. The full recovery of all of these species is an ambitious goal. The rich historic diversity of freshwater mussels in Kansas was the product of a pristine landscape dominated by prairie, not agriculture and industry. Therefore, some of these species may continue to experience range reductions, and perhaps even extirpation or extinction, despite aggressive conservation efforts. Nonetheless, these possibilities should not be an excuse to abandon efforts to recover these species. Instead, the full recovery of these species should be viewed as a worthwhile challenge.

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EXECUTIVE SUMMARY

This recovery plan outlines strategies and methods to recover and eventually delist four freshwater mussel species native to the Neosho, Spring, and Verdigris river basins (Arkansas River system) in southeast Kansas. These mussels are the Neosho mucket (*Lampsilis rafinesqueana*), Ouachita kidneyshell (*Ptychobranchus occidentalis*), rabbitsfoot (*Quadrula cylindrica cylindrica*), and western fanshell (*Cyprogenia aberti*). The recovery plan also provides a process of conserving—through proposed watershed enhancements—14 additional state-listed mussels that occur in these three basins: the bleedingtooth mussel[1] and elktoe (state-endangered); butterfly and flutedshell (state-threatened); and creeper (= squawfoot), deertoe, fat mucket, fawnsfoot, round pigtoe, spike, Wabash pigtoe, washboard, wartyback, and yellow sandshell (SINC).

The four targeted mussel species historically occurred in the Neosho, Spring, and Verdigris river basins; none is believed to have occurred elsewhere in the state. The rabbitsfoot mussel is considered extirpated from the Verdigris River basin, and is dangerously close to extirpation in the Neosho River basin. It has recently been collected alive in only the Spring and Neosho rivers. The Ouachita kidneyshell remains in only three Kansas streams—at scattered locales in the Fall, Verdigris, and Spring rivers—from a "historic" total of ten streams. The western fanshell remains at sporadic locations in the Fall, Verdigris, and Spring rivers; it is believed to be extirpated from the Neosho River basin. Although the Neosho mucket still occurs in all three river basins, it is extirpated from seven southeastern Kansas streams. It is presently found in the Neosho, Verdigris, Fall, and Spring rivers.

The recovery plan integrates two approaches for the recovery of these species: species-level and ecosystem. The ecosystem approach examines watersheds pertinent to all state-listed mussel species that occur in the three stream basins, and proposes practices that could help reverse a trend of watershed degradation that has occurred since Euro-American settlement. The ecosystem approach will also benefit non-target species associated with riverine habitats. The species-level approach includes projects such as life history, genetic, and demographic studies, as well as propagation of mussels into stream reaches where they are extirpated.

The estimated five-year cost of implementing proposed recovery tasks is $324,500. Additional costs, such as landowner participation in the state income tax incentive program and government conservation programs, are not included because these costs will be dependent upon landowner acceptance of such programs. Downlisting dates cannot be estimated because it may require up to ten years to fully assess population trends, and because funding is presently not available for many of the recovery tasks outlined in this plan.

[1] Genetic research at Southwest Missouri State University indicates that the bleedingtooth mussel (*Venustaconcha pleasii*) in the Spring River basin is more similar, both morphologically and genetically, to *V. ellipsiformis* (ellipse) than to the bleedingtooth mussel (Frank A. Riusech and Dr. Hsiu-Ping Liu, SMSU, pers. comm.). Consequently, ellipse will be used in place of bleedingtooth mussel hereafter in the recovery plan.

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I. INTRODUCTION

This recovery plan addresses the recovery needs of four freshwater mussel species native to the Neosho, Spring, and Verdigris river basins (Arkansas River system) in southeast Kansas. These mussels are the Neosho mucket (*Lampsilis rafinesqueana*), Ouachita kidneyshell (*Ptychobranchus occidentalis*), rabbitsfoot (*Quadrula cylindrica cylindrica*), and western fanshell (*Cyprogenia aberti*). Beginning in 1986, these species received legal protection by KDWP under the authority of the state's Nongame and Endangered Species Conservation Act of 1975. In 1992 their listing status was upgraded from SINC (species in need of conservation) to Threatened (Ouachita kidneyshell) and Endangered (Neosho mucket, rabbitsfoot, and western fanshell) (K.A.R. 115-15-1 and 115-15-2).

This plan, as governed by K.A.R. 115-15-4, outlines specific strategies and methods to recover and eventually delist these four mussel species. The plan also provides a process of conserving 14 additional state-listed mussel species (Table 1) that occur in southeast Kansas.

A. OVERVIEW OF FRESHWATER MUSSELS

The world's greatest diversity of freshwater mussels (Unionoida) is concentrated in North America, with approximately 300 species and subspecies (Turgeon *et al*. 1998). Freshwater bivalves have been around for a long time, dating back to the late Devonian Period (Gray 1988). Unfortunately, the rich historical mussel fauna of North America has recently become seriously jeopardized. In fact, freshwater mussels are now considered the most imperiled group of animals in North America (Allan and Flecker 1993). Sixty-one species are federally listed as endangered and eight as threatened (USFWS Box Score, 30 April 1999). Thirty-six species are believed extinct in North America (Neves *et al*. 1997), and that number is expected to increase (Shannon *et al.* 1993).

Unionids in Kansas have undergone a similar decline. Of the 46 species known to have occurred in Kansas, five are now state-listed as endangered, four as threatened, and 12 as SINC. Additionally, at least four species are thought to be extirpated from the state: the black sandshell (*Ligumia recta*), hickorynut (*Obovaria olivaria*), snuffbox (*Epioblasma triquetra*), and winged mapleleaf (*Quadrula fragosa*) (Couch 1997, Obermeyer *et al*. 1997a, Bleam *et al*. 1998).

TABLE 1. ***Status, distribution, and potential hosts of state-listed mussel species that presently occur in southeast Kansas.***

Species	Status	Basin [a]	Potential hosts found in SE KS
butterfly *(Ellipsaria lineolata)*	Threatened	N, V	freshwater drum and green sunfish
deertoe *(Truncilla truncata)*	SINC	N, V	freshwater drum
elktoe *(Alasmidonta marginata)*	Endangered	S	white sucker, northern hogsucker, shorthead redhorse, rock bass, and warmouth
ellipse (bleedingtooth mussel) *(Venustaconcha ellipsiformis)*	Endangered	S	banded sculpin, bluntnose minnow, fantail darter, greenside darter, Johnny darter, logperch, orangethroat darter [c], and redfin darter [c]
fat mucket *(Lampsilis siliquoidea)*	SINC	N, S, V	black crappie, bluegill, bluntnose minnow, largemouth bass, longear sunfish, orangespotted sunfish, rock bass, smallmouth bass, striped shiner, walleye, warmouth, white bass, white crappie, and white sucker
fawnsfoot *(Truncilla donaciformis)*	SINC	N, V	freshwater drum
flutedshell *(Lasmigona costata)*	Threatened	N, V	banded darter, common carp, and northern hogsucker
Neosho mucket [b] *(Lampsilis rafinesqueana)*	Endangered	N, S, V	largemouth bass, smallmouth bass, and spotted bass [c]
Ouachita kidneyshell [b] *(Ptychobranchus occidentalis)*	Threatened	N, S, V	orangethroat darter and greenside darter
rabbitsfoot [b] *(Quadrula cylindrica)*	Endangered	N, S	bigeye chub* and spotfin shiner
round pigtoe *(Pleurobema sintoxia)*	SINC	N, S, V	bluegill, bluntnose minnow, northern redbelly dace, smallmouth bass, and spotfin shiner
spike *(Elliptio dilatata)*	SINC	N, V	black crappie, flathead catfish, gizzard shad, and white crappie
creeper (= squawfoot) *(Strophitus undulatus)*	SINC	N, S, V	banded darter, black bullhead, bluegill, bluntnose minnow, creek chub, fantail darter, fathead minnow, golden shiner, green sunfish, largemouth bass, sand shiner, spotfin shiner, walleye, yellow bullhead, and white crappie
Wabash pigtoe *(Fusconaia flava)*	SINC	N, S, V	black crappie, bluegill, creek chub, and white crappie
washboard *(Megalonaias nervosa)*	SINC	N, V	American eel*, black bullhead, black crappie, bluegill, central stoneroller, channel catfish, flathead catfish, freshwater drum, gizzard shad, green sunfish, highfin carpsucker, largemouth bass, logperch, longear sunfish, longnose gar, slenderhead darter, white bass, and white crappie
wartyback *(Quadrula nodulata)*	SINC	N, V	black crappie, bluegill, channel catfish, flathead catfish, largemouth bass, and white crappie
western fanshell [b] *(Cyprogenia aberti)*	Endangered	S, V	banded sculpin, fantail darter, and logperch
yellow sandshell *(Lampsilis teres)*	SINC	N, S, V	black crappie, green sunfish, largemouth bass, longnose gar, orangespotted sunfish, shortnose gar, warmouth, and white crappie

[a] N = Neosho River basin, S = Spring River basin, V = Verdigris River basin; [b] Species targeted in the recovery plan; [c] Inferred host; * = presumed extirpated.

Reasons for protecting the state's rich diversity of freshwater mussels are numerous. Because mussels are filter feeders, they contribute to water quality by removing suspended particles of sediment and detritus. According to Allen (1914), an average-sized mussel can filter over eight gallons of water during a 24 h period. In high-density mussel beds, the filtering effect of thousands of mussels is ecologically significant. Let's consider a high density mussel bed in the Verdigris River near Syracuse, Montgomery County, which has been estimated to harbor from 128,000 to 313,000 individuals in a 300 m stretch of riffle habitat (Miller 1999a). Between 500,000 to 1,000,000 gallons of water may be siphoned[1] each day by mussels at this site, assuming optimal water temperatures. During a typical summer-time flow of 50 cubic feet/sec, roughly 1.6 to 3.9% of the stream flow may be siphoned by mussels at this site at any given moment.

Mussels are an important food source for aquatic and terrestrial animals. Furbearers such as the raccoon, muskrat, and otter feed extensively on mussels. Many fish species benefit because filter-feeding mussels discard undigested food in strands of mucus. This material is fed upon by other stream invertebrates that are, in turn, fed upon by fishes.

The shells of mussels are an economic resource. Currently, the monkeyface (*Quadrula metanevra*), threeridge (*Amblema plicata*), mapleleaf (*Q. quadrula*), and bleufer (*Potamilus purpuratus)* are commercially harvested in Kansas for the cultured pearl industry. During the early part of the century, most species in southeastern Kansas, especially in the Neosho River, were harvested for use in the manufacture of buttons and other pearly products. According to a musseler active during the late 1920s (A.A. Frischenmeyer, Chanute resident, pers. comm.), the mucket [Neosho mucket] was one of the most sought after species by the Iola shell-blank factory (also, see Coker 1919). Over 17,000 tons of shells were collected from the Neosho River during 1912, representing approximately 17% of the nation's total pearly products (Coker 1919, Murray and Leonard 1962). Coker (1919) estimated that a ton of shells taken from virgin beds equaled 5,000 to 10,000 live mussels. Based on this estimate, over 85 million mussels may have been harvested from the Neosho River in this one year. During 1918, a shell blank factory in Iola processed up to 30 tons of shells a week; most of these shells were collected from the Neosho River near Leroy (Iola Register, 6 April 1918). By 1920, annual harvest

[1] Filtering estimate is based on a summer filtering rate estimate of four gallons of water per mussel during a 24 h period.

yields had declined, with only 500 tons of shells processed at the Iola factory (Iola Register, 2 September 1920).

Mussel shells are collected by amateur and professional biologists, who find them aesthetically pleasing and educational. The shells provide a durable record of a species' historical presence. They also provide a record of the history of each individual in the annual rings of growth, showing that some species live over a century. This record also documents changes in stream health through time because of the mussels' sensitivity to pollution. Therefore, freshwater mussels, as important indicators of aquatic health, serve much the same purpose as canaries in a coal mine.

Perhaps the most fundamental reason for protecting any endangered species is the concept of stewardship. Mussels are an integral part of nature, yet can be destroyed all too easily by the acts of man. The concept of stewardship holds that, apart from any perceived utility or profit in a species, man has the moral obligation to protect and preserve nature. Each species is an irreplaceable part of our heritage and that of our children.

"To keep every cog and wheel is the first precaution of intelligent tinkering."

—Aldo Leopold, *Sand County Almanac*

1. Life History

The life history of freshwater mussels consists of four basic life stages: reproductive, larval or parasitic, juvenile, and adult (Figure 1). Most mussels are dioecious (having separate sexes). Males release sperm into the water, and the sperm are filtered from the water by the female. Fertilized eggs are brooded within the female's gills or marsupium, which contain hollow spaces for this purpose. Fecundity varies among species, ranging from 75,000 to 3,000,000 larvae (Surber 1912, Coker *et al.* 1921). Mussel larvae, called glochidia, may be released soon after they are mature, or may be retained in the gills for several months or until the next season (Ortmann 1911). Species that release glochidia soon after they are mature are called short-term breeders (tachytictic), whereas species that retain their glochidia for extended periods of time are called long-term breeders (bradytictic). Tachytictic species generally spawn in the spring, whereas bradytictic species usually spawn during summer months.

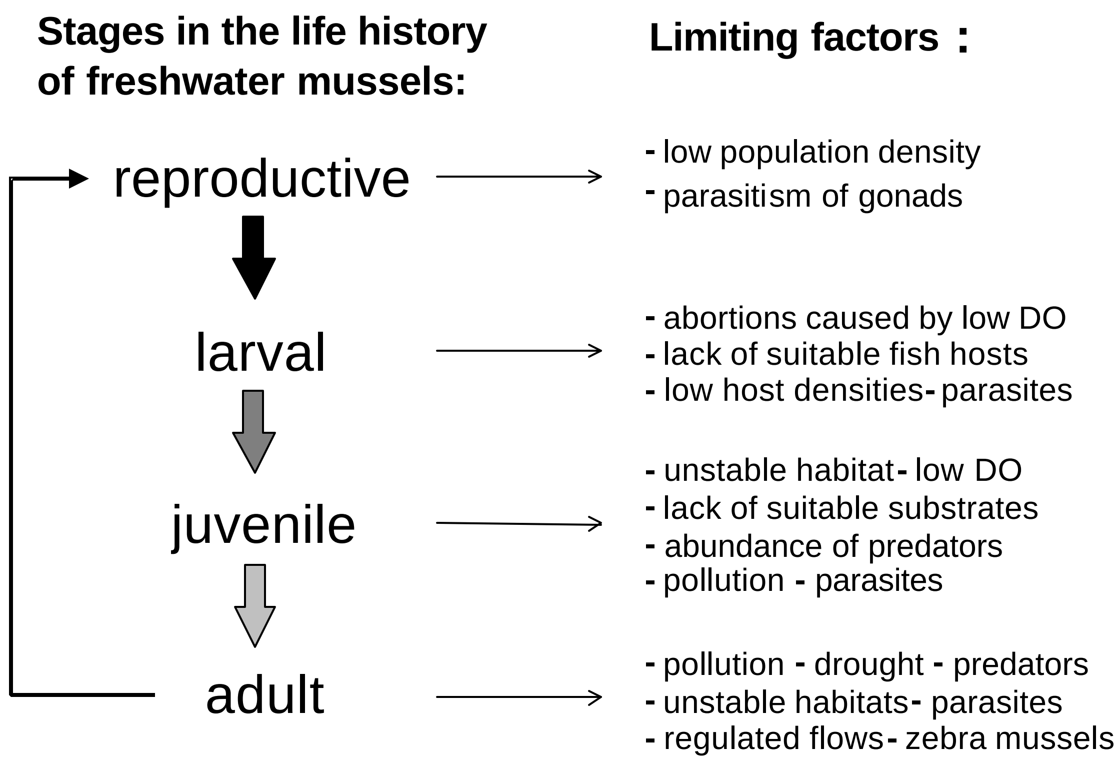

Figure 1. ***Four basic life stages of freshwater mussels and possible limiting factors.***

Glochidia must briefly parasitize a vertebrate host (usually a fish) to complete its development[1] (see Table 1). The primary function of larval parasitism on fish appears to be transport to upstream habitats (Surber 1913). Larvae attached to fish may be carried upstream, whereas adult mussels are not very mobile, and unattached larvae can only drift downstream. Glochidia must come in contact with a vertebrate host soon after leaving the female mussel. Only a small percentage of glochidia actually make contact with a suitable host. Upon contact with a gill filament, a fin, or the epithelium of a fish, a glochidium clamps on to host tissue. Glochidia, however, cannot discriminate between suitable and non-suitable tissue, and may snap shut in response to just about any stimulus. If the glochidium attaches to an unsuitable host, it will be rejected and sloughed off. On a suitable host, the tissue encapsulates the glochidium by proliferation of epithelial cells. In most species the encapsulation period lasts

[1] Only one North American species, the green floater (*Lasmigona subviridis*), is positively known to bypass the parasitic life phase (Barfield and Watters 1998, Lellis and King 1998).

from 2 to 3 weeks, although it can range from 6 days to 7 months (Howard 1915). Following metamorphosis, the juvenile mussel will excyst, drop from the fish, and take up life as a sedentary filter feeder. The percentage of glochidia that reach this stage is extremely small. Young and Williams (1984) estimated that only about 0.001% of the glochidia of *Margaritifera margaritifera* develop into juveniles.

The juvenile or post-parasitic stage represents the period from metamorphosis to when a young mussel produces gametes, which usually occurs from two to six years of age for most species in Kansas. This stage, especially during the first few months, is thought to be a vulnerable link in the life cycle of freshwater mussels (Dimock and Wright 1993, O'Beirn *et al*. 1998, Sparks and Strayer 1998), and may be affected by Kansas' eutrophic waters (Obermeyer *et al*. 1997a). Specific ecological requirements of juvenile mussels remain unknown for most species, and attempts to raise juveniles have only recently yielded acceptable results (Gatenby *et al*. 1996, 1997, O'Beirn *et al*. 1998).

The adult life stage is typically what most people envision when they think about freshwater mussels. Consequently, past mussel research has largely focused on this life stage. Fortunately, researchers have recently begun to address the entire life cycle of freshwater mussels. Nonetheless, emphasis on the adult life stage is appropriate for certain aspects of mussel research, such as distributional assessments.

2. Habitat Requirements

Characterization of specific habitat requirements for freshwater mussels is difficult because of their broad microhabitat tolerances and site-specific preferences (Strayer 1981, Kat 1982, Gordon and Layzer 1989, Strayer and Ralley 1993, Obermeyer *et al.* 1997a). Habitat use on a broader scale, however, is more predictable. Many of the state-listed mussels that occur in southeast Kansas are generally found in medium to large streams at depths less than one meter in predominantly stable and well compacted gravel substrate (Obermeyer 1996, Obermeyer *et al*. 1997b). Although some species are more abundant in deeper habitats, such as the washboard (*Megalonaias nervosa*) (Obermeyer 1997a), this abundance may be the result of deepwater habitat serving as refugia from drought and mussel harvesting rather than being a preferred habitat of a species (see Cochran and Layzer 1993). Another characteristic common to riverine mussels in Kansas is their association with stable instream habitats, which is especially noticeable in streams with a high rate of channel migration. In meandering streams like the Neosho River (Dort 1998), mussels are mostly restricted to stable reaches, such as where the river meets limestone outcrops (Obermeyer 1996, Obermeyer *et al*. 1997a).

3. Causes for the Decline

There are many potential causes for the decline of mussels in southeast Kansas. Factors such as habitat degradation and fragmentation and point and nonpoint source pollution are implicated in mussel declines throughout North America (*e.g*. Ortmann 1909, Baker 1928, van der Schalie 1938, 1958, Fuller 1974, Stansbery 1973, Bogan 1993, Neves 1993, Neves *et al*. 1997), including southeast Kansas (Obermeyer *et al*. 1997a). These factors may affect all four life stages of a species or may be especially detrimental to a particular life phase. More recently, the nonindigenous zebra mussel (*Dreissena polymorpha*), because of its reproductive prolificacy and competitive interaction with native mussels, has begun to wreak havoc on mussels in states as close as Oklahoma.

The deterioration of Kansas' water resources is a widespread problem for the state's freshwater mussel assemblage. The persistent influx of organic nutrients from point (*e.g*. municipal effluents) and nonpoint source pollution, particularly agricultural sources, is a major problem for mussels in Kansas. Eutrophication and resulting deficits in dissolved oxygen, especially in interstitial habitats, may be detrimental to juvenile mussels, resulting in poor recruitment in sensitive species. Sparks and Strayer (1998) observed stress responses (gaped valves, extended siphons, and surfacing) in juveniles of *Elliptio complanata* when subjected to dissolved oxygen (DO) levels less than 2 mg l^{-1}, and found a significant increase in mortality when they were held at this concentration of DO for one week. They speculated that behavioral responses to low DO may make juvenile mussels more vulnerable to predation and displacement. The reproductive stage of gravid females may also be adversely affected by an increased risk of bacterial and protozoan attacks to fertilized ova and glochidia (van der Schalie 1938, Fuller 1974).

Another cause of stream deterioration in Kansas is high sediment loads from chiefly agricultural runoff, which is considered the most serious pollutant of North American streams (Waters 1995). Anthropogenic sediment degrades mussel habitats by covering the substrate and by decreasing substrate permeability. Sparks and Strayer (1998) suggested that substrate permeability was an important factor in determining DO availability to juvenile mussels. Because juvenile mussels are restricted to primarily interstitial habitats (Isely 1911, Clarke 1986, Neves and Widlak 1987, Yeager *et al.* 1994), the smothering effect of silt is probably a major factor in preventing successful recruitment for sensitive species. The smothering effect of silt is also linked to mortality in adult mussels (Ellis 1936, Imlay 1972). Moreover, elevated levels of suspended solids can interfere with visually-oriented reproductive adaptations, gas exchange (Ellis 1936, Aldridge *et al*. 1987), and the brooding of glochidia (Ellis 1931). Suspended solids can also interfere with filter feeding, causing both a decrease in the productivity of the organisms consumed by mussels (Fuller 1974) and in the filtering efficiency of food particles (Ellis 1936, Stansbery 1970, Kat 1982).

The decrease in mussel abundance and diversity in Kansas' streams and rivers can be attributed to a combination of factors and the persistence of these factors rather than any single cause or event. However, abrupt mussel declines from events like exposure to toxic spills are documented in Kansas. Examples include oil and saltwater spills into the Cottonwood River (Doze 1926), feedlot runoff into the Cottonwood River during the 1960s (Cross and Braasch 1968, Prophet 1969, Prophet and Edwards 1973), and contamination by heavy metals from mine tailings into the Spring River (KDHE 1980, Davis and Schumacher 1992). These effluents can have devastating results to mussels, especially less tolerant species that are unable to close their valves and cease siphoning during intermittent pulses of toxins.

Anthropogenic habitat modifications can also lead to declines in mussel diversity and abundance (Stansbery 1970, 1973, Fuller 1974, Williams *et al*. 1993, Bogan 1993, Layzer and Madison 1995). Instream gravel mining affects mussels by increasing sediment loads downstream, accelerating bank erosion and channel migration, and upstream headcutting (Hartfield 1993). When a stream is dammed, the impounded stream channel is transformed from a free-flowing, well-oxygenated environment to one that is more stagnant and prone to silt deposition, an intolerable condition for many riverine mussel species. The suitability of downstream habitats for mussels is also influenced by the operation of dams. The discharge of accumulated flood waters from reservoirs may be maintained at half- to full-channel capacity for extended periods, confining the energy of a flood to the downstream channel rather than allowing it to be distributed over the flood plain. The result can be a degradation of the stream channel by bed downcutting and/or lateral migration (Williams and Wolman 1984, Obermeyer *et al*. 1997a, Poff *et al.* 1997, Hadley and Emmett 1998). Dams are also barriers to host fish, preventing upstream and downstream recolonization.

B. OVERVIEW OF RIVER BASINS

The Neosho, Spring, and Verdigris river basins are located in the Flinthills and Central Irregular Plains ecoregions (Omernik 1987), formerly an extensive area of grasslands dominated by warm season grasses, with riparian forests bordering most perennial streams. Although degraded from over a century of intensive cattle grazing, native grasslands remain in some of the uplands of the Neosho and Verdigris river basins where upland soils are too shallow to permit cultivation. Because of rich alluvial soils in the flood plains, bottomland prairie communities have been replaced by intensive agriculture, with the exception of a few relict patches. Many of the riparian forests along major streams have been reduced to thin ribbons of trees.

Principal streams and drainage areas (km^2) in the Neosho River basin include the Neosho (15,000) and Cottonwood (4,940) rivers. Major streams in the Verdigris River basin include the Verdigris (8,690), Fall (2,290), and Elk (1,820) rivers. Water flow in these streams are subject to flow interruptions during severe droughts (Deacon 1961, Miller and Obermeyer 1997) and by operation of flood-control impoundments. The flow regime of the Neosho River is regulated by Council Grove Lake and John Redmond Reservoir, and the flow of the Cottonwood River is affected by Marion Lake. Flows of the Verdigris, Fall, and Elk rivers are influenced by Toronto, Fall River, and Elk City dams.

The Spring River basin drains approximately 5,414 km^2 of southwest Missouri, and 1373 km^2 in southeast Kansas (Davis and Schumacher 1992). Principal streams of the basin in Kansas are the Spring River and Shoal Creek, both of which originate from the Ozark Plateau. Unlike streams in the Neosho and Verdigris basins, the hydrology of the Spring River basin has not been altered by flood-control impoundments. Moreover, the Spring River and Shoal Creek are more tolerant of drought because of spring-fed flows. Differences in geology and land use (*e.g.* 45% of the Shoal Creek watershed is forested, Davis and Schumacher 1992) result in lower turbidities than most other Kansas streams, and may help explain why the Spring River and Shoal Creek have richer aquatic faunas than other Kansas streams (Cross and Collins 1995). However, mussel species richness is not significantly different in the Spring River basin from the Neosho and Verdigris river basins (Obermeyer *et al.* 1997b). Despite the rich diversity of mussels and other aquatic organisms in the Spring River basin, past mining has resulted in the contamination of several streams with heavy metals, such as zinc, lead, copper, and cadmium (KDHE 1980, Davis and Schumacher 1992). This contamination has apparently eliminated much of the mussel fauna in the lower Spring River (Obermeyer *et al.* 1997a).

C. RECOVERY STRATEGY

An ecosystem approach is the most appropriate way to recover these four mussel species. The goal of ecosystem management of rivers is to restore the biological integrity of the river ecosystem (Poff *et al*. 1997). Accomplishment of this goal may require changing dam operations to mimic natural flow regimes. Adopting land management practices that reduce the delivery of nutrients and sediments into streams will also be required.

The recovery of these species will also require species-level management (Noss *et al.* 1995), especially for fragmented populations. Even in pristine environments, natural recolonization may be insufficient to balance extinction in sparse and fragmented populations (Vaughn 1993). The rabbitsfoot in the Neosho River is a good example. Because it is dangerously close to becoming extirpated in the Neosho River basin, watershed improvements alone are probably too little, too late. Instead, a species-level approach will be required, which might include, for example, reestablishing the species into stream reaches where it has become extirpated.

II. Species Accounts

A. NEOSHO MUCKET – *LAMPSILIS RAFINESQUEANA* FRIERSON 1927

1. Taxonomy and Description

Original Description.—*Lampsilis rafinesqueana* Frierson 1927, a classified and annotated check list of the North America naiades, Baylor University Press, 111 p. Type locality: Moodys, Oklahoma [Illinois River: 10 mi. N Tahlequah, Cherokee County]. Holotype (MZUM 87576) was figured in Frierson, L.S., 1928, Nautilus 41:138, pl. 1, figs. 1,2; paratypes are MZUM 90665 and ANSP 145238; allotype (MZUM) is presumed lost (Johnson 1980).

Taxonomic Discussion.—Prior to Frierson's (1927) description of the Neosho mucket, the species was identified in Kansas as *Actinonaias carinata, A. ligamentina, A. ligamentina carinata, Lampsilis ligamentina, L. ligamentina gibba, L. powellii, Unio ligamentina, and U. powellii* (Eberle 1994). Even after Frierson's published description of the Neosho mucket, it was often mistakenly identified as the mucket; that is, *A. ligamentina* or *A. carinata* (*e.g.* Murray and Leonard 1962) (Cope 1979, Mather 1990, D.H. Stansbery, Ohio State University Museum of Biodiversity, pers. comm.). The Neosho mucket was not referred to in Kansas prior to Cope (1979).

Shell characteristics of the Neosho mucket and mucket are remarkably similar, making them difficult to distinguish. The shell of the Neosho mucket can also be confused with the fat mucket (*Lampsilis siliquoidea*), plain pocketbook (*L. cardium*), and aged butterfly (*Ellipsaria lineolata*) females. However, the two species can be separated by locality information, because their ranges do not overlap; *A. ligamentina* does not occur in the Arkansas River system upstream from the Fourche le Fave River in Arkansas (D.H. Stansbery *in* Mather 1990). The two species can also be separated anatomically. The mantle edge of the Neosho mucket is orange with dark markings (Oesch 1984), whereas the mantle edge of the mucket is light to dark brown (Ortmann 1912, Oesch 1984). Neosho mucket females can also be positively identified by a pair of mantle flaps, which are characteristic of the genus *Lampsilis.*

Shell Description (Figure 2).—The shell is smooth, oblong, and relatively thick, especially specimens from the Neosho and Verdigris river basins. Maximum length for the species is 163 mm (6.4 inches) (Obermeyer 1996). The anterior and ventral margins of shell are gently rounded. The posterior end of the female shell is more inflated laterally and more

extended from dorsal to ventral margin than the shell of the male, which is more elliptical and compressed. Beaks extend only slightly beyond the hinge line. The periostracum is olive-yellow to dark brown, with rays consisting of chevrons across the disc of shell in younger specimens. The left valve has two pseudocardinal teeth, whereas the right valve has one erect tooth. The interdentum is broad and sometimes extends about the same distance in length as the lateral tooth, which curves slightly downward. The nacre is creamy white.

2. Historical and Current Distribution

***Historical Distribution*.—**The Neosho mucket is endemic to the Arkansas River system in southeast Kansas, southwest Missouri, northeast Oklahoma, and extreme northwest Arkansas (Obermeyer *et al*. 1997b). Streams where the species occurred in Kansas include the Neosho, Cottonwood[†], South Fork of the Cottonwood[†], Spring, Verdigris, Elk[†], Fall, and Caney[†] rivers, and Middle[†], Otter[†], and Shoal[†] creeks (Obermeyer *et al*. 1997a, 1997b).

***Current Kansas Distribution (Figure 3).*—**In the Spring River, the Neosho mucket is presently found from where the river first enters the state to just downstream from the confluence of Center Creek (Obermeyer *et al*. 1997a, 1997b). Relatively high densities of the Neosho mucket occur throughout this reach of stream. The highest density ever recorded for the species was in this reach, approximately 1.25 km downstream from K-96 highway bridge (site BKO-94-48, Obermeyer *et al*. 1995). Here, the maximum density of Neosho muckets was 67 in a single m^2 quadrat and the average density was 12.9 per m^2 (SD = 20.27) (n = 20 m^2). Although the Neosho mucket was apparently extirpated in the remaining downstream portion of the Spring River (*i.e*. below the confluence of Turkey Creek, near Hwy US-66), two recently dead valves were collected in the Oklahoma portion of this stream in 1996 (Vaughn 1998). In Shoal Creek, the species is likely extirpated downstream from the Joplin wastewater treatment plant (WWTP) near the state line (Clarke and Obermeyer 1996). It remains, however, in the Missouri portion of Shoal Creek (Clarke and Obermeyer 1996).

Obermeyer *et al*. (1997a, 1997b) collected 32 live Neosho muckets at seven of 23 sites in the Neosho River. These were found from near Burlington downstream to a site located in the old Neosho River cutoff channel near St. Paul (BKO-94-23, see Obermeyer *et al.* 1995).

[†] = Presumed extirpated.

The majority of live Neosho muckets were collected from three sites, located between Iola and Humboldt. These were the only sites in the Neosho River that revealed any evidence of recent recruitment (Obermeyer *et al*. 1995).

In the Verdigris River, Obermeyer *et al*. (1997a, 1997b) found the Neosho mucket restricted to an area from just downstream of the Altoona city dam to near Independence, collecting just five individuals at four of 14 Verdigris River sites. Miller (1992, 1993) found five live Neosho muckets at eight sites (from 320 m^2 quadrat samples) in a ten-mile reach near Sycamore. A follow-up survey at these eight sites in 1997 yielded only two Neosho muckets (Miller 1999b). Additional sampling (120 m^2 quadrats) in 1998 at a new site in this stream reach (EJM-98-01), which is located approximately one mile downstream from site BKO-94-15 (see Obermeyer *et al*. 1995), failed to yield any live or recently dead Neosho muckets (E.J. Miller, KDWP, pers. comm.).

In the Fall River, 34 Neosho muckets were collected at five of 12 sites in 1994 (Obermeyer *et al*. 1997a, 1997b). Live specimens were found downstream from the town of Fall River to near the river's confluence with the Verdigris River. Most of the live Neosho muckets collected were aged adults, although one individual was estimated to be six or seven years of age (Obermeyer *et al.* 1995).

3. Reproduction and Habitat

Reproduction.—Mussels have evolved some fascinating reproductive adaptations to increase the chances that glochidia will make contact with a suitable host. The female Neosho mucket extends a pair of mantle flaps (actually an extension of the inner lobe of the mantle edge, Kraemer 1970) that, from a side angle, remarkably resembles a small fish. Each mantle flap, in addition to its fish-like shape, has pigmentation that resembles an eyespot as well as a fish's lateral line. Muscular contractions of the mantle flaps create an undulating or "swimming" motion that apparently acts as a lure to attract potential fish hosts (Gordon and Layzer 1989, Barnhart and Roberts 1997). If a fish comes close or strikes at the lure, the female Neosho mucket may spray a cloud of glochidia at the fish through ostia or pores of the swollen marsupial gills, which extend between the two mantle flaps.

The Neosho mucket is a bradytictic breeder. Thirteen fish species have been tested under laboratory conditions to determine host suitability for the Neosho mucket. Of these, glochidia transformed on only two species, largemouth bass (*Micropterus salmoides*) and smallmouth bass (*M. dolomieu*) (Barnhart and Roberts 1997). The spotted bass (*M. punctulatus*) is another a likely host (M.C. Barnhart, SMSU, pers. comm.).

Habitat.—The Neosho mucket is most often found in shallow riffle and runs in moderately clean and compacted gravel substrate (Table 2, Figure 5) (Oesch 1984, Obermeyer 1996, Obermeyer *et al*. 1997b). More specific characterizations of habitat use for the species is difficult because of high variability of habitat use among streams, especially between prairie streams (Neosho, Fall, and Verdigris rivers) and Ozarkian streams (Obermeyer *et al*. 1997b, Figure 5). For example, mean current speed (60% depth) at specific locales where the species was collected was 51.8 cm/s higher in the Spring River than in other Kansas streams (Table 2) (Obermeyer 1996, Obermeyer *et al*. 1997b). Also, silt deposition at specific locales where the species was collected was substantially lower in the Spring River compared to the Neosho, Verdigris, and Fall rivers.

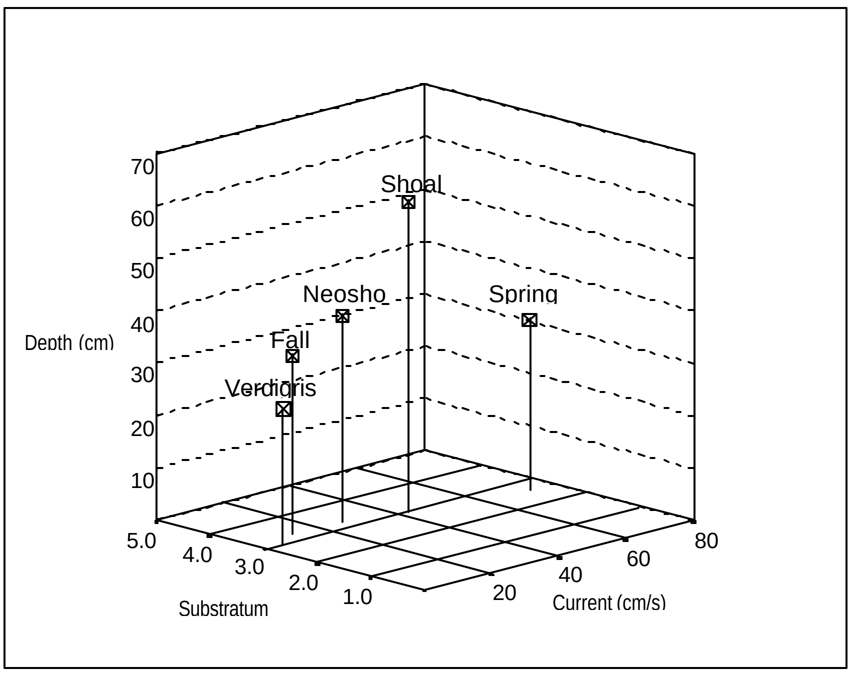

Figure 4. ***Three-dimensional ordination plot of habitat measurements taken for the Neosho mucket in southeast Kansas and southwest Missouri.*** *The substratum value is the proportion of mud (1), sand (2), gravel (3), cobble (4), and boulder (5). Current velocities were taken at depths of 60%. (From Obermeyer 1996)*

TABLE 2. *Habitat use (mean values) for the four mussel species targeted in the Recovery Plan.* *(From Obermeyer et al. 1997b) Data represents individual habitat use for each mussel collected, with the exception of the Neosho mucket in the Illinois River, Oklahoma[3].*

Species	Stream	n	Depth (cm)	Current speed (cm/s):		Substrate character (%)						
				100% depth	60% depth	Mud	Sand	Gravel	Cobble	Boulder	Compaction[1]	Silt[2]
Neosho mucket												
	Fall	34	34.1	12.4	13.2	0.7	11.7	48.4	37.6	1.5	1.2	1.3
	Verdigris	5	26.2	3.2	5.2	11.0	11.0	52.0	27.0	0.0	1.0	1.6
	Neosho	32	39.6	16.0	27.0	3.3	14.9	41.3	35.9	4.4	1.1	1.4
	Spring	258	33.0	43.5	72.4	1.0	16.4	74.3	0.0	0.0	1.0	0.2
	Shoal Cr.	20	59.4	20.4	42.2	0.3	17.1	74.5	8.3	0.0	0.9	0.1
	Illinois[3]	8	75.9	-	111.3	-	-	82.0	-	-	-	-
Ouachita kidneyshell												
	Fall	17	17.5	12.2	14.1	1.8	13.3	62.0	13.9	6.9	0.9	1.2
	Verdigris	9	19.0	13.2	18.6	2.6	15.3	73.2	8.9	0.0	1.0	1.3
	Spring	12	41.0	26.8	44.4	1.0	24.6	69.0	5.4	0.0	0.9	0.3
	Shoal Cr.	4	73.5	34.9	97.1	0.0	11.8	82.0	7.5	0.0	1.3	0.0
rabbitsfoot												
	Neosho	2	12.5	27.5	38.0	0.5	7.0	60.0	32.5	0.0	1.0	1.0
	Spring	5	44.2	23.8	56.2	0.0	20.0	80.0	0.0	0.0	0.9	0.2
western fanshell												
	Fall	5	29.6	8.4	16.8	0.2	14.2	18.4	45.2	22.0	1.0	1.2
	Verdigris	9	26.5	17.1	20.9	4.1	12.6	7.3	75.1	0.0	0.8	1.5
	Spring	3	37.3	27.2	65.0	0.0	30.0	1.7	68.3	0.0	0.7	0.3

1. Substrate compaction was based on a qualitative assessment, which was coded 0 through 2: loose = 0; moderately compacted = 1; very compacted = 2.
2. Silt deposition: 0 = no detectable silt, 1 = fine layer of silt; 2 = moderately covered with silt; 3 = heavy covering of silt.
3. Data represents average depth, flow, and percent gravel at eight sites in the Illinois River, OK. (Data taken from Vaughn 1998)

4. Designated Critical Habitat (Figure 5)

Critical habitat currently occupied:

- *Neosho River*: from John Redmond dam (Coffey Co.) to Parsons city dam (Labette Co.).
- *Spring River*: from where the Spring River first enters Kansas to the confluence of Turkey Creek, near Hwy US-66 (Cherokee Co.).
- *Fall River*: from Fall River dam (Greenwood Co.) to its confluence with the Verdigris River (Wilson Co.).
- *Verdigris River*: from K-47 (Wilson Co.) to the city of Coffeyville (Montgomery Co.).

Critical habitat, but lacking recent documentation of the species:

- *Neosho River*: from the Morris-Lyon county line to John Redmond Lake; from Parsons city dam (Labette Co.) to the Kansas-Oklahoma border.
- *Cottonwood River*: from Elmdale (Chase Co.) to the river's confluence with the Neosho River (Lyon Co.).
- *South Fork of the Cottonwood River*: from Bazaar to the river's confluence with the Cottonwood River (Chase Co.).
- *Spring River*: from Empire Lake dam (Cherokee Co.) to the Kansas-Oklahoma border.
- *Shoal Creek*: from the Kansas-Missouri border to Empire Lake (Cherokee Co.).
- *Big Caney River*: from US-166 (Chautauqua Co.) to the Kansas-Oklahoma border.
- *Elk River*: from Elk Falls (Elk Co.) to Elk City Lake (Montgomery Co.).
- *Fall River*: from K-99 to Fall River Lake (Greenwood Co.).
- *Otter Creek*: from K-99 to Fall River Lake (Greenwood Co.).
- *Verdigris River*: from Toronto Lake dam to K-47 (Wilson Co.), and from the city of Coffeyville (Montgomery Co.) to the Kansas-Oklahoma border.

B. Ouachita kidneyshell – *Ptychobranchus occidentalis* (Conrad 1836)

1. Description

Original Description.—*Unio occidentalis* Conrad 1836, monography of the Family Unionidae, or naiades of Lamarck, (fresh water bivalve shells) of North America, figures drawn on stone from nature, privately published in Philadelphia, Pennsylvania. 7:57-64, plates 32-36; type locality: Currant River [= Current River, Randolph County], Arkansas; figured holotype not found (Johnson and Baker 1973).

Shell Description (Figure 6).—The shell is compressed to slightly inflated and oblong; younger specimens are more oval in shape. Maximum length of shell in Kansas is 143 cm (5.5 inches) (BKO, unpub. data). The anterior end is gently and uniformly rounded, whereas the posterior end is pointed in a downward direction; ventral margin is straight to concave. The shell is sturdy and relatively thick, and the surface is smooth, other than concentric growth-rest lines. The posterior ridge is rounded to absent, and the posterior field is steeply sloped in males, more gradual in females. Beaks are slightly elevated and sculpturing is absent. The periostracum is straw-colored to greenish-yellow, with fine green rays that extend from the umbonal region to the shell margin. The left valve has two pseudocardinal teeth and two lateral teeth. The groove between the two lateral teeth in the left valve points to the middle of the posterior adductor muscle scar. The right valve has one pseudocardinal tooth and one lateral tooth. The lateral teeth curve downward about one-fourth the length of valve. A distinct shelf runs along the ventral edge of the lateral tooth in the right valve. The interdentum is broad and extends approximately three-fourths to an equal distance in length as the lateral teeth. A sulcus or groove, which accommodates the marsupial gill, originates in the umbonal region and extends in a posterior-ventral angle to near the pallial line. The sulcus is less pronounced in the shell of males. Nacre is creamy white, with iridescence posteriorly.

2. Historical and Current Distribution

Historical Distribution.—The Ouachita kidneyshell historically occurred in the Arkansas, Meramec, Ouachita, Red, St. Francis, and White river systems in Arkansas, Kansas, Missouri, and Oklahoma (Johnson 1980). Although earlier published accounts of the species in the Meramec River basin (Buchanan 1980, Oesch 1984) have been questioned because of possible specimen mislabeling (Obermeyer *et al*. 1997a), the species was apparently collected

from Meramec State Park in 1956 by Morris Jacobson (K.S. Cummings, Illinois Natural History Survey, pers. comm.). The species may have also occurred in the upper Osage River system, based on UMMZ specimens (K.S. Cummings, pers. comm.). Call (1885b) lists the species in the Wakarusa River (Call 1885b); however, Scammon (1906) failed to find the species there. The Wakarusa specimen may have been confused with the spike (*Elliptio dilatata*). The Ouachita kidneyshell is thought to be extirpated from the Neosho, Cottonwood, South Fork of the Cottonwood, Caney, and Elk rivers, and Shoal and Otter creeks (Obermeyer *et al.* 1997a). Its occurrence elsewhere in the state is questionable.

Current Kansas Distribution (Figure 7).—Miller (1992) collected seven live specimens at four of eight Verdigris River sites. Resampling of these sites in 1997 yielded 21 individuals from five sites (Miller 1999b). Twenty-one individuals were collected in 1998 from another site, EJM-98-01, in the same stretch of river (E.J. Miller, pers. comm.; Miller 1999a). Obermeyer *et al.* (1997a, 1997b) collected 11 live Ouachita kidneyshells at four Verdigris River sites between Altoona and Independence. The species is apparently extirpated above and below this reach. In the Fall River, 19 specimens were collected from near the city of Fall River to the river's confluence with the Verdigris River. In the Spring River, 34 live specimens were collected (Obermeyer *et al*. 1997a, 1997b). Although the species is apparently extirpated in the Kansas portion of Shoal Creek, Clarke and Obermeyer (1996) collected six individuals at Shoal Creek sites in Missouri.

3. Reproduction and Habitat

Reproduction.—The Ouachita kidneyshell is a bradytictic breeder (Johnson 1980, Barnhart and Roberts 1997), which releases glochidia packets from pleated marsupial gills in early spring (Barnhart and Roberts 1997). Each packet, which strikingly resembles a larval fish, contains 200-plus glochidia housed inside a membranous sheath measuring 1 to 1.5 cm in length (Barnhart and Roberts 1997). Glochidia packets are readily taken as food by darters, which, during the process of consumption, infect themselves with glochidia (Barnhart and Roberts 1997). The orangethroat (*Etheostoma spectabile*), greenside (*E. blennioides*), yoke (*E. juliae*), and rainbow (*E. caeruleum*) darters have been identified as potential hosts (Barnhart and Roberts 1997). Of these four species, only the greenside darter and orangethroat darter are found in southeast Kansas. The greenside darter is found in the Spring River basin, whereas

the orangethroat darter is widely distributed in all three stream basins (Pflieger 1975, Cross and Collins 1995).

Habitat.—According to Buchanan (1980) and Oesch (1984), the preferred habitat of the Ouachita kidneyshell is riffle habitat with a gravel-sand substrate having a moderate current at depths between 2.5 and 75 cm. In southeast Kansas and southwest Missouri, Obermeyer *et al.* (1997b) found the Ouachita kidneyshell in well compacted and relatively clean riffle habitats, usually in or near the swiftest flows, with stable sand and gravel substrate (Figure 8, Table 2). However, depth and current speed where the species was collected varied greatly between different streams (Figure 8, Table 2).

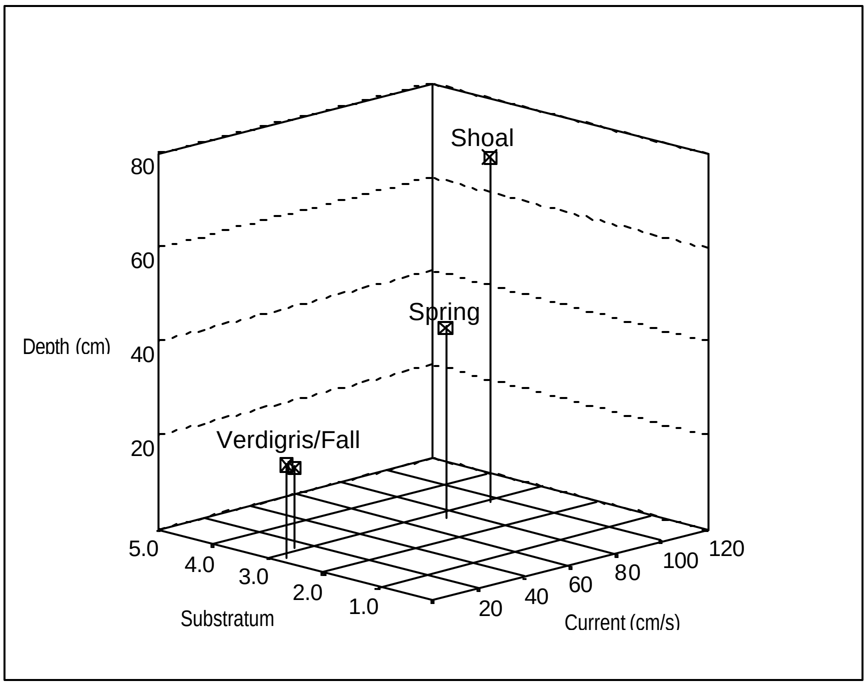

Figure 8. ***Three-dimensional ordination plot of habitat measurements taken for the Ouachita kidneyshell in southeast Kansas and southwest Missouri.*** *The substratum value is the proportion of mud (1), sand (2), gravel (3), cobble (4), and boulder (5). Current velocities were taken at depths of 60%. (From Obermeyer 1996)*

4. Designated Critical Habitat (Figure 9)

Critical habitat currently occupied:

- *Spring River*: from where the Spring River first enters Kansas to US-66 (Cherokee Co.).
- *Fall River*: from Fall River dam (Greenwood Co.) to its confluence with the Verdigris River (Wilson Co.).
- *Verdigris River*: from K-47 (Wilson Co.) to the city of Independence (Montgomery Co.).

Critical habitat, but lacking recent documentation of the species:

- *Neosho River*: from the Morris-Lyon county line to the Kansas-Oklahoma border.
- *Cottonwood River*: from Florence (Chase Co.) to its confluence with the Neosho River (Lyon Co.).
- *South Fork of the Cottonwood River*: from Bazaar to the river's confluence with the Cottonwood River (Chase Co.).
- *Spring River*: from Empire Lake dam (Cherokee Co.) to the Kansas-Oklahoma border.
- *Shoal Creek*: from the Kansas-Missouri border to Empire Lake (Cherokee Co.).
- *Big Caney River*: from US-166 (Chautauqua Co.) to the Kansas-Oklahoma border.
- *Elk River*: from Elk Falls (Elk Co.) to Elk City Lake (Montgomery Co.).
- *Fall River*: from K-99 to Fall River Lake (Greenwood Co.).
- *Verdigris River*: from Toronto Lake dam to K-47 (Wilson Co.), and from the city of Independence (Montgomery Co.) to the Kansas-Oklahoma border.

C. RABBITSFOOT – *QUADRULA CYLINDRICA CYLINDRICA* (SAY 1817)

1. Description

Original Description.—*Unio cylindricus* (Say 1817), article "Conchology," *In*: Am. Ed. of Nicholson's Encyclopedia of Arts and Sci., 1st ed.; type locality: Wabash River.

Shell Description (Figure 10).—The shell is elongate and rectangular, and inflated to the point that shells are nearly cylindrical in cross section. Valves are sturdy and relatively thick, although much thinner posteriorly. Maximum shell length in Kansas is 127 mm (5 inches) (Obermeyer 1996). The posterior ridge, which extends from the umbonal region to the posterior ventral margin, is rounded and sculptured with a row of knobs. The posterior slope is covered with fluting that angle posteriorly to the dorsal margin. The remaining surface of shell is smooth, with the exception of low concentric ridges formed by growth-rest lines. The umbonal region is moderately elevated above the hinge line, and is covered with irregular ridges and small pustules; lunule present. The periostracum is straw-colored to yellowish-brown, and is usually overlaid with dark green streaks, chevrons, and/or triangular markings. The left valve has two triangular pseudocardinal teeth and two straight lateral teeth. The right valve has a single serrated pseudocardinal tooth and a single straight lateral tooth. The anterior mussel scar is deeply incised in both valves. Interdentum is narrow to absent. The umbonal cavity is relatively deep. The nacre is white, iridescent posteriorly.

2. Historical and Current Distribution

Historical and Current Distribution (Figure 11).—The rabbitsfoot is native to the Ozarkian, Ohioan, and Cumberlandian faunal regions of 13 states (Williams *et al.* 1993). In Kansas, the species historically occurred in the Neosho, Cottonwood, Spring, Verdigris, and Fall rivers, and Shoal Creek (Obermeyer *et al.* 1997a). Extant representatives of the rabbitsfoot have recently been found in only two Kansas streams: the Neosho and Spring rivers. Two specimens were collected in the Neosho River in 1994, which was the first live collection of the species in the Neosho River since 1912 (Isely 1924, Obermeyer *et al*. 1997a, 1997b). Sampling at 21 additional Neosho River sites failed to recover evidence of extant populations, but relic valves of the species were found at nine of these sites. In the Spring River, five specimens were collected from one Kansas and two Missouri sites (Obermeyer *et al.* 1997b); five additional individuals were collected at the Kansas Spring River site in 1996 (BKO, unpub. data).

3. Reproduction and Habitat

Reproduction.—Except for breeding records by Utterback (1915) and Ortmann (1919), knowledge of the life history of the rabbitsfoot is based mostly on an eastern subspecies, the rough rabbitsfoot (*Q. cylindrica strigillata*). Yeager and Neves (1986) found the rough rabbitsfoot to be tachytictic, with the bigeye chub (*Notropis amblops*), spotfin shiner (*Cyprinella spiloptera*), and whitetail shiner (*C. galactura*) potential hosts. Obermeyer *et al*. (1997a) suspected that host specificity may be different between these two subspecies because suitable hosts identified by Yeager and Neves (1986) are believed to be absent in the Neosho River (Cross 1967, F.B. Cross, University of Kansas, pers. comm.).

Habitat.—The rabbitsfoot inhabits sand-gravel substrates at depths up to 10 feet of water (Parmalee 1967, Cummings and Mayer 1992) with a detectable current (Parmalee 1967), to shallow near-shore habitats in cobble substratum with a slack current (Stansbery 1974), or in close proximity to the swiftest flows (Gordon and Layzer 1989). In southeast Kansas and southwest Missouri, Obermeyer *et al*. (1997a) found the species in predominantly gravel substrates at depths up to a half meter (Table 2).

5. Designated Critical Habitat (Figure 12)

Critical habitat currently occupied:

- *Spring River*: from where the Spring River first enters Kansas to US-66 (Cherokee Co.).
- *Neosho River*: from Iola to Humboldt (Allen Co.).

Critical habitat, but lacking recent documentation of the species:

- *Neosho River*: from John Redmond dam (Coffey Co.) to the Kansas-Oklahoma border.
- *Cottonwood River*: from its confluence with the South Fork of the Cottonwood River (Chase Co.) to its confluence with the Neosho River (Lyon Co.).
- *Spring River*: from Empire Lake dam (Cherokee Co.) to the Kansas-Oklahoma border.
- *Shoal Creek*: from the Kansas-Oklahoma border to Empire Lake (Cherokee Co.).
- *Fall River*: from the Fredonia city dam to the river's confluence with the Verdigris River (Wilson Co.).
- *Verdigris River*: from K-47 (Wilson Co.) to the Kansas-Oklahoma border.

D. WESTERN FANSHELL – *CYPROGENIA ABERTI* (CONRAD 1850)

1. Taxonomy and Description

Original Description.—*Unio aberti* (Conrad 1850), descriptions of a new species of *Unio*, Proc. Acad. Nat. Sci. Phila. Vol. 5, p. 10. Holotype [presumed lost] was figured by Conrad in Proc. Acad. Nat. Sci. Phila., 2nd series, Vol. II, Plate XXIV, Figure 1 (1851); type locality: Verdigris River, Arkansas [Oklahoma].

Taxonomic discussion.—The western fanshell was first collected by Samuel Woodhouse in 1849 at Chamber's Ford in the Verdigris River, Oklahoma. Conrad (1850) described Woodhouse's specimen and named it *Unio aberti.* Two year's later, Isaac Lea described and figured a similar mussel from Arkansas, which he named *Unio lamarckianus* (Lea 1852) (Holotype USNM 84306; type locality: White River, Arkansas). Lea (1870) later surrendered *lamarckianus* to *aberti.* Despite Lea's dropping of *lamarckianus*, Simpson (1914) stated: "…apparently well worthy of a varietal name". Call (1885a) described and named specimens from the Verdigris River, Kansas, as *Unio popenoi* (Figure 13; Holotype MCZ 4943). He later acknowledged that *aberti* should take precedence over *popenoi* (Call 1887a). Simpson (1900) listed *Cyprogenia* from the St. Francis and Saline rivers as *irrorata* (= *stegaria*) var. *pusilla*, but mentioned that they may be *aberti.* Call (1895) regarded specimens taken from both the Saline River and St. Francis River as *irroratus* (= *stegaria*), although he mentioned that young specimens from the St. Francis River were similar to *aberti.* Scammon (1906) stated: "As compared with specimens before me from the White River, Arkansas, the Kansas form [Arkansas River system] is a much larger, more inflated, and massive shell, with smaller muscle cicatrices." Frierson (1927) noted that *stegaria, stegaria-pusilla,* and *aberti* nearly merge into one unbroken chain across Arkansas. Johnson (1980) stated that *aberti* and *stegaria* closely resemble one another, but that *aberti* has a narrower, more compressed posterior slope.

Shell Description (Figure 13).—The shell is thick, round to triangular, and moderately compressed. The maximum size of shell is 89 mm (3.5 inches) (Couch 1997). Beaks are low, extending only slightly beyond the hinge line, compressed, and turned forward over the lunule; beak sculpturing is absent. The outside surface of shell has a wrinkled appearance, especially in the dorsal region of a shallow sulcus, which is situated anteriorly to the posterior ridge. The shell is marked by raised growth-rest lines that form concentric ridges that can be pronounced,

particularly those produced by second- and third-year rest periods. The periostracum is olive-tan overlaid with dark green specks and dots that are arranged in rays, extending from the umbonal region to the shell margin. Two lateral teeth and two pseudocardinal teeth are found in the left valve, with the posterior pseudocardinal tooth being the largest. One triangular pseudocardinal tooth and one lateral tooth are found in the right valve. The interdentum is broad, the beak cavity is shallow, and the nacre is creamy white, often iridescent posteriorly.

2. Historical and Current Distribution

Historical Distribution.—The western fanshell is endemic to the Arkansas, Ouachita, White, and St. Francis river systems of Arkansas, Kansas, Missouri, and Oklahoma. Its previously reported presence in the Meramec River basin of Missouri (Buchanan 1980, Oesch 1984) is questionable because of suspected mislabeling of specimens (Obermeyer *et al*. 1997b). The species is locally common at a number of sites in the Ouachita and White river systems in Arkansas (J.L. Harris, Arkansas Transportation Department, pers. comm.; BKO, pers. observ.), but is restricted to a small reach of the St. Francis River in Missouri (Clarke 1985, Ahlstedt and Jenkinson 1991). In the Arkansas River system, the western fanshell is rare in Kansas and Missouri (Obermeyer *et al*. 1997b), and is considered extirpated in Oklahoma (Mather 1990). In Kansas, the species was historically found in the Neosho, Spring, Elk, Fall, and Verdigris rivers (Obermeyer *et al*. 1997a, 1997b). Although the species has not been reported from Shoal Creek, it is possible it has been overlooked.

Current Kansas Distribution (Figure 14).—In the Spring River, the western fanshell is apparently restricted from Carthage, Missouri, to near the confluence of Center Creek in Kansas (Obermeyer *et al.* 1996); it is unlikely that the species occurs downstream (Obermeyer *et al*. 1997b). The maximum number of individuals recently collected at any one site in the Spring River was seven (Obermeyer *et al*. 1995). The species was apparently more common in the Spring River in the early 1980s than at present (Charles Cope, KDWP, pers. comm.).

Miller (1992) collected four western fanshells in the Verdigris River near Syracuse. Obermeyer *et al*. (1995, 1997a, 1997b) collected 11 individuals at four Verdigris River sites. Resampling of refuge study sites by Miller (1999b) in 1997 yielded 16 specimens. Additional sampling during summer 1998 recovered three specimens (E.J. Miller,

pers. comm., Miller 1999a). The highest concentration of the western fanshell in this stream appears to be in southern Wilson and northern Montgomery counties. It is likely extirpated downstream from Independence and upstream from Altoona. In the Fall River, five specimens were collected from four sites, all of which were found downstream of Fall River Lake to near the river's confluence with the Verdigris River (Obermeyer *et al*. 1997a, 1997b).

3. Reproduction and Habitat

Reproduction.—The marsupial demibranchs of the female western fanshell are coiled (Call 1885a, 1887a, 1887b, Chamberlain 1934). These function to accommodate worm-like conglutinates (Ortmann 1912, Chamberlain 1934, Barnhart 1997a), which may be as much as 8 cm in length. Barnhart (1997a, 1997b) estimated that each conglutinate consists of approximately 30,000 eggs. Only the eggs along the periphery of the conglutinate are fertilized (~15-20% of the total). The unfertilized eggs may serve as bait for potential hosts by giving the conglutinate color (white; mature glochidia are transparent), as well as, perhaps, taste and odor.

Chamberlain (1934) observed the release of western fanshell conglutinates in late winter, whereas M.C. Barnhart (pers. comm.) noted the periodic release of conglutinates during winter and spring months. Barnhart (1997a) identified the banded sculpin (*Cottus carolinae*), fantail darter (*Etheostoma flabellare*), and logperch (*Percina caprodes*) as suitable hosts.

Habitat.—Generalized habitat descriptions for the western fanshell is shallow water (7-45 cm) with sand and gravel substrates (Buchanan 1980, Oesch 1984). In Kansas, average depth is approximately 25 to 40 cm (Table 2), although the species is often found at much greater depths in the White and Black rivers in Arkansas (J.L. Harris, unpub. data). Obermeyer *et al.* (1997b) found the species in a higher percentage of cobble substrate than the other target species (Table 2). The species is sometimes buried in coarser substrates (Oesch 1984, BKO, pers. observ.).

4. Designated Critical Habitat (Figure 15)

Critical habitat currently occupied:

- *Spring River*: from where the Spring River first enters Kansas to US-66 (Cherokee Co.).
- *Fall River*: from Fall River dam (Greenwood Co.) to the river's confluence with the Verdigris River (Wilson Co.).
- *Verdigris River*: from K-47 (Wilson Co.) to the city of Independence (Montgomery Co.).

Critical habitat, but lacking recent documentation of the species:

- *Neosho River*: from John Redmond dam (Coffey Co.) to the Kansas-Oklahoma border.
- *Spring River*: from Empire Lake dam (Cherokee Co.) to the Kansas-Oklahoma border.
- *Shoal Creek*: from the Kansas-Oklahoma border to Empire Lake (Cherokee Co.).
- *Fall River*: from K-99 to Fall River Lake (Greenwood Co.).
- *Verdigris River*: from Toronto Lake dam to K-47 (Wilson Co.), and from the city of Independence (Montgomery Co.) to the Kansas-Oklahoma border.

III. RECOVERY

A. OBJECTIVES

The ultimate objective of this recovery plan is to prevent the extirpation of the four target mussel species from Kansas, and to restore populations so they can be removed from the Kansas list of endangered, threatened, and SINC species. Reestablishment of viable populations[1] of these four species throughout their former range will not be an easy task given the current condition of watersheds and streams in southeastern Kansas. However, recovering these species to a point where delisting criteria can be met should be an obtainable goal, although, admittedly, not an easy one. Recovery and subsequent delisting of these mussels will require aggressive watershed conservation efforts as well as a propagation program. A better understanding of each species' ecological requirements is essential to successfully achieve this goal. Another important objective of this recovery plan is the recovery—through watershed enhancements—of other state-listed mussel species that occur in southeast Kansas (Table 1).

B. RECOVERY CRITERIA

The four target species should be considered for listing reclassification when: i.) recovery tasks outlined in *Section III—C* have been initiated or completed and ii.) populations are protected from current and foreseeable threats that might jeopardize their continued existence. Under such circumstances, KDWP's formal petition listing process will be followed. Recovery criteria specific to each species are summarized in Table 3.

[1] A viable population is defined as a group of reproducing individuals separated by barriers or unsuitable habitat (*e.g.* a riffle site isolated by unsuitable habitat by distances greater than 10 km).

TABLE 3. *Downlisting criteria for the Neosho mucket, Ouachita kidneyshell, rabbitsfoot, and western fanshell in southeast Kansas.* *In addition to the following criteria, downlisting will require completion or initiation of recovery tasks outlined in Section III—C and that populations are protected from any current and foreseeable threats that might jeopardize their continued existence.*

Species	Downlisting steps	Downlisting criteria
Neosho mucket	*Downlist to threatened*	A minimum of four populations present in each of the Neosho, Verdigris, Fall, and Spring rivers. A minimum of three age classes must be found in these populations, one of which has naturally produced within five years of the downlisting date. Gravid females and suitable host fishes must be present.
	Downlist to SINC	Same as above except six populations must be present in each of the above mentioned streams. In addition, four populations shall be reestablished in both the Cottonwood and Neosho rivers (two upstream from John Redmond Reservoir and two downstream from the Parsons city dam to the KS-OK border). Two populations shall also be reestablished in each the upper Fall and Verdigris rivers (above Federal impoundments), in the lower Spring River (downstream from Empire Lake), and in Shoal Creek. Reestablished populations must be self-perpetuating, with gravid females and suitable host fishes present.
	Delist	Self-perpetuating populations present throughout 75% of the species' historical range in Kansas.
Ouachita kidneyshell	*Downlist to SINC*	A minimum of six populations present in each of the Verdigris, Fall, and Spring rivers, with a minimum of three age classes, one of which has naturally produced within five years of the downlisting date. Gravid females and suitable host fishes must also be present. In addition, two reestablished populations shall be present in each the Elk River, lower Spring River (downstream from Empire Lake), Shoal Creek, and in each of the upper Neosho, Fall, and Verdigris rivers (above Federal impoundments). Four reestablished populations shall be present in both the Cottonwood River and in the Neosho River downstream from John Redmond dam. Reestablished populations must be self-perpetuating, with gravid females and suitable host fishes present.
	Delist	Self-perpetuating populations present throughout 75% of the species' historical range in Kansas.

TABLE 3 *(continued).*

Species	Downlisting steps	Downlisting criteria
rabbitsfoot	*Downlist to threatened*	Four distinct populations present in each of the Neosho and Spring rivers, with a minimum of three age classes, one of which has naturally produced within five years of the downlisting date. Gravid females and suitable host fishes must be present.
	Downlist to SINC	Same as above except that six distinct populations must be present in each of the above mentioned rivers, as well as three reestablished populations in each the lower Verdigris and Fall rivers, and two reestablished populations in the lower Spring River downstream from Empire Lake. Reestablished populations must be self-perpetuating, with gravid females and suitable host fishes present.
	Delist	Self-perpetuating populations present throughout 75% of the species' historical range in Kansas.
western fanshell	*Downlist to threatened*	Four distinct populations present in each of the Verdigris, Fall, and Spring rivers. A minimum of three age classes must be found in these populations, one of which has naturally produced within five years of the downlisting date. Gravid females and suitable host fishes must be present.
	Downlist to SINC	Same as above except: six distinct populations must be present in each of the Verdigris and Fall rivers; two reestablished populations shall be present in the lower Spring River (downstream from Empire Lake) and in both the upper Verdigris and Fall rivers; and four reestablished populations shall be present in the lower Neosho River (downstream from John Redmond dam to the KS-OK border). Reestablished populations must be self-perpetuating, with gravid females and suitable host fishes present.
	Delist	Self-perpetuating populations present throughout 75% of the species' historical range in Kansas.

IV. NARRATIVE OUTLINE

1. Protect existing populations and occupied habitats of state-listed mussels in the Neosho, Spring, and Verdigris river basins. Preservation of existing populations and critical habitats is essential in order to restore these species.

1.1. Promote stewardship to protect and/or restore essential habitats for the recovery of state-listed mussels and to reduce nonpoint source pollution. Because most Kansas streams and watersheds are privately owned, the willingness of landowners to participate in recovery activities is essential for the recovery of these mussels and critical habitats.

1.1.1. Provide state income tax credits to landowners who voluntarily enter into recovery plan agreements to protect and/or restore instream and riparian habitats. A recovery plan agreement must meet the following criteria: i.) participant shall carry out management activities specified in a recovery plan; ii.) property meets habitat designation criteria for the targeted T&E species; iii.) agreement shall be no less than five years; and iv.) KDWP and other essential personnel will have access to the property for the duration of the agreement for monitoring purposes. In exchange, landowners would receive state income tax credits equal to the amount of property taxes paid on acreages deemed by KDWP as necessary for the recovery of state-listed mussels and for costs incurred while complying with recovery plan agreements. Project eligibility will be dependent upon location (Appendix A). Tax credits would be granted for each year's enrollment in a recovery plan agreement. Before an agreement is signed, KDWP will outline the procedure for applying for state income tax credit.

1.1.1.1. Offer state income tax credits to landowners who agree to protect and restore riparian habitats. Eligible practices include maintaining and/or enhancing riparian habitats (see Appendix B for riparian buffer criteria), planting native vegetation along streams to serve as riparian buffers (Appendix B), preserving or restoring wetlands that are in the 100-year flood zone, and excluding livestock from riparian habitats and streams by building fences and developing alternative watering sources for livestock. The implementation of grazing strategies that minimize riparian damage will be considered along smaller streams, but these practices must first be approved by KDWP.

1.1.1.2. Provide tax credit incentives to farmers and ranchers who implement practices that reduce nonpoint source pollution. For example, planting buffer strips along riparian corridors can reduce nitrate and phosphorus concentrations from surface runoff (Osbourne and Kovacic 1993). Sites must be in a watershed with a HUC-11 (eleven-digit hydrologic unit code) point score of eight or more (see Appendix A). Eligible practices include the entrapment and proper disposal of animal wastes from confined livestock and the planting of field buffers and grassed waterways to retard soil erosion. Refer to the following Natural Resource Conservation Service (NRCS) Conservation Practice Standard Codes for technical specifications, located at http://www.ncg.nrcs.usda.gov/nhcp_2.html: 350 (sediment basins); 638 (water and sediment control basins); 393A (filter strips); 412 (grassed waterways); 570 (runoff management systems).

1.1.1.3. Provide tax credit incentives to landowners who participate in instream and channel rehabilitation projects, such as stream bank stabilization. Proposed instream and streambank stabilization projects must be approved by KDWP before being accepted into a recovery plan agreement.

1.1.1.3.1. Determine priority stream reaches and sites for instream and stream bank restoration projects. Streambank stabilization and instream projects may adversely affect channel morphology and instream habitats (both upstream and downstream). Because of possible risks to mussel habitats from such projects, only restoration sites with a high potential for benefiting mussels should be considered for inclusion into recovery plan agreements.

1.1.1.3.2. Review instream and stream bank restoration projects. Individual projects should be reviewed by experts (Task 10) to ensure that proposed projects would benefit mussels.

1.1.1.4. Provide tax credit incentives to landowners who grant stream access for research purposes. Because stream access is limited in Kansas, it is important to have a mechanism to acquire stream access for research purposes. A landowner of a desired research site would receive a state income tax credit equal to the amount of property tax for acreage on and near the research site, as well as acreage used for accessing the site. A landowner would also receive state income tax credit equal to costs incurred for the maintenance of access roads and other pertinent expenses related to the compliance of the recovery plan agreement. Research activities might include acquiring brood stock and suitable host fishes, seeding juvenile mussels for reintroduction/augmentation projects, and monitoring mussel populations and habitats.

1.1.1.5. Provide tax credit incentives to rural residents for non-mandated improvements to rural sewer systems in priority HUC-11 watersheds. Eligible sites must be within 100 m (~330 feet) of a perennial stream in a HUC-11 watershed with a point score of eight or more (Appendix A). All rural sewer system improvements must meet KDHE minimum standards (K.A.R. 28-5-6 to 9).

1.1.2. Encourage landowners to participate in State and Federal conservation programs to rehabilitate watersheds. Funding is currently available for a wide variety of watershed enhancement projects from state and federal conservation programs (Appendix C).

1.1.3. Provide safe harbor agreements for participants in recovery plan agreements. Landowners may be reluctant to enter into recovery plan agreements if they think they could be penalized if an endangered species is discovered or introduced on their property. A safe harbor agreement requires that the participant maintains or enhances suitable habitat currently unoccupied by state-listed species. In return, the participant is protected from land use restrictions that might result if a state-listed species becomes established into the habitat. However, state-listed species already inhabiting a property at the time the landowner signs into a recovery plan agreement would remain fully protected under the state's Nongame and Endangered Species Conservation Act.

1.2. Identify areas of concentrated land use, and investigate ways to mitigate water quality concerns. Large disturbances may negate other watershed enhancement projects.

1.3. Develop partnerships with state and federal agencies, local governments, private organizations, industries, and individuals to identify, assess, and mitigate projects that might impact state-listed mussels and mussel habitats.

1.4. Integrate mussel die-off emergency response strategies with the existing fish kill cooperative agreement between KDWP and KDHE, which outlines investigation procedures. It is important that appropriate agencies and individuals be promptly notified of mussel and fish kills, chemical spills, and other environmental emergencies in streams where state-listed mussels occur.

1.5. Solicit expertise and funding in protecting the four targeted species and essential mussel habitats.

1.6. Utilize existing state and federal legislation and regulations to protect species and habitats. Habitat and water quality degradation are largely to blame for the current fate of these mussel species. Therefore, it is essential to enforce existing laws and regulations designed to address these concerns.

1.7. Reevaluate commercial mussel harvesting in southeast Kansas. Disturbances from shell-fishing can dislodge juveniles and adults, leaving them vulnerable to predation and to floods. Handling protected mussels may also stress gravid females, causing them to abort glochidia prematurely (Lefevre and Curtis 1912, Coker 1919, Yokely 1972, Yeager and Neves 1986).

2. Improve the accessibility of historic and recent mussel distribution and demographic data.

2.1. Develop a centralized, georeferenced database of distribution data for state-listed mussels. Information regarding the distribution of Kansas' freshwater mussels (*e.g.* collections and databases maintained by KDWP, KDHE, Kansas Biological Survey, State universities, and individuals) is not readily accessible to any one individual or agency. Correcting nomenclature and identifications, and assembling this information into one georeferenced database are needed to identify distributional data gaps and to identify potential reintroduction sites. The database should include absence data and status information for presence data[1] of all mussels occurring in the state. The database would be linked to a GIS and made accessible to those involved in the conservation management of freshwater mussels.

2.2. Add species data as a resource element coverage to a GIS. Four categories of species data assembled by Task 2.1 would be tiled by HUC-11 boundaries, and added as resource element coverages to a GIS. These coverages would include the number of target species within each HUC-11 watershed (currently and historically), the number of extant state-listed species in each watershed, and the overall number of extant species in each watershed. This information would be used for making priority area designations (Appendix A).

2.3. Update distributional data with additional sampling in unsurveyed stream reaches. Fill distributional data gaps as identified in Task 2.1 and in the literature. This includes any reach of stream that is: 1.) within the historical range of one or more of the four target species, and 2.) lacking recent assessment of mussel populations in a stretch of stream exceeding 15 river km.

3. Conduct studies on genetics, life histories, population dynamics, and ecological requirements of target species. Knowledge of the biology and ecology of these species is inadequate to meet recovery objectives.

3.1. Conduct systematic studies to assess population genetic structure and to document hidden diversity. Taxonomic distinction of many mussel species in North America is based largely on shell morphology. However, recent advances in molecular genetic techniques have led to taxonomic revisions for several species, sometimes revealing a species complex within a single species. Although the taxonomy for the majority of Kansas species is not in question, clarification of possible species complexes is needed.

3.1.1. Conduct a systematic study of the western fanshell[2]. Populations of *Cyprogenia aberti* found west of the Mississippi River are considered one species. However,

[1] *i.e.* number of live specimens, recently dead valves, weathered valves, and relic or subfossil valves.
[2] This task is currently in progress (B.K. Obermeyer, C.L. Harris, C. Lydeard, and A.E. Bogan).

these populations may represent discrete taxa (either specific and/or infraspecific). A systematic study—using molecular genetic techniques (mtDNA sequence data) as well as anatomical and conchological (shell) characters—needs to be conducted throughout the current range of *Cyprogenia aberti* to assess the taxonomic distinction of populations among different river basins.

3.1.2. Conduct a systematic study of the Ouachita kidneyshell. A systematic study similar to that described in Task 3.1.1 needs to be conducted for the genus *Ptychobranchus* in the Ozarkian faunal province (van der Schalie and van der Schalie 1950) of Kansas, Arkansas, Missouri, and Oklahoma.

3.1.3. Assess population genetic structure and diversity for each of the four target species in southeast Kansas. Tissue samples (*e.g.* mantle clippings, see Berg *et al*. 1995) of each species would be collected from a minimum of three individuals per stream, and analyzed using molecular genetic techniques (mtDNA sequence data). Genetic diversity would be compared within a population, among populations within a drainage, and among populations between drainage basins. These data would help to establish management guidelines to protect the genetic integrity of each species. This information is critical when considering augmentation and reintroduction efforts.

3.2. Conduct research related to the life histories of the four target species. Knowledge of each species' life history is essential in determining management guidelines for recovery.

3.2.1. Determine fish hosts and the period of spawning and gravidity for the rabbitsfoot in Kansas.

3.2.2. Conduct ichthyofaunal surveys to determine the distribution and abundance of potential fish hosts for the four targeted mussel species. Knowledge of the distribution and relative abundance of potential fish hosts is critical for the restoration of freshwater mussels. A survey of the Verdigris River basin, especially in the Fall and Verdigris rivers, should be given priority because recent fish surveys in this basin are lacking. Additional sampling of stream fishes in the

Spring River basin is not critical at this time because of recent surveys (Edds and Dorlac 1995, Wilkinson and Edds 1996, Wilkinson *et al*. 1996, Wilkinson 1997).

3.2.2.1. Survey fishes in the Verdigris River basin. Priority streams and reaches include the Fall River from near Eureka to its confluence with the Verdigris River (excluding Fall River Lake), Verdigris River from Madison to the Kansas-Oklahoma border (excluding Toronto Lake), Elk River from near Longton to Elk City Wildlife Area, and Caney River from Cedar Vale to the Kansas-Oklahoma border.

3.2.2.2. Survey fishes in unstudied reaches in the Neosho River basin (Cottonwood and Neosho rivers). Priority reaches include the Cottonwood River from near Florence (Marion Co.) to the river's confluence with the Neosho River, and the Neosho River from near Dunlap (Morris Co.) to the Kansas-Oklahoma border (excluding John Redmond Reservoir).

3.2.3. Initiate fish surveys at proposed reintroduction sites (determined by Task 5.2). Potential fish hosts of target mussel species ***must*** be present to restore viable populations. Fish density and abundance data will be needed at proposed reintroduction sites, because species richness and abundance of mussels have been linked to diverse and abundant fish assemblages (Watters 1993, Vaughn 1997).

3.3. Determine population characteristics of each target species, including age and size at sexual maturity, growth rates, reproductive longevity, and mortality rates. This information is needed to determine the number of individuals and level of recruitment required to maintain long-term viable populations.

3.4. Determine ecological requirements of each species.

3.4.1. Determine habitat and nutritional needs, particularly during the juvenile stage, for each of the four target species. Knowledge of habitat and nutritional requirements would assist in the rearing of juvenile mussels for propagation purposes.

3.4.2. Evaluate physiochemical variables that potentially limit recruitment and/or survival of the four target species. Because juvenile mussels are more sensitive to environmental stresses than adults (Dimock and Wright 1993, Warren *et al.* 1995, Pohlhill and Dimock 1996), they should be emphasized for study. This task could establish minimum habitat and water quality standards at recovery sites.

3.4.2.1. Determine the sensitivity of juvenile mussels to physiochemical variables that may negatively affect them. Calculate LC50 endpoints for juveniles of the four targeted species for parameters identified by KDHE as being of primary and secondary concern in the three stream basins (Appendix D - E).

3.4.2.2. Conduct field bioassays of juvenile mussels. This task could be done in conjunction with juvenile reintroduction projects.

4. Conduct habitat and water quality studies of the four target mussel species.

4.1. Conduct surveys of stream habitats. Describe instream and riparian habitats within the historic and current distribution of target mussel species.

4.1.1. Quantify instream habitats by measuring habitat variables along priority stream reaches and relate to mussel populations.

4.1.2. Evaluate riparian and stream habitats using remote sensing. Use aerial and satellite imagery to fill data gaps in unsampled stream reaches. Remote imagery could also be used to classify riparian habitats (Clemmer 1994, Prichard *et al.* 1999).

4.2. Conduct a geomorphic study of stream stretches with a history of gravel mining.

4.2.1. Evaluate past and recent habitat changes from instream gravel mining, and assess the impact to mussels from instream gravel mining. Because most mussel species require relatively stable substrates, it is important to understand the potential threat to mussels from instream gravel mining. Such a study may be beneficial in locating suitable stream reaches for reintroduction efforts.

4.2.2. Work with appropriate agencies and Legislative Committees to develop guidelines for mining sand and gravel from alluvial channels and floodplains.

4.3. Evaluate the fate of the old Neosho River cutoff channel in Neosho County (Appendix F). An approximate 28 km (17.4 mi) stretch of the old river channel is becoming isolated from the active channel, and may eventually become an oxbow lake. This reach holds at least 21 extant species, including the Neosho mucket and eight other state-listed mussel species (see Obermeyer *et al*. 1995, site BKO-94-23). The study would evaluate the future suitability of mussel habitat in this stream reach.

4.4. Evaluate the effect of regulated lake releases and current minimum flow standards to mussels.

4.4.1. Study the effect of regulated releases on stream morphology (*e.g*. movement of the stream channel and substrate) in the Neosho, Verdigris, and Fall rivers. A better understanding of the fluvial geomorphic processes of these streams under regulated flow regimes may help efforts to restore unstable habitats (Task 1.1.1.3).

4.4.2. Evaluate the effect of stream flow on mussel populations, develop environmental instream flow requirements, and make recommendations to the U.S Army Corps of Engineers (USACE) and the Kansas Water Office (KWO). Assess the impact to mussels from abrupt reservoir gate changes[1], and make recommendations to the USACE to minimize potential threats. For instance, a recommendation might be made for more gradual gate changes following extended periods of high-volume lake releases, which would likely reduce mussel stranding. Gradual gate changes might also lessen instream habitat loss, because abrupt gate changes can contribute to stream bank sloughing, thus destabilizing instream habitats. This task would also reexamine current minimum stream flows agreements, and make recommendations to the KWO to ensure adequate minimum flows for mussels.

4.5. Study the impact to mussels from traditional wastewater disinfectants, and investigate the potential of converting municipal wastewater treatment plants (WWTPs) from chlorine to alternative disinfectant methods. Residual chlorine in wastewater reacts with effluent ammonia to form chloramines, which can be toxic to freshwater mussels (Goudreau *et al.* 1993). This effluent can cause the extirpation of mussels downstream from a WWTP (Stansbery and Stein 1976, Goudreau *et al.* 1993). Evidence of

[1] Obermeyer *et al*. (1995) found hundreds of mussels, including two freshly dead rabbitsfoots, stranded on a gravel bar in the Neosho River (site BKO-94-04) after the U.S. Army Corps of Engineers (USACE) abruptly reduced dam releases from John Redmond Reservoir in June of 1994. Stranding was attributed to the migration of mussels during an extended period of high lake discharge into areas that were exposed when normal flows resumed.

potentially toxic WWTP outfalls in Kansas includes a several mile reach of Shoal Creek, beginning at the outflow of Joplin's WWTP, near the Missouri-Kansas border, to the backwater of Empire Lake in Cherokee County.

5. Initiate a reintroduction/augmentation program using propagated juveniles and, to a lesser extent, translocated adults. Adherence to USFWS guidelines to protect the genetic integrity of aquatic mollusks (Appendix G) should be considered for all reintroduction/augmentation projects to prevent the introduction of unfavorable genetic traits to the recipient population (Berg and Guttman 1998, Butler 1998).

   5.1. Establish experimental population boundaries for future reintroduction projects. Reintroduced populations would be classified as experimental populations (EP). A species' critical habitat designation would be reclassified to EP habitat if: i.) the species has not been documented extant during the past 35 years, based on tasks 2.1 - 2.3, and ii.) there are active reintroduction projects for the species within the stream reach under consideration. Landowners within the habitat boundaries of an experimental population would not be imposed with additional land-use restrictions.

   5.2. Establish priority sites for reintroduction/augmentation projects. Specific sites would be selected based on habitat evaluations, water quality, and other ecological considerations, such as the presence of suitable hosts.

   5.3. Initiate reintroduction projects for the four target species.

      5.3.1. Initiate a pilot reintroduction project using juveniles. .

      5.3.2. Initiate a reintroduction project by releasing fish (suitable hosts) infected with glochidia. This method of reintroduction would be less expensive than Task 5.3.1, although it is less likely to succeed in establishing new populations. Suitable hosts of target species would be collected at or near the reintroduction site, exposed to glochidia, then immediately returned to the stream.

      5.3.3. Initiate a pilot reintroduction project using translocated adult mussels in the Spring River. A prospective pilot translocation project would be the relocation of non-listed adult mussels from one or more Spring River sites upstream from the confluence of Center Creek to the Spring River downstream from Empire Lake. A determination for relocating state-listed species to this stream reach would be made following a preliminary assessment of survival.

5.3.4. Consider relocating mussels from the old Neosho River cutoff channel (Appendix F). Mussels would be moved to other sites in the Neosho River that contain suitable mussel habitats as well as potential fish hosts. Initiation of this task would be dependent on the findings from tasks 3.2.3 and 4.3.

6. Develop a long-term monitoring program.

6.1. Establish long-term monitoring sites at locations where populations of target mussel species occur.

6.1.1. Continue to sample established quantitative sampling sites in the Neosho and Verdigris rivers at five-year intervals. Neosho River sites (*i.e.* eight sites) were sampled in 1994 (Obermeyer 1997b), whereas eight Verdigris River study sites were sampled in 1992 and 1997 (Miller 1993, 1999b).

6.1.2. Initiate quantitative sampling at eight sites in the lower Fall River and approximately four sites in the upper Kansas portion of the Spring River. Sample a minimum of 25, 1-m^2 quadrats at each site in a 100 m reach of habitat. Sites would be sampled at five-year intervals to assess population change. To correspond with long-term monitoring in the Neosho and Verdigris rivers, Fall River sites would be represented by sites within its mussel harvest refuge[1] and sites outside refuge boundaries (upstream and downstream).

6.1.3. Monitor mussel populations at reintroduction, augmentation, and translocation sites. Sites should be monitored annually for a minimum of five years following the release of propagated and/or translocated individuals. Thereafter, sites would be sampled at five-year intervals to evaluate long-term survival and reproductive success.

6.2. Reevaluate stream reaches within the historic range of the four target species using qualitative sampling methods to assess changes in species distribution, abundance, and

[1] The Fall River mussel refuge begins at a ford located 1.9 km (1.2 mi.) E of Hwy K-96 and 5.2 km (3.2 mi.) S of Fredonia, Wilson Co., and extends downstream to Dunn's Dam [4.0 km (2.5 mi.) W and 3.6 km (2.25 mi.) N of Neodesha, Wilson Co.] for a total of 15.9 stream km (9.9 mi.).

diversity of freshwater mussels. Streams should be re-surveyed at no less than ten-year intervals.

7. Prepare for the likely invasion of zebra mussels and other nonindigenous species. Although the zebra mussel is not presently found in Kansas, its likely invasion (see Strayer 1991) should be considered a threat to Kansas mussels. Such an invasion will likely compound efforts to restore the target mussel species in the near future.

   7.1. Implement a nonindigenous species management plan (NSMP) for Kansas.

      7.1.1. Provide input to the NSMP to educate the public about zebra mussels. The public needs to be aware of zebra mussels and how to prevent their spread into Kansas.

      7.1.2. Provide input to the NSMP to develop a risk assessment model (see Schneider *et al.* 1998) for the potential spread of zebra mussels in Kansas. This information would aid in the prioritization of sites for relocation efforts and habitat restoration.

      7.1.3. Provide input to the NSMP to develop guidelines and thresholds for mussel rescue efforts. Develop a protocol to determine when a population is at serious risk from zebra mussels. This task would develop procedures for the removal of native mussels from contaminated habitats to suitable relocation sites. The identification of potential quarantine habitats and facilities would be dictated by Task 7.1.2 and USFWS guidelines for protecting the genetic integrity of aquatic mollusks (Butler 1998).

      7.1.4. Provide input to the NSMP to develop a protocol for future monitoring of zebra mussels.

8. Develop and implement an educational program about Kansas' freshwater mussels and their recovery. The public's interest and support of freshwater mussels and watershed stewardship are essential for the recovery of these species and their habitat.

   8.1. Establish educational stream sites by acquiring access to streams through the use of state income tax incentives. A landowner of an educational stream site would receive state income tax credit equal to the amount of property tax for acreage on and near the learning site, land used for accessing the site, and maintenance of access roads.

8.2. Compile and distribute mussel-related educational materials. Specific learning materials might include a pictorial presentation of Kansas' mussels, educational mussel displays, and a Kansas mussel identification field guide with an illustrated, dichotomous key.

8.3. Develop a slide and/or video presentation that describes the mussel recovery plan and what it will mean to the public. The slide/video presentation would be targeted to landowners to inform them of the recovery plan. The presentation would provide information about threatened and endangered mussels in southeast Kansas, and would outline conservation programs pertinent to the recovery plan, especially the state income tax incentive program. It should prove to be a useful tool for District Biologists and other KDWP personnel when informing the public about the recovery plan at social gatherings, such as County Conservation District meetings and banquets.

8.4. Develop and publish an interactive Internet web site about the recovery plan and watershed stewardship. The web site would provide specific information about the recovery plan, including an online version in Portable Document Format (PDF), and would serve as a means to disseminate progress and success of recovery tasks. The web site would also provide in-depth information about state income tax incentives and conservation programs currently available to landowners, and would provide online inquiry forms, email and mailing addresses, phone numbers, links to other pertinent web sites (*e.g.* NRCS and USFWS web sites), and a list of frequently asked questions. In addition, the site would list case studies that identify and summarize successful habitat restoration and preservation projects related to this recovery plan, and provide a way to commend landowners that have participated in the recovery plan.

8.5. Create an automated toll-free phone hotline dedicated to provide information about the recovery plan and the state income tax incentive program.

8.6. Host meetings or workshops to educate and train aquatic resource managers and others about Kansas mussels and efforts to restore them. These workshops would include paper presentations, updates regarding recovery efforts, and training (*e.g.* mussel identification, habitat assessments, and mussel sampling). Workshops would be similar to previous mussel meetings hosted by KDWP.

8.7. Continue to publish a newsletter (semi-annually) about freshwater mussels, research, and progress of the recovery plan. A newsletter called the Pearly Mussel Newsline (Edwin J. Miller, editor), which is targeted towards persons interested in the conservation of freshwater mussels in Kansas, has been published by KDWP on an occasional basis since 1997.

8.8. Develop a video presentation about impacts to stream habitats from instream gravel dredging and other channel modifications.

9. Reevaluate recovery criteria and tasks once every five years, and recommend appropriate amendments. The recovery plan must be periodically reevaluated to determine if recovery objectives are being met.

10. Utilize experts to help implement the recovery plan. Persons with aquatic and other pertinent expertise from such affiliations as KDWP, other governmental resource agencies, and academia should be consulted to help review research proposals, evaluate recovery projects, and recommend amendments to the recovery plan as recovery tasks are completed and as new species information is gathered. KDWP may form technical committees to address such concerns as riparian stabilization projects.

IV. IMPLEMENTATION SCHEDULE

General Ranking Categories.—Actions necessary to recover the four targeted mussel species are ranked in three categories:

Priority 1 - an action that must be taken to prevent a species from irreversible decline or extirpation.

Priority 2 - an action that must be taken to prevent a further decline in species abundance/range, or other negative impacts to a species short of extirpation.

Priority 3 - all other actions necessary to meet recovery objectives.

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Appendix A. ***Worksheet to determine priority HUC-11 (11-digit hydrologic unit code) watersheds and sites.***

HUC-11 Watershed Designation

1. **Number of target mussel species with a historic presence[1] in watershed:**
   - Y none (**0**)[2]
   - Y one (**1**)
   - Y two (**2**)
   - Y three (**3**)
   - Y four (**4**)
2. **Number of extant target mussel species in watershed:**
   - Y none (**0**)
   - Y one (**1**)
   - Y two (**2**)
   - Y three (**3**)
   - Y four (**4**)
3. **Number of extant state-listed mussels in watershed:**
   - Y none (**0**)
   - Y 1-3 (**1**)
   - Y 4-6 (**2**)
   - Y 7-9 (**3**)
   - Y >9 (**4**)
4. **Overall species richness of extant mussels in watershed:**
   - Y 0-3 (**0**)
   - Y 4-7 (**1**)
   - Y 8-12 (**2**)
   - Y 13-17 (**3**)
   - Y >17 (**4**)

Total Points ______

Site Designation

1. **Proximity to stream:**
   - **a.** Y on property (**4**) - *go to **2***
   - **b.** Y not on property but within 100 year flood zone (**0**) - *go to **2,** items **b** or **c***
   - **c.** Y upland site (**0**) - ***stop***
2. **Proximity to extant mussel populations:**
   - **a.** Y on property (**4**)
   - **b.** Y upstream (**2**)
   - **c.** Y downstream (**1**)
3. **Historical presence of target species:**
   - Y Yes (**4**)
   - Y No (**0**)
4. **Presence of extant target species:**
   - Y none (**0**)
   - Y one (**2**)
   - Y two (**4**)
   - Y three (**6**)
   - Y four (**8**)
5. **Presence of other state-listed mussels:**
   - Y Yes (**2**)
   - Y No (**0**)
6. **Overall species richness of extant mussels:**
   - Y none (**0**)
   - Y 1-5 (**1**)
   - Y 6-10 (**2**)
   - Y 11-15 (**3**)
   - Y >15 (**4**)

Total Points ______

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[1] Species records for each HUC-11 watershed are not necessary for this category, provided there is documentation of a species in both upstream and downstream reaches of a stream that borders or transects the watershed.

[2] Numbers in parentheses represent an arbitrary point score.

Appendix B. *Eligibility criteria for riparian buffers along perennial streams for the state income tax incentive program.*

Riparian buffers must be at least 75 feet in width. Buffers will be broken into three management zones: streamside (Zone 1), middle (Zone 2), and outer (Zone 3). All buffers entered into a recovery agreement must consist of zones 1 and 2 regardless of stream size; the outer zone is optional. Property tax credit will be based on the amount of land from the middle of stream to the outer limits of either Zone 2 or Zone 3.

Management Zone Criteria:

Streamside Zone (Zone 1): Begins at the normal full bank water line (or from the top of steep, cut banks) to a width of 15 feet measured perpendicular from the edge of stream. Logging will not be allowed within the Streamside Zone. Grazing will also be prohibited along streams with a Strahler stream order classification greater than 1. However, grazing strategies that minimize riparian damage along smaller perennial and intermittent streams may be allowed in special circumstances. Dominant vegetation should be composed of native trees and associated understory plants and/or native grasses and forbs. Establishment of native trees will be required for property that is presently farmed within this zone.

Middle Zone (Zone 2): Begins from the outer edge of Zone 1 and occupies a minimum width of 60 feet. Predominant vegetation should be native trees and/or native grasses and forbs. Although grazing restrictions will mirror Zone 1, management for wildlife, aesthetics, and timber will be allowed as long as buffer objectives are not compromised[1]. Native trees and/or native grasses and forbs will be allowed for buffer plantings on land presently cropped.

Outer Zone (Zone 3): Begins from the outer edge of Zone 2 and occupies an area encompassing up to 50 percent of the 100-year floodplain. Acceptable vegetation will include native trees and associated understory plants and/or native grasses and forbs. Management for wildlife, aesthetics, and timber, as well as limited haying and grazing will be allowed in this zone[1]. Inclusion of Zone 3 into a recovery plan agreement will be optional, except where natural riparian buffers presently extend beyond 75 feet. For newly created buffers, the shape of a buffer may be squared or straightened; however, the narrowest portion of a riparian buffer must not be less than the combined minimum widths of zones 1 and 2.

[1] Additional management restrictions may apply for lands signed into other conservation programs. In the case of CP22 buffers, the harvest of timber resources and grazing is prohibited within all three management zones for the duration of CRP-1 (refer to NRCS Conservation Practice Standard Code 391A for riparian forest buffer specifications).

Appendix G. *Guidelines for maintaining genetic integrity for propagated freshwater mussels.*

1) Seed source – in order of decreasing importance:
   a) Brood stock from the recipient stream metapopulation;
   b) Brood stock from another metapopulation in the same stream basin;
   c) Brood stock from another metapopulation in an adjacent stream basin in the same physiographic province;
   d) Brood stock from another metapopulation in an adjacent stream basin in an adjacent physiographic province;
   e) Brood stock from the only metapopulation with sufficient adults to provide progeny.

2) Reduce homozygosity by maximizing brood stock numbers.

Taken from USFWS draft guidelines for maintaining genetic integrity in translocation efforts for aquatic mollusks (Butler 1998).

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Recently dead rabbitsfoot collected from the Neosho River, KS.

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