Appendix C:
Status and Life History of the Three Assessed Mussels

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General information on the habitat requirements, food habits, growth and longevity, reproduction, and past and current threats of the assessed mussels is provided below in Section C.1. Species-specific information for the following three assessed mussels is provided in Sections C.2 through C.4:

- Fat pocketbook pearly mussel
- Purple cat's paw pearly mussel
- Northern riffleshell

C.1 General Information

C.1.1 Habitat

Adult mussels are usually found in localized stream patches (beds) almost completely burrowed in the substrate with only the area around the siphons exposed (Balfour and Smock, 1995). The composition and abundance of mussels are directly linked to bed sediment distributions (Neves and Widlak, 1987; Leff et al., 1990), and physical qualities of the sediments (e.g., texture, particle size) may be important in allowing the mussels to firmly burrow in the substrate (Lewis and Riebel, 1984). In addition, other aspects of substrate composition, including bulk density (mass/volume), porosity (ratio of void space to volume), sediment sorting, and the percentage of fine sediments, may also influence mussel densities (Brim Box, 1999; Brim Box and Mossa, 1999). According to Huehner (1987), water velocity may be a better predictor than substrate for determining where certain mussel species are found in streams. In general, heavy-shelled species occur in stream channels with stronger currents, while thin-shelled species occur in more backwater areas.

Stream geomorphic and substrate stability is especially crucial for the maintenance of diverse, viable mussel beds (Vannote and Minshall, 1982; Hartfield, 1993; Di Maio and Corkum, 1995). Where substrates are unstable, conditions are generally poor for mussel habitation. Although several studies have related adult habitat selection with substrate composition, most species tend to be habitat generalists (Tevesz and McCall, 1979; Strayer, 1981; Hove and Neves, 1994; Strayer and Ralley, 1993).

Habitat and stream parameter preferences for juveniles are largely unknown (Neves and Widlak, 1987), although it is likely that juveniles may prefer habitats that have sufficient oxygen, are frequented by fish, and are free of shifting sand and silt accumulation (Isley, 1911). Neves and Widlak (1987) suggest that juveniles inhabit depositional areas with low flow, where they can feed and siphon water from interstitial spaces among substrate particles. Juvenile mussels of certain species stabilize themselves by attaching to rocks and other hard substrates with a byssus (protein threads) (Frierson, 1905; Isley, 1911; Howard, 1922). Strayer (1999) demonstrated in field trials that mussels in streams occur chiefly in flow refuges, or relatively stable areas that display little movement of particles during flood events. Flow refuges allow relatively immobile mussels to remain in the same general location throughout their entire lives. Strayer (1999) also suggested that features commonly used in the past to explain the spatial patchiness of mussels (e.g., water depth, current speed, sediment grain size) are poor predictors of where mussels actually occur in streams.

Neves and Widlak (1987) summarized stream parameter preferences of habitat, substrate, current velocity, and presence of other bivalves for juvenile unionids. Initially, juveniles were clumped in runs and riffles occurring primarily behind boulders, and were significantly correlated with fingernail clam presence. They surmised that the habitat of older juveniles (i.e., ages 2 to 3 years) was similar to that of adults. Nevertheless, it remains unknown if the juveniles of most species experience differential survival rates among different habitat parameters, remain in the habitat of the host fish, or exhibit any habitat preference (Neves and Widlak, 1987).

C.1.2 Food Habits

Adult freshwater mussels are filter-feeders, orienting themselves in the substrate to facilitate siphoning of the water column for oxygen and food (Kraemer, 1979). There are no known interspecific differences in feeding among freshwater mussels (Fuller, 1974). Mussels have been reported to consume detritus, diatoms, phytoplankton, zooplankton, and other microorganisms (Coker et al., 1921; Churchill and Lewis, 1924; Fuller 1974). According to Ukeles (1971), phytoplankton is the principal food of bivalves. However, other food sources (e.g., bacteria, organic detritus, assimilated organic material, phagotrophic protozoans) may also play an important role (Neves et al., 1996). Specific percentages of these food items within the mussel's diet are not known, although the available information indicates that adult mussels can clear and assimilate fine particulate organic matter (FPOM) particles ranging in size from 0.9 to 250 μm (Silverman et al., 1997; Wissing, 1997; and Nichols and Garling, 2000). This size range includes bacteria and algal cells, detritus, and soil particles (Allan, 1995). According to Baldwin and Newell (1991), bivalves feed on an entire array of naturally available particles (e.g., heterotrophic bacteria, phagotrophic protozoans, phytoplankton). Based on the findings of Baldwin and Newell (1991) and Neves et al. (1996), an omnivorous opportunistic diet allows mussels to take advantage of whatever food type happens to be abundant.

Juvenile mussels employ foot (pedal) feeding, and are thus suspension feeders (Yeager et al., 1994). Juveniles up to two weeks old feed on bacteria, algae, and diatoms with small amounts of detrital and inorganic colloidal particles (Yeager et al., 1994). The diet of the glochidia comprises water (until encysted on a fish host) and fish body fluids (once encysted).

No studies on the specific food habits of the three assessed mussel species has been conducted; therefore, required and/or preferred foods of the assessed species are unknown.

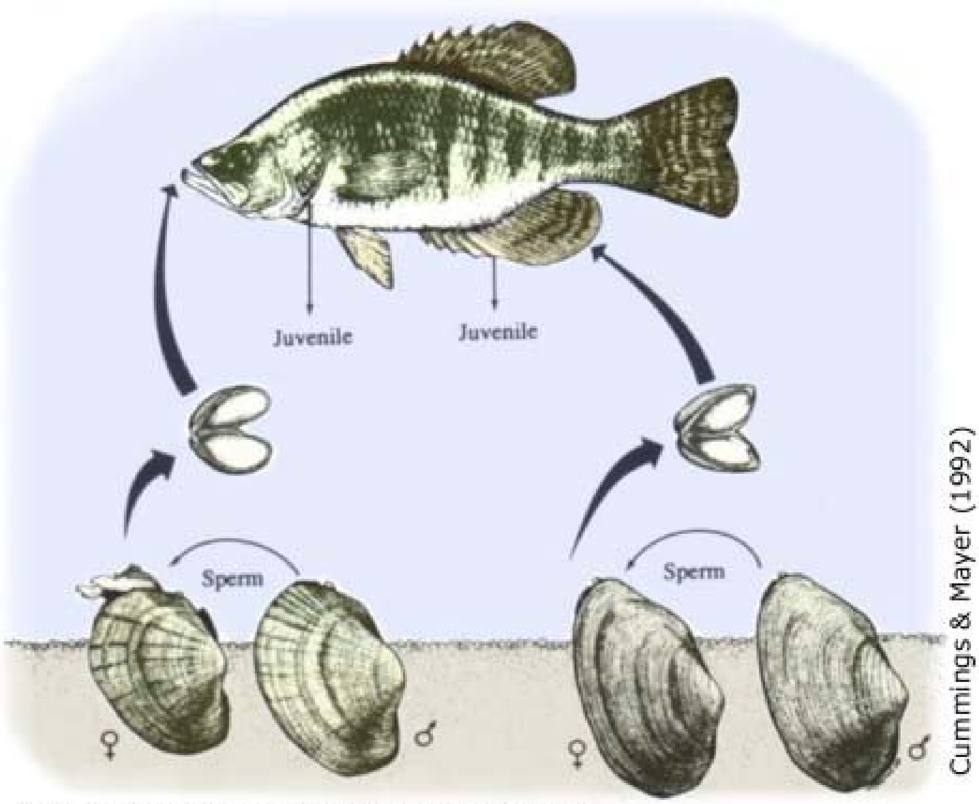
C.1.3 Growth and Longevity

Growth rates for freshwater mussels tend to be relatively rapid for the first few years (Chamberlain, 1931; Scruggs, 1960; Negus, 1966), and then slow appreciably (Bruenderman and Neves, 1993; Hove and Neves, 1994). The relatively abrupt slowing in growth rate occurs at sexual maturity, probably due to energies being diverted from growth to gamete production. Growth rates vary among species, with heavy-shelled species growing more slowly relative to thin-shelled species (Coon et al., 1977; Hove and Neves, 1994). Under shoal habitat conditions, where high water velocities in river shallows are characterized by increased oxygen levels and food availability per unit time, growth rates are probably higher (Bruenderman and Neves, 1993).

As a group, mussels are extremely long-lived, up to 50 years or more (USFWS, 1985). However, riffleshells appear to have a relatively short life-span for a freshwater mussel (Rodgers et al., 2001).

C.1.4 Reproduction

The reproductive cycle of freshwater mussels, which is depicted in the figure below, is similar among all species (see Watters [1994] for an annotated bibliography of mussel reproduction). The age of sexual maturity for mussels is variable, usually requiring from three (Zale and Neves, 1982) to nine (Smith, 1979) years, and may be sex dependent (Smith, 1979). During the spawning period, males discharge sperm into the water column, and the sperm are taken in by females through their siphons during feeding and respiration. The females retain the fertilized eggs in specialized gills (marsupia) that act as brood pouches for the developing larvae (glochidia). The mussel glochidia are released into the water where they must attach to the gills and fins of appropriate host fishes, which they parasitize for a short time until they develop into juvenile mussels. Once the glochidia metamorphose to the juvenile stage, they drop to the substrate. If the environmental conditions are favorable, the juvenile mussel will survive and develop. All three listed species are members of the Unionidae family, which exhibit two reproductive cycles based on the length of time glochidia are retained in the gills of females. Mussels are generally categorized as either short-term summer brooders (tachytictic) or longer-term winter brooders (bradytictic) (Neves and Widlak, 1988). Fertilization occurs in the spring in tachytictic mussels (short-term brooders) and glochidia are released during spring and summer. In bradytictic species (long-term brooders), fertilization occurs in mid-summer and fall, and glochidia are released the following spring and summer.



The freshwater mussel life-cycle (Unionidae).

C.1.6 Past and Current Threats

North America harbors the world's greatest diversity of freshwater mussels (Williams and Neves, 1995; Neves, 1999), with about 300 recognized species (Turgeon et al., 1998). Over 90 percent of these species inhabit the southeastern United States (Neves et al., 1997), with the majority of these species endemic to this area. In the last 150 years, there has been a steady decline in the number of freshwater mussels in the U.S. (Williams and Neves, 1993). Although mussel exploitation has proven to be destructive, significant anthropogenic alteration of aquatic habitats is likely the major cause of freshwater mussel declines on a grand scale (Lewis, 1868; Kunz, 1898; Kunz and Stevenson, 1908; Ortmann, 1909; and van der Schalie, 1938).

The alteration of aquatic habitats via dredging, channelization, and dam construction has significantly affected riverine ecosystems (Baxter and Glaude, 1980; Williams et al., 1992; Allan and Flecker, 1993; Ligon et al,. 1995; Sparks, 1995; Blalock and Sickel, 1996), and has been a major causal factor in the high extinction rate of freshwater mollusks (Johnson, 1978; Lydeard and Mayden, 1995; Neves et al. 1997). Waterway alteration in the Southeast especially has lead to major mussel population changes and extirpation from a large area of many species' historical ranges (USFWS, 1985). These dams and their impounded waters present physical barriers to the natural dispersal of mussels, including emigration (dispersal) of host fishes, and effectively isolate surviving mussel populations in limited portions of their range. Small isolated aquatic populations are subject to natural random events (i.e., droughts, floods) and to changes in human activities and land use practices (i.e., urbanization, industrialization, mining, certain agricultural activities and practices, etc.) that may severely impact aquatic habitats (Neves et al., 1997). Without avenues of emigration to less-affected watersheds, mussel populations gradually disappear where land use activities result in deterioration of aquatic habitats.

Freshwater mussels require fast flowing, silt free streams and rivers in order to survive. Therefore, they are susceptible to adverse effects caused by siltation in waterways. The main causes of siltation are road construction, poor agricultural land management practices, and deforestation. Specific biological impacts on mussels from excessive sediments include reduced feeding and respiratory efficiency from clogged gills, disrupted metabolic processes, reduced growth rates, increased substrata instability, limited burrowing activity and physical smothering (Ellis, 1936; Stansbery, 1971; Markings and Bills, 1979; Kat, 1982; Vannote and Minshall, 1982; Aldridge et al., 1987; and Waters, 1995). In addition to siltation, freshwater mussels are also threatened by heavy metals, agricultural chemical runoff, and acid mine drainage (Williams and Neves, 1993).

The recent introduction of non-native mussel species poses another serious threat to freshwater mussel survival. In particular, the rapid expanse of the Zebra mussel *Dreissenea polymorpha*) and Asian clam (*Corbicula fluminea*) ranges could pose a direct threat to endangered mussel populations within the United States. These invasive species have the ability to out compete native mussels, and population explosions of these species have been shown to adversely affect native populations (Williams and Neves, 1993).

C.2 Fat pocketbook pearly mussel (*Potamilus capax*)

C.2.1 Species Listing Status

On June 14, 1976, the fat pocketbook was designated by the USFWS as endangered throughout its entire range in Arkansas, Illinois, Indiana, Kentucky, Missouri, and Mississippi (USFWS, 1976: 41 FR 24062-24067). A recovery plan addressing the fat pocketbook was approved by the USFWS on November 14, 1989 (USFWS, 1989).

C.2.2 Description

The fat pocketbook is a large freshwater mussel (reaching approximately 130 mm in length) with a shiny, tan or light brown shell without rays (USFWS, 1989).

C.2.3 Historic and Current Range

The fat pocketbook was once widely distributed in the Mississippi River drainage from the confluence of the Minnesota and St. Croix rivers downstream to the White River system and was known to occur in Minnesota, Wisconsin, Iowa, Illinois, Indiana, Missouri, Kentucky, and Arkansas (NatureServe, 2007). Most historic records for this species are from the upper Mississippi River (above St. Louis), the Wabash River in Indiana, and the St. Francis River in Arkansas (USFWS, 1989). The fat pocketbook is currently known to exist in approximately 200 miles of the St. Francis River system, including the Floodway and associated drainage ditches; the lower Wabash River, Indiana; the mouth of the Cumberland River, Kentucky; and the Mississippi River, Missouri (USFWS, 1989). The species also remains in the Ohio and White Rivers (NatureServe, 2007). Over 2,000 individuals were transplanted from the St. Francis Floodway to the Mississippi River by the Missouri Department of Conservation in 1989 to augment that population in an effort to restore viability. Fresh dead shells have been collected from the Ohio River in Kentucky (USFWS, 1989). Populations appear to be stable in the lower Wabash and Ohio Rivers and the St. Francis River drainages as well as portions of the bootheel region in Missouri (NatureServe, 2007). The current range of the fat pocketbook mussel is depicted in Figure C-1.

C.2.4 Habitat

The fat pocketbook is a large river species which requires flowing water and stable substrate (USFWS, 1989). There is conflicting information in the literature regarding the fat pocketbook's habitat preference. Parmalee (1967) reported the fat pocketbook from sand and mud bottoms, in flowing water with depths ranging from a few inches to more than eight feet. Individuals have also been found in sand, mud, and fine gravel substrates in the St. Francis River, Arkansas (Bates and Dennis, 1983). Clarke (1985) reported this species primarily from sand substrates in the St. Francis River, Arkansas. Jenkinson and

Ahlstedt (1988) reported this species from the full range of habitat types, including shifting sand and flocculent mud, to hard clay and gravel. According to the USFWS Recovery Plan (1989), the most likely habitat is a mixture of sand, silt and clay. No critical habitat has been designated for the fat pocketbook mussel.

C.2.5 Reproduction

The reproductive cycle of the fat pocketbook is similar to that of other native freshwater mussels. The fat pocketbook mussel is likely to be a long-term (bradytictic) breeder (USFWS, 1989), and is reported gravid in June, July, August, and October (Surber, 1912; Ortmann, 1914). Available data indicate that the freshwater drum (*Aplodinotus grunniens*) is a suitable glochidial host (Barnhart, 1997; Watters, 1994).

C.2.6 Known Threats

The greatest threat to the continued existence of the fat pocketbook has been channel maintenance activities and impoundments related to navigation and flood control (USFWS, 1989). The upper Mississippi River has been impounded for navigation and is routinely dredged to maintain a nine-foot navigation channel. This species, once widespread in this river, has disappeared in recent years even from areas where other species (including the endangered species *Lampsilis higginsi*) continue to exist. The presence of the fat pocketbook in dredged portions of the St. Francis Floodway indicates a recolonization of the channelized river reaches. Dredging in the St. Francis basin has occurred primarily for irrigation and flood control. Drastic changes in the watershed have resulted in loss of much of the original river channel and its associated mussel fauna. The occurrence of the fat pocketbook in the St. Francis River below the Marked Tree siphon is likely dependent upon the population in the St. Francis Floodway and the passage of glochidia-infected fish through the siphons. Bates and Dennis (1983) reported that much of the substrate of the White River, Arkansas, now consists of shifting sand bars. The only stable substrate left in these areas is found along the bank where some undredged mud ledges remain. In addition, suspended silt, due primarily to erosion, appears to be increasing as mussel resources decline. This has been observed throughout the Mississippi River drainage (Ellis, 1936; Thiel, 1981).

C.3 Purple cat's paw pearly mussel (*Epioblasma obliquata obliquata*)

C.3.1 Species Listing Status

On July 10, 1990, the purple cat's paw pearly mussel (PCPP mussel) was designated by the USFWS as endangered throughout its entire range, excepted where listed as experimental populations (USFWS, 1990: 55 FR 28209-28213). A recovery plan addressing the PCPP mussel was approved by USFWS on March 10, 1992 (USFWS, 1992).

C.3.2 Description

The PCPP is a medium-sized freshwater mussel; the shell's outer surface is yellowish-green, yellow, or brownish in color with numerous distinct growth lines and a smooth, shiny surface. The inside of the shell is purplish to deep purple (USFWS, 1992).

C.3.3 Historic and Current Range

Historically, the PCPP mussel occurred in the Ohio, Cumberland, and Tennessee River systems in Ohio, Illinois, Indiana, Kentucky, Tennessee, and Alabama. Currently, the PCPP mussel exists in only Killbuck Creek and Walhonding River in Coshocton County, Ohio; Green River in Warren and Butler Counties, Kentucky; and the middle Cumberland River in Smith County, Tennessee (personal communication with Angela Zimmerman of the USFWS, 2007). All other records are historic. Individuals in the Green River in Kentucky and the Cumberland River in Tennessee are likely to be non-reproducing relic individuals (Zimmerman, 2007 pers. comm.). The current range of the PCPP mussel is shown in Figure C-2.

C.3.4 Habitat

The PCPP mussel inhabits large rivers with a sand/gravel substrate (Bates and Dennis, 1985). It has been collected in shallow to moderate depths with moderate to swift currents (Bogan and Parmalee, 1983; Gordon and Layzer, 1989). The species has also been reported to inhabit boulder to sand substrates. No critical habitat has been designated for the PCPP mussel.

C.3.5 Reproduction

The reproductive cycle of the PCPP mussel is similar to that of other freshwater mussels; however, the fish hosts utilized by glochidia are unknown (USFWS, 1992).

C.3.6 Known Threats

Most of the PCPP populations were apparently lost due to conversion of riverine sections into a series of large impoundments, which seriously reduced the availability of habitat and likely affected the distribution and availability of the mussel's fish host. As a result, the species distribution has been rapidly declining.

Current threats to the PCPP population in Killbuck Creek include sedimentation from land clearing, cattle grazing, and agricultural land-use practices (Hoggarth et al. 1995), as well as the presence of invasive species such as corbicula. The main population of PCPP in Killbuck Creek is located downstream of a farm where cattle routinely walk the stream and Amish farms are located (Zimmerman, 2007 pers. comm.).

Water quality degradation is also endangering the species. Runoff from oil and gas exploration and production is polluting the Green River, host of one of the species' last relic populations. At one time, 66 species of mussels inhabited this river (Ortmann 1926); now, only about 40 species are known to survive (USFWS, 1990). In the Cumberland

River, this species is impacted by gravel dredging, channel maintenance, and commercial mussel fishing for other species. In addition, several freshwater mussel die-offs occurred during the early to mid-80's in the Mississippi River drainage and its tributaries including the Tennessee River. The causes of the die-offs are unknown, but many species experienced significant losses. Other threats that are attributed to population declines are similar to those described in the general mussel description in Section C.1.6.

C.4 Northern riffleshell (*Epioblasma torulosa rangiana*)

C.4.1 Species Listing Status

On January 22, 1993, the northern riffleshell was designated by the USFWS as endangered (USFWS, 1993: 58 FR 5638-5642). The species is also considered as endangered by the freshwater mussel subcommittee of the endangered species committee of the American Fisheries Society (Williams et al., 1993). A recovery plan addressing the northern riffleshell was approved by the USFWS on September 21, 1994 (USFWS, 1994).

C.4.2 Description

The northern riffleshell is approximately 3 inches in length; the shell's exterior surface is brownish to yellowish-green with fine green rays. The inside of the shell is usually white, but can be pink (Stansbery et al., 1982).

C.4.3 Historic and Current Range

Historically, the riffleshell occurred throughout much of the Ohio River watershed; however, the range has been dramatically reduced. According to the most recent draft USFWS 5-year review for the species, all streams with known or fairly recent northern riffleshell populations are listed in Table C-1 below.

Successful recruitment of northern riffleshell populations is often difficult to detect when densities are very low or surveys are single-day, catch-per-unit efforts. Few intensive, statistically valid surveys have been conducted on northern riffleshell populations outside of French Creek and the Allegheny River (USFWS, 2007 draft). Populations with densities near or below the detection rate may not be practically assessed with quantitative techniques. The difficulty in detecting northern riffleshells results in poorly defined information about the species distribution and abundance, even within the streams where the species is known to occur (USFWS, 2007 draft).

The current range of the northern riffleshell is shown in Figure C-3.

Table C-1 Known or Possibly Extant Northern Riffleshell Populations[1]

Basin	Population (state)	Stream	Approximate Range	Status
St. Lawrence River system	Maumee River (OH)	Fish Creek	Last reported in early 1990s, 2-mile reach	Status unknown; possibly extirpated
	Detroit River (MI)	Detroit River	Freshly dead shells found in 2005	Status unknown; possibly extirpated
Ohio River	Green River (KY)	Green River	1-2 freshly dead shells found in 1987 and 1989 at 2 sites	Status unknown; possibly extirpated
	Scioto River (OH)	Big Darby Creek	1 live female reported in 2000 from 1 site near river mile 19	Status unknown; possibly extirpated
	Allegheny River (PA)	Allegheny River	Scattered over 66 miles in Warren, Forest, Venago, Clarion, and Armstrong Counties	Successful recruitment at multiple sites; stable
		Conewango Creek	Near confluence with the Allegheny River	A few live individuals found in 2005; no recruitment documented; status unknown
	French Creek (PA)	French Creek	Scattered over 60 miles in Venago and Crawford Counties	Successful recruitment at multiple sites; stable
		LeBoeuf Creek	3-mile reach	Recruitment documented; stable
		Muddy Creek	1 site near confluence with French Creek	Peripheral to French Creek; status unknown
	Kanawha River (WV)	Elk River	2 freshly dead shells found in 2003 at 1 site	Status unknown; possibly extirpated
TOTALS	9 populations	10 streams		4 recruiting populations in 7 streams

[1] From USFWS draft 5-year review of the northern riffleshell (USFWS, 2007 draft).

C.4.4 Habitat

This freshwater mussel occurs in a wide variety of large and small streams, preferring riffles and runs with bottoms composed of firmly packed sand and fine to coarse gravel (Watters, 1990; Stansbery et al., 1982). Preferred habitat appears to require flowing water in mid-size rivers. High dissolved oxygen concentrations in streams may be necessary for survival (NatureServe, 2007). The northern riffleshell is also known to occur in relatively slow-flowing, more lentic, or deep run habitats; however, it is unclear if specimens living in more typical riffle/run areas can adapt to slower water should conditions change (USFWS, 2007 draft). No critical habitat has been designated for the riffleshell.

C.4.5 Reproduction

Based on information for the closely related tan riffleshell (*E. florentina walkeri*), it is likely that the northern riffleshell is a long-term brooder with spawning occurring in August and September (Rodgers et al., 2001). Watters (1996) and O'Dee and Watters (2000) determined that the following four fish species are suitable hosts for northern riffleshell glochidia: banded darter (*Etheostoma zonale*), bluebreast darter (*E. camurum*), brown trout (*Salmo trutta*), and banded sculpin (*Cottus carolinae*). McNichols et al. (2007) reported that Iowa darters (*E. exile*), Johnny darters (*E. nigrum*), and mottled sculpin (*C. bairdi*) also transformed northern riffleshell glochidia. These studies did not test all of the fish species that are native to the range of the northern riffleshell. Further, these fish species do not occur in all habitats that support northern riffleshells. Therefore, there are probably other, as yet unidentified, suitable fish host species for the northern riffleshell – most likely several species of *Etheostoma* and *Percina* (Zanatta and Murphy, 2007). Glochidia are discharged primarily in May and June and become encysted on a suitable fish host where they transform into juvenile mussels over a period of days to weeks.

Riffleshells appear to have a relatively short life-span for a freshwater mussel. Sexual maturity can be reached in as little as three years, and most individuals probably live for only eight to 15 years (Rodgers et al., 2001). Most mussels probably experience very low annual juvenile survival. The combination of short life span and low fecundity indicates that populations depend on a large annual cohort resulting from a large population (Musick, 1999). Species following this reproductive strategy are susceptible to loss of individuals from predation and stochastic events, and are slow to recover from such losses (Rodgers et al., 2001), but may be well suited to exploit dynamic micro-habitat shifts characteristic of free-flowing rivers.

C.4.6 Known Threats

The primary factors that can be attributed to the reduction in riffleshell's range include impoundments, channelization, loss of riparian habitat, and the impacts of silt from poor land use (USFWS, 1995). Water pollution from municipalities, chemical discharges, coal mines, and reservoir releases have also impacted the species. The invasion of the exotic zebra mussel (*Dreissena polymorpha*) poses another potential threat to this species. Zebra mussels in the Great Lakes have been found attached in large numbers to the shells of live and freshly dead native mussels, and zebra mussels have been implicated in the loss of entire mussel beds. The zebra mussel has recently been reported from the Ohio River System, including the Green River in Kentucky. However, the full extent of zebra mussel impacts on the basin's freshwater mussels are unknown. Other threats that are attributed to population declines are similar to those described in the general mussel description in Section C.1.6.

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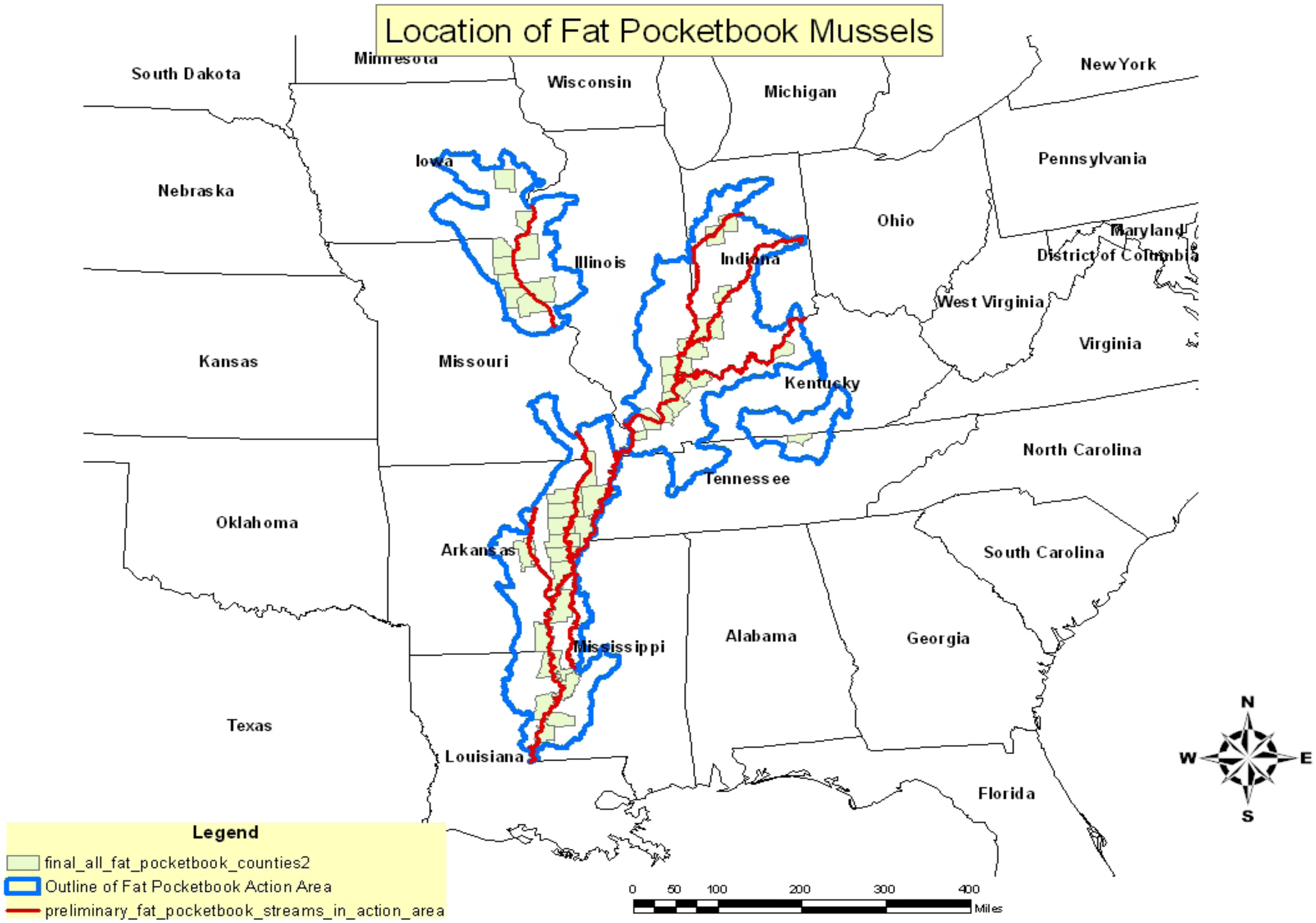

Figure C-1: Current Range of the Fat Pocketbook Pearly Mussel

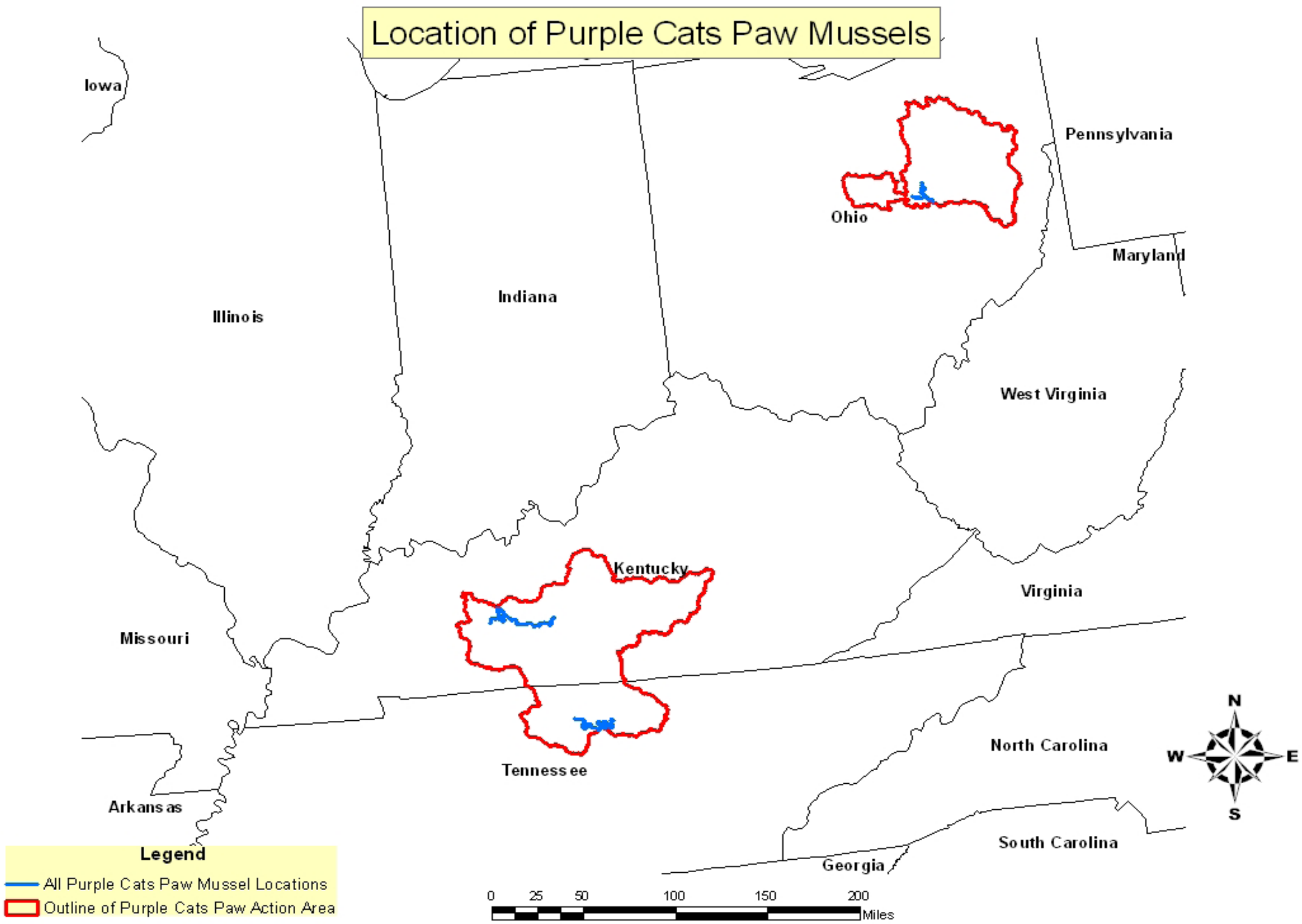

Figure C-2: Current Range of the Purple Cat's Paw Pearly Mussel

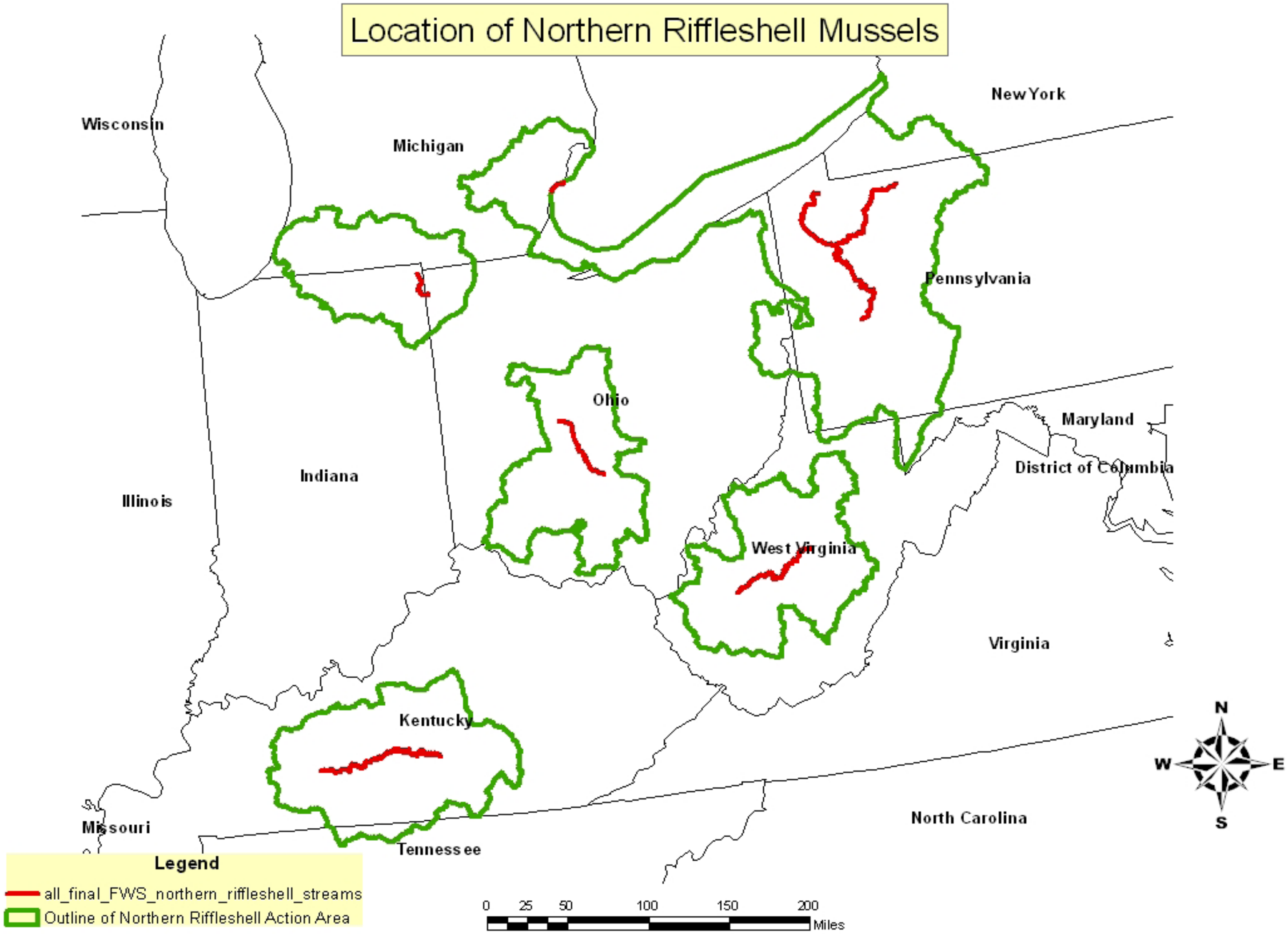

Figure C-3: Current Range of the Northern Riffleshell