Endemic, Endangered and Select Uncommon Fauna of the Green River, Kentucky

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1. Overview of the Basin

The Green River is over 370 miles in length from its headwaters to its confluence with the Ohio River with a total drainage area of 9,229 square miles with over five major tributaries contributing flow to this main river (Figure 1). The largest of the tributaries to the Green River is Barren River with a total drainage area of 2,262 square miles at its mouth. Rough River, Nolin River, Pond River, and Mud River have drainage areas of 1081, 727, 799, and 375 square miles respectively at their mouths (Table 1). Both the regulated and unregulated streams within the Green River basin show a wide variety of seasonal variation with the highest flows generally occurring from December through May, although, it is possible for major floods to occur at any time of the year. Lowest flows for the basin are expected during late summer and early fall.

Table 1. Drainage areas for the major rivers within the Green River Basin

Tributary	**Green River Drainage Areas (Square Miles)**
Green River @ Green River Lake	682
Green River above Nolin River	2031
Nolin River @ Nolin Lake	703
Nolin River @ mouth	727
Green River incl Nolin River	2758
Green River above Barren River	3140
Barren River @ Barren River Lake	940
Barren River mouth	2262
Green River incl Barren River	5402
Green River above Rough River	6429
Rough River @ Rough River Lake	454
Rough River @ mouth	1081
Green River incl Rough River	7510
Green River above Pond River	7623
Pond River @ mouth	799
Green River incl Pond River	8422
Green River @ Mouth	9229

The Green River basin is one of the top four river systems in the United States in terms of its aquatic biodiversity. Few streams rival the 151 species of fishes and 71 species of freshwater mussels in its system. Among these are multiple endemic species and approximately 35 aquatic species that are considered imperiled. The mineral dissolution of the watershed's underlying

limestone bedrock makes the Green River a natural companion to the Mammoth-Flint Ridge Cave System (the world's longest mapped cave system) and home to one of the most visited national parks. Other rare, threatened, or endangered plants and animals depend on the river and its tributaries for their survival. Examples include the eastern hellbender, American eel, and gray and Indiana bats.

Flood Control Dams and Navigational Lock and Dams

A series of Corps of Engineer lakes protect many communities and farmlands from floods along many of the streams and rivers within this basin. These Corps of Engineer lakes include Green River, Barren River, Nolin, and Rough River with controlled drainage areas of 682, 940, 703, and 454 square miles.

The Green River also contains a system of locks and dams that were once used to transfer goods throughout the basin. In 1818, the Commonwealth of Kentucky requested the U.S. Army Corps of Engineers to conduct a navigation study from the mouth of the river to Bowling Green, Kentucky. Based upon the survey, the Commonwealth of Kentucky authorized and funded a slackwater navigation project on the Green and Barren Rivers. Construction of Locks and Dams (L&D) Nos.1 through 4 on the Green River and L&D No. 1 on the Barren River began in 1831 and was completed by 1842. Due to damage caused by military activity during the Civil War, the navigation system was not operational until the Commonwealth leased the project to the Green and Barren River Navigation Company in 1868. The navigation company entered the lease under the provision that the company would repair and maintain the system and receive revenue from tolls and waterpower leases in return. In order to prevent the Green and Barren River Navigation Company from monopolizing transportation on the Green River, Congress intervened in 1886. The Commonwealth of Kentucky ceded its rights of eminent domain to the United States on the condition that the rights of the navigation company would also be obtained. Congress appropriated $135,000 for this purchase under the River and Harbor Act 10 1888; and the United States took possession after the deed was certified on 11 December 1888. To extend the system upstream and open extensive mineral resources along Bear Creek and Nolin River, Congress planned construction of L&D Nos. 5 and 6 on the Green River under the River and Harbor Act of 19 September 1890. Construction of L&D Nos. 5 and 6 were completed in 1900 and 1906, respectively.

By the early 1930's, the old timbercrib L&Ds were in need of major repair. In 1934, the U.S. Army Corps of Engineers constructed new facilities at Green River L&D No.5 and installed a new lock at Barren River L&D No. 1 (Figure 1). Due to the lack of commercial activity, L&D Nos. 5 and 6 were closed to traffic and deactivated in 1951. Modernization of the lower 103

miles of the Green River began in 1953 and involved the reconstruction of Locks Nos. 1 and 2, reconstruction of Dam No. 2, partial rehabilitation of Dam No. 1, and widening the channel to 200 feet and deepening it to 9 feet (Figure 1). Construction of the modernization project was completed within three years. On 24 March 1965, Green River L&D No. 4 was breached causing the water level above the dam to fall six feet and made navigation to Barren River L&D No.1 by barge impossible. The Corps conducted a study of the failure and concluded that insufficient economic justification existed for the repair of Dam 4. Consequently, Barren River L&D No. 1 was deactivated. In 1970 a new concrete filled cellular sheet pile dam was constructed just downstream of the existing Green River L&D No.1. Due to decreased commercial activity, Green River L&D No. 3 was closed to traffic and deactivated in 1981. Currently, L&D Nos. 1 and 2 are maintained by the Corps and are the only navigational facilities open to commercial and recreational traffic on the Green River.

Lock and Dam 6 has been considered for removal but no action has taken place. Presently the dam is failing and presents a safety hazard. Dam removal would allow restoration of 17 miles of the Green River, almost all within Mammoth Cave National Park (MCNP), to near natural conditions. Green River, upstream of MCNP, is designated an Outstanding Resource Water by the Commonwealth of Kentucky. Such designation ends at the upper reach of Pool 6. It is reasonable to expect that the 17 mile stretch would attain the same physical and biological characteristics as that of the near 100 miles of Outstanding Resource Water upstream if the dam were removed. Benefits to the cave system are also expected.

Land Use and Environmental Concerns

Generally, the lower third of the basin, with both the richest agricultural lands and the most populated, has more flooding problems due to the relatively level flood plain terrain. The middle third, especially tributaries, is greatly impacted by acid mine drainage from orphaned mine lands and by current coal mining and petroleum extraction activities (Figure 2). Threats to the upper third, the area of the Green River Bioreserve, MCNP and the most pristine stretch of river, include: agricultural runoff primarily from beef cattle operations, timbering, and subdivision of family farms into weekend and/or retirement retreats. Barren River is being counted on as the primary source of water supply for Bowling Green, Kentucky, a fast growing urban area on a karst plain about an hour north of Nashville, Tennessee. Both the river and Barren River Lake are major sources of recreation for the region. Rough River is heavily laden with sediments from runoff from row cropped agricultural lands, as is the smaller Nolin River. The lower half of Rough River is also impacted by past and present strip-mining activities. Pond Creek, in the coalfields region, has long-term water quality problems relating to past disposal of polychlorinated biphenyls or PCB's (Figure 3).

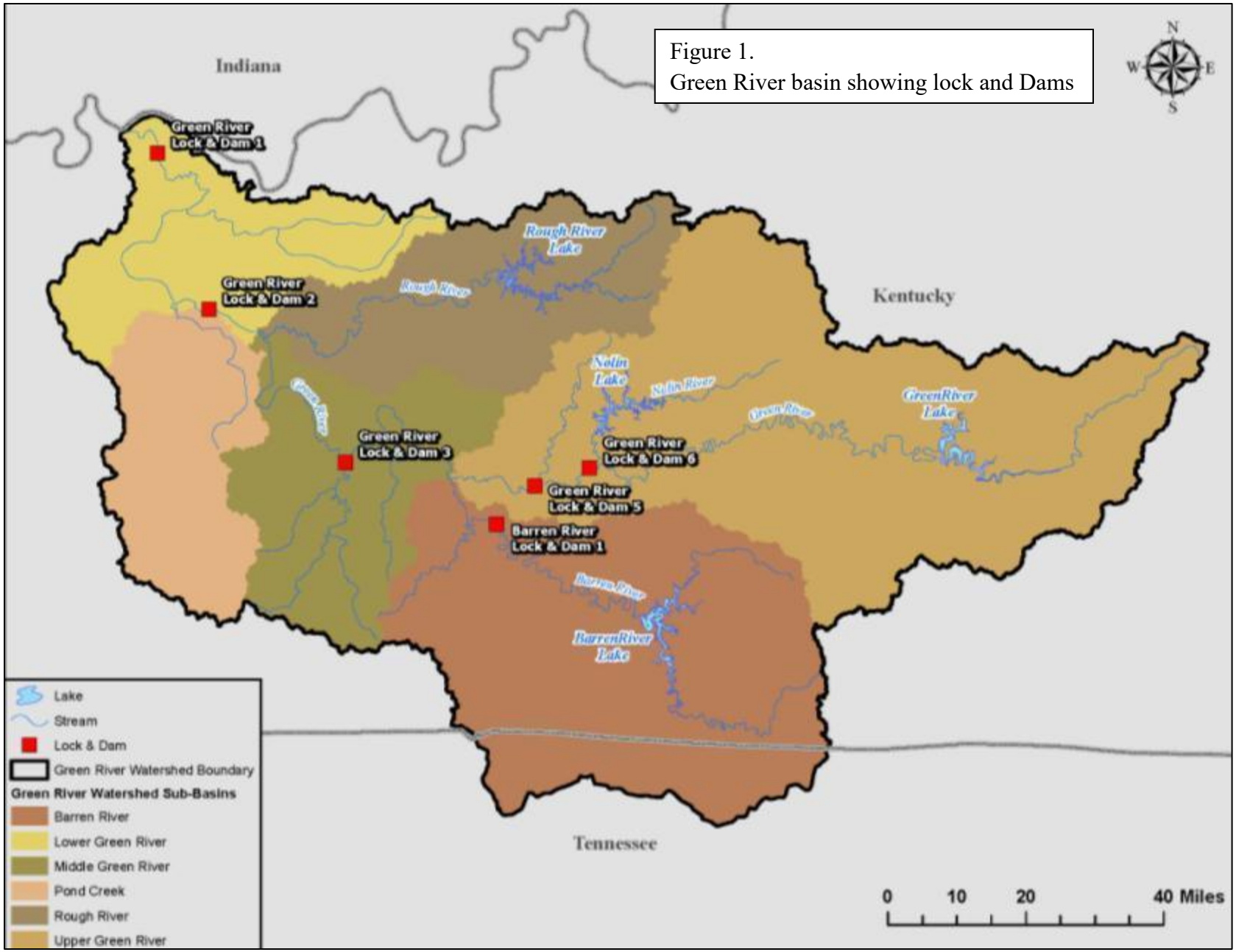
Figure 1.
Green River basin showing lock and Dams
Indiana
Kentucky
Tennessee
N
W
E
S
Green River Lock & Dam 1
Green River Lock & Dam 2
Green River Lock & Dam 3
Green River Lock & Dam 6
Green River Lock & Dam 5
Barren River Lock & Dam 1
Rough River Lake
Rough River
Nolin Lake
Nolin River
Green River
GreenRiver Lake
Barren River
BarrenRiver Lake
Lake
Stream
Lock & Dam
Green River Watershed Boundary
Green River Watershed Sub-Basins
Barren River
Lower Green River
Middle Green River
Pond Creek
Rough River
Upper Green River
0
10
20
40 Miles

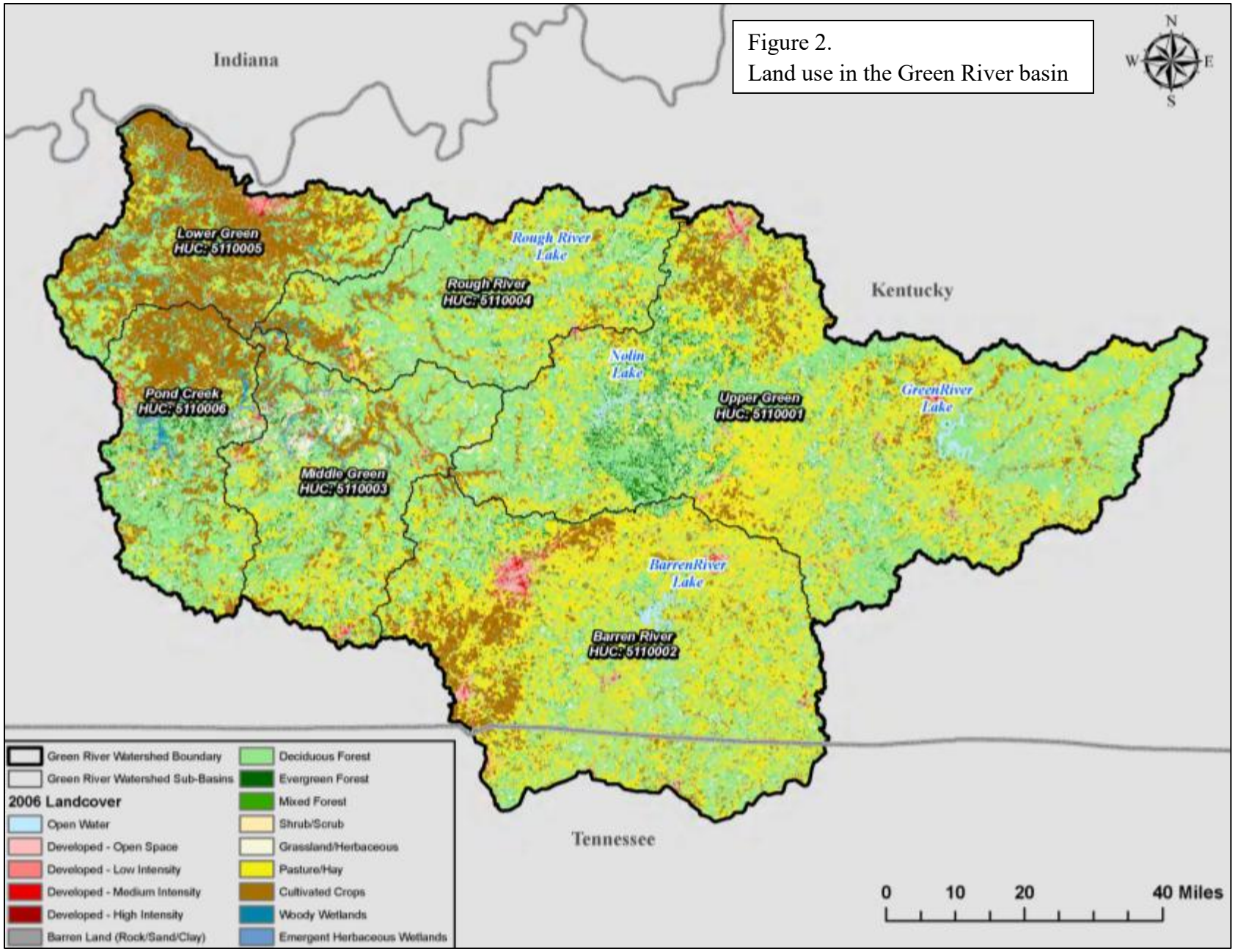
Figure 2.
Land use in the Green River basin
Indiana
Kentucky
Tennessee
N
W
E
S
Lower Green
HUC: 5110005
Rough River
Lake
Rough River
HUC: 5110004
Nolin
Lake
Pond Creek
HUC: 5110006
Upper Green
HUC: 5110001
GreenRiver
Lake
Middle Green
HUC: 5110003
BarrenRiver
Lake
Barren River
HUC: 5110002
Green River Watershed Boundary
Green River Watershed Sub-Basins
2006 Landcover
Open Water
Developed - Open Space
Developed - Low Intensity
Developed - Medium Intensity
Developed - High Intensity
Barren Land (Rock/Sand/Clay)
Deciduous Forest
Evergreen Forest
Mixed Forest
Shrub/Scrub
Grassland/Herbaceous
Pasture/Hay
Cultivated Crops
Woody Wetlands
Emergent Herbaceous Wetlands
0
10
20
40 Miles

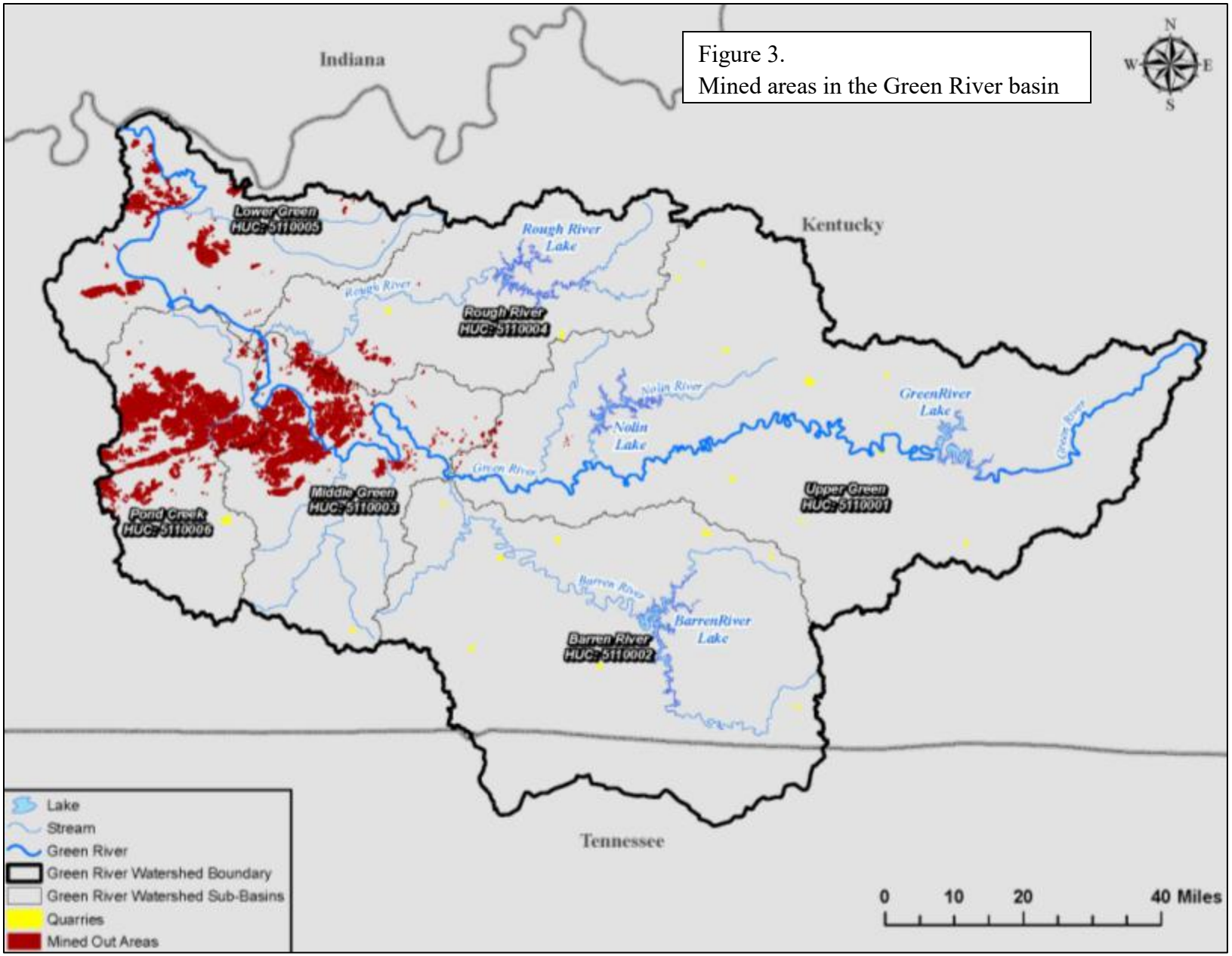
Figure 3.
Mined areas in the Green River basin
Indiana
Kentucky
Tennessee
N
W
E
S
Lower Green
HUC: 5110005
Rough River
Lake
Rough River
HUC: 5110004
Nolin River
Nolin
Lake
GreenRiver
Lake
Green River
Middle Green
HUC: 5110003
Upper Green
HUC: 5110001
Pond Creek
HUC: 5110006
Barren River
BarrenRiver
Lake
Barren River
HUC: 5110002
Lake
Stream
Green River
Green River Watershed Boundary
Green River Watershed Sub-Basins
Quarries
Mined Out Areas
0
10
20
40 Miles

2. Major Streams of the Green River Basin

Green River

The Green River basin lies almost entirely within the Commonwealth of Kentucky with a small portion extending into northern Tennessee. It encompasses a total drainage area of 9,229 square miles at its mouth. The headwaters of the Green River, a tributary to the Ohio River, begin in central Kentucky, in Lincoln County, and generally run westerly through the state of Kentucky to near the confluence with Barren River, and then travels in a northwesterly direction to the confluence with Rough River, and then to the Ohio River near Henderson, Kentucky for a total distance of about 370 miles. The Green River enters the Ohio River between Ohio River mile 785 and 784. The Green River is very sinuous with numerous sharp bends, except in the extreme lower sections. The floodplain is narrow in the upper and middle reaches of the Green River with considerable widening in the lower reaches.

The Green River is impounded by an earth and rock fill dam at river mile 79.2. The drainage area above the dam is 682 square miles, with major land uses being agricultural. The largest urban center in the watershed is Campbellsville. Little commercial or residential development has occurred in conjunction with Green River Lake since its construction. The dam was constructed to reduce flood damages downstream from the dam. The lake also provides recreational opportunities, economic benefits to the local economy, and water supply. The winter pool elevation is 664 (feet above mean sea level); this elevation creates a lake with a surface area of approximately 6,650 acres and a length of about 21 miles. The summer pool elevation is 675 (feet above mean sea level); this elevation creates a lake with a surface area of approximately 8,210 acres and a length of about 25 miles.

Barren River

The largest tributary to the Green River is Barren River. The Barren River lies in south-central Kentucky and north-central Tennessee, and includes an area of 2,262 miles, of which 1,852 are in Kentucky and 410 in Tennessee. It is bounded on the north and west by the watershed of the Green River and on the south and east by the Cumberland River basin. The drainage area of the Barren River comprises 40 percent of the area in the Green River basin above the confluence of the two streams (Green River Mile 149.6) and about ¼ of the entire drainage area. The Barren River watershed is roughly triangular in shape, about 55 miles long and 40 miles wide. The Barren River is formed by the confluence of Line Creek and East Fork in Monroe County, Kentucky, and generally flows in a northwesterly direction for 139 miles until its junction with the Green River at Woodbury, Kentucky, 149 miles upstream from the Ohio River. It drains part or all of eight counties in Kentucky and in Tennessee. The principal tributaries are Drakes

Creek, Skaggs Creek, and Gasper River. The remaining tributaries are much smaller and descend rapidly from their headwaters to the main stream, each draining an area less than 150 square miles. The Barren River basin is relatively rugged to rolling, with the more gently rolling are near the center of the basin, and the more rugged areas in the headwaters and near the mouth. The northwest-central portion of the basin is traversed by a belt of cavernous limestone, in which subterranean drainage has developed to an advanced stage. The lower 30-mile reach of the Barren River, from the mouth to Bowling Green, Kentucky, is canalized for navigation with a minimum depth of 5.5 feet. A lock and dam is located at Greencastle, river mile 15.

Barren River is impounded by a rolled earth fill with random rock dam at river mile 79.2. The drainage area above the dam is 940 square miles. The dam was constructed to reduce flood damages downstream from the dam. The lake also provides a water supply, recreational opportunities, and economic benefits to the local economy. The winter pool elevation is 525 (feet above mean sea level); this elevation creates a lake with a surface area of approximately 4,340 acres and a length of about 21 miles. The summer pool elevation is 552 (feet above mean sea level); this elevation creates a lake with a surface area of approximately 10,000 acres and a length of about 33 miles.

Rough River

The Rough River is the second largest tributary of the Green River and drains an area of 1,081 square miles including major parts of Breckinridge, Grayson, Hardin, and Ohio Counties. This comprises approximately 12 percent of the Green River watershed. The Rough River flows 141 miles in a westerly direction from its headwaters in west central Hardin County to its confluence with the Green River in McLean County at Green River Mile 71.3. Many small tributary streams to Rough River lie both above and below Rough River Lake. Major tributaries which drain into the lake include the North Fork Rough River, Rough Creek, and Clifty Creek. Rock Like Creek, Adams Fork, Halla Creek, and Caney Creek enter the Rough River downstream from the lake. The Rough River watershed is rural in nature, with the major land usage being agriculture.

Rough River is impounded by an earth core with rock fill dam. The drainage area above the dam is 454 square miles. The dam was constructed to reduce flood damages downstream from the dam. The lake also provides recreational opportunities, economic benefits to the local economy, and water supply. The winter pool elevation is 470 (feet above mean sea level); this elevation creates a lake with a surface area of approximately 2,890 acres and a length of about 29 miles. The summer pool elevation is 495 (feet above mean sea level); this elevation creates a lake with a surface area of approximately 5,100 acres and a length of about 39 miles. Water is stored in the lake between March 15 and April 15 to reach summer pool. Between September 15 and

October 15, drawdown of the lake begins, bringing the lake down two feet during this period. Drawdown of the lake continues through December 1 to bring the lake down to the winter pool elevation level.

Pond River

The Pond River is the third largest tributary of the Green River and drains an area of 799 square miles, entering the Green River at mile 55 near Jewel City. No flood control or navigational dams are present on the Pond River. The upper section of the Pond River is relatively healthy and contains a good representation of plants and animals. The lower section of Pond River is impaired due to acid mine runoff.

Nolin River

The Nolin River is the fourth largest tributary of the Green River and drains an area of 727 square miles, entering the Green River at mile 183.5. The confluence is 1.8 miles upstream of Green River L&D No. 6. The Nolin River basin encompasses portions of Edmonson, Grayson, Hardin, Hart, and Larue Counties.

The Nolin River is impounded by an earth and rock fill dam approximately eight miles upstream of its confluence with the Green River. The drainage area above the dam is 703 square miles. The dam was constructed to reduce flood damages downstream from the dam. The lake also provides recreational opportunities, economic benefits to the local economy, and water supply. The winter pool elevation is 490 (feet above mean sea level); this elevation creates a lake with a surface area of approximately 2,890 acres and a length of about 30 miles. The summer pool elevation is 515 (feet above mean sea level); this elevation creates a lake with a surface area of approximately 2,890 acres and a length of about 39 miles.

Other Tributaries

Smaller tributaries of the Green River include (from upstream to downstream): Russell Creek, Big Pitman Creek, Brush Creek and Little Barren River.

3. Green River Basin Endemic Species

The Green River basin ranks second to the Cumberland River basin in Kentucky with respect to species diversity and endemism. Endemic species in the Green River basin include six darters (family Percidae), one sucker (family Catostomidae), one freshwater mussel (family Unionidae), and one cave shrimp (family Atyidae). Five of these species are distributed throughout the basin. The remaining species are more restricted in their distribution. The Green River contains one endemic species, Barren River contains three endemic species, and the headwaters of Pond River contain one endemic species. No species are known to be endemic to the Nolin River; however, there is a unique color variation of the bottle brush crayfish in the Nolin River that may represent a distinct subspecies (Taylor and Schuster 2004).

In addition to aquatic species, one or two species of endemic terrestrial species are known from the basin. These species are cave obligates or associated with caves. A species of pseudoscorpion (family *Chthonidae*) is known from Edmonson County and a species of Cave Beatle or cave cricket may be known from the same area.

Bottlebrush Crayfish (*Barbicambarus cornutus*)

The bottlebrush crayfish is the one of the largest species of crayfish in Kentucky, reaching total lengths of up to 5.3 inches (Taylor and Schuster 2004). Males and females are similar in color, with a base color of olive green to brown. This species can be easily distinguished from other species by the presence of dense setae along the antennae (Taylor and Schuster 2004). There is a distinct color form of bottlebrush crayfish found in the Nolin River watershed that has dark blotches on its body and usually has dark longitudinal bands along its abdomen (Taylor and Schuster 2004).

The bottlebrush crayfish is endemic the Green River Basin and is found throughout the basin. It is most common in the Barren River basin, the Green River (below Green River Dam), and the Nolin River above Nolin Lake (Taylor and Schuster 2004).

The bottlebrush crayfish is found in both large and small streams under large flat boulder and along creek margins where current is present (Taylor and Schuster 2004).

Teardrop Darter (*Etheostoma barbouri*)

The teardrop darter (*Etheostoma barbouri*) is found throughout the Green River basin. It prefers pools with fine substrates, such as sand, that are relatively free of debris. This species is rarely found in riffles or in water greater than two feet in depth (Kuehne and Small 1971).

Splendid Darter (*Etheostoma barrenense*)

The splendid darter (*Etheostoma barrenense*) typically occurs in gravel riffles in small tributaries and in riffle margins in the main stem of the Barren River. The splendid darter spawns from mid-April to mid-May. Eggs are laid on slanted rocks in areas with low current in depths of 30 centimeters or less (Kuehne and Barbour 1983). This species is most common in rock pools and adjacent riffles **(**Page and Burr 2011).

Orangefin Darter (*Etheostoma bellum*)

The orangefin darter (*Etheostoma bellum*) is found throughout the Green River basin above the confluence of the Green and Barren Rivers. It is most often found in riffles with fine gravel substrates in water depths of 3 to 6 inches (Zorach 1968). It prefers areas with fine substrates.

Highland Rim Darter (*Etheostoma kantuckeense*)

The Highland Rim darter (*Etheostoma kantuckeense*) was described by Ceas and Page in 1997. The Highland Rim darter is a member of the orange throat darter (*E. spectabile***)** species complex and is closely related to the Shawnee darter. Non-breeding males and females appear similar to other species within the species complex. Breeding males have a distinct powder blue belly. This coloration is not found in other members of the *E. spectabile* species complex. The unique belly coloration of this species is created by reflective pigments rather than carotenoids (Ceas and Page 1997). The Highland Rim darter is found in the upper the Barren River and its tributaries (Ceas and Page 1997). The Highland Rim darter is endemic to the Barren River and its tributaries. It prefers head water streams with moderate flow. It most often occurs in riffles but in the dry season may be found in pools (Ceas and Page 1997). Females may be found in debris along the edge of streams outside of the breeding season (Ceas and Page 1997). The Highland Rim darter is typically found over substrates consisting of gavel and cobble (Ceas and Page 1997).

Kentucky Snub Nose Darter (*Etheostoma rafinesquei*)

The Kentucky snub nose darter (*Etheostoma rafinesquei*) is found throughout the upper Green River basin, but is most common upstream of the confluence of the Nolin River. The range within the basin may be extended as additional surveys are conducted (Kuehne and Barbour 1983). The Kentucky snub nose darter spawns in late March through early May. This species most often occurs over fine or course gravel in rocky pools, runs and riffles **(**Weddle and Burr 1991).

Shawnee Darter (*Etheostoma tecumsehi*)

The Shawnee darter (*Etheostoma tecumsehi*) was described as a species by Ceas and Page in 1997. The Shawnee darter is a member of the orange throat darter (*E. spectabile*) species complex. Non-breeding males and females appear similar to other species within the species complex. Breeding males are predominately blue and orange. The color patterns of breeding males are used to distinguish this species (Ceas and Page 1997). The Shawnee darter is found in the upper Pond River. This species is separated from other similar species by long expanses of the lower Pond River and the lower Green River that lack suitable habitat (Ceas and Page 1997). The Shawnee darter is endemic to the Pond River and its tributaries. It prefers head water conditions with moderate flow. It is typically found over substrate consisting of gravel and cobble (Ceas and Page 1997). Females may be found in debris along the edge of streams outside of the breeding season (Ceas and Page 1997).

Kentucky Cave Shrimp (*Palaemonias ganteri*)

The Kentucky cave shrimp (*Palaemonis ganteri*) is a small freshwater crustacean with a body shape similar to a crayfish, with a strong, flexible, translucent shell without color pigment. It is characterized by rudimentary eyestalks lacking facets of pigmentation, subequal first and second chelae, and terminal tufts of setae on each of the chelae. The Kentucky cave shrimp is distinguished from its closest relative, the Alabama cave shrimp (*P. alabamae* Smalley), by having more than 15 dorsal teeth on the rostrum and more than 15 spine-like setae on the appendix masculine (Hobbs, Hobbs, and Daniel 1977). Hatchlings are approximately 3 millimeters (mm) total length and adults are up to 30 mm (Holsinger and Leitheuser 1983). The Kentucky cave shrimp is found only in the Mammoth Cave system of Kentucky and is also called the Mammoth Cave shrimp. It is one of only four species of cave shrimp known from the United States.

The current known distribution of the shrimp includes nine distinct groundwater basins in the Mammoth Cave National Park region (Quinlan and Ray 1981). Three of these basins (the Echo River Spring, Ganter Cave, and Running Branch Cave Groundwater Basins) are located more or less entirely within Mammoth Cave National Park. Two other basins (Mile 205.7 Spring and Pike Spring) extend well beyond the east boundary of the park. Approximately one-third of the Mile 205.7 Spring and one-half of the Pike Spring groundwater basins are located on private lands. Although Sandhouse Cave is located in Mammoth Cave National Park, the majority of the Double Sink Groundwater Basin is located on private lands southwest of the park. The only locality known to contain shrimp in the Turnhole Spring groundwater basin, Snake River in Lee Cave, is located within Mammoth Cave National Park. The majority of this basin, however, is located on private lands south of the park. The remaining basins known to contain shrimp (McCoy Blue Spring and Suds Spring Groundwater Basins) are both entirely on private lands east of Mammoth Cave National Park. Ganter Cave, Running Branch Cave, and McCoy Blue Spring are all on the north side of the Green River, which bisects Mammoth Cave National Park, while remaining basins are on the south side of the river.

Localities from which shrimp have been collected, observed, or reported, have not been mapped with sufficient precision to allow the direct calculation of population densities. It is, however, possible to estimate relative population densities over a section of passage known to contain shrimp. A population density estimate has been based upon only one dimension, that of length of the passage. Population densities appear to be highly variable. Shrimp density has been reported (Holsinger and Leitheuser 1982b and 1983). For example, one locality varies from a density of 0.022 shrimp/foot to 0.148 shrimp/foot (Holsinger and Leitheuser 1983). The passages from which these data were obtained were approximately 1 to 3 feet wide and 1 to 3 feet deep (Leitheuser, unpublished data).

The reproduction life cycle of the Kentucky cave shrimp is continual, meaning the female can produce eggs at any time of the year. Reproduction may be influenced by increased food supply brought in by flooding. The Kentucky cave shrimp sheds its exoskeleton, or molts, every 40-50 days. As it grows, the molted shell includes the covering of the antennae, mouthparts and legs so that the old shell looks almost exactly like the living shrimp. The female carries up to 33 eggs under the abdomen until ready to hatch. The eggs hatch late summer and fall, with hatchlings approximately 3 mm (0.118 in.) long and ready to swim. There is no parental care given to young. The Kentucky cave shrimp has a low reproductive rate due to a short life span and small number of eggs per reproductive cycle. Life expectancy is 1-2 years.

The Kentucky cave shrimp is an important contributor to the cave's cycle. It is a scavenger, feeding on decaying organic matter and converting it back to food for animals that eat the shrimp. It is also a grazer: that is, it uses teeth-like mouthparts to scrape tiny organic, or nutrient,

particles from the stream bottom. The darkness of the cave prevents photosynthesis, therefore nutrients, or food, for the cave shrimp enters by way of floodwaters. The shrimp has specific habitat requirements, and is adapted to a highly specialized and restricted environment. This environment consists of the parameters characteristic of the cave systems in the Mammoth Cave National Park region. The caves are extensive in development and include both complex networks of interconnected and active underground streams and cover a large basin influenced by surface activities, including both natural and human-induced events. Natural events, primarily precipitation, greatly influence the underground environment through direct input of organics, detritus, and other food items that form the base of the food web for the cave system. In an ecological context, the cave system is thought to represent a very unique and relatively simple ecosystem since boundaries to the system are well defined. Heterotrophs populating the cave system depend upon food imported by trogloxenes, accidentals, and nutrient-laden water. Therefore, food is scarce and population densities are low. Obviously, an event that affects the groundwater basin known to contain shrimp will have a direct impact on the species.

The Kentucky cave shrimp was listed an endangered, under the Endangered Species Act, by the USFWS November 14, 1983.

Blackfin Sucker (*Thoburnia atripinni*)

The blackfin sucker (*Thoburnia atripinni*) reaches a maximum length of 6.1 inches (Etnier and Starnes 1993). It is identified by the presence of several lateral stripes extending the length of the body and a dark blotch on the anterior rays of the dorsal fin (Etnier and Starnes 1993, Timmons et al. 1983). The blackfin sucker occurs in headwater streams of the Barren River (Timmons et al. 1983). The blackfin sucker occurs in clear headwater streams usually 1.5 to 9 meters wide. This species is found in both shoals and pools often under large slab rock or near undercut banks (Timmons et al. 1983). Spawning groups have been observed over riffles (Timmons et al. 1983). The diet of this species consists primarily of midge larvae, supplemented with micrucrustacea and larger insect larvae (Timmons et al. 1983). Males typically become sexually mature in two years with females reaching sexual maturity in three years (Timmons et al. 1983).

Pseudoscorpion (*Tyrannochthonius hypogeus*)

This is a small species of *Tyrannochthonius* that has a body color of light brown to light tan. This species lacks eyes (Muchmore 1996). It is known only from Bruce Hollow in Edmonson County, Kentucky (Muchmore 1996). All individuals were found in log litter. Due to the

proximity of Mammoth Cave and anatomical features it was presumed that this species most often inhabits caves (Muchmore 1996). This is the northern most record for a member of the *Ttrannochthonius* genus (Muchmore 1996).

Kentucky Creekshell (*Villosa Ortmanni*)

The Kentucky creekshell (*Villosa Ortmanni*) was described by Lea in 1837. It is a small to medium-sized mussel, to about three inches in length. The males and females are similar in color, either yellowish-brown or yellowish-green with fine green rays. Although the colors are the same, there is sexual dimorphism in regard to shape (NatureServe 2010). This species is found throughout the Green River basin. The Kentucky creekshell occurs in both the mainstem of the Green and its smaller tributaries.

The Kentucky creekshell occurs in small to medium sized river in sand and gravel. It is most commonly found in riffles, runs and areas adjacent to these habitat types (Cicerello and Schuster 2003). Like most Unionid mussels, the Kentucky creekshell is very tolerant and can occur or persist in unfavorable conditions for significant periods of time. However, in unfavorable conditions the reproduction may be reduced or eliminated. Most occurrences of the Kentucky Creekshell are reported in shallower depths in the riffle complexes.

4. Endangered Species of the Green River

Range Maps, produced by the Kentucky Department of Fish and Wildlife (2010), of each endangered species discussed below are shown in appendix 1.

Northern Riffleshell (*Epioblasma tortulosa rangiana*)

The northern riffleshell is a small to medium-sized mussel, to about three inches in length, averaging 1.5 inches. Based on growth annuli, the northern riffleshell may live for 15 years (USFWS 1994). The males and females are similar in color, either yellowish-brown or yellowish-green with fine green rays. Although the colors are the same, there is a great deal of sexual dimorphism in regard to shape (NatureServe 2010, USFWS 1994). *Epioblasma* is the most diverse genus of Unionid in the United States (Williams et al. 1993). Many authors have considered the northern riffleshell a headwater form or subspecies of the *E. t. torulosa* (USFWS 1994).

The northern riffleshell is an Ohio River system species recorded from most of the tributaries in Kentucky, Illinois, Indiana, Ohio and north into Michigan and Ontario in the tributaries of Lake

Erie, Lake St. Clair, and the Detroit and St. Clair Rivers (USFWS 1994). This species has declined drastically and has experienced a greater than 95% reduction in range (USFWS 1994).

Currently, this species may still survive, in exceptionally small numbers, in the Green River in Edmondson and Hart Counties, Kentucky. The largest remaining populations of the northern riffle shell are found in the Allegheny River and French Creek. Although at the time of listing, it was found in large numbers and reproducing in several watersheds, currently it is only known to be reproducing in the Allegheny River Watershed, Allegheny River and French Creek (and tributaries). In the Allegheny River, the populations range from viable to those with apparently depressed vigor, with an overall known broken distribution of some 80 miles (C. Bier, WPAAC, in litt 6 January 1994, cited in FWS 1994). The distribution in the Allegheny River is from the city of Warren downstream to Pool 8 (mile 58.85). Fresh dead shells were located in Green River in 1993 (USFWS 1994). However, 1992 surveys in the lower Green River did not locate any northern riffleshells, (Miller and Payne 1992).

The northern riffleshell occurs in a wide variety of streams, large and small. The northern riffleshell occurs in packed sand and gravel in riffles and runs. It buries itself to the posterior margin of the shell. Most occurrences of the northern riffleshell are reported in shallower depths in the riffle complexes. Like most Unionid mussels, the northern riffleshell is very tolerant and can occur or persist in unfavorable conditions for significant periods of time. However, in unfavorable conditions the reproduction may be reduced or eliminated.

The northern riffleshell was listed by the USFWS as endangered under the Endangered Species Act of 1973 on January 22, 1993.

Pink Mucket (*Lampsilis abrupta*)

The pink mucket has been known by several different scientific names. When the USFWS listed it in 1976 it was listed as *Lampsilis orbiculata* (Federal Register June 14, 1976). This naming was based on Hildreth's (1828) description for *Unio orbiculata* (USFWS 1985). However, that description does not fit *Lampsilis orbiculata* (Ahlstedt 1985). The earliest description that fits *Lampsilis abrupta* is that of Say (1831) for *Unio abruptus*. Since the USFWS has listed *Lampsilis orbiculata* the name has been changed to the appropriate name of *Lampsilis abrupta*.

There is a great deal of sexual dimorphism in the pink mucket with a shell that is generally round to elliptical, solid, and inflated. In males, the anterior end is rounded and posterior end is bluntly pointed. The shells of females are truncated with a straight dorsal margin and ventral margin straight to slightly curved. The umbos are turned forward and elevated above the hinge line.

The beak sculpture, if visible, has three or four double-looped ridges. The shell is smooth, yellow or yellowish green and rayless or with faint green rays. The mature length is four inches. The pseudocardinal teeth are triangular, thick, and divergent with two in the left valve, one in the right and occasionally with a smaller tubercular tooth in front. The lateral teeth are short, heavy, and relatively thick.

The pink mucket has been known to occur in the Tennessee, Cumberland, and Ohio Rivers (Ahlstedt 1985). There were occasional records reported for the Mississippi River drainage (Ahlstedt 1985). Historically, it occurred in 25 river systems and had an extremely widespread distribution (Ahlstedt 1985). This mussel was never considered very abundant and large numbers have never been collected (Ahlstedt 1985).

Currently, the pink mucket is found in lesser numbers but remaining in most of its former range (Ahlstedt 1985). However, it is extirpated from Ohio, Pennsylvania and Illinois (NatureServe 2010). It is known from 16 different rivers and three geographic regions (Ahlstedt 1985). Based on the number of locations where specimens have been found or observed, the greatest concentrations are reported from the Tennessee River, Cumberland River, Osge River and the Meramec River (Ahlstedt 1985). The pink mucket was reported in the early 1980's on the Green River, at Lock and Dam #5 by Clarke (1982) and USEPA (1981). The exact locations of the records are unknown but they are listed as Butler County, Kentucky. Additionally, a fresh dead pink mucket was reported from the Green River (Hart County) in 2010.

The pink mucket is a medium to large river (20m wide or greater) species. It occurs in substrate with silt to boulders, rubble, gravel, and sand substrates in fast flowing water. The water depths range from 2.5 cm to 1.5 m in standing and flowing water. However, it has been collected to depths of 2.7 m to 8.0 m in moderate to fast-flowing water (Ahlstedt 1985). It appears that the pink mucket has adapted to existence in the impounded Tennessee and Cumberland Rivers (Ahlstedt 1985). The river-lake conditions in the upper reaches of the Tennessee and Cumberland rivers are suitable for the survival and propagation (Ahlstedt 1985).
The pink mucket is a bradytictic or long-term breeder, becoming gravid in August and the females discharge the glochidia the following year (Ortman 1912 & 1919; cited in Ahlstedt 1985). The pink mucket was listed as endangered by the USFWS on June 14, 1976.

Clubshell (*Pleurobema clava*)

The clubshell was described by Lamarck in 1819 and is easily identified within its range. It is a small mussel with thick, yellow to brown colored shell with green rays. Small stream specimens

are considerably smaller (NatureServe 2010). Shells grow to about three inches in length and average 1 to 1.5 inches. There is no sexual dimorphism in the species.

A similar species, which is difficult to differentiate, is the Cumberlandian analog (*Pleurobema oviforme*), which may represent a set of sibling taxa (USFWS 1994). Specimens of Cumberlandian collected from the Cumberland and lower Tennessee Rivers are virtually indistinguishable from the northern clubshell (*Pleurobema clava*).

Historically, the clubshell is an Ohio River system species recorded from the mainstem Ohio River and many tributaries in Kentucky, Illinois, Indiana, and Ohio, as well as from more isolated systems in Michigan, Pennsylvania, and West Virginia (USFWS 1994, NatureServe 2010). The clubshell was also found in the Maumee River basin and tributaries of Western Lake Erie (USFWS 1994, Stansbery et al. 1982). This species has declined drastically and has experienced a greater than 95% reduction in range (USFWS 1994).

Populations, some considered large, now exist in the Allegheny River and Tributaries. LeBoeuf Creek in particular, below Lake LeBoeuf to its mouth at French Creek, has a dense, apparently reproducing population. Additionally, French Creek, for about a mile, below this confluence also supports numerous clubshells. The species also occurs in the Ohio, Elk, and Green Rivers. There are records of the clubshell on the upper reaches of the Green River. In a survey of the lower portion of the Green River no clubshell were found (Miller et al. 1994). However multiple reproducing populations of this species now occur in the Green River near Greensburg KY (Green County) (personal observation 2008-2010).

The clubshell occurs in clean swept sand and gravel in medium to small rivers (USFWS 1994). It buries itself, sometimes completely, in clean loose sand/gravel substrate in riffle/runs (USFWS 1994; NatureServe 2010; Stansbery et al. 1982). Because it buries in the substrate it is a difficult species to find, even in areas where it is suspected to be abundant (NatureServe 2010).
Very little specific information is known about its food habits and reproductive biology, but they are probably similar to other unionids. The hosts for the clubshell glochidia are unknown. However, the closely related mussel species Cumberland analog has been shown to use the central stoneroller (*Campostoma anomalum*), common shiner (*Luxilis cornutus*), fantail darter (*Etheostoma flabellare*), river chub (*Nocomis micropogon*), and whitetail shiner (*Cyprinella* glactura) as a host (Neves 1983, Weaver et al. 1991). Related fishes within the range of the clubshell may be possible hosts. It was found to be gravid from May through July (USFWS 1994). Based on counts in the annular growth lines the clubshell may reach 30+ years of age (NatureServe 2010).

The clubshell was listed by the USFWS as endangered under the Endangered Species Act of 1973, on January 22, 1993.

Rough Pigtoe (*Pleurobema plenum*)

The rough pigtoe pearly mussel was described in 1840 by Lea. The shell is somewhat triangular, higher than it is long, and moderately thick and inflated. The dorsal and ventral margins are curved. It is textured with a satin-like appearance (NatureServe 2010). The periostracum is yellowish brown or light brown in small shells, becoming dark brown in adults, with faint green rays visible near the beaks in some shells. Their mature length is four inches. The pseudocardinal teeth are well developed with two in the left valve and one in the right. The lateral teeth are straight. Beak cavity is moderately deep. The nacre is usually white and occasionally pink. The systematic status of *Pleurobema plenum* has led to confusion in the *Pleurobema* complex (Ahlstedt 1984). The members of *Pleurobema* are among the most difficult to identify in North America (NatureServe 2010).

Historically the rough pigtoe was very widespread, being reported throughout four major geographic regions. Presently, the rough pigtoe is still widely distributed but with greatly fragmented populations. In 1984, the USFWS listed the distribution as only the Tennessee, Cumberland, Clinch, Green and Barren Rivers. However, natural heritage records include these areas with an expansion into the headwater areas of the Ohio River Valley in Allegheny River watershed (NatureServe 2010).

Currently the rough pigtoe is present in the Tennessee, Cumberland, Green, Barren and Ohio Rivers. Since the early 1970's, there are records of the rough pigtoe from the upper reaches of the Green River between L&D Nos. 4 & 5 and on the Barren River from the mouth to below L&D No. 1 (Ahlstedt 1984, NatureServe 2010).

The rough pigtoe is found in medium to large rivers in sand, gravel, and cobble substrate in shoals (NatureServe 2010). It is occasionally found in flats and muddy sand (Gordon and Layzer 1989, FWS 1984). Very little is known about the specific reproductive biology of the rough pigtoe. However, it is considered to be a tachytictic breeder (short-term breeder) based on gravid females found in May (Ortman 1919). According to the definition, tachytictic breeders breed in the spring and release glochidia by mid to late summer of the same year (Ahlstedt 1984). Hosts for the rough pigtoe are unknown but host fish studies for the closely related P. cordatum by Yokley (1972) indicate the rosefin shiner (*Notropis ardens*) as a fish host (Ahlstedt 1984).

The rough pigtoe was listed as endangered by the USFWS on June 14, 1976. Critical habitat has not been designated for this species. In the 1984 recovery plan the reasons for decline were not clearly understood. However, it was stated that the long lived species, like most mussels, and their sedentary nature, make them especially vulnerable to stream perturbations such as impoundments, siltation, and pollution (Ahlstedt 1984). Mussels are sessile organisms and are considered to be good indicators of ecosystem health (Williams et al. 1993). Williams et al. (1993) lists the primary causes of freshwater mussel decline as habitat destruction from dams, channel modifications, siltation, and the introduction of non-indigenous mollusks. Dams affect mussels by changing the physical, chemical and biological environment (Williams et al. 1993, Ahlstedt 1984).

Catspaw (*Epioblasma O. obliquata*)

A large river species, the catspaw (*Epioblasma O. obliquata*) has a medium-sized shell that is subquadrate in outline. The shell's outside surface has numerous distinct growth lines. It is yellowish-green, yellow or brownish in color and has fine, faint, wavy green rays with a smooth, shiny surface. The shells of the young often have a satin like surface. The inside of the shell is purplish to deep purple. The catspaw is the southern subspecies of the cat's paw. In 1976, the northern subspecies, white cat's pearly mussel, was listed as endangered. The two species resemble each other but the northern subspecies has a white shell interior (USFWS 1990).

The catspaw pearly mussel was historically distributed in the Ohio, Cumberland and Tennessee River systems in Ohio, Illinois, Indiana, Kentucky, Tennessee and Alabama. The distribution and reproductive capacity of this subspecies has been seriously impacted by the construction of impoundments on the large rivers it once inhabited (Sickel 1985). Populations occur in the Green River in Kentucky, Tennessee River in Alabama and Tennessee, and the Cumberland River in Tennessee.

Little is known of this rare subspecies' life history. This species has been characterized as a large-river mussel and has been found inhabiting streams of shallow to moderate depth with moderate to swift currents. This mussel has been reported in boulder and sand substrates. The specific food habit of the catspaw is unknown, but likely feeds on detritus, diatoms, phytoplankton and zooplankton (USFWS 1990).

This subspecies' reproductive biology remains unknown, but it likely reproduces like other freshwater mussels. Males release sperm into the water column that are taken in by the females through their siphons during feeding and respiration. The fertilized eggs are retained in the females' gills until the glochidia fully develop. The glochidia are released into the water where

they attach and encyst on the gills or fins of a fish host. When metamorphosis is complete, they drop to the streambed as juvenile mussels. The fish hosts utilized by the catspaw and the habitat of the juvenile mussel are unknown (USFWS 1990). Most of the catspaw mussel populations were apparently lost when many sections of the bigger rivers in which it lived were converted to a series of large impoundments.

The catspaw was listed by the USFWS as endangered under the Endangered Species Act on July 10, 1990.

Orangefoot Pimpleback (*Plethobasus cooperianus*)

The orangefoot pimpleback (*Plethobasus cooperianus*) has a medium-sized round shell with pustules on the posterior three-fourths of the shell with no green ray on the umbo. The live mussel has an orange foot. The shell is thick, solid and round to bluntly pointed. The dorsal margin is straight to slightly curved, with the ventral margin curved. The umbos are low and directed forward, and slightly elevated above the hinge line. The anterior fourth of the shell is smooth. The periostracum is rayless and light brown in small shells, becoming chestnut or dark brown in larger shells. The orangefoot pimpleback is normally four inches in length. The pseudocardinal teeth are well developed with two in the left valve and one in the right with a smaller tooth on either side. Its lateral teeth are short, straight or slightly curved with two in the left valve and one in the right. The beak cavity is very deep and the nacre white, usually with pink or salmon near the beak cavity with an iridescent posterior (Beliaeff, O'Connor, Daskalakis, Smith 1986 to 1994).

This freshwater species historically occurred in the Ohio, Cumberland, Kanawha, Tennessee and Wabash Rivers and in the waterway's major tributaries in Ohio, Indiana, Illinois, Kentucky, Pennsylvania, Alabama, and Tennessee (Beliaeff, O'Connor, Daskalakis, Smith 1986 to 1994).

In recent years, the orangefoot pimpleback has been encountered in six waterbodies. All six of these are flowing reaches of the mainstem Ohio and Tennessee Rivers, downstream from the following dams: Kentucky, Pickwick, Wilson, Guntersville, Watts Bar, Ft. Loudoun and downstream of the Olmsted Locks and Dam presently under construction. The records from most of these waterbodies are based on sightings of just a few mussels; however, this species has been encountered fairly often in the river downstream from Pickwick and Olmsted Dams (Beliaeff, O'Connor, Daskalakis, Smith 1986 to 1994).

The orangefoot pimpleback mussel has been collected downstream of the Olmsted Locks and Dam presently under construction. No other populations are known in the Ohio River but the tributaries of the Green River support populations of this species (USFWS 2010).

Little is known of this rare species' life history. This species, which is characterized as a large-river mussel, has also been found inhabiting streams of shallow to moderate depth with moderate to swift currents. This mussel has been collected from boulder and sand substrates. The specific food habits of the orangefoot pimpleback are unknown, but it likely feeds on detritus, diatoms, phytoplankton and zooplankton (Beliaeff, O'Connor, Daskalakis, Smith 1986 to 1994).

Reproduction requires stable, relatively undisturbed habitat similar to the found in tail water areas immediately downstream of the dams. Also needed to complete the mussel's larval development is a sufficient population of fish hosts. However, low mussel population density reduces the chances of successful reproduction. Most of the orangefoot pimpleback's populations were apparently lost when many sections of the bigger rivers in which it lived were converted to a series of large impoundments.

The orangefoot pimpleback likely reproduces like other freshwater mussels. Males release sperm into the water column that are taken in by the females through their siphons during feeding and respiration. The fertilized eggs are retained in the females' gills until the glochidia are fully developed. The glochidia are released into the water where they attach and encyst on the gills or fins of a fish host. When metamorphosis is complete, they drop to the streambed as juvenile mussels. The fish hosts utilized by the orangefoot pimpleback and the habitat of the juvenile mussel are unknown (Beliaeff, O'Connor, Daskalakis, Smith 1986 to 1994).

The orangefoot pimpleback was listed as endangered under the Endangered Species Act by the USFWS on July 10, 1990.

Fanshell (*Cyprogenaria stegaria*)

The fanshell *Cyprogenaria stegaria*) has a medium-sized, subcircular shell, which seldom exceeds 3.2 inches (80 millimeters) in length (Department of Interior 1990). The exterior of the shell has green rays on a light green or yellow surface ornamented with green mottling. Strong concentric ridges cover the shell's lower surface. The interior of the shell is usually silvery white, sometimes flesh-colored. The pseudocardinal teeth are relatively large and serrated with two located in the left valve and one in the right. The lateral teeth are roughened, straight to slightly curved, heavy and very short. The interdentum is wide with the beak cavity shallow to moderately deep (Cummings and Mayer 1992).

Since the turn of the century, the fanshell has undergone a substantial reduction in its range. Historically, it was widely distributed in the Ohio, Wabash, Cumberland, and Tennessee Rivers and their larger tributaries in Pennsylvania, Ohio, West Virginia, Illinois, Indiana, Kentucky, Tennessee, Alabama, and Virginia (Johnson 1980, Kentucky State Nature Preserves Commission 1980, Ahlstedt 1986, Bates and Dennis 1985, Lauritsen 1987, Cummings et al 1987 and 1988, Starnes and Bogan 1988). Many of these historically known populations were lost when riverine habitat in the Ohio River system was converted to a series of large reservoirs. These reservoirs and other habitat-altering factors (e.g., navigation projects and gravel and sand dredging) have diminished the species' preferred riverine gravel/sand habitat and eliminated or reduced the availability of the mussel's fish host. As a result, this species' distribution has been substantially reduced.

Based on current literature on the species and information provided by State and Federal agency personnel, it was believed that reproducing populations are present in only three rivers – the Clinch River, Hancock County, Tennessee, and Scott County, Virginia; the Green River, Hart and Edmonson Counties, Kentucky and the Licking River, Kenton, Campbell, and Pendleton Counties, Kentucky. However, biologists recently discovered a new site for the endangered fanshell mussel in the backchannel of Muskingum Island when they examined shells from a muskrat midden (piles of mussel shells left by feeding muskrats) on the Ohio River Islands National Wildlife Refuge. The freshly dead mussels were 9 and 11 years of age. These findings support the theory that the upper Ohio River is an important recovery area for this species (USFWS 1996). One reproducing population, in the Green River, has been degraded by runoff from oil and gas exploration production sites and by alteration of stream flows by an upstream reservoir. Fresh-dead fanshells of various age classes from juvenile to adults have been recently found in muskrat middens along the Green River.

Additionally, a small remnant of non-reproducing populations may still persist in Muskingum River in Morgan and Washington Counties, Ohio; the Wabash River in White and Wabash Counties, Illinois, and Posey County, Indiana; the East Fork White River, Martin County, Indiana; the Tippecanoe River, Tippecanoe County, Indiana; the Kanawha River, Fayette County, West Virginia; and Tygarts Creek, Greenup and Carter Counties, Kentucky.

Most of the fanshell populations are small and all the populations are geographically isolated from each other. This isolation restricts the natural interchange of genetic material among populations.

Like other freshwater mussels, this animal feeds by filtering food particles from the water. It has a complex reproductive cycle in which the mussel's larvae likely parasitize fish. The mussel's

life span, parasitic host, and most aspects of its life history are unknown. However, it is assumed that it reproduces like other freshwater mussels, in which, males release sperm into the water column. The sperm are taken in by the females through their siphons during feeding and respiration. The fertilized eggs are retained in the gills until the larvae (glochidia) fully develop. When the glochidia are released into the water, they attach and encyst on the gills or fins of a fish host. When metamorphosis is complete, they drop to the streambed as juvenile mussels.

The fanshell was listed as endangered by the USFWS on July 23, 1990.

Fat Pocketbook (*Potamilus Capax*)

The fat pocketbook mussel (*Potamilus Capax*) is a large-river mussel whose shell is round to oblong with a swollen/inflated appearance. The shell is thin during the juvenile phase changing to moderately thick when adult (Cummings and Mayer 1992). Anterior and posterior ends are plainly rounded with the umbos (beaks) inflated, elevated, and turned-in above the S-shaped hinge line. Small wing forms are delineated dorsally on the anterior and posterior of the shell. The exterior shell coat (periostracum) is smooth, shiny, without colored rays (banding) and yellowish (or yellowish tan to olive) (Cicerello and Scheuster 2010). The interior of the shell (nacre) is white, sometimes to a tinged pink. The pseudocardinal (cardinal) teeth, two per valve, are thin, compressed, elevated, and bladelike; while the lateral teeth, two in the left valve and one in the right valve, are thin and curved (Cummings and Mayer 1992; Cicerello and Schuster 2010). The fat pocketbook is reported to resemble the more familiar pocketbook (*Lampsilis ovata)* causing some occasional confusion when identifying the species in the field. A normal adult fat pocketbook's estimated length is 127 mm (5 inches) (Cummings and Mayer 1992 and Cicerello and Schuster 2003).

The historic range of the fat pocketbook mussel included the upper Mississippi River, the Wabash River, Indiana, and the St. Francis River Arkansas and likely the lower Ohio and lower Mississippi Rivers. The fat pocketbook still occurs in the St. Francis River, Arkansas, the Mississippi, lower Ohio, the lower Wabash River, the White River in Indiana, and the extreme lower reaches of the Cumberland River (Cicerello and Schuster 2003).

Fat pocketbook is a riverine species. They are frequently found in shallow waters, although dive surveys have found the species at depths of 13 ft and 26 ft in the Ohio River (Clarke Survey 1995). The species occupies areas of variable flow gradients, relatively stable substrates of slit and mud, and moderately turbid (2 to 3 foot visibility) water.

Although little is known about the reproductive biology of the fat pocketbook, it is thought that the species reproduces similarly to other members of the sub-family *Lampsilinae* (Ortmann 1912). As such, males release sperm into the water, which are taken in by the females through their siphons during feeding and respiration. The fertilized eggs are retained in the females' gills until the larvae (glochidia) fully develop. The fat pocketbook is a long-term breeder (bradytictic), and gravid females have been observed in June, July, August, and October (Ortmann 1914).

Once glochidia are released from the female, they attach and encyst onto a host fish's gills and fins. Following completion of metamorphosis, the developed larvae drop to the streambed as juveniles. Although the specific fish host for the fat pocketbook is not known, some researchers think the fat pocketbook would likely encyst the same fish host species, freshwater drum (*Aplodinotes grunniens*), as other members of *Potamilus*. (Barnhart and Roberts 1977).

Food habits of the fat pocketbook are unknown, but in general, freshwater mussels are filter feeders consuming detritus, diatoms, phytoplankton, and zooplankton.

The fat pocketbook mussel was listed as endangered by the USFWS on June 14, 1976.

Ring Pink (*Obovaria retusa*)

The ring pink (*Obovaria retusa*) or golf stick pearly mussel is a large-river mussel whose shell is a medium to large ovate outline that ranges from concentrically compressed to moderately inflated and thick. The female can be differentiated as having distinct grooves on the posterior edge (Cummings and Mayer 1992). The dorsally located umbos (beaks) are inflated and even with the hinge line. The shell exterior ranges from yellow-green to tan-brown to almost reddish in color with a smooth surface texture that is comparable to the feel of cloth (Bogan and Parmalee 1979). Older species usually will exhibit an exterior shell color that is a darker brown to black. The interior of the shell (nacre) is pink to purple in color with pearl-white outer margins. The pseudocardinal (cardinal) teeth are large, heavy, and serrated (Cummings and Mayer 1992; Cicerello and Schuster 2003) while the lateral teeth features are thick, short, and straight to slightly curved. A normal adult ring pink's estimated length is 76 mm (3 inches) (Cummings and Mayer 1992).

Historically, ring pink was widely distributed within the Ohio, Cumberland, and Tennessee River systems encompassing the states of Pennsylvania, West Virginia, Ohio, Illinois, Indiana, Kentucky, Tennessee, and Alabama (Department of Interior). It inhabited large river shoals throughout the Ohio River basin. In 1926, Ortman described the ring pink as "not rare" in a

study of the Green River (Ortman 1926). The last live ring pink from the Ohio River was found in the Markland pool, near river mile (RM 474). There have been numerous relic finds from various Ohio River locations ranging from the Racine pool at RM 237.3 to Newburg pool at RM 776.1.

The ring pink mussel population today is confined to five sites—two in the Tennessee River (one within the Commonwealth of Kentucky and one within the State of Tennessee), one in the Upper Green River in Kentucky, one in the Cumberland River in Tennessee, and the Kanawha River in West Virginia. The ring pink mussel colonies have primarily been relegated to the upper tributary reaches of the Green River, and to the Tennessee and Cumberland Rivers. In addition, one live specimen was reported in West Virginia's Kanawha River in Fayette Co. (USFWS 2010b).

Ring pink mussels have been found in shallow waters with variable flow gradients, stable substrate of gravel and sand, with relatively clear and silt free water. Although little is known about the reproductive biology of the ring pink, it is thought that the species reproduces similarly to other river mussels. As such, males release sperm into the water which are taken in by the females through their siphons during feeding and respiration. The fertilized eggs are retained in the females' gills until the larvae (glochidia) fully develop. Gravid ring pinks have been observed in late August (Ortmann 1909 and 1912). Once glochidia are released from the female, they attach and encyst onto a host fish's gills or fins. When metamorphosis is complete, glochidia drop to the streambed as juveniles. The fish host utilized by the ring pink is unknown.

The ring pink was listed as endangered by the USFWS on October 30, 1989.

Indiana Bat (*Myotis sodalis*)

The Indiana bat (*Myotis sodalis*) is a medium-sized bat, closely resembling the little brown bat (*Myotis lucifugus*). The head and body length of the Indiana bat ranges from 4-5 centimeters (1.6-1.9 inches). Its weight ranges from 6 to 9 grams with a wingspan of 24-28 centimeters. Its fur is dull grayish chestnut rather than bronze with the basal portion of the hairs of the back dull lead colored. The bats' under parts are pinkish to cinnamon, and its hind feet smaller and more delicate than is the brown bat. The calcar (heel of the foot) is strongly keeled (Romme, Tyrell, and Brack, Jr. 1995).

Historically, the Indiana bat is known over much of the eastern half of the United States. Including the winter and summer habitats, the Indiana bat ranges from Oklahoma, Iowa, and Wisconsin, east of Vermont and south to northwestern Florida (Brack Jr. 1983). During summer,

adult females and young have been found hundreds of miles north of hibernacula caves. Densest concentrations of reproductive females in summer have been documented in northern Indiana, southern Michigan, Illinois, northern Missouri and southern Iowa (Cope, Richter and Searley 1978).

The Indiana bat is a monotypic species that occupies much of the eastern half of the United States, from Oklahoma, Iowa, and Wisconsin east to Vermont, and south to northwestern Florida (Romme, K.Tuyrell and Brack, Jr. 1995). The Indiana bat is migratory and the above-described range includes both winter and summer habitat. The winter range is associated with regions of well-developed limestone caverns. Major populations of this species hibernate in Kentucky, Indiana, and Missouri. Smaller winter populations have been reported in Alabama, Arkansas, Georgia, Illinois, Maryland, Mississippi, New York, North Carolina, Ohio, Oklahoma, Pennsylvania, Tennessee, Virginia, and West Virginia. About 85% of the population hibernates in only seven caves and nearly 50% may hibernate in only two caves (USFWS, 1983).

The Indiana bat utilizes areas along the entire reach of the study area. Limestone caverns are used as winter habitat. Floodplains and riparian forests are the primary roosting and foraging areas, as well as upland forests. The bat roosts are ephermeral and frequently associated with dead or dying trees (Tyrell, and Brack, Jr. 1995).

Indiana bats spend the winter hibernating in caves in the southern areas along the Ohio River and migrate north to establish small maternity colonies. Indiana bats winter in caves or mines that meet highly restrictive temperature requirements (Tuttle and Stevenson 1977). They winter in relatively few caves, suggesting that very few caves meet those winter habitat requirements. Generally, hibernation occurs from October through April in caves with stable temperatures below 50 degrees F, preferably between 39-46 degrees F. Bats cluster on cave ceilings in densities ranging from 300-484 bats per square foot.

Hibernation facilitates survival during winter when prey is unavailable. However, the bat must store sufficient fat to support metabolic processes until spring. Substantial risks are posed by events during the winter that interrupt hibernation and increase metabolic rates. After hibernation ends in late March or early April, most Indiana bats migrate to summer roosts. Female bats emerge in late March or early April followed by the males. The period after hibernation, but prior to migration, is typically referred to as staging (Humphrey, Richter and Cope 1977). Most populations leave their hibernacula by late April. Migration is stressful for the bat, particularly in the spring when their fat reserves and food supplies are low. As a result, adult mortality may be the highest in late March and April.

Scattered records suggest that some male bats disperse throughout the species range during the summer and roost individually in small numbers in the same types of trees and in the same areas as females. Other male bats summer near hibernacula. Relatively little is known about the males' roosting habitats (Gardner, Garner and Hoffmann 1991).

Summering Indiana bats roost in trees and forage for flying insects between dusk and dawn in riparian and upland forests (Clark, Bowles and Clark. 1987). Bats forage at a height of 7 to 98 feet; they feed primarily on moths and aquatic insects. Indiana bats may forage up to 3.1 miles from their roost site. Roost trees generally have exfoliating bark, which allows the bat to roost between the bark and bole of the tree. Cavities and crevices in trees may also be used for roosting. Most roost trees may be habitable for 2-8 years (depending on the species and condition of the roost tree) under natural conditions (Clark, Boles and Clark 1987). A variety of suitable roosts are needed within a colony's traditional summer range for the colony to continue to exist. Bats move among roosts within a season or when a particular roost becomes unavailable from one year to the next. It is not known how many alternate roosts must be available to assure retention of a colony within a particular area, but large nearby forest tracts appear important. In addition to having exfoliating bark, roost trees must be of sufficient diameter. They will roost in trees as small as nine inches in diameter at breast height (dbh), but prefer to roost in the largest trees available. Bachelor males have been found in trees with loose bark as small as 4 inches dbh. A variety of tree species are used for roosts including shagbark hickory, slippery elm, American elm, cottonwood, northern red oak, post oak, white oak, shingle oak, sassafras, sugar maple, silver maple, green ash, and bitternut hickory. Recent discoveries have noted that the Indiana bat has been found roosting in barns, splintered telephone poles, and old houses. Some have been found in bat houses.

Female Indiana bats give birth to a single young in June or early July (Humphrey, Richter, and Cope 1977). During that time, they join together in maternity colonies beneath the loose bark of dead or living trees. Maternity colonies, which may contain up to 100 adult female bats and their young, may be occupied from mid-May to mid-September. Young Indiana bats are capable of flight within a month of birth.

After the summer maternity period, Indiana bats migrate back to traditional winter hibernacula (Romme, Tyrell and Brack Jr. 1995). Some male bats may begin to arrive at hibernacula as early as July. Females typically arrive later and by September the numbers of males and females are almost equal. Autumn "swarming" occurs prior to hibernation. During swarming, bats fly in and out of cave entrances from dusk to dawn, while relatively few roost in the caves during the day. By late September many females have entered hibernation, but males may continue swarming well into October in what is believed to be an attempt to breed late arriving females.

Swarming is important to the life history of the bat as most copulation occurs during this time (Tuttle and Stevenson 1977). Females store sperm through the winter and fertilization occurs in the spring. Females are pregnant when they arrive at the maternity roost. Fecundity is low as female Indiana bats produce only one young per year. The Indiana bat was listed as federally endangered by the USFWS on March 11, 1967.

Many winter caves of Indiana bats are in public ownership and being protected; however, the species is declining in number. In addition to pesticide accumulation, the other main threat to the species is its summer habitat. It appears the diminishing acreage of forest and wetlands is having significant impact on the Indiana bat population. The roost trees selected by Indiana bats in summer must be located near rivers or reservoirs. Disturbance of a maternity colony may cause young to be dropped to the forest floor where they perish; excessive disturbance may cause a colony to completely abandon a site. Other factors, which contribute to the decline, include pesticide poisoning, natural calamities such as flooding and cave-ins at hibernacula caves, loss of caves due to inundation by man-made impoundments, and possibly a reduction in insect prey over streams that have been degraded through excessive pollution and siltation. Improper cave gating or cave commercialization could also contribute to some population declines. Indiana bats feed in forested riparian habitat. The system of navigation locks and dams and associated operation and maintenance activities have altered the Ohio River. Impoundment has caused inundation of some caves used by the Indiana bat. Commercialization has decreased the acres of available forested riparian habitat by reducing roosting trees due to development along the river.

Gray Bat (*Myotis grisescens*)

The largest member of its genus in the eastern United States, the gray bat (*Myotis grisescens*) weighs from 7 to 16 grams. Its forearm ranges from 40 to 46 mm (1.6 to 1.8 in.) and a wingspread of 275 to 300 mm (10.8 to 11.8 in.) (Tuttle 1976). The skull has a distinct sagittal crest. One feature, which distinguishes this species from all other eastern bats, is its uni-colored dorsal fur. The other bats have bi- or tri-colored fur on their backs. Also, the gray bat's wing membrane connects to the foot at the ankle instead of at the base of the first toe, as in other species of *Myotis* (USFWS 1982). The calear, a cartilaginous rod behind the ankle, lies along the free edge of the wing membrane and is not keeled. The fur is gray immediately following the molt in midsummer but may bleach to chestnut-brown or bright russet by the following May or June, especially in females during their reproductive season of May or June.

Historically, gray bat distribution was limited to limestone cave areas of the southeastern United States. Major populations are found in Alabama, Arkansas, Kentucky, Missouri and Tennessee

(Tuttle 1976). Smaller populations did occur in surrounding states. In Oklahoma, the historic populations probably were limited to the limestone region of the northeastern part of the state.

Populations are found mainly in Alabama, northern Arkansas, Kentucky, Missouri, Tennessee, but a few occur in northwestern Florida, western Georgia, southwestern Kansas, southern Indiana, south and southwestern Illinois, northeastern Oklahoma, northeastern Mississippi, western Virginia and possibly western North Carolina. Distribution within range has always been patchy, but fragmentation and isolation of populations have been a problem for the past three decades (Locke 2002).

The total gray bat population has declined drastically since the early 1960's. Although difficult to estimate, population reductions based on extensive research indicate the severity of the situation. In the early 1960s, a census of 27 maternity caves in Missouri found a total population of 238,000 gray bats. By 1978, 16 of these colonies had been abandoned and the remaining colonies had a population of only 46,500 bats, which is an 80-percent reduction over the 15-year period. A census of Kentucky caves in the late 1970's indicated that 20 caves with a maximum population of 515,400 bats had been reduced to 8 caves with a total population of 61,100 bats, an 88-percent decline (Brady, Kunz, Tuttle and Wilson 1982).

A census of 22 summer colonies in Alabama and Tennessee from 1968 through 1977 conservatively estimated a 54-percent decline in gray bat populations during that period and a 76-percent decline from known past maximum population levels (Tuttle 1979). The estimated maximum past population for the 22 colonies was 1,199,000 individuals; by 1970, numbers had dropped to 635,000, a 47-percent reduction. By 1976, the combined population had fallen to 293,000 bats, an additional 54-percent reduction. Some major colonies disappeared entirely within the 6-year period. Seven colonies at their all time maximums in 1970 had been reduced to four colonies by 1976, and the largest maternity colony (111,400 bats) in the stable category had declined by at least 95 percent.

In 2002 the Bat Conservation International organization reported that the gray bat populations in its historical range is now recovering rapidly because many of its winter caves are in public ownership and being protected. The total known gray bat population, based on the most recent hibernacula census, is roughly 1,500,000. However, many hibernating populations, especially in Kentucky and Missouri, have increased in number.

The states of Kentucky, Indiana and Illinois along the Ohio River have populations of the gray bat. In Edmonson County, Kentucky a major hibernation colony exists. Counties in Kentucky that have summer populations of gray bats are Adair, Allen, Barren, Breckinridge, Bullitt, Caldwell, Calloway, Christian, Clark, Clinton, Franklin, Garrard, Grayson, Green, Hardin,

Harlan, Hart, Hopkins, Jefferson, Jessamine, Lee, Livingston, Logan, Meade, Menifee, Metcalfe, Monroe, Muhlenberg, Nelson, Pulaski, Shelby, Simpson, Taylor, Trigg, Warren and Wayne. Counties in Illinois that have summer populations of gray bats are Adams, Alexander, Hardin, Jackson, Johnson, Monroe, Pike, Pope and Pulaski. Counties in Indiana that have summer populations of gray bats are Clark, Crawford, Floyd, Harrison, Jennings, Lawrence, Perry and Spencer. Summer populations most likely do occur in southern Ohio and western West Virginia, however, no literature can be cited to support this conclusion (Bagley Unpublished USFWS Census).

The gray bat lives in caves year-round and is probably more restricted to cave habitats than any other mammal native to the United States. A much wider variety of cave types are used during the spring and fall transient periods than during winter and summer. In all seasons, males and yearling females seem less restricted to specific cave and roost types than reproductive females (Clark, LaVal and Swinford 1978). Because of highly specific roost and habitat requirements, fewer than 5 percent of available caves are suitable for occupation by gray bats. Few caves in the northeastern United States are warm enough for rearing young, and few in the Southeast are cold enough for successful hibernation. Caves used by the gray bat must have temperatures appropriate for necessary metabolic processes; i.e., warm caves for digestion and growth in summer and cool caves for torpor and hibernation in fall and winter.

Most winter caves are deep and vertical (Tuttle, 1975). They provide large volume below the lowest entrance and function as cold-air traps with multiple entrances and good airflow. Winter caves average 10 'C (50 'F) below the mean annual surface temperature, and preferred temperatures range from 6 to 9 'C (43 to 48 'F). Temperatures were 10 to
11 'C (50 to 52 'F) at winter roosts in Kentucky, and reported a mean temperature of 8.7 'C (47.7 'F) for winter caves in Missouri. These caves are already cold when gray bats arrive in September.

On the summer home range, colony members disperse in groups among several different caves (Rabinowitz and Tuttle 1980). Reproductive females form maternity colonies of a few hundred to many thousands of individuals, while males and non-reproductive females congregate in smaller bachelor colonies. Only females and their young occupy the maternity cave, while the other groups use more peripheral caves within the area. After the young are volant, gray bats are more transient within the colony home range and frequently use alternate roost sites.

Nursery populations succeed because gray bat maternity caves contain structural heat traps that capture the metabolic heat from a large number of clustered individuals. Maternity colonies prefer roost caves that are able to trap the body heat from thousands of bats (Tuttle 1979). Typical cave configurations that trap this heat include small chambers, high places in domed

ceilings, domes or small pockets within these locations, and depth of etching and porosity of the rock surface. It was found that growth rates of nonvolant young are positively affected by the presence of porous or domed ceilings at roosts.

Gray bats feed along reservoirs, rivers and associated riparian habitats (Brady, Kunz, Tuttle and Wilson 1982). They consume large numbers of flying insects over aquatic habitats. During a 4-year study to determine feeding preferences of gray bats on Guntersville Reservoir, Alabama, gray bats were recorded foraging over and adjacent to aquatic weed beds more than any other habitat type investigated.

A few gray bat colonies roost at artificial (man-made) sites that simulate summer caves. Gray bats have been known to use storm sewers. These storm drains have high humidity and running water without sewage, both typical characteristics of natural caves (Stevenson. and Tuttle 1981).

Hibernation facilitates survival during winter when prey is unavailable. However, the bat must store sufficient fat to support metabolic processes until spring (Tuttle 1977). Substantial risks are posed by events during the winter that interrupt hibernation and increase metabolic rates.

Swarming is important to the life history of the bat as most copulation occurs during this time. Females store sperm through the winter and fertilization occurs in the spring. Females are pregnant when they arrive at the maternity roost (Tuttle 1976). The gray bat was listed by the USFWS as endangered under the Endangered Species Act of 1973 on April 28, 1976.

Gray bat colonies roost only in caves and cave-like habitats. The restricted habitat requirements of the gray bat render this species highly vulnerable to impacts resulting from human activities. Factors, which contributed to the decline, included pesticide poisoning, natural calamities such as flooding and cave-ins, loss of caves due to inundation by man-made impoundments, and possibly a reduction in insect prey over streams that have been degraded through excessive pollution and siltation. Improper cave gating or cave commercialization has also contributed to some population declines. The few roost caves selected by gray bats in summer must be located near rivers or reservoirs, and the winter caves must be deep and vertical with unusually low temperatures. Disturbance of a maternity colony may cause thousands of young to be dropped to the cave floor where they perish; excessive disturbance may cause a colony to completely abandon a cave.

5. Other Species of Interest

Eastern Hellbender (*Cryptobranchus alleganiensis alleganiensis*)

The eastern hellbender (*Cryptobranchus alleganiensis alleganiensis*) is a large aquatic salamander. Adults can reach a length of up to 30 inches and this species is the largest salamander by weight in North America (Dodd 2004). Adults have a brown base color with black splotches. The head is large and compressed dorsoventrally compressed with small eyes and many sensory pores. The sides of the body are covered in folds of skin to provide greater surface area for the absorption of oxygen.

The eastern hellbender needs clean, cool, well oxygenated water to survive. The eastern hellbender is largely nocturnal. The preferred habitat of the eastern hellbender is areas with large slabs of rocks and ledges that provide cover for the salamander during the daytime. Its diet consists largely of crayfish but a variety of food items are opportunistically taken. The eastern hellbender is occasionally caught by fishermen using live bait.

The range of the hellbender's range includes most of Kentucky and Tennessee south to Northern Georgia and Northern Alabama, West to Central Missouri, and east and north, roughly along the Appalachian Mountains, to Pennsylvania (Conant and Collins 1998). In the Green River, the hellbender has been reported from Green County in the Greensburg area.

6. Field Sampling

USACE Louisville District provided technical expertise and assistance in conducting field work to three Universities (Campbellsville University, Tennessee Technological University, and Lindsey Wilson College) and the Kentucky Department of Fish and Wildlife, as part of this effort. All sampling was designed to detect the presence of invertebrate endemic, endangered, and uncommon fauna in the Green River. All sampling occurred from the Green River Dam downstream to Interstate I-65 (Figure 4). Only one endemic species, the bottlebrush crayfish was observed in the course of sampling. The Kentucky creekshell was not detected at any sampling site. In addition to the sampling events listed below, USACE Louisville District made several incidental observations of the bottlebrush crayfish, at locations in Green County (Greensburg canoe ramp), and Taylor County (Green River Dam stilling basin).

Campbellsville University

Site 1
Date: August 05, 2010
Location: end of Tucker Road, Green County (Figure 4)
GPS: N 37.23806 / W 85.55027
Samplers: R. Kessler, Scott Blakeman, Amy Etherington, Lili S., Spencer, Jesse Helton
Sample design: Quadrats, 62 sq. meter samples and general snorkeling
Mussel Species: (12) *Tritigonia verrucosa, Quadrula cylindrical, Q. nodulata, Q. pustulosa, Amblema plicata, Fusconaia flava, Cyclonais tuberculata, Ptychobranchus fasciolaris, Actinonaias ligamentina, Truncilla truncata, Potamilus alatus, Lampsilis fasciola*
Endemic Species: *Barbicambarus cornutus*

Site 2
Date: August 28, 2010
Location: Richardson Farm, Hart County (Figure 4)
GPS: N 37.2784 / W 85.8551
Samplers: R. Kessler, Jesse Helton, Spencer Adams, Conner, Amy Etherington, Jonathan Price
Sample design: Quadrats, 66 sq. meter samples and general snorkeling
Species (22): *Lasmigona costata, Megalonaias nervosa, Tritigonia verruscosa, Quadrula metanevra, Q. pustulosa, Amblema plicata, Fusconaia ebena, F. flava, F. subrotunda, Cyclonaias tuberculata, Plethobasus cyphyus, Pleurobema sintoxia, P. cordatum, Elliptio crassidens, E. dilatata, Obliquaria reflexa, Cyprogenia stegaria, Actinonaias ligamentina, Truncilla truncata, Ligumia recta, Lampsilis ovata, L. fasciola.*

Site 3
Date: October 14, 2010
Location: TNC Timberlake Property, Hart County (Figure 4)
GPS: N 37.28851 / W 85.83066
Samplers: R. Kessler, Jesse Helton, Amy Etherington, Spencer Adams., James Linker
Sample design: General snorkeling in variety of mussel habitat.
Species (22): *Lasmigona costata, Megalonais nervosa, Tritogonia verrucosa, Quadrula cylindrical, Q. metanevra, Q. pustulosa, Amblema plicata, Fusconaia subrotunda, Cyclonais tuberculata, Plethobasus cyphyus, Pleurobema sintoxia, P. cordatum, Elliptio dilatata, Phtycobranchus fasciolaris, Obliquaria reflexa, Cyprogenia stegaria, Actinonaias ligamentina, Truncilla truncate, Leptodea fragilis, Potamilus alatus, Lampsilis ovata, L. fasciola*
Endemic Species: *Barbicambarus cornutus*

Tennessee Technological University

Site 4
Date: November 9-10, 2010
Location: Romaine Loop, Taylor County (Figure 4)
GPS: N 37 14.746 / W 85 21.944
Samplers: Jim Layzer, Jesse Helton, Drew Russell
Sample design: systematic quadrats with excavation (totaling 10 sq. meters) and general snorkeling and observation
Species (*Actinonaias ligamentina, Quadrula pustulosa, Amblema plicata, Cyclonaias tuberculata*):
Endemic Species: *Barbicambarus cornutus*

Kentucky Department of Fish and Wildlife

Site 5
Date: October 7-8, 2010
Location: Munfordville Island, Hart County (Figure 4)
GPS: N 37 16.314 / W 085 52.788
Samplers: Monty McGregor, Jesse Helton, Drew Russell, Ben Davis, Chris, Adam Sheaperd, Chris Owens and others
Sample design: Systematic snorkeling (100 sq. meters) and general snorkeling and observation
Species (28): *Actinonaias ligamentina, Amblema plicata, Cyclonaias tuberculata, Cyprogenia stegaria, Ellipsaria lineolata, Elliptio crassidens, Elliptio dilatata, Elliptio dilatata, Fusconaia flava, Fusconaia subrotunda, Lampsilis cardium, Lampsilis fasciola, Lasmigona costata, Leptodea fragilis, Ligumia recta, Megalonaias nervosa, Obliquaria reflexa, Plethobasus cyphyus, Pleurobema cordatum, Pleurobema sintoxia, Potamilus alatus, Ptychobranchus fasciolaris, Quadrula cylindrica, Quadrula metanevra, Quadrula pustulosa, Tritogonia verrucosa, Truncilla truncata,*
Endemic Species: *Barbicambarus cornutus*

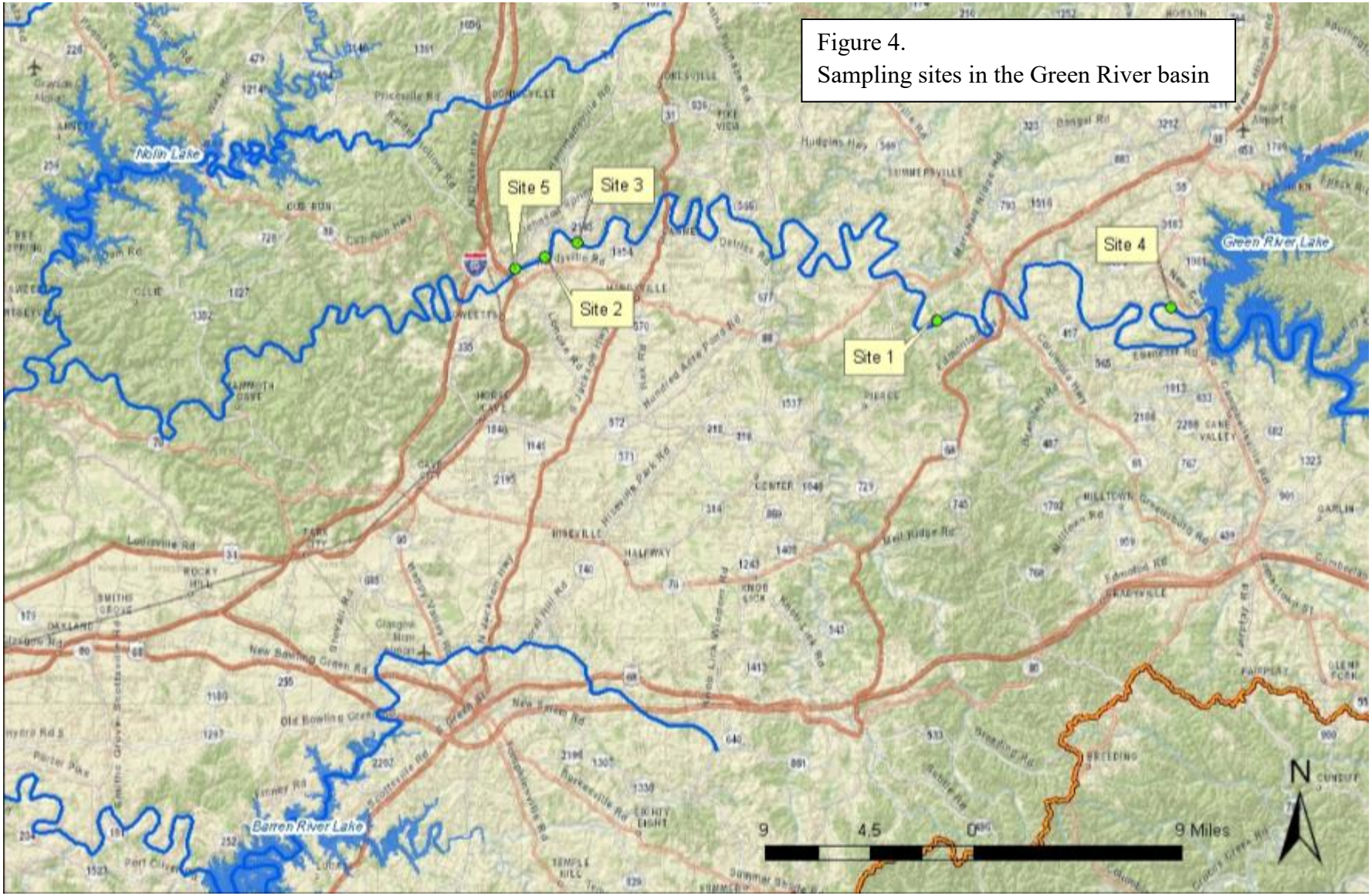

Figure 4.
Sampling sites in the Green River basin

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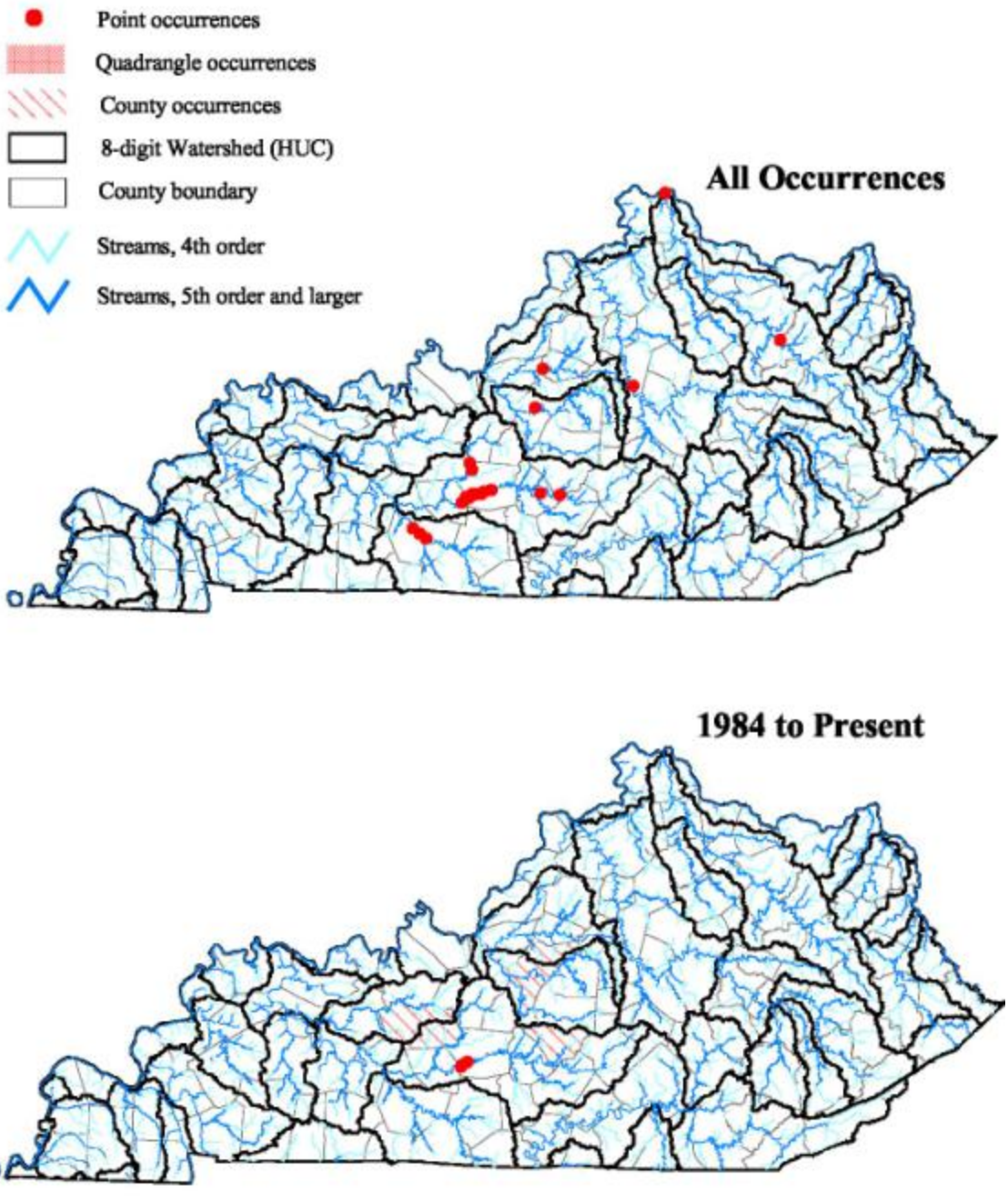
APPENDIX 1

Endangered species range maps from Kentucky Department of Fish and Wildlife (2010)

Northern Riffleshell

Epioblasma torulosa rangiana

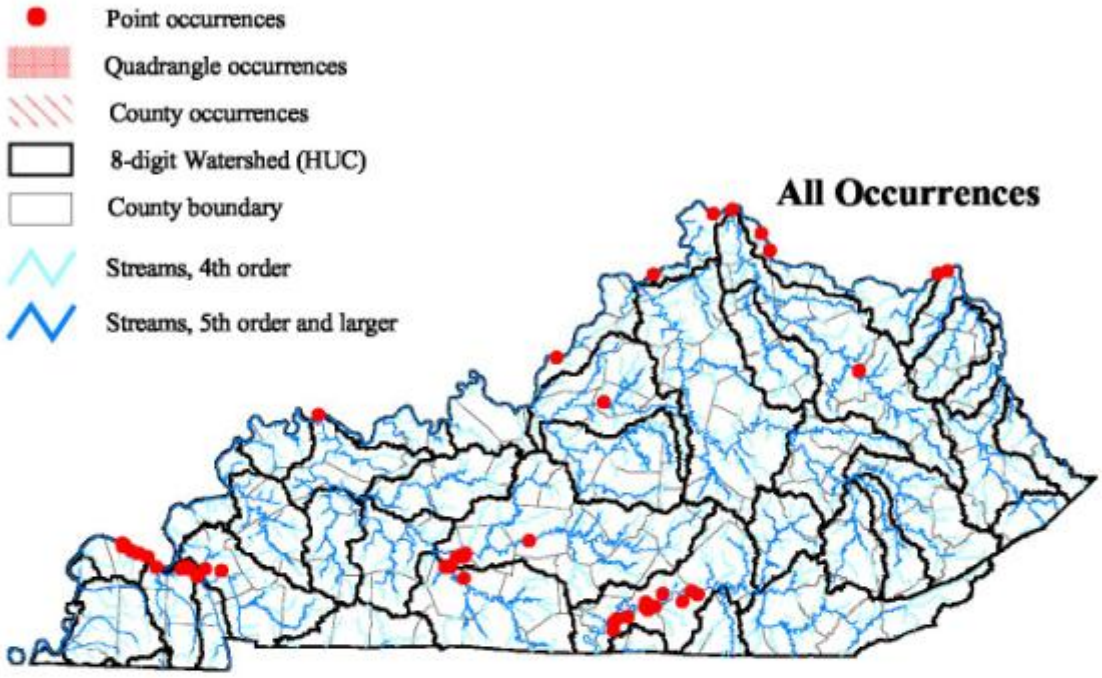
(Data current as of May 11, 2005)

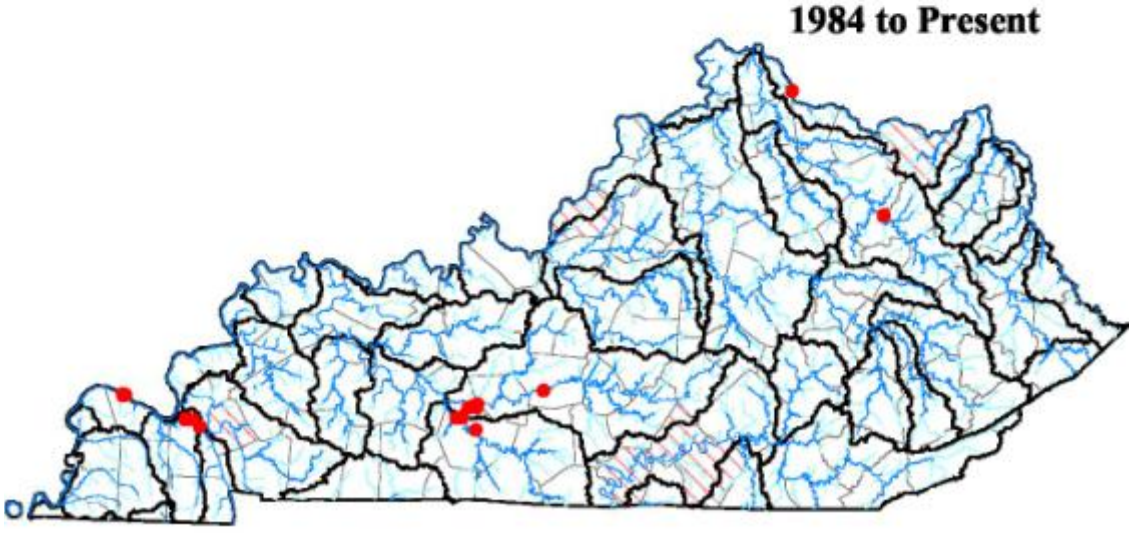


Pink Mucket

Lampsilis abrupta

(Data current as of May 11, 2005)

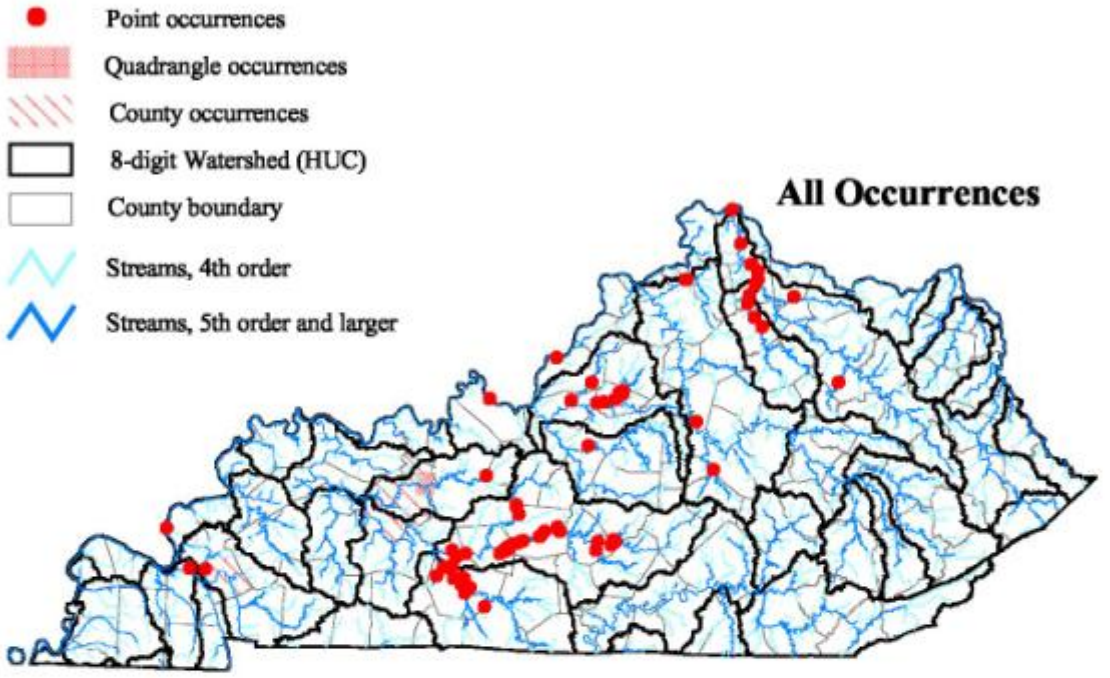


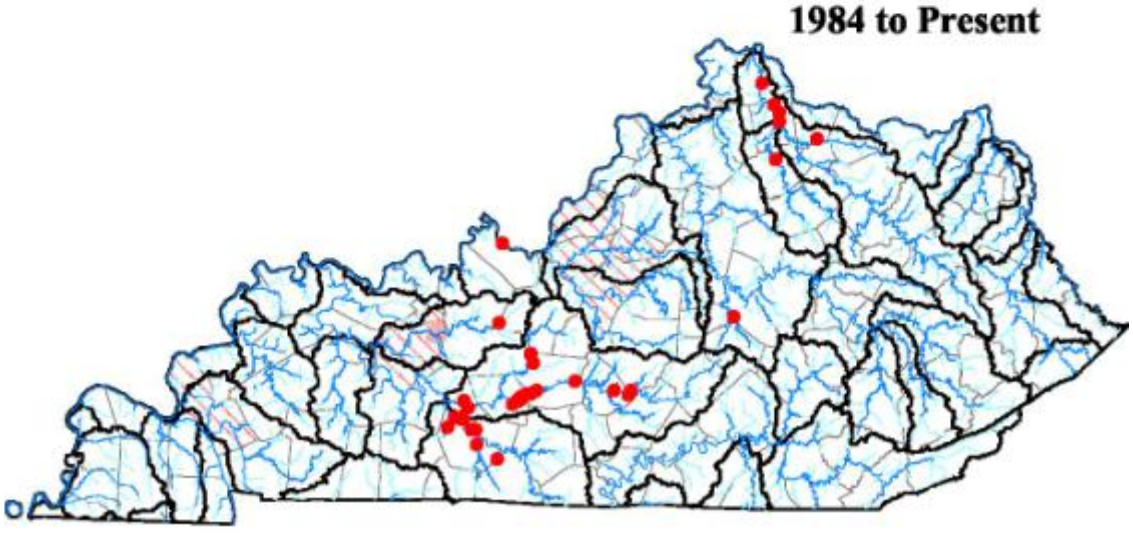


Clubshell

Pleurobema clava

(Data current as of May 11, 2005)





Rough Pigtoe

Pleurobema plenum

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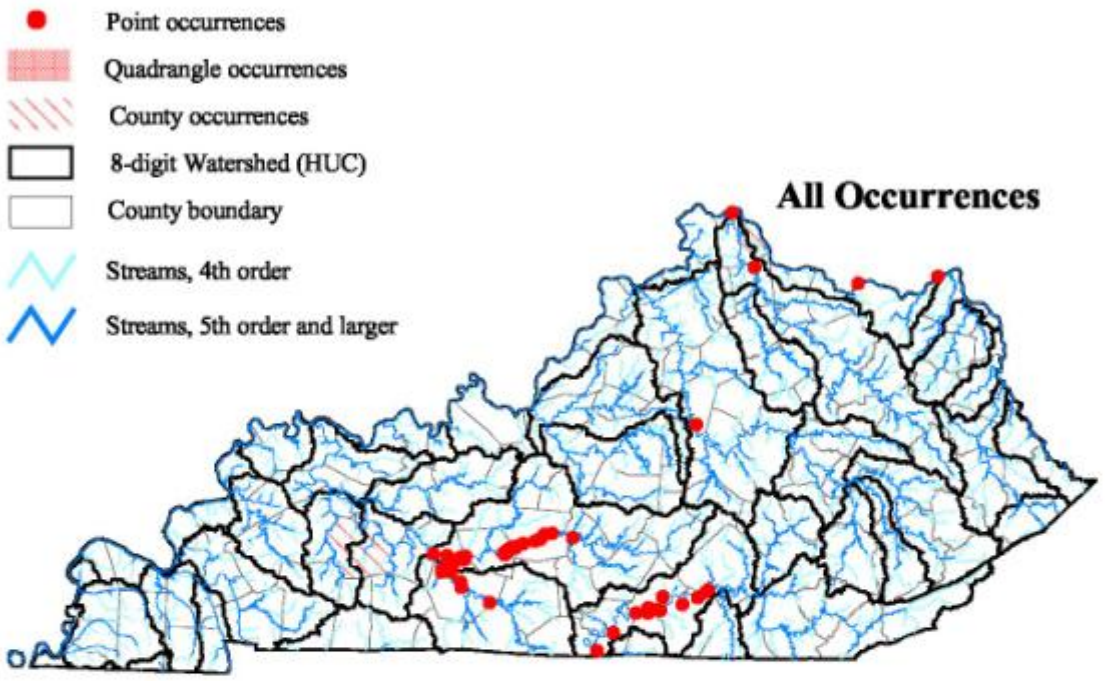
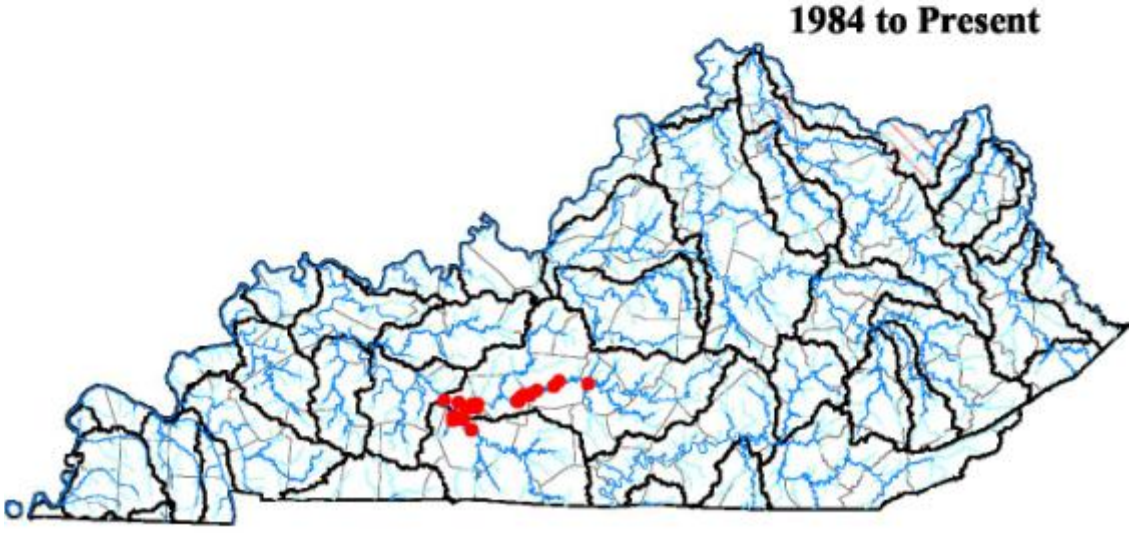
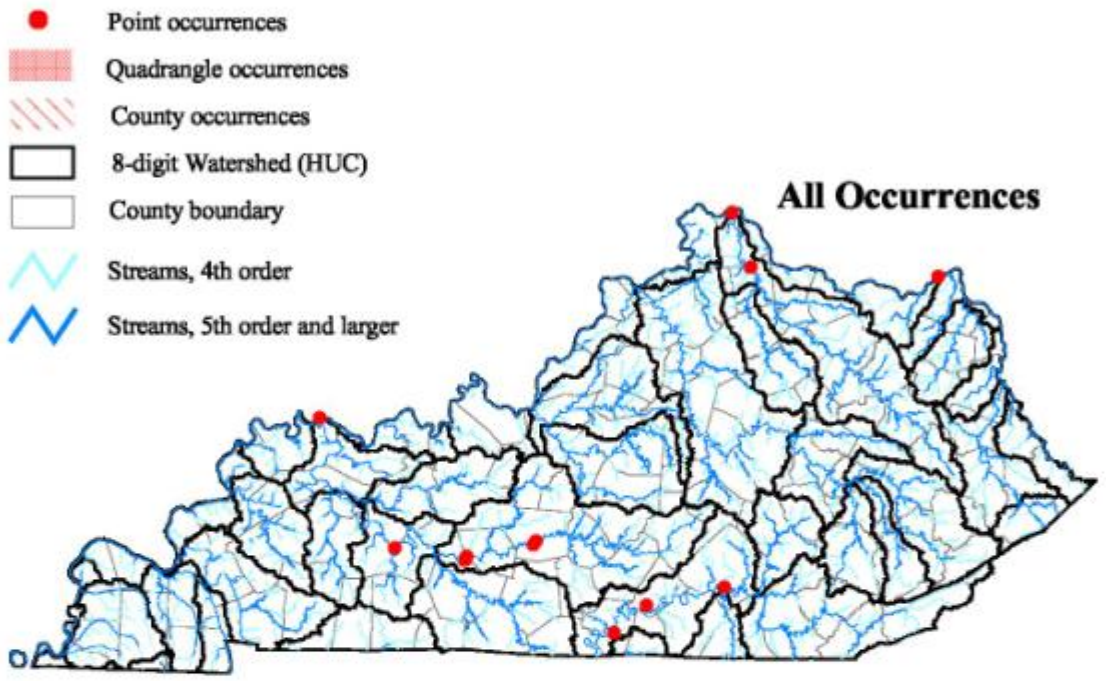


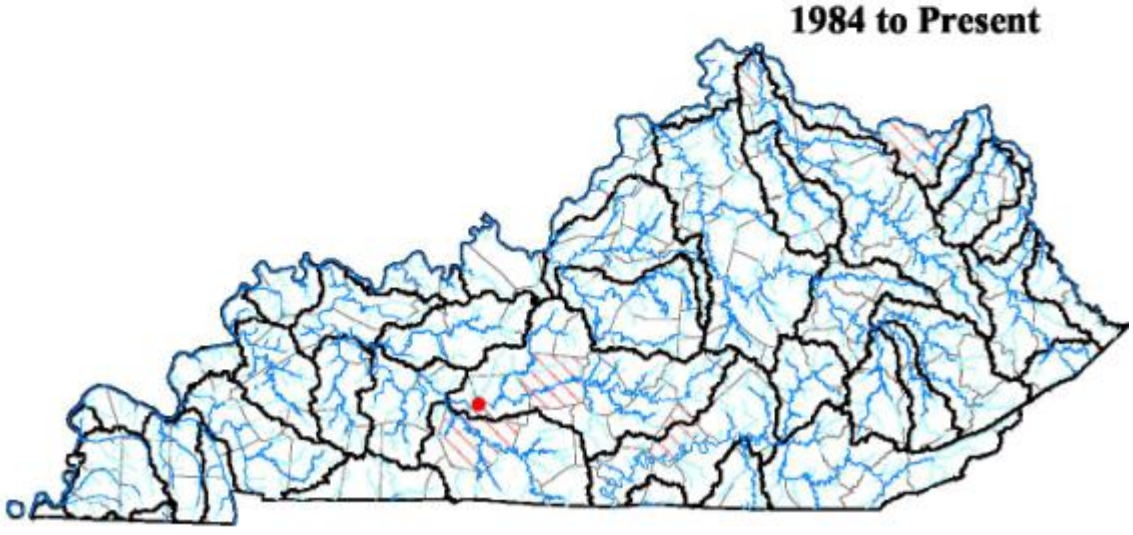


Catspaw

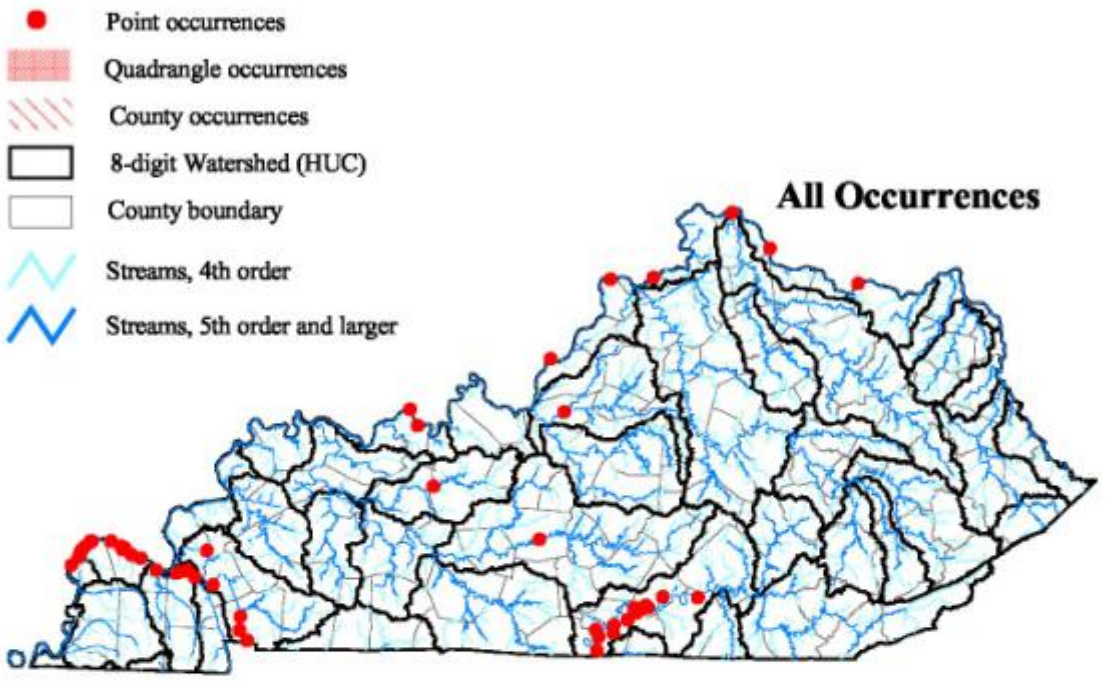
Epioblasma obliquata obliquata

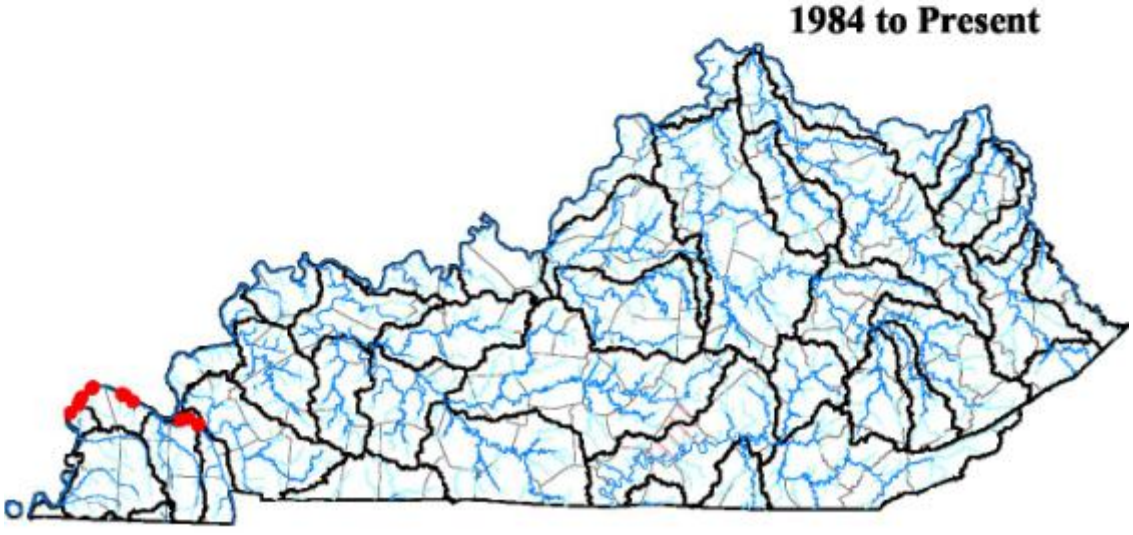
(Data current as of May 11, 2005)





Orangefoot Pimpleback
Plethobasus cooperianus
(Data current as of May 11, 2005)

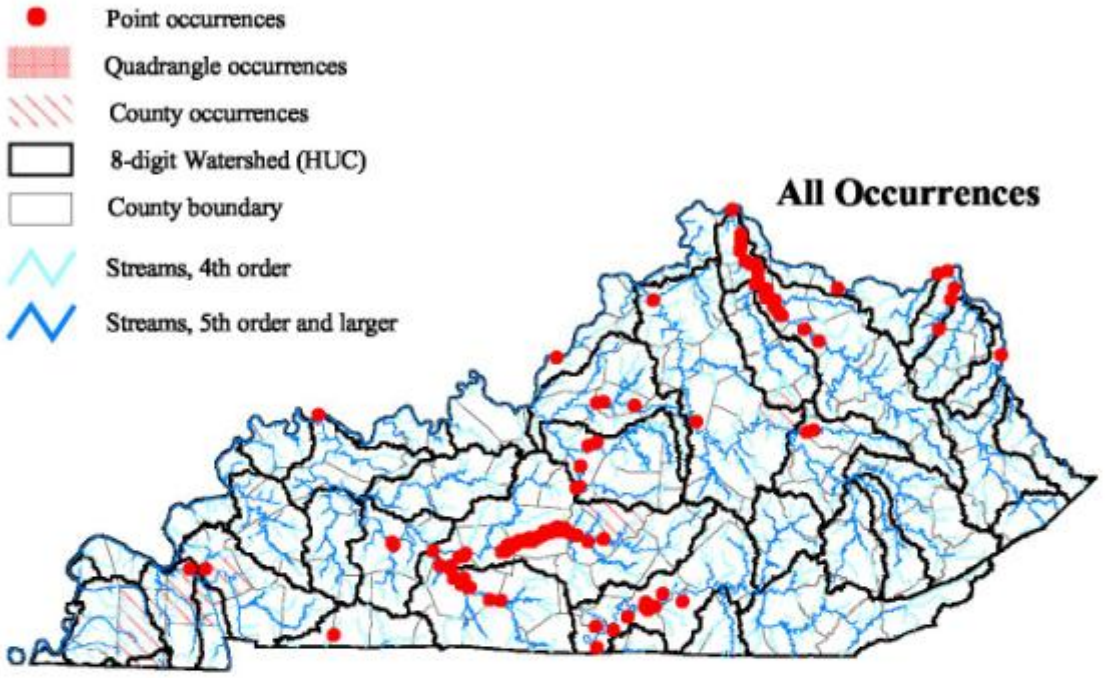


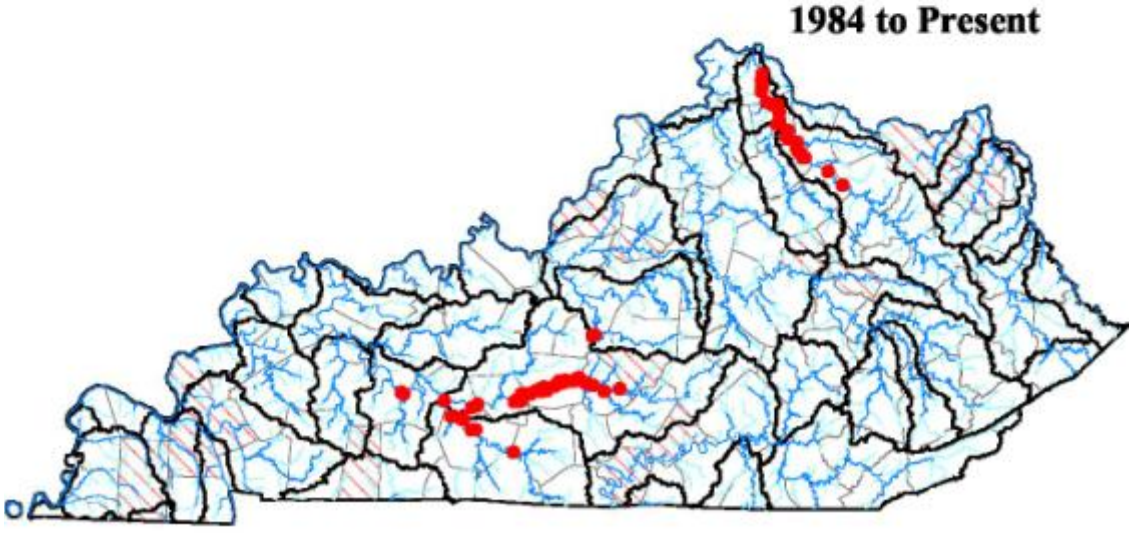


Fanshell

Cyprogenia stegaria

(Data current as of May 11, 2005)

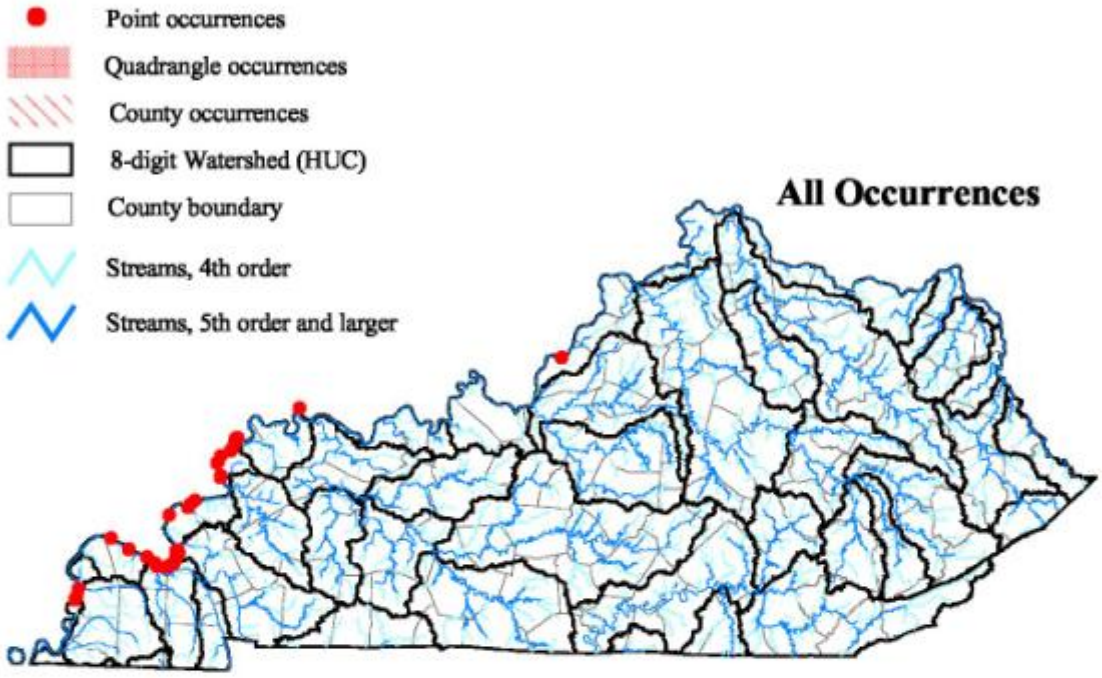


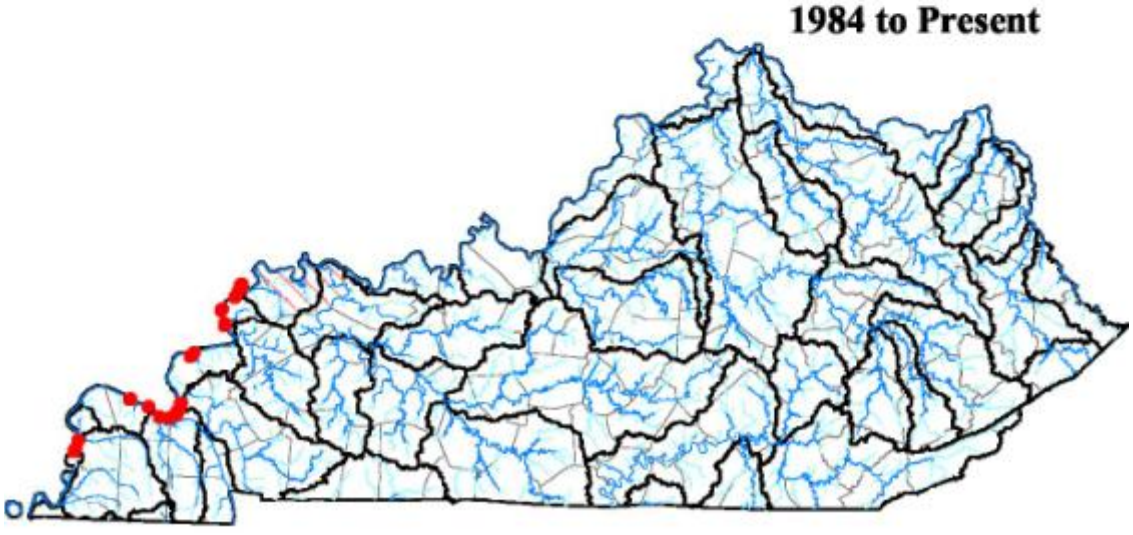


Fat Pocketbook

Potamilus capax

(Data current as of May 11, 2005)

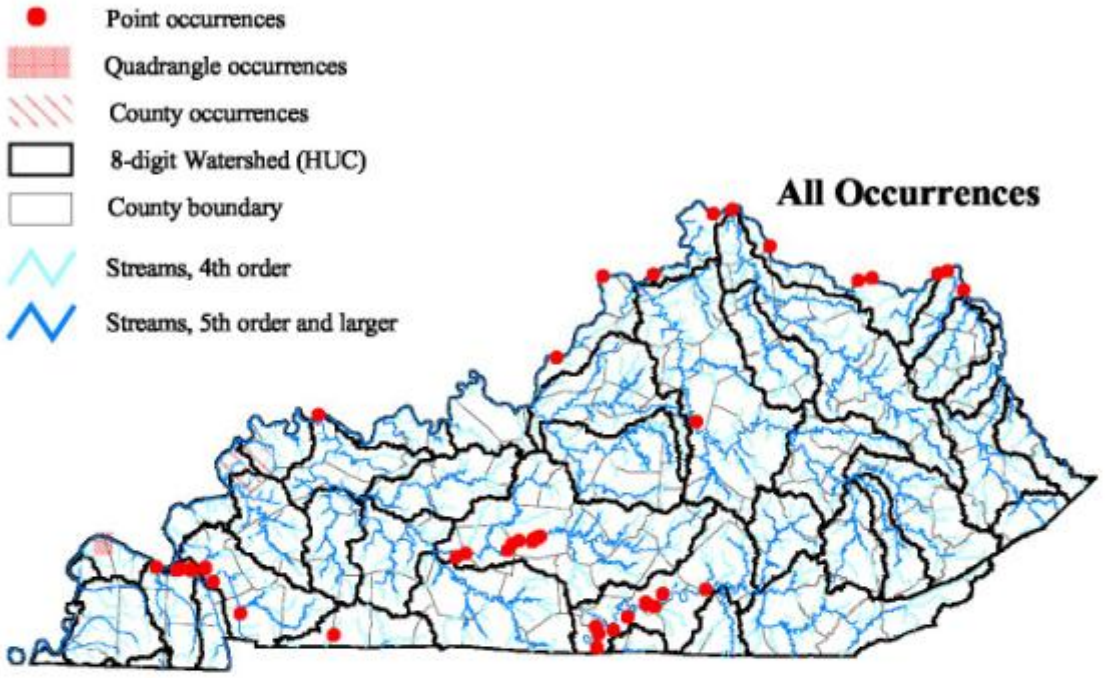


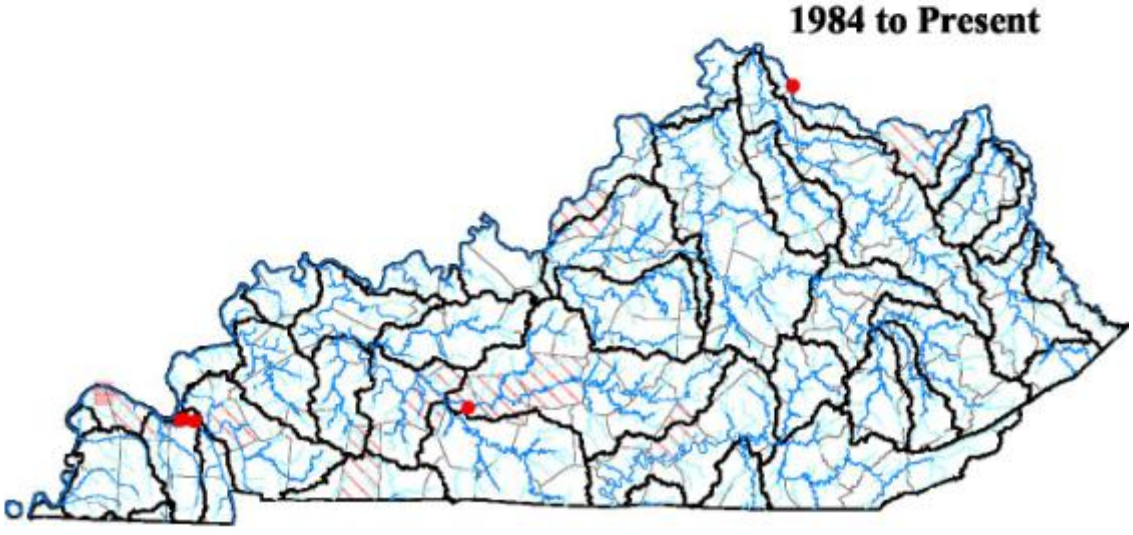


Ring Pink

Obovaria retusa

(Data current as of May 11, 2005)





Indiana Bat

Myotis sodalis

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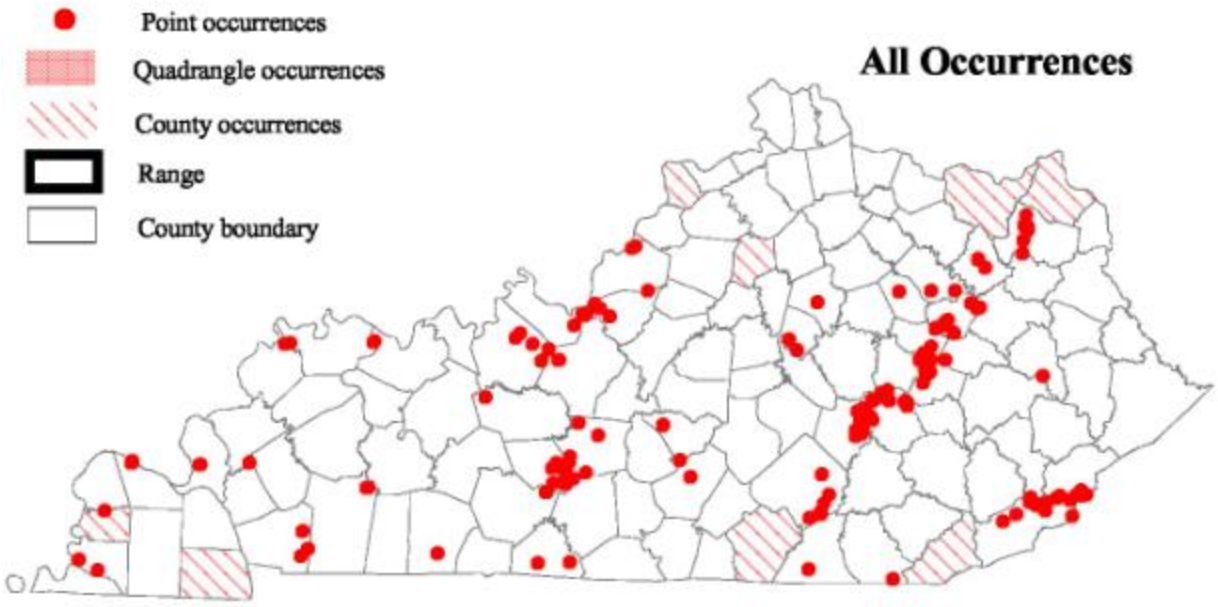

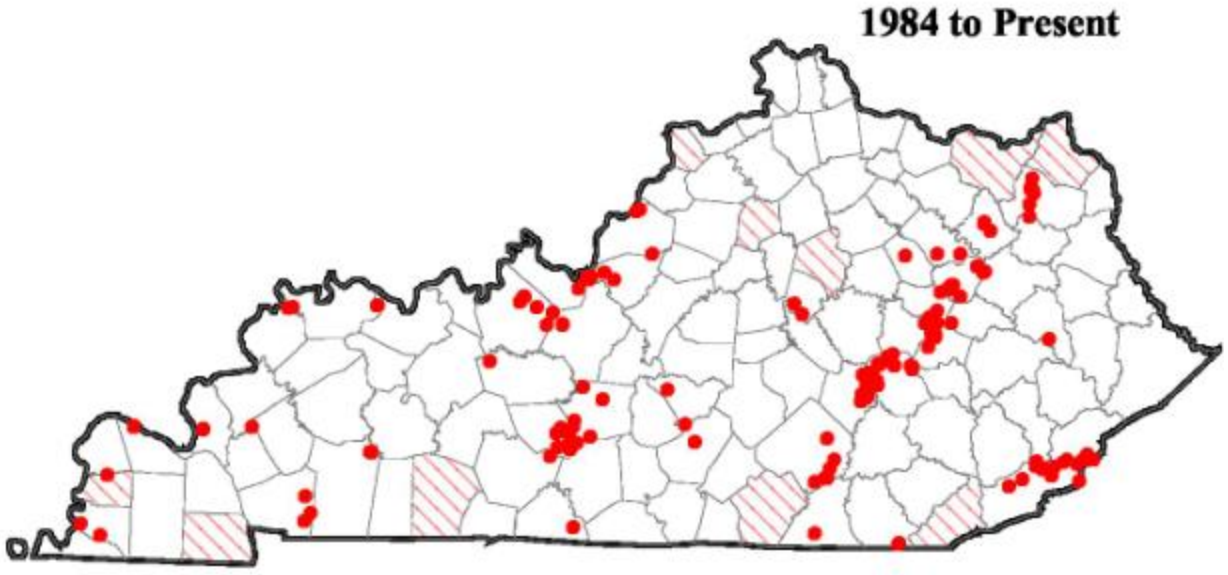

Gray Myotis

Myotis grisescens

(Data current as of May 11, 2005)