Current Distribution and Relative Abundance of the Crayfish, Mussels, and Aquatic Salamanders of the Spring River, Arkansas

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Executive Summary

The persistent problem of declining biodiversity has held the attention of scientists for several decades. Even more disturbing is the high proportion of aquatic species that are declining. Within Arkansas, almost half of the taxa listed as Species of Greatest Conservation Need and three quarters of the federally protected animals have ties to aquatic ecosystems. In many cases the decline in aquatic taxa is tied to degradation/loss of habitat. The continual mixing within aquatic systems can cause a system-wide response to a local perturbation. In addition, the complex nature of aquatic food webs can allow for a perturbation to have many indirect effects.

The Spring River of the eastern Ozark Mountains is one of the most prized natural resources in Arkansas, largely due to the nine million gallons of 14.4°C water produced by Mammoth Spring, one of the largest springs in the nation. The magnitude of this spring creates a coldwater ecosystem with limestone falls and chert gravel riffles that transition into a warm-water ecosystem downstream, thereby providing habitat for a diverse freshwater community. The Arkansas Department of Environmental Quality considers the Spring River to be an Ecologically Sensitive Waterbody, as well as an Extraordinary Resource Water (APCEC 2004), a designation that is given to Arkansas waters whose chemical, physical, and biological aspects can be "characterized by scenic beauty, aesthetics, scientific values, broad scope recreation potential, and intangible social values." The very features that make the Spring River unique are the very factors that constantly provide a barrage of threats to this river system. This water supply and the associated scenic beauty of the Ozark Mountains have allowed for the establishment of year-round recreational activities such as canoeing/rafting and sport-fishing for exotic

trout and tiger muskellunge. The extensive use of this unique river is alarming, considering the river is home to many species that are endemic to the Ozark Mountains, listed as Species of Greatest Conservation Need, or federally protected.

The objective of this project was to conduct a multi-taxonomic survey of the benthic community of crayfish, mussels, and aquatic salamanders within selected sites on the Spring River between Mammoth Spring and Imboden, AR. Declines in these species are commonly reported in the scientific literature, and little is known about the ecological status of this river. Because these three taxonomic groups are ecologically tied to each other in many ways, it is important to gather a baseline set of data that will allow for the development of a management strategy for the Spring River.

We surveyed 49 locations between the Arkansas/Missouri state line and the Arkansas Game and Fish Commission access boat launch at Imboden, AR, between August 2003 and July 2005. Our survey revealed that the Spring River hosts a diverse community within its main channel. Although we detected four species of crayfish, 29 species of mussels and two species of salamanders, the relative abundance of these species indicates that the community is dominated by two species of crayfish and five mussel species, and that the salamander populations are extremely small.

Introduction

The world-wide decline in biodiversity is a concern to scientists, resource managers, and private citizens. The disproportionate extinction rate of North American freshwater fauna is even more alarming. According to a review by Ricciardi and Rasmussen (1999), 48.5% of North American freshwater mussels, 22.8% of freshwater gastropods, 32.7% of crayfishes, 21.3% of freshwater fishes, and 25.9% of amphibians are considered imperiled. Unfortunately, many of these species may already be functionally extinct. For instance, it has been estimated that 40% of the freshwater mussels in Tennessee's rivers are no longer reproducing (Neves et al. 1997).

Currently, at least 47% (173 of 369) of the animals considered as Species of Greatest Conservation Need Arkansas Game and Fish Commission (Anderson 2006) and 62% (16 of 26) of the federally protected species as listed in the Arkansas Game and Fish Commission Code of Regulations (AGFC 2007) have direct ties to aquatic environments. The Spring River (Fulton, Sharp, and Lawrence counties) is known to harbor several such species (e.g., Pink Mucket, *Lampsilis abrupta*; Ozark hellbender, *Cryptobranchus alleganiensis bishopi*) and, hence, has been designated an Ecologically Sensitive Waterbody (APCEC 2004).

The Arkansas Department of Environmental Quality also considers the Spring River an Extraordinary Resource Water (APCEC 2004). This designation is given to Arkansas waters whose chemical, physical, and biological aspects can be "characterized by scenic beauty, aesthetics, scientific values, broad scope recreation potential, and intangible social values." The Spring River flows southward through the Ozark Mountains over limestone falls and chert gravel riffles. Mammoth Spring, located at the town of Mammoth Spring, feeds the river with 14.4 ^{o}C water at an average rate of 9 million gallons per hr. The sheer magnitude of this spring creates a cold-water ecosystem which transitions into a warm-water ecosystem further downstream. The diverse habitats associated with this complex system support a diversity of fish (Bickford 2004; Robison and Buchanan 1988), freshwater mussels (Davidson et al. 1997; Harris and Gordon 1987; Harris et al.1997; Rust 1993), and amphibians and reptiles (Trauth et al. 2004). This water supply and the associated scenic beauty of the Ozark Mountains allow for the establishment of year-round recreational activities such as commercial canoeing and exotic trout and tiger muskellunge sport-fishing. In many ways the local economy has become dependent on the estimated annual $50 million tourist industry (Haddigan 2001b).

The ecologically-sensitive nature of this river is in direct conflict with its value as a recreational resource. The land surrounding the river was historically cleared for pasturing cattle, and currently there is an increase in the development of riverfront resorts and housing subdivisions. In addition, the Burlington-Northern Santa Fe Railway follows the river valley, and in some areas the chat base of the tracks is the river bank. This alteration of natural riparian zones for these land uses has been shown to cause increased rates of bank erosion, sedimentation, and eutrophication (Karr and Schlosser 1978; Roth et al. 1996). There are also currently three municipal wastewater treatment plants (West Plains, MO; Thayer, MO, and Mammoth Spring, AR) and 2 major fish production facilities (USFWS Mammoth Spring National Fish Hatchery and AG&FC Spring River State Fish Hatchery) that empty into the upper Spring River drainage. The fishing pressure within the Ozark Mountains has increased to the point that the Spring

River State Fish Hatchery has been remodeled so as to increase exotic trout production from 400,000 lbs. per year to over 750,000 lbs. per year (Richard Sheldon, pers. comm.).

The exploitation of this river is disturbing, in that many of the organisms in the Spring River are endemic to the drainage and/or are experiencing recent range-wide declines (e.g., Curtis Pearly Mussel, *Epioblasma florentina curtisi*; Snuffbox, *E. triquetra*; Pink Mucket or Pearly Mussel, *Lampsilis abrupta*; Scaleshell, *Leptodea leptodon*; Ozark Hellbender, *Cryptobranchus alleganiensis bishopi*; Mammoth Spring Crayfish, *Orconectes marchandi*). Three benthic groups currently under pressure within the Spring River are the crayfishes, mussels, and salamanders. Furthermore, our understanding of the community composition and distribution of these taxa is largely limited to historic surveys of sites within close proximity to river access points.

Crayfish.—Crayfish play a complex role in aquatic ecosystems by functioning as herbivores, carnivores, and detritivores (Lorman and Magnuson 1978). As generalists, crayfish are able to convert energy within various trophic levels into a form that can be used by both higher (e.g., predatory fishes) and lower tropic levels (i.e., conversion of organic matter into smaller particle sizes and compositions that are useable by insect larvae and mussels). Therefore, crayfish may strongly influence the trophic structure within a stream. Some crayfish species, in fact, have specific habitat requirements making their influence on the ecosystem quite specific in scope. Consequently, the monitoring of crayfish populations can provide valuable insights into changes within the ecosystem.

Eleven species of crayfish (see Appendix Ia) have been identified from the Spring River and its tributaries, including the endemic Mammoth Spring Crayfish—O*rconectes* *marchandi* (Flinders 2000; Reimer 1963). Reimer (1963) summarized the known localities of crayfish for the entire state of Arkansas and reported a limited number of collection sites on individual rivers. He only reported the endemic Mammoth Spring Crayfish from 5 collections within the drainage, only one of which was within the main stem of the river (6.4 km NW of Imboden). Flinders (2000) conducted a broad survey of the entire Spring River drainage in Arkansas and Missouri, but only sampled from 4 collection sites on the main channel of the river. Although *Orconectes marchandi* was reported from 25 sites within the drainage, only one of these sites (~1.6 km upstream from Ravenden) was on the main channel. In summary, our knowledge of crayfish in the upper 72 km of the Spring River is limited to 8 different collection localities.

Mussels.—Mussels have been described as the most imperiled taxa of freshwater organisms in North America (Ricciardi and Rasmussen 1999). Harris et al. (1997) considered 29.3% (22 of 75) of the native Arkansas bivalves to be imperiled and in need of protection. There have been 49 species of mussels (see Appendix Ib) identified from the Spring River drainage; these include the federally endangered Curtis' Pearly Mussel (*Epioblasma florentina curtisi*), Pink Mucket (*Lampsilis abrupta*), and the Scaleshell (*Leptodea leptodon*). Harris and Gordon (1987) and Harris et al. (1997) reported 9 rare and/or endangered species from museum records as well as from *in situ* observations of live and relic shells. Davidson et al. (1997) surveyed Myatt Creek, a major tributary of the Spring River, and reported 19 species of mussels which included the endangered *Leptodea leptodon*. Rust (1993) reported 40 species of mussels within the lower Spring River from the Arkansas Game and Fish Commission boat launch at Imboden, AR, to the confluence with the Black River. These reports are based primarily on an in-depth survey of the lower Spring River and selected sites in the upper Spring River. To date, there has not been a thorough survey of the mussel fauna between the Spring River headwaters and Imboden, AR.

Salamanders.—The Spring River harbors the two large aquatic salamanders known to inhabit Arkansas rivers (Appendix Ic). The Ozark Hellbender (*Cryptobranchus alleganiensis bishopi*) is currently listed by the United States Fish and Wildlife Service as candidate for listing under the Endangered Species Act due to its range-wide decline in population numbers (Federal Register 2001; Wheeler et al. 2003). These declines were first reported from and appear to be greatest in the Spring River (Trauth et al. 1992, 1993). Historically, at least 370 hellbenders were known to inhabit three locations in the Spring River (Peterson 1985). Trauth et al. (1992, 1993) surveyed 12 sites and reported capturing a total of only 20 individuals in two of the historic sites and noted the extirpation of the third population. A single salamander covered with tumors was captured from a previously undocumented site in the Spring River in 1994 (Trauth et al. 2002). In summary, the Spring River has lost one localized hellbender population and appears to be on the verge of losing all known populations.

The Red River Mudpuppy, *Necturus maculosus louisianensis*, is the second aquatic salamander found in the Spring River. Although, the Red River Mudpuppy is thought to have stable populations throughout Arkansas, the species has been reported from only three locations in the middle and lower Spring River (Trauth et al. 2004). Little is actually known about the demographics of this species within individual rivers in the state. The habitat of the mudpuppy is typically considered as backwater pools with submerged vegetation and leaf litter; however, this salamander apparently also regularly uses the main channel habitat of swift-flowing, rocky Ozark streams (unpub. data). It is within this type of habitat that the mudpuppy plays a crucial role in the life history of *Simpsonaias ambigua* (Oesch 1995), the rare Salamander Mussel (Harris and Gordon 1987; Harris et al. 1997). Consequently, the distribution of the salamander mussel is directly dependent upon waters that harbor the Red River Mudpuppy. It is, however, unknown whether the rarity of this mussel is directly related to any, as yet unsubstantiated, Red River Mudpuppy population declines.

Objectives

The primary objective of this study was to determine the species composition, distribution, and relative abundance of the crayfish, mussel, and salamander communities within the upper and middle Spring River, from Mammoth Spring to Imboden, AR. This survey will not only identify optimal locations of high species density and diversity of each target group (through the multi-taxonomic approach and design of this survey), but will also allow the determination of less optimal areas harboring individuals that might otherwise be ignored. Ultimately, data derived from this survey will also provide crucial base-line information necessary to developing a management strategy for the Spring River.

Materials and Methods

Study Site Selection and Habitat Characterization.—The habitat of the Spring River was visually assessed between Mammoth Spring and the Arkansas Game and Fish Commission access at Imboden during a float-through survey. In order to obtain a profile of the benthic community, survey sites focused on areas with flowing water and mixed gravel/cobble to boulder/bedrock substrate that appeared suitable for all three target taxa. Survey sites were photographed, and GPS coordinates were recorded.

The habitat types associated with each survey site were classified using the standard nomenclature of the Basin Area Stream Survey (BASS) of Clingenpeel and Cochran (1992) and McCain et al. (1990) (Table 1). The 24 habitat types described therein are relatively stable through time, thus, coupled with GPS coordinates, will allow for the relocating of specific sites in the future. In addition, a complete BASS assessment was conducted at 14 sites.

Methods for Sampling Crayfish.—We attempted to sample crayfish at a minimum of 1 site per 2 river km above Hardy and 1 site per 5 river km between Hardy and Imboden. A site was defined as a cross-channel, strip transect (Lancia et al. 1996). Initially, shallow riffle habitats (<0.5 m) were sampled using a 1.5 m (7 mm mesh) seine, which involved a 1 m^2 area upstream of the seine being thoroughly kicked to dislodge crayfish, which were swept downstream into the seine. However, we found that the habitat of the main channel habitat of the river was not conducive for kick seining due to the size and embeddedness of the substrate. Additionally, we attempted to sample vegetated areas and pools with high silt loads using crayfish traps baited with fish, cat food, dog biscuits and/or chicken liver; however poor trapping results led to our abandoning trapping and seining efforts. Therefore, all habitats at remaining sites were sampled using 60-min time constraint searches during which weed beds were searched, and rocks were overturned. We utilized snorkel and scuba techniques to aid in the hand-capture of observed individuals. We attempted to pursue and capture every crayfish encountered during the search.

Crayfish were sampled during the fall and winter of 2004/2005 and 2005/2006 to target Form I males that are required for identification. Live crayfish collected were divided into groups based on phenotypic similarities and sub-grouped based on size and sex. A representative sample of individuals from each subgroup was immediately preserved in 10% formalin for later identification. Care was taken to avoid over-collection of sensitive species (see Appendix Ia). All identifications were made based on Hobbs (1972; 1989) and Pflieger (1996). Specimens are stored in 70% ethanol and housed in the Arkansas State University Museum of Zoology.

Methods for Sampling Mussels.—Qualitative mussel surveys were conducted using a timed snorkeling/scuba technique of at least 60 person min per sampling reach. This level of effort been shown to be successful at maximizing mussel species richness counts based on the analysis species area curves of search time versus species richness (Smith and Strayer 2003; Strayer et al. 1997; Vaughn et al. 1997). Qualitative survey techniques minimize disruptions to the mussel beds by avoiding the removal of all the individuals from a defined area. During this process, individual mussels or groups of mussels (in areas of high mussel densities) were flagged within the sampling reach. A special effort was made to locate federally endangered, threatened, or sensitive mussel species (Appendix Ib). Fresh dead shells were cleaned and processed for long-term storage at the Arkansas State University Museum of Zoology, Unionoidae Collection.

A species list, relative abundance, estimated densities, habitats occupied and areal extent of the mussel assemblage were recorded. Additionally, the presence and visual estimate of concentrations of the exotic Asian Clam, *Corbicula fluminea*, were noted.

Photo documentation of each species was taken at each site as no live individuals were collected for preservation.

Quantitative sampling of the qualitative survey sites was conducted in the summer of 2005. Quantitative sampling was conducted only at qualitative sites with estimated densities of > 1 individual/m^2, thus deemed as a mussel aggregate for this study. Mussel aggregates were quantitatively sampled using a stratified random sampling design (Harris et al. 1993; Christian and Harris 2005). If appropriate, these areas were first divided into strata based on substrate composition (e.g., gravel, sand, silt, and clay), general physical river morphology (e.g., bendway or straightaway), and/or river depth. The number of samples taken from an aggregate was determined by total bed area where: (1) a minimum of 10 1 m^2 samples were sampled from beds of 500-999 m^2 area; (2) a bed with an area between 1000-2500 m^2 were sampled by 1 % of the area (i.e., 10-25 samples); (3) a bed with area > 2500 m^2 were sampled by a maximum of 25 samples. Quadrat sample coordinates were determined using a random numbers table generated in Microsoft Excel. The number of samples taken from each stratum was based on the proportion of stratum size to total bed area; however, a minimum of three samples were taken from each stratum for statistical validity. In the laboratory, a species area (or time searched) curve was constructed to estimate if all species were detected using the software program PC-ORD (McCune and Mefford 1999).

Mussels within a 1 m^2, 2.5 cm weighted PVC pipe quadrat were hand collected by excavating the substrate to a depth of 10-15 cm and visually or tactually searching through the substrate (or by excavating substrate and sending it to the surface to be sieved). Mussels were placed in a mesh dive bag and transported to the surface for identification. Nomenclature followed Turgeon et al. (1998). Length (anterior to posterior), depth (dorsal to ventral margin) and width (right and left margin) measurements (mm), collected in accordance with the legal harvest dimensions set by Arkansas Game and Fish Commission, as well as sex, estimated age, and total wet mass (g) were recorded for each individual. In a situation where an endangered or threatened species was collected, it was uniquely marked prior to being released. All mussels were promptly returned to the excavation quadrat, and reburied to their previous depth within the substrate.

Quantitative surveys produced the following population and assemblage indices: population estimate, community numerical standing crop (CNSC), density (#/m^2), relative abundance, size frequency distribution, and recruitment. We estimated the standard error of our sampling protocol following the procedures described in Southwood (1978) and Downing and Downing (1992). These calculations were used to determine the number of quadrat samples required to estimate mean species richness and mean density with 80% and 90% confidence limits.

We also assessed our ability to sample all species within a bed by comparing our observed species richness to first and second order jackknife estimates using PC-ORD software (McCune and Mefford 1999). The first order jackknife was calculated

$$Jack1 = S + r1(n-1)/n$$

where S = number of species observed, r1 = the number of species occurring in one sample unit, and n = the number of sample units. The second order jackknife was calculated

$$Jack2 = S + r1(2n-3)/n - r2(n-2)^2/(n(n-1))$$

where r2 = number of species occurring in exactly two sample units.

Methods for Sampling Salamanders.—Survey sites for aquatic salamanders (see Appendix Ic) were chosen based on the presence of several key habitat characteristics, as described in Fobes (1995) and Trauth et al. (2004). The characteristics include but are not limited to the following: (1) moderate to fast flowing water; (2) bedrock with ledges, cracks and crevices; (3) large, loose boulders scattered on substrate; and (4) a lack of aquatic vegetation. Special attention was paid to historical localities. Efforts were initially conducted using a timed snorkeling or scuba search, employing standard survey techniques; i.e., rock turning and examination of cracks, crevices, etc. (Nickerson and Krysko 2003). The duration of time spent surveying each site was relative to the total area of available habitat, and was conducted in 15 min increments until > 75% of the potential habitat had been surveyed.

Baited minnow traps were also used at selected sites (i.e., historic or highly vegetated sites) to increase the likelihood of detecting the Red River Mudpuppy and smaller size classes of Ozark Hellbenders. This technique has been successful in capturing mudpuppies in the Spring River (SET, unpub. data). Traps were baited with fish, cat food, dog biscuits or chicken liver, and, left overnight and checked the following morning. Additionally, a drawdown of the pool above the AGFC Jim Hinkle State Fish Hatchery at Dam Site 3 (see Trauth et al. 1992) enabled a thorough survey of a historic population of Ozark Hellbenders immediately below the dam (Peterson 1985; see Trauth et al. 1992).

Standard measurements (total length, snout-vent length, and mass) and sex, when possible, were recorded for each captured animal. General notes regarding body condition and the presence of abnormalities such as missing digits or tumors were noted and photographed. Hellbenders were scanned for Trovan PIT (passive integrated transponder) tags that were implanted during previous studies. Unmarked hellbenders were implanted with an AVID® PIT tag for future identification and placed in a raceway at the Federal Fish Hatchery in Mammoth Spring, AR, as part of an ongoing captive propagation effort (per K. Irwin). Captured Red River Mudpuppies were released, unmarked at the site of capture.

Results

We surveyed and identified the three target taxa (crayfish, mussels, and salamanders) at 49 locations within the main channel of the Spring River upstream from Imboden, Arkansas (Table 2; Figs. 1 and 2). In addition, we qualitatively categorized the aquatic habitats at these study sites and quantitatively assessed the habitat within 14 of those sites. Four species of crayfish, 29 species of mussels, and two species of salamanders were found during this study.

Survey Site Descriptions.—Survey sites were generally moderate to swift flowing areas with cobble to boulder sized substrate on a gravel/bedrock base. A description of each study site is provided in Appendix II and a map and photograph of selected survey sites are provided in Appendix III to better illustrate the habitat and surrounding land use. The BASS assessment results of 14 selected sites are presented below.

Site 14 was comprised of three habitat types: low gradient riffle, run, corner pool. Bankfull width, water width, thalweg depth and average depth were 57.7 m, 30.5 m, 89.3 cm, and 40.6 cm, respectively. Substrate composition was dominated by gravel, while sand had the lowest composition (Table 3). In-stream cover was dominated by rooted vegetation, while undercut bank had the lowest composition (Table 4). Bank characteristics included bank angles greater than 130 degrees, stability greater than 87%, and terrestrial vegetation of mixed grass and forested (Table 4). Canopy coverage was 96.6% open.

Site 15 was made up of two habitat types: low gradient riffle, and run. Bankfull width, water width, thalweg depth and average depth were 43.7 m, 30.0 m, 76.7 cm, and 51.1 cm, respectively. Substrate composition was dominated by gravel, while fines had the lowest composition (Table 3). In-stream cover ranged from rooted vegetation being the most dominant to white water being the least abundant habitat (Table 4). Bank characteristics included bank angles greater than 171 degrees, stability greater than 77%, and terrestrial vegetation of mixed grass and forested (Table 4). Canopy coverage was 98% open.

Site 17 was comprised of two habitat types: low gradient riffle, and run. Bankfull width, water width, thalweg depth and average depth were 30.0 m, 18.5 m, 77.8 cm, and 39.0 cm, respectively. Substrate composition was dominated by cobble, whereas sand had the lowest composition (Table 3). In-stream cover was dominated by undercut bank, while bedrock ledge had the lowest composition (Table 4). Bank characteristics included bank angles greater than 134.5 degrees, stability greater than 74%, and terrestrial vegetation of mixed grass and forested (Table 4). Canopy coverage was 83.0% open.

Site 20 was composed of four habitat types: high gradient riffle, glide, run, and mid channel pool. Bankfull width, water width, thalweg depth and average depth were 54.0 m, 39.8 m, 124.2 cm, and 59.4 cm, respectively. Substrate composition was dominated by bedrock, while sand had the lowest composition (Table 3). In-stream cover was dominated by rooted vegetation, while bedrock ledge had the lowest composition (Table 4). Bank characteristics included bank angles greater than 149 degrees, stability greater than 88%, and terrestrial vegetation of mixed grass and forested (Table 4). Canopy coverage was 99.8% open.

Site 31 was made up of four habitat types: low gradient riffle, lateral scour pool bedrock formed, glide and run. Bankfull width, water width, thalweg depth and average depth were 87.3 m, 55.3 m, 120.0 cm, and 63.7 cm, respectively. Substrate composition was dominated by gravel, while sand had the lowest composition (Table 3). In-stream cover was dominated by rooted vegetation and terrestrial vegetation, while white water had the lowest composition (Table 4). Bank characteristics included bank angles greater than 112 degrees, stability greater than 89%, and terrestrial vegetation of mixed grass and forested (Table 4). Canopy coverage was 79.5% open.

Site 32 was made up of four habitat types: low gradient riffle, lateral scour pool bedrock formed, run, and corner pool. Bankfull width, water width, thalweg depth and average depth were 61.0 m, 45.5 m, 1500 cm, and 74.3 cm, respectively. Substrate composition was dominated by gravel, while fines had the lowest composition (Table 3). In-stream cover was dominated by clinging vegetation, while undercut bank and bedrock ledge had the lowest composition (Table 4). Bank characteristics included bank angles greater than 136.3 degrees, stability greater than 88%, and terrestrial vegetation of mixed grass and forested (Table 4). Canopy coverage was 99.9% open.

Site 33 was made up of four habitat types: low gradient riffle, high gradient riffle, lateral scour pool bedrock formed, and run. Bankfull width, water width, thalweg depth and average depth were 98.8 m, 87.0 m, 118.3 cm, and 58.1 cm, respectively. Substrate composition was dominated by boulders, while sand had the lowest composition (Table 3). In-stream cover was dominated by rooted vegetation, while undercut bank had the lowest composition (Table 4). Bank characteristics included bank angles greater than 127.5 degrees, stability greater than 90%, and terrestrial vegetation of mixed grass and forested (Table 4). Canopy coverage was 99.8% open.

Site 43 was made up of five habitat types: low gradient riffle, lateral scour pool, run, and mid channel pool. Bankfull width, water width, thalweg depth and average depth were 62.3 m, 44.0 m, 173.1 cm, and 92.1 cm, respectively. Substrate composition was dominated by gravel, while bedrock had the lowest composition (Table 3). In-stream cover was dominated by terrestrial vegetation, while whitewater had the lowest composition (Table 4). Bank characteristics included bank angles between 56.4 and 60.7 degrees, stability between 67.9 and 74%, and terrestrial vegetation of mixed grass and forested (Table 4). Canopy coverage was not recorded at this site.

Site 44 was made up of three habitat types: low gradient riffle, run, corner pool. Bankfull width, water width, thalweg depth and average depth were 57.7 m, 30.5 m, 89.3 cm, and 40.6 cm, respectively. Substrate composition dominated by gravel and sand had the lowest composition (Table 3). In-stream cover was dominated by rooted vegetation, while undercut bank had the lowest composition (Table 4). Bank characteristics included bank angles greater than 130 degrees, stability greater than 87%, and terrestrial vegetation of mixed grass and forested (Table 4). Canopy coverage was 96.6% open.

Site 45 was made up of three habitat types: low gradient riffle, run, and mid channel pool. Bankfull width, water width, thalweg depth and average depth were 46.9

m, 30.0 m, 94.0 cm, and 41.1 cm, respectively. Substrate composition was dominated by cobble, while bedrock and boulder had the lowest composition (Table 3). In-stream cover was dominated by large woody debris, while boulder had the lowest composition (Table 4). Bank characteristics included bank angles greater than 90.7 degrees, stability greater than 90%, and terrestrial vegetation of mixed grass and forested (Table 4). Canopy coverage was 99.8% open.

Site 46 was made up of three habitat types: low gradient riffle, run, and mid channel pool. Bankfull width, water width, thalweg depth and average depth were 58.0m, 43.2 m, 146.5 cm, and 61.1 cm, respectively. Substrate composition was dominated by cobble and fines, while sand had the lowest composition (Table 3). In-stream cover was dominated by rooted vegetation, while undercut bank had the lowest composition (Table 4). Bank characteristics included bank angles greater than 108.8 degrees, stability greater than 81%, and terrestrial vegetation of mixed grass and forested (Table 4). Canopy coverage was 97.5% open.

Site 47 was made up of four habitat types: low gradient riffle, glide, run, and corner pool. Bankfull width, water width, thalweg depth and average depth were 62.3 m, 51.0 m, 210 cm, and 93.4cm, respectively. Substrate composition was dominated by gravel, while sand had the lowest composition (Table 3). In-stream cover was dominated by terrestrial vegetation and rooted vegetation, while undercut bank had the lowest composition (Table 4). Bank characteristics included bank angles greater than 137 degrees, stability greater than 87%, and terrestrial vegetation of mixed grass and forested (Table 4). Canopy coverage was 98.3 % open.

Site 48 was made up of four habitat types: low gradient riffle, glide, mid channel pool, and channel confluence pool. Bankfull width, water width, thalweg depth and average depth were 45.0 m, 26.2 m, 120.2 cm, and 65.9 cm, respectively. Substrate composition was dominated by gravel, while sand had the lowest composition (Table 3). In-stream cover was dominated by large woody debris, while undercut bank had the lowest composition (Table 4). Bank characteristics included bank angles greater than 106 degrees, stability between 64 and 65%, and terrestrial vegetation of mixed grass and forested (Table 4). Canopy coverage was 90.5% open.

Site 49 was made up of three habitat types: run, mid channel pool, and lateral scour pool. Bankfull width, water width, thalweg depth and average depth were 52.7 m, 40.3 m, 208.0 cm, and 97.9 cm, respectively. Substrate composition was dominated by gravel and fines, while boulder had the lowest composition (Table 3). In-stream cover was dominated by clinging vegetation, while undercut bank had the lowest composition (Table 4). Bank characteristics included bank angles greater than 116.7 degrees, stability between 61.7 and 87%, and terrestrial vegetation of mixed grass and forested (Table 4). Canopy coverage was 90.5% open.

Crayfish.—A total of 10.75 man-hrs (mhr) and 46 trap nights was spent surveying for crayfish within the main channel of the Spring River, yielding 382 captures of four species at 16 sites (Table 5). The number of crayfish captured per site ranged from 0-81 (mean = 23.9). However, when the 6 sites that were only sampled by traps (4, 8, 11,12, 13, 43) and the 4 sites where no crayfish were found (11, 13, 48, and 49) the number of crayfish per site ranged from 6-81 with a mean of 38.2 per site.

Hubb’s Crayfish (*Cambarus hubbsi*) was found in every site where crayfish were collected, except sites 4 and 12 where only a few specimens were captured. It was the most common species encountered in the river and accounted for 46% of all captured specimens (Table 6). The Coldwater Crayfish (*Orconectes eupunctus*) was the second most common species found (29% of all captured specimens), and was the most common species found at 4 (31, 32, 46, and 47) of the 6 downstream most sites surveyed (Table 6). The Spothand Crayfish (*Orconectes punctimanus*) was the third most common species captured and represents 18% of the specimens identified (Table 6). The least common species encountered was the Ozark Crayfish (*Orconectes ozarkae*) and only accounted for 7% of the specimens captured (Table 6). This species was only found in small numbers, but was the most common species in areas where only a few crayfish were found.

Freshwater Mussels.—We quantitatively sampled 7 of the 14 stations on the Spring River that were identified as harboring mussel populations. Twenty-nine species were identified from a total of 1248 specimens (Table 7). Seventeen of the 29 species (59%) identified were ranked as S1, S2, or S3 under the 2004 Arkansas State Heritage Program Ranking Codes. The mussel aggregates areas ranged in size from 375-9520 m^2 (Tables 8 – 14). Mean densities ranged from 1.04 to 24.0 mussels m^{-2} at sites 33 and 46, respectively, with an overall mean of 7.4 mussels m^{-2} (SD ± 4.87) (Tables 8-14). Species richness ranged from 3 to 23 species per site. Total number of mussels, CNSC estimates, ranged from 288 ± 200 to 9883 ± 3504 at sites Site 33 and Site 45, respectively (Tables 8-14).

Ellipto dilatata, Ptychobranchus occidentalis, Cyclonaias tuberculata, *Actinonaias ligamentina*, and *Quadrula cylindrica* comprised 72.6% of all mussels collected during this study (Table 7). The above five species occurred at five of the seven sites sampled. *Ellipto dilatata* alone made up 46.3% of the total number of specimens collected and was found at six of the seven sites sampled. With only one individual detected in their respective sites, *Lampsilis siliquoidea*, *Quadrula nodulata*, *Quadrula quadrula*, and *Venustaconcha pleasii* were the least abundant species.

Calculated confidence levels for mean density of our sampling effort ranged from 73 to 93% for Site 43 and Site 46, respectively (Table 15). In order to obtain 80% confidence level for obtaining true mean densities, it was estimated that we required 3 - 45 samples for the Southwood (1979) equation and 5 - 25 samples based on the Downing and Downing (1992) equation (Table 15). In order to obtain a 90% confidence level to achieve true mean densities, it was estimated that we needed between 13 - 179 samples based on the Southwood (1979) and 20 - 98 samples based on the Downing and Downing (1992) equation (Table 15).

Total species richness ranged from 3 - 23 species at Site 33 and Site 46, respectively (Table 16). The number of species with only 1 occurrence in the sampling area ranged from 1 - 8 at sites 33 and 45, respectively, and the number of species with only 2 occurrences in the sampling area ranged from 0 - 5 at sites 33 and 46, respectively (Table 16). Assessment of our sampling precision using a 1st and 2nd order Jackknife estimates of richness reveled that all sites probably had more species, with an upward range of 5 - 34 species for Site 33 to Site 45 (Table 16).

Aquatic Salamanders.—A total of 74 man-hrs (mhr) was spent specifically searching for the Red River Mudpuppy (*Necturus maculosus louisianensis*) and the Ozark Hellbender (*Cryptobranchus alleganiensis bishopi*) at 49 locations (Table 2). These efforts yielded 15 captures of 14 hellbenders at three locations and two mudpuppies at two locations. Further effort of 46 trap nights at six locations yielded no additional salamander captures.

Two of the three locations where hellbenders were found were historical study sites. Three individuals were found at Site 6 (beneath the US Hwy 63 bridge at Mammoth Spring). One of these individuals was covered in tumors and died in transport to Arkansas State University for further examination. Ten hellbenders were found at Site 14 (downstream of Dam Site #3). Three of these hellbenders were captured immediately below the dam by AGFC Jim Hinkle Fish Hatchery personnel during routine maintenance on the dam, one of which was captured twice. A fourth hellbender was captured above the dam by the hatchery personnel, where it was found stuck in a water intake screen that supplies water to the hatchery (see Figure 3). This capture is unusual in that to our knowledge, this is the only record of a hellbender found in the area immediately above the dam and, furthermore, there is no conceivable reason that the hellbender would be at the surface of a >6m deep pool of water. The third site where hellbenders were found was Cooper's Fall (Site 20). The hellbender captured at this location was covered with lesions, tumors, and fungal infections, similar to a hellbender with tumors that was captured at this same site (Trauth et al. 2002). These 14 hellbenders were all large adults (see Table 17) and many had noticeable abnormalities (see Hiler

2005). In addition, local fishermen informed us of two unverified hellbender populations, one at Many Island Campground and one just above the confluence with Rock Creek.

Each of the two sites where mudpuppies were found yielded one individual. The individual found at Site 31 was an adult salamander found by John Harris (Arkansas Department of Transportation). The individual found at Site 32 was a juvenile found by WRH. Neither surveyor was able to hand-capture either of these specimens, but the experience of the surveyors allows us to consider these to be valid records.

Discussion

The multi-taxonomic approach to this survey allowed for the thorough examination of three major benthic taxa found in the Spring River. We found the benthos of the Spring River to be a diverse community of four species of crayfish, 29 species of freshwater mussels, and two species of large aquatic salamanders. Although we were able to detect 36 species during this survey, we found this community to be dominated by two species of crayfish (*Cambarus hubbsi*) and five species of freshwater mussel (*Elliptio dilatata*), as neither of the salamanders were present in large numbers. It should be noted that we biased our search efforts by restricting site selection to areas that were conducive for all three target taxa. Our results reflect the current status within the swift main stem of the Spring River.

Crayfish.—We found four species of crayfish during our survey of the main channel of the Spring River. The habitat of the sites surveyed consisted largely of moderate-to-swift flowing water with a cobble-boulder on gravel or bedrock substrate, which is typical of these four species (*Cambarus hubbsi*, *Orconectes eupunctus*, *O. ozarkae*, and *O. punctimanus*). All of these species were found throughout the Spring

River except for *O. eupunctus*, which was not found above Dam 3. This distribution is consistent with habitat descriptions given by Pflieger (1996) and Flinders (2000). The community composition of the Spring River was also similar to that found by Hiler (2005) in the Eleven Point River, a major tributary that enters the Spring River near its confluence with the Black River.

From information gleaned from the primary literature regarding the distribution of crayfish within the Spring River drainage, it is not surprising that the other 7 of the 11 expected species were not encountered. Two species, *Cambarus diogenes* and *C. ludovicianus*, are considered to be the same species within Missouri and this watershed by Pflieger (1996) and the 4 specimens found by Flinders (2000) were identified as *C. diogenes*. According to Pflieger (1996), the burrows of *C. diogenes* can be found in the banks of streams and in swampy areas, but we restricted our searches to aquatic areas with swift flowing rocky bottomed areas. The endemic Mammoth Spring Crayfish (*Orconectes marchandi*) was not encountered during this survey; however, Flinders (2000) only encountered this species in slow moving, shallow areas with gravel/cobble substrate, which included only one location on the main channel of the Spring River. The Northern Crayfish, *O. virilis*, was not encountered by Flinders (2000), and she suggested that it may be extirpated from the drainage. This may be the case as Reimer (1963) reported this species to be found in association with *O. marchandi* and, therefore, should have been found by Flinders (2000). Three species (*O. neglectus*, *Procambarus acutus*, and *P. viaveridis*) have only been reported from the Spring River in small numbers and are likely isolated releases from bait buckets.

Freshwater Mussels.—Based upon our quantitative sampling of Spring River mussel populations, the Spring River mussel fauna is species rich and relatively abundant with just over half of the species being of greatest conservation concern (S1-S3 rankings). In terms of distribution of mussel aggregates in the Spring River, mussel aggregates of densities greater than 1 m^{-2} have now been shown to occur as far upstream as our sampling Site 33, which is commonly known as Camp Kierl, just north of Hardy, AR. Thus, mussel aggregates have now been shown to occur from Camp Kierl down to Imboden, which increases the distribution of known mussel aggregates to above Imboden, which was the upper most survey extent of a 1991 survey of the Spring River by Rust (1993).

Our density and community numerical standing crops estimates from the upper Spring River were similar to that of Rust's (1993) 1991 survey conducted from the Imboden boat ramp (Lawrence County, AR) downstream to the Spring River confluence with the Black River near Black Rock (Lawrence County, AR). Rust (1993) reported 36 surveyed sites, with three major and three minor mussel aggregates defined. From those six aggregates, he reported a total of 25 species from 167 samples and 1049 individuals.

From the three major beds (= aggregate), Rust (1993) recorded 24 species with *Actinonaias ligamentina*, *Elliptio dilatata*, and *Quadrula pustulosa* being the most abundant species comprising 23, 9, and 9 percent of the total abundance, respectively. Rust (1993) also reported mean densities from these major aggregates ranging from 5 to 7 mussels m^{-2}, with community numerical standing crops ranging from 3160 to 9103 individuals per aggregate, for an average of 5601 individuals per aggregate.

For the three minor beds, Rust (1993) reported 20 species with four species (*Actinonaias ligamentina*, *Quadrula pustulosa*, *Elliptio dilatata* and *Cyclonaias turbiculata*) that made up 27, 11, 10, and 10% of the aggregate composition, respectively. Average densities in the three minor beds ranged from 4.2 to 9.7 individuals m^{-2} with an overall average of 7.1 individuals m^{-2}.

Suitable habitat for mussels increased downstream of the upper reaches, which were typically lacking mussel aggregates of $\geq 1\ m^{-2}$ and typically had large substrates such as bedrock and boulders. Those substrate types generally decreased downstream. Bedrock and boulders generally prevent mussels from burrowing into the substrate and, thus, they are subject to being swept downstream by water currents. In addition to bedrock and boulders decreasing in percent composition downstream, the percentage of rooted vegetation in-stream cover also generally decreased downstream. It is possible that this could be a secondary factor in the distribution of freshwater mussels, as plants may fill in substrate that may otherwise be available for freshwater mussels. Conversely, plants also trap sediment which could form habitat for mussels. This relationship requires further investigation in terms of the relationship and possible mechanisms of this pattern.

There were three habitats occupied by the mussel aggregates located in this survey: low gradient riffles, runs, and mid channel pools. Several sites (43, 45, 47, and 48) were located in low gradient riffles. Sites 33 and 49 were located in runs, and Site 46 was located in a mid-channel pool. These are typical habitats for mussels in streams of comparable size to the Spring River.

Based on the present and previous surveys, the Spring River has a diverse and abundant mussel assemblage with a majority of species that rank as Species of Greatest Conservation Need. This survey provided additional information on the distribution, composition, and habitat of freshwater mussels in the Spring River, AR, and reports the aggregate distributions upstream of Hardy. Baseline species composition, density, and population and community numerical standing crops estimates have been established that can be used for future monitoring. Finally, baseline habitat characterization of mussel aggregates in the upper Spring River has been documented and can be used as a comparison for future monitoring.

Aquatic Salamanders.—Despite an extensive search effort, the 14 Ozark Hellbenders found during this survey were restricted to the upper portions of the Spring River at previously known sites. Previous studies of the Spring River hellbender populations were restricted to locations with easy access points. The large number individuals found at there locations made it unnecessary to work in less accessible sites (R. F. Wilkerson, pers. comm.). As a result, there is no record of other historic populations. Therefore, it is unknown if the currently observed limited distribution of known populations is representative of the past hellbender distribution or if populations in the lower reaches of the Spring River have been extirpated.

The large size of the hellbenders found in this study indicates that they are old individuals. In addition, the lack of small individuals indicates there has been a reduction in recruitment within the populations. It can be concluded that the two remaining populations are merely remnants of the previously extensive populations. Hiler (2005) compared the current length frequency distribution of our sample to that of past populations (filling a gap left by Wheeler et al. 2003), confirming the declines in this population began during or even before the 1970's. The cause for this dramatic decline is unknown. Furthermore, it is unknown if the abnormalities found in these salamanders are a result of the causal agent of the decline or a result of compromised immune systems due to contaminants or the senescent nature of the populations.

During our efforts, we conversed with people from the surrounding community that were familiar with the hellbender (the majority from the signs posted at access points, rather than from personal observations). We were told of two anecdotal sites that we were unable to verify: Many Islands Campground (between Sites 29 and 30) and the riffle above the confluence with Rock Creek. These locations have previously been surveyed without success.

Conclusions

The multi-taxonomic approach to this survey allowed for the through examination of three major benthic taxa found in the Spring River. We found the benthos of the Spring River to be a diverse community comprised of four species of crayfish, 29 species of freshwater mussels, and two species of large aquatic salamanders. Although, the Spring River harbors a large diversity of aquatic species, many of these species have a limited geographic distribution and many were only found in low densities. The ecological interactions between these taxa groups are poorly understood and therefore the effects of changes in community composition are largely subject to speculation. The data presented in this report, however, provide baseline data that will allow for the development of a conservation strategy, as well as more detailed examinations of the benthic ecology of this unique river.

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Figure 1. Distribution of survey locations within the main channel of the Spring River between Mammoth Spring and Hardy AR.

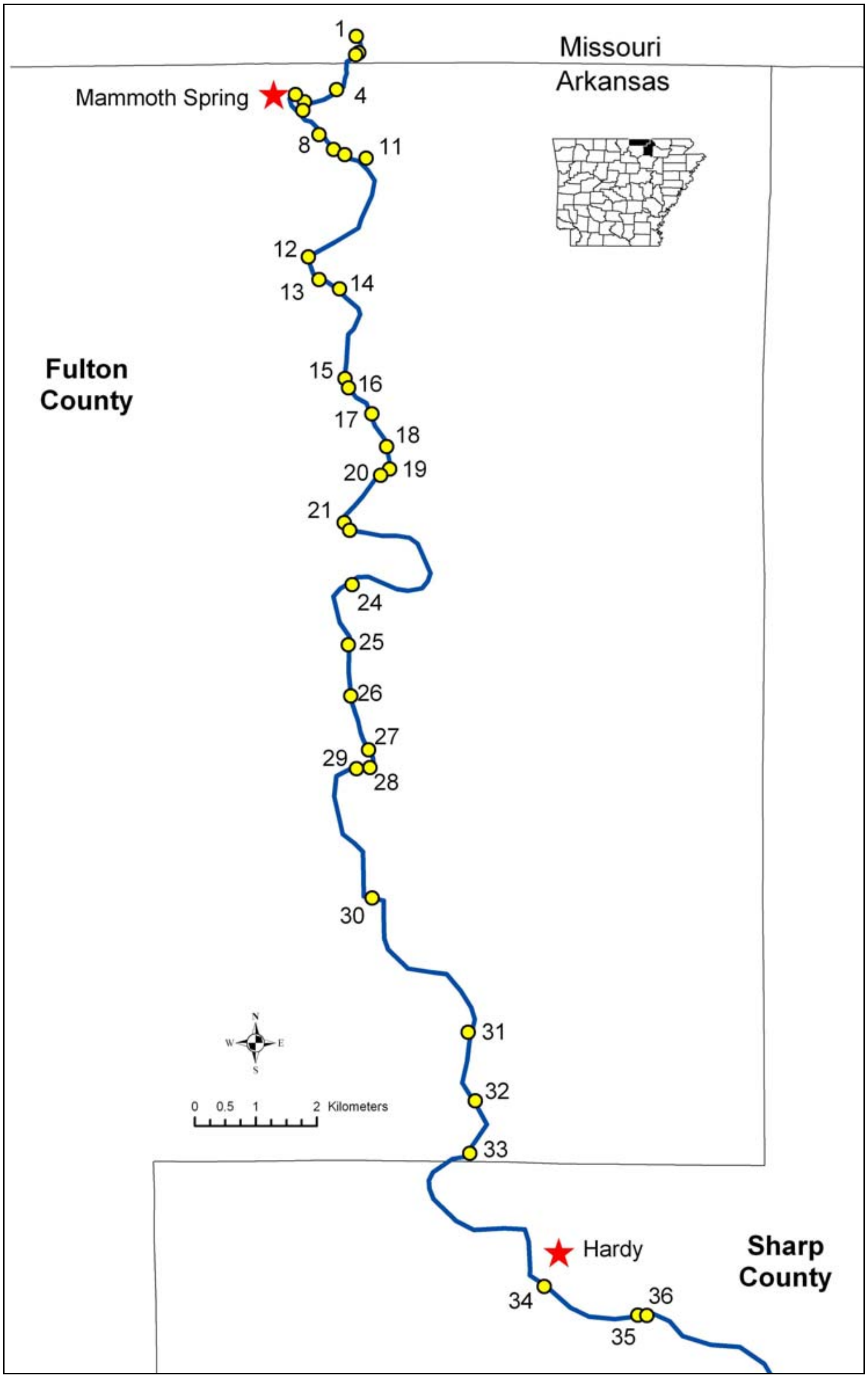


Figure 2. Distribution of survey locations within the main channel of the Spring River between Hardy and Imboden, AR. See Table 2 for GPS coordinates for each site. Inset shows the selected counties in relation to the entire state of Arkansas.

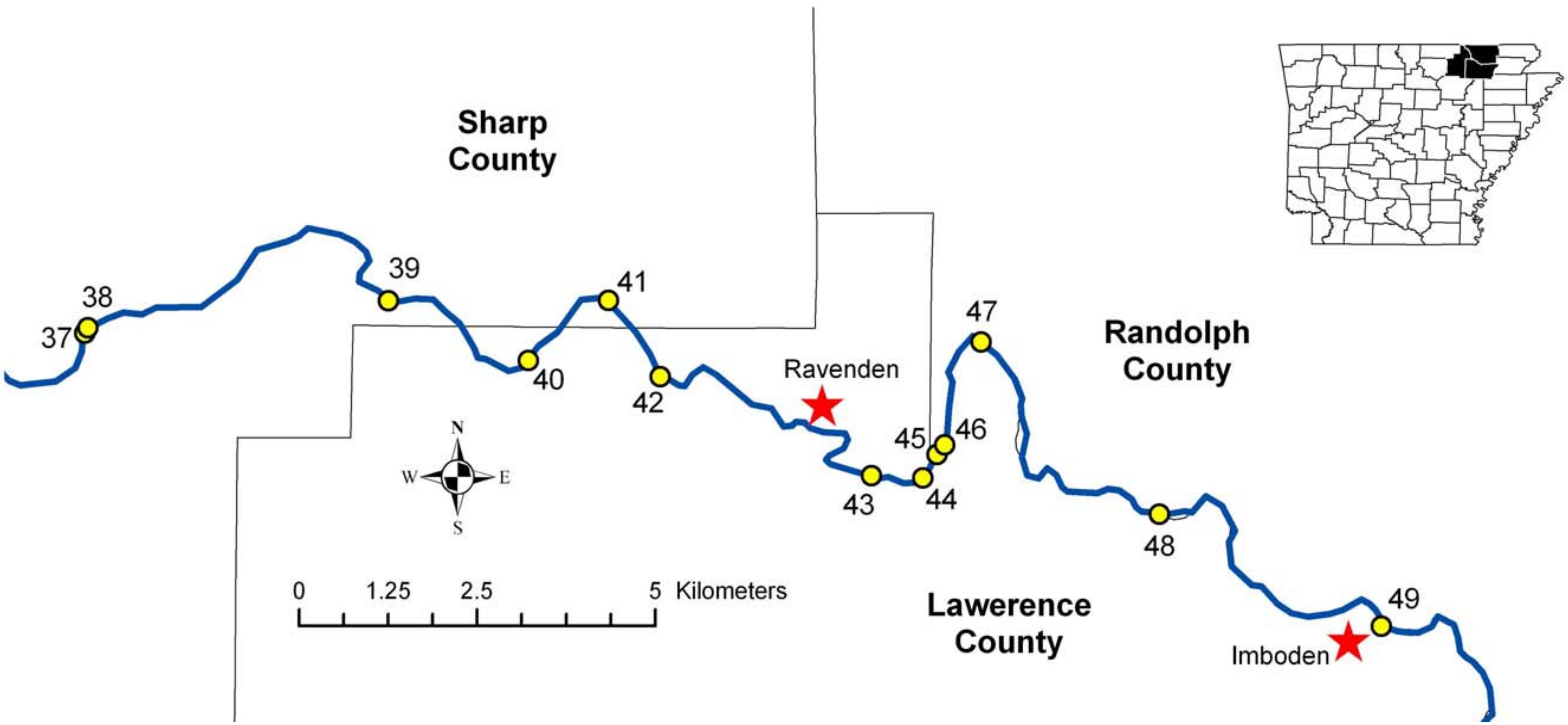


Figure 3. The habitat above the dam at the Jim Hinkle State Fish Hatchery. Picture A. illustrates the habitat directly above the dam facing to the West. Picture B. shows the wing dam that was built to facilitate the intake of river water for the fish hatchery. Picture C. is the screen over the water intake pipe where a hellbender was found.

Table 1. Basin Area Stream Survey habitat codes, habitat acronyms, and habitat types used to characterize the mussel aggregate habitats, including one habitat above and one habitat below, for the Spring River survey.

Code	Acronym	Habitat Type
00	DRY	Dry Channel
01	LGR	Low Gradient Riffle
02	HGR	High Gradient Riffle
03	SCP	Secondary Channel Pool
04	CAS	Cascade
05	BWP-BF	Backwater Pool Boulder Formed
06	BWP-RF	Backwater Pool Rootwad Formed
07	BWP-LF	Backwater Pool Log Formed
08	TRC	Trench/Chute
09	PLP	Plung Pool
10	LSP-LF	Lateral Scour Pool Log Formed
11	LSP-RF	Lateral Scour Pool Rootwad Formed
12	LSP-BF	Lateral Scour Pool Bedrock Formed
13	DPL	Dammed Pool
14	GLD	Glides
15	RUN	Run
16	SRN	Step Run
17	MCP	Mid-channel Pool
18	EGW	Edgewater
19	CCP	Channel Confluence Pool
20	LSP-BoF	Lateral Scour Pool Boulder Formed
21	POW	Pocket Water
22	CRP	Corner Pool
23	STP	Step Pool
24	BRS	Bedrock Sheet

Table 2. The following is a summary of sites searched during this survey, listed in order from upstream to downstream. The site GPS coordinates are listed in both Latitude/Longitude (NAD 27) format, as well as in UTM (WGS 84) for the convenience of the reader. Search time specifically for salamanders is given in man hours, unless otherwise specified (TN = trap nights). An "X" designates whether a site was specifically searched for crayfish (C), mussels (M), or Salamanders (S).

Site	Description	NAD27	WGS 84	Search Time	C	M	S
1	Warm Fork #1	N 36.50293, W 91.52557	15S N632028, W4040751	0.33			X
2	Warm Fork #2	N 36.50051, W 91.52518	15S N632082, W4040505	1.00			X
3	Warm Fork #3	N 36.50018, W 91.52571	15S N632020, W4040446	0.67			X
4	Warm Fork, behind Hatchery	N 36.49510, W 91.52934	15S N631705, W4039877	5 TN	X		X
5	Warm Fork RR Trestle	N 36.49336, W 91.53522	15S N631181, W4039675	0.83			X
6	Hwy 63 Bridge	N 36.49449, W 91.53682	15S N630998, W4039858	2.33	X		X
7	Motel Island	N 36.49212, W 91.53552	15S N631159, W4039540	6.00			X
8	Lassiter Access	N 36.48850, W 91.53266	15S N631418, W4039139	5 TN	X		X
9	Below Lassiter Access	N 36.48627, W 91.53005	15S N631657, W4038899	0.67			X
10	Bluff above Cold Spring	N 36.48551, W 91.52802	15S N631839, W4038815	1.50			X
11	Mouth of Trace Creek	N 36.48493, W 91.52413	15S N632246, W4038758	1.00	X		X
12	2nd Bluff above Dam 3	N 36.47050, W 91.53492	15S N631247, W4037139	1.00	X		X
13	1st Bluff above Dam 3	N 36.46709, W-91.53304	15S N631419, W4036766	0.40	X		X
14	Dam 3	N 36.46568, W 91.52933	15S N632058, W4036267	1.67	X	X	X
15	No specification	N 36.45245, W 91.52857	15S N631846, W4035390	2.25	X	X	X
16	Just above small riffle	N 36.45107, W 91.52796	15S N631902, W4034994	0.33			X
17	No specification	N 36.44719, W 91.52377	15S N631876, W4035460	0.67		X	X
18	No specification	N 36.44231, W 91.52117	15S N632527, W4034030	0.67			X
19	No specification	N 36.43899, W 91.52070	15S N632575, W4033664	1.00			X
20	Cooper's Fall	N 36.43806, W 91.52238	15S N632395, W4033541	4.50		X	X
21	1st Bend below Bayou	N 36.43119, W 91.52913	15S N631831, W4032787	1.50			X
22	Above 1st fall below Bayou	N 36.43005, W 91.52814	15S N631923, W4032662	1.17			X
23	Below 1st fall below Bayou	N 36.43005, W 91.52814	15S N631923, W4032662	1.00			X
24	Dead Man's Curve	N 36.42200, W 91.52785	15S N631961, W4031768	1.33			X

(Table 2 *cont.*)

Site	Description	NAD27	WGS 84	Search Time	C	M	S
25	Below H Jewell Low Takeout	N 36.41312, W 91.52872	15S N631899, W4030784	1.33			X
26	No specification	N 36.40556, W 91.52843	15S N631937, W4029943	1.00			X
27	Bluff accross Sp Rr. Oaks	N 36.39768, W 91.52531	15S N632231, W4029076	1.17			X
28	Bedrock Platform	N 36.39503, W 91.52514	15S N632251, W4028780	1.25			X
29	Falls above Many Is.	N 36.39490, W 91.52758	15S N632032, W4028764	1.17			X
30	Falls below Many Is.	N 36.37578, W 91.52506	15S N632291, W4026645	1.33			X
31	1st fall above Taylor Camp	N 36.35575, W 91.50794	15S N633841, W4024462	1.00	X	X	X
32	Islands below Taylor's Ca	N 36.34560, W 91.50684	15S N633958, W4023408	1.00	X	X	X
33	CR 42 low water bridge	N 36.33788, W 91.50797	15S N633890, W4022467	1.00		X	X
34	1st falls above Hardy Beach	N 36.31804, W 91.49482	15S N635102, W4020283	1.83			X
35	No specification	N 36.31360, W 91.47785	15S N636633, W4019814	1.00			X
36	No specification	N 36.31355, W 91.47620	15S N636783, W4019810	1.17			X
37	Step falls	N 36.24439, W 91.37325	15S N646154, W4012288	0.66			X
38	1 km upstream – St. Hwy 58	N 36.24505, W 91.37273	15S N646200, W4012363	1.00	X		X
39	Rock outcrop	N 36.24777, W 91.32579	15S N650414, W4012736	1.50			X
40	Low waterfall	N 36.23999, W 91.30410	15S N652378, W4011907	1.50			X
41	3 riffles	N 36.24734, W 91.29145	15S N653500, W4012744	0.33			X
42	Bluff bank	N 36.23763, W 91.28362	15S N654223, W4011678	0.50			X
43	Ravenden Access	N 36.22472, W 91.25094	15S N657184, W4010298	1.00	X	X	X
44	Just below Ravenden Access	N 36.22433, W 91.24295	15S N657949, W4010262	1.00	X	X	X
45	Jt. above Hwy 63, Ravenden	N 36.22725, W 91.24064	15S N658106, W4010596	0		X	
46	Riffle and secondary channel	N 36.22845, W 91.23943	15S N658162, W4010602	0.75	X	X	X
47	1 km downstr.Hwy 63, Ravenden bridge	N 36.24128, W 91.23348	15S N658842, W4012034	1.00	X	X	X
48	No specification	N 36.21919, W 91.20615	15S N661373, W4009698	1.00	X	X	X
49	Hwy 62 brdg. to Imb. launch	N 36.20459, W 91.17188	15S N664336, W4008278	1.00	X	X	X

Table 3. Basin Area Stream Survey bankfull width, water width, thalweg depth, average depth, % bottom substrate, and embeddedness average values for mussel aggregate habitat, including 1 habitat above and 1 habitat below the mussel aggregate. For % Bottom substrate: B= bedrock; Bo = boulder; C = cobble; G = gravel; S = sand; F = fines. Emb = Embeddedness.

						% Bottom Substrate						
Site	Habitat Type	Bankfull Width (m)	Water Width (m)	Thalweg Depth (cm)	Average Depth (cm)	B	Bo	C	G	S	F	emb (%)
14	1,15,22	57.7	30.5	89.3	40.6	25	17	18	27	2	12	NA
15	1,15	43.7	30.0	76.7	51.1	20	17	17	23	10	3	NA
17	1,15	30.0	18.5	77.8	39.0	23	13	38	15	3	10	NA
20	2,14,15,17	54.0	39.8	124.2	59.4	32	13	18	18	3	12	NA
31	1,12,14,15	87.3	55.3	120.0	63.7	18	3	25	45	3	5	21.0
32	2,12,15,22	61.0	45.5	150.0	74.3	4	0	24	36	10	6	18.2
33	1,2,12,15	98.8	87.0	118.3	58.1	35	10	30	18	3	5	13.8
43	1,12,14,15,17	62.3	44.0	173.1	92.1	0	29	31	46	11	9	NA
44	1,11,14,17	58.0	43.2	131.6	54.7	10	22	38	10	0	20	NA
45	1,15,17	46.9	30.0	94.0	41.1	7	7	34	19	16	17	29.5
46	1,15,17	62.3	43.8	146.5	61.1	13	18	25	15	5	25	31.9
47	1,14,15,22	62.3	51.0	210.0	93.4	27	5	20	28	0	18	0.0
48	1,14,17,19	45.0	26.2	120.2	65.9	0	0	24	50	20	14	21.6
49	15,17,20	52.7	40.3	208.0	97.9	3	0	20	27	20	27	42.1

Table 4. Basin Area Stream Survey % instream cover, left and right bank angel (bka), stability (s) and terrestrial vegetation (tv) and % canopy open average values for mussel aggregate habitat including 1 habitat above and 1 habitat below the mussel aggregate. For % instream cover: uc-b = undercut bank; lwd = large woody debris; swd = small woody debris; t-v = terrestrial vegetation; ww = whitewater; bo = boulder; brl= bedrock ledge; ; cv = clinging vegetation; and rv = rooted vegetation.

	% Instream Cover									Left Bank				Right Bank		
Site I.D.	uc-b	lwd	swd	t-v	ww	bo	brl	Cv	rv	bka	s	tv	% canopy open	Bka	s	tv
14	1.7	6.7	1.7	15.8	0.0	1.7	1.7	14.2	41.7	156.7	87.5	2.8	96.6	130.0	92.0	2.8
15	6.7	3.3	3.3	15.0	3.3	15.0	5.0	20.0	26.7	171.7	76.7	2.5	97.6	175.0	93.0	3.5
17	30.0	6.3	1.3	6.3	1.3	18.0	0.0	16.3	23.8	158.8	85.0	3.5	83.0	134.5	74.0	3.6
20	11.7	6.7	4.2	10.0	10.0	8.3	0.8	28.3	43.3	149.0	93.3	2.7	99.8	159.0	88.3	3.1
31	2.5	2.5	5.0	10.0	0.0	3.8	0.0	16.3	10.0	155.0	95.0	3.5	79.5	112.5	89.0	3.5
32	0.0	5.0	2.5	16.3	2.5	1.3	0.0	27.5	18.8	136.3	90.0	3.5	99.9	155.0	88.0	2.4
33	0.0	2.5	1.3	37.5	10.0	7.5	0.0	16.3	48.8	127.5	91.3	2.3	99.8	155.0	90.0	2.8
43	2.1	12.1	3.6	20.7	0.0	1.4	0.0	8.5	7.1	56.4	67.9	2.6	NA	60.7	74.0	2.8
44	0.0	7.0	5.0	21.0	5.0	6.0	1.0	21.0	20.0	153.0	83.0	2.9	97.9	137.0	94.0	3.5
45	2.9	20.7	2.9	20.0	3.6	2.1	0.7	15.0	19.3	157.9	92.1	2.9	99.8	90.7	90.0	3.5
46	0.0	8.8	2.5	21.3	5.0	6.3	1.3	17.5	20.0	161.3	81.3	2.8	97.5	108.8	96.0	3.5
47	0.8	12.5	1.7	15.0	1.7	6.7	10.0	12.5	15.0	165.0	88.0	3.2	98.3	137.0	87.0	3.5
48	0.0	13.0	6.0	4.0	1.0	3.0	0.0	12.0	2.0	133.0	65.0	3.1	85.5	106.0	64.0	3.5
49	0.0	6.7	5.0	10.0	0.0	5.0	0.0	21.7	13.3	116.7	61.7	2.7	90.5	135.0	87.0	3.5

Table 5. Summary of the Crayfish captured during survey efforts. Search Time is the cumulative time (min) spent by all searchers.

Species	4	6	8	11	12	13	14	15	31	32	38	43	44	46	47	48	49	Total
Cambarus diogenes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cambarus hubbsi	0	63	3	0	0	0	40	27	7	7	3	0	6	1	19	0	0	176
Cambarus ludovicianus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Orconectes eupunctus	0	0	0	0	0	0	18	17	22	19	2	0	0	12	19	0	0	109
Orconectes marchandi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Orconectes neglectus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Orconectes ozarkae	2	5	5	0	1	0	0	0	11	0	0	0	3	0	0	0	0	27
Orconectes punctimanus	0	13	0	0	0	0	23	18	4	7	0	0	0	3	1	0	0	69
Orconectes virilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Procambarus acutus (blandingii)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Procambarus viaveridis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unknown	0	0	0	0	0	0	0	0	0	0	1*	0	0	0	0	0	0	1
Total	2	81	8	0	1	0	81	62	44	33	6	0	9	16	39	0	0	382
Search Time (min)	5[T]	60	5[T]	5[T]	5[T]	5[T]	60	60	60	60	60	21[T]	60	45	60	60	60	645, 46[T]
Catch per Unit Effort	0.4	1.4	1.6	0	0.2	0	1.4	1.0	0.7	0.6	0.1	0	0.2	0.4	0.7	0	0	0.58, 0.24[T]

* This specimen was an unidentifiable female soft-shell with a body form similar to *Orconectes punctimanus* or *Orconectes eupunctus*.

[T] This is the number of trap nights spent at a site.

Table 6. Percent Composition of the Crayfish Community at each of the sampling sites based upon the actual capture numbers presented in Table 5.

Species	Rank	4	6	8	11	12	13	14	15	31	32	38	44	46	47	48	49	% of Total
Cambarus hubbsi		0	78	38	0	0	0	49	44	16	21	50	67	6	49	0	0	46
Orconectes eupunctus		0	0	0	0	0	0	22	27	50	58	33	0	75	49	0	0	29
Orconectes ozarkae		100	6	62	0	100	0	0	0	25	0	0	33	0	0	0	0	7
Orconectes punctimanus		0	16	0	0	0	0	28	29	9	21	0	0	19	2	0	0	18
Unknown		0	0	0	0	0	0	0	0	0	0	17	0	0	0	0	0	<1
Total		2	81	8	0	1	0	81	62	44	33	6	9	16	39	0	0	382

Table 7. Species list and relative abundance of freshwater mussel assemblages at selected sites within the Spring River. See Table 2 for specific site location.

Taxa	**Rank**	**33**	**43**	**45**	**46**	**47**	**48**	**49**	**Total**
Actinonaias ligamentina	S5	0	0	12	17	3	7	17	56
Alasmidonta marginata	S3	0	0	2	6	2	0	2	12
Amblema plicata	S5	0	3	11	8	0	1	18	41
Cyclonaias tuberculata	S3	0	2	22	50	8	7	12	101
Cyprogenia aberti	S2	0	2	0	0	0	1	0	3
Ellipsaria lineolata	S3	0	0	1	1	0	0	0	2
Elliptio dilatata	S4	0	33	49	373	36	34	53	578
Fusconaia ebena	S3	0	0	1	2	0	5	4	12
Fusconaia flava	S4	0	1	7	7	0	5	19	39
Lampsilis cardium	S4	0	0	1	1	1	2	4	9
Lampsilis hydiana	S3	0	0	0	2	0	0	3	5
Lampsilis reeviana	S3	10	0	1	3	0	1	1	16
Lampsilis siliquoidea	S3	0	1	0	0	0	0	0	1
Lasmigona costata	S3	0	0	0	7	1	0	1	9
Obliquaria reflexa	S4	0	0	1	2	0	1	2	6
Pleurobema cordatum	S1	0	0	10	14	0	0	0	24
Pleurobema sintoxia	S3	0	1	4	5	0	3	15	28
Potamilus purpuratus	S4	0	0	0	2	0	0	0	2
Ptychobranchus occidentalis	S3	0	2	14	34	50	9	8	117
Quadrula cylindrica	S2	0	1	16	15	1	8	13	54
Quadrula metanevra	S3	0	0	17	6	1	4	6	34
Quadrula nodulata	S4	0	1	0	0	0	0	0	1
Quadrula pustulosa	S5	0	0	2	3	0	0	7	12
Quadrula quadrula	S5	0	0	0	0	0	1	0	1
Tritigonia verrucosa	S4	0	0	1	3	1	0	3	8
Truncilla donaciformis	S3	0	0	1	3	0	0	1	5
Truncilla truncata	S4	0	0	7	11	13	0	21	52
Venustaconcha pleasii	S3	1	0	0	0	0	0	0	1
Villosa iris	S2	14	4	1	0	0	0	0	19
Total		25	51	181	575	117	89	210	1248
Species Richness		3	11	21	23	11	15	20	29

Table 8. Site 33 freshwater mussel collection information from the quantitative sampling during the summer of 2005. Numerical data includes by species: number collected, percent of total, population estimate (± 95% CI), mean density, and standard deviation (SD) of mean density. The Totals row represents the overall values, including the community numerical standing crop estimate (± 95% CI), which is at the bottom of the population estimate column.

Date: 20050729
Location: Easting 633890 Northing 4022467
Stratum Size:122m x 4m = 488m^2
Substrate: gravel/cobble
Total Samples: 25
Minimum - Maximum density (#/m^2): 0.0-3.0
Mean density #/m^2 (SD):1.04 (1.20)

Species	**Number Collected**	**Percent of Total**	**Population Estimate (±95% CI)**	**Mean density (#/m^2)**	**SD of Mean Density**
Lampsilis reeviana	10	40	195±130	0.4	0.78
Venustaconcha pleasii	1	4	273±109	0.6	0.65
Villosa iris	14	56	20±34	0.04	0.20
Totals	25	100	288±200	1.04	1.20

Table 9. Site 43 freshwater mussel collection information from the quantitative sampling during the summer of 2005. Numerical data includes by species: number collected, percent of total, population estimate (± 95% CI), mean density, and standard deviation (SD) of mean density. The Totals row represents the overall values, including the community numerical standing crop estimate (± 95% CI), which is at the bottom of the population estimate column.

Date: 20050510
Location: Easting 657184 Northing 4010298
Stratum Size: 69m x 12m = 828m^2
Substrate: cobble/gravel/sand
Total Samples: 25
Minimum - Maximum density (#/m^2): 0.0 - 12.0
Mean density #/m^2 (SD): 2.13 (2.84)

Species	**Number Collected**	**Percent of Total**	**Population Estimate (±95% CI)**	**Mean density (#/m^2)**	**SD of Mean Density**
Amblema plicata	3	5.9	99±97	0.10	0.34
Cyclonaias tuberculata	2	3.9	66±81	0.10	0.28
Cyprogenia aberti	2	3.9	66±81	0.10	0.28
Elliptio dilatata	33	64.7	1093±608	1.37	2.12
Fusconaia flava	1	2.0	33±59	0.04	0.20
Lampsilis siliquoidia	1	2.0	33±59	0.04	0.20
Pleurobema sintoxia	1	2.0	33±59	0.04	0.20
Ptychobranchus occidentalis	2	3.9	66±81	0.10	0.41
Quadrula cylindrical	1	2.0	33±59	0.04	0.20
Quadrula nodulata	1	2.0	33±59	0.04	0.20
Villosa iris	4	7.8	132±109	0.20	0.38
Totals	51		1656±758	2.13	2.84

Table 10. Site 45 freshwater mussel collection information from the quantitative sampling during the summer of 2005. Numerical data includes by species: number collected, percent of total, population estimate (± 95% CI), mean density, and standard deviation (SD) of mean density. The Totals row represents the overall values, including the community numerical standing crop estimate (± 95% CI), which is at the bottom of the population estimate column.

Date: 20050622
Location: Easting 658106 Northing 4010596
Stratum Size: 105m x 13m = 1365m^2
Substrate: gravel/cobble/sand
Total Samples: 25
Minimum - Maximum Mean density (#/m^2): 0.0 - 24.0
Mean density #/m^2 (SD): 7.9 (7.36)

Species	**Number Collected**	**Percent of Total**	**Population Estimate (±95% CI)**	**Mean density (#/m^2)**	**SD of Mean Density**
Actinonaias ligamentina	12	6.6	655±450	0.6	0.95
Alasmidonta marginata	2	1.1	109±137	0.1	0.29
Amblema plicata	11	6.1	608±347	0.4	0.73
Cyclonaias tuberculata	22	12.2	1201±526	1.0	1.11
Ellipsaria lineolata	1	0.6	55±99	0.1	0.21
Elliptio dilatata	49	27.1	2675±1211	2.1	2.55
Fusconaia ebena	1	0.6	55±99	0.1	0.21
Fusconaia flava	7	3.9	382±266	0.3	0.59
Lampsilis cardium	1	0.6	55±99	0.1	0.21
Lampsilis reeviana	1	0.6	55±99	0.1	0.21
Obliquaria reflexa	1	0.6	55±99	0.1	0.21
Pleurobema cordatum	10	5.5	546±472	0.4	0.99
Pleurobema sintoxia	4	2.2	218±154	0.2	0.39
Ptychobranchus occidentalis	14	7.7	764±399	0.6	0.84
Quadrula cylindrica	16	8.8	874±440	0.7	0.93
Quadrula metanevra	17	9.4	928±435	0.7	0.92
Quadrula pustulosa	2	1.1	109±137	0.1	0.29
Tritigonia verrucosa	1	0.6	55±99	0.1	0.21
Truncilla donaciformis	1	0.6	55±99	0.1	0.21
Truncilla truncate	7	3.9	382±364	0.3	0.76
Villosa iris	1	0.6	55±99	0.1	0.21
Totals	181		9883±3504	7.9	7.36

Table 11. Site 46 freshwater mussel collection information from the quantitative sampling during the summer of 2005. Numerical data includes by species: number collected, percent of total, population estimate (± 95% CI), mean density, and standard deviation (SD) of mean density. The Totals row represents the overall values, including the community numerical standing crop estimate (± 95% CI), which is at the bottom of the population estimate column.

Date: 20050628
Location: Easting 658162 Northing 4010602
Stratum Size:30m x 14m = 420m^2
Substrate: gravel/cobble
Total Samples: 25
Minimum - Maximum density (#/m^2): 10.0 - 41.0
Mean density #/m^2 (SD): 24.0 (8.54)

Species	**Number Collected**	**Percent of Total**	**Population Estimate (±95% CI)**	**Mean density (#/m^2)**	**SD of Mean Density**
Actinonaias ligamentina	17	3.0	286±123	0.6	0.86
Alasmidonta marginata	6	1.0	101±63	0.2	0.44
Amblema plicata	8	1.4	134±81	0.3	0.56
Cyclonaias tuberculata	50	8.7	840±231	2.0	1.61
Ellipsaria lineolata	1	0.2	17±29	0.4	0.20
Elliptio dilatata	373	64.9	6266±1095	15.4	7.64
Fusconaia ebena	2	0.3	34±40	0.1	0.28
Fusconaia flava	7	1.2	17±29	0.3	0.20
Lampsilis cardium	1	0.2	17±29	0.3	0.20
Lampsilis hydiana	2	0.3	34±40	0.1	0.28
Lampsilis reeviana	3	0.5	50±64	0.1	0.49
Lasmigona costata	7	1.2	118±66	0.3	0.46
Obliquaria reflexa	2	0.3	34±58	0.1	0.41
Pleurobema cordatum	14	2.4	235±133	0.5	0.93
Pleurobema sintoxia	5	0.9	84±73	0.1	0.51
Potamilus purpuratus	2	0.3	34±40	0.1	0.28
Ptychobranchus occidentalis	34	5.9	571±193	1.3	1.35
Quadrula cylindrical	15	2.6	252±145	0.5	1.01
Quadrula metanevra	6	1.0	101±87	0.2	0.61
Quadrula pustulosa	3	0.5	50±64	0.1	0.45
Tritigonia verrucosa	3	0.5	50±48	0.1	0.34
Truncilla donaciformis	3	0.5	50±48	0.1	0.34
Truncilla truncate	11	1.9	185±94	0.3	0.66
Totals	575		9677±1222	24.0	8.54

Table 12. Site 47 freshwater mussel collection information from the quantitative sampling during the summer of 2005. Numerical data includes by species: number collected, percent of total, population estimate (± 95% CI), mean density, and standard deviation (SD) of mean density. The Totals row represents the overall values, including the community numerical standing crop estimate (± 95% CI), which is at the bottom of the population estimate column.

Date: 20050730
Location: Easting 658842 Northing 4012034
Stratum Size:136m x 70m = 9520m^2
Substrate: gravel/cobble
Total Samples: 25
Minimum - Maximum density (#/m^2): 0.0 - 13.0
Mean density #/m^2 (SD): 4.7 (3.70)

Species	**Number Collected**	**Percent of Total**	**Population Estimate (±95% CI)**	**Mean density (#/m^2)**	**SD of Mean Density**
Actinonaias ligamentina	3	2.6	25±41	0.1	0.60
Alasmidonta marginata	2	1.7	16±19	0.1	0.28
Cyclonaias tuberculata	8	6.8	66±43	0.3	0.63
Elliptio dilatata	36	30.8	297±116	1.4	1.71
Lampsilis cardium	1	0.9	8±14	0.1	0.20
Lasmigona costata	1	0.9	8±14	0.1	0.20
Ptychobranchus occidentalis	50	42.7	412±114	2.0	1.68
Quadrula cylindrica	1	0.9	8±14	0.1	0.20
Quadrula metanevra	1	0.9	8±14	0.1	0.20
Tritigonia verrucosa	1	0.9	8±14	0.1	0.20
Truncilla truncate	13	11.1	107±48	0.5	0.71
Totals	117		964±252	4.7	3.70

Table 13. Site 48 freshwater mussel collection information from the quantitative sampling during the summer of 2005. Numerical data includes by species: number collected, percent of total, population estimate (± 95% CI), mean density, and standard deviation (SD) of mean density. The Totals row represents the overall values, including the community numerical standing crop estimate (± 95% CI), which is at the bottom of the population estimate column.

Date: 20050608
Location: Easting 661373 Northing 4009698
Stratum Size: 120m x 23m = 2760m^2
Substrate: gravel/cobble
Total Samples: 25
Minimum - Maximum density (#/m^2): 0.0 - 17.0
Mean density #/m^2 (SD): 3.9 (4.76)

Species	**Number Collected**	**Percent of Total**	**Population Estimate (±95% CI)**	**Mean density (#/m^2)**	**SD of Mean Density**
Actinonaias ligamentina	7	7.9	773±739	0.3	0.76
Amblema plicata	1	1.1	110±201	0.1	0.21
Cyclonaias tuberculata	7	7.9	773±679	0.3	0.70
Cyprogenia aberti	1	1.1	110±201	0.1	0.21
Elliptio dilatata	34	38.2	3754±1973	1.5	2.04
Fusonaia ebena	5	5.6	552±579	0.2	0.21
Fusconaia flava	5	5.6	552±579	0.2	0.60
Lampsilis cardium	2	2.2	221±278	0.1	0.29
Lampsilis reeviana	1	1.1	110±201	0.1	0.21
Obliquaria reflexa	1	1.1	110±201	0.1	0.21
Pleurobema sintoxia	3	3.4	331±442	0.1	0.46
Ptychobranchus occidentalis	9	10.1	994±756	0.4	0.78
Quadrula cylindrica	8	9.0	883±625	0.3	0.65
Quadrula metanevra	4	4.5	442±374	0.2	0.39
Quadrula quadrula	1	1.1	110±201	0.1	0.21
Totals	89		9826±4599	3.9	4.76

Table 14. Site 49 freshwater mussel collection information from the quantitative sampling during the summer of 2005. Numerical data includes by species: number collected, percent of total, population estimate (± 95% CI), mean density, and standard deviation (SD) of mean density. The Totals row represents the overall values, including the community numerical standing crop estimate (± 95% CI), which is at the bottom of the population estimate column.

Date: 20050609
Location: Easting 664336 Northing 4008278
Stratum Size: 25m x 15m = 375m^2
Substrate: gravel/cobble/sand
Total Samples: 25
Minimum - Maximum density (#/m^2): 0.0 - 19.0
Mean density #/m^2 (SD): 8.4 (5.51)

Species	**Number Collected**	**Percent of Total**	**Population Estimate (±95% CI)**	**Mean density (#/m^2)**	**SD of Mean Density**
Actinonaias ligamentina	17	8.1	255±102	0.6	0.80
Alasmidonta marginata	2	1.0	30±35	0.1	0.28
Amblema plicata	18	8.6	270±182	0.8	1.43
Cyclonaias tuberculata	12	5.7	180±91	0.5	0.71
Elliptio dilatata	53	25.2	795±263	2.1	2.06
Fusconaia ebena	4	1.9	60±60	0.2	0.47
Fusconaia flava	19	9.0	285±118	0.7	0.93
Lampsilis cardium	4	1.9	60±48	0.2	0.37
Lampsilis hydiana	3	1.4	45±56	0.1	0.44
Lampsilis reeviana	1	0.5	15±25	0.1	0.20
Lasmigona costata	1	0.5	15±25	0.1	0.20
Obliquaria reflexa	2	1.0	30±51	0.1	0.40
Pleurobema sintoxia	15	7.1	225±133	0.6	1.04
Ptychobranchus occidentalis	8	3.8	120±80	0.3	0.63
Quadrula cylindrica	13	6.2	195±83	0.6	0.65
Quadrula metanevra	6	2.9	90±84	0.2	0.63
Quadrula pustulosa	7	3.3	105±86	0.3	0.68
Tritigonia verrucosa	3	1.4	45±42	0.1	0.33
Truncilla donaciformis	1	0.5	15±25	0.1	0.20
Truncilla truncate	21	10.0	315±146	0.8	1.14
Totals	210		3150±702	8.4	5.51

Table 15. Spring River mussel bed area, number of samples taken, proportion of the bed sampled, mean mussel density, calculated sampling error, and number of samples needed to obtain 80% and 90% sampling error based on equations provided by Southwood (1979) and Downing and Downing (1992).

Site	Area (m^2)	Samples (*n*)	Proportion sampled (%)	Mean density ($\#/m^2$)	Calculated CL (Southwood 1979)	*n* required for 80% CL (Southwood 1979)	*n* required for 90% CL (Southwood 1979)	*n* required for 80% CL (Downing and Downing 1992)	*n* required for 90% CL (Downing and Downing 1992)
33	488	24	5	1.0	76	33	133	25	98
43	828	24	3	2.1	73	45	179	17	69
45	1365	23	2	7.9	81	22	87	9	36
46	420	24	6	24.0	93	3	13	5	20
47	9520	25	1	4.7	84	16	63	12	46
48	2760	23	1	3.9	74	38	151	13	51
49	375	25	7	8.4	87	11	43	9	35

Table 16. Spring River mussel bed sample sizes, total species richness observed, first and second order Jackknife estimates, and number of species with only 1 and 2 occurrences in samples.

Site	Samples (*n*)	Total Species richness observed	1st order Jackknife estimate of richness	2nd order Jackknife estimate of richness	# of species with only 1 occurrence	# of species with only 2 occurrences
33	24	3	4	5	1	0
43	24	11	14	15	5	3
45	23	21	29	34	8	2
46	24	23	28	27	4	4
47	25	11	17	21	5	1
48	23	15	20	23	5	1
49	25	20	24	26	3	2

Table 17. A summary of the hellbender salamanders found during this study.

PIT Number	TL	SVL	Mass	Sex	Site	Date
043*323*531	499	332	653	M	14	2003-08-13
043*332*084	520	364	875	M	14	2003-08-13
043*334*785	560	379	1282	F	14	2003-08-13
Deceased	522	367	812	F	6	2004-02-20
066*789*789	535	372	901	F	6	2004-02-20
067*300*828	504	361	821	F	6	2004-09-03
067*258*631	479	342	830	M	14	2004-09-06
073*571*094	533	357	864	M	14	2004-10-04
Deceased	545	366	792	F	20	2004-10-04
072*353*357	521	352	852	M	14	2004-10-15
132-D87A+	486	333	1077	M	14	2005-03-14
072*574*051	504	350	1007	M	14	2005-03-14
133-9B3E+	525	358	851	M	14	2005-06-28
132-D87A+	495	327	1173	M	14	2005-06-28
073*367*328	412	273	347	?	14*	2006-03-10

+ These animals were PIT tagged with Trovan tags during previous studies.
* This hellbender was actually captured above the dam at Site 14.

Appendix I. List of Species Previously Identified from the Spring River Drainage.

Appendix Ia. – List of crayfish species expected to be found in the upper reaches of the Spring River, based upon literature records. Taxonomic and Common names follow Wagner (2004).

Common Name	**Scientific Name(status)***	**Citation**
Devil crayfish	*Cambarus diogenes* R	Flinders 2000; Pflieger 1996; Reimer 1963
Hubb's crayfish	*Cambarus hubbsi*	Flinders 2000; Pflieger 1996
Unnamed crayfish	*Cambarus ludovicianus* N	Reimer 1963
Coldwater crayfish	*Orconectes eupunctus* U	Flinders 2000; Pflieger 1996, Reimer 1963
Mammoth Spring crayfish	*Orconectes marchandi* C	Flinders 2000; Pflieger 1996; Reimer 1963
Ringed crayfish	*Orconectes neglectus* U	Flinders 2000
Ozark crayfish	*Orconectes ozarkae* W	Flinders 2000; Pflieger 1996; Reimer 1963
Spothanded crayfish	*Orconectes punctimanus* W	Flinders 2000; Pflieger 1996
Northern crayfish	*Orconectes virilis* N	Pflieger 1996; Reimer 1963
White River crayfish	*Procambarus acutus (blandingii)* R	Flinders 2000; Reimer 1963
Vernal crayfish	*Procambarus viaveridis* R	Flinders 2000

* Status within the Spring River is based on Flinders (2000). R = Rare, U = Uncommon, C = Common, W = Widespread, N = Not found

Appendix Ib.—List of Freshwater mussel species expected to be found in the upper reaches of the Spring River based upon literature records.

Common Name	**Scientific Name**	**Citation**
Mucket	*Actinonaias ligamentina*	Davidson et al. 1997; Rust 1993
Elktoe	*Alasmidonta marginata*	Rust 1993
Slippershell	*Alasmidonta viridis*	Davidson et al. 1997; Harris et al 1997
Threeridge	*Amblema plicata*	Davidson et al. 1997; Rust 1993

Paper floater	*Andonta imbecilis*	Oesch 1995
Rock pocketbook	*Arcidens confragosus*	Rust 1993
Purple wartyback	*Cyclonais tuberculata*	Oesch 1995; Rust 1993
Western fanshell	*Cyprogenia aberti*	Harris and Gordon 1987; Harris et al. 1997; Rust 1993
Ladyfinger	*Elliptio dilatata*	Davidson et al. 1997; Oesch 1995; Rust 1993
Butterfly	*Ellipsaria lineolata*	Rust 1993
Curtis pearly mussel	*Epioblasma florentina curtisi*	Harris and Gordon 1987
Turgid blossom shell	*Epioblasma turgidula*	Harris and Gordon 1987
Snuffbox	*Epioblasma triquetra*	Harris and Gordon 1987; Rust 1993
Ebony	*Fusconaia ebena*	Rust 1993
Wabash pig-toe	*Fusconaia flava*	Davidson et al. 1997; Rust 1993
Ozark pigtoe	*Fusconaia ozarkensis*	Davidson et al. 1997; Oesch 1995; Rust 1993
Unnamed mussel	*Fusconaia undata*	Rust 1993
Pink mucket	*Lampsilis abrupta*	Harris and Gordon 1987; Harris et al. 1997; Rust 1993
Plain pocketbook	*Lampsilis cardium*	Davidson et al. 1997; Rust 1993; Oesch 1995
Louisana fatmucket	*Lampsilis hydiana*	Rust 1993
Fatmucket	*Lampsilis radiate* / *siliquoidea*	Davidson et al. 1997; Rust 1993
Arkansas broken-ray	*Lampsilis reeviana*	Davidson et al. 1997; Oesch 1995; Rust 1993
Yellow sandshell	*Lampsilis teres*	Rust 1993
Heel splitter	*Lasmigonia complanata*	Rust 1993
Fluted shell	*Lasmigonia costata*	Davidson et al. 1997; Rust 1993
Scaleshell	*Leptodea leptodon*	Davidson et al. 1997; Harris and Gordon 1987; Harris et al. 1997
Fragile papershell	*Leptodea fragilis*	Rust 1993
Black sandshell	*Ligumia recta*	Oesch 1995; Rust 1993
Washboard	*Megalonaias nervosa*	Rust 1993
Three horned warty-back	*Obliquaria reflexa*	Rust 1993

Hickory nut	*Obovaria olivaria*	Rust 1993
Bankclimber	*Plectomerus dombeyanus*	Rust 1993
Round pigtoe	*Pleurobema sintoxia*	Davidson et al. 1997; Oesch 1995; Rust 1993
Purple shell	*Potamilus purpuratus*	Davidson et al. 1997; Rust 1993
Kidney shell	*Ptychobranchus occidentalis*	Davidson et al. 1997; Oesch 1995; Rust 1993
Rabbitsfoot	*Quadrula cylindrical*	Harris and Gordon 1987; Harris et al. 1997; Rust 1993
Monkeyface	*Quadrula metanevera*	Rust 1993
Wartyback	*Quadrula nodulata*	Rust 1993
Pimpleback	*Quadrula pustulosa*	Davidson et al. 1997; Rust 1993
Mapleleaf	*Quadrula quadrula*	Rust 1993
Salamander mussel	*Simpsonaias ambigua*	Harris and Gordon 1987; Rust 1993
Squawfoot	*Strophitus undulates*	Davidson et al. 1997; Oesch 1995; Rust 1993
Pistolgrip	*Tritogonia verrucosa*	Rust 1993
Deertoe	*Truncilla truncate*	Rust 1993
Ellipse	*Venustaconcha ellipsiformis*	Davidson et al. 1997; Oesch 1995
Rainbow	*Villosa iris*	Davidson et al. 1997; Oesch 1995; Rust 1993
Little spectacle-case	*Villosa lienosa*	Davidson et al. 1997; Oesch 1995

Appendix Ic.—List of aquatic salamander species expected to be found in the upper reaches of the Spring River based upon literature records.

Common Name	**Scientific Name**	**Citation**
Ozark hellbender	*Cryptobranchus alleganiensis bishopi*	Trauth et al. 2004
Red River Mudpuppy	*Necturus maculosus louisianensis*	Trauth et al. 2004

Appendix II. General Survey Site Descriptions

Site No. 1. -- Search Date: June 10, 2004. N 36.50293, W 91.52557. Site 1 is located on the Warm Fork River (Fulton County, Arkansas), 51 m below the first low water bridge upstream from the confluence of the Warm Fork and Spring River. The substrate is comprised of fine particulates, cobble, small boulders, and small slabs of bedrock. There was a minimal amount of silt covering the habitat throughout the reach (< 1.0 cm), which stretches ca. 50 m upstream to downstream. The maximum diameter of the river was 9 m and the maximum depth did not exceed 1.5 m. A total 0.33 mhr was spent searching this site. Water temperature was 21.0°C.

Site No. 2. -- Search Date: June 10, 2004. N 36.50051, W 91.52518. Site 2 is located on the Warm Fork River, 185 m downstream of site 1. The site is a low-gradient riffle with a maximum channel width of 13 m and the habitat extends 42 m upstream to downstream. The substrate is comprised of large cobble, small boulders, and slab rock. The water is swift and the habitat is very similar to that of Cooper's Creek (Lumpkin County, Georgia), which supports a healthy population of eastern hellbenders. There is a cold water spring located on the left bank. This site had the most potential to support hellbenders among survey sites on the Warm Fork. A total of 1 mhr was spent searching this site. Water temperature was 21.0°C.

Site No. 3. -- Search Date: June 10, 2004. N 36.50018, W 91.52571. Site 3 is a lateral scour pool (bedrock formed) located 30 m downstream from site 2. The maximum water depth of the site was 1.5 m, and the habitat extends 46 m upstream to downstream. The substrate was comprised gravel and large boulders intermittently spaced with a small amount of silt covering the benthos (< 1 cm). A total of 0.66 mhr was spent searching this site. Water temperature was 21.0°C.

Site No. 4. -- Search Date: July 14, 2005. N36.49510, W 91.52571. Site 4 is a glide that ends in a narrow riffle located adjacent to the Mammoth Spring National Fish Hatchery. Maximum water depth was < 1 m and substrate was largely gravel with scattered cobble and an occasional boulder. Small areas of emergent vegetation lined the north bank of the creek. After a brief visual search of the boulders, five minnow traps were set overnight in this location.Search Date: July 14, 2005. N36.49510, W 91.52571. Site 4

Site No. 5. -- Search Date: June 10, 2004. N 36.49336, W 91.53522. Site 5 is a lateral scour pool located on the Warm Fork River ca. 100 m upstream from the confluence of the Warm Fork and Spring River. The upstream edge of the site is located directly below the Burlington-Northern Santa Fe railroad bridge, and extends downstream 111 m to the confluence of the two rivers. Although the majority of site 5 can be searched via skin diving, the lower end of the site required scuba diving to thoroughly search the locality. The habitat directly downstream of the bridge is comprised of large chunks of concrete rip-rap with a moderate amount of overlaying silt (ca. 1 cm). Downstream of the rip-rap, gravel and large boulders dominate the substrate. A total of 0.83 mhr was spent searching this site. There is an anecdotal report of a hellbender being caught on hook and line from this site in the late 1990's (SET, unpub. data). Water temperature was 21.0°C.

Site No. 6. – Search Dates: June 23, 2004; July 9, 2004; September 3, 2004; November 27, 2004; December 18, 2004. N 36.49449, W 91.53682. Site 6 (Dam Site 1) is the first of three historical sites surveyed and is located directly downstream of the Arkansas State Highway 63 Bridge (Appendix III). Site 6 is also the most upstream locality on the Spring River ca. 150 m downstream from Dam 1. The substrate is dominated by intermittently spaced large boulders overlying gravel with large amounts of rooted vegetation throughout the entire site during each return visit. The maximum channel width was 54 m, and maximum water was depth of 2.5 m. Potential hellbender habitat extended from just above the Arkansas State Highway 63 Bridge ~ 100 m downstream. A total of 10.83 mhr was spent searching this site. Water temperature was 17.5°C

Site No. 7. -- Search Date: June 9, 2004. N 36.49212, W 91.53552. Site 7 is located ca. 564 m below Dam 1 and is the second of three historical sites surveyed. Two sets of small waterfalls define the upstream edge of habitat. Directly below the falls the benthos is comprised of fine particulates, gravel, cobble, and large boulders with patches of aquatic vegetation, which are distributed throughout the entire site. The water depth below both set of falls varies between 0.5 m and 4 m. A large island divides the river downstream of the falls, with good hellbender habitat on both sides. The substrate on the west side of the island is made up of gravel, cobble, boulders, with large amounts of rooted vegetation. However, the east side of the island possesses far less vegetation and the substrate is primarily composed of cobble and boulders. It is important to note that this site historically was inhabited by what was thought to be a healthy population of hellbenders (Peterson 1985); only, one animal has been found since then. The potential hellbender habitat extends 291 m downstream from the falls. A total of 6 mhr was spent searching this site. Water temperature was 19.6°C.

Site No. 8. -- Search Date: July 14,2005. N 36.48850, W 91.53266. Site 8 is the Arkansas Game and Fish Commission Lassiter Access at Mammoth Spring , AR. This site was the extreme upper end of the SRRR 01 study site for the habitat assessment survey by Christian et al. (2004). The entire stretch of the river around this sites is comprised of a low gradient riffle ranging from a few centimeters deep near the bank to 1 m deep at the thalwegs. The substrate is largely loose gravel with an occasional embedded boulder. The bottom of the river is nearly completely covered with rooted vegetation, covering most of the cover rocks. This site has been unsuccessfully searched for hellbenders in the past. We attempted to kick-seine and trap this site with limited success.

Site No. 9. -- Search Date: June 8, 2004. N 36.48627, W 91.53005. Site 9 is located 933 m upstream from the mouth of Trace Creek. The upstream section of potential habitat can be characterized as a low gradient riffle, which transfers to a run and then to a lateral scour pool (bedrock formed). The substrate throughout the entire length of the search area varies from fine particulates to bedrock boulders. Rooted vegetation begins to dominate the benthos downstream of the riffles; however, the lateral scour pool along the right side of the river contains patches of very good hellbender habitat. Both banks along the study site have been residentially developed. The riparian zone along the left bank has been severely affected by clear cutting. A total of 0.66 mhr was spent searching this site.

Site No. 10. -- Search Date: June 17, 2004. N 36.48551, W 91.52802. Site 10 is located ca. 1.3 km above the Arkansas Game and Fish Commissions Cold Spring Curve River Access. A bedrock bluff along the right bank extends down into the water ca 1.5 m. The potential hellbender habitat extends 25 m into the channel, primarily comprised of large boulders divided by patches of gravel and rooted vegetation. There was a minimal amount of silt covering the habitat (< .01 cm). Substrate beyond the potential hellbender habitat becomes completely dominated by rooted vegetation and gravel. The survey area extends 80 m from upstream edge to downstream edge. A total of 1.5 mhr was spent searching this site. Water temperature was 19.3°C.

Site No. 11. -- Search Dates: June 8, 2004; June 17, 2004. N 36.48493, W 91.52413. Site 11 is located 488 m upstream from the Arkansas Game and Fish Commission Cold Spring

Curve river access, at the mouth of Trace Creek. The banks at the mouth of Trace Creek are completely dominated by rip-rap from the rail road, which runs along the west side of the river. The majority of substrate was comprised of cobble and slab-rock/boulder. There was a minimal amount of silt covering the habitat (< 0.05 cm). The maximum water depth was ca. 4 m. The habitat searched extends 103 m from the upstream edge to downstream edge. A total of 3.25 mhr was spent searching this site. It is important to note that there has been anecdotal evidence of a hellbender caught on hook and line at this site.

Site No. 12. -- Search Date: June 2, 2004. N 36.47050, W 91.53492. Site 12 is located 1,098 m downstream of the Arkansas Game and Fish Commissions Cold Spring Curve river access and 675 m upstream of Dam No. 3. The habitat searched lines the right bank for 54 m and extends into the channel ca. 20 m. Site 12 is a lateral scour pool (bedrock formed) with a maximum water depth of 7.2 m. The substrate is comprised of primarily chunk and slab rock, which has eroded from the bluff above the river. There is also a minimal amount of rooted vegetation along the right side of the river channel. However, the entire habitat is covered in 2-3 cm of silt. A total of 1 mhr was spent searching this site. Water temperature was 19.6°C.

Site No. 13. -- Search Date: June 8, 2004. N 36.46709, W 91.53304. Site 13 is located 350 m downstream of site12 and 300 m upstream of Dam No. 3. The habitat searched stretches 70 m along the right bank and extends 30 m into the channel. The substrate consists primarily of intermittently spaced large slab and chunk rocks. The entire habitat searched was covered with a thick layer of silt (ca. 2-4 cm); ca. 1.8 km of the river upstream of Dam Site 3 was essentially lentic. The maximum water depth was 7 m. A total of 0.4 mhr was spent searching this site.

Site No. 14. -- Search Dates: August 13, 2003; June 21, 2004; September 6, 2004; October 4, 2004; October 15, 2004; October 27, 2004; March 14, 2005. N 36.46117, W

91.52615. Site 14 (Dam Site 3) is located directly below Dam No. 3 and is divided by a substantial island, on which the Arkansas Game and Fish Commission Jim Hinkle State Fish Hatchery is situated (Appendix III). Hellbender habitat is located on both sides of the island and extends ca. 100 m downstream of the southern island tip. Historically, this site possessed more hellbenders than any other on the Spring River (Peterson et al. 1988). Presently, the habitat has been overtaken by rooted and clinging vegetation, which in turn has resulted in a thick layer of silt covering patches of habitat. The maximum water depth on either side of the island is 1.5 m and 2.5 m directly below the island. A total of 18.58 mhr was spent searching this site. The water temperature on 21 June 2004 was 18.8°C.

Site No. 15. -- Search Date: June 18, 2004. N 36.45254, W 91.52857. Site 15 is located approximately 1.7 km downstream of Dam Site 3, below a rock lined bank on the right side of the river. The riparian zone of the right bank has been clear cut and extends 846 m upstream. Solid bedrock dominates the substrate, with scattered boulders overlying throughout the site. There was a minimal amount of silt covering the habitat within the site. Rooted vegetation, gravel, and sand dominate the entire river left side of the river channel. The maximum water depth was 1.7 m. A total of 2.25 mhr was spent searching this site. Water temperature was 19.2°C.

Site No. 16. -- Search Date: July 6, 2004. N 36.45107, W 91.52796. Site 16 is located along the right bank ca. 93 m downstream of site 15. The area searched consists of a small patch of excellent hellbender habitat, with the total area of the site not exceeding ca. 310 m^2. The habitat extends 16 m from the bank into the channel. The substrate was comprised of cobble, chunk rock and small boulders. There was little to no silt covering the potential habitat. Site 16 is located upstream of a low gradient riffle, which apparently contributes to the increased water velocity noted at this locality. There is also a small spring flowing into the river upstream of this site. At the time of the survey a dense population of *Lampsilis reeviana* inhabited this site. The maximum water depth was 1.5 m. A total of 0.33 mhr was spent searching this site.

Site No. 17. -- Search Date: July 6, 2004. N 36.44719, W 91.52377. Site 17 is located ca. 527 m downstream of site 16. The potential hellbender habitat was situated along the left bank, and the substrate was primarily solid bedrock with boulders intermittently distributed throughout the site. The majority of the habitat was devoid of any silt. The maximum water depth was 2 m, which was recorded at mid-channel. A total of 0.66 mhr was spent searching this site.

Site No. 18. -- Search Date: July 6, 2004. N 36.44231, W 91.52117. Site 18 is located ca. 540 m downstream of site 17. The potential hellbender habitat is located along the left bank, and extends ca. 50 upstream from the GPS point. The habitat is very similar to that of site 27; patches of boulders lying on solid bedrock with little or no silt covering the benthos. The maximum water depth was 2 m. A total of 0.66 mhr was spent searching this site.

Site No. 19. -- Search Date: June 18, 2004. N 36.43899, W 91.52070. Site 17 is located ca. 846 m upstream of the Arkansas Game and Fish Commission Bayou Access. The potential hellbender habitat is situated along the left bank, and extends ca. 50 downstream of the GPS point. The substrate consists primarily of solid bedrock, with only a few boulders scattered throughout the site. The left bank is completely covered in rip-rap, a result of the railroad tracks that border this section of the river. The rip-rap extends out into the river channel ca. 3 m from the bank; however, this section of the survey site was covered with a thin layer of silt (< 1 cm). The maximum water depth was 2.5 m. A total of 1 mhr was spent searching this site. Water temperature was 19.0°C.

Site No. 20. -- Search Dates: June 18, 2004; October 4, 2004. N 36.43806, W 91.52238. Site 20 is located ca. 746 m above the Arkansas Game and Fish Commission Bayou Access and is known locally as "Cooper's Fall." The right side of the river is a shallow low gradient riffle, while the left side actually comprises the fall (Appendix III). There is little or no suitable hellbender habitat in the riffles; however, the area below the falls is dominated by boulders and chunk rock. There is potential refuge beneath the fall, which extends ca. 2 m from the fall line. The maximum water depth below the fall is 4 m. This site has produced two verified hellbender records, one of which was described in Trauth et al. (2002). This is the only non-historic site where hellbenders have been found. A total of 5.5 mhr was spent searching this site.

Site No. 21. -- Search Date: June 21, 2004. N 36.43119, W 91.52913. Site 21 is located 185 m downstream of the Arkansas Game and Fish Commission Bayou Access. Cobble dominated the substrate along the right bank and extends out ca. 17 m to mid-channel. Beyond which, solid bedrock and intermittent boulders became the predominate characteristics of the substrate. The available hellbender habitat had little or no silt covering it, and the flow was swift enough to send a diver downstream if he/she were to let go of an anchor point. The maximum water depth at site 19 was 4 m. A total of 1.5 mhr was spent searching this site. Water temperature was 18.8°C.

Site No. 22. -- Search Date: June 21, 2004. N 36.43005, W 91.52814. Site 22 is located directly above the first set of falls ~ 379 m downstream of the Arkansas Game and Fish Commission Bayou Access. The potential hellbender habitat lines the right bank and extends 24 m into the channel. Solid bedrock dominates the substrate, with boulders scattered throughout the site. There was silt (< 1 cm) covering most of the potential hellbender rock. A total of 1.17 mhr was spent searching this site. Water temperature was 19.0°C.

Site No. 23. -- Search Date: June 21, 2004. N 36.43005, W 91.52814. Site 23 is located directly below site 22 and ca. 437 m downstream of the Arkansas Game and Fish Commission Bayou Access. Potential hellbender habitat extends approximately 5 m downstream of the fall line (Appendix III). Beyond that the river bottom is scoured and consists primarily of solid bedrock. The maximum water depth directly below the fall was 1.5 m and 3 m in the pool area below the falls. There is also suitable habitat along the right bank; however, a layer of silt (< 1 cm) has settled on the rocks. A total of 1 mhr was spent searching this site. Water temperature was 19.0°C.

Site No. 24. -- Search Date: June 8, 2004. N 36.42200, W 91.52785. Site 24 is located ca. 627 m upstream of Saddler Falls and ca. 660 m downstream of the Saddler Falls Resort. The upstream edge of the habitat is a small water fall with depth below varying between 1.5 m and 3.0 m. The substrate directly downstream of the fall is a composite of woody debris, fine particulates, large boulders and aquatic vegetation. The river below the fall is divided by a series of small islands. The substrate in the west channel is dominated by an abundance of rooted vegetation, while the east channel substrate is dominated by moderate sized cobble, and small boulders. A total of 1.33 mhr was spent searching site 24.

Site No. 25. -- Search Date: July 28, 2004. N 36.41312, W 91.52872. Site 25 is located ca. 100 m downstream from the lower takeout of the Saddler Falls Resort and Campground. Potential hellbender habitat is situated along the left bank extending to mid channel (Appendix III). The substrate is dominated by solid bedrock, cobble, and gravel, which has embedded most of the boulders present; however the majority of the substrate was void of any silt. The maximum water depth was 1 m. A total of 1.33 mhr was spent searching this site.

Site No. 26. -- Search Date: July 28, 2004. N 36.40556, W 91.52843. Site 26 is located ca. 775 m downstream of site 25. The upstream edge of habitat is a fall line, which stretches across the entire river channel (Appendix III). Gravel and solid bedrock dominate the substrate directly below and underneath the fall. The substrate behind the fall line was absent of any potential hellbender habitat. The maximum depth below the fall was 1 m. A total of 1 mhr was spent searching this site.

Site No. 27. -- Search Date: July 28, 2004. N 36.39768, W 91.52531. Site 27 is located directly across from the Spring River Oaks Resort lower take-out point (See picture on cover, Appendix III). The potential hellbender habitat was situated below a large bluff along the right bank and was comprised of cracks in the bluff wall, along with large boulders laying on the benthos. A substantial layer of silt (< 1.5 cm) covered the entire habitat surveyed. The area searched extends 75 m from upstream edge to downstream edge, and 4 m from the bluff wall into the channel. There was an abrupt drop in depth from 0.5 to 3.5 m ca. 1 m from the bank. A total of 1.17 mhr was spent searching this site. Water temperature was 21.0°C.

Site No. 28. -- Search Date: July 28, 2004. N 36.39503, W 91.52514. Site 28 is located ca. 284 m downstream of site 27. The habitat searched lies on the left side of the river channel along a bend in the river. There is a large bedrock platform with undercut walls and unattached boulders scattered throughout the site. This site possesses a substantial amount of silt and settled debris scattered about. The platforms surface is submerged in ca. 1 m water. To the right edge of the platform, which is about mid-channel, there is a sharp drop off to a maximum water depth of 4 m. The potential hellbender habitat improves as you move closer to the right bank and downstream edge of the site, with increasing numbers of large boulders and less silt. A total of 1.25 mhr was spent searching this site. Water temperature was 21.0°C.

Site No. 29. -- Search Date: July 28, 2004. N 36.39490, W 91.52758. Site 29 is located ca. 204 m downstream of site 28. The survey area includes a set of falls divided at mid-channel by an island complex (Appendix III). Below the falls the habitat is solid bedrock with gravel covering the superficial surface. The falls themselves are undercut ca. 1.5 m and gravel dominates the substrate behind the fall line. The bedrock, which the falls are composed of lack any real potential hellbender holes or cracks. The fall drop on the left side of the island is much more severe in comparison to the right channel, dropping almost 2 m in some spots. There is excellent hellbender habitat below the corner of the falls and left bank which extends ca. 10 m downstream. The maximum water depth below either set of falls did not exceed 2 m. A total of 1.17 mhr was spent searching this site. Water temperature was 21.0°C.

Site No. 30. -- Search Date: July 28, 2004. N 36.37578, W 91.52506. Site 30 is located ca. 769 m downstream of the Many Islands Resort lower property line. The upper edge of habitat is a fall line, which stretches across the entire channel. A chute below the falls on the right side of the river has a maximum depth of 1.5 m, and solid bedrock dominates the substrate. Gravel dominated the substrate below the rest of the fall. Any boulders that might present themselves as potential hellbender habitat were embedded by the gravel. The fall was undercut ca. 1 m, and the maximum water depth below the fall did not exceed 2 m. A total of 1.33 mhr was spent searching this site. Water temperature was 21.0°C.

Site No. 31. -- Search Date: October 5, 2004. N 36.35575, W 91.50794. Site 31 is located ca. 200 m above Taylor's Camp river access. The area upstream edge of the habitat is a fall line that stretches across the majority of the channel; however there is a small island complex, which divides the river ~ 10 m from the right bank. To the right of the island the river was a low gradient riffle as opposed to a waterfall. The substrate downstream of the fall line was almost entirely comprised gravel with small patches of cobble directly below the fall. Cobble dominated the substrate in the low gradient riffle to the right of the island. A total of 1 mhr was spent searching this site. Water temperature was 18.7°C.

Site No. 32. -- Search Date: October 5, 2004. N 36.34560, W 91.50684. Site 32 is located ca.1 km upstream of the Camp Kierl low water bridge. The river is divided by a large island complex, with potential hellbender habitat situated in the left channel and below the confluence of channels along the right bank. The substrate is dominated by gravel and cobble; however, the right bank below the confluence is solid bedrock and extends down into the water column. A total of 1 mhr was spent searching this site. Water temperature was 18.7°C.

Site No. 33. -- Search Date: October 5, 2004. N 36.33788, W 91.50797. Site 33 is located above and below the CR 42 low water bridge at the Fulton/Sharp county line. This site was designated as the SRRR03 in Christian et al. (2005) and is locally known as Camp Kierl. The site is a complex of glides, low-gradient riffles, and lateral scour pools. The majority of the substrate within this site was gravel/cobble, with areas of exposed bedrock and boulders. The deepest areas within the site are < 1.5 m. A total of 1 mhr was spent search this site.

Site No. 34. -- Search Date: July 2, 2004. N 36.31804, W 91.49482. Site 34 located ca. 2.36 km upstream of the Arkansas Game and Fish Commission Hardy Beach Access. The upstream edge of the survey site is a fall line that stretches across the entire river (Appendix III). At mid-channel the fall is partially divided by an island complex. The substrate below the right fall line is comprised mostly of solid bedrock, gravel, and a few embedded boulders. While solid bedrock alone is the predominant substrate class beneath the fall on the left side of the river. The maximum water depth was 2.5 m. There was a very small amount of potential hellbender habitat. A total of 1.83 mhr was spent searching this site. Water temperature was 22.4°C.

Site No. 35. -- Search Date: July 2, 2004. N 36.31360, W 91.47785. Site 35 is located ca. 471 m upstream of the Arkansas Game and Fish Commission Hardy Beach Access (Appendix III). From the surface there appeared to be a decent amount of potential hellbender habitat; however; once investigated the boulders seen from the surface were found to be either embedded or solid bedrock. The maximum water depth was 2.5 m. A total of 1 mhr was spent searching this site. Water temperature was 22.4°C.

Site No. 36. -- Search Date: July 2, 2004. N 36.31355, W 91.47620. Site 36 is located ca. 340 m upstream of the Arkansas Game and Fish Commission Hardy Beach Access. The site was divided by a bedrock island covered in rooted vegetation whose roots were submerged in ca. 0.33 m of water. The maximum depth along the right channel 3.0 m, while that on the left side of the vegetation did not exceed 1.5 m. The substrate was comprised primarily of solid bedrock and gravel. There was a small amount of potential hellbender habitat, which was represented by several large boulders scattered throughout the site. A total of 1.17 mhr was spent searching this site. Water temperature was 22.4°C.

Site No. 37. -- Search Date: July 18, 2005. N 36.24439, W 91.37325. Site 37 is located ca. 340 m upstream of the Arkansas Game and Fish Commission Hardy Beach Access. This site consists of a series of step falls. The depth within the site was shallow (< 10 cm) at the lip of the fall to 2.5 m at the base of the fall. The site was mostly a solid, bedrock substrate. Water temperature was 26.4°C.

Site No. 38. -- Search Date: July 18, 2005. N 36.24505, W 91.37273. Site 38 is located approximately 1 km upstream from the St Hwy 58 bridge near Williford, Sharp County. The site is a lateral scour pool adjacent to the Burlington Northern Santa Fe Railroad tracks. We spent 1 mhr searching this site.

Site No. 39. -- Search Date: July 18, 2005. N 36.24777, W 91.32579. Site 39 is a rock outcrop in the middle of the Spring River floodplain. It is located at the lower end of a series of braided channels around numerous islands. The maximum depth at this site was 3 m, with a substrate primarily composed of solid bedrock with gravel filled crevices. We spent ca. 1.0 mhr at this site.

Site No. 40. -- Search Date: July 18, 2005. N 36.23999, W.91.30410. Site 40 is a run bounded on the upper end by a low waterfall. The maximum depth just below the fall was approximately 1.5 m. The substrate consisted of gravel with some exposed bedrock and scattered cobble/boulders. We spent 1.5 mhr searching this site.

Site No. 41. -- Search Date: July 18, 2005. N 36.24734, W 91.29145. Site 41 is located at the base of a bluff and is the downstream most of three consecutive riffles. The substrate along the left bank was composed of many large boulders and cobble. We considered the habitat to be ideal for hellbenders but were only able to spend 0.33 mhr searching this site. The water was extremely swift at this site and should be revisited with SCUBA gear.

Site No. 42. -- Search Date: July 18, 2005. N 36.23763, W 91.28362. Site 42 is another site with excellent hellbender habitat. It is located at the head of a bluff and contains numerous large boulders as the primary substrate. The water depth at this site exceeded 3 m, and should be revisited with SCUBA gear. We spent 0.5 mhr surveying the shallower areas within this site.

Site No. 43. -- Search Date: July 18-19, 2005. N 36.22472, W 91.25094. Site 43 is located beneath the CR 107 bridge near Ravenden, Lawrence County. The site is a shallow riffle with bedrock base that ends in a glide with cobble and scattered boulders as substrate. The maximum depth was 1.5 m, with moderate flow. We spent 21 trap nights targeting crayfish and salamanders within the riffle portion of this site and 0.25 mhr searching the glide portion of this site. Local residents use lower end of this site as a recreational swimming hole, as evidenced by a rope swing. Search Date: XX. N 36.24777, W 91.32579.

Site No. 41. -- Search Date: July 18, 2005. N 36.24734, W 91.29145. Site 41 is located at the base of a bluff and is the downstream most of three consecutive riffles. The substrate along the left bank was composed of many large boulders and cobble. We considered the habitat to be ideal for hellbenders but were only able to spend 0.33 mhr searching this site. The water was extremely swift at this site and should be revisited with SCUBA gear.

Site No. 42. -- Search Date: July 18, 2005. N 36.23763, W 91.28362. Site 42 is another site with excellent hellbender habitat. It is located at the head of a bluff and contains numerous large boulders as the primary substrate. The water depth at this site exceeded 3 m, and should be revisited with SCUBA gear. We spent 0.5 mhr surveying the shallower areas within this site.

Site No. 43. -- Search Date: July 18-19, 2005. N 36.22472, W 91.25094. Site 43 is located under the CR 107 bridge near Ravenden, Lawrence County. The site is a shallow riffle with bedrock base that ends in a glide with cobble and scattered boulders as substrate. The maximum depth was 1.5 m, with moderate flow. We spent 21 trap nights targeting crayfish and salamanders within the riffle portion of this site and 0.25 mhr searching the glide portion of this site. Local residents use lower end of this site as a recreational swimming hole, as evidenced by a rope swing.

Site No. 44. -- Search Date: October 6, 2004. N 36.22433, W 91.24295. Site 44 is located just below the AGFC access at Ravenden, Lawrence County. This was a site chosen for habitat analysis, and thus a detailed site description is given in the Results section. The maximum depth on the day of searching was 1.5 m and the temperature was 16.7° C. We spent 1 mhr searching this site.

Site No. 45. -- Search Date: October 6, 2004. N 36.22725, W 91.24064. Site 45 is located upstream of the Hwy 63 bridge near Ravenden, Lawrence County and immediately upstream of site 46. This site was chosen for habitat analysis and a detailed description is given in the Results section.

Site No. 46. -- Search Date: October 6, 2004. N 36.22845, W 91.23943. Site 46 is a run located at the head of a riffle and includes a secondary side channel. This was a site chosen for habitat analysis, and thus a detailed site description is given in the Results section. We spent 0.75 mhr searching this site.

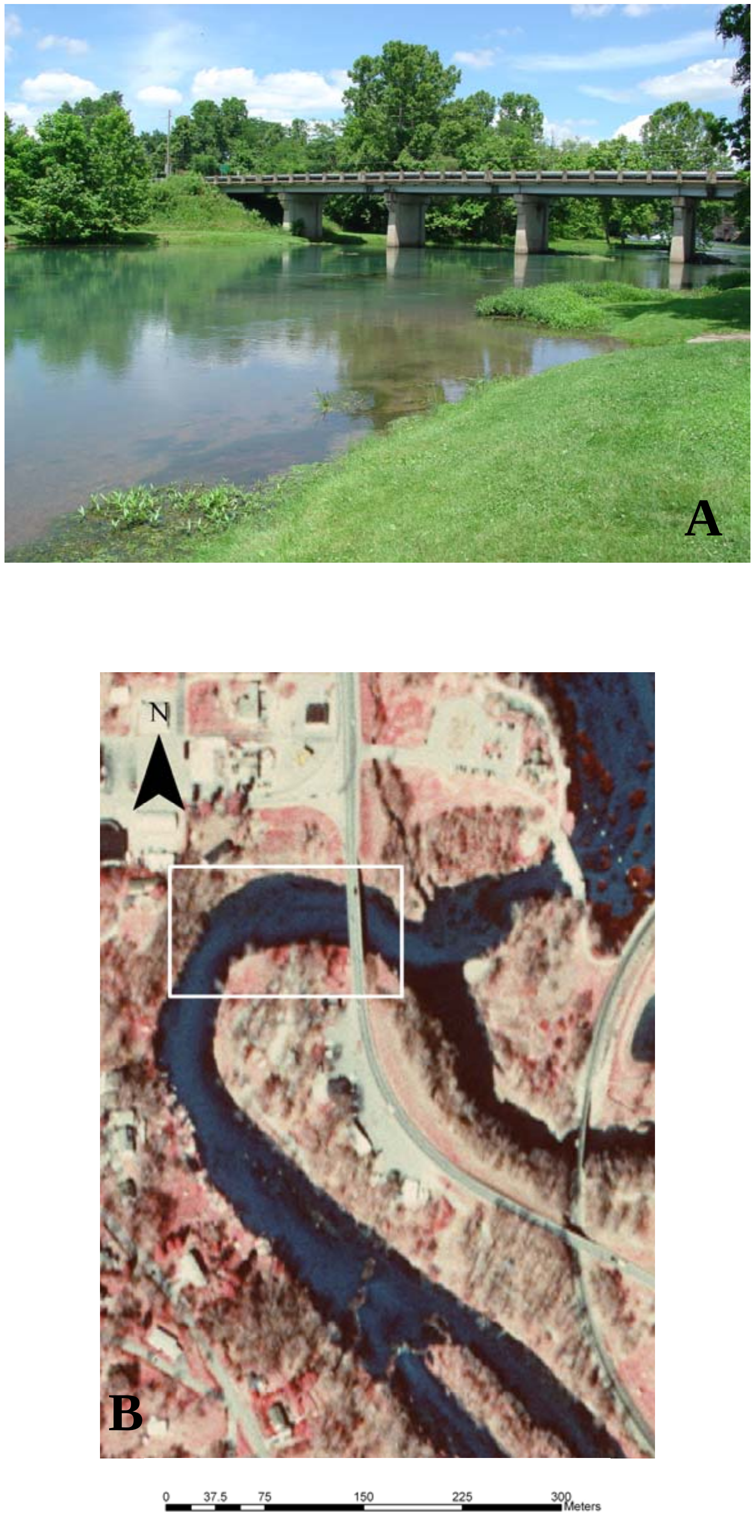
Site No. 47. -- Search Date: October 6, 2004. N 36.24128, W 91.23348. Site 47 is located about 1 km downstream of the Hwy 63 bridge near Ravenden, Lawrence County. This was a site chosen for habitat analysis, and thus a detailed site description is given in the Results section. The water temperature was 15.5ºC and max depth was 1 m on the day we surveyed the site. We spent 1 mhr searching this site.

Site No. 48. -- Search Date: October 7, 2004. N 36.21919, W 91.20615. Site 48 is an island complex with the best habitat located at the lower end of the islands. This was a site chosen for habitat analysis, and thus a detailed site description is given in the Results section. Water temperature was 16.7 and maximum depth was 1.5 m on the day of sampling. We spent 1 mhr searching this site.

Site No. 49. -- Search Date: October 7, 2004. N 36.20459, W 91.17188. Site 49 was a riffle followed by a deep pool located between the Hwy 62 bridge and the AGFC boat launch at

Imboden, Lawrence County. This was the final site for habitat assessment and a detailed description is given in the Results section. We spent 1 mhr searching this site.

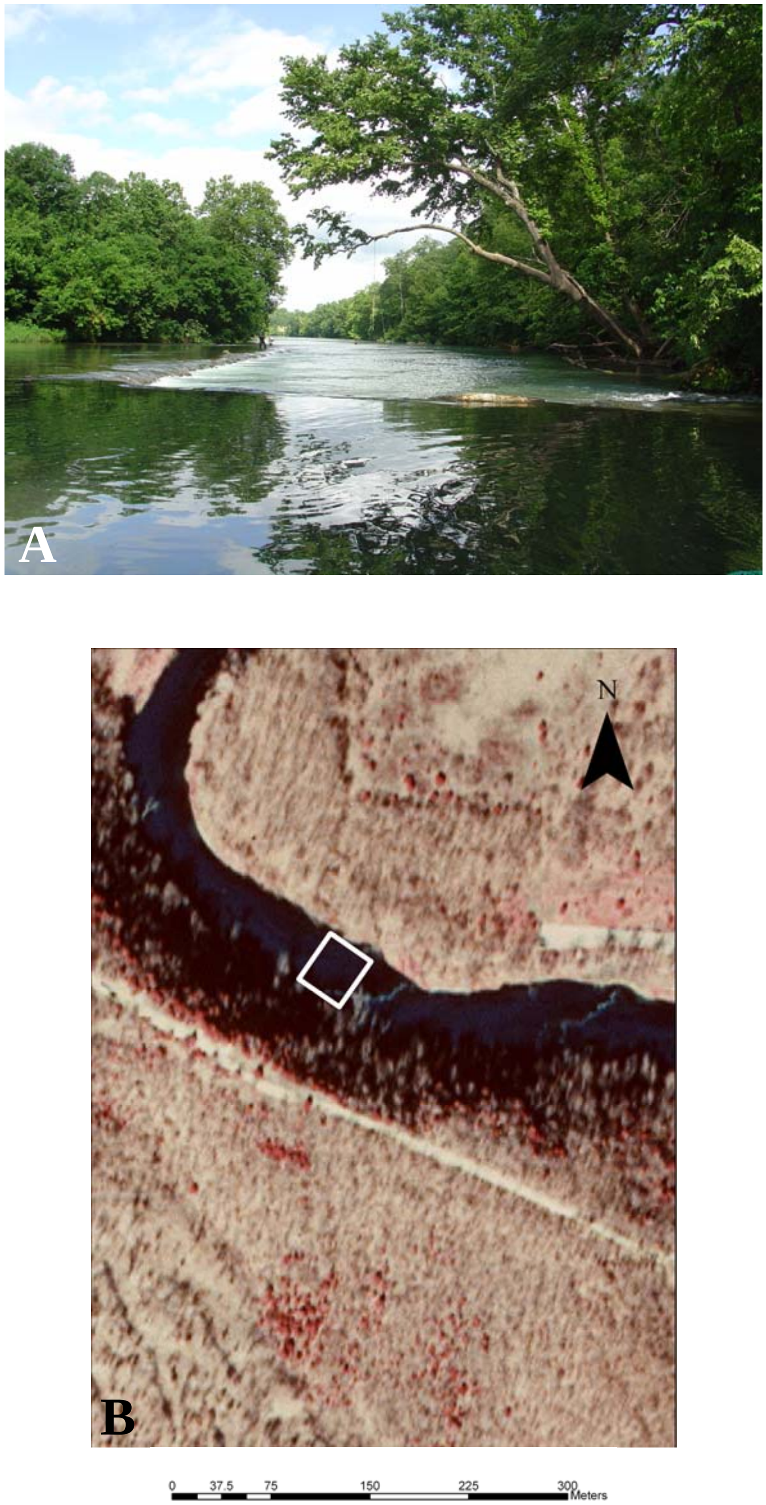
Appendix III. Maps and Photographs of Selected Survey Sites.



Site 6. A. Photograph of site 6, positioned directly downstream of the Arkansas State Highway 63 bridge. B. Aerial photograph of site 6, white box represents the approximate area of habitat searched.

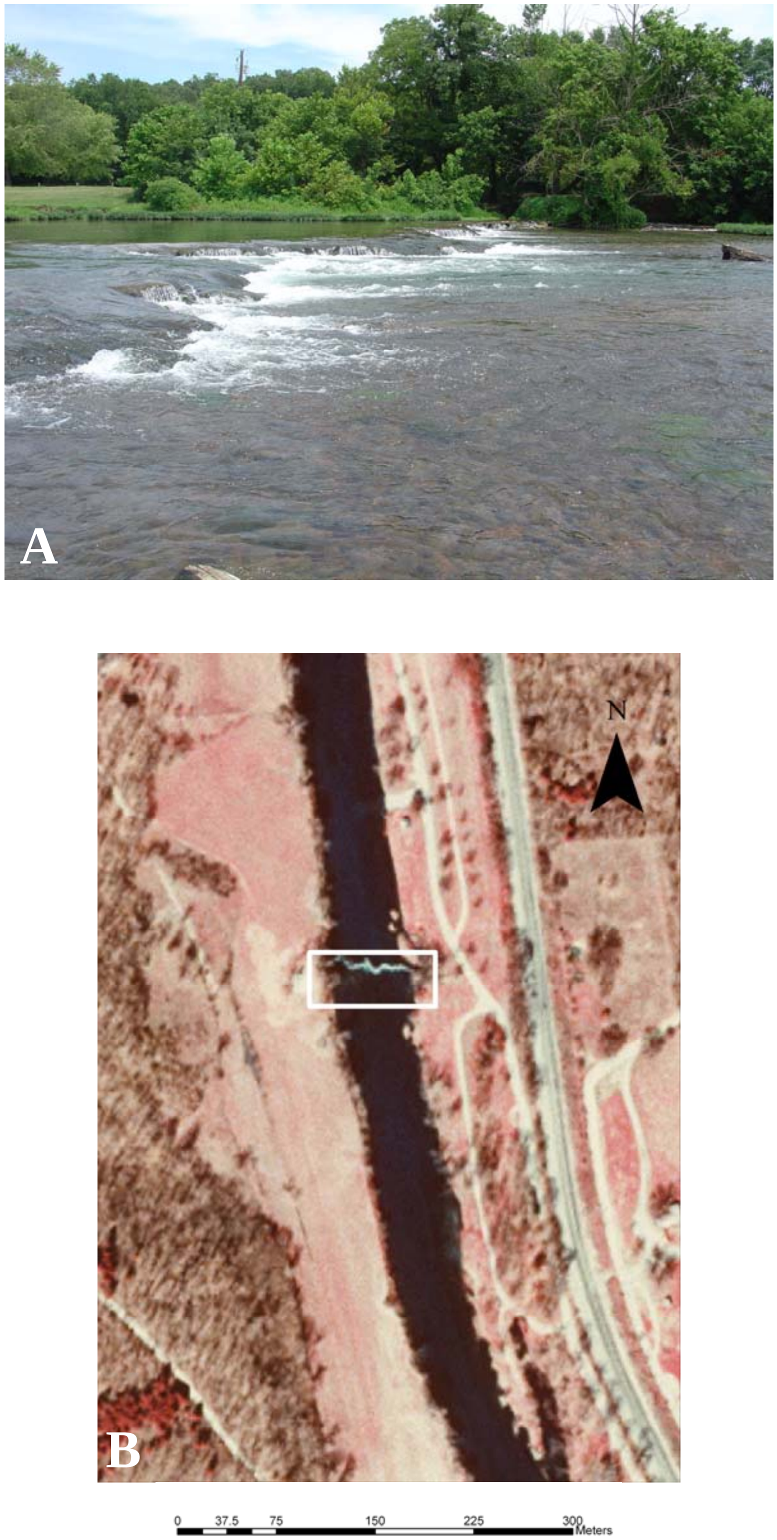
Site 14. A. Photograph of site 14, right channel of Dam 3 at the Jim Hinkle State Fish Hatchery. B. Aerial photograph of site 14; white-outlined boxes represent the approximate area of habitat searched.

Site 20. A. Photograph of site 20, facing upstream. B. Aerial photograph of site 20; white-outlined box represents the approximate area of habitat searched.

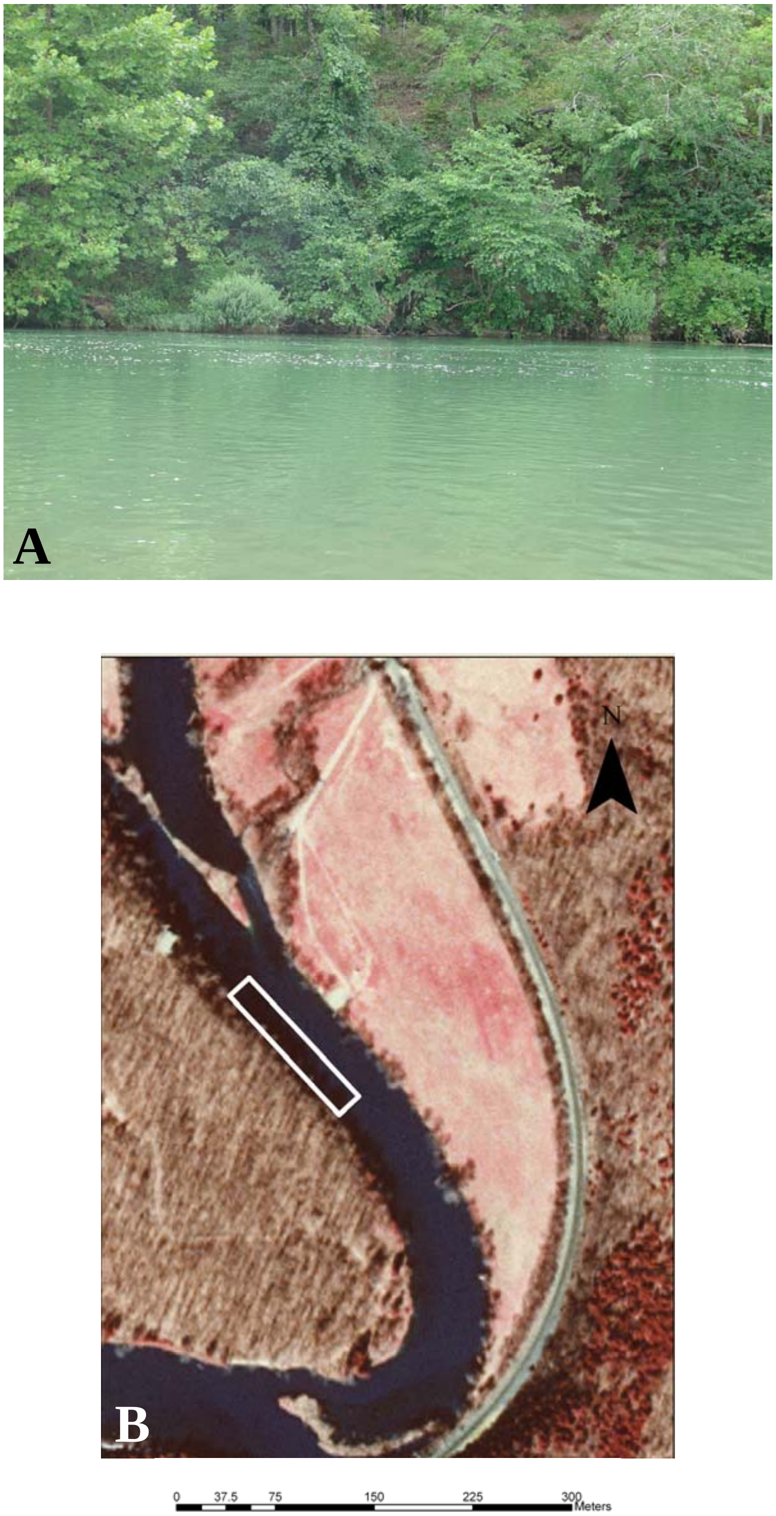


Site 23. A. Photograph of site 23, facing downstream overlooking a small water fall. B. Aerial photograph of site 23; white-outlined box represents the approximate area of habitat searched.

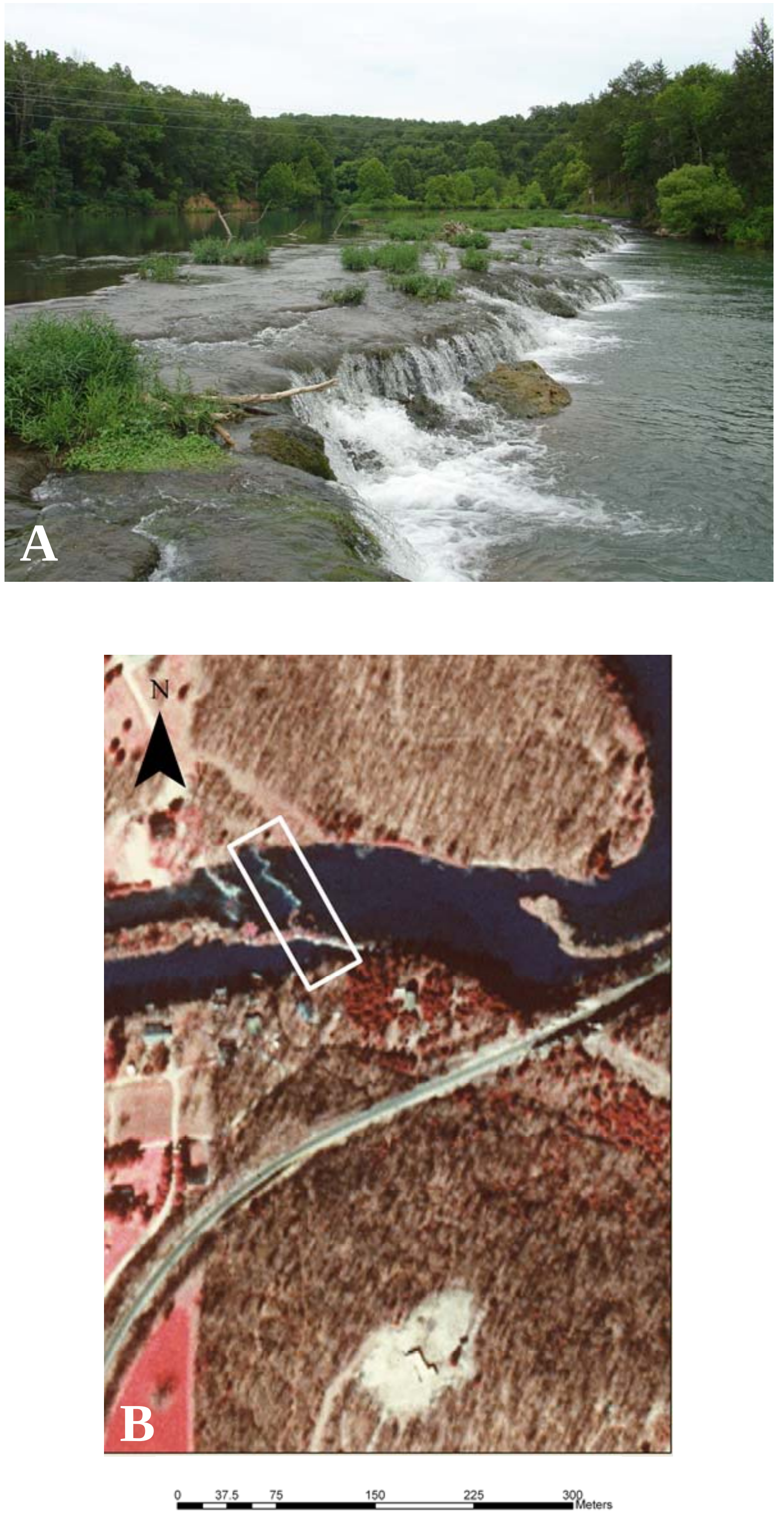
Site 25. A. Photograph of site 25, facing the left bank. Notice the train in the background. B. Aerial photograph of site 25; white-outlined box represents the approximate area of habitat searched.



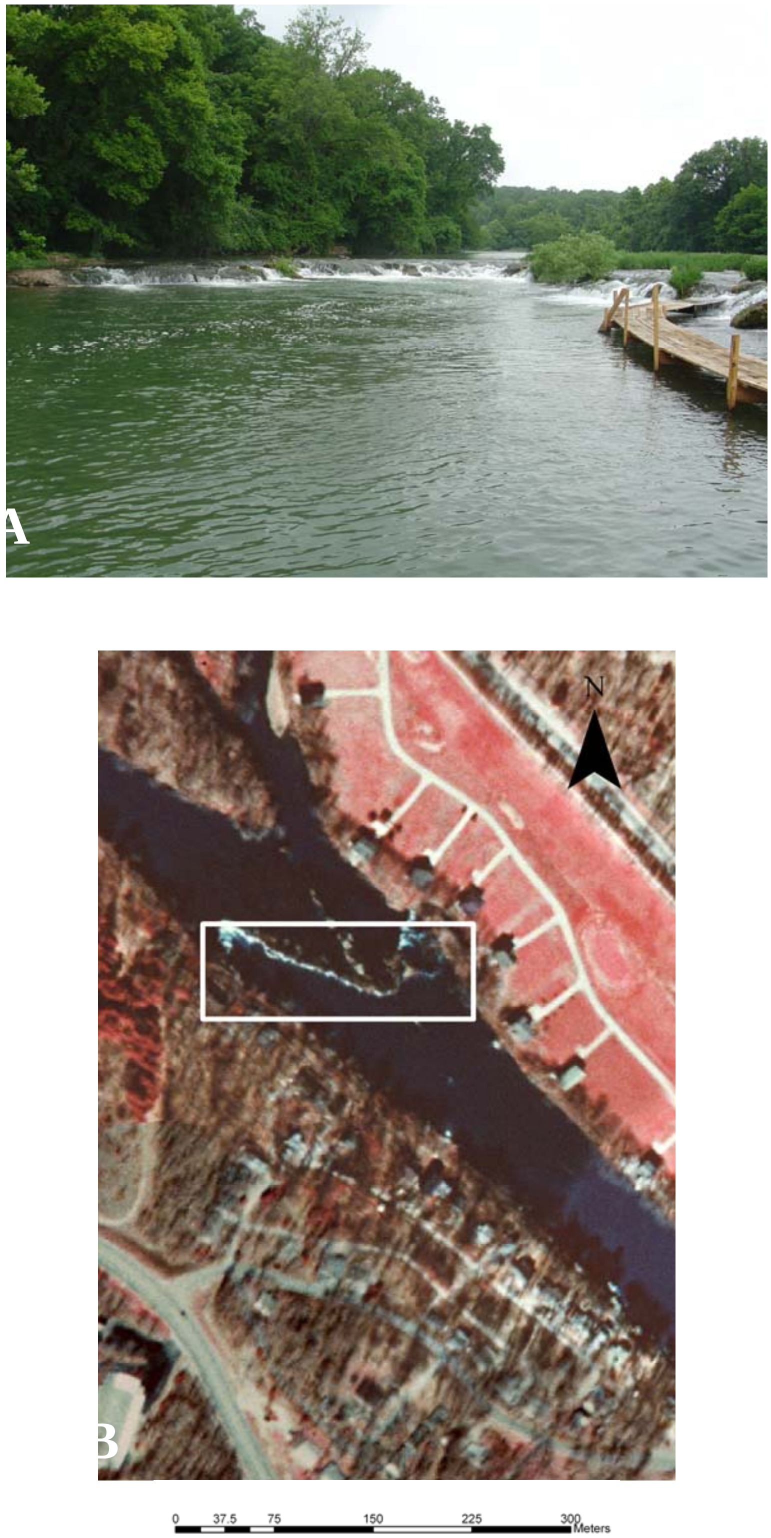
Site 26 A. Photograph of site 26, facing the left bank. B. Aerial photograph of site 26; white-outlined box represents the approximate area of habitat searched.



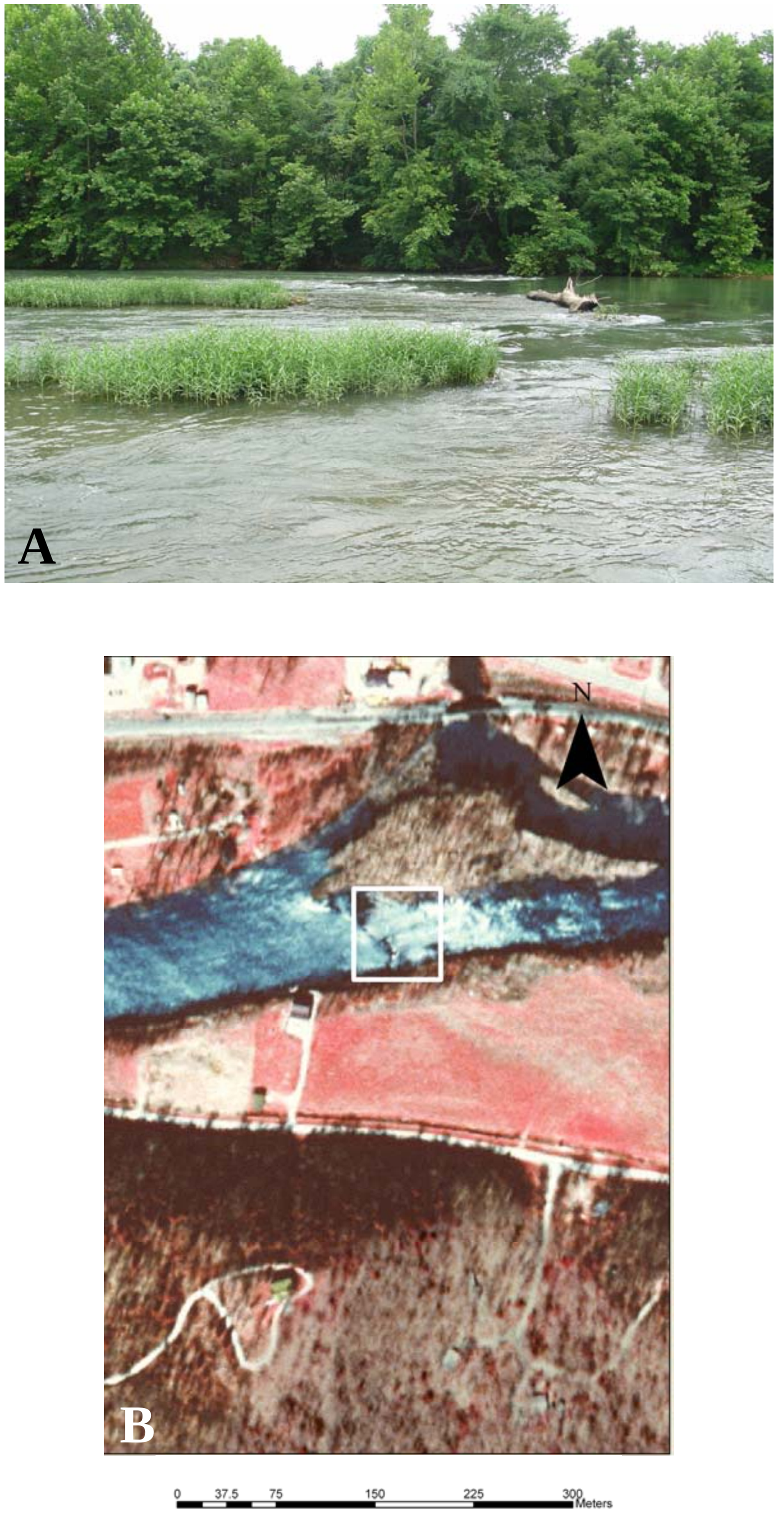
Site 27 A. Photograph of site 27, facing the right bank. B. Aerial photograph of site 27; white-outlined box represents the approximate area of habitat searched.



Site 29. A. Photograph of site 29, facing upstream along the fall line on the left side of the river. B. Aerial photograph of site 29; white-outlined box represents the approximate area of habitat searched.



Site 34. A. Photograph of site 34, facing right fall line from a downstream position. B. Aerial photograph of site 34; white-outlined box represents the approximate area of habitat searched.



Site 35. A. Photograph of site 35, facing right bank. B. Aerial photograph of site 35; white-outlined box represents the approximate area of habitat searched.