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A Survey of Crayfish in the Pigeon River and its Tributaries in Tennessee and North Carolina

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To the Graduate Council:

I am submitting herewith a thesis written by David Casey B. Dunn entitled "A Survey of Crayfish in the Pigeon River and its Tributaries in Tennessee and North Carolina." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Wildlife and Fisheries Science.

J. Larry Wilson, Major Professor

We have read this thesis and recommend its acceptance:

Richard J. Strange, Jonathon E. Burr

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

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A Survey of Crayfish in the Pigeon River and its Tributaries in Tennessee and North Carolina

A Thesis Presented for

the Master of Science

Degree

The University of Tennessee, Knoxville

David Casey B. Dunn

December 2010

Dedication

I dedicate this thesis to my parents David and Brenda Dunn for their encouragement to follow my passion for understanding the natural world. I sincerely appreciate their support while I explored the great rivers of the Eastern United States which led me to continue my education at the University of Tennessee and join the Pigeon River Recovery Team.

Acknowledgements

I owe much appreciation and thanks to my major professor, Dr. Larry Wilson, for his valuable input on developing this project and seeking financial support for my education here at the University of Tennessee. Thanks for guiding and helping me make better decisions to create a thorough survey of the crayfish in the Pigeon River Watershed. Thank you to Dr. Richard Strange for serving on my committee and for encouraging me with good advice on how to tackle writing the largest research report I have ever written! I also want to thank Jonathon E. Burr (JEB) for joining my committee and sharing his knowledge of the Pigeon River watershed and identifying some of the more particular problems that the Pigeon River watershed is experiencing.

Thanks to Joyce Coombs for her helpful suggestions and encouragement during my time at the University of Tennessee. I have enjoyed our time traveling together to the Pigeon River each day where we got to spend a lot of time brainstorming scientific principles and discussing news from listening to National Public Radio (NPR). I have learned a lot from working with Joyce in the field and asking her valued opinion to make this thesis more solid. I want to extend my thanks to Dr. Agnes Vanderpool, my undergraduate advisor and research mentor from Lincoln Memorial University. Her motivation gave me the tenacity to tough out another two and one-half years of continued education in hopes of becoming a good scientist someday. Many of the puzzles that I have tackled as an up-and-coming scientist have been solved using the elementary scientific principles she instilled in me.

This project would not have been realized without the help of my fellow peers at the University of Tennessee. I want to thank and recognize the following students for helping me complete the data collection portion of this project and for teaching me by allowing me to accompany them during their own field outings: Trent Jett, Michael Jones, Nikki Maxwell, Will Pruitt, Daniel Schilling, and Sommai Janekitkarn. Snorkeling the East Tennessee waterways with these guys has been such a pleasure. I have been inspired by watching each of these people work through his and her own scientific endeavors.

Abstract

The Pigeon River watershed has been the focus of a major recovery project to reintroduce fish and other aquatic species into the river where they were historically present. A paper mill at Pigeon River Kilometer/Mile (PRKM 102.1/PRM 63.2) began operations in 1908 and discharged effluents which had a detrimental impact on the aquatic wildlife. Recent modifications to the mill have significantly improved effluent quality such that most aquatic organisms are recolonizing the river. The present study is a baseline survey of crayfish species in the Pigeon River and its tributaries; it also includes a comparison of the mean Catch Per Unit Effort (CPUE) in four different reaches of the stream and documents diversity upstream and downstream of the paper mill.

Crayfish are important to the aquatic ecosystem and food web because they serve as cutters that help to break down leaf litter and carrion and are also a food source for predators. Crayfish were collected using modified minnow traps and electroshocking and by snorkeling along 'turning' rocks; the method used was based on characteristics of the stream reach sampled, including water depth, flow, transparency, and type of substrate. A total of 1,320 crayfish specimens representing seven species was collected during the eight-month study. Crayfish were found in nine Pigeon River tributaries , in the main stem of the Pigeon River upstream of the paper mill (PRKM 102.1/PRM 63.2), and below the Progress Energy Dam (PRKM 61.1/PRM 38.0). No crayfish were found downstream of the paper mill in the river itself; however, crayfish

were found downstream from the Progress Energy Dam down to the Pigeon River's confluence with the French Broad River.

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Chapter 1

Introduction

From 1908 to the early 1990s, the Pigeon River in Haywood County, North Carolina, and Cocke County, Tennessee, was subjected to paper mill effluents which led to the demise of many fish and other aquatic species. Before the paper mill was established at Pigeon River Mile (PRM 63.2) the Pigeon River was a free flowing, cool water stream (Bartlett, 1995). After the mill's opening in 1910, the water quality of the river began to degrade and become a waste dump for the mill's effluent by-products. Furans, chloroform, and dioxins were among the most severe toxins released into the river during the early part of the 1900s (Bartlett, 1995). Some of the less harmful effluents were lignin and tannins which made the water the color of coffee and produced a very distinctive odor. During this period the river was found to contain only the hardiest of fish species; previously the river was thought to have contained 95 native fish species, including sensitive shiner and darter species (Etnier and Starnes, 1993). Crayfish in the Pigeon River and tributaries were surveyed to determine if crayfish may have used the tributaries as refugia from the historic riverine conditions and more recently as a resource for recolonizing the river.

Extensive modifications in mill process operations have contributed to much-improved water quality and subsequent efforts to enhance biodiversity in the river. Improvements to the paper mill began in 1992 when the chlorine bleaching process was abandoned and the much needed chlorine dioxide and oxygen delignification systems were established (Maxwell, 2009). The Index of Biological Integrity (IBI) used by the Tennessee Valley Authority (TVA) ranks stream health based on 12 metrics such as the number of intolerant species found and the number of darter species collected. Scores are scaled from 1 to 60 with the latter being the highest (Coombs, 2003). Scores for the Pigeon River remained low through much of the 1980s and early 90s with scores at 38 and less, and in 1993 those scores began to improve to a score of 54 being recorded in 2007, at Denton and Tannery in Tennessee (TVA, 2007). These improvements made way for the Pigeon River Recovery Project (PRRP) to begin work restocking the river with many of the extirpated fish in anticipation of creating founder populations.

The Pigeon River Recovery Project (PRRP) was initiated in 2001 and has re-introduced fish and snail species of which some appear to be recolonizing the river. In addition to these efforts, surveys of benthic macro-invertebrates, salamanders, and crayfish have also been conducted to document the river's recovery. This inventory of crayfish in the Pigeon River watershed will allow researchers to better understand crayfish population dynamics and also how these organisms are adapting to the changes in the river. Crayfish are important to riverine food webs because they are a keystone species which can consume a variety of foods from different trophic levels (Creed, 2004). They can serve as decomposers by feeding on dead organisms; they also feed on aquatic vegetation, which allows nutrients to be returned to higher and lower food chain levels. Crayfish are an important food resource for aquatic predators and terrestrial foraging animals.

The Pigeon River has also been altered by Walters Dam at (PRM 38.0), which began operation in 1930 and now backs up a 154 surface hectare section of stream in North Carolina called the Waterville Reservoir (Etnier and Saylor, 2001). Sediments are able to collect in the reservoir along with tannins and other siltation from the North Carolina portion of the watershed. This creates cleaner water discharges from Walters Power Plant, which is at the border of Tennessee and North Carolina and regulates the flow regimes into the Tennessee reach of stream by pulling water from the epilimnion of the Waterville Reservoir.

The purpose of this study is to determine what species of crayfish occupy the Pigeon River watershed both in the main stem and selected tributaries. Crayfish abundances can be compared across four different reaches of the Pigeon River's main stem to determine if any significant differences can be found. A review of historical documentation of species accounts and the use of three different crayfish collection techniques were used to determine crayfish community dynamics. Tributaries were important to sample to determine if whether crayfish were able to find refugia during the years of harmful effluent discharges.

Chapter 2

Literature Review

Crayfish Biology

Crayfish belong to the order Decopoda and are close relatives to many marine organisms such as shrimp, crabs, and their closest relatives, lobsters. There are currently up to 400 different species of crayfish being described or already described by scientists worldwide (Butler et al., 2003). Crayfish diversity is highest on the North American continent where two major families, the Astacidae and Cambaridae, contain approximately 363 native species (Taylor et al., 2007). The family Astacidae is primarily found in western United States and Canadian provinces, whereas the Cambaridae family is distributed throughout the eastern United States along the Mississippi River drainage. The crayfish diversity is so high in the southeastern United States that it is third only to that of fish and mussels in numbers of species (Taylor et al., 2007). Diversity is thought to be so high in the mid-reaches of the southeastern streams because of the vagility of many aquatic organisms colonizing throughout the Mississippi River Drainage from marine estuaries (Vannote, 1980). Many problems have developed over the past century with respect to crayfish conservation because they have been over shadowed by the conservation efforts of fish and mussels. Taylor et al. (2007) stated that "of the 363 native species of crayfish in North America 2 (1%) crayfish taxa are considered endangered, possibly extinct, 66 (18.2%) are endangered, 52 (14.3%) are threatened, 54 (14.9%) are vulnerable, and 189 (52.1%) are currently stable".

Crayfish can be categorized into three major groups based on the type of habitats they partition. Primary burrowers, often called hypogean crayfish, are considered those species which spend their entire lives in a network of burrows that typically consist of multiple chambers that reach down into the water table. The only time a primary burrower leaves its chambers is to hunt for food or find a mate. Burrows can often be found in gardens and agricultural fields as well as in the earthen dams; this can have a negative impact, as humans view burrowing crayfish as pests (Cooper, 2007). Secondary burrowers are those crayfish species that spend only a portion of their lives in burrows during periods of extreme weather conditions; otherwise, they can be found in water under rocks. These burrows are usually less complex and may consist only of one tunnel with one other escape tunnel branching off. Tertiary burrowers, termed epigean crayfish, spend their lives in bodies of water and will only burrow up to a foot or two under a boulder during periods of extreme drought or freezeovers. All three groups of crayfish have one thing in common; they all must keep their gills moist to respire and extract oxygen from the air (Taylor et al., 2007). The present survey of crayfish targeted those crayfish thought to be found in streams only.

Molting is a frequent growth event that takes place during a crayfish's life-cycle. During this period the crayfish is left vulnerable to predation and to the absorption of harmful chemical pollutants (Butler et al., 2003). Once the crayfish has shed its old carapace it will then utilize the carapaces' nutrients by ingesting it along with any other chemicals that may be covering the shell. Crayfish have a life span of of 1 to 3.5 years with the exception of many troglodytic crayfish, which can live for many decades (Butler et al., 2003). Male crayfish are dimorphic and alter the appearance of their gonopods during spawning seasons. Gonopod morphology changes are typically characterized by finer definition at the tip of the gonopod and will often times have a coloration change to an off-white or a yellowish tint. Ovigerous females will find shelter and remain dormant for several days with eggs attached to their abdomen which is often termed "in berry" (Taylor et al., 2007). Once the eggs are hatched they remain attached to the female under the abdomen and are considered to be a clutch for several more days. After two or three molts the juvenile crayfish detach and go their separate ways (Taylor et al., 2007).

Fishes, amphibians, reptiles, birds, and many mammals actively forage for and consume crayfish. However, the diets of crayfish are much more diversified in taxa than the number of predator taxa that consume crayfish. For this reason crayfish are vital to aquatic ecosystem stability. Crayfish diets include everything from algae, carrion, other invertebrates, macrophytes, fish and amphibian eggs, and detritus (Dorn and Wojdak, 2004). Due to the crayfish's broad diet, they play an important role in the trophic transfer of energy across many different guilds in an aquatic food web. Crayfish are considered to be shredders and can break down leaf pack detritus which is then converted into animal protein and then transferred to higher predators (Momot et al., 1978; Vannote et al., 1980; Holdich, 2002). Ecosystem engineers are considered to be those animals which directly or indirectly alter their environment such as beavers, mayflies, and crayfish (Creed, 2004). Crayfish are considered to be ecosystem engineers because they can affect community structure by indirectly altering aquatic substrate coverage (i.e., increasing periphyton production) or by processing aquatic vascular macrophytes in littoral zones. In a controlled microcosm experiment, periphyton primary productivity increased 4-7 times in the presence of crayfish whereas total macroinvertebrate and herbivore densities decreased by 47-58% and 55-72%, respectively (Charlbois, 1996).

Crayfish also have an effect on their environment by providing habitat for crayfish worms. Branchiobdellidans have an ecosymbiotic relationship with crayfish which is typically non-beneficial to the crayfish. Many people think that branchiobdellidans are parasitic to the crayfish; however, a lead researcher on branchiobdellidans suggested that the relationship was more commensal than anything (Gelder et al., 2002). Currently there are 15 endemic genera of branchiobdellidans with 21 species native to Tennessee and 10 native to North Carolina (Gelder et al., 2002).

Epigean Crayfish of the Pigeon River Watershed

Three genera of crayfish from the Cambaridae family can be found in the Pigeon River watershed. *Cambarus* is the most common, with four species represented, and is typically associated with highland provinces such as the upper elevations of the Appalachian Mountains (Butler et al., 2003). *Orconectes* is the second most common genus with three species found most often in the valleys and lowlands (Butler et al., 2003). One species of crayfish has been found in the Pigeon River watershed from the genus *Procambarus,* which is more associated with Coastal Plain regions than it is to the high elevations of Haywood County, North Carolina. Crayfish species that have been found in the Pigeon River watershed, either through historical documentation or via this survey, are described as follows with a brief description of their habitats and life history and any recordings of the species occurrence in the watershed.

Cambarus bartonii

Common crayfish, *C. bartonii,* can be found in small- to-medium size streams in the Blue Ridge Mountains (Bouchard, 1972). Williams and Bevins, (2001) stated that they have recorded this species at an altitude as high as 360 meters (1810 feet) in elevation. The common crayfish can be found in headwaters, predominantly in pools under rocks. This species can also be found in tertiary burrows along stream banks and around tree roots (Hobbs, 1981). *C. bartonii* has been found in the Pigeon River by TVA (2009) on two different occasions. The first was on 16 August 2005 at (PRM 61), and the second documentation of this species was on 28 August 2005 at (PRM 59).

C. bartonii has been collected many times by Simmons and Fraley (2008) from the Pigeon River watershed. Upstream of Canton, North Carolina, he found *C. bartonii* off NC Highway 215 on 19 May 2004. He also documented this species downstream of the paper mill. *C. bartonii* was collected on 25 August 2005 at Hyder Mountain (PRM 59). Simmons and Fraley (2008) documented the collection of five *C. bartonii* in Jonathon's Creek off of White Oak Road and State Road 1338. He also noted two were captured in Jonathon's Creek at the intersection of Hall Road, State Road 1394, and US 276 (Simmons and Fraley, 2008). Mount Sterling Creek also has a population of *C. bartonii* off a 4x4 trail in Pisgah National Forest (Simmons and Fraley, 2008). An unnamed tributary to Waterville Reservoir has been noted to have *C. bartonii* off Forest Road 286, Pisgah National Forest (Simmons and Fraley, 2008).

Cambarus sp. nov

Cataloochee morph crayfish, *Cambarus sp. nov.,* has not yet been taxonomically described; it prefers large rocks in streams and rivers (Williams and Bevins, 2001). "This species was collected in the Pigeon River system from under large slab boulders and cobble in streams 2-3 m wide with moderate to high gradient and little sediment deposition" (Simmons and Fraley, 2008). Simmons and Fraley (2008) also encountered this species in Mount Sterling Creek off a 4x4 trail in Pisgah National Forest.

Cambarus longirostris

Longnose crayfish*, C. longirostris,* can be found in small streams primarily using riffles as its main habitat (Williams and Bevins, 2001). Hobbs (1981) described this crayfish in "the Tennessee River basin from northeastern Mississippi to Georgia and northward at least to the vicinity of Knoxville." Historical recordings of *C. longirostris* were documented by the University of Tennessee and TVA during an IBI survey of the Pigeon River where they found it in the Pigeon River at PRM 19.3 and in Denton, Tennessee, 7 July 2010.

Cambarus robustus

Big Water crayfish, *C. robustus,* can be found in small to large lotic systems, typically in the larger streams under rocks (Williams and Bevins, 2001; Taylor and Schuster, 2004). One documented occurrence of this species was found during a fish collection event in Cosby Creek, Tennessee, by the University of Tennessee and Tennessee Department of Environment and Conservation on 3 March 2010 at State Highway 321 South and Wilton Springs Road intersection, just downstream of the bridge.

Orconectes forceps

Surgeon crayfish, *O. forceps,* are found in small streams but more commonly in the larger streams, especially in riffle areas and under rocks (Bouchard, 1972). Williams and Bevins (2001) stated that "*O. forceps* can be found in the Blue Ridge, Ridge and Valley, and Highland Rim provinces." *O. forceps* is documented to have occurred at PRM 0.5 and PRM 0.6 on 17 June 2010. It has also been found in the Pigeon River at Denton, Tennessee, on 7 July 2010 during a stream assessment survey by state agencies.

Orconectes virilis

Virile crayfish, *O. virilis,* are an introduced species to the East Tennessee region (Williams and Bevins, 2001). The East Tennessee range for *O. virilis* is Douglas Lake watershed (Bouchard, 1972). The virile crayfish's range has been extended to the southeastern region when fishermen released them from bait buckets when they were done fishing. Williams and Bevins (2001) stated that "the introduced species is well-established in Douglas Reservoir and its tributaries in Jefferson and Cocke County." *O. virilis* is recorded to have a life span up to three years and can reproduce once a year (Dorn, 2004). Momot (1978) considered *O. virilis* an ecological equivalent to the rusty crayfish, *Orconectes rusticus*, which has had a detrimental impact on many lakes and rivers in the United States. In 1963, the range of *O. virilis* was documented to be "largely confined to watersheds of the Upper Mississippi River and Great Lakes drainages from Saskatchewan to Ontario, Canada, and Montana and Wyoming to New York" (Schwartz, 1963). Recordings of the virile crayfish in the Pigeon River watershed are from a fish collection event by the University of Tennessee and the Tennessee Department of Environment and Conservation on 30 March 2009 in Cosby Creek at the State Highway 321 South and Wilton Springs Road intersection.

Orconectes erichsonianus

Reticulate crayfish, *O. erichsonianus,* can be found in the Blue Ridge and Ridge and Valley provinces (Williams and Bevins, 2001). *O. erichsonianus* partitions under rocks as a primary source for habitat and is typically located in small to large streams with a moderate current (Hobbs, 1981). There are no recorded occurrences of reticulate crayfish found in the literature reviewed.

Procambarus acutus

White River crayfish, *P. acutus,* have been found along the Mississippi Embayment province and less commonly in tributaries of the Tennessee River on the Western Highland Rim upstream to Lincoln County (Bouchard, 1972; Distefano et al., 2009). *P. acutus* is not native to East Tennessee and Western North Carolina. *P. acutus* can be found in fluctuating bodies of water and burrow beneath the substrates when the water table begins to freeze or water begins to get too low (Hobbs, 1981). White River crayfish have been documented in the Pigeon River on 28 August 2008 and 25

August 2005 at PRM 59 (Simmons and Fraley 2008; TVA, 2009). They have also been found to occur off Golf Course Road, State Road 1649, in the Pigeon River (Simmons and Fraley, 2008).

Hypogean Crayfish of the Pigeon River Watershed

Two species of burrowing crayfish have been found in the Pigeon River watershed (Cooper, 2008). The red burrowing crayfish, *Cambarus carolinus,* is a primary burrower that is typically uncommon, usually found around small springs and seeps, and has a northern most range thought to end within the Pigeon River watershed (Williams and Bevins, 2001). Upland burrowing crayfish, *Cambarus dubius,* is another burrowing crayfish usually found on the Cumberland Plateau and Ridge and Valley and Blue Ridge provinces. This species is thought to occur in the northern regions of the Pigeon River watershed and has a distribution from there north through the Appalachian Mountains. Two accounts of *C. dubius* have been documented by Simmons and Fraley (2008). The first was an unnamed tributary to the Waterville Reservoir found off Forest Road 286, Pisgah National Forest, and the second was found in a wetland along the West Fork Pigeon River, off Lake Logan Road, NC Highway 215 (Simmons and Fraley, 2008).

Invasive Crayfish

The introductions of *O. virilis* and *P. acutus* to East Tennessee and western North Carolina was probably due to the result of fishermen dumping their bait buckets after use. A survey of Missouri bait shops that sold crayfish as live bait revealed that 80.8%

of their crayfish were *P. acutus* (Distefano et al., 2009). The bait shop survey by Distefano et al. (2009) revealed that, in a phone survey, 87% of bait shop owners did not know what species of crayfish they were selling. Another vector for non-native crayfish introductions is the use of crayfish for sale through biological supply companies (Lodge et al., 2000). Through these biological supply companies, schools and golf courses buy crayfish to use either for learning purposes or for aquatic weed control, respectively (Larson and Olden, 2008). Larson also gave an example of a teacher in western Washington admitting to letting her students take home the crayfish after they were studied in school (Larson and Olden, 2008). These pathways for introducing non-native crayfish can have adverse affects on indigenous populations. Introduced crayfish have also been documented to hybridize with native crayfish. In northern Wisconsin *Orconectes rusticus*, a similar species to *O. virilis,* was found to have hybridized with the native *Orconectes propinquus* (Perry et al., 2001).

Amphibians are also suffering the brunt of crayfish invasions. There are many studies that show how native amphibian populations are having an inverse relationship with introduced crayfish invasions (Gamradt et al., 1997; Kates and Ferrer, 2003; Cruz et al., 2006; Davidson, 2010). Gamradt et al. (1997) observed that 7 of 11 California newts, *Taricha torosa*, captured from a stream in the Santa Monica Mountains had recent abrasions and were bleeding. They also found that newts caught in a nearby stream that lacked the invasive crayfish *P. clarkii* showed no mutilations (Gamradt et al., 1997). Kates and Ferrer (2003) demonstrated that *P. clarkii* was associated with decreased egg and larval survivorship of *T. torosa*. A study by Davidson et al. (2010)

has recently documented how, in Arizona, *O. virilis* has contributed to the decline of the native Arizona ranid frogs. In streams where no Arizona ranid frogs were found, the sites were 2.6 times more likely to have *O. virilis* present (Davidson et al., 2010). The Pigeon River watershed is home to many different species of salamanders. A recent study indicated that the eastern hellbender and the Blue Ridge two-lined salamander both occur in the Pigeon River and could be impacted if invasive crayfish encroach on the reaches of stream where these salamanders are found to occur (Maxwell, 2009).

Established populations of non-native crayfish have the potential to negatively affect indigenous crayfish populations as well as amphibian populations, and may, in the future, need management strategies. Simmons and Fraley (2008) claimed that, at the present time, invasive crayfish have not posed a tremendous threat to native crayfish populations; however, if the distributional expansion of *O. virilis* or *O. rusticus* continues, then several native crayfish populations are at risk of being threatened.

Many techniques are used to control invasive crayfish populations. One approach was to use baited minnow traps to capture non-indigenous crayfish from certain lakes in Wisconsin (Hein et al., 2007). Hein et al. (2007) claimed that the Catch Per Unit Trap Effort (CPUTE) in 2002 was 11 crayfish per trap per day, whereas in 2004 the number decreased to 0.65 and further dropped to 0.5 the following year. Another method for control of invasive crayfish is to restrict the harvest of fish known to be crayfish predators (Hein et al., 2007). Biological controls are being studied as an alternative for invasive crayfish management in Arizona where no native crayfish populations are found to occur (Davidson et al., 2010). Davidson et al. (2010) discussed the idea of releasing nematodes, bacteria, or white spot syndrome virus into the wild as a means of dealing with the invasive *O. virilis*. This method would not be best suited for any streams found in the Mississippi Drainage system because diversity of crayfish is so robust in the eastern United States.

Bioaccumulation of Contaminants in Crayfish

Toxins often can be easily incorporated into the food chains of aquatic ecosystems. Crayfish are excellent indicators of water quality because they directly consume the exoskeleton they shed in order to benefit from its nutritional value. Taylor et al. (2007) stated that "reported higher mortality rates for juveniles than adult crayfish exposed to cadmium uptake, and that calcium metabolic disruption [is greater] in more rapidly molting juveniles." A toxicology study based on manganese (Mn) accumulation in crayfish collected below a thermo-mechanical paper mill contained up to 274% more Mn concentrations when compared to crayfish collected upstream of the paper mill (King et al., 1999). King et al. (1999) also noted that prior to crayfish molts, carapaces were found to be a dark brownish and black color, while crayfish in control groups displayed lighter coloration. The intake of such metals by crayfish can create pathways for the metals to be transferred to higher level predators such as catfish and black bass.

Chapter 3

Methods

Study Area

The Pigeon River is part of the Upper Tennessee River Basin and flows from the Blue Ridge Province's Unaka Mountains in North Carolina and follows Interstate 40 through the Ridge and Valley Province of East Tennessee. The Pigeon River main stem is considered to be a 5th order stream fed by many tributaries (Vannote et al., 1980). The geologic makeup for the Unaka Mountains consists mostly of Precambrian and Cambrian sedimentary rocks and metamorphic and igneous rocks. "The sedimentary rocks are mainly clastics that have undergone varying degrees of metamorphism and are now conglomerates, quartzose sandstones, graywacks, and slates" (Bouchard, 1972). The Ridge and Valley Province is underlain with prehistoric sandstone, limestones, dolomite, chert, siltstone, and shale primarily from the Cambrian and Ordovician periods (Bouchard, 1972; Etnier and Starnes, 1993). These metamorphic rocks have eroded over millions of years forming them into large boulders and rubble which serves as prime habitat for the crayfishes of the Pigeon River and its tributaries.

Sites in the Pigeon River and its tributaries were selected for sampling by determining how much suitable habitat was available for crayfish and how feasible it was to survey using snorkeling and trapping capture techniques. Sites were selected in each of four main reaches of the Pigeon River and surveyed: 1) three sites upstream of the paper mill, starting at the confluence of the east and west forks of the Pigeon River and ending at Canton Park, 2) three sites downstream of the paper mill, where the oxygenation station was site 1, and site 3 was downstream of Ferguson Bridge, 3) three in the by-pass channel, where site 1 was just off the Harmon Den exit, and the last site was just upstream of Walter's Power plant, and 4) three sites downstream of Walter's Power Plant on the Tennessee side of the river with the first site located in Hartford just upstream of the Lindsey Gap Bridge and the 3rd site just upstream of the confluence to the French Broad River (Figure 1). More information on site locations and coordinates can be found in the Appendix section. Locations of the main stem sites are denoted with a Pigeon River Mile (PRM) number as opposed to a Pigeon River Kilometer (PRKM); this was done because it is the common method of locating river landmarks. Tributaries were also sampled at three different locations: 1) at the upper reach of the stream, 2) in the middle of the stream reach, and 3) at the mouth of the creek. The nine tributaries surveyed were a representative sample of all streams from the Pigeon River watershed which include: Beaver Creek, Richland Creek, Jonathon's Creek, Cataloochee Creek, Hurricane Creek, Cold Springs Creek, Big Creek, Tobes Creek, and Cosby Creek. A description of each site with collection data (i.e., water quality and physical characteristics information) can be found in the Appendix.

Field Sampling

River flow and depth information were checked using the United States Geological Survey's National Water Information System: Web Interface before going to sites scheduled to be surveyed. Once sites were selected for the main stem of the river, they were identified by average stream width and a transect length was set at 30 meters (98 feet). Transect width was kept consistent by including any obstructions such as logs, stumps, or boulders and by excluding islands (Platts et al., 1983). Basic water chemistry parameters were recorded where flows were the most uniform. Temperature, dissolved oxygen, pH, conductivity, salinity, turbidity, and stream flow were recorded at each site.

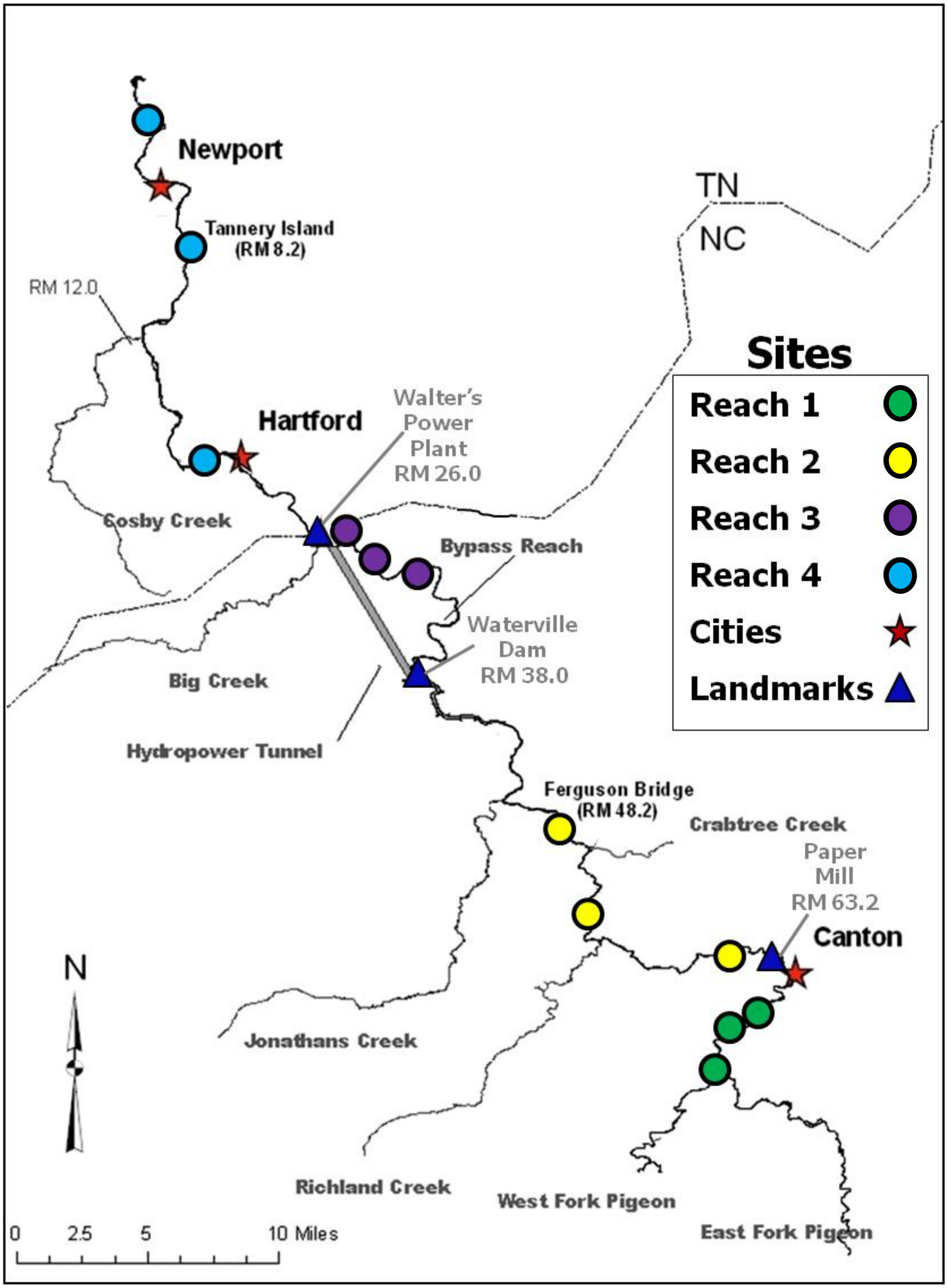

Figure 1. Map of the Pigeon River and tributaries in North Carolina and Tennessee showing the sampling sites in all four reaches of the main stem.

Pigeon River main stem sites were sampled by using a zigzag snorkeling method described by (Murphy and Willis, 1996; Coombs, 2003; Williams et al., 2003; Maxwell, 2009) and by lifting rocks from the starting point at the downstream border of the transect and finishing after 30 meters (98 feet) of snorkeling upstream (Figure 2). All crayfish were hand collected during the snorkeling effort and were placed in a 1.0-L hard plastic bottle. Tributaries to the Pigeon River were surveyed using minnow traps. Traps were baited using nylon mesh stuffed with canned dog food (Rach end Bills, 1987; Alonso, 2001; Taylor and Schuster, 2004; Larson and Olden, 2008) and catfish cheese bait suspended in the traps using paper clips looped over fish hooks, and clasped to the minnow trap walls (Figure 3). Nine black minnow traps (¼ inch mesh) were placed in groups of three at each site and aligned across the width of the stream using 7.62-meter (24.99-foot) lead weighted ropes. Traps were baited and placed in the stream and then collected after 3 to 5 days (Hein et al., 2007). Remote areas with limited access or rough terrain were sampled using a backpack shocker and a 3-meter (10-foot), ¼-inch mesh seine. The seine was set in fast current and large rocks were turned upstream followed by a swift kicking action towards the seine (Williams et al., 2003). Each effort time was recorded in order to duplicate and analyze efforts (Williams et al., 2004). Electrofishing was used in anticipation of increasing catch rates by helping to dislodge crayfish from crevices. "Previous experience showed… that electrofishing efficiency on crayfish seemed to improve using a low voltage output (30-50v), and switching on and off the circuit for one or two seconds" (Alonso, 2001).

Figure 2. The zigzag snorkeling method was used to sample sites in the main stem of the Pigeon River.

Figure 3. Baited nylon mesh pouches were suspended in the 1/4-inch mesh minnow traps and the traps was tied closed using plastic zip ties and 7.62-meter lead weighted rope.

Data Collection

A 45-Liter cooler was used to hold crayfish while they were identified and measured, and were returned to the stream afterward. All specimens were identified to species and sexed and measured using their total carapace length (CL) in millimeters (Hein et al., 2007). Any specimens (up to 10 individuals) which could not be identified in the field were preserved using a 70% alcohol solution and were taken to C.E. Williams at the Tennessee Wildlife Resource Agency for identification. All crayfish that were preserved were inventoried and were distributed to the Tennessee Wildlife Resource Agency's collection of crayfishes in Morristown, Tennessee, and to J.E. Cooper at the Museum of Natural History in Raleigh, North Carolina.

Habitat Observations

Crayfish can be found in a variety of different habitats and substrate combinations. The parameters for the selected substrate classifications used in the present study, according to Platts et al. (1983) are: fine sediment (sand), 0.83- 4.71-millimeter; gravel, 4.81- 76.0-millimeter; cobble 76.1- 304.0-millimeter; rubble, 305.0-609.0-millimeter; and bedrock. Substrate types defined for the present study are organic, silt, sand, gravel, cobble, rubble, bedrock (Strange and Habera, 1993). Techniques for recording substrate composition at study sites were modified from Strange and Habera (1993). Sites were divided into six cross sectional transects spaced at 5.0 meters apart, beginning at the downstream section of the site transect and ending 30 meters upstream (Figure 4). The stream was then divided into three longitudinal divisions from stream bank to stream bank where 1/4 of the distance from the closest bank was one division, the middle division was 1/2 across the stream reach from bank to bank, and the third division was marked as 3/4 of the way across the stream (Strange and Habera, 1993). At each point where the river's cross-sections encountered a longitudinal division of the stream considered 1/4, 1/2 or 3/4, a substrate composition was recorded from a 1.0-meter (3.3-foot) diameter circle area around the intersecting point. One site consisted of 18 intersecting points. Substrate compositions were determined based on the dominant substrate and a sub-dominant substrate. Substrates that comprised over 50% of the one-meter area around the intersecting point were considered dominant. Those substrates that comprised less than 50% were considered sub-dominant. Any substrates that span the entire circular one-meter area were considered to be both 50% dominant and 50% sub-dominant (Strange and Habera, 1993).

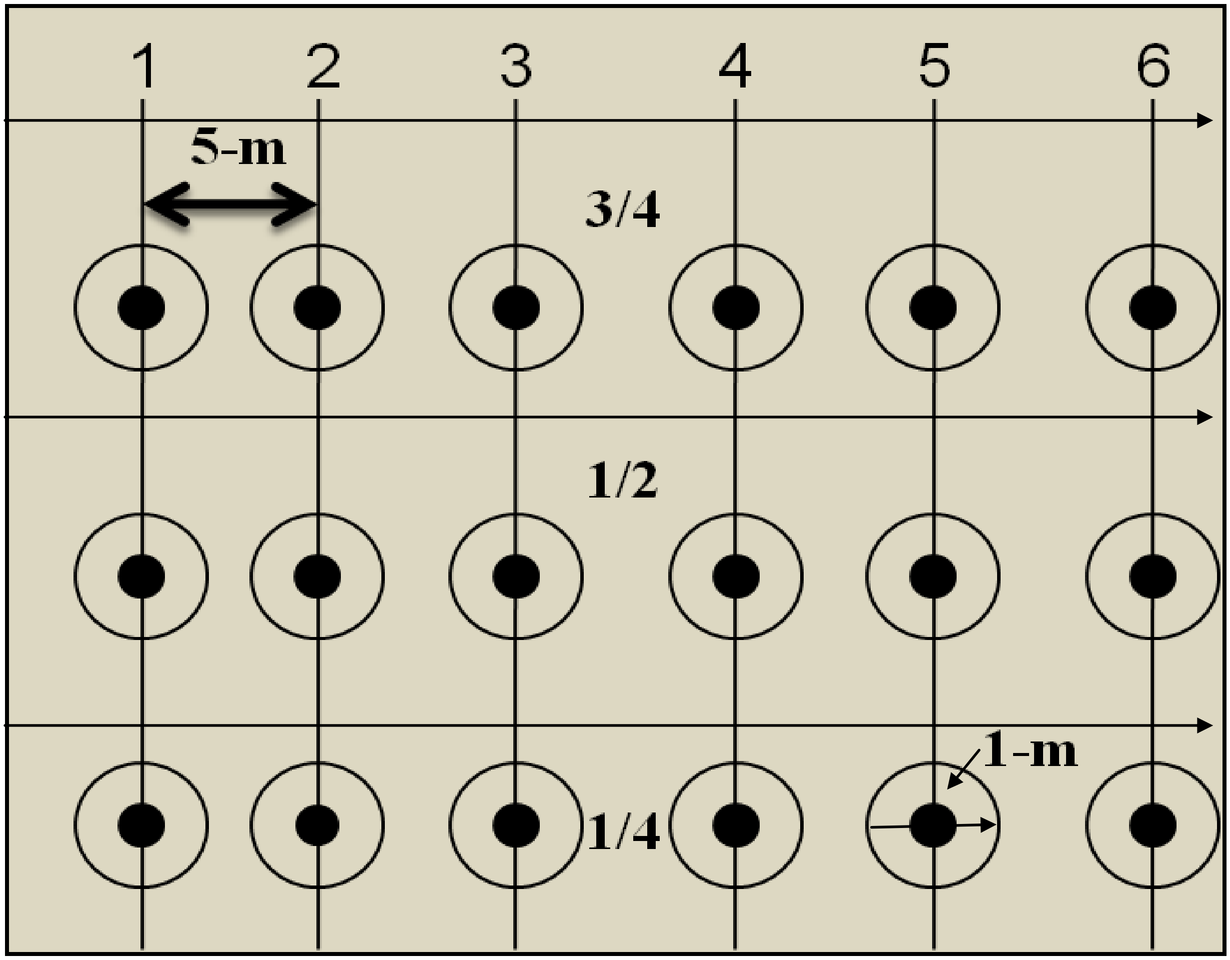

Figure 4. Schematic demonstrates the substrate recording technique. The river is divided into three divisions (1/4, 1/2, 3/4), and dominant and subdominant substrate compositions are recorded every 5.0 meters (3.3 feet) starting at the downstream section of the transect and ending 30 meters (98.4 feet) at the upstream end of the site.

Statistical Analyses

Catch rates of crayfish from all sites were standardized using CPUE to make comparisons among sites. CPUE was calculated for snorkel sites on the main stem by using CPUE = (# of observed crayfish)/(snorkel time per observer)(number of observers) (Williams et al., 2004). To calculate the catch rate for traps, the number of hours that minnow traps were deployed in the water was multiplied by the number of traps (9) set at the study site, and once the total hours was established, that number was divided into the number of crayfish caught in all nine traps, giving the total (CPUTE) (Hein et al., 2007). CPUE using a seine was calculated by dividing the total number of crayfish found at a site by the total time in minutes of all seine efforts combined.

Crayfish CPUE mean values from the Pigeon River main stem were compared across the four different stream reaches to find whether there were any significant differences among reaches. A univariate ANOVA test was used to compare the crayfish CPUE values. The two classic requirements for the univariate ANOVA are that the means should be in a normal distribution and that the variances of the means should be the same. To test if the means were normally distributed, a Shapiro-Wilk test was used, followed by the Levene's test to determine whether variances were relatively the same. A nonparametric test (Kruskal-Wallis test) was chosen to rank the sites and compare for differences if the variances of the CPUE means were not equal. A Chi-square test would be administered to detect the significance of the Kruskal-Wallis test.

Each site's crayfish population abundances were run through the Chang Bioscience Inc (2004) Shannon- Weiner Diversity Index/Shannon Entropy calculator to determine the level of diversity for each site. The Shannon Weiner Diversity Index ranks on a scale from 0 to 6, where 0 is considered to be a low diversity index, and 6 is considered to be optimum (Brower et al., 1997). Along with the diversity index number, an evenness number was also calculated, which is how the individuals are distributed among the number of species present at each site (Brower et al. 1997). The evenness number ranges for 0 to 1, where 0 is considered to be very uneven, and 1 is perfectly even.

Chapter 4

Results

Crayfish

A total of 1,320 crayfish were collected during this 2009-2010 survey from both the main stem of the Pigeon River and tributaries. The total number of each species collected was: 326 *C. bartonii*, 214 *C. sp. nov.*, 159 *C. longirostris*, 76 *O. forceps*, 55 *O. virilis*, 19 *P. acutus*, 3 *O. erichsonianus*, 415 *Cambarus spp.*, and 53 *Orconectes spp.* Totals are also presented in Table 1.

Table 1. Total number of crayfish collected during the 2009-2010 survey in the Pigeon River watershed.

Common Name	Species Name	Total
common crayfish	*Cambarus bartonii*	326
Cataloochee morph	*Cambarus sp. nov.*	214
longnose crayfish	*Cambarus longirostris*	159
surgeon crayfish	*Orconectes forceps*	76
virile crayfish	*Orconectes virilis* [Introduced]	55
White River crayfish	*Procambarus acutus* [Introduced]	19
reticulate crayfish	*Orconectes erichsonianus*	3
-	*Cambarus spp.* †	415
-	*Orconectes spp.* *	53
Total	-	1320

† = The 415 *Cambarus spp.* were mostly collected from the Cosby Creek during late May and early June in a cascading riffle. It is presumed that those *Cambarus spp.* found at the Cosby Creek sites were mostly *C. longirostris* collected during spawning season using a 10-foot, 1/4 inch mesh seine. The crayfish could not be positively identified by the collector due to inexperience of field identifications during the first few weeks of this study. A limit of 10 crayfish of each species was permitted to be taken from each site.

* = The 53 *Orconectes spp.* were mostly found in the Pigeon River mainstem at the site in Hartford (reach 4, site 1), where juvenile *O. forceps* and *O. virilis* were very similar in appearance and could not be identified to species in the field.

Tennessee crayfish diversity was found to be the highest in taxa with 76 described species of native crayfish (Williams et al., 2004). Crayfish diversity in North Carolina is currently at 42 named species with several others yet to be described in the literature (Cooper, 2007). Tennessee's physiographic makeup is so diversified that it creates a range of different habitats for crayfish to have taxonomically diverged from one another. North Carolina also shares many of the same landscapes which create good habitats in which crayfish populations strive. It is thought that 48% of crayfish species nationwide are in danger of imperilment caused by human disturbances, such as the introduction of nonindigenous crayfish and destruction of habitat (Butler et al., 2003).

Pigeon River reaches one, three, and four were compared excluding reach two, because no crayfish were found downstream of the paper mill down to Walter's Lake. Once the variances in CPUE mean were calculated for each reach, it was determined that all reaches had zero in the variance's range. The Shapiro-Wilk test was run on means for the main stem to determine whether means were normally distributed in order to analyze data using a univariate ANOVA. The Shapiro-Wilk test was 0.0 (which does not exceed the value of 0.90), indicating that the CPUE means were normally distributed. Levene's test was used to determine if each reach's mean CPUE variance was significantly different. The Levene's test results, ($F = 9.679$; d.f. = 2; $P = 0.013$), alpha =.05, indicated that the variances for mean CPUE values compared across reaches were unequal. Unequal variances make comparisons using ANOVA weaker, but they were calculated because variances would have been more similar if additional data were collected from more sites along the main stem. Analyses using an unequal variance nonparametric test were also calculated and will be discussed later. CPUE comparisons for reaches upstream and downstream of the paper mill were not significantly different by univariate ANOVA. Mean CPUE Total does not differ by reach (1, 3, 4); F= 0.946; d.f. = 2, 6; P= 0.439, using alpha=.05.

Since the equality of variance assumption was not met, a nonparametric (NPar) test was used to test for differences in CPUE by reach. The Kruskal-Wallis test compares independent groups using an ANOVA on the ranks of the dependent variable CPUE and assumes the hypothesis that mean ranks are equal. The CPUE values are ranked from lowest to highest and then separated by reach to calculate the mean rank for each group. CPUE mean total ranks for each reach are as follows: reach one= 3.00, reach two= 5.67, and reach three= 6.33. These means suggested that reach one has the lowest CPUE values and reach three and four have fairly similar values in that their mean ranks are not significantly different. The Chi-square test calculates the significance of the Kruskal-Wallis test and the results are Chi-square= 2.489; d.f. = 2; P= 0.336, indicating that no significant differences in CPUE among reaches were found.

Water Quality

Water conditions in the Pigeon River have been unpredictable over the past four years with a drought occurring in 2007, and heavy rains throughout 2009. Crayfish were collected by the Tennessee Valley Authority and North Carolina Wildlife Resource Commission during the summer of 2005 downstream of the paper mill in the mainstem at Hyder Mountain, the oxygenation station, and off Golf Course Road, but were not found during this survey. A possible reason for this was the drought in 2007 which caused the Pigeon River to have low flows that in turn caused paper mill effluents to concentrate in the river. The concentration of effluents could have created uninhabitable water quality conditions for crayfish to thrive directly downstream of the paper mill in reach two. Table 2 depicts conductivity (μs) levels in the Pigeon River upstream of the paper mill and downstream of the paper mill. Data presented in the following graph was obtained from the Tennessee Department of Environment and Conservation, in Knoxville, Tennessee. Discharge #001 was the direct point source of paper mill effluent discharge.

Table 2. Conductivity levels, in µs, in the Pigeon River above the paper mill in Canton, and below the paper mill in Fiberville, and the paper mill effluent discharge pipe during May, June, July, and August, of 2005, 2007, and 2009.

	2005				2007				2009			
	May	June	July	August	May	June	July	August	May	June	July	August
Canton (PRM 64.5) upstream of paper mill	29.26	25.32	31.44	30.15	28.84	31.20	32	34.30	25.4	24.22	31.60	N/A
Fiberville (PRM 62.9) downstream of paper mill	333	197	543	370	635	887	1094	1438	335	246	883	N/A
Discharge # 001	2319	2477	2391	2487	2302	2211	2236	2089	2599	2470	2333	N/A

Habitat Analyses

Each site's substrate compositions were documented from a 14-meters² area and can be found in the Appendix section. Substrate percentages were calculated for each site by summing each substrate classification's percentages (i.e., percent bedrock, rubble, cobble, etc.) and then dividing that number by the sum of all substrate percentages. The three most dominant substrate classifications for each stream reach or tributary are presented in Table 2, and were calculated by dividing the total substrate classification percentages from each site by the sum of all substrate classification percentages from the entire stream reach or tributaries.

Table 3. The three highest substrate compositions for the four reaches of the Pigeon River main stem and all nine tributaries.

Stream Reach and tributaries	**First Highest Substrate Percentages (%)**	**Second Highest Substrate Percentages (%)**	**Third Highest Substrate Percentages (%)**
Pigeon River Reach 1	Rubble 47	Cobble 26	Silt 9
Pigeon River Reach 2	Rubble 58	Cobble 11	Bedrock 10
Pigeon River Reach 3	Rubble 55	Bedrock 21	Cobble 20
Pigeon River Reach 4	Rubble 54	Cobble 24	Silt 10
Beaver Creek	Sand 42	Rubble 18	Gravel 14
Richland Creek	Rubble 70	Gravel 11	Cobble 8.5
Jonathon's Creek	Rubble 58.5	Bedrock 18	Sand 9
Cataloochee Creek	Bedrock 56	Rubble 30	Cobble 7
Hurricane Creek	Rubble 48	Sand 14	Bedrock 12
Cold Springs Creek	Rubble 49	Sand 19	Cobble 18
Big Creek	Rubble 57	Cobble 24	Bedrock 11
Tobes Creek	Rubble 36	Gravel 23	Cobble 2
Cosby Creek	Rubble 57	Sand 18	Cobble 14
Total	**Rubble 53**	**Cobble 23**	**Bedrock 21**

Anecdotal Information

One specimen of *C. bartonii* was found at the mouth of Beaver Creek and had a stained carapace when visually compared to a *C. bartonii* collected upstream in the tributary (Figure 6). Beaver Creek also had the invasive *P. acutus* present at both study sites above the low head dam where stream flows are backed up and warmer with sluggish flows. One specimen of *P. acutus* was also collected in Richland Creek just below the Lake Junaluska Dam where water was very warm and black fly larvae blanketed the substrates. The mouth of Richland Creek harbored a small population of *C. bartonii* that were found during a single snorkel session. *C. bartonii* was the only species found in Jonathon's Creek, which is a cold-water, medium to high gradient stream. Cataloochee Creek has limited access outside the park boundaries and was only sampled at the confluence to Waterville Lake. The Cataloochee morph crayfish, *Cambarus sp. nov.,* was the only species found to occur in Cataloochee Creek (using a seine and backpack shocker). *C. bartonii* was the only crayfish species observed to co-habit with *Cambarus sp. nov*., while Hurricane Creek had both species present at all three sites using baited minnow traps and a backpack shocker with a seine. It was observed that the two largest *C. bartonii* (44 CL ♀) found during this study were collected in Hurricane Creek co-habiting with the largest species of crayfish in the watershed, *Cambarus sp. nov*. This co-habitation was true for the Cold Springs Creek confluence as well, but only *C. bartonii* was found in the upper and middle sections. Conversely, Big Creek and Tobes Creek only had *Cambarus sp. nov.;* they were found at all the study sites. Tobes Creek harbored the largest crayfish observed during this study, a female *Cambarus sp. nov.* with a CL of 56 mm. Tributaries of the Pigeon River presented higher diversity than the main stem, with Cosby Creek having six of the eight species found in the watershed.

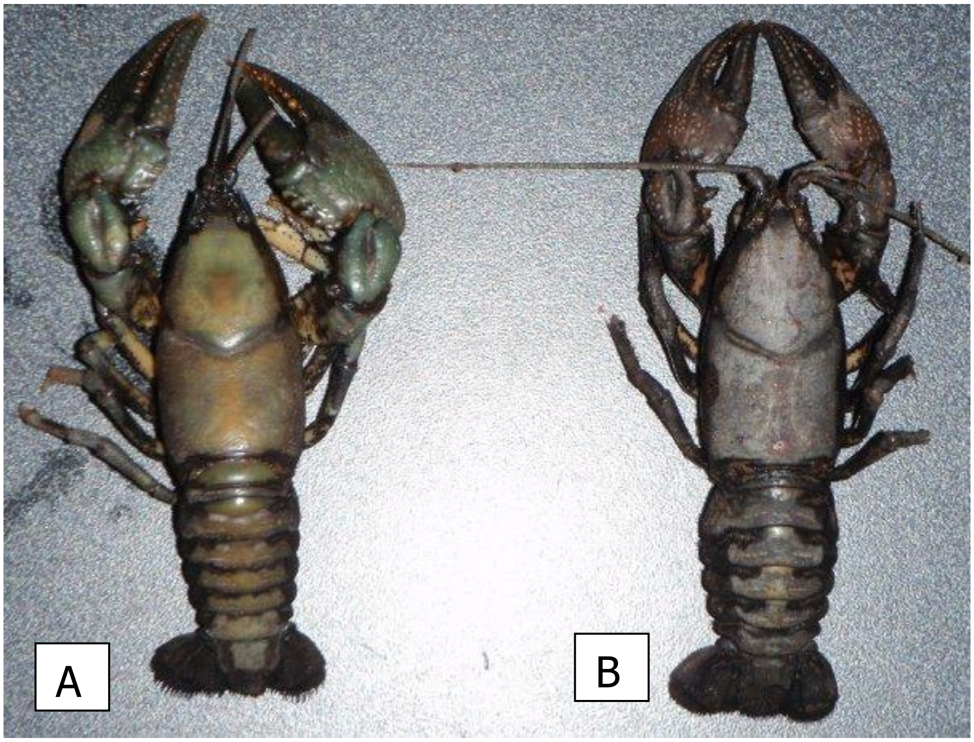

Figure 5. Two specimens of *C. bartonii* found in Beaver Creek. A) was found in the most upstream site (site 1) of Beaver Creek and has a normal carapace coloration, and B) has a stained carapace, and was found at the confluence of Beaver Creek and the Pigeon River main stem (site 3).

Snorkel surveys, as a means of collecting crayfish, were found to be quite effective. Visibility while snorkeling to capture crayfish was not as imperative to this study as that discussed in studies where snorkeling is used to observe and identify fish (Coombs, 2003). Stream reaches with moderate flows were best for catching crayfish because siltation would be swept away to reveal the individual before a "startle/escape" reaction could be achieved. Two crayfish startle reactions were observed during this study. In the first, crayfish escaped upwards into the water column and allow currents to help them relocate. The second was a retreat into a burrow under a rock. Often burrows could be dug out and the individual collected; however, at times crayfish would be lost in the substrates. Burrow retreats were found to be more prominent in areas with smaller crayfish, whereas swim-off retreats were observed most often in areas with larger individuals.

Baited minnow traps were determined to be the most efficient and replicable method used to survey the Pigeon River tributaries. Due to the variation of gradients and stream flows with respect to depth in the eight tributaries, the trapping technique was the only method that could consistently be applied to every stream sampled. Bait scents were capable of flowing downstream and luring crayfish out from habitats that might not have been easily sampled with the use of other techniques. Sites sampled with a seine often caught abundant numbers of crayfish, which was an effective technique if water was deep enough and stream flows were relatively swift. The seine method would have been more efficient if used to compare crayfish populations in streams which have similar hydrologic makeup.

Crayfish are vital to riverine ecosystems because their extensive diets allow them to feed on multiple levels of the food chain. This creates a pathway for energy to be captured from primary producers and transferred to other predatory organisms. Crayfish are considered to be ecosystem engineers, which means they can alter their environments to create habitat. An example of this ecosystem engineering behavior was when an individual of *P. acutus* was encountered occupying a self-made sand mound surrounding a flat stone at Beaver Creek-Site 1.

Chapter 5

Discussion

Eight species of crayfish were represented, including those documented in historical recordings conducted outside this survey's data collecting criteria. Tributaries in the upper reaches of the Pigeon River in the Unaka Mountains showed less diversity than those tributaries found in the Ridge and Valley Province, with crayfish diversity of six different species found at the lower reaches of Cosby Creek in Cocke County, Tennessee. This skewing in diversity from the upper reaches of a stream to the more diversified middle/lower reaches of the stream followed the same theoretical paradigm discussed by Vannote et al. (1980), (Figure 7). Significant differences in crayfish diversity among reaches of the Pigeon River were not found to exist. Since no crayfish were found immediately downstream of the paper mill in the mainstem (Figure 8), the entire second reach of stream was excluded from the analyses. CPUE variances were all within the range of zero, which statistically indicated that all four reaches of the main stem were the same with respects to crayfish abundances.

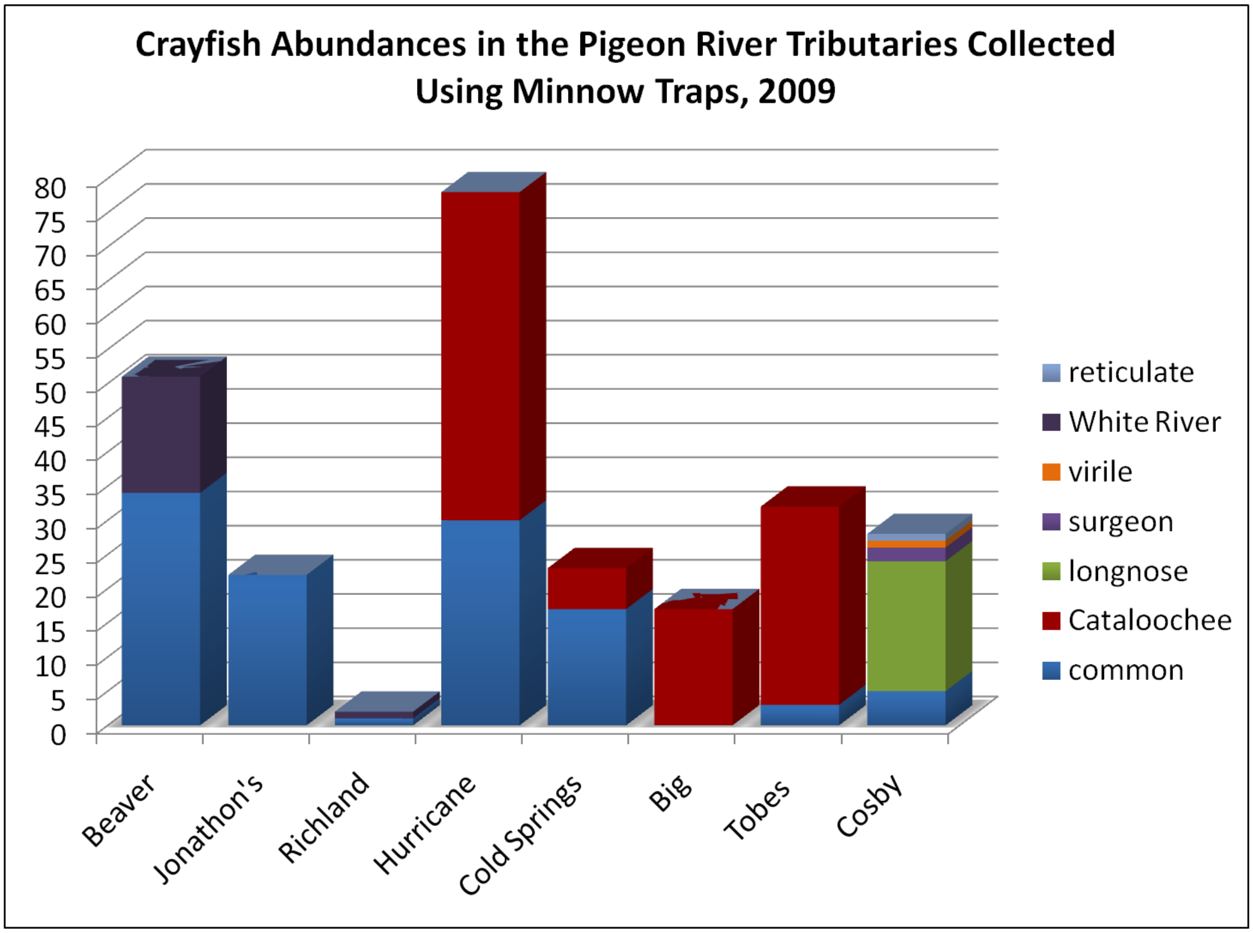

Figure 6. Graph of crayfish abundances from tributaries of the Pigeon River starting with Beaver Creek, having two species of crayfish, and ending with Cosby Creek having five species of crayfish. Cataloochee Creek is not illustrated because only one site was sampled at the confluence into Walter's Lake where the crayfish abundance value was N= 22 *Cambarus sp.nov*.

Salinity and conductivity were found to be linked and have a direct relationship when comparing study sites in the main stem. Maxwell (2009) stated that conductivity can have adverse effects on amphibian development. Crayfish juveniles were found to be sensitive to toxins due to their permeability between molts (Taylor et al., 2007). High salinity concentrations or increased conductivity levels could also be a cause for crayfish abundances to be low in reach two of the Pigeon River with respect to historical recordings of crayfish collected downstream of the paper mill. Crayfish were not found in the second reach of Pigeon River beginning at the site at the oxygenation station (PRM 0.5) downstream to Ferguson Bridge (PRM 48); however, crayfish were found in the mouths of two tributaries that empty into the second reach of stream (i.e., Beaver Creek and Richland Creek). These two tributaries may serve as pathways for founding populations of crayfish to re-colonize the main stem of the Pigeon River at some point in the future.

The drought in 2007 may have caused crayfish to retreat from the main stem, and seek out refugia when salinity concentrations were twice as high as they were in 2005. This increase in salinity was probably due to the low water levels in the river which concentrated the effluent discharges from the paper mill. This situation was probably the reason that crayfish were collected in 2005 below the paper mill by TVA and NCWRC, and not collected during the present 2010 study. During the drought of 2007, conductivity levels were almost 10X higher than the conductivity levels from 2005 (Table 2). In 2009, conductivity levels below the paper mill were almost half of what they were in 2007. In 2010, conductivity levels were slightly higher than in 2009 (Appendix); this was more than likely due to reduced rainfall in 2010.

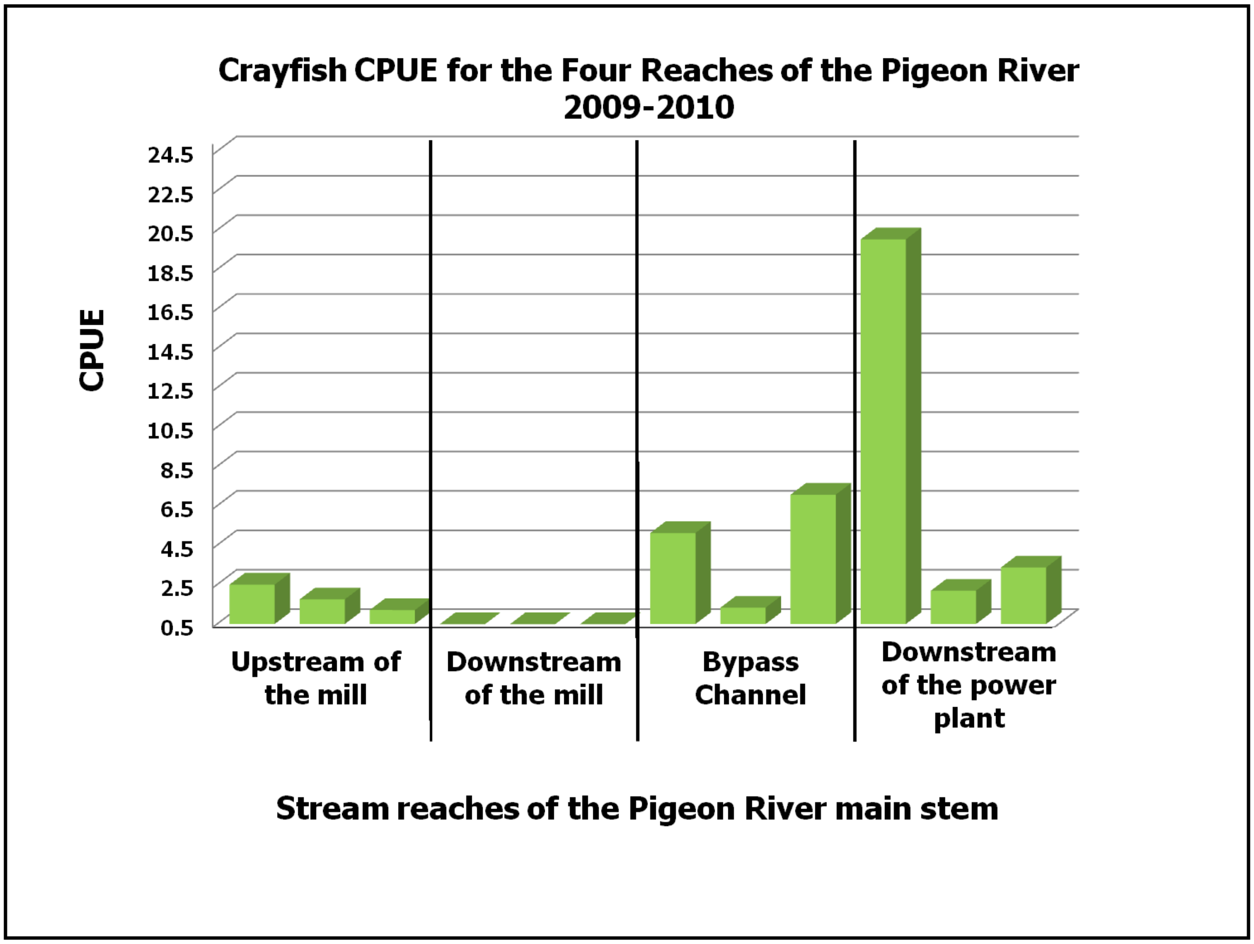

Figure 7. Graph depicts the CPUE across the four different reaches of the Pigeon River main stem. Each reach is made up of three sites.

Invasive crayfish have the potential to create a detrimental shift in the native crayfish community structure. It has been proven through other studies that invasive crayfish can impact the integrity of native benthic guilds that share the same habitats. North Carolina has developed ordinances that ban the possession of *O. virilis* in hopes of stopping its encroachment in the state (Simmons and Fraley, 2008). Tennessee is in the processes of developing similar laws to prevent any relinquishment of the state’s diversity in crayfish fauna. If using crayfish as bait, it is important that the fisherman either use crayfish caught in the water body being fished, or use artificial crayfish lures.

Weather conditions during the 2009 portion of this survey may have affected the catch rates of four of the minnow traps deployed in Cold Springs Creek- sites three and four. When traps were set, the stream was deep enough to cover the openings on both ends of the minnow traps, but on retrieval day the minnow traps were no longer submerged completely. Crayfish were still collected from these traps. In Cold Springs Creek-site two, three minnow traps were found crushed by what was believed to be by a black bear that tried to retrieve the bait (Figure 9). A dead black snake and a field mouse were also found in two traps from Cold Springs Creek - site two.

Crayfish in the Pigeon River watershed utilized rubble, cobble, and bedrock as their preferred habitat types. The four reaches of the main stem were comprised of 53% rubble, 20% cobble, and 11% bedrock. Reach one and Reach four had the most similar substrate compositions, where both sites had approximately 50% rubble, 25% cobble, and 10% silt. Rubble was also the highest ranked substrate percentage found in all nine tributaries, followed by cobble, then bedrock.

Figure 8. Minnow traps set in Cold Springs Creek were crushed by a bear trying to retrieve the bait.

Chapter 6

Summary

This study will provide beneficial information for the Pigeon River Recovery Project. Crayfish are crucial to breaking down solid foods for other benthic invertebrates and can serve as a food resource for predatory fishes which makes them valuable to aquatic ecosystems. The major findings of this study are listed below.

1.) There were no crayfish collected directly downstream (Reach 2) of the paper mill; crayfish were collected in the Pigeon River downstream of Walter’s Dam.

2.) Crayfish diversity (eight species) in the tributaries increased as the Pigeon River flows from the western Blue Ridge province (North Carolina) into the lower elevation landscapes of Cocke County, Tennessee.

3.) Crayfish were found in all nine of the sampled tributaries, which suggested recolonization of the main stem may be possible in the river downstream of the paper mill down to Waterville Reservoir.

4.) The drought during 2007 caused paper mill effluents to concentrate in the Pigeon River and may have created uninhabitable conditions for crayfish to thrive directly downstream of the paper mill, which could be a reason why no crayfish were collected during this survey.

Specimens collected and preserved during this study will be distributed to the locations at the TWRA crayfish collection in Morristown, Tennessee, and at the Museum of Natural History in Raleigh. The native crayfish community for the Pigeon River watershed will need to be monitored with respect to the encroachment of invasive crayfish. The Pigeon River serves as a livelihood for many people in its surrounding communities. Providing biological surveys, such as this crayfish survey, will allow future researchers to better understand the river's food web and to continue to improve its overall health and aesthetic appeal.

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Appendix

Study Sites

Study sites listed below summarize each site's location, sample date, physical parameters, and accounts of crayfish collected. Each site was sampled for temperature, pH, conductivity, stream flow, salinity, dissolved oxygen (DO), and Turbidity. Catch Per Unit Effort (CPUE) or Catch Per Unit Trap Effort (CPUTE) for each site is listed and was calculated to account for all individual crayfish collected at the site. Shannon's Diversity Index, and evenness are listed for those sites that had more than one species of crayfish collected. Total abundance and relative abundance are listed for each species followed by the number of individuals from each sex (♀♂) collected with the sexes' average carapace length (CL). Any crayfish that were form I are noted along with any ovigerous female crayfish. Substrate percentages summarize a 14-m² area for each site and are listed from most dominate to least dominate substrate.

Pigeon River Main Stem

Reach 1. Above Paper Mill (North Carolina)

Site 1. Pigeon River- Upper Confluence. This site is located at the confluence of the East and West Prong of the Pigeon River off of Pisgah Drive at Riverhouse acres. The water conditions were clear with low flow.
Date: 13 July 2010
Crew: 3 people, Snorkel Time in hours: 1.35

Coordinates: N35.28486 – W82.52550
Width: 32.9 m, Depth: 0.85cm
Temperature: 22.6°C, pH: 7.20, Conductivity: 21.5 μs, Stream Flow: 0.06 cms
Salinity: 17.7ppm, D.0.: 7.86 mg/L, Turbidity: 1.715 NTU
Crayfish Accounts: CPUE Total: 2.5, Total Abundance: 12,
Species Richness: 1, H': 0, Evenness: 0
C. bartonii- Relative Abundance: 100%, 7♀ 19.17μ CL, 5♂ 20.75 μ CL
Substrate Percentages: Cobble 31.7%, Rubble 25%, Gravel .08%,
Sand .08%, Silt .27%

Site 2. Pigeon River- Filter Plant Road. This site is located just downstream of the second bridge past Canton Park off of Filter Plant Road. The water conditions were clear with normal flows.
Date: 24 June 2009
Crew: 4 people, Snorkel Time in hours: 3.
Coordinates: N35.312057– W82.505676
Width: 33.25 m, Depth: 190cm
Temperature: 21.0°C, pH: 9.7, Conductivity: 23.3 μs, Stream Flow: 2.39 cms
Salinity: 17.7ppm, D.0.:6.53 mg/L, Turbidity: 1.18 NTU
Crayfish Accounts: CPUE Total: 1.75, Total Abundance: 21,
Species Richness: 1, H': 0, Evenness: 0
C. bartonii- Relative Abundance: 100%, 10♀ 26.53μ CL, 3 Ovigerous ♀,
11♂ 30.36 μ CL,
Substrate Percentages: Rubble 63%, Cobble 20%, Sand 7%, Gravel 4%

Site 3. Pigeon River- Canton Park. This site is located at the Canton City Park off of Penland Street behind the soccer field. Water conditions were slightly cloudy but still had good visibility and flows were normal.
Date: 27 July 2009
Crew: 6 people, Snorkel Time in hours: 1.45
Coordinates: N35.312730– W82.504331
Width: 29.75 m, Depth: 27cm
Temperature: 22.2°C, pH: 6.63, Conductivity: 23.6 μs, Stream Flow: 3.73 cms
Salinity: 19.3ppm, D.0.: 8.42 mg/L, Turbidity: .85 NTU
Crayfish Accounts: CPUE Total: 1.21, Total Abundance: 14, Relative Abundance: 100%,
Species Richness: 1, H': 0, Evenness: 0
C. bartonii- 5♀ 25.2μ CL, 9♂ 27.8μ CL
Substrate Percentages: Rubble 50%, Cobble 24%, Bedrock 10%, Sand 9%, Gravel 6%

Reach 2. Below Paper Mill (North Carolina)

Site 1. Pigeon River- Oxygenation Station. This site required permission from the Blue Ridge Paper Mill to access beyond the gates. It is located off of Wrightsville Road. Water conditions were dark brown water with very low visibility.
Date: 23 July 2009
Crew: 4 people, Snorkel Time in hours: 1.
Width: 24.3 m, Depth: 64cm
Temperature: 26.1°C, pH: 7.9, Conductivity: 918 µs, Stream Flow: 2.21 cms
Salinity: 453 ppm, D.0.: 7.46 mg/L, Turbidity: 1.95 NTU
Substrate Percentages: Rubble 54%, Cobble 15%, Gravel 11%,
Bedrock 11%, Sand 4%, Silt 4%

Site 2. Pigeon River- River View Drive. This site is located below Ferguson Bridge off Iron Duff Road next to the two story white house by the bridge. The water conditions were dark brown with low flows.
Date: 1 July 2009
Crew: 4 people, Snorkel Time in hours: .40
Width: 27.25 m, Depth: 58 cm
Temperature: 24.3°C, pH: 7.85, Conductivity: 404 µs, Stream Flow: 3.114 cms
Salinity: 194 ppm, D.0.: 6.55 mg/L, Turbidity: 4.16 NTU
Substrate Percentages: Rubble 89%, Sand 4%, Cobble 4%, Gravel 2%

Site 3. Pigeon River- Below Richland Creek. This site is located off of Richland Creek Road below the confluence of Richland Creek into the Pigeon River. Water conditions were dark with low visibility and low flows.
Date: 21 July 2009
Crew: 4 people, Snorkel Time in hours: 1.10
Width: 33.25 m, Depth: 27 cm
Temperature: 21.0°C, pH: N/A, Conductivity: 23.3 µs, Stream Flow: 2.22 cms
Salinity: 17.7 ppm, D.0.: 6.53 mg/L, Turbidity: 1.18 NTU
Substrate Percentages: Rubble 30.5%, Sand 20%, Bedrock 20%,
Gravel 16%, Cobble 13%

Reach 3. By- Pass Channel (North Carolina)

Site 1. Pigeon River- Harmon Den. This site is located right off of the Harmon Den exit at the small bridge. Due to limited habitat and access this site was divided in half by the bridge and sampled fifteen meters upstream and fifteen meters downstream. Water conditions were clear with low, sluggish flows.
Date: 10 June 2010
Crew: 3 people, Snorkel Time in hours: 2.28
Coordinates: N35.43581– W83.01309

Width: 19.79 m, Depth: 19 cm
Temperature: 19.3°C, pH: 7.24, Conductivity: 70.9 µs, Stream Flow: .211 cms,
Salinity: 36.8 ppm, D.0.: 8.98 mg/L, Turbidity: 2.51 NTU
Crayfish Accounts: CPUE Total: 5.12, Total Abundance: 40,
Species Richness: 2, H': .117, Evenness: .169
C. bartonii- Species Abundance 1, Relative Abundance 2.5 %, 1♂, 28 CL
C. sp. nov.- Species Abundance 39, Relative Abundance 97.5%, 14♀ 28.9µ CL,
25♂ 29.2µ CL
Substrate Percentages: Rubble 79%, Cobble 16%, Sand 16%, Silt 2%

Site 2. Pigeon river- Dry Gorge Middle. This site is located downstream of the first tunnel in the Pigeon River when traveling east on Interstate I-40. Access to this site is located behind Walter's Power Plant off of the Waterville exit. Water quality was omitted from this site due to the encumbrance of equipment between the crew and the distance hiked into the gorge. Water conditions were clear with very low and sluggish flows.
Date: 11 June 2010
Crew: 3 people, Snorkel Time in hours: 3.
Coordinates: N35.46277– W83.05416
Width: 17.58 m, Depth: 46 cm, Stream Flow: 1.495 cms, Turbidity: .72 NTU
Crayfish Accounts: CPUE Total: 1.33, Total Abundance: 12,
Species Richness: 2, H': .636, Evenness: .92
C. bartonii- Species Abundance 4, Relative Abundance 33 %, 3♀ 31.7, 1♂, 26 CL
C. sp. nov.- Species Abundance 8, Relative Abundance 66%, 2♀ 32µ CL, 6♂ 36.7µ CL
Substrate Percentages: Rubble 48%, Cobble 44%, Gravel 6%

Site 3. Pigeon River- Dry Gorge Mouth. This site is located directly behind Walter's Power Plant off of the Waterville exit. The site transect began at the point where the water ends backing up into the dry gorge from being discharged from the power plant. Water conditions were clear with moderate flows.
Date: 29 October 2009
Crew: 2 people, Snorkel Time in hours: .45
Coordinates: N35.462876– W83.054399
Width: 20.6 m, Depth: 46 cm
Temperature: 12.4°C, pH: 7.3, Conductivity: 40.6 µs, Stream Flow: 1.101 cms,
Salinity: 20.4 ppm, D.0.: 10.2 mg/L, Turbidity: .525 NTU
Crayfish Accounts: CPUE Total: 7.065, Total Abundance: 13,
Species Richness: 2, H': .67, Evenness: .97
C. bartonii- Species Abundance 4, Relative Abundance 31%, 4♀ 27.25µ CL
C. sp. nov.- Species Abundance 9, Relative Abundance 69%, 5♀ 30.µ CL, 4♂ 22.5µ CL
Substrate Percentages: Rubble 78%, Cobble 13%, Silt 5%, Gravel 3%

Reach 4. Below Power Plant (Tennessee)

Site 1. Pigeon River- Hartford. This site is located off of the Hartford exit at the Smoky Mountain Outdoors rafting company. The site transect begins downstream of the companies' boat takeout. This site had to be sampled during a period where the power plant was not discharging water. Water conditions were clear and low flows. This site had to be sampled during a period where the power plant was not discharging water.
Date: 11 June 2010
Crew: 3 people, Snorkel Time in hours: 4.22
Coordinates: N35.48479– W82.09562
Width: 60 m, Depth: 98 cm
Temperature: 20.8°C, pH: 7.83, Conductivity: 23.6 μs, Stream Flow: 3.73 cms
Salinity: 19.3ppm, D.0.: 8.42 mg/L, Turbidity: 1.25 NTU
Crayfish Accounts: CPUE Total: 20.03, Total Abundance: 251,
Species Richness: 3, H': 1.29, Evenness: .93
C. longirostris- Species Abundance 113, Relative Abundance 45%, 46♀ 20.2μ CL, 68♂ 20.25μ CL
O. virilis- Species Abundance 53, Relative Abundance 21%, 32♀ 21.7μ CL, 23♂ 16.45μ CL
O. forceps- Species Abundance 34, Relative Abundance 13%, 13♀ 18.4μ CL, 23♂ 25.27μ CL
Orconectes spp.- Abundance 52, Relative Abundance 20%, 24♀ 12.08μ CL, 25♂ 12.29μ CL
Substrate Percentages: Rubble 74%, Bedrock 12%, Sand 8%, Cobble 4%

Site 2. Pigeon River- Tannery Island. This site is located in front of Grace Missionary Baptist Church off of U.S. Highway 73. The site includes a small island on river right that is located above the named Tannery Island. Water conditions were moderately cloudy with normal flows. Crayfish concentrations were more abundant around the river right bank around all sides of the small island.
Date: 8 October 2009
Crew: 3 people, Snorkel Time in hours: 1.40
Coordinates: N35.56409– W83.10419
Width: 59.2 m, Depth: 1.2 cm
Temperature: 15.2°C, pH: 6.96, Conductivity: 163.6 μs, Stream Flow: 2.201 cms
Salinity: 77.2 ppm, D.0.: 9.12 mg/L, Turbidity: 3.1 NTU
Crayfish Accounts: CPUE Total: 2.19, Total Abundance: 12,
Species Richness: 2, H': .45, Evenness: .65
O. forceps- Species Abundance 10, Relative Abundance 83%, 9♀ 28.4μ CL, 1♂ 29 CL
O. virilis- Species Abundance 2, Relative Abundance 16%, 2♀ 36.5μ CL
Substrate Percentages: Rubble 70.5%, Sand 21%, Cobble 7%

Site 3. Pigeon River- Mouth. This site is the confluence to the French Broad River. Site three is located off of Industrial Road on the Parker family's farm. This site did not have the rubble dominated substrates that most other sites had. Water conditions were low flows with poor visibility the day of being sampled.
Date: 15 July 2010
Crew: 3 people, Snorkel Time in hours: 2.34
Coordinates: N35.48473– W83.09562
Width: 41 m, Depth: 50 cm
Temperature: 25.5°C, pH: 7.4, Conductivity: 213 µs, Stream Flow: 2.76 cms
Salinity: 103 ppm, D.0.: 7.42 mg/L, Turbidity 6.84 NTU
Crayfish Accounts: CPUE Total: 3.37, Total Abundance: 26,
Species Richness: 1, H': 0, Evenness: 0
O. forceps- Species Abundance 26, Relative Abundance 83%, 10♀ 11.1µ CL,
16♂ 14.25 µ CL
Substrate Percentages: Cobble 60.5%, Gravel 22%, Rubble 17%

Pigeon River Tributaries

Beaver Creek (North Carolina)

Site 1. Beaver Creek- Upper Section. This site is located off of 825 Beaverdam Street in Canton, North Carolina. The water conditions were clear, with low, sluggish flows.
Date: 21 July 2009
Trap Time in hours: 72.
Coordinates: N35.325084– W82.502685
Width: 3.4 m, Depth: 0.8 cm
Temperature: 19.1°C, pH: 7.57, Conductivity: 83.3 µs, Stream Flow: 1.076 cms
Salinity: 42.7 ppm, D.0.: 8.53 mg/L, Turbidity 3.55 NTU
Crayfish Accounts: CPUTE Total: .02, Total Abundance: 17,
Species Richness: 2, H': .678, Evenness: .98
C. bartonii- Species Abundance 7, Relative Abundance 41%, 4♀ 34.25µ CL, 4♂ 34µ CL
P. acutus- Species Abundance 9, Relative Abundance 53%, 4♀ 44.5µ CL, 5♂ 43.4µ CL
Substrate Percentages: Sand 38%, Gravel 31%, Bedrock 10%, Organic 9%,
Silt 5.5%, 2% Rubble

Site 2. Beaver Creek- Middle Section. This site is located off of 34 Beaverdam Street in Canton, North Carolina. The transect is right behind the church under a bamboo patch. The water conditions were clear, with low, sluggish flows.
Date: 21 July 2009
Trap Time in hours: 72.

Coordinates: N35.323254– W82.503860
Width: 3.4 m, Depth: 15 cm
Temperature: 19.1°C, pH: 7.57, Conductivity: 83.3 µs, Stream Flow: 1.076 cms
Salinity: 42.7 ppm, D.0.: 8.53 mg/L, Turbidity 3.55 NTU
Crayfish Accounts: CPUTE Total: .18, Total Abundance: 10,
Species Richness: 2, H': .679, Evenness: .98
C. bartonii- Species Abundance 5, Relative Abundance 28%, 1♀ 36 CL, 4♂ 36.25µ CL
P. acutus- Species Abundance 7, Relative Abundance 39%, 1♀ 42 CL, 7♂ 42.1µ CL
Substrate Percentages: Sand 77%, Organic 15%, Silt 7%, Gravel 5%, Rubble .05%

Site 3. Beaver Creek- Lower Section. This site is located at the mouth of Beaver Creek under the Blackwell Drive Bridge. The transect ends where a low head dam obstructs the streams flow.
Date: 21 July 2009
Trap Time in hours: 72.
Coordinates: N35.323001– W82.504779
Width: 7.07 m, Depth: 22 cm
Temperature: 19.1°C, pH: 7.57, Conductivity: 83.3 µs, Stream Flow: 2.23 cms
Salinity: 42.7 ppm, D.0.: 8.53 mg/L, Turbidity 3.55 NTU
Crayfish Accounts: CPUTE Total: .03, Total Abundance: 21,
Species Richness: 1, H': 0, Evenness: 0
C. bartonii- Species Abundance 21, Relative Abundance 100%, 14♀ 33.57µ CL,
7♂ 34.4µ CL
Substrate Percentages: Rubble 53%, Bedrock 25%, Sand 13%, Gravel 8%

Richland Creek (North Carolina)

Site 1. Richland Creek- Upper Section. This site is located just downstream of the Lake Junaluska Dam where the stream crosses under 1909 County Road. Black fly larvae covered the substrates in this section of stream. Flows were normal and the water had low visibility.
Date: 8 June 2009
Trap Time in hours: 96.
Coordinates: N35.323254– W82.503860
Width: 12.2 m, Depth: 1.3 cm
Temperature: 26°C, pH: 7.5, Conductivity: 4.97 µs, Stream Flow: 1.98 cms
Salinity: 30.3 ppm, D.0.: 4.53 mg/L, Turbidity 2.09 NTU
Crayfish Accounts: CPUTE Total: .001, Total Abundance: 1,
Species Richness: 1, H': 0, Evenness: 0
P. acutus- Species Abundance 1, Relative Abundance 100%, 1♂ 42 CL
Substrate Percentages: Rubble 87%, Cobble 12%

Site 2. Richland Creek- Middle Section. This site is located just downstream of the Lake Junaluska Dam where the stream crosses under 802 Crabtree Road. Flows were moderately low.
Date: 25 June 2009
Trap Time in hours: 96.
Coordinates: N35.3249– W82.57350
Width: 12.5 m, Depth: 60 cm
Temperature: 25.2°C, pH: 6.4, Conductivity: 31.3 μs, Stream Flow: 1.782 cms
Salinity: 30.5 ppm, D.0.: 4.15 mg/L, Turbidity 1.685 NTU
Substrate Percentages: Rubble 83%, Gravel 13%, Cobble 4%

Site 3. Richland Creek- Lower Section. This site is located at the mouth of Richland Creek off of 1280 Richland Creek Drive. Water conditions here were normal flows and cloudy visibility
Date: 8 June 2009
Trap Time in hours: 72.
Coordinates: N32586– W82.56481
Width: 12.2 m, Depth: 2.53 cm
Temperature: 22.2°C, pH: 7.3, Conductivity: 51.1 μs, Stream Flow: 1.03 cms
Salinity: 29.4 ppm, D.0.: 7.16 mg/L, Turbidity 2.53 NTU
Crayfish Accounts: CPUTE Total: .001, Total Abundance: 1,
Species Richness: 1, H': 0, Evenness: 0
C. bartonii- Species Abundance 1, Relative Abundance 100%, 1♂ 22 CL
Substrate Percentages: Rubble 57%, Gravel 17%, Sand 10%, Cobble 9%, Silt 5.5%

Site 4. Richland Creek- Lower Section. This site is located at the same place as Richland Creek- Lower Site three, but the snorkel method was used at the confluence of the creek simultaneously while a salamander survey was being conducted. Water conditions were at normal flows with limited visibility.
Date: 22 May 2009
Crew: 4 people, Time in hours: 1.
Coordinates: N35.32984– W82.56823
Width: 14.1m, Depth: 70 cm
Temperature: 16.5°C, pH: 7.15, Conductivity: 46.3 μs,
Salinity: 26.4 ppm, D.0.: 8.71 mg/L
Crayfish Accounts: CPUE Total: 11, Total Abundance: 11,
Species Richness: 1, H': 0, Evenness: 0
C. bartonii- Species Abundance 11, Relative Abundance 100%, 3♀ 28μ CL, 1 Ovigerous ♀, 8♂ 26.75μ CL, 8 Form I ♂
Substrates: Rubble 52%, Organic 19%, Gravel 14%, Cobble 8%, Sand 6%

Jonathon's Creek (North Carolina)

Site 1. Jonathon's Creek- Upper Section. This site is located at 4138 Soco Road in Maggie Valley. Water conditions were clear and flows were normal.
Date: 16 July 2009
Trap time in hours: 96.
Coordinates: N35.31085– W83.05541
Width: 5.33m, Depth: 50 cm
Temperature: 16.5°C, pH: 7.33, Conductivity: 29.8 µs, Stream Flow: 2.187 cms
Salinity: 18.2 ppm, D.0.: 8.90 mg/L, Turbidity: 8.505 NTU
Crayfish Accounts: CPUTE Total: .012, Total Abundance: 11,
Species Richness: 1, H': 0, Evenness: 0
C. bartonii- Species Abundance 11, Relative Abundance 100%, 6♀ 30µ CL, 5♂ 29.2µ CL
Substrates: Rubble 83%, Bedrock 10%, Cobble 5%, Gravel 2%

Site 2. Jonathon's Creek- Middle Section. This site is located just upstream of the bridge on Joe Carver Road in Maggie Valley. Water conditions at this site were clear with low flows.
Date: 16 July 2009
Trap time in hours: 96.
Coordinates: N35.34322– W83.01048
Width: 11.25 m, Depth: 40 cm
Temperature: 19.4°C, pH: 7.35, Conductivity: 39.1 µs, Stream Flow: 2.295 cms
Salinity: 23.6 ppm, D.0.: 8.62 mg/L, Turbidity: 5.675 NTU
Crayfish Accounts: CPUE Total: .015, Total Abundance: 13,
Species Richness: 1, H': 0, Evenness: 0
C. bartonii- Species Abundance 13, Relative Abundance 100%, 2♀ 25µ CL, 11♂ 27µ CL
Substrates: Rubble 79%, Bedrock 10%, Cobble 7%, Gravel 4%

Site 3. Jonathon's Creek- Lower Section. This site was located close to the confluence of Jonathon's Creek to the Pigeon River at the end of Bob Lane. Water conditions were low flows and muddy.
Date: 16 July 2009
Trap time in hours: 96.
Coordinates: N35.37373– W83.00117
Width: 19 m, Depth: 20 cm
Temperature: 19°C, pH: 7.49, Conductivity: 47.8 µs, Stream Flow: 2.422 cms
Salinity: 27 ppm, D.0.: 8.71 mg/L, Turbidity: 7.03 NTU
Crayfish Accounts: CPUE Total: .01, Total Abundance: 9,
Species Richness: 1, H': 0, Evenness: 0
C. bartonii- Species Abundance 13, Relative Abundance 100%, 6♀ 27µ CL, 3♂ 29µ CL
Substrates: Rubble 68%, Bedrock 13%, Cobble 9%, Sand 5%, Gravel 4%

Site 4. Jonathon's Creek- Lower Section. This site is located just downstream of Jonathon's Creek- Lower Site three, but the snorkel method was used at the confluence of the creek simultaneously while a salamander survey was being conducted. Water conditions were modestly high with low visibility.
Date: 29 June 2009
Crew: 4 people, Time in hours: .45
Coordinates: N35.373767– W83.000107
Width: 12.1m, Depth: 43 cm
Temperature: 18.6°C, pH: 7.56, Conductivity: 45.6 µs, Stream Flow: 3.447 cms
Salinity: 26 ppm, D.0.: 7.08 mg/L, Turbidity 4.985 NTU
Crayfish Accounts: CPUE Total: 5, Total Abundance: 9,
Species Richness: 1, H': 0, Evenness: 0
C. bartonii- Species Abundance 9, Relative Abundance 100%, 5♀ 20.8µ CL,
4♂ 19.5µ CL,
Substrates: Bedrock 50.5%, Rubble 41%, Sand 7%

Site 5. Jonathon's Creek- Lower Section. This site is located upstream of Jonathon's Creek- Lower Site four. The snorkel method was used at this site simultaneously while a salamander survey was being conducted.
Water conditions were clear with moderate visibility.
Date: 20 July 2009
Crew: 4 people, Time in hours: 1.45
Coordinates: N35.37364– W83.00135
Width: 16.2m, Depth: 40 cm
Temperature: 18.8°C, pH: 7.7, Conductivity: 47.1 µs, Stream Flow: 1.067 cms
Salinity: 26.9 ppm, D.0.: 9.02 mg/L, Turbidity 3.46 NTU
Crayfish Accounts: CPUE Total: 7.75, Total Abundance: 45,
Species Richness: 1, H': 0, Evenness: 0
C. bartonii- Species Abundance 45, Relative Abundance 100%, 26♀ 21.65µ CL,
18♂ 24.4µ CL,
Substrates: Rubble 40%, Sand 18%, Gravel 17%, Bedrock 15%, Cobble 10%

Site 6. Jonathon's Creek- Lower Section. This site is located upstream of Jonathon's Creek- Lower Site five. The snorkel method was used at this site simultaneously while a salamander survey was being conducted.
Water conditions were clear with moderate visibility, flows were medium to high.
Date: 23 July 2009
Crew: 4 people, Time in hours: .45
Coordinates: N35.373571– W83.001903
Width: 11.4m, Depth: 4.145 cm
Temperature: 18.3°C, pH: 7.66, Conductivity: 46.2 µs, Stream Flow: 3.435 cms
Salinity: 26.3 ppm, D.0.: 8.9 mg/L, Turbidity 4.145 NTU
Crayfish Accounts: CPUE Total: 5, Total Abundance: 38,

Species Richness: 1, H’: 0, Evenness: 0
C. bartonii- Species Abundance 38, Relative Abundance 100%, 12♀ 18.41µ CL, 10♂ 24.6µ CL,
Substrates: Rubble 37%, Sand 24%, Cobble 20%, Bedrock 9%, Gravel 9%,

Cataloochee Creek (North Carolina)

Cataloochee Creek- Lower Section. This site is located at the confluence of Cataloochee Creek into Walter’s Lake just behind the Progress Energy dam. This site was accessed by boat at the mouth of the stream. An electric backpack shocker and a 10-foot, ¼” mesh seine was used to survey this site due to limited access, and time constraints. Water conditions were low with clear visibility.
Date: 11 August 2009
Time in minutes: 6.20
Coordinates: N35.373571– W83.001903
Width: 17.4m, Depth: 70 cm
Temperature: 18.2°C, pH: 7.14, Conductivity: 16.7 µs, Stream Flow: 1.641 cms
Salinity: 14.1 ppm, D.0.: 9.05 mg/L, Turbidity 1.45 NTU
Crayfish Accounts: CPUE Total: 3.38, Total Abundance: 21,
Species Richness: 1, H’: 0, Evenness: 0
Cambarus sp. nov.- Species Abundance 21, Relative Abundance 100%, 11♀ 24.18µ CL, 11♂ 23.6µ CL,
Substrates: Bedrock 57%, Rubble 30%, Cobble 7%, Gravel 5%, Sand 2%

Hurricane Creek (North Carolina)

Site 1. Hurricane Creek- Upper. This site is located at the end of the first opening on Hurricane Creek Road. The vehicle used was too large to continue further to reach more upstream reaches. This road is accessed by vehicle on Interstate I-40 Westbound and is located off the shoulder of the interstate behind the first Harmon Den Exit sign. Water conditions for this stream were normal flows with clear visibility.
Date: 20 October 2009
Trap time in hours: 72.
Coordinates: N35.43083– W83.01024
Width: 6.1 m, Depth: 30 cm
Temperature: 8.1°C, pH: 7.64, Conductivity: 32.4 µs, Stream Flow: 1.208 cms
Salinity: 15.7 ppm, D.0.: 11.05 mg/L, Turbidity: .725 NTU
Crayfish Accounts: CPUE Total: .037, Total Abundance: 24,
Species Richness: 1, H’: 0, Evenness: 0
C. bartonii- Species Abundance 24, Relative Abundance 100%, 15♀ 40.93µ CL, 9♂ 41.4µ CL
Substrates: Bedrock 32%, Rubble 30.5%, Sand 20%, Cobble 9%, Organic 5%, Gravel 3%

Site 2. Hurricane Creek- Middle Section. This site is located downstream of Hurricane Creek- Upper Site one. It is off of Hurricane Road after the first steep left turn at the bend in the road. Water conditions here were moderate flows with good visibility.
Date: 20 October 2009
Trap time in hours: 72.
Coordinates: N35.430830– W83.010668
Width: 5.35 m, Depth: 40 cm
Temperature: 8.1°C, pH: 7.64, Conductivity: 32.4 μs, Stream Flow: 1.208 cms
Salinity: 15.7 ppm, D.0.: 11.05 mg/L, Turbidity: .725 NTU
Crayfish Accounts: CPUE Total: .033, Total Abundance: 22,
Species Richness: 2, H': .3, Evenness: .44
C. bartonii- Species Abundance 2, Relative Abundance 9%, 2♀ 44μ CL
Cambarus. sp. nov- Species Abundance 20, Relative Abundance 91%, 13♀ 38.85μ CL, 7♂ 40.85 μ CL
Substrates: Rubble 67%, Gravel 13%, Cobble 12%, Sand 8%, Organic 5%

Site 3. Hurricane Creek- Lower Section. This site is located at the confluence of Hurricane Creek into the Pigeon River By- Pass Channel. Access to this site is at the beginning of Hurricane Road next to Interstate I-40. Site three is found under the large culvert that is under the interstate. A 10-foot, ¼" mesh seine was used to sample this site due to the steep ravine that the site is located in. Water quality samples were also omitted for this site due to the rough terrain. Water conditions for site three were clear with low flows.
Date: 23 October 2009
Time in minutes: 8.23
Coordinates: N35.432613– W83.014163
Width: 7.1 m, Depth: 20 cm
Crayfish Accounts: CPUE Total: 63.5, Total Abundance: 33,
Species Richness: 2, H': .425, Evenness: .61
C. bartonii- Species Abundance 28, Relative Abundance 85%, 21♀ 02.38μ CL, 7♂ 26.86 μ CL
Cambarus sp. nov- Species Abundance 5, Relative Abundance 15%, 3♀ 32.67μ CL, 2♂ 26.5μ CL
Substrates: Rubble 47%, Sand 15%, Organic 13% Gravel 11%, Cobble 10%, Bedrock 4%

Cold Springs Creek (North Carolina)

Site 1. Cold Springs Creek- Upper Section. This site is located on Cold Springs Creek Road off the Harmon Den Exit off Interstate I-40. Follow the road up to the park at the intersection of Fall Branch Road. Site One begins upstream of the bridge on Fall Branch Road. Water conditions for this site were clear with high flows.

Date: 22 June 2009
Trap time in hours: 72.
Coordinates: N35.454103– W83.584536
Width: 4.90 m, Depth: 60 cm
Temperature: 14.5°C, pH: 6.7, Conductivity: 18.5 µs, Stream Flow: 2.531 cms
Salinity: 13.6 ppm, D.0.: 7.91 mg/L, Turbidity: 2.205 NTU
Crayfish Accounts: CPUTE Total: .017, Total Abundance: 11,
Species Richness: 1, H': 0, Evenness: 0
C. bartonii- Species Abundance 11, Relative Abundance 100%, 10♀ 22.9µ CL,
10♂ 26.7 µ CL, 1 Form I ♂
Substrates: Rubble 49%, Sand 20%, Cobble 19%, Gravel 11%

Site 2. Cold Springs Creek- Middle Section. This site is located on Cold Springs Creek Road at the horse staging area on the right side of the road. Site two begins right next to the horse staging area. Water conditions for this site were clear with moderately high flows.
Date: 22 June 2009
Trap time in hours: 72.
Coordinates: N35.4599– W83.59506
Width: 9.4 m, Depth: 47 cm
Temperature: 15.4°C, pH: 6.82, Conductivity: 21.1 µs, Stream Flow: 2.812 cms
Salinity: 14.95 ppm, D.0.: 7.26 mg/L
Crayfish Accounts: CPUTE Total: .009, Total Abundance: 6,
Species Richness: 1, H': 0, Evenness: 0
C. bartonii- Species Abundance 6, Relative Abundance 100%, 6♀ 26.83µ CL,
6♂ 24.83 µ CL
Substrates: Rubble 44%, Bedrock 27%, Sand 13%, Cobble 9%, Gravel 7%

Site 3. Cold Springs Creek- Lower Section. This site is located right off the Interstate I-40, Harmon Den Exit. Access to the confluence of Cold Springs Creek is directly in front of the off- ramp west bound. Water conditions were clear with moderately high flows.
Date: 22 June 2009
Trap time in hours: 72.
Coordinates: N35.44167– W83.01233
Width: 5.825 m, Depth: 50 cm
Temperature: 16.1°C, pH: 6.5, Conductivity: 22.8 µs, Stream Flow: 3.934 cms
Salinity: 15.8 ppm, D.0.: 7.03 mg/L
Crayfish Accounts: CPUTE Total: .009, Total Abundance: 6,
Species Richness: 1, H': 0, Evenness: 0
C. bartonii- Species Abundance 6, Relative Abundance 100%, 2♀ 33µ CL,
4♂ 30.25 µ CL, 1 Form I ♂
Substrates: Rubble 57%, Sand 17%, Cobble 15%, Gravel 4%, Organic 6%

Site 4. Cold Springs Creek- Upper Section. This site is at the same location as Cold Springs Creek- site one. A 10-foot, ¼″ mesh seine was used to sample this site to compare methods between using traps and using a seine for crayfish captures. Water conditions at this site were shallow fast moving riffles.
Date: 19 June 2009
Time in minutes: 5.45
Coordinates: N35.45415– W82.58452
Width: 4.90 m, Depth: 20 cm
Temperature: 14.5°C, pH: 6.76, Conductivity: 18.3 μs, Stream Flow: 2.957 cms
Salinity: 13.8 ppm, D.0.: 8.51 mg/L, Turbidity: 3.585 NTU
Crayfish Accounts: CPUE Total: 8.07, Total Abundance: 44,
Species Richness: 1, H': N/A, Evenness: N/A
C. bartonii- Species Abundance 9, 3♀ 21μ CL, 6♂ 26.17μ CL, 1 Form I♂
Cambarus sp. - Species Abundance 35, 20♀ 17.25μ CL, 15♂ 18.4μ CL
Substrates: Rubble 56%, Sand 18%, Cobble 15%, Organic 6%, Gravel 4%

Site 5. Cold Springs Creek- Middle Section. Site five is located at the same location as Cold Springs Creek- site two. A 10-foot, ¼″ mesh seine was used to sample this site to compare methods between using traps and using a seine for crayfish captures. Water conditions were clear with normal to low flows.
Date: 19 June 2009
Time in minutes: 5.10
Coordinates: N35.45097– W82.59515
Width: 9.4 m, Depth: 30 cm
Temperature: 16.1°C, pH: 6.6, Conductivity: 20.6 μs, Stream Flow: 2.796 cms
Salinity: 16.8 ppm, D.0.: 7.71 mg/L, Turbidity: 3.12 NTU
Crayfish Accounts: CPUE Total: 17.65, Total Abundance: 90,
Species Richness: 1, H': N/A, Evenness: N/A
C. bartonii- Species Abundance 10, 5♀ 27.6μ CL, 5♂ 25.8μ CL
Cambarus sp. - Species Abundance 80, 42♀ 19.54μ CL, 38♂ 20.36μ CL
Substrates: Rubble 42%, Cobble 22%, Sand 19, Gravel 12%, Silt 5%

Site 6. Cold Springs Creek- Lower Section. Site six is located at the same location as Cold Springs Creek- Site three. A 10-foot, ¼″ mesh seine was used to sample this site to compare methods between using traps and using a seine for crayfish captures. Water flows were at normal levels with good visibility.
Date: 18 June 2009
Time in minutes: 7.35
Coordinates: N35.44129– W83.01299
Width: 10.55 m, Depth: 25 cm
Temperature: 16.0°C, pH: 7.17, Conductivity: 23.5 μs, Stream Flow: 4.247 cms

Salinity: 16.0 ppm, D.0.: 8.31 mg/L, Turbidity: 2.865 NTU
Crayfish Accounts: CPUE Total: 10.20, Total Abundance: 75,
Species Richness: 2, H': N/A, Evenness: N/A
C. bartonii- Species Abundance 7, 4♀ 26µ CL, 3♂ 26.7µ CL, 1 Form I♂
Cambarus sp. nov - Species Abundance 3, 3♂ 35.33µ CL, 1 Form I♂
Cambarus sp. - Species Abundance 65, 27♀ 21µ CL, 38♂ 24.5µ CL
Substrates: Rubble 50.5%, Sand 28%, Cobble 14%, Gravel 5%, Organic 28%

Big Creek (North Carolina)

Site 1. Big Creek- Upper Section. This site is located just upstream of the Waterville Road and Mount Sterling Road intersection off of the Waterville Exit from Interstate I-40. Water conditions were at normal flows with clear visibility.
Date: 15 June 2009
Trap time in hours: 72.
Coordinates: N35.45435– W83.06160
Width: 14.85 m, Depth: 90 cm
Temperature: 15.5°C, pH: 6.89, Conductivity: 16.2 µs, Stream Flow: 2.991 cms
Salinity: 13 ppm, D.0.: 9.04 mg/L, Turbidity: .635 NTU
Crayfish Accounts: CPUTE Total: .007, Total Abundance: 5,
Species Richness: 1, H': 0, Evenness: 0
Cambarus sp. nov.- Species Abundance 4, Relative Abundance 100%, 3♀ 36.33µ CL, 2♂ 34.5µ CL
Substrates: Rubble 71%, Sand 12%, Bedrock 10%, Cobble 6%

Site 2. Big Creek- Middle Section. Site two is located at the first pull off on the right side of the road when headed towards Big Creek Camp Grounds. Go past the two story white house on the left and enter the forest. The pull off will be almost immediately on right, and the site is located at the swim hole the trail leads down to. Water conditions for this site were at normal flows with clear visibility.
Date: 15 June 2009
Trap time in hours: 72.
Coordinates: N35.4649– W83.633
Width: 14.85 m, Depth: 90 cm
Temperature: 15.5°C, pH: 7.1, Conductivity: 174.9 µs, Stream Flow: 0.875 cms
Salinity: 13 ppm, D.0.: 9.04 mg/L, Turbidity: .84 NTU
Crayfish Accounts: CPUTE Total: .006, Total Abundance: 4,
Species Richness: 1, H': 0, Evenness: 0
Cambarus sp. nov.- Species Abundance 4, Relative Abundance 100%, 4♂ 36.75µ CL
Substrates: Rubble 61%, Bedrock 25.5%, Gravel 7%, Silt 6%

Site 3. Big Creek- Lower Site. This site is located just upstream of the low head dam at the Big Creek confluence into the Pigeon River. Water conditions for this site were normal flows with clear visibility.
Date: 15 June 2009
Trap time in hours: 72.
Coordinates: N35.46266– W83.616
Width: 17.6 m, Depth: 87 cm
Temperature: 15.5°C, pH: 7.53, Conductivity: 17.8 μs, Stream Flow: 4.714 cms
Salinity: 14.1 ppm, D.0.: 9.15 mg/L, Turbidity: .99 NTU
Crayfish Accounts: CPUTE Total: .01, Total Abundance: 8,
Species Richness: 1, H': 0, Evenness: 0
Cambarus sp. nov.- Species Abundance 8, Relative Abundance 100%, 1♀ 23 CL, 7♂ 39.28μ CL, 1 Form I♂
Substrates: Rubble 80%, Bedrock 9%, Cobble 5%, Sand 4%, Gravel 1%

Site 4. Big Creek- Middle Section. This site is located at the same location as Big Creek-site two. The snorkel survey method was used at this site to compare crayfish capture methods. Water conditions for this site were at normal flows with clear visibility.
Date: 13 June 2009
Trap time in hours: 1.20
Coordinates: N35.4659– W83.627
Width: 12.05 m, Depth: 49 cm
Temperature: 18.5C, pH: 7.28, Conductivity: 18.7 μs, Stream Flow: 1.170 cms
Salinity: 15.1 ppm, D.0.: N/A mg/L, Turbidity: .80 NTU
Crayfish Accounts: CPUE Total: 26.7, Total Abundance: 32,
Species Richness: 1, H': 0, Evenness: 0
Cambarus sp. nov.- Species Abundance 32, Relative Abundance 100%, 17♀ 32.59μ CL, 14♂ 35.85μ CL
Substrates: Rubble 86%, Cobble 14%

Tobes Creek (Tennessee)

Site 1. Tobes Creek- Upper Section. This site is located at the intersection of Tobes Creek Road and Pine Hill Way from the Waterville Exit off Interstate I-40. Follow Tobes Creek Road to the third house on the right. Water conditions were at medium to high flows with clear water visibility.
Date: 6 October 2009
Trap time in hours: 120.
Coordinates: N35.46460– W83.07265
Width: 4.1 m, Depth: 21 cm
Temperature: 12.9C, pH: 7.93, Conductivity: 34.4 μs, Stream Flow: 2.394 cms
Salinity: 25 ppm, D.0.: 9.83 mg/L
Crayfish Accounts: CPUTE Total: .01, Total Abundance: 11,

Species Richness: 1, H': 0, Evenness: 0
Cambarus sp. nov.- Species Abundance 11, Relative Abundance 100%, 8♀ 35.63μ CL, 3♂ 42μ CL
Substrates: Rubble 56%, Gravel 37%, Sand 4%, Gravel 3%

Site 2. Tobes Creek- Middle Section. This site is located on Tobes Creek Road next to the second house on the right. Water conditions were normal flows with clear visibility.
Date: 6 October 2009
Trap time in hours: 120.
Coordinates: N35.46497– W83.07171
Width: 4.45 m, Depth: 10 cm
Crayfish Accounts: CPUTE Total: .007, Total Abundance: 8,
Species Richness: 1, H': 0, Evenness: 0
Cambarus sp. nov.- Species Abundance 8, Relative Abundance 100%, 2♀ 49.5μ CL, 6♂ 31.5μ CL
Substrates: Bedrock 63%, Gravel 13%, Sand 10%, Rubble 7%

Site 3. Tobes Creek- Lower Section. Site three is located at the confluence of Tobes Creek into the Pigeon River below Brown's Bridge. Water conditions for this site were clear with normal flows.
Date: 6 October 2009
Trap time in hours: 120.
Coordinates: N35.46497– W83.07171
Width: 7.425 m, Depth: 20 cm
Crayfish Accounts: CPUTE Total: .012, Total Abundance: 29,
Species Richness: 1, H': 0, Evenness: 0
C. bartonii- Species Abundance 1, Relative Abundance 3.5%, 1♂ 25 CL
Cambarus sp. nov.- Species Abundance 28, Relative Abundance 96.5%, 5♀ 36.4μ CL, 7♂ 39.28μ CL
Substrates: Rubble 39%, Cobble 40%, Gravel 20.5%

Site 4. Tobes Creek- Lower Section. This site is located in the same spot as Tobes Creek- site three.
A 10-foot, ¼" mesh seine was used to sample this site to compare methods between using traps and using a seine for crayfish captures. Water conditions for this site were clear with low flows.
Date: 18 June 2009
Time in minutes: 9.78
Coordinates: N35.47086– W83.6467
Width: 7.425 m, Depth: 10 cm
Temperature: 11.6°C, pH: 7.27, Conductivity: 38.3 μs,
Salinity: 20.3 ppm, D.0.: 10.41 mg/L

Crayfish Accounts: CPUE Total: 2.86, Total Abundance: 28,
Species Richness: 1, H': 0, Evenness: 0
C. bartonii- Species Abundance 28, Relative Abundance 100%, 17♀ 19.41µ CL,
11♂ 17.81µ CL
Substrates: Cobble 40%, Rubble 39%, Gravel 20.5%

Cosby Creek (Tennessee)

Site 1. Cosby Creek- Upper Section. This site is located on State Highway 321 South at the Cosby Campgrounds park entrance. Site one transect begins just downstream of the bridge next to the Park Entrance Grocery Store. Water conditions were at normal flows with clear visibility.
Date: 7 June 2009
Trap time in hours: 96.
Coordinates: N35.4731– W83.13109
Width: 9.8 m, Depth: 63 cm
Temperature: 15.8°C, pH: 6.98, Conductivity: 16.2 µs, Stream Flow: 1.419 cms
Salinity: 13.1 ppm, D.0.: 9.07 mg/L, Turbidity: .98 NTU
Crayfish Accounts: CPUTE Total: .007, Total Abundance: 6,
Species Richness: 2, H': .637, Evenness: .91
C. bartonii- Species Abundance 4, Relative Abundance 67%, 4♀ 29µ CL
C. longirostris- Species Abundance 2, Relative Abundance 33%, 2♂ 32µ CL, 2 Form I♂
Substrates: Rubble 77%, Cobble 12%, Gravel 7%, Sand 4%

Site 2. Cosby Creek- Middle Section. This site is located on State Highway 32 South, upstream of the bridge next to Indian Camp Road. Water conditions were clear with normal flows.
Date: 19 May 2009
Trap time in hours: 72.
Coordinates: N35.48142– W83.14537
Width: 13.95 m, Depth: 70 cm
Temperature: 13.8°C, pH: 7.17, Conductivity: 28.1 µs, Stream Flow: N/A
Salinity: 16.8 ppm, D.0.: 9.91 mg/L
Crayfish Accounts: CPUTE Total: .023, Total Abundance: 15,
Species Richness: 1, H': 0, Evenness:
C. longirostris- Species Abundance 15, Relative Abundance 100%, 7♀ 22.71µ CL,
8♂ 24.25µ CL, 8 Form I♂
Substrates: Rubble 51%, Gravel 22%, Cobble 14%, Organic 9%, Sand 4%

Site 3. Cosby Creek- Lower Section. This site is located off of Wilton Springs Road at the confluence of Cosby Creek into the Pigeon River. The water conditions for this site were normal to high flows with cloudy visibility.
Date: 15 May 2009
Trap time in hours: 72.
Coordinates: N35.52573– W83.11529
Width: 38.9 m, Depth: 100 cm
Temperature: 18°C, pH: 7.54, Conductivity: 91.0 μs, Stream Flow: .17 cms
Salinity: 44 ppm, D.0.: 9.19 mg/L
Crayfish Accounts: CPUTE Total: .023, Total Abundance: 7,
Species Richness: 1, H': 0, Evenness:
C. bartonii- Species Abundance 1, Relative Abundance 14%, 1♀ 19 CL
C. longirostris- Species Abundance 3, Relative Abundance 43%, 3♂ 16.6μ CL
O. erichsonianus- Species Abundance 1, Relative Abundance 14%, 1♂ 28 CL
O. forceps- Species Abundance 2, Relative Abundance 28%, 2♂ 20.5μ CL
Substrates: Rubble 49%, Gravel 16%, Sand 14%, Cobble 13%, Silt 7%

Site 4. Cosby Creek- Upper Section. This site is located at the same place as Cosby Creek- site one. A 10-foot, ¼" mesh seine was used to sample this site to compare methods between using traps and using a seine for crayfish captures. Water conditions here were low flows with clear visibility.
Date: 3 June 2009
Time in minutes: 11.17
Coordinates: N35.4726– W83.1310
Width: 10.82 m, Depth: 30 cm
Temperature: 15.2°C, pH: 8.04, Conductivity: 16.2 μs, Stream Flow: 1.14 cms,
Salinity: 13 ppm, D.0.: 5.37 mg/L, Turbidity: 1.02 NTU
Crayfish Accounts: CPUE Total: 12.53, Total Abundance: 140,
Species Richness: 2, H': 0, Evenness: 0
C. bartonii- Species Abundance 3, 3♀ 28.67μ CL
C. longirostris- Species Abundance 8, 4♀ 17.75μ CL, 2♂ 22.25μ CL
Cambarus sp.- Species Abundance 129, 60♀ 17.62μ CL, 69♂ 19.56μ CL
Substrates: Rubble 62%, Cobble 23%, Gravel 11%, Sand 3%

Site 5. Cosby Creek- Middle Section. Site five is located at the same place as Cosby Creek- site two. A 10-foot, ¼" mesh seine was used to sample this site to compare methods between using traps and using a seine for crayfish captures. Water conditions were at normal flows with clear visibility.
Date: 29 May 2009
Time in minutes: 13.08
Coordinates: N35.48147– W83.14559
Width: 14.08 m, Depth: 36 cm

Temperature: 16.3°C, pH: 7.22, Conductivity: 34.9 μs, Stream Flow: 1.04 cms
Salinity: 20.6 ppm, D.0.: 9.14 mg/L, Turbidity: 3.475 NTU
Crayfish Accounts: CPUE Total: 7.95, Total Abundance: 104,
Species Richness: 2, H': 0, Evenness: 0
C. bartonii- Species Abundance 2, 1♀ 28 CL, 1♂ 30 CL
C. longirostris- Species Abundance 9, 5♀ 23.75μ CL, 5♂ 25.75μ CL, 3 Form I♂
Cambarus sp.- Species Abundance 93, 37♀ 17.22μ CL, 57♂ 19.70μ CL
Substrates: Rubble 83%, Gravel 9%, Sand 8%

Site 6. Cosby Creek- Lower Section. This site is at the same location as Cosby Creek-site three. A 10-foot, ¼" mesh seine was used to sample this site to compare methods between using traps and using a seine for crayfish captures. Water conditions for this site were low and muddy with sluggish flows.
Date: 29 May 2009
Time in minutes: 16.78
Coordinates: N35.52560– W83.11563
Width: 16.65 m, Depth: 54 cm
Temperature: 17.30°C, pH: 7.66, Conductivity: 85.3 μs, Stream Flow: 1.91 cms
Salinity: 42.7 ppm, D.0.: 8.83 mg/L, Turbidity: 5.705 NTU
Crayfish Accounts: CPUE Total: 7.95, Total Abundance: 29,
Species Richness: 2, H': 0, Evenness: 0
O. forceps- Species Abundance 3, 1♀ 25 CL, 2♂ 15.5μ CL
C. longirostris - Species Abundance 12, 6♀ 18.6μ CL, 1 Ovigerous♀, 7♂ 21.33μ CL
Cambarus sp.- Species Abundance 15, 6♀ 18.4μ CL, 10♂ 17.22μ CL
Substrates: Rubble 66%, Cobble 24%, Sand 6%, Gravel 4%

Vita

Casey Dunn began his studies in biology at South East Kentucky Community College where he received an Associates of Science degree, majoring in Biology and an Associates of Art. He matriculated to Lincoln Memorial University and received a Bachelors of Science degree in Environmental Science and studied how zooplankton can be used as biological indicators of water quality. In 2008 he became a graduate student at the University of Tennessee working on the Pigeon River Recovery Project, and completed a Master's of Science degree, in December 2010, majoring in Wildlife and Fisheries Science.