

SEASONAL VARIATIONS IN FISH ASSEMBLAGES
OF SMALL WARMWATER STREAMS IN FOUR
SOUTHEASTERN NATIONAL PARKS

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Joseph Carl Zimmerman

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DEDICATION

To my Dad and Brother, Chris, for taking me fishing and sparking my interest in stream ecosystems

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ABSTRACT

Small warm-water streams in the southeastern United States experience significant differences in temperature, as well as changes in physical parameters due to seasonal fluctuations. It has been generally thought that fish assemblage patterns change as a direct result of these seasonal variations. This study was designed to determine the effects of variable flow regimes on fish species composition, diversity, and abundance. Eight small warm-water streams in four national parks (Chickamauga and Chattanooga National Military Park, Fort Donelson National Battlefield, Abraham Lincoln Birthplace National Historic Site, and Russell Cave National Monument) were sampled May-June 2005 for the summer trials, October-November 2005 for the fall trials, and April 2006 for the spring trials. All trials were conducted when water levels and flows were at normal seasonal stages. Fish populations were determined by electrofishing a 100-m reach at each site. Physical parameters including temperature, dissolved oxygen, conductivity, pH, and flow rate were also measured at each site. From summer to fall, the majority of the streams decreased in flow until temporary pools were formed. The lack of flow caused increased temperatures, decreased dissolved oxygen, and increased conductivity levels. As a direct result, overall fish abundance and diversity values decreased. From fall to spring, all the streams increased in flow, which brought back the riffle to pool habitat sequences. Dissolved oxygen levels increased, conductivity levels decreased, and temperatures became more stable. As a result, overall fish abundance and diversity values increased. Results indicated that fish assemblage patterns in the four parks did change as a direct result of the seasonal variations in habitat and water quality.

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CHAPTER I-INTRODUCTION

National Park Service I & M Program

In 1998, the National Parks Omnibus Management Act was passed by Congress, which confirmed the need for credible scientific information on multiple parks around the country. To fulfill this need, Congress authorized an inventory and monitoring program to help gain information on the condition of the National Park System's natural resources. "Due to the lack of scientific and credible information about the natural resources in the parks, especially biological resources, Congress funds the Servicewide Inventory and Monitoring (I&M) Program of the National Park Service" (NPS 1999).

The main goal of the NPS I&M program is to provide employees and the public with credible information about the status of biological resources within some 265+ parks with significant natural resources. The data collected will be in the form of GIS maps or integrated into GIS formats to further enhance the usefulness of the data. "The data sets include information on air quality, water quality, base cartography, weather, geology, soil, and information about the occurrence, distribution, and relative abundance of vertebrate and vascular plant species in the parks". This information will help form effective management plans, aid scientific research, and provide public education (NPS 1999).

Fish Inventory

As part of a National I&M Program, the National Park Service was in need of an ichthyofauna inventory for four different parks in the southeastern United States. The

goal of the inventory is to document the relative abundance and at least 90% of the fish species present in the multiple parks (NPS 1999). The parks included for this research project are Chickamauga and Chattanooga National Military Park (CHCH) (TN), Fort Donelson National Battlefield (FODO) (TN), Abe Lincoln Birthplace National Historic Site (ABLI) (KY), and Russell Cave National Monument (RUCA) (AL) (Figure 1). The streams studied in Chickamauga/Chattanooga, Fort Donelson, and Abe Lincoln Birthplace are small, warm-water, intermittent and perennial streams. Russell Cave consists of entrance springs and underground pools. GPS coordinates (ACC) at general localities of sites sampled in the four parks can be found in Appendix B.

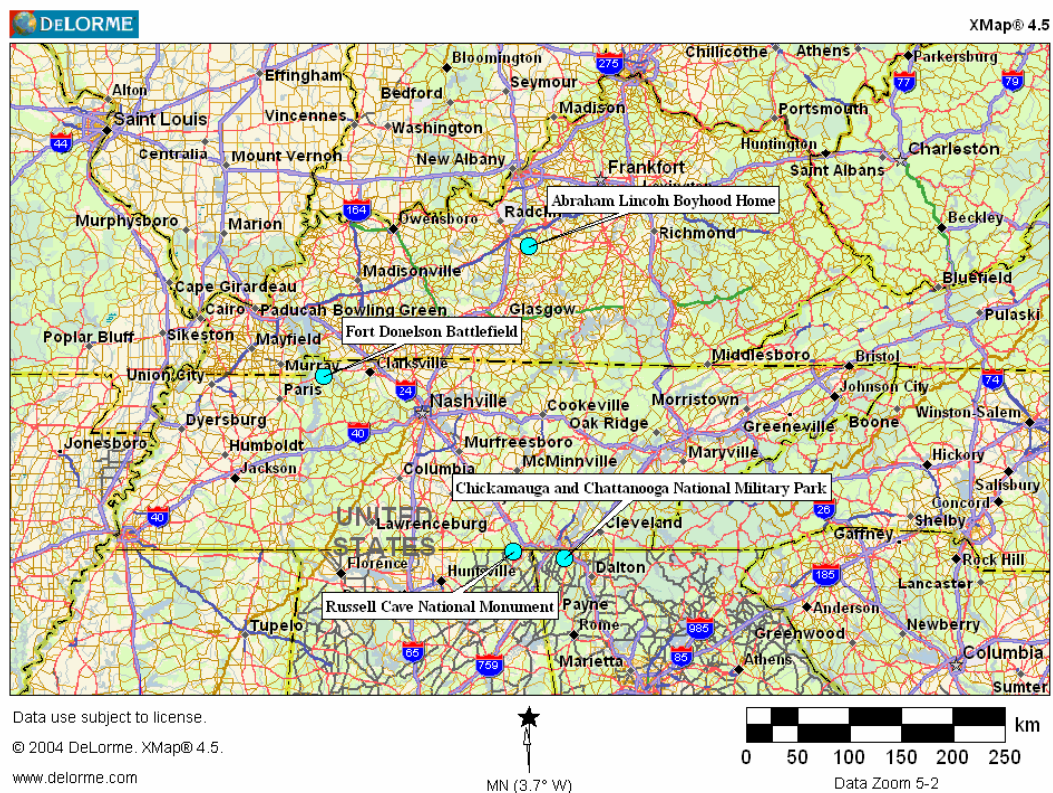


Figure 1. Map of Chickamauga and Chattanooga National Military Park, Fort Donelson National Battlefield, Abraham Lincoln Boyhood Home, and Russell Cave National Monument. Locations are marked by blue circles.

Intermittent Streams

Intermittent streams are streams that only contain flowing water during wet seasons. Low flow seasons may be late summer or fall depending on the weather patterns in the region, geology, elevation, and soil type. Intermittent streams may be headwater streams or small tributaries depending on the geology in the region. For instance, in “ridge and valley” regions, creeks may run for many kilometers without joining to form higher order streams or without any inflow from other tributaries (Matthews 1998). Intermittent streams are partially supplied by groundwater that rises to the surface at stream base flow, then dry up when groundwater levels drop (Figure 2) (Doll et al. 2004). Small headwater streams tend to have higher gradients and larger substrate particle size than in downstream areas. During dry seasons, flow of small streams may reside and a series of isolated pools will be formed.

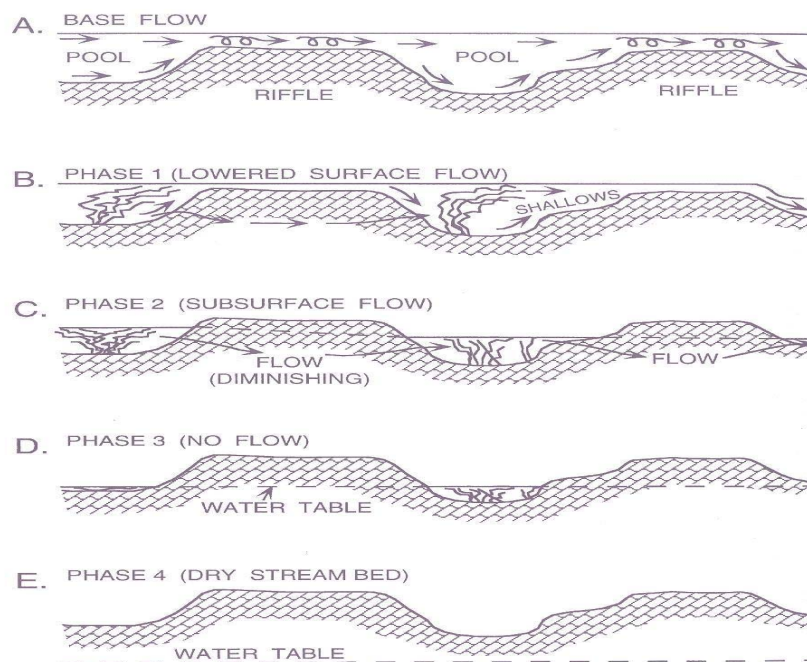


Figure 2. Severities of drought for a small gravel-bedded stream (Matthews 1998).

As a result of water level fluctuations, fish assemblages tend to be less diverse than in more stable downstream areas (Rabeni and Jacobson 1999). Fishes inhabiting these intermittent streams are usually small and tend to tolerate fluctuations in water quality and flow. Minnows tend to predominate in abundance and biomass in upstream areas. In downstream areas, minnows' relative abundance are lower in relation to an increase in the number of larger fish species, such as sunfish and suckers (Schlosser 1987). Depending on the severity of low flow, fish species inhabiting these streams will quickly recolonize dry stream reaches as flow resumes (Rabeni and Jacobson 1999).

Objectives

The objectives of this study are to: (1) complete a fish inventory in all lotic and intermittent systems within the four National Parks, and (2) determine if seasonal variations in habitat and water quality affect the fish assemblages within each system. The null hypothesis is that fish assemblages will not change due to seasonal variation in habitat and water quality parameters.

CHAPTER II-LITERATURE REVIEW

Intermittent Streams

Few fish inventory studies have been published for intermittent streams in the southeastern United States region. The streams, usually of small size and with seasonal periods of drought, are typically considered biological deserts. "Intermittent streams generally are regarded as poor habitat for fish owing to the inconstancy of the flow regime and, therefore, have received little consideration in land-use planning" (Meador et al. 1990). Researchers are now beginning to realize the important roles these small streams play in the ecosystem. The need for biological information on the natural variation of fish assemblages and their systems is important in detecting natural or anthropogenic effects and their causes. Long term monitoring of variation in fish community structure is crucial for researchers and biologists to distinguish natural from anthropogenic effects (Schlosser 1990). The information is also essential in planning adequate times of the year for sampling and monitoring different fish or aquatic invertebrate populations (Meador and Matthews 1992). This is especially important in intermittent streams because variable environmental conditions will directly affect fish and aquatic invertebrate populations. Seasonal changes of small warmwater streams affect fishes in multiple ways, and most importantly, by fluctuating water temperature, water movement, and light penetration that influence movements and biology of fishes (Matthews 1998).

Intermittent streams are important for multiple fish species in that they provide cover from predators for smaller fish species, food, and spawning habitat. Despite the

fact that these streams have extreme variances in flow regimes, the fishes that successfully occupy the streams are adapted for such conditions. In an intermittent Oklahoma prairie stream, Spranza and Stanley (2000) found fishes with high condition factors in areas with the largest environmental fluctuations. Also, some fishes may have life histories that allow them to easily adapt to times of harsh conditions. Schlosser (1985) found a large increase in adult striped shiners and bluntnose minnows during extreme low flow conditions in a second order Illinois stream. Matthews and Styron (1981) found a headwater cyprinid and darter species (*Phoxinus oreas*, *Etheostoma flabellare*) to be more tolerant of water quality changes than mainstream cyprinid and darter species (*Notropis ardens*, *N. albeolus*, and *N. cerasinus*, *E. podostemone*, *Percina roanoka*). "Since there is as much consistency in fish assemblages among months in harsh intermittent streams as permanent upland streams, it proves that intermittent streams should not be considered harsh environments for the resident fish species" (Meador and Matthews 1992).

During different seasons of the year, fish assemblages change due to temporal shifts and flow regime changes. Ostrand and Wilde (2004) found a decrease in cyprinid abundance and an increase in cyprinodontid abundance as pools evaporated and conductance increased in a portion of the Brazos River, Texas. In an Illinois headwater stream, Schlosser (1982) found lower diversity in winter when habitat availability was low. During the spring, diversity increased due to recolonization as habitat availability and resources increased.

As fish begin to re-populate an intermittent stream, a pattern can sometimes be seen between different fish species. Closs and Lake (1994) found that in an intermittent

Australian stream, species richness increased as flow began to increase. They also found the dominant trophic level for the majority of the year was detritivores. Once flow returned and recolonization began, the presence of predators increased slightly, but was still less than that of detritivores. In Gould Creek, Minnesota, Schlosser and Ebel (1989) found an increase in the abundance of cyprinids as flows increased in the spring. After the spring spawning period, cyprinid abundance decreased, except for creek chub (*Semotilus atromaculatus*) abundance, which remained stable.

During the summer and fall low water events, a crucial component to the consistency of fish assemblage structure is the presence of persistent pools throughout the entire dry season (Schlosser 1987). "There is a major difference in the dynamics of fishes of a stream reach without deep pools, which dries completely and only by migration attains a new fish assemblage after flow resumes, and a stream reach that includes permanent pools in which physicochemically tolerant species can persist to rapidly move up or downstream when flow resumes" (Meador and Matthews 1992). In upstream areas of midwestern streams, Schlosser (1990) noted small pool development and temporal variation in water quality, while downstream areas showed large pool development and little variation in water quality. In a past study on an intermittent stream adjacent to Lake Lavon in Texas, lower reaches of the stream with better stability showed higher diversity and richness values of fishes relative to the more variable headwater reaches (Meador et al. 1990). Pires et al. (1999) found higher densities of fishes and larger fish species in more stable downstream areas versus variable upstream areas of an intermittent Portugal stream.

The formation of these important pools depends on the type of substrate in the stream bed and geographic elevation changes. Other factors that affect size and flow of a stream are watershed area, land use, soil types, topography, and climate (Doll et al. 2004). Meador et al. (1990) found that headwater reaches during low flow seasons did not contain stable pools due to porous gravel substrates; however, lower stream reaches with higher substrate compositions of clay and sand contained more stable pools for fish refuge during low flow seasons. Subsiding flows can be devastating to fish assemblages, depending on their duration and magnitude. “Physicochemical conditions are harsher overall, with less flow to oxygenate water, less flushing of sediments from stream pools, more fines filling interstitial spaces in riffles and in cobble-bottomed pools, and general homogenization of the formerly well-defined riffle and pool structure (that was maintained by occasional high flow events)” (Matthews 1998).

Competition between both predators and detritivores is another factor in the structure of intermittent stream fish communities. As flow ceases and pools begin to form, fish are aggregated intensively, resulting in competition for food and space. This is when exotic species can truly jeopardize a fish population (Pires et al. 1999). In a small warmwater Illinois stream, Schlosser (1987) found “decreased minnow abundance associated with a large increase in biomass of sunfish and suckers”. Total fish abundance decreased with the influx of fewer, but larger fish species. As stated earlier, some fish species are accustomed to variable habitats, whether by fluctuating water levels or water quality. Pires et al. (1999) found that during harsh times, endemic species adapted well and survived until adequate flows returned, with no exotic species or negative habitat alterations present. But, “habitat degradation and possibly the

introductions of exotic species could contribute to marked variability in species composition” (Pires et al. 1999).

Cave Pools

In 1988, the protection of natural cave resources on federal lands was sealed with the passage of the Federal Cave Resource Protection Act (Thorne 1988). This action documented the need for biological cave research to determine the value and extent of the resources for management purposes (Hobbs 1994).

The cavefishes, Amblyopsidae, are extremely difficult to sample due to their keen sense of vibration and light. Cave pools usually have multiple openings along the floor that allow for habitat and cover when disturbed. This adds to the difficulty of sampling and gaining adequate population estimates on cavefishes (Bernard Kuhajda, University of Alabama, personal communication). The cave ecosystems have varying degrees of light (depending on location), low food resources, complete silence, and little variation in physicochemical parameters. The species inhabiting the ecosystem show different levels of adaptation to their surroundings (Hobbs 1994).

While searching for the endangered Alabama cavefish, *Speoplatyrhinus poulsoni*, researchers experimented with baited minnow traps, bankside observations (Figure 3), and snorkeling with dipnets to collect the specimens. Bankside observations were the best method of assessment and no fish were captured in the baited minnow traps (Kuhajda and Mayden 2001).



Figure 3. Bankside observation of a cave pool for fishes with high powered spotlights in Russell Cave (RUCA), Alabama (Summer 2006).

Hobbs (1994) assessed all ecological resources in Russell Cave. He observed one Southern cavefish (*Typhlichthys subterraneus*) in a deep pool between the Picnic and Canoe entrances. He also collected bluegill (*Lepomis macrochirus*), an incidental species, and banded sculpin (*Cottus carolinae*) in Russell Cave. Similar to other cavefish studies, bankside observations were the most successful method of assessment for fish in cave pools.

CHAPTER III-STUDY SITES

Chickamauga and Chattanooga National Military Park covers an area of 3318 hectares and is located in Catoosa County, Georgia, and Hamilton County, Tennessee (NPS 2006 CHCH). The park lies within the Ridge and Valley physiographic province. “Smaller streams of this region are characterized by limestone rubble and bedrock riffles with silty, sand pool areas; chert gravel occurs in some smaller streams” (Etnier and Starnes 1993). The park contains five streams within the Tennessee River drainage, four of which are intermittent. All are small warmwater streams ranging from 3.0 to 5.0 m in width and 0.1 to 0.5 m in depth depending on habitat and season. Late summer to fall are typical intermittent flow seasons.

Black Branch, Jays Mill Creek, Glenn Viniard Creek, and Cave Spring are located at Chickamauga Battlefield and are intermittent streams that are tributaries to West Chickamauga Creek (Figure 4). Jays Mill Creek and Glenn Viniard Creek had no original names and have been named after the road in closest proximity to the streams. West Chickamauga Creek (order 5 stream) at Fort Oglethorpe, GA, is negatively impacted from several point and non-point sources resulting in low fish abundance (Haines 1982). There are many records on the fishes of West Chickamauga Creek, but these small tributaries to the stream have never been sampled within the park boundaries. Black Branch and Jays Mill Creek are comprised of limestone cobble areas with some bedrock shelves. Black Branch originates in the northwestern corner of the park and flows in a northeast direction for approximately 6.5 km into Spring Creek, a tributary to West Chickamauga Creek. Jays Mill Creek originates in the center portion of the park

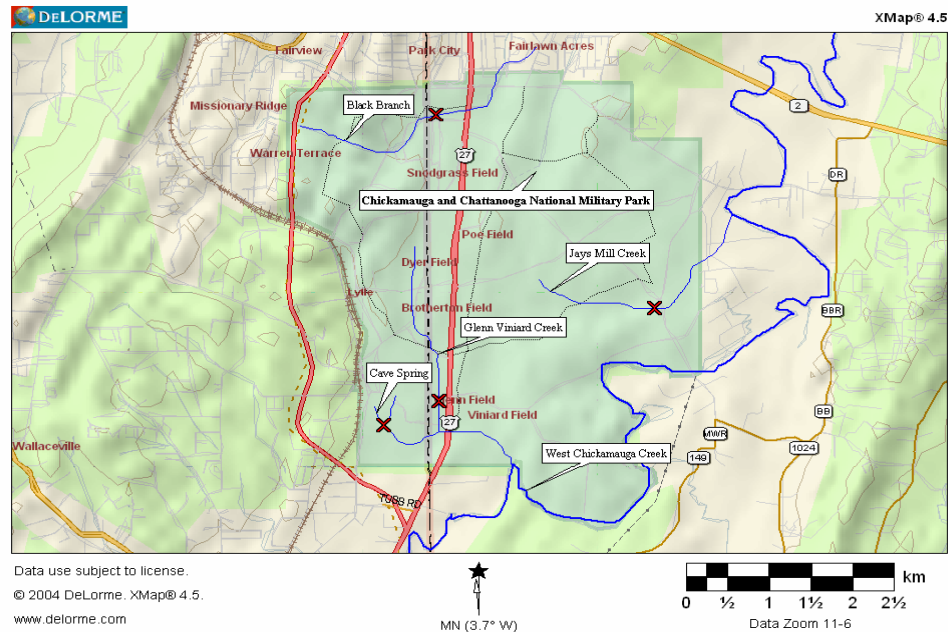


Figure 4. Map of Chickamauga/Chattanooga National Military Park showing sampling sites (X) on Black Branch, Jays Mill Creek, Glenn Viniard Creek, and Cave Spring.

and flows in a northeast direction for approximately 4.0 km into West Chickamauga Creek. Black Branch has been slightly degraded, probably due to the lack of riparian zone and channelization from the large battlefield through which it flows (Figure 5). The entrenched channel and incised, steep banks can be seen by looking at the cross section profile (Appendix A.1).

Glenn Viniard Creek is a channelized, degraded creek with little riparian zones as it flows through large battlefields (Figure 6). It flows parallel with Highway 27 in a southern direction for approximately 2.5 km to its confluence with Cave Spring. The incised channel with its steep, undercut banks can be seen by examining the cross section profile (Appendix A.3). The stream reach has little habitat delineation and substrate comprised of fine gravel and silty sandy areas.



Figure 5. Degraded stream channel of Black Branch (CHCH)-Spring 2006.



Figure 6. Degraded stream channel of Glenn Viniard Creek (CHCH)-Winter 2004.

Cave Spring is a small spring-fed stream with its origin on the southwestern side of the park (Figure 7). From its origin, Cave Spring flows in a southeastern direction for approximately 2.5 km to its confluence with West Chickamauga Creek. Glenn Viniard Creek joins Cave Spring at the Highway 27 crossing. The site sampled at Cave Spring is a 100-m reach downstream from the origin of outflow. The upper portion of Cave Spring is spring-like with cold flows and vegetated cobble, but the lower portion had warmer temperatures and a higher concentration of sand and silt substrate. “Springs have typical characteristics, such as cold (15-17 C, or 59-63 F) outflows and abundant vegetation, primarily watercress” (Etnier and Starnes 1993). The substrate of Cave Spring is primarily comprised of limestone cobble and gravel.



Figure 7. Cave Spring (CHCH) -Summer 2005.

Skyuka Spring is located at the Lookout Mountain Battlefield Unit of Chickamauga and Chattanooga National Military Park and is a tributary to Lookout Creek (Figure 8). Skyuka Spring is a perennial spring-fed stream with small chert gravel substrate. The stream is approximately 1.0 m in width and ranged from 0.1 to 0.3 m in depth depending on habitat and season. It originates from the west side of Lookout Mountain where it flows out of the ground in a western direction approximately 150 m into Lookout Creek (Figure 9). Lookout Creek (order 4 stream) is unaffected by point source effluents, and receives only minor impacts from non-point source pollutants (Haines 1982). There are many records on the fishes of Lookout Creek, but the small tributary, Skyuka Spring, has never been sampled within the park boundaries.

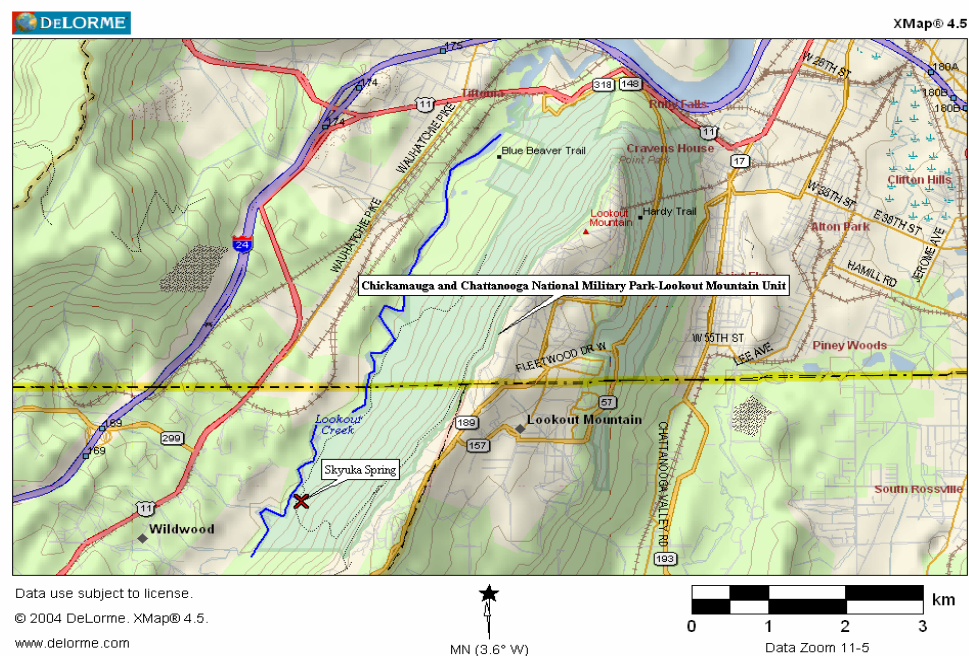


Figure 8. Map of Lookout Mountain National Military Park showing the sampling site (X) on Skyuka Spring.



Figure 9. Origination of Skyuka Spring at Lookout Mountain Battlefield (CHCH)-Spring 2006.

Fort Donelson National Battlefield covers an area of 243 hectares and is located in Stewart County, Tennessee. The park lies within the Highland Rim section of the Interior Low Plateaus Physiographic Province (NPS 2006 FODO). It contains one intermittent stream, Indian Creek, which flows approximately 2.3 km in a northeastern direction into Lake Barkley of the Cumberland River system (Figure 10). Indian Creek is a spring-fed stream originating from the southeastern portion of the park with limestone cobble and chert gravel substrate (Figure 11). Although the stream is spring-fed, flow tends to be relatively low and runs intermittent during late summer to fall depending on weather. The stream is approximately 0.7 m in width and ranged from 0.1 to 0.3 m in depth depending on habitat and season. There are no records on the fishes of Indian Creek within the park.

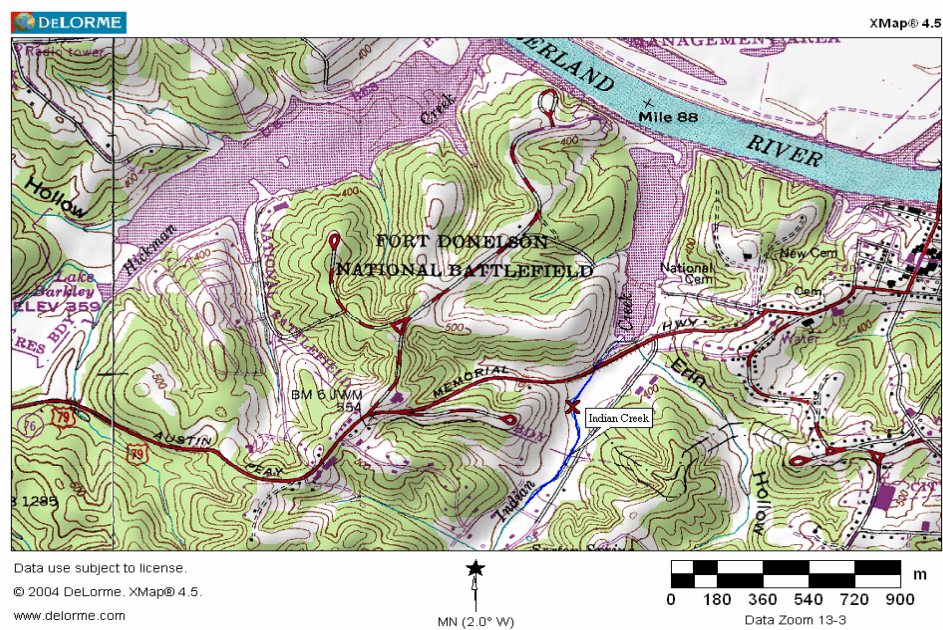


Figure 10. Map of Fort Donelson National Battlefield showing the sampling site (X) on Indian Creek.



Figure 11. Indian Creek (FODO)-Fall 2005.

Abe Lincoln Birthplace National Historic Site covers an area of 47 hectares and is located in Larue County, Kentucky. Abe Lincoln Boyhood Home (92 hectares) is located 10 miles northeast of park headquarters on US31E (NPS 2006 ABLI). The park lies within the Bluegrass Section of the Interior Low Plateaus Physiographic Province. The basin is rimmed by Knobstone Escarpment and drained completely by Ohio River tributaries (Licking River, Kentucky River, Salt River, and Kinniconick Creek) (Burr and Warren, Jr. 1986). Within the Boyhood Home unit is one intermittent stream, Knob Creek, a tributary of the Rolling Fork River in the Salt River drainage (Figure 12). Knob Creek flows in a northeast direction approximately 3.0 km to its confluence with the Rolling River just south of New Haven, Kentucky. The substrate is comprised of limestone cobble and extensive bedrock shelves. The large areas of bedrock

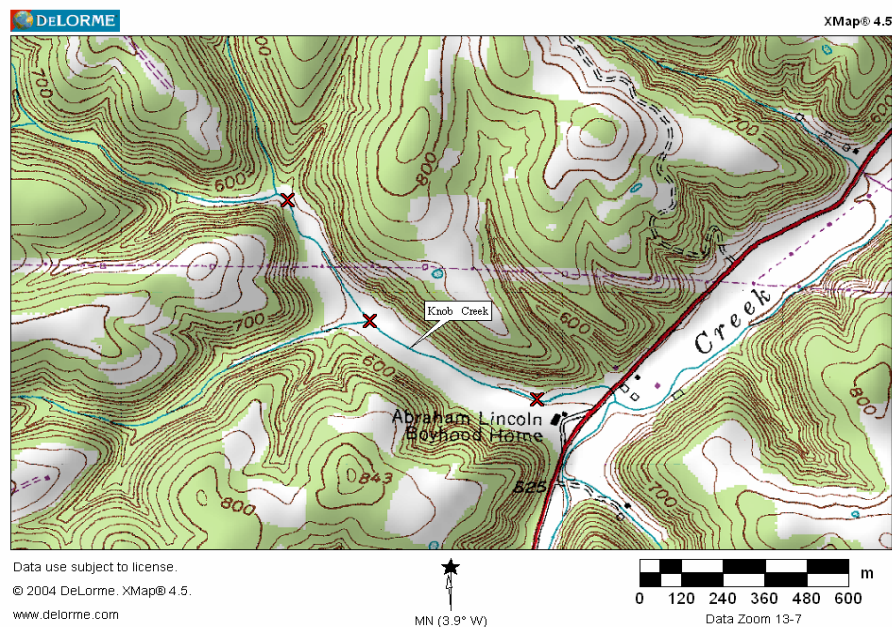


Figure 12. Map of Abe Lincoln Birthplace National Historic Site showing the sampling sites (X) on Knob Creek.



Figure 13. Knob Creek at Abe Lincoln Boyhood Home (ABLI)-Summer 2005.

substrate made sampling all possible habitats (pool, run, riffle, glide) difficult. Therefore, multiple sites had to be sampled to collect an adequate relative abundance of fish (Figure 12). The stream was approximately 3.3 m in width and ranged from 0.1 to 0.5 m in depth depending on habitat and season (Figure 13). There are no records on the fishes of Knob Creek within the park boundaries.

Russell Cave National Monument encompasses an area of 125 hectares and is home to over 16 kilometers of mapped cave systems in Jackson County, Alabama (NPS 2006 RUCA). The park lies on the Cumberland Plateau. This province is capped with a sandstone layer (Pottsville Formation) with shale, limestone, and more sandstone beneath (Hobbs 1994). This region is “characterized as a karst region noted for numerous extensive and intricate caves, and for deep pits” (Hobbs 1994). Russell Cave National Monument contains one cave entrance spring and seven accessible cave pools within the

park boundaries (Figure 14 and 15). The cave pools add tremendous difficulty and danger to sampling fish. The entrance spring substrate is comprised of limestone and chert cobble. The stream is approximately 1.6 m in width and ranged from 0.2 to 0.3 m in depth depending on habitat and season. After leaving the cave, the water enters Widow's Creek in the Tennessee River drainage area (NPS 2006 RUCA). The limestone formation in Russell Cave is connected to formations that pass beneath multiple surface drainage areas including the Tennessee, Cumberland, and Mississippi Rivers (Armstrong and Williams 1971).

Weather

The study sites of Chickamauga and Chattanooga National Military Park, Fort Donelson National Battlefield, Abe Lincoln Birthplace National Historic Site, and Russell Cave National Monument lie in and around the Interior Low Plateau



Figure 14. Entrance spring to Russell Cave-November 2004.

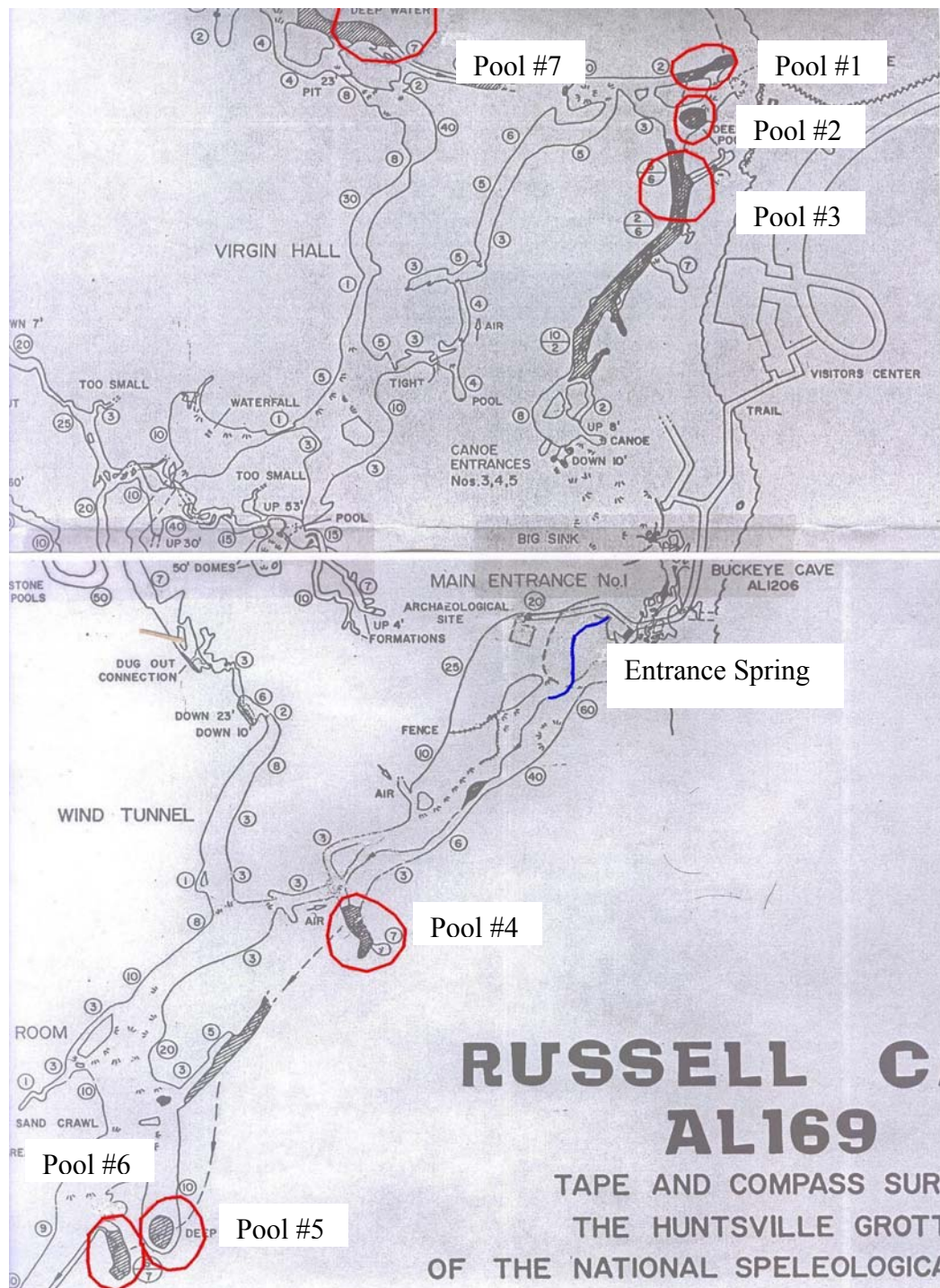


Figure 15. Map of Russell Cave National Monument showing the entrance spring and cave pools. Provided by the National Speleological Society.

physiographic province. The climate of this region is temperate with relatively hot, humid summers and cool winters. Annual precipitation averages from 111 to 137 cm with lowest rainfall occurring in late summer to fall. Average temperatures range from 12 to 16 C (McNab and Avers 1994). During the study period, annual precipitation for the Interior Low Plateau area ranged from normal to abnormally dry (NCDC 2006). Rainfall is one of the crucial components to the severity of low flow in intermittent streams (Matthews 1998). Many studies on intermittent streams have been completed in other regions of the country with substantially less annual rainfall than the Interior Low Plateaus (Oklahoma: Spranza and Stanley 2000--Arizona: John 1964--Illinois: Schlosser 1982, 1985, 1987--Texas: Ostrand and Wilde 2002, 2004, Meador et al. 1990, Meador and Matthews 1992, Ostrand and Marks 2000).

CHAPTER IV-METHODS

Fish Collection

Selected sites were sampled during three seasons to determine changes in fish assemblages in relation to habitat variation. Selection of sampling sites was based on accessibility and location within the watershed and all sites had a variety of habitats (pool, run, riffle, glide). The summer season was completed during May and June 2005, while the fall season spanned October and November 2005. The 2006 spring season was completed during the month of April. Single pass efforts of 100-m reaches were sampled in an upstream direction. “The first pass through a reach should provide the best opportunity to collect fish while they are still naïve to sampling. Therefore, a single-pass approach may provide a better estimate of relative abundance than a depletion approach, especially if some species are more likely to develop avoidance behaviors” (Edwards et al. 2003). Fish were collected using backpack electrofishing units and a 3.0-m x 1.2-m straight seine. Fish were shocked into the seine when applicable. At lower flows, stunned fish were collected with dip nets. All fish were sorted by species, counted, and then released. Specimens not identifiable in the field were placed in 10% formalin and housed at the University of Tennessee for further identification.

Selected sites in Russell Cave were sampled only twice due to the difficulty and danger of caving. Six cave pools were sampled in October 2005 and June 2006. The inner most pool was not sampled due to inaccessibility. Snorkeling with underwater spotlights, bankside observations, and minnow traps were used to sample fish in the pools at Russell Cave. Ten minnow traps baited with different combinations of canned dog



Figure 16. Preparing minnow traps to be set in cave pools of Russell Cave (RUCA), Alabama (Fall 2005).

food, boiled eggs, crickets, and light sticks were used to attract fish (Figure 16). The traps were set for approximately 24 hours. All fish were sorted by species, counted, and then released. Specimens not identifiable in the field were placed in 10% formalin and housed at the University of Tennessee for further identification.

Physical Parameters

Water quality parameters were measured for three seasons (Summer 2005, Fall 2005, and Spring 2006) at all sites to determine changes in habitat over time. All water quality parameters were collected once at the same time and place as the fish collections (page 23). Temperature (C), dissolved oxygen (mg/L), pH (su), and conductivity

($\mu\text{S}/\text{cm}$) were taken with a YSI model 85 meter (Yellow Springs Instrument) at each site. Dissolved oxygen, pH, and conductivity had a resolution of 0.01, while temperature had a resolution of 0.1.

Flow rate (m/sec) was taken using a timed orange float in a 2.0-m stretch of the thalweg at each site. Bottom channel width, wetted channel width, and depth were taken to calculate a cross-sectional area. Cross-sectional area was then used to calculate volume of flow in cubic feet per second (cfs). Cubic feet per second (not cms) is the common terminology used for discussion of stream discharge.

A cross section dimension profile as described by Doll et al. (2004) was taken with a CST/Berger LaserMark automatic self-leveling rotary laser level at each site (Appendix A). The profile can be used to determine the stability of the stream reach and the need for restoration (Figure 17). Elevations of stream channels can directly affect water levels and habitat delineation in stream channels. The cross section placement was across riffle habitats, the most stable portion of a stream. Permanent markers were set with stakes, bankfull marks were set, and a tape was stretched across the channel between the permanent markers. Starting at the zero end of the tape (left bank), elevation and distance readings were taken across the channel at every significant change in elevation. Readings were also taken at the permanent markers, top of banks, bankfull marks, edges of water, and thalweg. Cross section calculations and profile were designed in a Microsoft Excel datasheet designed by the Ohio Department of Natural Resources-Division of Soil and Water Conservation (Mecklenburg 2006).

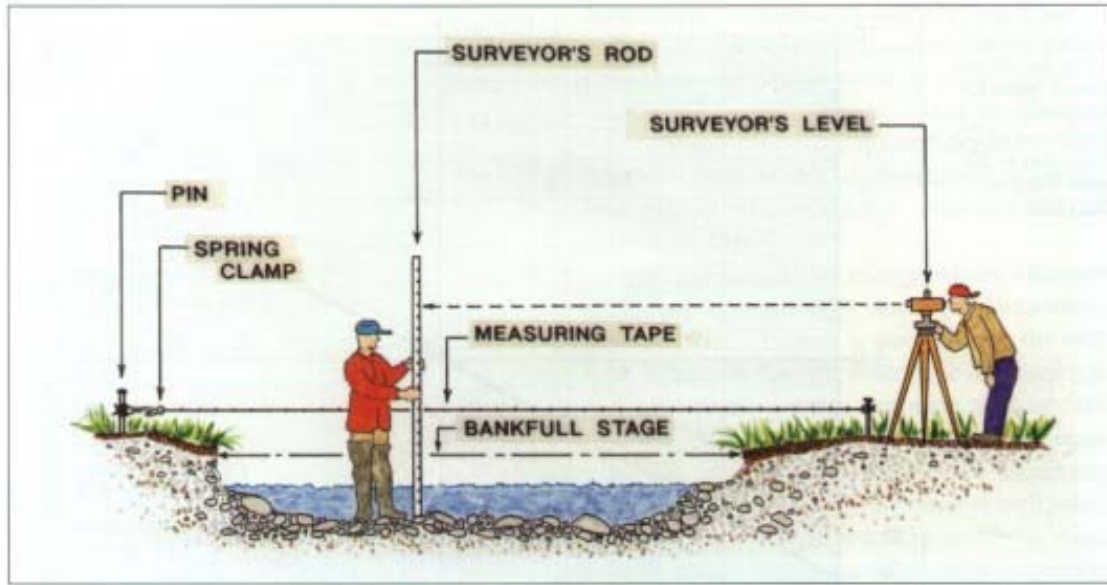


Figure 17. Surveying a cross section of a stream (Rosgen 1996).

Fish Assemblage Analysis

Abundance (N), relative abundance (%), species richness (number of species), and Shannon-Weaver Index of Diversity (H') were used to analyze fish assemblages among seasons for each site. The Shannon-Weaver Index of Diversity was calculated using the formula

$$H' = -\sum_{i=1}^S (p_i) (\ln p_i),$$

where p_i is the frequency of species i in the assemblage (Shannon and Weaver 1949).

The descriptive statistics were used in conjunction with the physical parameters for further analysis. The most dominant species were used for relative abundance graphs, with species representing less than 3% of the total sample for all seasons combined being

excluded. No quantitative statistical tests were used because of the low number of data points for each site. Sites were not compared to each other due to differences in stream origin, location, size, and substrate composition.

CHAPTER V-RESULTS

Chickamauga and Chattanooga National Military Park (TN)

Black Branch

In Black Branch, the fish assemblage for all seasons combined was dominated by largescale stoneroller, striped shiner, and bluntnose minnow (Figure 18). Populations of bluntnose minnows showed large variations across seasons with the lowest abundance in fall 2005. However, largescale stoneroller, striped shiner, mosquitofish, and blacknose dace populations increased in relative abundance during the fall. Total abundance of fishes was highest in the spring and lowest in the summer. Species diversity was lowest in the fall and highest in the spring and summer. While abundance, relative abundance, and diversity varied across seasons, species richness stayed approximately the same during the entire 12-month period (Table 1).

The physical parameters of Black Branch fluctuated greatly from season to season. Stream discharge ranged from no flow (temporary pools) to 10.0 cfs across the seasons, with lowest flows during the fall. Even though flow stopped, large pools were formed that allowed for fish refuge during harsh times of the year. Temperatures ranged from 13.4 to 20.0 (C), with the highest temperatures of all streams sampled occurring during the fall. Dissolved oxygen levels ranged from 2.9 to 6.1 mg/L with the lowest levels occurring during the fall. Conductivity ranged from 223.7 to 423.2 μ S, with highest levels occurring in the fall. pH levels varied across all seasons, ranging from 6.1 to 8.4 (Table 2).

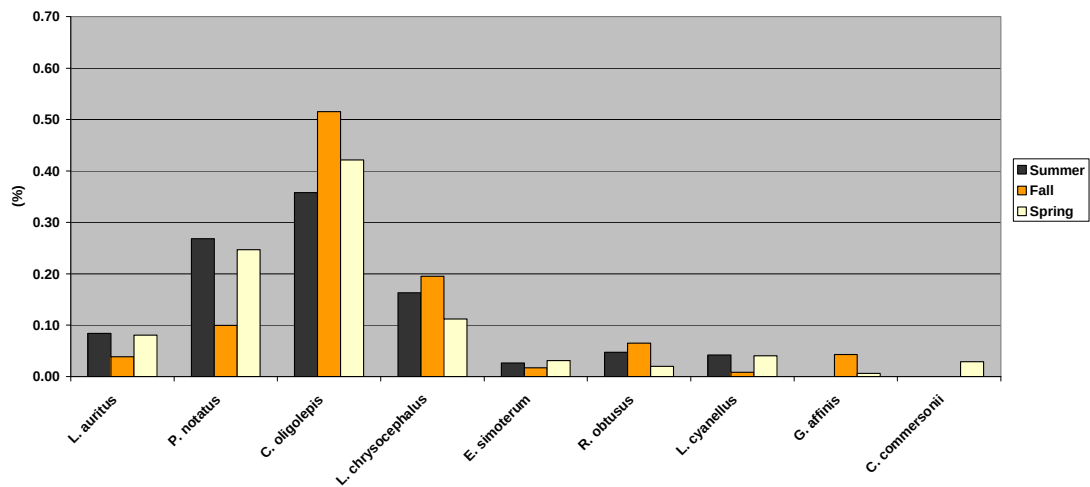


Figure 18. Seasonal variation in relative abundance of dominant fish collected in Black Branch (CHCH) from Summer 2005 to Spring 2006.

Table 1. Abundance, species richness, and species diversity of Black Branch (CHCH) for Summer/Fall 2005 and Spring 2006.

<u>Species</u>	<u>Common Name</u>	<u>Summer</u> #	<u>Fall</u> #	<u>Spring</u> #
<i>Camptostoma oligolepis</i>	Largescale stoneroller	68	119	188
<i>Luxilus chrysocephalus</i>	Striped shiner	31	45	50
<i>Rhinichthys obtusus</i>	Western blacknose dace	9	15	9
<i>Pimephales notatus</i>	Bluntnose minnow	51	23	110
<i>Semotilus atromaculatus</i>	Creek chub	0	1	0
<i>Catostomus commersonii</i>	White Sucker	0	0	13
<i>Hypentelium nigricans</i>	Northern hogsucker	1	0	0
<i>Gambusia affinis</i>	Mosquitofish	0	10	3
<i>Lepomis auritus</i>	Redbreast sunfish	16	9	36
<i>Lepomis cyanellus</i>	Green sunfish	8	2	18
<i>Lepomis macrochirus</i>	Bluegill	1	3	0
<i>Etheostoma caeruleum</i>	Rainbow darter	0	0	5
<i>Etheostoma simoterum</i>	Snubnose darter	5	4	14
Total		190	231	446
Species Richness		9	10	10
Species Diversity		1.69	1.48	1.67

Table 2. Temperature (C), dissolved oxygen (mg/L), conductivity ($\mu\text{S}/\text{cm}$), pH (su), and discharge (ft^3/sec) of Black Branch (CHCH) for Summer/Fall 2005 and Spring 2006.

	<u>Summer</u>	<u>Fall</u>	<u>Spring</u>
Temperature ($^{\circ}\text{C}$)	13.4	20.0	17.3
DO (mg/L)	5.0	2.9	6.1
Conductivity ($\mu\text{S}/\text{cm}$)	282.2	423.2	223.7
pH (su)	6.9	6.1	8.4
Discharge (ft^3/sec)	8.0	0.0	10.0

Jays Mill Creek

In Jays Mill Creek, the fish assemblage for all seasons was dominated by mosquitofish, bluegill, bluntnose minnow, and green sunfish (Figure 19). The assemblage structure changed from being dominated by cyprinids in the spring to centrarchids in the summer and fall. The spring fish assemblage was dominated by bluntnose minnow, mosquitofish, and striped shiner. The summer and fall fish assemblages were dominated by bluegill, green sunfish, redbreast sunfish and mosquitofish. Total abundance of fishes was highest in the fall and lowest in the summer. Interestingly, species richness was lowest in the fall. Species diversity was highest during the spring and lowest during the fall (Table 3).

The physical parameters of Jays Mill Creek fluctuated greatly from season to season. Stream discharge ranged from no flow (temporary pools) to 5.0 cfs across the seasons, with lowest flows during the fall. The stream reach sampled was close to being

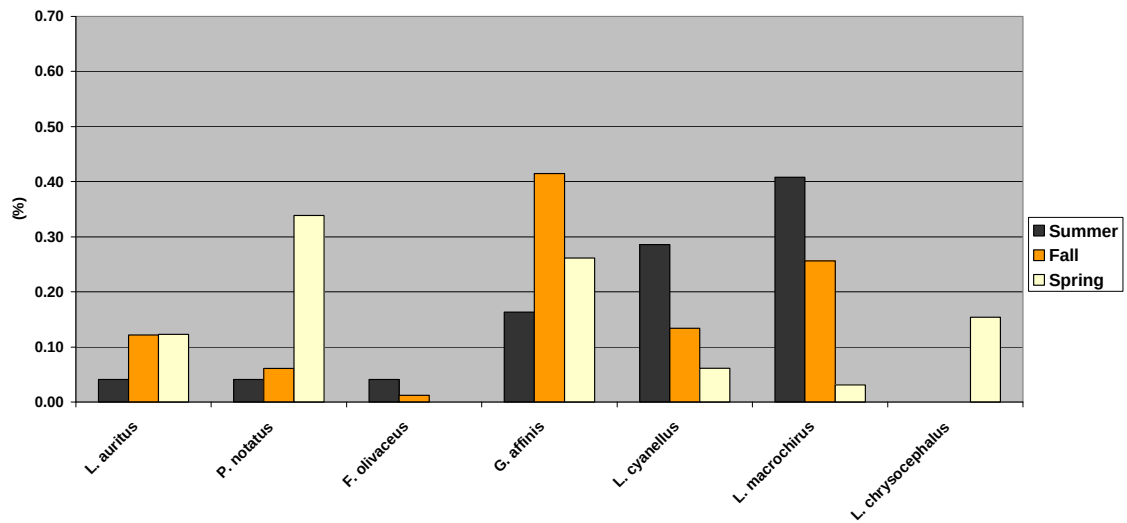


Figure 19. Seasonal variation in relative abundance of dominant fish collected in Jays Mill Creek (CHCH) from Summer 2005 to Spring 2006.

Table 3. Abundance, species richness, and species diversity of Jays Mill Creek (CHCH) for Summer/Fall 2005 and Spring 2006.

<u>Species</u>	<u>Common Name</u>	<u>Summer</u> #	<u>Fall</u> #	<u>Spring</u> #
<i>Campostoma oligolepis</i>	Largescale stoneroller	1	0	0
<i>Luxilus chrysocephalus</i>	Striped shiner	0	0	10
<i>Pimephales notatus</i>	Bluntnose minnow	2	5	22
<i>Fundulus olivaceus</i>	Blackspotted topminnow	2	1	0
<i>Gambusia affinis</i>	Mosquitofish	8	34	17
<i>Cottus carolinae</i>	Banded sculpin	0	0	1
<i>Lepomis auritus</i>	Redbreast sunfish	2	10	8
<i>Lepomis cyanellus</i>	Green sunfish	14	11	4
<i>Lepomis macrochirus</i>	Bluegill	20	21	2
<i>Micropterus salmoides</i>	Largemouth bass	0	0	1
<i>Etheostoma simoterum</i>	Snubnose darter	1	0	0
Total		50	82	65
Species Richness		8	6	8
Species Diversity		1.56	1.45	1.69

Table 4. Temperature (C), dissolved oxygen (mg/L), conductivity ($\mu\text{S}/\text{cm}$), pH (su), and discharge (ft^3/sec) of Jays Mill Creek (CHCH) for Summer/Fall 2005 and Spring 2006.

	<u>Summer</u>	<u>Fall</u>	<u>Spring</u>
Temperature (C)	12.9	16.2	16.3
DO (mg/L)	5.1	4.2	5.2
Conductivity ($\mu\text{S}/\text{cm}$)	425.8	324.0	348.4
pH (su)	7.4	6.8	8.3
Discharge (ft^3/sec)	2.0	0.0	5.0

completely dry during the fall with only a few pools remaining for fish refuge.

Temperatures ranged from 12.9 to 16.3 C, with highest temperatures occurring during the spring. Dissolved oxygen levels ranged from 4.2 to 5.2 mg/L, with the lowest levels occurring during the fall. Conductivity ranged from 324.0 to 425.8 μS , with highest levels of all streams sampled occurring in the summer. pH levels stayed varied across all seasons ranging from 6.8 to 8.3 (Table 4).

Glenn Viniard Creek

In Glenn Viniard Creek, the fish assemblage for all seasons was dominated by bluegill and redbreast sunfish (Figure 20). The assemblage structure stayed relatively the same across seasons. Total abundance was highest during the summer and fall and lowest during the spring. Species richness decreased drastically from summer and fall to spring. Species diversity was highest during the summer and lowest during the spring (Table 5).

The physical parameters of Glenn Viniard Creek fluctuated greatly from season to season. Stream discharge ranged from no flow (temporary pools) to 7.0 cfs across

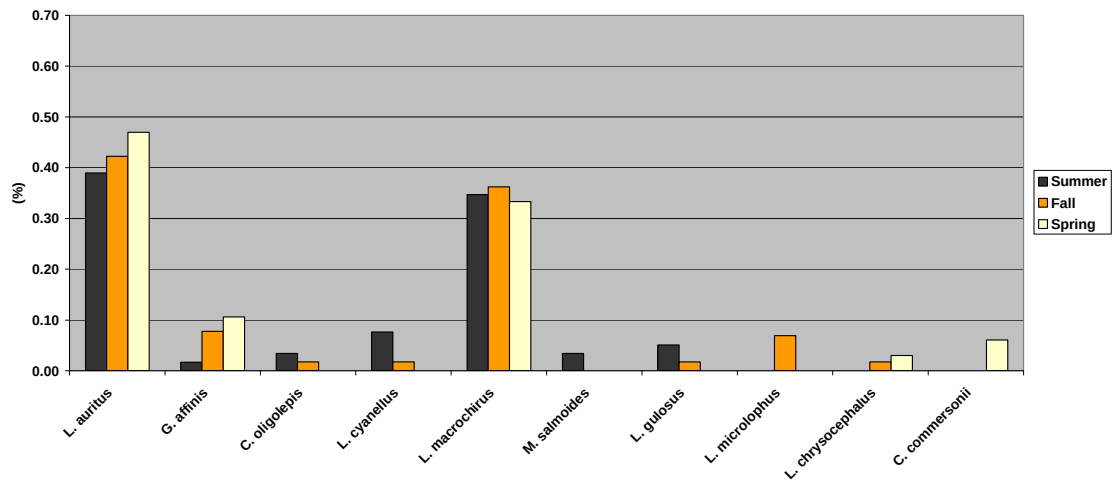


Figure 20. Seasonal variation in relative abundance of dominant fish collected in Glenn Viniard Creek (CHCH) from Summer 2005 to Spring 2006.

Table 5. Abundance, species richness, and species diversity of Glenn Viniard Creek (CHCH) for Summer/Fall 2005 and Spring 2006.

<u>Species</u>	<u>Common Name</u>	<u>Summer</u> #	<u>Fall</u> #	<u>Spring</u> #
<i>Campostoma oligolepis</i>	Largescale stoneroller	4	2	0
<i>Luxilus chrysocephalus</i>	Striped shiner	0	2	2
<i>Catostomus commersonii</i>	White sucker	0	0	4
<i>Hypentelium nigricans</i>	Northern hogsucker	3	0	0
<i>Gambusia affinis</i>	Mosquitofish	2	9	7
<i>Lepomis auritus</i>	Redbreast sunfish	46	49	31
<i>Lepomis cyanellus</i>	Green sunfish	9	2	0
<i>Lepomis gulosus</i>	Warmouth	6	2	0
<i>Lepomis macrochirus</i>	Bluegill	41	42	22
<i>Lepomis microlophus</i>	Redear sunfish	0	8	0
<i>Micropterus salmoides</i>	Largemouth bass	4	0	0
<i>Etheostoma simoterum</i>	Snubnose darter	3	0	0
Total		118	116	66
Species Richness		9	8	5
Species Diversity		1.75	1.59	1.24

Table 6. Temperature (C), dissolved oxygen (mg/L), conductivity ($\mu\text{S}/\text{cm}$), pH (su), and discharge (ft^3/sec) of Glenn Viniard Creek (CHCH) for Summer/Fall 2005 and Spring 2006.

	<u>Summer</u>	<u>Fall</u>	<u>Spring</u>
Temperature (C)	14.9	15.1	19.3
DO (mg/L)	8.0	5.2	5.8
Conductivity ($\mu\text{S}/\text{cm}$)	385.0	293.2	323.3
pH (su)	7.3	7.2	8.8
Discharge (ft^3/sec)	7.0	0.0	3.0

the seasons, with lowest flows during the fall. The stream reach sampled was extremely incised with little habitat delineation. Even though flows ceased during the fall, the channel was relatively full of water.

Temperatures ranged from 14.9 to 19.3 C, with highest temperatures occurring during the spring. Dissolved oxygen levels ranged from 5.2 to 8.0 mg/L with lowest levels occurring during the fall. Conductivity ranged from 293.2 to 385.0 μS with highest levels occurring in the summer. pH levels varied across all seasons ranging from to 7.2 to 8.8 (Table 6).

Cave Spring

In Cave Spring, the fish assemblage for all seasons was dominated by banded sculpin and blacknose dace (Figure 21). The assemblage structure did change drastically across seasons. The summer fish assemblage was dominated by banded sculpin, while the fall fish assemblage was dominated by blacknose dace. The spring fish assemblage was dominated by both banded sculpin and blacknose dace. Total abundance was highest

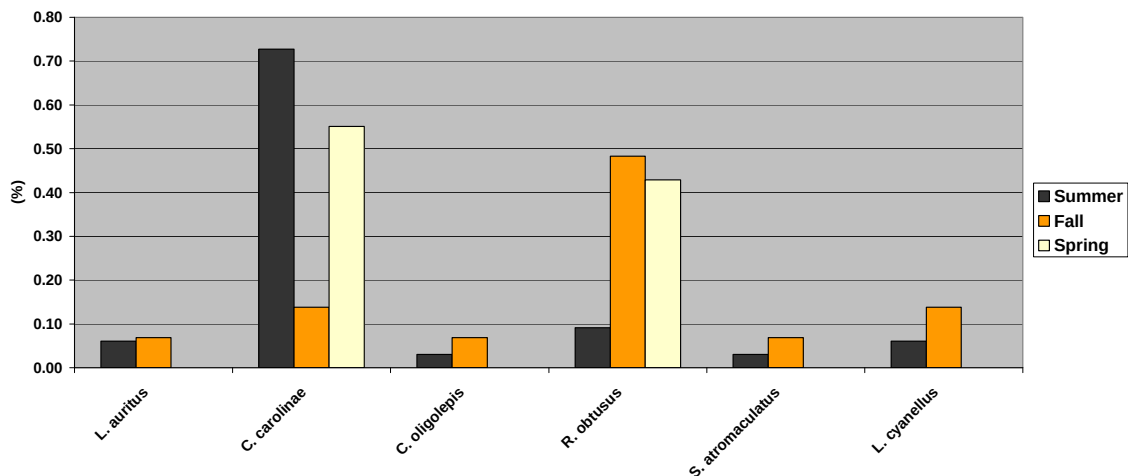


Figure 21. Seasonal variation in relative abundance of dominant fish collected in Cave Spring (CHCH) from Summer 2005 to Spring 2006

during the spring and lowest during the fall. Interestingly, the species richness was lowest during the spring and highest during the summer and fall. Species diversity was highest during the fall and lowest during the spring (Table 7).

The physical parameters of Cave Spring varied greatly across all seasons except for temperature and pH. Stream discharge ranged from no flow (temporary pools) to 3.0 cfs across the seasons, with lowest flows during the fall. The stream reach sampled was close to being completely dry during the fall with only a few pools remaining for fish refuge. Temperatures were stable ranging from 15.0 to 15.2 C. Dissolved oxygen levels ranged from 2.0 to 4.9 mg/L with the lowest levels of all streams sampled occurring during the fall. Conductivity ranged from 248.0 to 304.9 μ S with highest levels occurring in the fall. pH levels stayed relatively stable across all seasons ranging from 6.4 to 7.5 (Table 8).

Table 7. Abundance, species richness, and species diversity of Cave Spring (CHCH) for Summer/Fall 2005 and Spring 2006.

<u>Species</u>	<u>Common Name</u>	<u>Summer</u>	<u>Fall</u>	<u>Spring</u>
		#	#	#
<i>Campostoma oligolepis</i>	Largescale stoneroller	1	2	0
<i>Rhinichthys obtusus</i>	Western blacknose dace	3	14	21
<i>Semotilus atromaculatus</i>	Creek chub	1	2	0
<i>Cottus carolinae</i>	Banded sculpin	24	4	27
<i>Lepomis auritus</i>	Redbreast sunfish	2	2	0
<i>Lepomis cyanellus</i>	Green sunfish	2	4	0
<i>Lepomis macrochirus</i>	Bluegill	0	0	1
<i>Etheostoma simoterum</i>	Snubnose darter	0	1	0
Total		33	29	49
Species Richness		6	7	3
Species Diversity		1.01	1.57	0.77

Table 8. Temperature (C), dissolved oxygen (mg/L), conductivity (µS/cm), pH (su), and discharge (ft³/sec) of Cave Spring (CHCH) for Summer/Fall 2005 and Spring 2006.

	<u>Summer</u>	<u>Fall</u>	<u>Spring</u>
Temperature (C)	15.2	15.0	15.1
DO (mg/L)	4.7	2.0	4.9
Conductivity (µS/cm)	248.0	304.9	286.8
pH (su)	6.4	6.4	7.5
Discharge (ft³/sec)	2.0	0.0	3.0

Skyuka Spring

In Skyuka Spring, the fish assemblage for all seasons combined was dominated by banded sculpin, blacknose dace, and striped shiner (Figure 22). Assemblage structure stayed relatively the same across seasons. Total abundance was highest in the spring and lowest during the fall. Species richness stayed the same across all seasons. Species diversity was highest during the spring and fall and lowest in the summer (Table 9).

The physical parameters of Skyuka Spring stayed relatively stable across all seasons, except for stream discharge, conductivity, and pH. The perennial stream has a large groundwater source flowing throughout the year. Stream discharge ranged from 1.0 to 11.0 cfs across the seasons, with lowest flows during the fall. Conductivity ranged from 103.5 to 171.6 μS with highest levels occurring in the fall. Temperatures and dissolved oxygen levels stayed relatively stable across all seasons (Table 10).

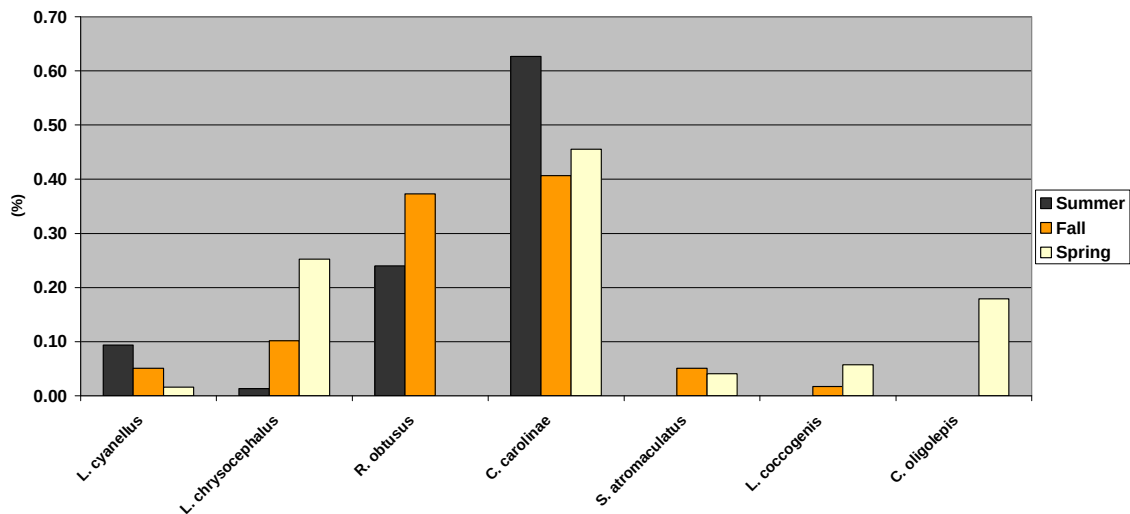


Figure 22. Seasonal variation in relative abundance of dominant fish collected in Skyuka Spring (CHCH) from Summer 2005 to Spring 2006.

Table 9. Abundance, species richness, and species diversity of Skyuka Spring (CHCH) for Summer/Fall 2005 and Spring 2006.

<u>Species</u>	<u>Common Name</u>	<u>Summer</u>	<u>Fall</u>	<u>Spring</u>
		#	#	#
<i>Ichthyomyzon</i> spp.	Lamprey spp.	1	0	0
<i>Campostoma oligolepis</i>	Largescale Stoneroller	0	0	22
<i>Luxilus chrysocephalus</i>	Striped shiner	1	6	31
<i>Luxilus coccogenis</i>	Warpaint shiner	0	1	7
<i>Rhinichthys obtusus</i>	Western blacknose dace	18	22	0
<i>Semotilus atromaculatus</i>	Creek chub	0	3	5
<i>Gambusia affinis</i>	Mosquitofish	1	0	0
<i>Cottus carolinae</i>	Banded sculpin	47	24	56
<i>Lepomis cyanellus</i>	Green sunfish	7	3	2
Total		75	59	123
Species Richness		6	6	6
Species Diversity		1.03	1.34	1.37

Table 10. Temperature (C), dissolved oxygen (mg/L), conductivity (μ S/cm), pH (su), and discharge (ft^3/sec) of Skyuka Spring (CHCH) for Summer/Fall 2005 and Spring 2006.

	<u>Summer</u>	<u>Fall</u>	<u>Spring</u>
Temperature (C)	14.1	14.5	13.7
DO (mg/L)	7.9	8.7	8.9
Conductivity (μS/cm)	134.1	171.6	103.5
pH (su)	7.4	6.2	8.6
Discharge (ft^3/sec)	5.0	1.0	11.0

Fort Donelson National Battlefield (TN)

Indian Creek

In Indian Creek, the fish assemblage for all seasons combined was dominated by fringed darter, creek chub, rainbow darter, and largescale stoneroller (Figure 23).

Assemblage structure did change across seasons. The spring and summer season fish assemblages were dominated by fringed darter, creek chub, rainbow darter, and largescale stoneroller. The fall season fish assemblage was dominated by only two species, the creek chub and fringed darter. Total abundance was highest during the summer and lowest during the fall. Species richness stayed approximately the same across all seasons. Species diversity was highest during the spring and summer and lowest in the fall (Table 11).

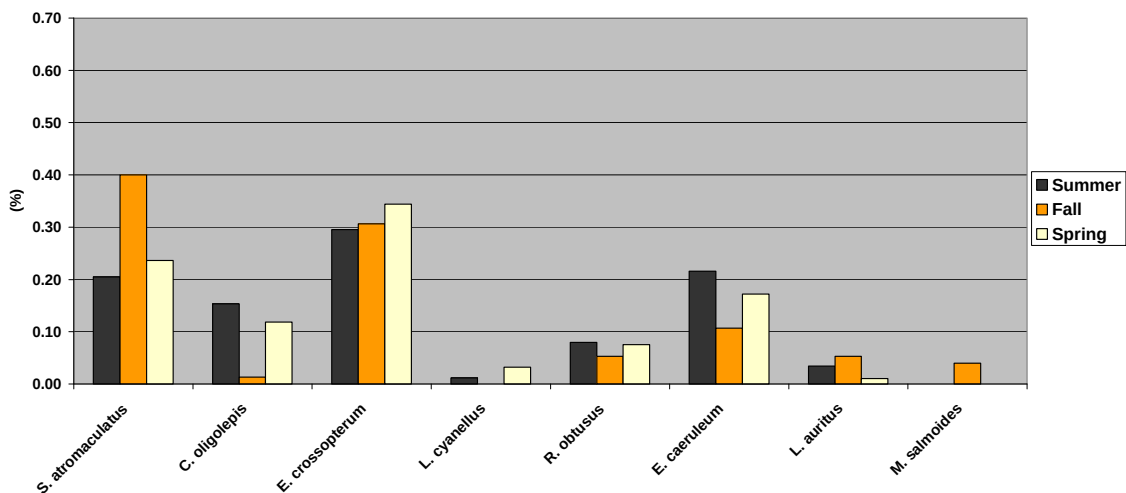


Figure 23. Seasonal variation in relative abundance of dominant fish collected in Indian Creek (FODO) from Summer 2005 to Spring 2006.

Table 11. Abundance, species richness, and species diversity of Indian Creek (FODO) for Summer/Fall 2005 and Spring 2006.

<u>Species</u>	<u>Common Name</u>	<u>Summer</u>	<u>Fall</u>	<u>Spring</u>
		#	#	#
<i>Campostoma oligolepis</i>	Largescale stoneroller	27	1	11
<i>Rhinichthys obtusus</i>	Western blacknose dace	14	4	7
<i>Semotilus atromaculatus</i>	Creek chub	36	30	22
<i>Ameiurus natalis</i>	Yellow bullhead	1	0	1
<i>Gambusia affinis</i>	Mosquitofish	0	1	0
<i>Lepomis auritus</i>	Redbreast sunfish	6	4	1
<i>Lepomis cyanellus</i>	Green sunfish	2	0	3
<i>Micropterus salmoides</i>	Largemouth bass	0	3	0
<i>Etheostoma caeruleum</i>	Rainbow darter	38	8	16
<i>Etheostoma crossopterum</i>	Fringed darter	52	23	32
<i>Etheostoma flavum</i>	Saffron darter	0	1	0
Total		176	75	93
Species Richness		8	9	8
Species Diversity		1.67	1.54	1.66

The physical parameters of Indian Creek fluctuated greatly from season to season. Stream discharge ranged from no flow (temporary pools) to 3.0 cfs across the seasons, with lowest flows during the fall. During the fall season, the stream reach sampled was almost dry with only a few pools remaining for fish refuge. Temperatures ranged from 16.0 to 18.8 C with highest temperatures occurring during the fall. Dissolved oxygen levels stayed relatively stable (6.4 to 7.4 mg/L) across the seasons, probably due to the influx of groundwater. Conductivity ranged from 249.8 to 299.6 μ S, with highest levels occurring in the fall. pH levels stayed relatively the same across all seasons ranging from 7.1 to 8.2 (Table 12).

Table 12. Temperature (C), dissolved oxygen (mg/L), conductivity ($\mu\text{S}/\text{cm}$), pH (su), and discharge (ft^3/sec) of Indian Creek (FODO) for Summer/Fall 2005 and Spring 2006.

	<u>Summer</u>	<u>Fall</u>	<u>Spring</u>
Temperature (C)	16.7	18.8	16.0
DO (mg/L)	6.4	7.3	7.4
Conductivity ($\mu\text{S}/\text{cm}$)	282.2	299.6	249.8
pH (su)	7.1	8.2	7.7
Discharge (ft^3/sec)	3.0	0.0	1.0

Abe Lincoln Birthplace National Historic Site (KY)

Knob Creek

In Knob Creek, the fish assemblage for all sites and seasons combined was dominated by creek chub, western blacknose dace, central stoneroller, and fantail darter (Figure 24). Assemblage structure did change across seasons. The summer fish assemblage was dominated by fantail darter, western blacknose dace, and creek chub. The fall fish assemblage was dominated by creek chub, western blacknose dace, and central stoneroller. The spring fish assemblage was dominated by central stoneroller, creek chub, and orangethroat darter. Total abundance was highest during the spring and lowest during the fall. Species richness was highest in the spring and lowest in the summer and fall. Species diversity was highest in the spring and stayed approximately the same for summer and fall samples (Table 13).

The physical parameters of Knob Creek fluctuated greatly from season to season. Stream discharge ranged from no flow (temporary pools) to 8.0 cfs across the seasons, with lowest flows occurring during the fall. The stream reach sampled was close to being completely dry during the fall with only a few pools remaining for fish refuge.

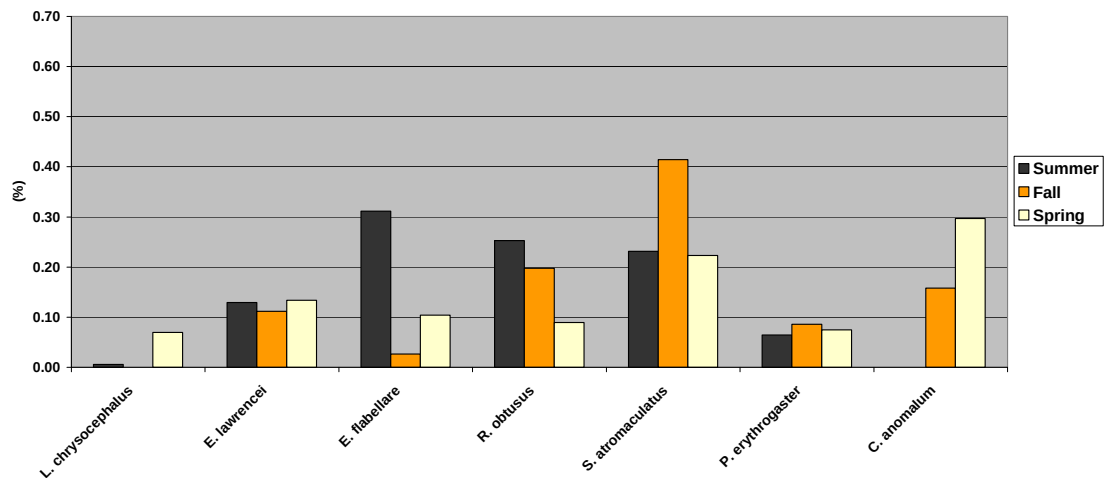


Figure 24. Seasonal variation in relative abundance of dominant fish collected in Knob Creek (ABLI) from Summer 2005 to Spring 2006.

Table 13. Abundance, species richness, and species diversity of Knob Creek (ABLI) for Summer/Fall 2005 and Spring 2006.

<u>Species</u>	<u>Common Name</u>	<u>Summer</u> #	<u>Fall</u> #	<u>Spring</u> #
<i>Campostoma anomalum</i>	Central stoneroller	0	24	60
<i>Luxilus chrysocephalus</i>	Striped shiner	1	0	14
<i>Lythrurus ardens</i>	Rosefin shiner	0	0	1
<i>Rhinichthys obtusus</i>	Western blacknose dace	47	30	18
<i>Phoxinus erythrogaster</i>	Southern redbelly dace	12	13	15
<i>Pimephales notatus</i>	Bluntnose minnow	1	0	2
<i>Semotilus atromaculatus</i>	Creek chub	43	63	45
<i>Fundulus catenatus</i>	Northern studfish	0	1	0
<i>Etheostoma lawrencei</i>	Orangethroat darter	24	17	27
<i>Etheostoma flabellare</i>	Fantail darter	58	4	21
Totals		186	152	203
Species Richness		7	7	9
Species Diversity		1.57	1.59	1.82

Table 14. Temperature (C), dissolved oxygen (mg/L), conductivity ($\mu\text{S}/\text{cm}$), pH (su), and discharge (ft^3/sec) of Knob Creek (ABLI) for Summer/Fall 2005 and Spring 2006.

	<u>Summer</u>	<u>Fall</u>	<u>Spring</u>
Temperature (C)	16.8	11.6	14.9
DO (mg/L)	4.7	6.2	8.1
Conductivity ($\mu\text{S}/\text{cm}$)	352.3	375.5	197.9
pH (su)	7.5	n/a	n/a
Discharge (ft^3/sec)	3.0	0.0	8.0

Temperatures ranged from 11.6 to 16.80 C with highest temperatures occurring during the summer. Dissolved oxygen levels ranged from 4.7 to 8.1 mg/L with lowest levels occurring in the summer. Conductivity ranged from 197.9 to 375.5 μS with highest levels occurring in the fall. pH levels could not be taken due to equipment failure during the fall and spring season (Table 14).

Russell Cave National Monument (AL)

Entrance Spring

In Russell Cave entrance spring, the fish assemblage for all seasons combined was dominated by banded sculpin (Figure 25). The assemblage structure did not change across seasons. Total abundance was highest during the summer and lowest during the spring and fall. Species richness and diversity stayed relatively the same across all seasons (Table 15).

Figure 25. Seasonal variation in relative abundance of dominant fish collected in Russell Cave Entrance Spring (RUCA) from Summer 2005 to Spring 2006.

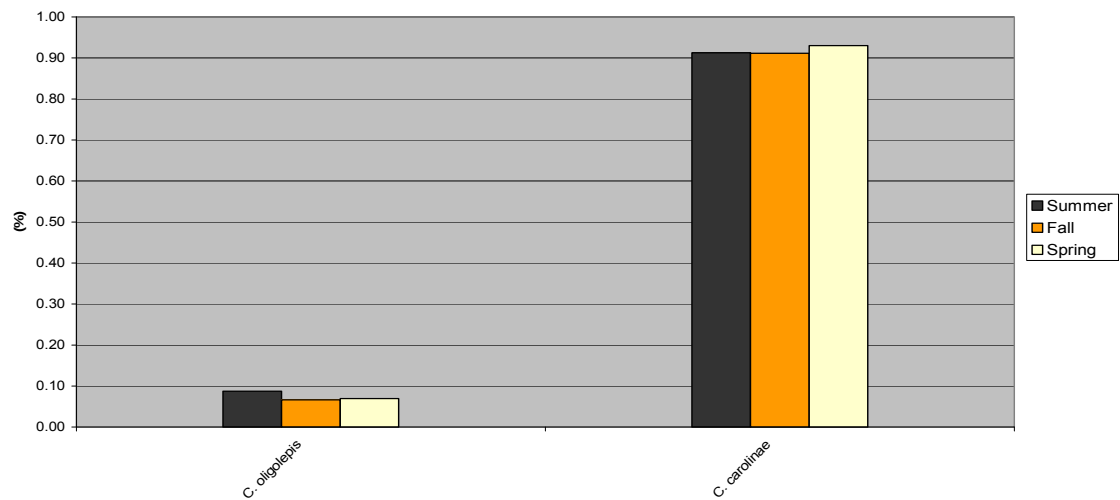


Table 15. Abundance, species richness, and species diversity of Russell Cave Entrance Spring (RUCA) for Summer/Fall 2005 and Spring 2006.

<u>Species</u>	<u>Common Name</u>	<u>Summer</u>	<u>Fall</u>	<u>Spring</u>
		#	#	#
<i>Campostoma oligolepis</i>	Largescale stoneroller	5	3	3
<i>Rhinichthys obtusus</i>	Western blacknose dace	0	1	0
<i>Cottus caroliniae</i>	Banded sculpin	52	41	40
Total		57	45	43
Species Richness		2	3	3
Species Diversity		0.30	0.35	0.25

Table 16. Temperature (C), dissolved oxygen (mg/L), conductivity ($\mu\text{S}/\text{cm}$), pH (su), and discharge (ft^3/sec) of Russell Cave Entrance Spring (RUCA) for Summer/Fall 2005 and Spring 2006.

	<u>Summer</u>	<u>Fall</u>	<u>Spring</u>
Temperature (C)	13.7	13.3	14.1
DO (mg/L)	8.0	6.1	9.1
Conductivity ($\mu\text{S}/\text{cm}$)	154.5	207.2	199.1
pH (su)	7.1	n/a	8.1
Discharge (ft^3/sec)	4.0	1.0	3.0

The physical parameters of Russell Cave entrance spring stayed relatively stable, except for stream discharge. Stream discharge ranged from 1.0 to 4.0 cfs across the seasons, with lowest flows during the fall. Temperatures stayed relatively stable, ranging from 13.7 to 14.1 C with highest temperatures occurring during the spring. Dissolved oxygen levels stayed relatively stable across the seasons, ranging from 6.1 to 9.1 mg/L with lowest levels occurring in the fall. Conductivity ranged from 154.5 to 207.2 μS with highest levels occurring in the fall. pH levels stayed relatively the same across all seasons ranging from 7.1 to 8.14 (Table 16). pH levels were not recorded during the fall due to equipment failure.

Cave Pools

One banded sculpin, *Cottus carolinae*, was collected from Pool #1 in fall 2005. No fish were collected from Pools #2-6. In summer 2006, no fish were collected from pools #2-6. Pool #7 was not accessible (Figures 26 and 27). It should be noted that many crayfish were collected in the minnow traps during both sampling trips (fall 2005 and summer 2006). Crayfish, salamanders, and sculpins were observed during bankside observations.



Figure 26. Joyce Coombs trying to access pool #7 (RUCA).



Figure 27. Wes Selecman trying to access pool #7 (RUCA).

CHAPTER VI-DISCUSSION

Chickamauga and Chattanooga National Military Park (TN)

Black Branch

The variation in fish assemblages and water quality in Black Branch was due to the seasonal changes in stream discharge. Flow ceased in the fall and temporary pools with large aggregations of fish were formed (Figure 28). The lack of canopy cover and flow resulted in increased conductivity and water temperatures and decreased dissolved oxygen levels in the fall (Table 2). In an Oklahoma prairie stream, Spranza and Stanley (2000) found increases in temperature, turbidity, and conductivity as flows declined and isolated pools were formed. In the variable stream reach they studied, the highest readings of temperature, conductivity, and turbidity were recorded in August and September when isolated pools were present.



Figure 28. Temporary pools of Black Branch (CHCH)-Fall 2005.

As a direct result of intermittency, increased temperatures, and decreased dissolved oxygen in Black Branch, species diversity decreased from summer to fall. The lower diversity resulted from an increase in largescale stoneroller and striped shiner, while bluntnose minnow and centrarchid populations decreased (Figure 18). In a small Illinois stream, Schlosser (1985), found both bluntnose minnow and striped shiner juvenile and adult abundance to increase during low flow periods. At the same time, decreases in juvenile abundance of several centrarchid species were seen. In the present study, competition from a large population of largescale stoneroller, striped shiner, and mosquitofish could have resulted in the lower abundance of bluntnose minnow.

In Black Branch, flow increased to 10.0 cfs from fall to spring. The higher flows brought back the riffle to pool habitat sequence along with higher dissolved oxygen levels and lower water temperatures as compared to fall. As a direct result, species diversity and abundance increased from fall to spring. Abundance levels were highest in the spring season. This was due to immigration of fishes for spawning purposes and greater habitat availability from higher flows. Abundance increases were found in largescale stoneroller, bluntnose minnow, white sucker, redbreast sunfish, green sunfish, and snubnose darter (Table 1).

Jays Mill Creek

The variation in fish assemblages and water quality in Jays Mill Creek was due to the seasonal changes in stream discharge. Flow ceased in the fall and the stream was almost completely dry except for a few pools that contained large aggregations of fish (Figure 29 and 30). The lack of flow resulted in increased water temperatures and



Figure 29. Intermittent conditions of Jays Mill Creek (CHCH)-Fall 2005.



Figure 30. One of the few temporary pools in Jays Mill Creek (CHCH)-Fall 2005.

decreased dissolved oxygen levels in the fall (Table 4). As a direct result, species diversity decreased from summer to fall. The large relative abundance of centrarchids caused the lower diversity values in fall. In a small second order Illinois stream, Schlosser (1987) found a significant decrease in minnow abundance associated with increased presences of sunfish and suckers. The shift in the fish assemblage caused a shift in trophic structure from generalized insectivores to insectivores/piscivores and benthic insectivores. When confined to pools, predatory species, such as centrarchids, can out-compete and exclude smaller species (cyprinids) from the areas (Spranza and Stanley 2000).

In Jays Mill Creek, flow increased to 5.0 cfs from fall to spring. The higher flows brought back the riffle to pool habitat sequence along with higher dissolved oxygen levels as compared to fall. As a direct result, species diversity increased from fall to spring. Interestingly, abundance levels were highest in the fall season. This was due to an increase in mosquitofish, a tolerant fish species, and the intense congregation of fish due to the lack of available pools for refuge. In the reach sampled, only one large available pool remained in Jays Mill Creek during the fall. Due to their great parental care, internal fertilization, tolerance to high temperatures, and low dissolved oxygen levels, mosquitofish are extremely successful (Etnier and Starnes 1993). This can be detrimental to smaller fish species of intermittent streams during harsh environmental periods. Species diversity levels did increase in the spring with higher flows, but abundance was lower than the past fall season (Table 3). Due to the extreme lack of water during the fall, recolonization rates were slower than streams with more available pools for refuge during low flow seasons. An influx of two cyprinid species, bluntnose

minnow and striped shiner, resulted in higher diversity values for the spring season. In colonizing communities, such as Jays Mill Creek, the bluntnose minnow and striped shiner tend to predominate due to their “prolonged breeding season, rapid maturity, high reproductive rates, and strong dispersal capability of young” (Schlosser 1987).

Glenn Viniard Creek

The lack of variation in fish assemblages in Glenn Viniard Creek was due to the available habitat across all seasons. Although flow varied across seasons, the pool within the sampled reach was large with available cover from undercut banks. Flow ceased during the fall while abundance and richness stayed relatively the same as compared to the summer. Species diversity decreased from summer to fall, due to the lack of flow. The lower diversity values resulted from a decrease in snubnose darter, warmouth, green sunfish, and largemouth bass (Table 5). Furthermore, the lack of flow resulted in decreased dissolved oxygen levels in the fall (Table 6).

From fall to spring, flow slightly increased to 3.0 cfs. Although flow increased, the habitat diversity remained low and water temperatures continued to increase as compared to fall. Surprisingly, species richness, diversity, and abundance decreased as compared to the fall season (Table 5). Within the stream reach sampled, there was no riffle to pool sequence. The degraded/channelized stream channel and erosive banks have caused little habitat delineation (Figure 6). “Channelization creates unfavorable stream habitat; the resulting uniform channel lacks pools, riffles, and boulders or log jams that are essential for sustaining fish abundance” (Orth and White 1999). The large pool was suitable for and dominated by centrarchid species resulting in low diversity levels.

The lack of riffles excluded the presence of obligate riverine species, such as darters and various cyprinid species.

Cave Spring

The variation in fish assemblages and water quality in Cave Spring was due to the seasonal changes in stream discharge. Flow ceased in the fall and the stream was almost completely dry except for a few pools that contained large aggregations of fish (Figure 31). The large canopy cover and water source kept water temperatures relatively stable across the seasons. The lack of flow and underground water source resulted in the lowest dissolved oxygen levels of all streams sampled and increased conductivity in the fall (Table 8). Larimore et al. (1959, cited in Schlosser 1990) found insufficient oxygen levels in intermittent streams with leaf decomposition and high temperatures. Interestingly, in Cave Spring, species richness and abundance stayed relatively stable, while species diversity increased from summer to fall (Table 7). During spring and



Figure 31. Intermittent conditions of Cave Spring (CHCH)-Fall 2005.

summer, Cave Spring was dominated by only two fish species, banded sculpin and western blacknose dace (Figure 21), resulting in lower diversity values. During the fall, banded sculpin populations decreased and increased numbers of other fishes resulted in a higher diversity value.

From fall to spring, flow increased to 2.91 cfs. The higher flow brought back the riffle to pool habitat sequence along with higher dissolved oxygen levels and lower conductivity levels as compared to fall (Table 8). As a direct result, the dominant banded sculpin population increased resulting in a decrease in species diversity. Species richness also decreased, indicating that recolonization took longer as compared to a stream reach that has more available habitat during low flow seasons. If possible, fishes must emigrate further when the rate of dewatering is highest, causing further distances to immigrate when flows resume. Horwitz (1978) found lower longitudinal replacement rates in variable upstream sections of rivers as compared more stable downstream areas.

Skyuka Spring

The variation in fish assemblages and water quality in Skyuka Spring was due to the seasonal changes in stream discharge. Flow decreased in the fall, but a riffle to pool habitat structure was still available. The large canopy cover, groundwater source, and constant flow kept water temperatures and dissolved oxygen levels relatively stable across the seasons. Interestingly, species richness and abundance stayed relatively stable, while species diversity increased from summer to fall (Table 9). During the summer, Skyuka Spring was dominated by banded sculpin, resulting in lower diversity values.

Similar to Cave Spring, during the fall, banded sculpin populations decreased and abundance of other fishes resulted in a higher diversity value.

From fall to spring, flow increased and conductivity levels decreased as compared to the fall (Table 10). As a direct result, the banded sculpin population increased, but species diversity stayed similar to the fall season. Abundance also increased as compared to the fall (Table 9). This was due to the immigration of other cyprinid fish species in the spring for spawning purposes. The cyprinid species collected were largescale stoneroller, striped shiner, warpaint shiner, and creek chub. Skyuka Spring's substrate was dominated by clean small gravel, which is utilized by many cyprinid fish species for spawning purposes. The warpaint shiner (*Luxilus coccogenis*) was a unique fish species with a relatively small distribution collected in Skyuka Spring.

Fort Donelson National Battlefield (TN)

Indian Creek

The variation in fish assemblages and water quality in Indian Creek was due to the seasonal changes in stream discharge. Flow decreased in the fall, but a riffle to pool habitat structure was still available. The lack of flow resulted in a slight increase in water temperatures in the fall. As a direct result, species diversity and abundance decreased from summer to fall. All fishes showed a decrease in abundance, with the largest decreases appearing in largescale stoneroller, rainbow darter, and western blacknose dace (Table 11). This differs from Cave Spring and Black Branch, where an increase in abundance of western blacknose dace was seen (Table 7 and Table 1). This was due to the lack of available pools in Indian Creek and competition/predation from the dominant

creek chub. The large mouth of creek chubs allows them to feed on a variety of organisms that other cyprinids can not utilize. "Creek chubs are voracious predators, consuming small fish, crayfish, and other large invertebrates" (Etnier and Starnes 1993). Despite the decreases, higher relative abundance of creek chubs and fringed darters showed dominance across the seasons (Figure 23). Studies have shown the large tolerance of other *Catnotus* species similar to the fringed darter. In a laboratory study, fantail and rainbow darters were found to be more adaptable to temperature variation than the greenside darter. The fantail darter also showed the widest temperature tolerance across all seasons as compared to the other species (Hlohowskyj and Wissing 1987).

From fall to spring, flows increased slightly to 1.0 cfs. The higher flows brought back lower water temperatures as compared to fall (Table 12). As a direct result, species diversity and abundance increased from fall to spring. Interestingly, abundance levels were highest in the summer season (Table 11). The summer season resulted in the highest flows as compared to fall and spring. Higher flows yielded more habitat availability in the form of riffles, pools, and undercut banks of the small stream. The saffron darter (*Etheostoma flavum*) and fringed darter (*E. crossopterygion*) were two unique fish species with relatively small distributions collected in Indian Creek.

Abe Lincoln Birthplace National Historic Site (KY)

Knob Creek

The variation in fish assemblages and water quality in Knob Creek was due to the seasonal changes in stream discharge. During the summer, flow was very low and best



Figure 32. Temporary pools of Knob Creek (ABLI)-Fall 2005.

available habitat was in the pool areas. Flow ceased in the fall and temporary pools with large aggregations of fish were formed (Figure 32). As a direct result of flow, species abundance decreased from summer to fall, while species diversity and richness stayed relatively stable. Abundance decreases were seen in orangethroat darter, fantail darter, and western blacknose dace, while increases were seen in central stoneroller and creek chub (Table 13).

From fall to spring, flow increased to 8.0 cfs. The higher flow brought back the riffle to pool habitat sequence. As a direct result, species richness, diversity, and abundance increased from fall to spring. Species richness, diversity, and abundance levels were highest in the spring season (Table 13). This was due to immigration of fishes for spawning purposes and increased habitat availability from higher flows. Along with increased abundance in dominant fish species, an influx in cyprinids and an increase in darter abundance was noticed.

Russell Cave National Monument (AL)

Russell Cave Entrance Spring

The lack of variation in fish assemblages in Russell Cave Entrance Spring was due to the stable habitat across all seasons and the isolated stream reach. The source of water comes out of the ground approximately 150 m from Russell Cave entrance. Although flow varied across seasons, the stream reach maintained riffle to pool habitat availability. Species abundance, richness, and diversity remained relatively stable across all seasons (Table 15). The low diversity value was due to the presence of only two to three species and the large dominance of banded sculpin (Figure 25). The collection of banded sculpin in Russell Cave supports past research completed by Hobbs III (1994). Interestingly, in the present study, a small population of largescale stonerollers and one western blacknose dace was found which was not collected in past research (Table 15). These are considered incidental species because the isolated stream reach does not allow for immigration/emigration of fish from other tributaries. Hobbs III (1994) found bluegill in Russell Cave, an “accidental epigeal sunfish that is washed occasionally into caves”. The topography and weather patterns of Russell Cave result in huge flash floods that fill the cave from floor to ceiling (Figure 33 and 34). The floods will wash in new fish species that would not normally be found. The lack of cave formations and constantly changing corridors supports the occurrence of floods in Russell Cave.

Cave Pools

The collection of banded sculpin in cave pools of Russell Cave is similar to past research completed by Hobbs (1994). In the present study, the lack of cavefish



Figure 33. Flash flood at Russell Cave. Picture provided by Shelia Reed of Russell Cave National Monument (February 2004).



Figure 34. Normal flows of entrance spring to Russell Cave at Russell Cave National Monument-Summer 2005

collected or observed in cave pools of Russell Cave also supports past research. Hobbs (1994) assessed all ecological resources in Russell Cave. He was able to sample beyond park boundaries, therefore, he sampled more cave pools than the present study. He observed only one southern cavefish, *Typhlichthys subterraneus*, in a deep pool (Pool #3, Figure 15) between the Picnic and Canoe entrances throughout the entire research study. As stated earlier, the cavefishes are extremely difficult to sample due to their keen sense of vibration and light. The multiple openings along cave pool floors, which allow for habitat and cover when disturbed, add to the difficulty of sampling and gaining adequate population estimates (Bernard Kuhajda, University of Alabama, personal communication).

CHAPTER VII-SUMMARY

“Fishes of upstream areas experience greater temporal variability in physical and chemical conditions than downstream areas, especially in intermittent streams” (Schlosser 1990). This was seen in the majority of the streams of Chickamauga and Chattanooga National Military Park (TN), Fort Donelson National Battlefield (TN), and Abe Lincoln Birthplace National Historic Site (KY).

From summer to fall, the majority of the streams studied decreased in flow until temporary pools were formed (Figure 31). The lack of flow caused increased temperatures, decreased dissolved oxygen, and increased conductivity levels. As a direct result, overall fish abundance and diversity values decreased. *Etheostoma*, *Cottus*, and *Lepomis* species commonly showed decreased relative abundance from summer to fall (Figure 35). Some fish species like creek chub, striped shiner, mosquitofish, and western blacknose dace commonly showed increased relative abundance from summer to fall. Seasonal trends in species richness were variable across all streams sampled. Severity of intermittency and competition were crucial factors affecting richness values across seasons. This differs from Schlosser (1987) who found lower species richness and density



Figure 35. *Etheostoma*, *Cottus*, and *Lepomis* species. From left to right: rainbow darter, banded sculpin, and redbreast sunfish.

in late winter or early spring and increased species richness and density in summer and autumn in variable streams. This could be due to the duration and magnitude of drought. Longer periods of harsh drought could result in a loss of non-dominant fish species.

The fish species that establish dominance during intermittent periods are physiologically adapted for such conditions. Many ancestral soft rayed teleosts (e.g., salmonids, cyprinids, catfishes, livebearers) are physostomous fishes (Figure 36). Physostomous fishes have a connection between the swimbladder and gut, allowing them to breathe by gulping air at the air/water interface. Other fish species that are not physiologically adapted to intermittent periods tend to be physoclistous fishes. This includes most spiny-rayed teleosts (e.g., sculpins, sunfishes, perches). Physoclistous fishes lack the connection between the swimbladder and gut, thus hindering use of the oxygen-rich air/water interface (Moyle and Cech 1988).

From fall to spring, all the streams studied increased in flow, which brought back a riffle to pool habitat sequences (Figure 37). The increased flow caused more favorable conditions and greater habitat selection for fishes. Dissolved oxygen levels increased,



Figure 36. Physostomous fishes that are tolerant of intermittent stream conditions. From left to right: creek chub, western blacknose dace, and mosquitofish.



Figure 37. Riffle to pool habitat sequence of Knob Creek (ABLI) in Spring 2005.

conductivity levels decreased, and temperatures became more stable. As a result, overall fish abundance and diversity values increased. Creek chub, mosquitofish, and western blacknose dace relative abundance's decreased as other fish species, mostly cyprinids, darters, and centrarchids, began to recolonize the once dry stream reaches.

Recolonization rates varied among creeks based on the magnitude of drought during the previous season in the sampled reaches. Creeks with more available pools for refuge during the fall, such as Black Branch, Skyuka Spring, and Knob Creek, showed larger increases in abundance and/or richness of fishes the following spring as (Figure 31), such as Cave Spring and Jays Mill Creek, showed lower abundance and/or richness in the spring as compared to the fall. Horwitz (1978) found that “longitudinal compared to the fall. Creeks that were close to completely dewatering during the fall replacement

rates of fishes were very low in all rivers studied, but were generally larger in the most temporally constant rivers”.

The need for information on variability in fish assemblages is crucial to determine whether water quality and habitat changes are due to natural or anthropogenic disturbances (Schlosser 1990). The variability in physical factors, chemical factors, and fish assemblages of the streams studied shows that they should not be overlooked or excluded from management plans in the parks. Furthermore, the fishes that successfully occupy variable stream reaches are adapted for such conditions. Spranza and Stanley (2000) found that growth and condition factors of juvenile fishes was adequate proof that the upper intermittent segment of the Wild Hog Creek Drainage, Oklahoma, produced robust individuals and rapid juvenile growth. Therefore, the consistency of assemblages during low flow periods proves that intermittent streams should not be considered harsh environments for resident fish species (Meador and Matthews 1992).

The general public may view the small streams studied as “biological deserts”, especially during intermittent periods. However, results show that multiple fish species utilize these streams year round. Park visitors should be informed of this research to increase public awareness of small stream ecosystems and spark interests in biological and environmental issues.

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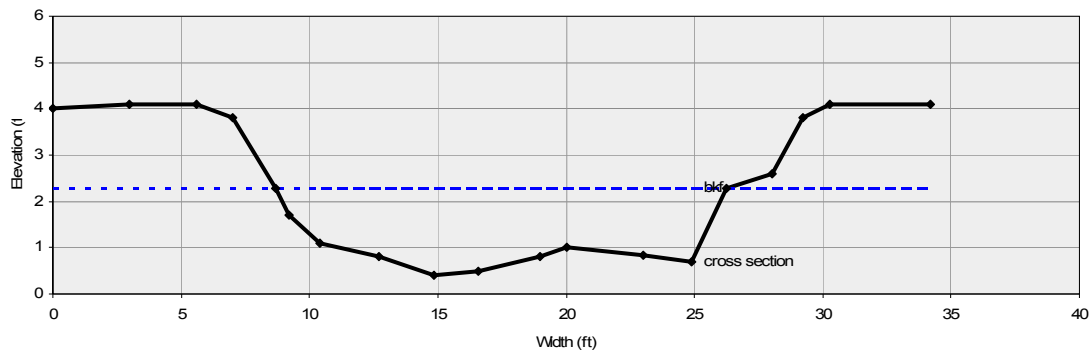
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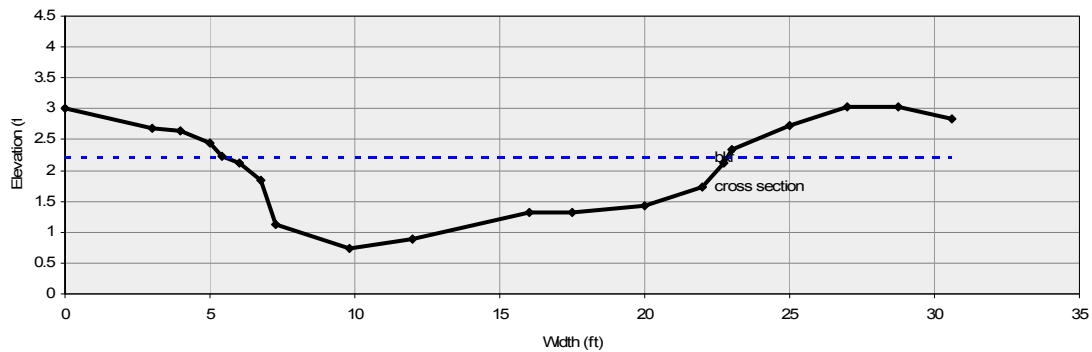
APPENDICES

Appendix A. Cross section profiles for streams in Chickamauga and Chattanooga National Military Park (TN), Fort Donelson National Battlefield (TN), Abe Lincoln Birthplace National Historic Site (KY), and Russell Cave National Monument (AL) 2006. All profiles were surveyed in riffle habitats facing downstream.

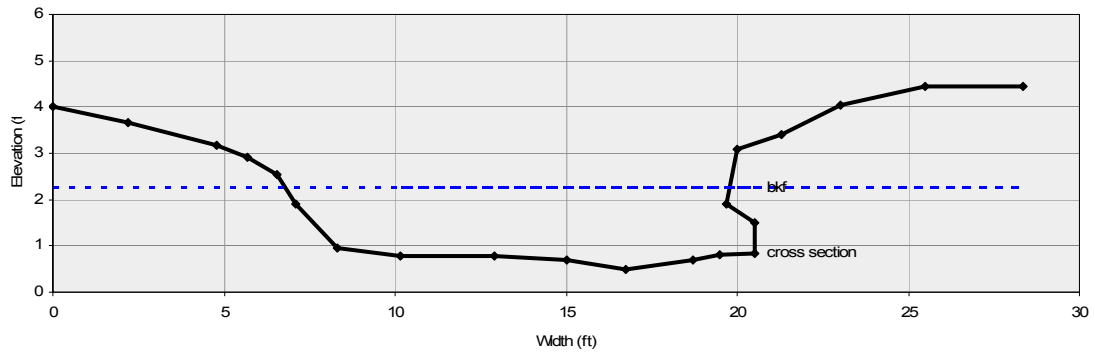
Chickamauga and Chattanooga National Military Park (TN)



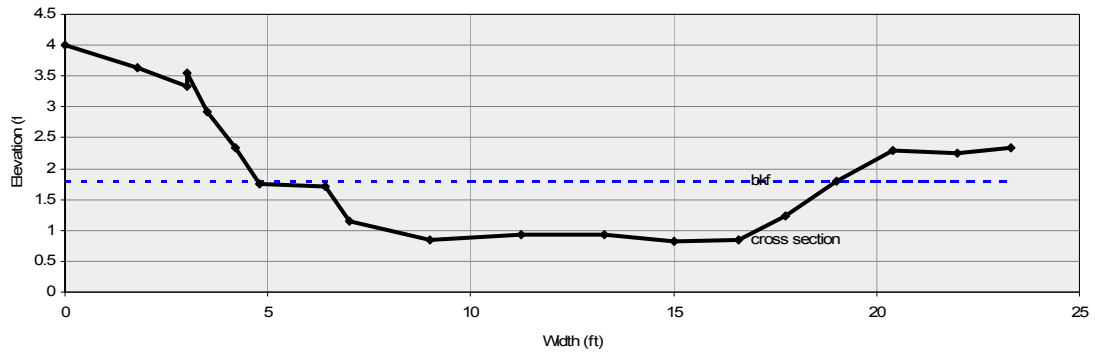
Appendix A.1. Cross section profile of Black Branch (CHCH).



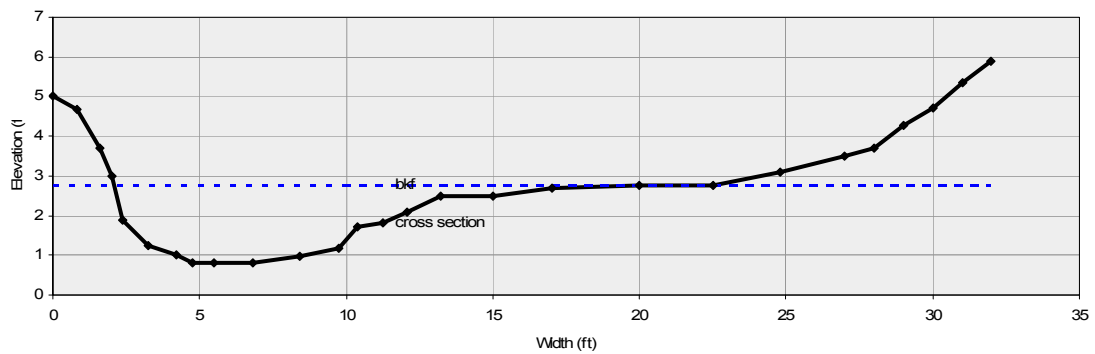
Appendix A.2. Cross section profile of Jays Mill Creek (CHCH).



Appendix A.3. Cross section profile of Glenn Viniard Creek (CHCH).

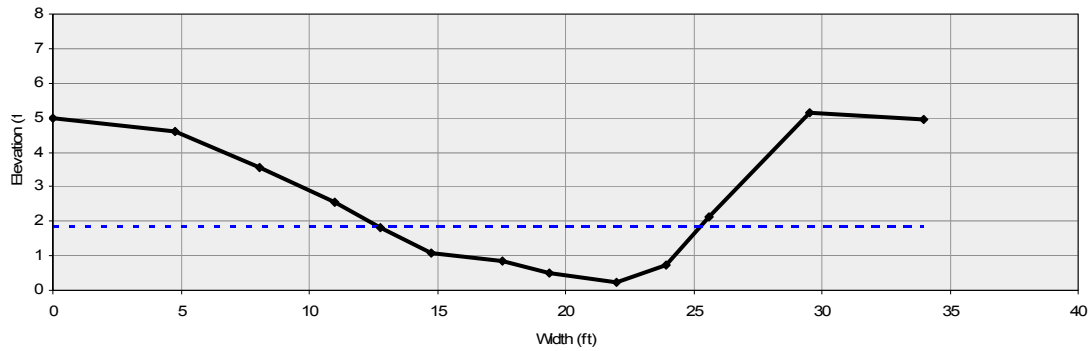


Appendix A.4. Cross section profile of Cave Spring (CHCH).



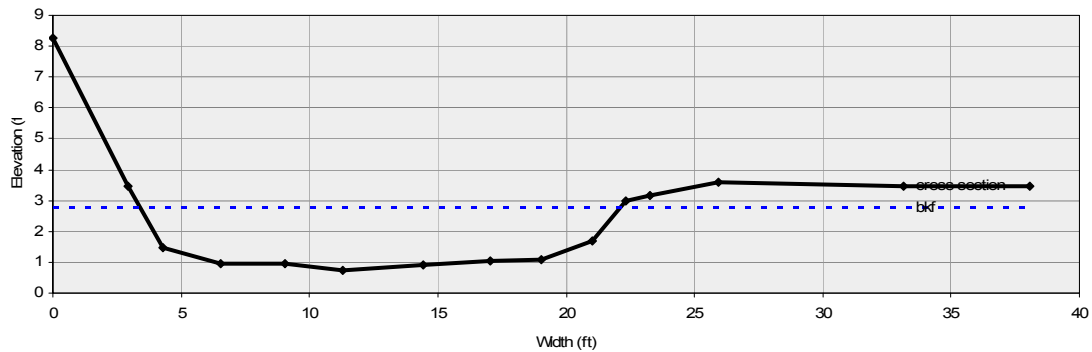
Appendix A.5. Cross section profile of Skyuka Spring (CHCH).

Fort Donelson National Battlefield (TN)



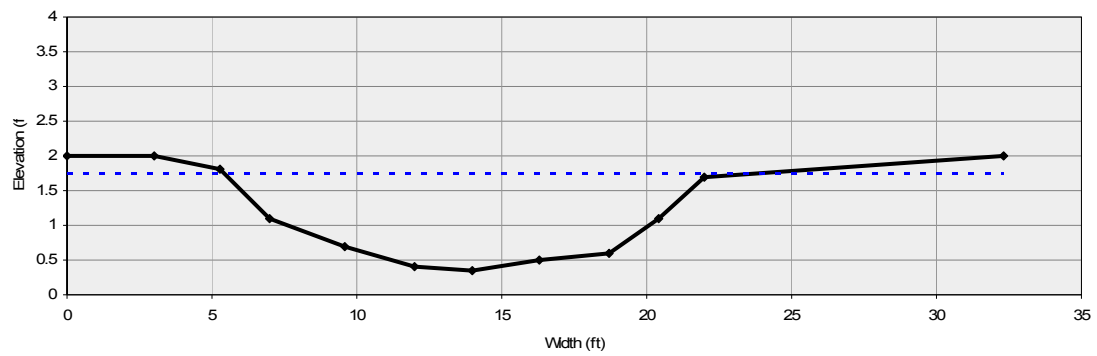
Appendix A.6. Cross section profile of Indian Creek (FODO).

Abe Lincoln Birthplace National Historic Site (KY)



Appendix A.7. Cross section profile of Knob Creek (ABLI).

Russell Cave National Monument (AL)



Appendix A.8. Cross section profile of Russell Cave Entrance Spring (RUCA).

Appendix B. GPS coordinates (accuracy <15.0 m) of general localities at sites sampled in Chickamauga and Chattanooga National Military Park (TN), Fort Donelson National Battlefield (TN), Abe Lincoln Birthplace National Historic Site (KY), and Russell Cave National Monument (AL) 2006.

<u>Park/Stream Site</u>	<u>GPS Coordinates</u>
Chickamauga and Chattanooga National Military Park	
Black Branch	N 34 56.336' / W 85 15.574'
Jays Mill Creek	N 34 54.941' / W 85 14.022'
Glenn Viniard Creek	N 34 54.073' / W 85.15.700'
Cave Spring	N 34 54.172' / W 85 16.314'
Skyuka Spring	N 34 58.221' / W 85 23.333'
Fort Donelson National Battlefield	
Indian Creek	N 36 28.937' / W 87 51.281'
Abe Lincoln Birthplace Nat. Historic Site	
Knob Creek	N 37 36.730' / W 85 38.277'
	N 37 36.837' / W 85 38.651'
	N 37 36.948' / W 85 38.797'
Russell Cave National Monument	
Entrance Spring	N 34 58.376' / W 85 48.339'

75

75

VITA

Joseph Carl Zimmerman was born January 31, 1982, and raised in Crossville, Tennessee. As a graduate in the top 10 % of his class from Cumberland County High School, he received a full academic scholarship to Roane State Community College. He graduated in May 2002 with an Associates degree in Wildlife and Fisheries Science. Wanting to pursue a degree in fisheries science, he attended Tennessee Technological University on full academic scholarship. He graduated in August 2004 with a B.S. degree in Fisheries Science.

Upon graduation, Mr. Zimmerman married his best friend, the former Hillary Ann Touton, in July 2004. Wanting to pursue an advanced degree in fisheries science, he then began study towards a Master of Science degree at the University of Tennessee, Knoxville. He received the advanced degree in May 2007.

The author will continue studying and working as a Fisheries Biologist II with a specialization in stream restoration for the Kentucky Department of Fish and Wildlife Resources.