To the Graduate Council:

I am submitting herewith a thesis written by Erin Elizabeth Schiding entitled "Survival and reproduction of re-introduced species of selected darters and shiners in Coal Creek, TN." 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:

Lisa Muller

Jonathon Burr

Accepted for the Council:

Carolyn R. Hodges
Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

SURVIVAL AND REPRODUCTION OF RE-INTRODUCED SPECIES OF SELECTED DARTERS AND SHINERS IN COAL CREEK, TN.

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Erin Elizabeth Schiding
May 2009

Dedication

This thesis is dedicated to my family for always supporting and encouraging my education and goals; to my husband for all his love, support, and patience; and to my advisor, who has guided me with patience through years of research.

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I wish to express my gratitude to the University of Tennessee’s Department of Forestry, Wildlife and Fisheries for funding my research assistantship and for supporting this project. Thank you to the Tennessee Wildlife Resources Agency for additional funding.

Abstract

Coal Creek and its tributaries have historically suffered the effects of run-off from coal strip mining. Mining activity has ceased in the Coal Creek watershed and recovery in the stream was documented in 2004 when ecological indices based on fish and aquatic invertebrate samples from Coal Creek increased significantly. Although the Coal Creek watershed continues to support most of its native fish species, several common species are still missing and have been targeted for re-introduction. The species selected for initial re-introduction were the rainbow darter (*Etheostoma caeruleum*), Tennessee shiner (*Notropis leuciodes*), warpaint shiner (*Luxilus coccogenis*), and telescope shiner (*N. telescopus*). Other species that were collected opportunistically and re-introduced were the fantail darter (*E. flabellare*) and whitetail shiner (*Cyprinella galactura*).

All fish were collected from two area streams, Indian Creek and Cove Creek, with similar habitat within the Clinch River drainage. From February 2007 through May 2008, two fantail darters, 509 rainbow darters, 308 Tennessee shiners, 247 warpaint shiners, 494 telescope shiners, and 47 whitetail shiners were released at six locations in Coal Creek. Rainbow darters were batch tagged with two colors of visible implant elastomer (VIE) before release at one or more of six re-introduction sites to assess the survival and reproduction of the relocated darter species.

Four monitoring surveys, which were conducted late summer through late fall and which used seining, electroshocking, or a combination of the two methods, revealed representatives of three out of four re-introduced species. Surveys extended both upstream and downstream of all original sites to locate fish which may have moved from

the immediate re-introduction site. Surveys were conducted in suitable habitat, and continued for three consecutive seine hauls or kick seines until no new species were collected. Five tagged rainbow darters, three untagged (second year) darters, and two young of the year darters were documented during kick seining and electroshocking efforts. Six young of the year telescope shiners were collected upstream of the Joe E. Day Bridge and 10 warpaint shiners were seined from small pools.

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CHAPTER 1

Introduction

Coal Creek is a third order stream with a drainage area of approximately 93 km^2 and is a tributary of the Clinch River in East Tennessee. The headwaters originate in Anderson County, TN, and flow north into the Clinch River (Figure 1). The Coal Creek watershed has a rich, local history which has contributed to the recreational and aesthetic values of the three surrounding areas of Briceville, Fratersville, and Lake City. Coal Creek also supports a small stream fishery and a spring spawning run by Clinch River rainbow trout (*Oncorhynchus mykiss*). Prior to the Surface Mining Control and Reclamation Act (SMCRA) of 1977 (Office of Surface Mining Reclamation and Enforcement 1993), pollution from coal mining drained into Coal Creek, which caused the elimination of many native species.

Run-off from abandoned mine sites and mine seepage into a creek causes an increase in acidity, which is deadly to fish (Sams and Beer 2000). Following the establishment of the SMCRA in 1977, restoration of Coal Creek to pre-mining conditions was needed. Fortunately, the recent reclamation of abandoned mine sites along with the geology of Coal Creek have helped to mitigate these damaging effects. The geology of Coal Creek consists of limestone rock, which acts as a natural buffer by bringing the pH to a safe range for aquatic life. The United States Environmental Protection Agency (1986) considers a pH range of 6.5-9 as safe for aquatic life.

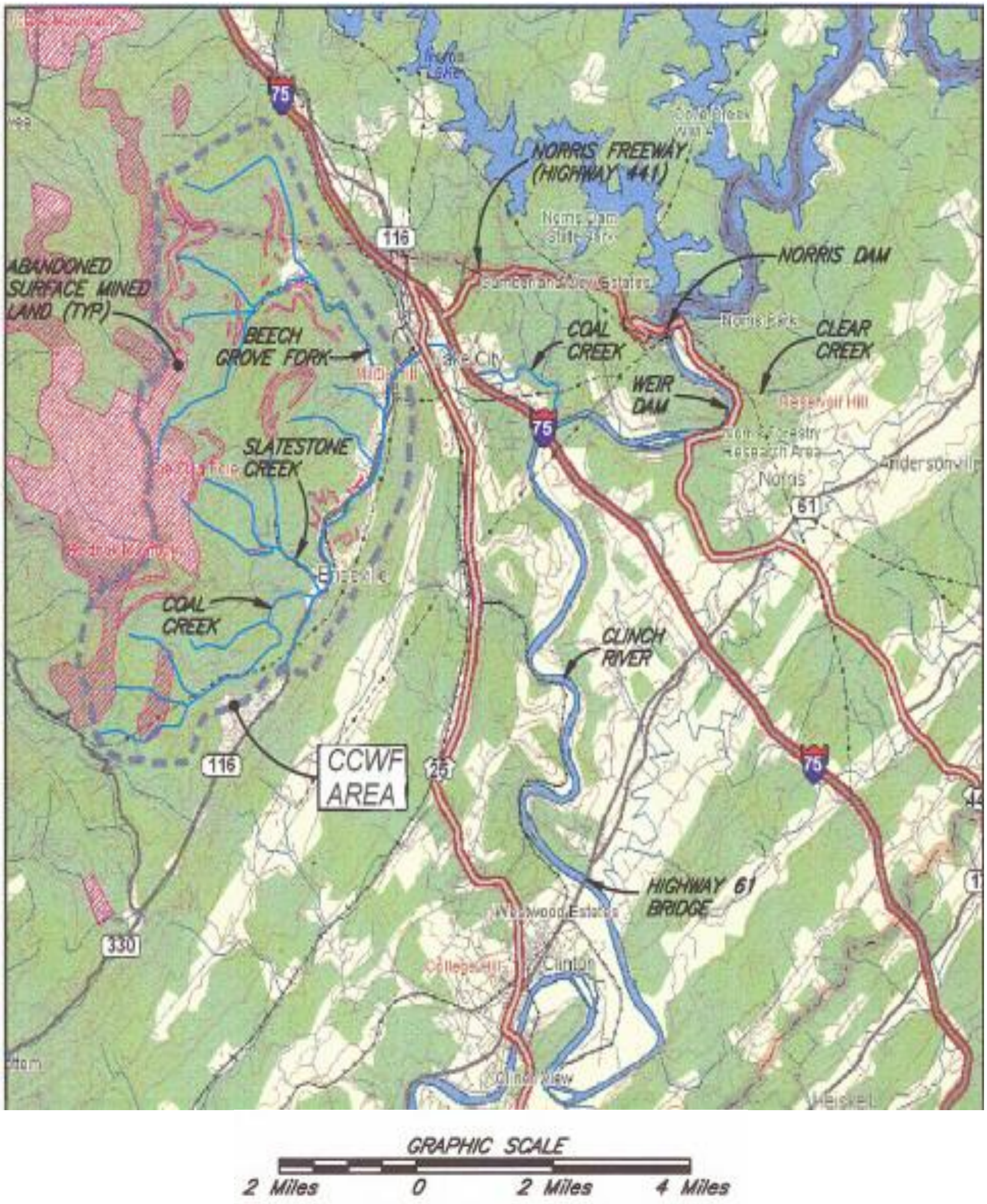


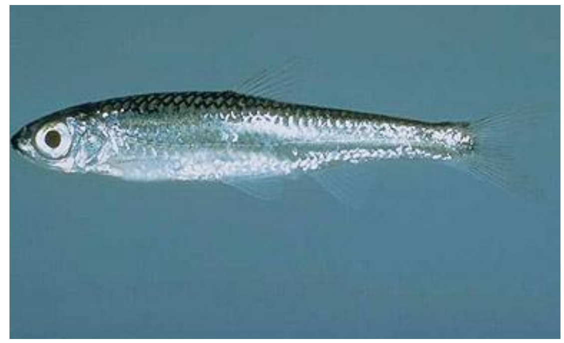
Figure 1. Map of Coal Creek Watershed, Anderson County, TN. Map courtesy of the Coal Creek Watershed Foundation (CCWF).

Fish populations in the Coal Creek watershed have been stressed by land use practices dominated by a history of coal mining. The Coal Creek Watershed Foundation (CCWF), a non-profit organization, was created from the Coal Creek Clean Stream Initiative (CCCSI). This initiative, established in 2000, was developed to create and enhance suitable habitat for trout spawning. The CCCSI was intended to reclaim abandoned mine land and decrease runoff. Coal Creek Watershed residents expressed concerns to broaden the scope of the reclamation. With the community involved, the CCCSI joined with the Coal Creek Flood Prevention Committee (CCFPC) later in 2000 to form the CCWF with a new mission to improve the quality of life in the Coal Creek watershed (CCWF 2008). With efforts to restore Coal Creek, now led by the CCWF, there were new signs of environmental recovery including improved water quality, additional insect diversity, improved IBI (index of biotic integrity) values for the fish species, and an increase of public support and community education (Appendices A1, A2). With increased environmental recovery, restoration and recovery of extirpated, native fish populations began. Re-introductions were needed since some species were not able to return naturally to Coal Creek due to cold water releases from Norris Dam.

Local activities and media coverage helped to integrate the Coal Creek watershed into community life to foster support and awareness. Briceville Elementary School schedules activities to educate students about the watershed, Coal Creek, and the aquatic life living in the creek. Such organizations as the CCWF, the Clinch River Chapter of Trout Unlimited, the Tennessee Valley Authority (TVA), and the University of Tennessee joined Briceville Elementary for an annual Health Day, which educates students on various aspects including health of the creek. The CCWF continues to educate students and the community on the history, the current conditions, the recovering aquatic life, and the future of Coal Creek. The local newspapers, the Clinton Courier and the Knoxville News Sentinel, continue to spread awareness on various aspects surrounding the Coal Creek Watershed including the restoration of native species.

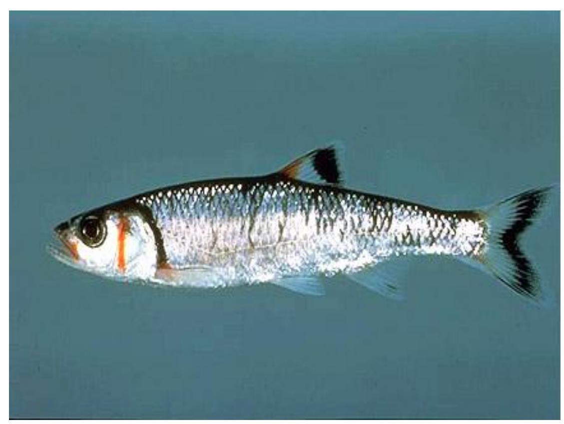
The focus of this project was: 1) to re-introduce fishes that were extirpated by pollution from mining practices or other sources, 2) to monitor the success of re-introductions, and 3) to determine the best collection method for rainbow darters. Target re-introduction species were the rainbow darter (*Etheostoma caeruleum*), telescope shiner (*Notropis telescopus*), Tennessee shiner (*N. leucoides*), and warpaint shiner (*Luxilus coccogenis*) (Figure 2). The fantail darter (*E. flabellare*) and whitetail shiner (*Cyprinella galactura*) were also collected when encountered with the targeted species. The success of these fish re-introductions will contribute to the ecological recovery in the watershed and also to the conservation of native species biodiversity.

a) rainbow darter (*E. caeruleum*)



b) telescope shiner (*N. telescopus*)

c) Tennessee shiner (*N. leucoides*)



d) warpaint shiner (*L. coccogenis*)

Figure 2. Photos of the four species targeted for re-introduction in Coal Creek, Anderson County, TN. Photos courtesy of the Virginia Tech Virtual Aquarium.

CHAPTER II

Literature Review

Re-introduction

Re-introductions are an important conservation tool, especially when a species is unable to recruit naturally (Griffith et al. 1989). Re-introductions are used to recolonize selected streams and re-establish populations. The success of a re-introduction is determined if a new, self-sustaining population is established (Griffith et al. 1989; Dunham and Gallo 2008). Information on re-introductions for fish species, particularly non-game species, has been uncommon, but currently increasing. Guidelines for re-introducing fish species include: 1) assessing the feasibility of the effort, 2) determining if implementation is possible, and 3) monitoring to determine if the re-introduction was a success or why it failed (Dunham and Gallo 2008). Many other factors should also be considered when re-introducing fish species: 1) the collection source should be considered to prevent over-harvesting from the population, 2) the number of individuals collected and the sex ratio should be high enough to sustain and promote reproduction at the release site, 3) suitable habitat must be available at release sites, and 4) timing must be considered depending on reproduction and fecundity of the species (Poly 2002).

Re-introducing extirpated species helps to improve the native biodiversity of the ecosystem and re-establish historical populations. Historically, re-introduction efforts have been rare and the successes of such efforts have been few. In 1976 in Tennessee, a successful translocation of the snail darter (*Percina tanasi*) was accomplished (Etnier and

Starnes 1993). According to Etnier and Starnes (1993), endangered snail darters were moved from the Tennessee River to the Hiwassee River, which resulted in an established population of over 2,500 individuals. Following the snail darter controversy and translocations, successful re-introductions have increased for both game and non-game fish species. The United States Fish and Wildlife Service (USFWS) successfully moved adult bull trout (*Salvelinus confluentus*) beyond Sunset Falls, a waterfall barrier on the South Fork Skyomish River in WA, and established new populations upstream of the waterfall (USFWS 2002; Dunham and Gallo 2008). Conservation Fisheries Incorporated (CFI) in Knoxville, TN, has successfully propagated and re-introduced several federally listed species, including the spotfin chub (*Erimonax monachus*), smoky madtom (*Noturus baileyi*), yellowfin madtom (*N. flavipinnis*), and duskytail darter (*Etheostoma percnurum*), back to historical habitats in Abrams Creek, Great Smoky Mountains National Park, TN (Rakes et al. 1999; Shute et al. 2003; Conservation Fisheries, Inc. 2008). In 2001, a breeding population of fringed darters (*Etheostoma crossopterum*) was successfully re-introduced back to native drainage areas near the Cache River in Illinois (Poly 2002).

Since 1908, the Pigeon River, running between North Carolina and Tennessee, has suffered from water degradation due to paper mill discharges (Coombs 2003). In 1988, IBI scores indicated "poor" results from downstream of the mill (Saylor et al. 1993). With water quality standards of the Tennessee Water Quality Control Act of 1977 later enforced (Coombs 2003), improvements in water quality and fish indices were soon visible (Saylor et al. 1993). Unfortunately, many native species were lost and some were unable to recruit back naturally due to barriers. Beginning in 2001, efforts attempted to re-introduce eight native, extirpated species back to the Pigeon River (Harrison 2004). During a two-year study following re-introductions, 175 target species from initial re-introductions in 2001 were visually observed (Coombs 2003). Re-introduction and monitoring efforts are ongoing in order to determine success of restoring fish populations and native biodiversity to the Pigeon River.

Fish Collection Methods

The collection method of any species of fish may contribute greatly to fish survival. Two of the most common collection methods are electrofishing (electroshocking) and seining. Electroshocking uses electric currents to collect fish (Murphy and Willis 1996). Fish in the shocked area are temporarily stunned and easily collected with a net. Electroshocking is efficient, involves less handling time, and is dependent on knowledge about proper voltage. Seining can also be an efficient collection method. Etnier and Starnes (1993), described seine hauls, and kick seining. Seine hauls are conducted by pulling the seine through the water, keeping the bottom lead line in contact with the substrate. Fish can be trapped by quickly lifting the seine horizontally or by pulling the seine to the shore. Kick seines are conducted by setting the seine in a fixed downstream position, usually across a riffle or run, and kicking the upstream substrate toward the net. Kick seining is used more often when collecting riffle/run habitat associated species. Since fish tend to move upstream to escape a disturbance, kicking the substrate disorients their direction (Etnier and Starnes 1993). With seining, the fish are fully aware, there is more handling time involved, and there is a longer duration of immediate stress.

There is not much research that exists comparing the collection methods of shocking and seining. Seining seems to have minimal impact on fish and most mortality may be due to physical injuries or stress from handling the fish (Barrett and Grossman 1988). Shocked fish exhibit responses that are grouped into two categories: behavioral movements, and stress and physical-induced injuries (Murphy and Willis 1996). Fish can suffer negatively from electroshocking, but there is little information about the sensitivity threshold between species (Henry et al. 2004). According to Henry and Grizzle (2003), evaluations of the negative effects of electroshocking on fish have most commonly involved gross external examination, necropsy, radiography, blood analysis, and histological assessments. The most common cause of death was related to hemorrhaging or necrosis of skeletal muscle fibers. These types of injuries may lead to such difficulties as paralysis or decreased respiration, which may significantly reduce survival depending on severity.

Checking for mortality indicators or stress levels in the field may be possible with larger species like salmonids. There is limited information about checking stress levels in the field for smaller species such as darters, probably due to their size. Darters are very fragile and it would be difficult to take any samples without doing damage. Tagging a darter has to be done with caution. Although the needle is very fine, it can easily hit a vein or even break the bones (spine) and cause mortality. Therefore, for this reason, darters or smaller fish are either observed in captivity or, after they expire, are dissected for additional stress or mortality information. To reduce mortality, the best collection method must be determined based on species.

Reproduction

Suitable conditions are required for reproduction and vary among species. Conditions include: 1) stream habitat characteristics such as substrate, flow, channel structure, depth, pollution, 2) weather and climatic factors such as temperature, seasonality, and rainfall, and 3) predator-prey relationships. Many of these conditions can be influenced by human disturbance. Since suitable spawning habitat may already be limited for darters due to spawning behavior (Page 1983), some human interference such as siltation can cause detrimental effects to spawning activities of darters and other fish species. Although suitable conditions must be met for all species living within the same water body, different fish species may have slightly different habitat requirements.

Study Species

The following life history information is summarized from Etnier and Starnes (1993) and Page (1983) concerning the species targeted for re-introduction. The rainbow darter is a member of the Percidae family, and although members of this family display a range of spawning behaviors, darters have evolved a more specific, detailed spawning behavior. The rainbow darter is a benthic species found in riffles and pools of small rivers and streams. They prefer spawning areas of fine gravel substrate; spawning activity usually occurs from spring to early summer and may be motivated by water temperatures of 15°C or higher. Rainbow darters live up to four years and reach sexual maturity at one year of age. Fecundity ranges from 500-1500 eggs per season, and when deposited, they are fertilized by one or many males and buried in the gravel by spawning activity.

Shiners are members of the Cyprinidae family. Although spawning behavior in this family is varied, many shiner species have similar spawning activities and spawning site selection. Shiners are known to spawn directly over unaltered gravel substrate, by hollowing out areas of substrate, or by making use of existing nesting areas. Warpaint, telescope, and Tennessee shiners prefer rocky/gravel substrates with moderate to swift currents. Most spawning in these three species occurs in late spring to early summer. Spawning of these species commonly occurs over river chub (*Nocomis micropogon*) nests, with eggs deposited in rock crevices. There is considerable variation of fecundity and age at sexual maturity among the shiner species.

Drought Effects

Spawning activities are dependent on multiple factors including water levels, stream flow, pollution, and temperature. These factors are all significantly affected by drought or extremely low water flow. In order to understand fish responses to drought, data must be collected prior to, during, and after a drought. Since drought is unpredictable, data on fish responses to drought are uncommon (Huntingford et al. 1999). Observations in natural settings have yielded conflicting results to the behavioral patterns of fish during drought times. During a drought, Saunders and Gee (1964) found that Atlantic salmon (*Salmo salar*) aggregate in pools, while Egglishaw and Shackley (1977) reported Atlantic salmon remained in the shallower water. Researchers have been able to hypothesize on fish reactions to drought due to experiments in controlled, drought simulated environments. Huntingford et al. (1999) reported that 95 percent of the experimental population of juvenile Atlantic salmon moved from riffles to areas of deeper water. Of the portion that moved, approximately 74 percent of those juvenile salmon moved in an upstream direction toward pools. Huntingford et al. (1999) also noted that the salmon may have been more motivated to move due to their ability to scout the entire artificial stream area.

Conflicting research supports both the behaviors of fishes to move to either pool areas or to stay in low-flow areas during droughts. Fish survival during drought conditions may depend on their ability to effectively find refuge areas within their habitat (Davey et al. 2006). Once a fish finds refuge, many other factors play a role in survival. In drought conditions, areas of suitable habitat are minimal and often isolated to pools. These pools provide refuge for competing species as well as predatory species. Although impacts of drought sometimes take years to be noted, fish species composition may be affected due to the increased intensity of fish interactions in the limited available space (Closs and Lake 1996). Reactions to stressors induced by lack of rain vary by species. Some species are more tolerant to environmental conditions and are able to temporarily adapt, while other species may be less tolerant depending on environmental conditions. Abiotic and biotic factors contribute to the survival of fish species during harsh environmental conditions and may determine fish distribution (Closs and Lake 1996). Decreases in water levels are often accompanied by increases in water temperature, increases in the concentration of pollutants, and decreases in water flow, which may in turn affect fish interactions such as predation and competition.

CHAPTER III

Methods

Study Sites

Collection sites for targeted species were selected by personnel from the Department of Forestry, Wildlife and Fisheries (FWF), the Tennessee Department of Environment and Conservation (TDEC), and the Tennessee Valley Authority (TVA). Sites for collection were determined as having suitable attributes as the stocking sites, such as similar habitat, access for collection, shortest transportation distances to release sites, available populations of target species, and being within the same drainage as release sites. Release sites were also determined by FWF and TDEC personnel. The sites were originally chosen based on suitable habitat.

Darter Collection

Little is known about the effects of seining and shocking on rainbow darters; therefore, prior to collection, the most efficient and safest collection method for rainbow darters had to be determined. Darter species are able to hide in uneven substrate and easily escape seining efforts. Electrofishing efforts also may not be effective since darters do not have air bladders and can get caught up under substrate. Since an objective of the project was to release healthy darters with a high survival rate, the rationale for choosing a collection method depended on three main ideas: 1) the lowest initial stress would promote long-term survival, 2) the most efficient method would decrease the stress of a long holding period, and 3) direct mortality would be minimized. To select the best method for efficient rainbow darter collection, a small assessment was designed focused on finding the most efficient collection method that caused the lowest mortality.

At Cove Creek, 60 darters were collected by two methods: kick seining and backpack electroshocking. Thirty darters were collected by seining and 30 darters were collected by shocking, and the two groups were divided into two 5-gallon buckets. The buckets were topped with mesh and placed in the stream to allow for the natural maintenance of oxygen and temperature (Figure 3). The groups were monitored for the 5-hour duration of the assessment.

After collection, rainbow darters were anesthetized using tricaine methanesulfonate (MS-222). The MS-222 (100 mg) was mixed in a 1.0-L container with water (Figure 4). Fish were added to the anesthesia bath no more than 5 at a time to prepare for tagging. Temperature and dissolved oxygen (DO) were monitored at all times with a YSI meter (Yellow Springs, OH). The sex and total length (TL) in mm of each tagged fish was recorded while they were under anesthesia. Before and after tagging, darters were kept in aerated coolers from the time of capture until transport to the release site. While anesthetized, fish were tagged with a visible implant fluorescent elastomer (VIE) (Northwest Marine Technology, Inc, WA). The VIE was injected into the fish at both sides of the base of the first or second dorsal fin, depending on seasonality (Figure 5, Table 1). Tag placement and pink or orange colored VIE were used to distinguish between the first tagging effort and the second. The needle was placed just below the skin and elastomer was injected parallel to the body of the fish (Figure 6). Pressure was

Figure 3. Five-gallon buckets holding test specimens of rainbow darters.

Figure 4. A 1.0-L container of water containing MS-222 for anesthetizing rainbow darters.


Figure 5. Tagging a rainbow darter using visible implant elastomer.

Table 1. Re-introduced fish species[1] in Coal Creek, Anderson County, TN, with date of collection[2], tag color and location on fish[3], collection site[4], release site[5], and number of individuals[6] from 2007-2008.

Collection Dates[2]	No VIE Tags Darter[1] RD	Shiner[1] TNS	WAS	TES	VIE Tag Location/Color[3]	Collection Site[4]	Release Site[5]
2/20/2007	96				O ant	CC	BG
2/26/2007	140				O ant	CC	W
10/26/2007	50				P ant	CC	BE
3/30/2007		115	32	300	no tag	IC	W
6/15/2007		81	15	112	no tag	PR	RR
12/14/2007		112	71	82	no tag	IC	JEDB
12/17/2007			129		no tag	BC	JEDB
1/29/2008	123				P ant	CC	FC
5/2/2008	100				P pos	CC	W
Totals[6]	509	308	247	494			

Key:
Fish Species: RD = rainbow darter, TNS = Tennessee shiner, WAS = warpaint shiner, TES = telescope shiner
VIE Tag Color: O = orange, P = pink
VIE Tag Location: ANT = anterior dorsal fin, POS = posterior dorsal fin
Fish Collection Site: IC = Indian Creek, PR = Powell River, CC = Cove Creek, BC = Beaver Creek
Fish Release Site: JEDB = Joe E. Day Bridge, BE = Briceville Elementary, RR = Railroad Tracks near BE, W = Wye, BG = Beech Grove Fork, FC = Fratersville Church

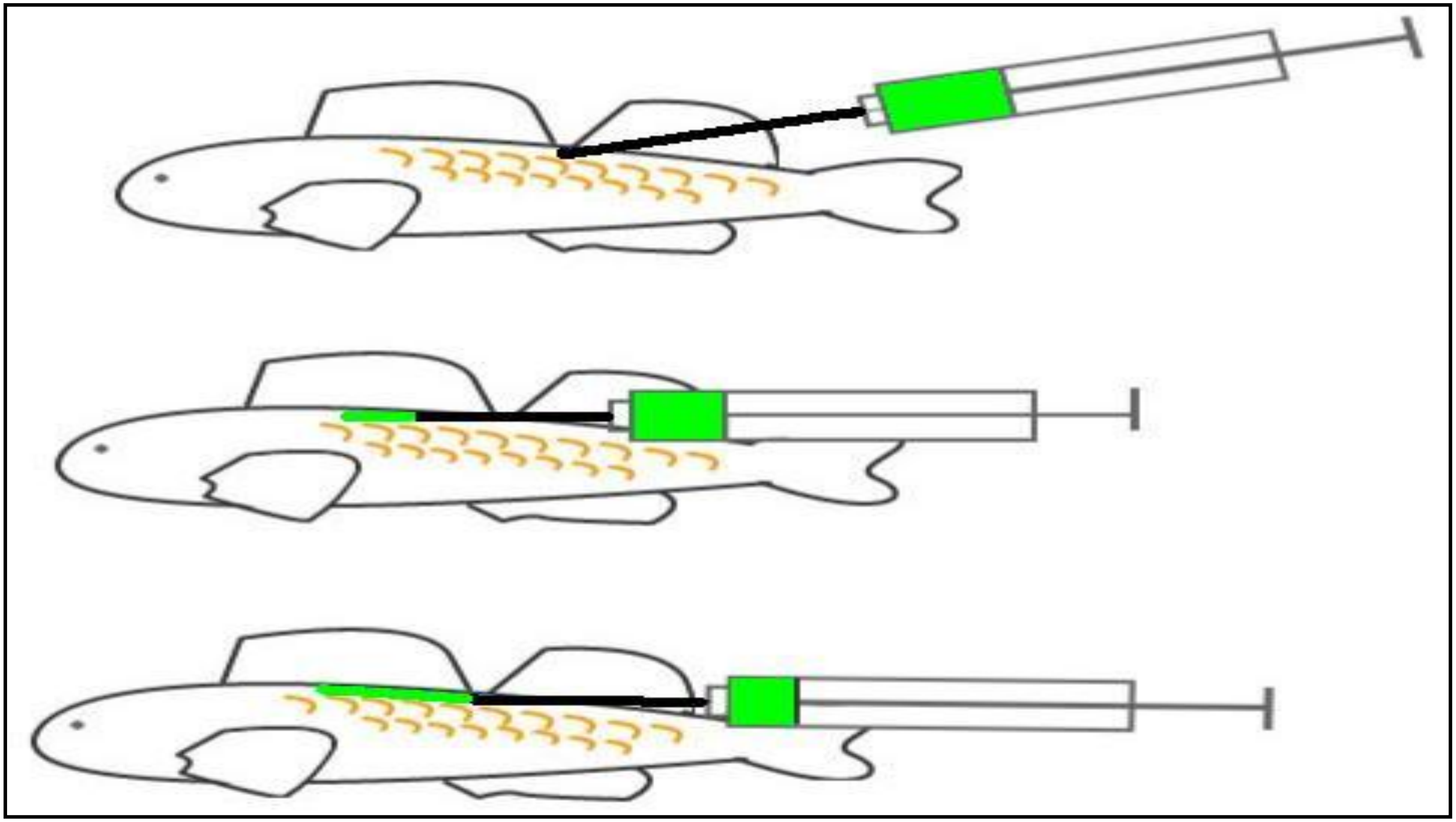


Figure 6. Schematic of tagging with VIE. Schematic courtesy of Coombs (2003).

applied to the syringe during retraction of the needle to fill the void with VIE. Any excess elastomer on the exterior of the fish was wiped off. According to Coombs (2003), VIE is a safe, effective method to tag fish and was first used by CFI to tag darters.

After tagging, fish recovered in an oxygenated cooler monitored for temperature and DO. Water temperatures were cooled by adding ice if they exceeded 5°C beyond the collection site temperatures. For transport to the re-introduction site, fish were placed in large, oxygenated, plastic bags, and held in 30-L coolers. Once the fish arrived at the appropriate site, the bags were placed in the creek and water was exchanged slowly for proper acclimation. Fish were acclimated to release sites according to Coombs (2003) until temperatures came within 2°C (Stickney 1979). According to Stickney (1979), fish should be acclimated slowly, not to exceed more than 5°C per hour. Acclimation also helps fish adjust to other changes in water quality such as DO and pH (Piper et al. 1982).

Shiner Collection

Shiners are more sensitive than darters to electroshocking, and usually show higher mortality when collected in this manner. Due to this heightened sensitivity to electroshocking, additional stress of fish beyond the stress of collection and transport was undesirable; therefore, shiners were only collected by seine. The seines were hauled in suitable habitat to collect shiners (Figure 7). The fish were held and released according to the same procedures as the darters, but without the anesthesia and tagging procedures. It had been previously determined by Coombs (2003) that VIE tagging of shiners substantially increased mortality.

Figure 7. Conducting seine hauls on Indian Creek, Claiborne, County, TN.

Monitoring Surveys

Survey sites must be monitored to determine success of fish re-introductions. There are important factors that should be noted in determining success: 1) fish should be directly observed and in sustainable numbers, and 2) there should be evidence of spawning (Shute et al. 2003). Although direct observation through snorkel surveys has been noted as the best method to monitor re-introductions and estimate species abundance (Coombs 2003), seining surveys were conducted and supplemented with electroshocking when needed in order to monitor for success or reproduction. Due to extreme low water levels and high turbidity, snorkel surveys were impossible. Initially, electroshocking was not an option due to the heightened sensitivity of the re-introduced shiners. With water levels decreasing through the study, the ability to efficiently seine decreased. Electroshocking was later incorporated as a monitoring method due to the unpredictable, heightened effects of the drought and to help supplement seining, which can only provide point samples instead of continuous sampling within the habitat (Goldstein 1978).

Electroshocking was performed during late fall, when water and air temperatures were lower, to help avoid stress to the fish. Four monitoring surveys were conducted from late summer through late fall. Three out of four surveys extended both upstream and downstream of all original sites to locate fish which may have moved from the immediate re-introduction site. Fish will disperse both upstream and downstream (Freeman 1995), but may stay within small ranges (Schaefer et al. 2003). Previous studies indicated that the movement of rainbow darters was minimal (Reed 1968). Surveys were conducted in suitable habitat, and much like IBI surveys, with continued surveys for three consecutive seine hauls or kick seines until no new species were collected. The third monitoring effort set forth to survey the small number of darters released at Briceville Elementary. Movements of re-introduced darters orient toward an upstream direction (Mundahl and Ingersoll 1983; Schaefer et al. 2003). Therefore, this effort used only electroshocking upstream of the site. A combination of electroshocking and kick seining was conducted on the fourth survey. Electroshocking was conducted in a similar manner as the seining surveys and was only used during the last two monitoring surveys.

Water Quality

Water quality is an important aspect of fisheries related research. In order to acclimate fish species to a new location, water parameters should be measured at the collection and release locations. Acclimating collected fish to the release site helps to decrease stress and mortality. To compare collection and release sites and to properly acclimate species to new conditions, three water parameters were measured: temperature, dissolved oxygen (DO), and pH. Water quality readings were taken with a YSI meter by holding the probe in the main channel of the stream (Table 2). Water quality data at the collection sites was recorded at the start of the collection efforts; at an approximate depth of 30 cm. Release site water quality readings were measured in late afternoon (1:00 p.m.-3:00 p.m.), which resulted in higher water temperatures.

Table 2. Water quality measurements at collection and release sites on Cove Creek, Indian Creek, and Coal Creek, TN from 2007-2008.

Collection/ Release Date	Water Quality Measurement at Collection Site			Collection Site	Water Quality Measurement at Release Site			Release Site
	Temp. °C	DO mg/L	pH		Temp. °C	DO mg/L	pH	
2/20/2007	4.1	9.5	8.3	CC	7.9	10	8.4	BG
2/26/2007	6.3	10.03	7.9	CC	9.2	14.15	8.12	W
10/26/2007	14.0	8.6	7.0	CC	16.3	8.0	8.15	BE
3/30/2007	18.2	8.0	7.77	IC	20.4	7.92	8.3	W
6/15/2007	*	*	*	PR	*	*	*	RR
12/14/2007	9.9	10.91	8.0	IC	11.2	10.38	8.15	JEDB
12/17/2007	7.1	10.29	8.1	BC	4.0	12.68	8.2	JEDB
1/29/2008	4.4	12.25	8.2	CC	6.0	11.76	8.2	FC
5/2/2008	14.2	9.7	7.5	CC	18.4	8.77	7.9	W

*Note-YSI meter inoperable; no measurements taken. The sampling was based on professional experience from field crew.

Fish Collection Site: IC = Indian Creek, PR = Powell River, CC = Cove Creek, BC = Beaver Creek

Fish Release Site: JEDB = Joe E. Day Bridge, BE = Briceville Elementary, RR = Railroad Tracks near BE, W = Wye, BG = Beech Grove Fork, FC = Fratersville Church

CHAPTER IV

Results and Discussion

Results

The numbers of individuals collected were as follows: 509 rainbow darters, 308 Tennessee shiners, 247 warpaint shiners, and 494 telescope shiners. The 500 original individuals per species targeted for collection was adjusted according to drought effects so as to alleviate additional stress to collection site populations. Rainbow darters were collected from Cove Creek in Campbell County, TN, by using a combination of electroshocking and kick seining. The rainbow darter collection assessment observed one mortality from both the shocking group and the seining group at the end of the day. The mortality from electroshocking indicated visible signs of broken vertebrae. The seining mortality did not show any physical indications of stress. During monitoring efforts, the rainbow darter showed high survival when the electroshocking current was fairly low, (i.e., less than 100 volts of direct current), which was implemented due to higher conductivity levels in Coal Creek. The three shiner species (Tennessee, telescope, warpaint) were collected from two locations in Claiborne County, TN: 1) the confluence of the Powell River and Indian Creek, and 2) Indian Creek at Indian Creek Road near the Ike M. Shoffner Bridge (Table 3). Warpaint shiners were also collected from Beaver Creek in Knox County, TN, due to the periodic low flow of Indian Creek and the lack of finding the species (Table 3).

Table 3. GPS coordinates of corresponding fish collection sites in Claiborne County, Campbell County, and Knox County, TN.

Collection Site	GPS Coordinates
Cove Creek	*36°19.05 N, 84°14.16 W
Powell River at Indian Creek	*36°33.34 N, 83°36.27 W
Indian Creek at Indian Creek Road	*36°35.21 N, 83°36.21 W
Beaver Creek	*35°57.35 N, 84°07.59 W

***Estimated from USGS National Map**

Due to drought effects, additional release sites were selected during the study according to available stream flow. Re-introduced species were released at one of six sites along Coal Creek in Anderson County, TN, above the sewage treatment plant (Table 4, Figures 8-14). Shiner species were released at three sites: 1) the Joe E. Day Bridge, 2) the Wye, and 3) the Railroad Tracks (Table 4, Figures 8-9, 12, 14). Darters were released at four sites including 1) Beech Grove Fork, 2) the Wye, 3) Fratersville Church, and 4) Briceville Elementary (Table 4, Figures 8, 10-13).

Monitoring surveys, which totaled four days of effort including an IBI survey by TDEC during the summer/fall of 2008, revealed representatives of three out of four re-introduced species (Table 5). The numbers of any opportunistically collected species were probably too low to promote long term survival and subsequent sampling efforts revealed none of these species. All the monitoring surveys extended both upstream and downstream of all sites to locate fish, which may have moved from the immediate re-introduction site.

Table 4. GPS coordinates of corresponding fish release sites on Coal Creek, Anderson County, TN.

Species	Release Site	GPS Coordinates
TNS, WAS, TES	Joe E. Day Bridge	36°13.124 N, 84°09.659 W
RD	Beech Grove Fork	36°13.020 N, 84°10.164 W
TNS, WAS, TES	Railroad Tracks	36°10.699 N, 84°10.919 W
RD, TNS, WAS, TES	Wye	36°12.946 N, 84°09.954 W
RD	Fratersville Church	36°11.694 N, 84°10.419 W
RD	Briceville Elementary	36°10.584 N, 84°11.052 W

Species codes are as follows: RD = rainbow darter, TNS = Tennessee shiner, WAS = warpaint shiner, TES = telescope shiner

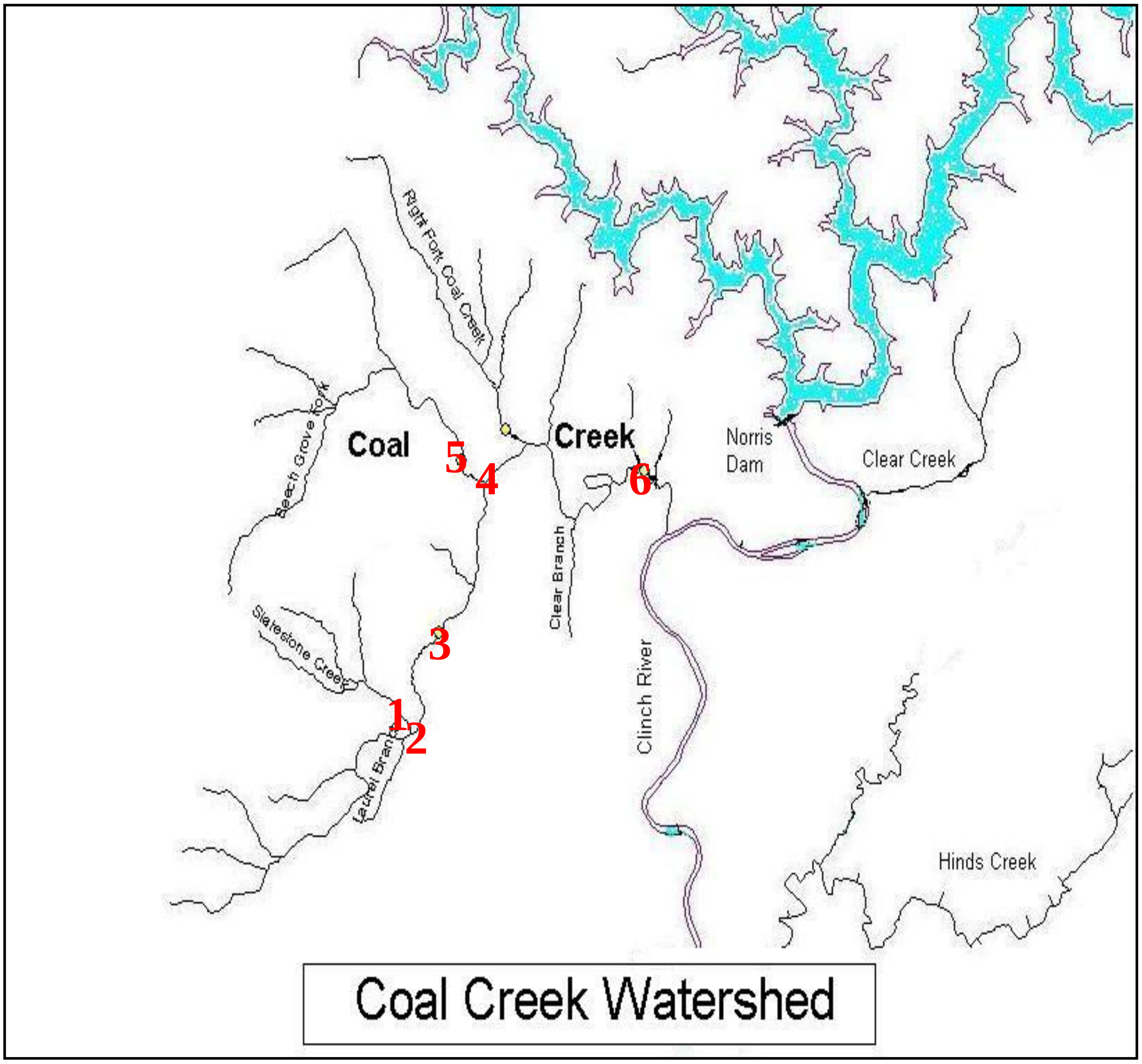


Figure 8. Map of Coal Creek, Anderson County, TN, with release sites of re-introduced fish species. Site codes are as follows: 1: Railroad Tracks, 2: Briceville Elementary, 3: Fratersville Church, 4: Wye, 5: Beech Grove Fork, 6: Joe E. Day Bridge. Base map courtesy of CCWF.

Figure 9. Photo of release site 1: Railroad Tracks, Coal Creek, Anderson County, TN. June 2007.

Figure 10. Photo of release site 2: Briceville Elementary, Coal Creek, Anderson County, TN. October 2007.

Figure 11. Photo of release site 3: Fratersville Church, Coal Creek, Anderson County, TN. December 2004. Photo courtesy of Barry Thacker.

Figure 12. Photo of release site 4: Wye, Coal Creek, Anderson County, TN. January 2007.

Figure 13. Photo of release site 5: Beech Grove Fork, Coal Creek, Anderson County, TN. January 2007.

Figure 14. Photo of release site 6: Joe E. Day Bridge, Coal Creek, Anderson County, TN. September 2008.

Table 5. Re-introduced species[1] found in Coal Creek, Anderson County, TN, during 2008 monitoring dates[2] with tag location[3] and color[4], location where fish was found[5], method of monitoring[6], and release date(s)[7].

Species[1]	Monitoring Date[2]	VIE Tag Color[3]	VIE Tag Location[4]	Site Found[5]	Method[6]	Release Date[7]
RD	7/14/2008	P	post	JEDB	Seine	5/2/2008
RD	7/14/2008	O	ant	W/BG	Seine	2/20/07or 2/26/2007
WAS	7/14/2008			FC	Seine	3/30/07 - 12/17/07
WAS	7/14/2008			FC	Seine	3/30/07 - 12/17/08
WAS	7/14/2008			FC	Seine	3/30/07 - 12/17/09
WAS	7/14/2008			FC	Seine	3/30/07 - 12/17/10
WAS	7/14/2008			FC	Seine	3/30/07 - 12/17/11
WAS	7/14/2008			FC	Seine	3/30/07 - 12/17/12
RD	9/3/2008		no tag	JEDB	Shock	repro
RD	9/3/2008	P	post	JEDB	Shock	5/2/2008
WAS	9/3/2008			JEDB	Shock	3/30/07 - 12/17/07
WAS	9/3/2008			JEDB	Seine	3/30/07 - 12/17/08
WAS	9/3/2008			JEDB	Seine	3/30/07 - 12/17/09
WAS	9/3/2008			JEDB/W	Seine	3/30/07 - 12/17/10
TES	9/3/2008			JEDB/W	Seine	repro
TES	9/3/2008			JEDB/W	Seine	repro
TES	9/3/2008			JEDB/W	Seine	repro
TES	9/3/2008			JEDB/W	Seine	repro
TES	9/3/2008			JEDB/W	Seine	repro
TES	9/3/2008			JEDB/W	Seine	repro
RD	9/3/2008	P	post	JEDB/W	Shock	5/2/2008
none found	9/4/2008				Seine	
none found	9/4/2008				Seine	

Table 5. Continued

Species[1]	Monitoring Date[2]	VIE Tag Color[3]	VIE Tag Location[4]	Site Found[5]	Method[6]	Release Date[7]
RD	10/31/2008		no tag	BE	Shock	repro
RD	10/31/2008		no tag	BE	Shock	repro
RD	10/31/2008		no tag	BE	Shock	repro
RD	11/21/2008	P	ant	BE	Shock	10/26/07 or 1/29/08
RD	11/21/2008		no tag	RR	Shock	repro

Key:
Fish Species: RD = rainbow darter, TNS = Tennessee shiner, WAS = warpaint shiner, TES = telescope shiner
VIE Tag Color: O = orange, P = pink
VIE Tag Location: ANT = anterior dorsal fin, POS = posterior dorsal fin
Site Found: JEDB = Joe E. Day Bridge, BE = Briceville Elementary, RR = Railroad Tracks, W = Wye, BG = Beech Grove Fork, FC = Fratersville Church, W/BG = halfway between W and BG, JEDB/W = halfway between JEDB and W

In late fall of 2008, an electroshocking effort yielded one untagged, second year, male rainbow darter and two young of the year rainbow darters in riffles just upstream of the site at Briceville Elementary. The final electroshocking effort resulted in one tagged rainbow darter and one (approximately second year) untagged darter. Four tagged rainbow darters and one untagged darter were kick seined in shallow riffles. Six young of the year telescope shiners were collected during and IBI survey by TDEC, just upstream of the Joe E. Day Bridge (Appendices A1, A2). Warpaint shiners (10) were seined in small pools.

Discussion

The results of this study may have been affected by a significant drought in 2007-2008 and the subsequent changes in water levels. According to the Tennessee Valley Authority (2008), FY 2008 was the ninth driest year in 118 years of record for rainfall and the second driest year in 133 years of record for runoff. Low water flows, especially in East TN, brought about stressful conditions, including higher water temperatures, higher concentrations of predators, increased competition, and limited available habitat for the fish species in Coal Creek. The direct response of the targeted species to the effects of the drought is unknown.

Two of the target species, telescope shiners and rainbow darters, had successful spawns which appeared unaffected by decreasing water levels. More young of the year telescope shiners were found than adults, so eggs may have been able to survive environmental conditions when adults could not. Adults may have been forced into refuge areas with predators, experienced increased competition, or found refuge pools which dried completely. Only warpaint shiner adults were found along with adult, juvenile, and young of the year rainbow darters. Rainbow darters may be hardier than the shiners and may be able to tolerate increased competition and predation. Rainbow darters were also found in later sampling attempts at upstream sites in which they were not found during previous sampling efforts. Finding darters at upstream sites later in the monitoring period may indicate a tendency for the species to move upstream, whether to avoid predators or competition or to find suitable spawning habitat.

The rainbow darter collection assessment revealed low mortality to both electroshocking and kick seining, although juveniles or young of the year are usually more susceptible to overall mortality than adults. The single electroshocking sampling mortality was due to a spinal injury, but, there has been no proven relationship between spine injuries and electroshocking mortality (Henry et al. 2004). Fish survival, after electroshocking, can usually be determined within the first 5 minutes. If fish are not responsive after one hour, recovery is severely limited (Henry and Grizzle 2003; Henry et al. 2004). Conflicting research has indicated that some effects of electroshocking may not be known in the short term (Murphy and Willis 1996). To study the effects of electrofishing usually requires holding the fish in captivity and monitoring mortality for extended periods of time or dissection (Hauck 1949). From this collection assessment, it was determined the best collection method for darters was a combination of kick seining and electroshocking to help increase efficiency and promote long-term survival at the time of release (Figure 15). A higher number of fish were captured in the seine in a shorter amount of time by combining the benefits of electroshocking and kick seining.

Figure 15. Electroshocking in combination with kick seining at Cove Creek, Campbell County, TN.

Tennessee shiners were the only target species not found in the monitoring effort. They prefer larger streams, but have been found in small streams across East TN (Etnier and Starnes 1993). Due to the preference for larger streams and the decreased water levels in Coal Creek, Tennessee shiners may not have been able to survive during this study period. Since Tennessee shiners prefer larger streams, they are more sensitive to changes due to decreased water flow, especially an increase in pollution concentrations.

During periods of decreased water flows, pollutants are more concentrated. In Coal Creek, those pollutants consist of increased silt loads, human pollutants, and acid mining seepage (i.e., iron, aluminum, manganese, and sulfate) (Sams and Beer 2000). Metal toxicity in streams with acid mine runoff can build to fatal levels for aquatic life and sediments may settle on the stream bottom (Sams and Beer 2000; Commonwealth of PA 2009). In suitable habitat, streams flows naturally dilute and flush pollutants. High conductivity in Coal Creek may be due to the inability of the system to naturally flush mining seepage. Seepage concentrations may have increased with low water flows, and stressed less tolerant fish species, resulting in mortality of re-introduced species.

Monitoring surveys were used to assess the survival and reproduction of re-introduced species. Low water levels affected the efficiency of monitoring and the ability to cause the lowest possible stress to fish. Seining and electroshocking provide only point samples and may cause stress to fish; some species may have been disturbed during surveys and were not efficiently sampled. Snorkeling surveys were initially intended to monitor re-introductions, but with high turbidity and shallow waters, they were not an option. Therefore, a complete picture of the undisturbed fish community was not documented.

CHAPTER V

Summary and Recommendations

Attempts to re-introduce native extirpated species to Coal Creek were completed February 2007 - May 2008, while monitoring efforts for re-introduced species continued through November 2008. Although drought during 2007-2008 affected water levels and fish communities, valuable information was gained. Results of the study are as follows:

1. Four targeted species were re-introduced into Coal Creek: rainbow darter (509), Tennessee shiner (308), telescope shiner (494), and warpaint shiner (247).
2. Successful spawning of telescope shiners (6) and rainbow darters (5) was documented.
3. Although no reproduction was apparent in warpaint shiners, adults were found during the duration of the study.
4. No Tennessee shiners were found, providing evidence they did not adapt to the environmental conditions during the study period.
5. The best collection method for rainbow darters was determined to be a combination of electroshocking and kick seining.

The author recommends that for future re-introductions, release sites should be chosen with knowledge about the movement of darters. This study complements other research that reports the tendency of darters to move in an upstream direction. Although little research is available documenting re-introduction or drought sensitivity in the study species, the author noted that some species are more sensitive than others to re-introduction procedures and drought effects such as decreasing water levels, pollutant concentrations, predation, and competition. Although the study design was to collect more individuals of some targeted species, the author did not want to stress existing populations at collection sites or re-introduce fish to conditions where environmental stressors were increased.

The author also recommends that snorkel surveys be performed in available habitat so fish communities can be efficiently assessed. Ongoing monitoring is recommended to assess success of re-introductions. Despite difficulties due to a prolonged drought, this study suggests that spawning activities in at least two of the four targeted species will promote long-term survival, although the numbers needed to establish self-sustaining populations have yet to be determined.

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Appendices

Appendix A

Coal Creek IBI Data

A1. A summary of fish IBI scores from Coal Creek, Anderson County, TN, 1999-2004, and 2008.

Stream name	Site name	Stream mile	Sample date	IBI Score	IBI Classification	Site Coordinates
Coal Creek	Lovely Bluff	1	29-Aug-95	40	fair	36.21716 N -84.1282 W
Coal Creek	Lovely Bluff	1	30-Aug-95			
Coal Creek	Lovely Bluff	1	2-Apr-04	44	fair	
Coal Creek	Upper	7.3	30-Aug-95	38	poor/fair	36.19194 N -84.1776 W
Coal Creek	Upper	7.3	22-Mar-99	32	poor	
Coal Creek	Upper	7.3	17-Mar-04	34	poor	
Coal Creek	Hwy 116	4.6	3-Sep-08	44	fair	*36.13.124 N -84.09.659 W
Beech Grove Fork		0.5	28-Aug-95	30	poor	36.21906 N -84.1715 W
Beech Grove Fork		0.5	12-Apr-04	44	fair	
Right Fork Coal Creek		0.3	29-Aug-95	38	poor/fair	36.22393 N -84.1715 W

***2008 site coordinates reported by author. 1999-2004 data courtesy of TVA (Charlie Saylor), 2008 data courtesy of TDEC (Jonathon Burr)**

A2. Modified metrics used in calculating IBI scores for Coal Creek, Anderson County, TN.

Metric Description	Scoring Criteria		
	1	**3**	**5**
Total number of native fish species	<11	12 - 20	>20
Number of darter species	<2	2-4	>4
Number of sunfish species, less Micropterus	<2	2	>2
Number of sucker species	<2	2	>2
Number of intolerant species	<2	2 -3	>3
Percent of individuals as tolerant species	>33%	16% - 33%	<16%
Percent of individuals as omnivores and stoneroller species	>39%	20% - 39%	<20%
Percent of individuals as specialized insectivores	<19%	19% - 38%	>38%
Percent of individuals as piscivores	<2%	2% - 4%	>4%
Catch rate(average number of fish per 300 sq. ft. sampling unit)	<21	21 - 42	>42
Percent of individuals as hybrids	>1%	TR-1%	0%
Percent of individuals with disease, tumors, fin damage, and other anomalies	>5%	2% - 5%	<2%

Metrics modified by TVA (Charlie Saylor) and courtesy of TDEC (Jonathon Burr).

Vita

Erin E. Schiding was born in Annville, Pennsylvania, on September 27, 1980, but grew up in Knoxville, TN. She attended the University of Montana in 1999 and eventually transferred to the University of Tennessee to finish her undergraduate work. She graduated in May 2005 with a Bachelor of Science degree in Wildlife and Fisheries Science and a minor in Forestry.

She started as a terrestrial zoology intern at the Tennessee Valley Authority in 2005, where she was later employed as a terrestrial zoology contractor in 2006. In 2006, she began her graduate classes at the University of Tennessee and was enrolled as a graduate assistant in 2007. She received her Master of Science degree in Wildlife and Fisheries Science in May 2009.