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The Movements and Reproductive Success of Re-introduced Darters in the Pigeon River, TN

Virginia Anne Harrison

University of Tennessee - Knoxville

To the Graduate Council:

I am submitting herewith a thesis written by Virginia Anne Harrison entitled "The Movements and Reproductive Success of Re-introduced Darters in the Pigeon River, 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:

Jonathon E. Burr, David A. Etnier

Accepted for the Council:
Dixie L. Thompson

Vice Provost and Dean of the Graduate School

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

To the Graduate Council:

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J. Larry Wilson_______
Major Professor

We have read this thesis
and recommend its acceptance:

Jonathon E. Burr____________

David A. Etnier_____________

Accepted for the Council:

____Anne Mayhew________
Vice Chancellor and
Dean of Graduate Studies

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

THE MOVEMENTS AND REPRODUCTIVE SUCCESS OF RE-INTRODUCED DARTERS IN THE PIGEON RIVER, TN

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

Virginia Anne Harrison
May 2004

Dedication

This thesis is dedicated to my family; Mom, Dad, John David, Emily and Jason; who love, support, and encourage me.

"*A river is more than an amenity, it is a treasure. It offers a necessity of life that must be rationed among those who have power over it*."

Justice Oliver Wendell Holmes

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Many thanks to Richard Bryant, who readily allowed me to use his illustrations. These illustrations were published in The Fishes of Tennessee and their use was permitted throughout this thesis.

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Lastly, I would like to thank my family and friends, also a special thanks is due to my sister, Emily.

Abstract

The Pigeon River has a history of degraded water quality that lasted nearly seven decades, from 1908 until the 1970s, thereby resulting in the loss of many native species. In recent years, recovery efforts have been initiated by numerous agencies to re-introduce selected fish and other aquatic species. Three species of darters (gilt darter *Percina evides*, bluebreast darter *Etheostoma camurum*, and blueside darter *E. jessiae*) were re-introduced into the river in 2001-03; re-introduction of a fourth species, the stripetail darter (*E. kennicotti*) began in 2003. Since 2002, these species have been monitored by snorkel surveys for movements and reproductive success. In addition to the two release sites, 23 sites deemed suitable as potential darter habitat were identified between Newport and Denton, Tennessee. Eighteen sites were upstream of the release site for gilt darters and five sites were downstream. Snorkel surveys of 21 of these sites were conducted in the summer and fall of 2003; two sites were inaccessible due to high, fast water resulting from unusually high summer precipitation. Habitat characteristics were recorded at these sites to define preferred habitat of the darter species. The gilt darter was the only species observed during snorkel surveys in 2003 and they were found to have moved 0.3 km upstream and 3.7 km downstream from the release site. The movements of gilt darters could have been influenced by abundant precipitation. The presence of untagged adults, juveniles, and young-of-the-year (YOY) indicated successful reproduction. Long-term monitoring efforts will determine if reproductive success will be perpetuated.

Table of Contents

Chapter

Page

I. Introduction……1

II. Literature Review……13

Re-introduction……13

Movement……16

Reproduction……19

III. Methods……21

Study Area……21

Collection Procedures……23

Snorkel Surveys……25

IV. Results and Discussion……30

Movement……30

Reproduction……42

V. Summary and Recommendations……50

Literature Cited……54

Vita……58

List of Tables

Table

Page

1. Re-introduced fish species with date of collection, species, number of individuals (N), collection source, tag color (VIE), and release site…………………………… 6

2. Sites (PRK) with substrate (%), velocity (m/s), number, and age groups of gilt darters observed…………………… 31

3. Distributions of gilt darters with survey date, site, age and tag (if present)……………………………………… 46

List of Figures

Figure

Page

1. The Pigeon River begins at the confluence of the East Fork Pigeon and West Fork Pigeon Rivers in Haywood County, NC…………………………………………………………………... 2
2. The release site PRK 8.7 (circled in red) for blueside darters, which is upstream of McSween Bridge, Newport, TN………………………… 9
3. The release site PRK 13.2 (circled in red) for bluebreast, gilt, and stripetail darters, upstream of Newport, TN …………………………... 10
4. Four species of darters re-introduced into the Pigeon River, 2001-2003: a)gilt darter, b)bluebreast darter, c)blueside darter, d)stripetail darter………………………………………………………. 11
5. Study area of the Pigeon River, TN (study area circled in red)………...22
6. Tagging in the field…………………………………………………. 24
7. VIE tagging, base of second dorsal fin………………………………24
8. Snorkelers line up parallel and move downstream to locate darters…. 26
9. Measuring stream velocity: an orange was timed on a 10-m float downstream…………………………………………………………. 28
10. Sites where gilt darters were observed (circled in red), release site (circled in blue) at 13.2 PRK…………………………………………... 33
11. Relative number and age classes of gilt darters observed at seven sites (PRK) in the Pigeon River, TN, 2003…………………………… 35
12. Pigeon River flows (cfs) on June 15, 1999-2003, at Newport, TN……. 38
13. PRK 11.6…………………………………………………………… 39
14. Fish community associated with gilt darters: a)logperch; b)greenside

darter; c)snubnose darter; d)redline darter; e)northern hogsucker; f)whitetail shiner; g)Tennessee shiner; h)central stoneroller; i)banded sculpin……………………………………………………………43

15. Age groups of gilt darters observed in snorkel surveys in 2003……… 49

CHAPTER I

Introduction

The Pigeon River is a medium-sized river with a watershed that encompasses 1,725 km^2, with 81.6% of the area in North Carolina and the remainder in Tennessee. It is located in the mountainous region of western North Carolina and eastern Tennessee (Figure 1). A headwater tributary to the Tennessee River system, the Pigeon has a length of nearly 113 km. The Pigeon begins at the confluence of the East Fork Pigeon and West Fork Pigeon rivers in Haywood County, North Carolina, and flows north to the French Broad River in Cocke County, Tennessee. The Pigeon originates at an elevation of 803 m and ends with an elevation of 305 m above mean sea level (Saylor et al. 1993). The Pigeon headwaters begin approximately 32 km west southwest of Asheville, North Carolina, in Pisgah National Forest (Bartlett 1995).

Historically, the Pigeon River has been environmentally degraded since 1908 when an Ohio paper mill was built on the river in Canton, North Carolina, at Pigeon River km (PRK) 101.1. The paper mill meant stable jobs and a better economy for the region. Regrettably, the paper industry is one of the most degrading industries for the environment (Bartlett 1995). In 1908, the mill went online, discharging large amounts of sulfur, chlorine, sodium hydroxide, sodium carbonate, sodium sulfate, sodium chlorate, titanium dioxide, aluminum sulfate, rosin sizing, and lime into the river. In addition, the bleached paper process introduced pollutants such as tannin, lignin, dioxins, furans, and chloroform (Bartlett 1995). As a result, many fish species and other aquatic organisms were extirpated. In 1930, an impoundment for hydroelectric power at Walters Dam

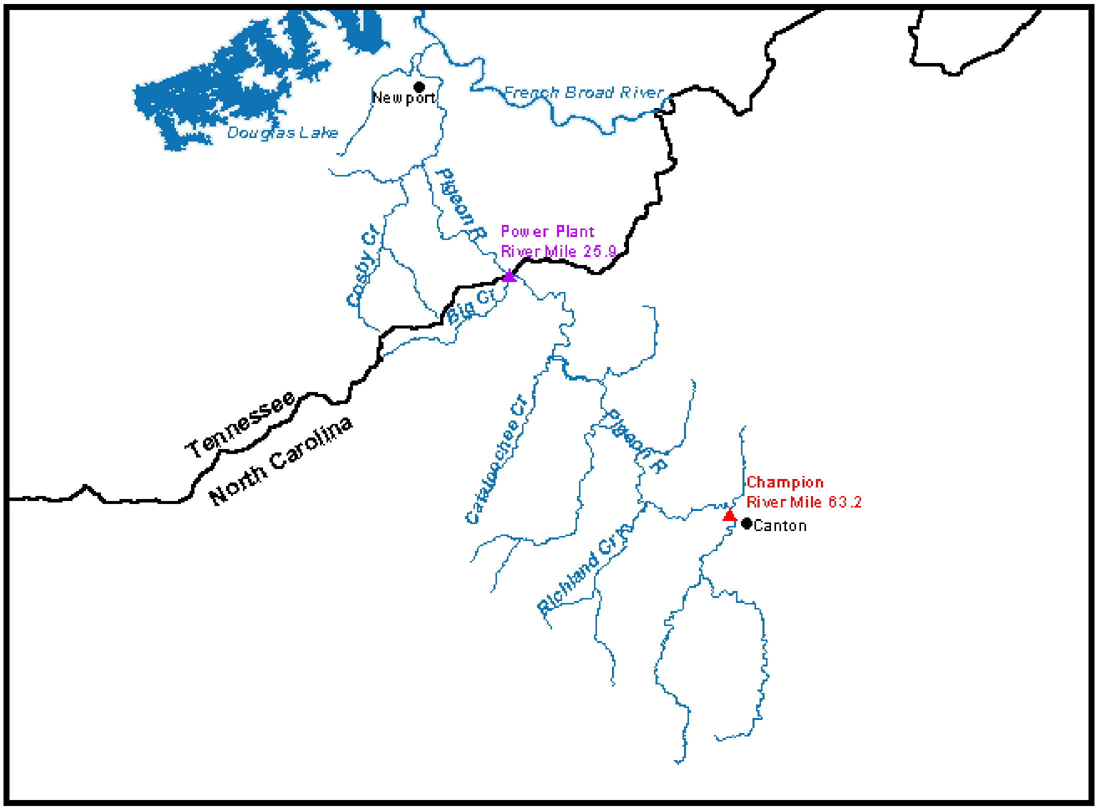

Figure 1. The Pigeon River begins at the confluence of the East Fork Pigeon and West Fork Pigeon Rivers in Haywood County, NC. It flows north to the French Broad River in Cocke County, TN. The headwaters begin in Pisgah National Forest and the paper mill is located at PRK 101.1 (PRM 63.2).

(PRK 61.1) further harmed the riverine ecology by altering the hydrology. The formerly clean, clear water of the Pigeon turned foamy and black after 1908 as a result of discharge from the mill. The pollution caused by the mill was overlooked for decades because of the social and economic benefits that the plant provided (Saylor et al. 1993).

In 1988, the Tennessee Department of Environmental Control (TDEC), the Tennessee Wildlife Resources Agency (TWRA), and the Tennessee Valley Authority (TVA) conducted biological monitoring on the Tennessee portion of the Pigeon River. The goal of this monitoring was to assess the quality of the river and to attempt to determine recovery time. Fish samples were collected to determine the Index of Biotic Integrity (IBI) for the river. The IBI is an assessment of a fish community obtained by scoring a fish sample from a given stream site according to 12 parameters (Karr 1981). These parameters reflect the degree of impairment in species richness and composition, trophic structure, fish abundance, and fish condition. The IBI indicates the degree of environmental degradation. The result was 38 or less out of a possible 60, resulting in the classification of this portion of the Pigeon River as "poor". Results from IBIs upstream of the mill rated "good" to "excellent" (Saylor et al. 1993). In 1988 and again in 1996, a variance of the mill's National Pollution Discharge Elimination System (NPDES) permit was issued, allowing them to exceed standards of the Clean Water Act. When the second variance was issued, Tennessee took legal action. After battles over the NPDES permit, a new permit was issued that significantly reduced the loading of pollutants in the discharges (dioxin, increased temperature, objectionable odors) allowed into the Pigeon River. This new permit changed the Pigeon River and the water became cleaner and clearer (TDEC 1997). IBI scores improved and fish species richness increased (EA Engineering 2001).

The years of continuous pollution in the Pigeon River caused many native fish species to become extirpated. Some native species have recolonized the Pigeon River, but many species have not returned on their own. Many have not returned or can not return because of possible barriers. Large distances surviving populations would have to travel, the presence of dams and impoundments, thermal barriers, and the lack of refugia such as tributaries prevent many species from recolonizing in the Pigeon River**.** Also, there is a substantial gradient from the area just downstream of the mill to the river's confluence with the French Broad River. Some of the smaller, less mobile species have been unable to transverse the distance between their existing remaining habitat and the severely impacted portion of the Pigeon below the mill. In Tennessee, state and federal agencies have been working together to try to restore these native populations by beginning a series of re-introductions into the Pigeon River downstream of the paper mill. Cooperators include Blue Ridge Paper Products Incorporated (formerly Champion International), TDEC, TVA, TWRA, and the University of Tennessee.

In 2001, three species were re-introduced: the blueside darter, *Etheostoma jessiae*, bluebreast darter, *E. camurum*, and the gilt darter, *Percina evides*. In 2002, the stargazing minnow, *Phenacobius uranops,* and the mountain madtom, *Noturus eleutherus,* were released into the river. And finally, in 2003, the stripetail darter, *E. kennicotti*, American brook lamprey, *Lampetra appendix*, and mountain brook lamprey, *Ichthyomyzon reeleyi*, were re-introduced resulting in a total of eight species returned into the Pigeon River

(Table 1). Fish were collected from the Little Pigeon River, Nolichucky River, French Broad River, Little River, and Wilhite Creek in East Tennessee.

Two release sites were designated for the re-introduced darters; PRK 8.7 and PRK 13.2 were identified as preferred darter habitat. PRK 8.7 is located in Newport, Tennessee, and is the release site for blueside darters, *E. jessiae* (Figure 2). PRK 13.2 was selected for the three remaining darters (Figure 3). The first blueside darter release was at PRK 13.2, but was moved to PRK 8.7 for the remaining releases because blueside darters have different habitat requirements.

According to the Clean Water Act (US EPA 1977) ,". . . a balanced and indigenous community is characterized as one that has diversity, has the capacity to sustain itself through cyclical seasonal changes, contains the necessary food chain species, and is not dominated by pollution tolerant species." The re-introductions of native fish populations in the Pigeon River can eventually restore biodiversity into the river and return the Pigeon into what it once was before the effects of paper mill effluents severely impacted the river. Darters are sensitive to environmental degradation as a result of their specific reproductive and habitat requirements (EA Engineering 2001). The restoration of the Pigeon River to historical conditions can be augmented by re-introducing such sensitive species as darters, providing they are able to survive and reproduce. Re-introductions can be considered a success if they result in a self-sustaining population (Griffith et al. 1989).

The objective of this study was to determine if the attempt to re-establish darter populations (Figure 4) was successful by monitoring the re-introduced species for

Table 1. Re-introduced fish species with date of collection, species, number of individuals (N), collection source, tag color (VIE), and release site.

Key

Species	Collection Source
BS = Blueside Darter	MPLP = Middle Prong, Little Pigeon
G = Gilt Darter	N = Nolichucky
BB = Bluebreast Darter	FB = French Broad
S = Stargazing Minnow	LRCB = Little River, Coulters Bridge
MM = Mountain Madtom	LRT = Little River, Townsend
ST = Stripetail Darter	WC = Wilhite Creek
ABL = American Brook Lamprey	LC = Little Chucky Creek
MBL = Mountain Brook Lamprey	

VIE Color	Release Site
R = Red	TI = Tannery Island (PRK 13.2)
G = Green	MMB = McSween Memorial Bridge (PRK 8.7)
Y = Yellow	
O = Orange	
P = Pink	
NT = No Tag	

Date	Species	N	Collection Source	VIE color	Release Site
3/14/2001	BS	128	MPLP	R	TI
5/23/2001	G	120	MPLP	R	TI
	BS	1	MPLP	R	TI
10/2/2001	G	132	MPLP	G	TI
	BS	4	MPLP	G	TI
10/9/2001	G	41	N	Y	TI
	BB	121	N	Y	TI
11/6/2001	G	52	N	Y	TI
	BB	122	N	Y	TI
	BS	6	N	Y	TI

Table 1. (Continued)

Date	Species	N	Collection Source	VIE color	Release Site
2/8/2002	BS	113	MPLP	O	MMB
	G	51	MPLP	O	TI
	S	4	MPLP	O	TI
2/15/2002	BS	107	MPLP	O	MMB
	G	43	MPLP	O	TI
	S	18	MPLP	NT	TI
3/15/2002	BS	145	MPLP	O	MMB
	S	31	MPLP	NT	TI
4/26/2002	MM	116	FB	NT	TI
5/21/2002	G	157	MPLP	O	TI
	S	56	MPLP	NT	TI
5/28/2002	G	136	MPLP	O	TI
	S	116	MPLP	NT	TI
6/25/2002	MM	68	FB	NT	TI
8/28/2002	BB	86	N	P	TI
	G	28	N	P	TI
	MM	9	N	NT	TI
10/23/2002	G	126	MPLP	P	TI
	S	6	MPLP	NT	TI
3/13/2003	BS	115	MPLP	R	MMB
	G	61	MPLP	R	TI
	S	2	MPLP	NT	TI
	ST	5	MPLP	R	TI
4/3/2003	BS	84	MPLP	R	MMB
	G	42	MPLP	R	TI
	ST	29	MPLP	R	TI
5/30/2003	MM	163	FB	NT	TI
6/3/2003	ST	64	MPLP	R	TI
	BS	20	MPLP	R	MMB
7/21/2003	BB	5	LRCB	R	TI
	G	14	LRCB	R	TI
	MM	2	LRCB	NT	TI
	S	5	LRCB	NT	TI
7/28/2003	ABL	48	LRT	NT	TI
	MBL	10	LRT	NT	TI

Table 1. (Continued)

Date	Species	N	Collection Source	VIE color	Release Site
8/15/2003	ST	66	WC	R	TI
	BS	5	WC	R	MMB
8/21/2003	MBL	108	LRT	NT	TI
	ABL	237	LRT	NT	TI
8/26/2003	MM	23	FB	NT	TI
9/26/2003	ABL	192	LRT	NT	TI
	MBL	121	LRT	NT	TI
10/14/2003	ST	141	MPLP	G	TI
	BS	27	MPLP	G	MMB
	S	4	MPLP	NT	TI
10/28/2003	ST	188	MPLP	G	TI
	BS	11	MPLP	G	MMB
	G	12	MPLP	G	TI
	S	28	MPLP	NT	TI
2/20/2004	BS	211	LC	O	TI

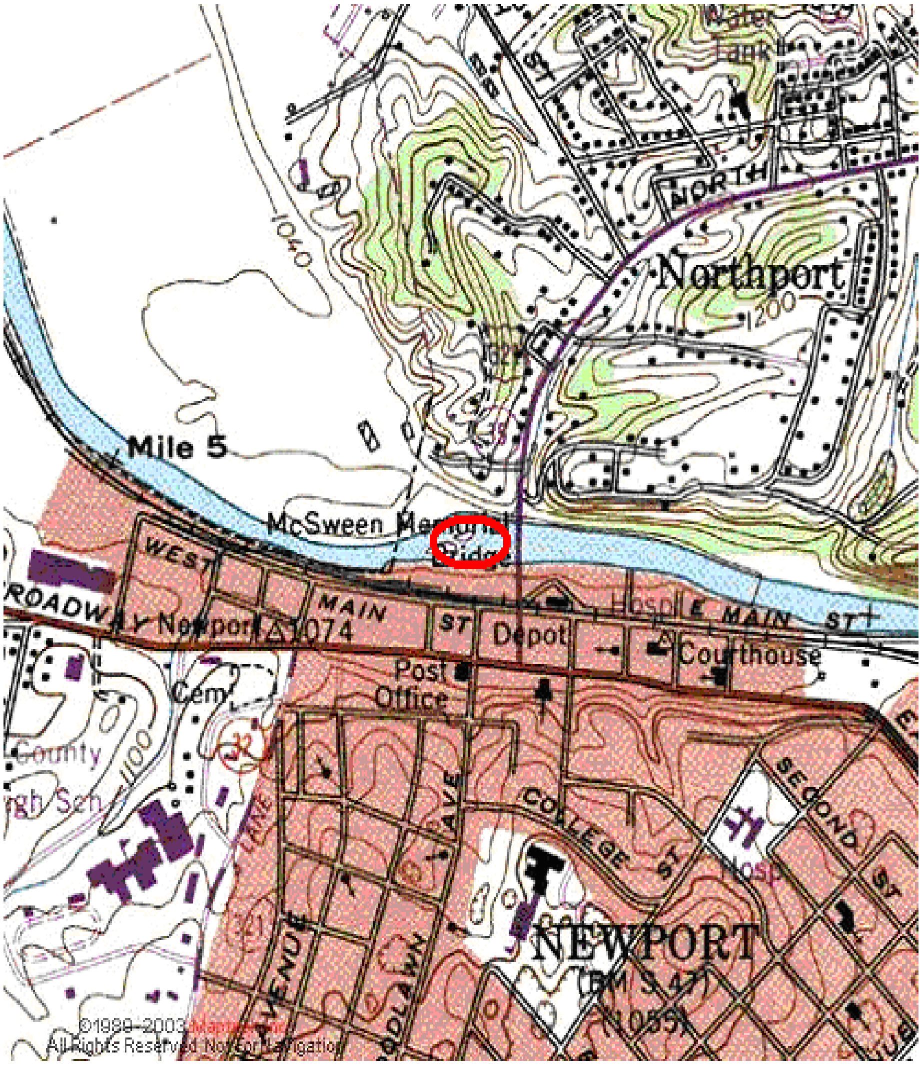

Figure 2. The release site PRK 8.7 (circled in red) for blueside darters, which is upstream of McSween Bridge, Newport, TN. (USGS Newport Quadrangle, Tennessee – Cocke County, 173 – NW).

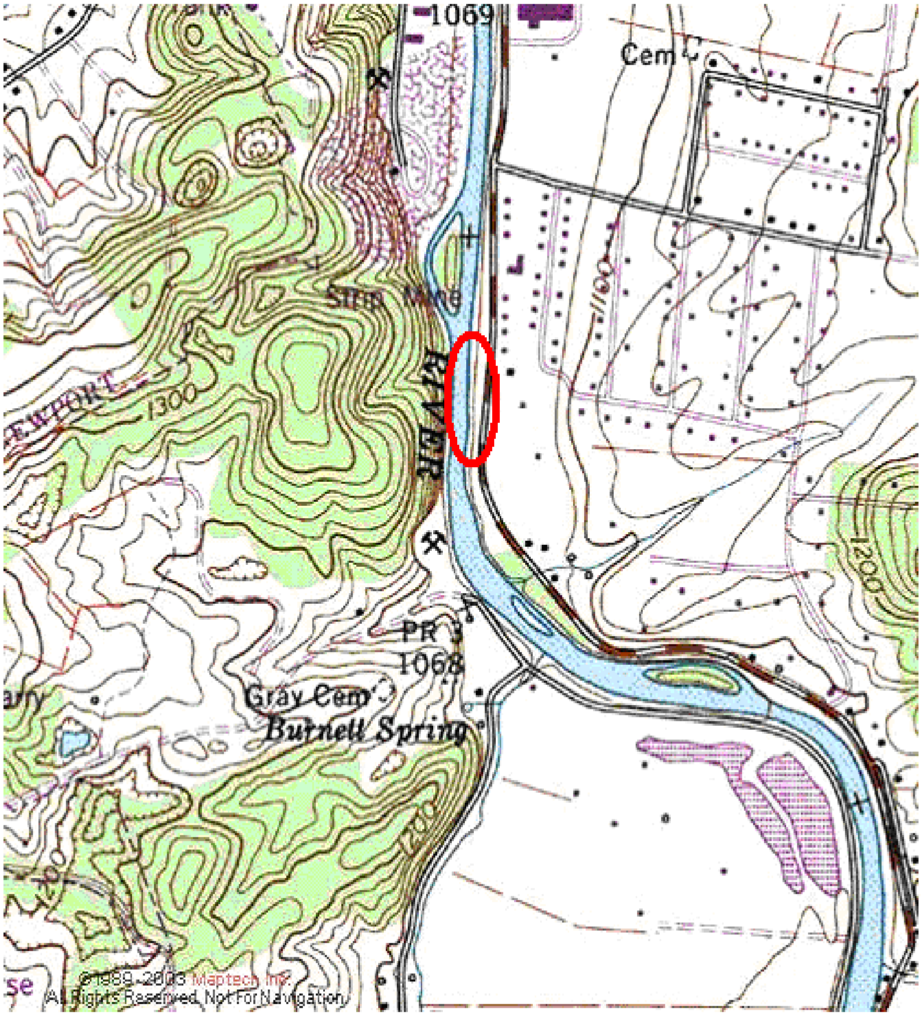

Figure 3. The release site PRK 13.2 (circled in red) for bluebreast, gilt, and stripetail darters, upstream of Newport, TN. (USGS Newport Quadrangle, Tennessee – Cocke County, 173 – NW).

a)

b)

c)

d)

Figure 4. Four species of darters re-introduced into the Pigeon River, 2001-2003: a)gilt darter, b)bluebreast darter, c)blueside darter, d)stripetail darter. Illustrations courtesy of Richard Bryant, Fishes of Tennessee (Etnier and Starnes 1993).

movement and reproduction. One or two years of successful spawns will not necessarily mean a species has "recovered". Therefore, the efforts to re-establish darter populations will continue for several years along with monitoring reproductive success of the re-introduced species.

CHAPTER II

Literature Review

Re-introduction

A re-introduction is a planned release of native species into an area for the purpose of re-establishing that population (Griffith et al. 1989). When native species disappear from their home range, restoring that area requires re-establishing fish communities. Species become extirpated due to certain conditions; when these conditions no longer exist, re-introductions become an option. For species that can not physically return to their historical range, re-introductions are necessary to re-build populations (Poly 2002). Therefore, re-introductions are becoming increasingly important as a conservation tool (Griffith et al. 1989).

In the southeastern United States, there have been few re-introductions and even fewer attempts to monitor their success. A few successes in the Southeast are the snail darter, *Percina tanasi*; watercress darter, *Etheostoma nuchale*; and the spring pygmy sunfish, *Elassoma alabamae* (Shute et al. 2003). In 1986, Shute et al. (2003) began re-introducing four rare non-game fishes into Abrams Creek. The smoky madtom, *Notorus baileyi*; yellowfin madtom, *N. flavipinnis*; spotfin chub, *Erimonax monachus*; and duskytail darter, *Etheostoma percnurum* were all re-introduced into Abrams creek, Great Smoky Mountains National Park, Tennessee. All species were first re-introduced in 1986 except the duskytail darter, which was re-introduced in 1993. By 2000, all four species had successfully reproduced; snorkel surveys have been used to monitor these species. During these surveys, reproduction was documented by the observed presence of young-of-the-year (YOY) and by the increasing numbers of individuals observed. These observations indicated successful re-establishment of all four re-introduced species in Abrams Creek. Snorkel surveys have proved to be the best method for estimating abundance, collecting life history information, and documenting microhabitat use for rare, benthic non-schooling species. Snorkeling also produces minimal injuries and is less invasive than other methods (Coombs 2003). In order to determine the success of a re-introduction, direct observation, abundance indices, and consistent evidence of spawning may be the only indicators needed to define success (Shute et al. 2003).

In Illinois, Poly et al. (2002) introduced the fringed darter, *E. crossopertum*, into a stream in its native drainage basin. This introduction was made to establish additional populations of the species within the same river basin. This was done as a protective measure to ensure the survival of the species in Illinois. Before introductions began, the study considered factors required for the success of the species. For example, a large enough number of individuals should be introduced that represented several age classes and suitable sex ratios. In addition, introductions should occur shortly before the onset of the reproductive season so that spawning can take place immediately in the new habitat. Introductions should only occur where suitable habitat is available for the introduced species. While monitoring the success of the fringed darter, Poly et al. (2002) observed rapid and normal breeding activity, presence of juveniles and adults, and an increase in nests during the second year. This could be considered successful reproduction, but they were unsure if this initial success was long-term. Therefore, the authors proposed that monitoring introduced populations for longer periods of time would be necessary to determine the overall success of the species. This extended monitoring period has been lacking in a majority of similar studies (Poly et al. 2002).

Griffith et al. (1989) stated that a re-introduction is a success if it results in a self-sustaining population. There are a number of factors that can contribute to a self-sustaining population. Population persistence is promising if the number of individuals is large, the rate of population increase (breeding success) is high, and competition is low. Other factors that may contribute to success are low variance in the rate of increase, the presence of refugia, reduced environmental variation, and high genetic diversity among re-introduced species. In addition, increased habitat quality and introducing wild caught versus captive reared individuals promotes success (Griffith et al. 1989).

In the southeastern U.S., most of the fishes classified as “rare” fall in three general groups: madtoms, darters, and minnows (Etnier and Starnes 1993). Re-introductions for these fish are becoming increasingly necessary in order to save the species. Re-introductions of non-game and game fishes are also becoming more prevalent; to restore aquatic communities by stocking extirpated native fishes. Although there is little or no evidence to suggest that following a disturbance an ecosystem can return to its former state, efforts to restore native species composition are surely beneficial (Mittelbach et al. 1995).

Movement

The movement of fish within lotic environments is an area of interest to biologists and conservationists. Understanding the movements of fish can help conserve species and habitat in streams and rivers. Becoming aware of the distance and direction that a fish moves in a stream will add insight to the habitat requirements of a species. Knowledge of fish movement patterns also provides an understanding of the population dynamics within a stream (Storck and Momot 1981). The general consensus regarding fish movement defines a majority of the population as stationary, with only a few mobile individuals (Funk 1955; Smithson and Johnston 1999; Schaefer et al. 2003). Fish tend to remain in a home range, with only a few individual fish moving long distances (Smithson and Johnston 1999; Schaefer et al. 2003).

Freeman (1995) studied movements of stream fish and concluded that most fish do stay in small areas, although movements greater than 33 m by mobile individuals may not be rare occurrences. This study monitored the movement of blackbanded darters, *Percina nigrofasciata*, and juvenile red-breast sunfishes, *Lepomis auritus.* Blackbanded darters moved both upstream and downstream directions equally. Twenty individual fish moved farther than 33 m; 62% of their movements were less than or equal to 33 m. Freeman (1995) also found that the distance moved was not correlated to fish size.

In a study of the leopard darter, *P. pantherina*, movements were for short distances (200 m) in both stream directions, although most movements were upstream. These movements were among habitat patches, displaying only short-term localized movement (Schaefer et al. 2003).

Smithson and Johnston (1999) studied the movements of four stream species using a mark-recapture method with passive integrated transponder (PIT) tags. The movements of the blackspotted topminnow, *Fundulus olivaceus*; creek chub, *Semotilus atromaculatus*; green sunfish, *L. cyanellus*; and longear sunfish, *L. auritus*, were studied. They discovered that the blackspotted topminnow had twice the proportion of mobile individuals as did the three other species. Thirty-three percent of blackspotted topminnows were mobile, whereas in the rest of the species, 12%, 12%, and 14%, respectively, were mobile. These results indicated that different species of fish have distinguishable movement patterns. This 1999 study defined exploratory movement as a mechanism for recolonization for fish. It also demonstrated that the small portion of the population that are mobile will move to explore new habitats for future recolonization. Funk (1955) also proposed that exploratory movements by these individuals occur from population pressure, allowing the mobile, exploring portion of the population to colonize elsewhere in the stream. Smithson and Johnston (1999) also found that length and weight of fish did not differ between mobile and sedentary individuals. Although the latter study demonstrated very little movement overall, exploratory movement was observed.

The autumn movements of johnny and fantail darters, *Etheostoma nigrum* and *E. flabellare*, were studied to determine the degree and direction of movements in adjoining pool and riffle habitats (Mundahl and Ingersoll 1983). Over 75% of the movements were upstream. The fantail darter's average distance moved was 62 m, whereas the johnny darter's movements averaged 55 m. Johnny darters moved from areas of high population densities to areas with low population densities. Conversely, fantail darters moved into areas with higher populations densities. These results confirmed that population density was not the only factor regulating movement. Availability and varieties of food and cover, stream flow and depth, and the threat of predators all contributed to fish movement. This study established that population density along with habitat quality influenced fish movement (Mundahl and Ingersoll 1983).

Storck and Momot (1981) monitored creek chub movements in a small Ohio stream. The upstream movement of creek chubs greatly exceeded downstream movement. Immature creek chubs were found to move upstream on a regular basis. Adult chubs also moved upstream, and both immature and adults generally moved less than 300 m. The YOY chubs moved downstream, most probably due to passive drift.

In a study of the orangebelly darter, *E. radiosum cyanorum*, fish movements were observed by mark-recapture methods (Scalet 1973). No fish were found to move more than approximately 30 m. Only 5.5% of the marked fish had moved from the point of initial capture. The larval and YOY fish did move downstream, although the study documented little movement, reflecting a small home range for the orangebelly darter.

The motives responsible for fish movement are complex and not entirely understood. The fact that conditions in a stream are constantly changing makes it more difficult to define movements. Population densities and habitat quality control the movement of stream fishes (Mundahl and Ingersoll 1983). The distances and directions that a fish moves seem to vary. Whether fish populations are comprised of a large, stationary group and a small, mobile group (Funk 1955; Smithson and Johnston 1999;

Schaefer 2003), or whether this small population of exploratory individuals is larger and moves farther and more frequently than we think (Freeman 1995), is unknown.

Reproduction

Most darters have specific habitat requirements regarding substrate composition, water velocity, and water depth. Page (1983) suggested that because of darters specialized reproductive behaviors, suitable spawning habitat may be limited.

The following information has been summarized from Page (1983), Etnier and Starnes (1993), and Jenkins and Burkhead (1994). Gilt darters, *P. evides*, spawn from late April to early July in the Southeast, when water temperatures reach 17-20 C. The bluebreast darter, *E. camurum*, blueside darter, *E. jessiae*, and stripetail darter, *E. kennicotti*, spawn in late May-early August, March-April, and early April-late May, respectively. Spawning occurs once a year in the spring season in the southeast U.S and is dependent upon water temperatures. There are two distinct spawning behaviors in darters; they either bury the eggs in the substrate or attach the eggs to an object. In either case, the adhesive eggs will adhere to each other or to the surface where they are deposited. While egg burying is more primitive and occurs in the more primitive *Percina* species, the attachment of eggs to some substrate occurs in most of the *Etheostoma* species. Considering egg placement, it is crucial for darter species to have specialized habitat, especially substrate

Since the purpose of re-introducing species into a river is to develop a self-sustaining population, reproductive success is essential. Determining the ideal habitat for a species is critical so that the species can be released where this habitat is available. Darters will not be able to reproduce successfully without the proper habitat.

Rare fishes can be re-populated by transporting individuals from other locations. However, many darters occur in populations too small to remove the needed number of individuals from the area and captive propagation is necessary for the restoration of these species (Rakes et al. 1999). Because of the limited localities of these species, captive propagation of darters such as the bloodfin, *E. sanguifluum*, and the boulder darter, *E. wapiti*, were initiated. The results were successful and provided crucial information on the spawning and habitat requirements for these species. Captive propagation is now critical in order to re-establish populations of some fishes (Rakes et al. 1999).

CHAPTER III

Methods

Study Area

Four re-introduced darter species (gilt, blueside, bluebreast, and stripetail darters) were released at one of two sites located near Newport, Tennessee. One release site (PRK 13.2), at Tannery Island, was designated for bluebreast darters, blueside darters (1^{st} release only), gilt darters, and stripetail darters. The second release site (PRK 8.7), at McSween Memorial Bridge, was the site for the remaining blueside darter releases. These sites were chosen based on the most suitable habitat for each species. The Pigeon River is characterized as a riffle, run, pool river with substrates of predominately boulder and cobble (Saylor et al. 1993). The release sites were riffle habitats with substrates of primarily cobble with boulder, and some gravel and sand.

Twenty-three sites from Newport to Denton, Tennessee, were selected as suitable habitat for darters. These locations were chosen to serve as monitoring sites for re-introduced darter species. The monitoring sites were all riffle habitats which are ideal for the blueside, bluebreast, and gilt darters (Etnier and Starnes 1993). The riffle sites encompassed a stream reach of 19.5 river kilometers, the most upstream site was located at PRK 28.2 and the furthest downstream site was at PRK 8.7 (Figure 5).

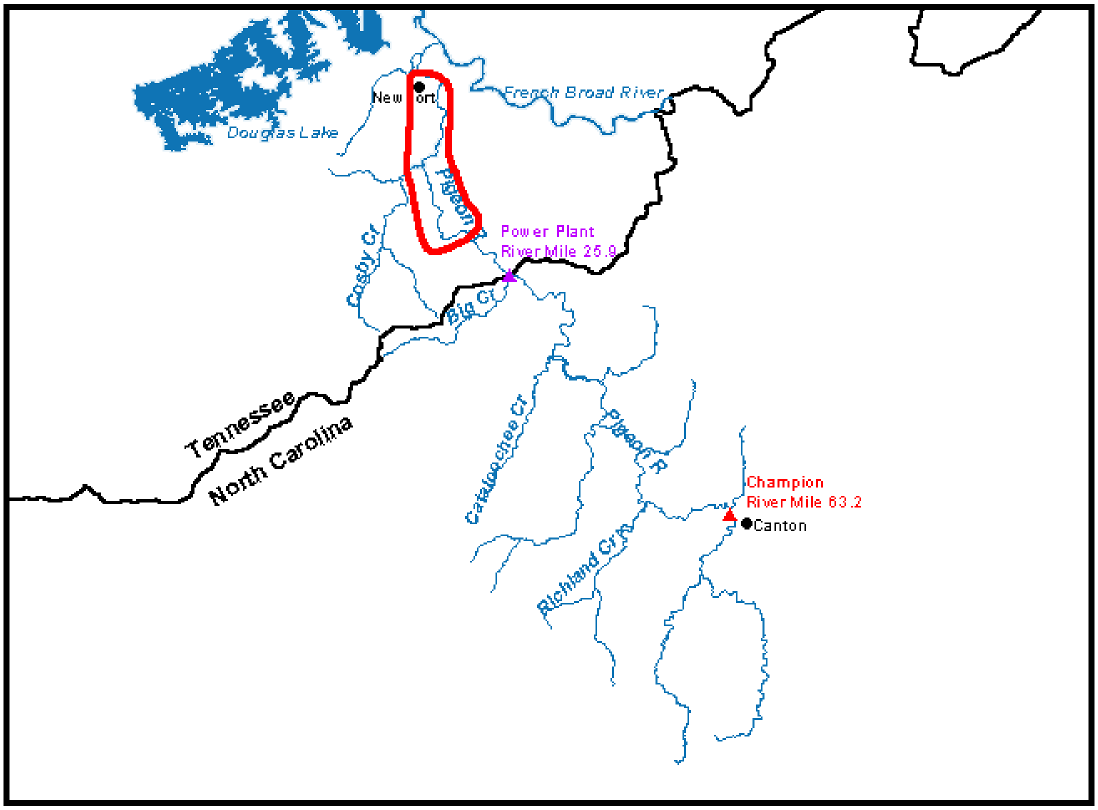

Figure 5. Study area of the Pigeon River, TN (study area circled in red). Study area covers PRK 28.2 to PRK 8.7.

Collection Procedures

All re-introduction procedures were performed according to Coombs (2003). All darters were collected by kick-seining, a method accomplished by holding a 4.6 m seine with 5 mm mesh in a riffle while several people kick downstream towards the net. The kicking stirs up the substrate and causes the fish to move into the net for capture. Kick-seining causes minimal injuries and is appropriate for riffle-dwelling fish.

Bluebreast darters were collected from the Nolichucky River and the Little River. Blueside darters were collected from the Little Pigeon River, Nolichucky River, Little Chucky Creek, and Wilhite Creek in Tennessee. Gilt darters were collected from the Little Pigeon, Nolichucky, and Little River; while stripetail darters were collected from Little Pigeon River or Wilhite Creek.

After collection, fish were anesthetized with tricaine methanesulfonate (MS-222). This was done by mixing MS-222 in a 1.0-L container with water (Figure 6). Fish were added to the anesthetic solution a few at a time; temperature and dissolved oxygen (DO) were monitored at all times. The sex and total length (TL) in mm of each tagged fish was recorded. Darters were kept in aerated coolers from the period of capture until transport; during the tagging process, darters were kept in an aerated 1.0- L container. While anesthetized, fish were tagged with visible implant fluorescent elastomer, VIE (Northwest Marine Technology, Inc). It was injected into the fish at the base of the first or second dorsal fin (Figure 7). The needle was placed just below the dermis, and parallel

Figure 6. Tagging in the field

Figure 7. VIE tagging, base of second dorsal fin

to the skin. While it was being retracted, the puncture caused by the needle was filled with liquid elastomer. Different colors of elastomer were used to distinguish separate collection seasons. After VIE tagging, fish were allowed to recover in a cooler supplied with oxygen; temperature and DO were monitored at regular intervals. For transport to the relocation site, fish were placed in large plastic bags with oxygen added and then released into the river after an appropriate water temperature acclimation period.

Snorkel Surveys

Snorkel surveys were used to determine the status of re-introduced fish species by direct observation. This information was recorded and utilized to document survival and the location and overall movements of each group. Snorkeling has been documented as the least invasive and most efficient method for determining darter presence (Mattingly and Galat 2002).

At each site, experienced snorkelers moved slowly downstream, remaining parallel to each other during the surveys (Figure 8). In previous studies, gilt darters were observed to have shown flight behavior from snorkelers moving upstream; therefore, downstream surveys were conducted (Coombs 2003). Surveys were always performed during daylight and with maximum water clarity. Generally, there were two snorkelers, but up to four or five participated on some snorkeling surveys. Each survey began slightly upstream of the designated riffle site and continued until the preferred riffle habitat ended. When darters were located, lead weight markers were placed at the site; tag color (if present), gender,

Figure 8. Snorkelers line up parallel and move downstream to locate darters

and age class of each darter were recorded. Snorkelers communicated during the survey to minimize duplicate counts.

Habitat characteristics were described by snorkelers where the re-introduced darter species were found. The substrate composition, associated fish species, and water velocity were also recorded. Substrate was classified visually according to the Wentworth scale for classification of substrate composition (Murphy and Willis 1996). This scale defines boulder as greater than 256 mm in diameter and cobble as 64-256 mm. For this study, pebble, gravel, and sand substrates were classified together as gravel/sand. The particle size for gravel/sand substrates are up to 64 mm in diameter. Substrate was divided into four classes: boulder, cobble, bedrock, and sand and gravel. The approximate proportion of each substrate class within a riffle was recorded. Visual estimates based on size can be biased due to differences in individual perception and magnification under water (Murphy and Willis 1996). The populations of associated fish species were determined by recording all fish species observed. Velocities were measured by timed floats of an orange over a 10-m distance (Figure 9). All velocity measurements were performed three times and the average was recorded.

Of the 23 sites chosen for monitoring, 21 were surveyed by snorkelers. Two of the sites had high water velocities making them impossible to survey. Of the 21 sampling sites, each site was surveyed at least once; both release sites were also surveyed. All sites were surveyed when the sun was out and water clarity

Figure 9. Measuring stream velocity: an orange was timed on a 10-m float downstream. Three velocity measurements were recorded at the site where gilt darters were observed and a mean value determined.

was ideal. Snorkel surveys occurred from June to October of 2003 with most performed during August and September. Few surveys were made during the summer due to unusually abundant precipitation, which caused high, fast flows in the Pigeon along with increased turbidity.

CHAPTER IV

Results and Discussion

Movement

The movements of stream fish are difficult to determine because rivers and streams are open ecosystems. Fish movement is obviously regulated by a number of factors, including population pressure, habitat or reproduction requirements, and many other factors. Habitat requirements must be met because they are the features of the environment that are necessary for the persistence of the population (Rosenfeld 2003). If habitat requirements are suitable, then fish may move for other reasons. During this study, snorkel surveys were performed and gilt darters were observed for movement, reproduction, and preferred habitat. It was crucial to determine favored habitat for the gilt darters to establish reasons behind movement and to extend our knowledge of gilt darter biology. Within a given riffle habitat, the percentages of different substrates were determined and the fish community was recorded. Where gilt darters were observed, water velocity was also measured and recorded (Table 2).

Gilt darters have been found to occur in moderate to fast current with substrates of gravel, sand, and scattered rubble, free of vegetation (Etnier and Starnes 1993). In a life study of the gilt darter, Hatch (1982) determined that breeding adults preferred substrates of predominantly embedded cobble in sand

Table 2. Sites (PRK) with substrate (%), velocity (m/s), number, and age groups of gilt darters observed.

Site	adult	juvenile	YOY	velocity	cobble	boulder	sand/gravel	bedrock/slabrock
8.7*R	0	0	0		80	10	10	
9.5	2	0	0	0.70	80	15	5	
10.9	1	0	0	0.69	80 and 50	15 and 50		5 and 0
11.6	6	10	48	0.44	80	5	5	10
11.9	0	0	1	0.58	85	5	5	5
12	0	0	2	0.46	85	5	5	5
13.2*R	53	3	0	0.54	80	15	5	
13.5	27	2	0	0.53	80	15	5	
13.7	0	0	0		50	50		
15.5	0	0	0		40	60		
16.1	0	0	0		40	60		
17.2	0	0	0		65	35		
18	0	0	0		30	70		
18.5	0	0	0		30	70		
19.3	0	0	0		30	70		
20.4	0	0	0		50 and 65	50 and 35		
21.7	0	0	0		60	20	20	
22.5	0	0	0		30	70		
23.3	0	0	0		0	40	10	50
23.7	0	0	0		30	65	5	
26.4	0	0	0		0	80	10	10
27.4	0	0	0		40 and 5	60 and 95		
28.2	0	0	0		95 and 60	0 and 40	5 and 0	

and gravel. Clean sand and gravel are used as spawning substrate. Therefore, these substrates needed to be present for a successful re-introduction.

During this study, bluebreast, blueside, and stripetail darters were not observed after re-introduction into the Pigeon River. Bluebreast re-introduction numbers were low in comparison with the other darters. Only five individual bluebreast darters were introduced in 2003, with a total of only 334 re-introduced into the Pigeon since 2001. The low numbers of bluebreast darters are most likely the reason they were not observed. Stripetail darters were not re-introduced until March 2003, and a total of 493 have been released in the Pigeon. They were a recent re-introduction and stripetails occupy a different habitat than gilt darters. It is probably for these reasons that stripetail darters were not observed. Stripetail darters prefer pool areas with slabrock (Etnier and Starnes 1993).

The blueside darters also differ in habitat preferences from gilt darters; they prefer more sandy areas (Etnier and Starnes 1993). Blueside darters were released at a different site than other darters; the release site had more sandy substrate than the alternate release site. As of February 2004, a total of 977 blueside darters had been released into the Pigeon River. The bluesides may have moved further downstream to find more suitable habitat.

Only gilt darters (N=1015) re-introduced into the Pigeon were observed in the river in 2003. Therefore, all results will pertain only to this species. From the release site, PRK 13.2, gilt darters were found to move 0.3 km upstream to PRK 13.5 and 3.7 km downstream to PRK 9.5 (Figure 10). Within this range of movements, there were six

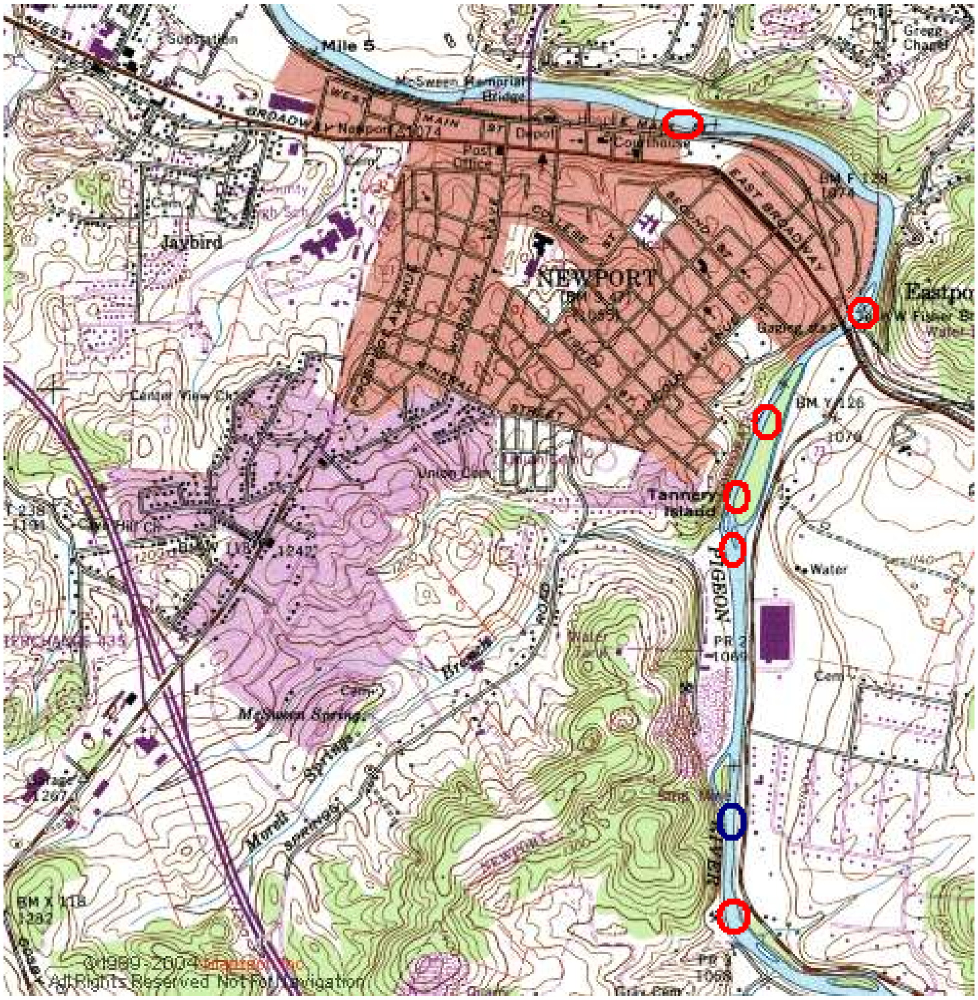

Figure 10. Sites where gilt darters were observed (circled in red), release site (circled in blue) at 13.2 PRK.
(USGS Newport Quadrangle, Tennessee – Cocke County, 173 – NW).

sampling sites (not including the release site PRK 13.2), one upstream from the release site and five downstream; gilt darters were observed at all six sites.

Each gilt darter observed was classified according to one of three age classes (YOY, juvenile, adult) based on their length. According to Hatch (1982), the minimum length at which males appear to become mature is approximately 50 mm standard length (SL). In his study, no males under 50 mm SL had breeding tubercles. Etnier and Starnes (1993) determined that gilt darters averaged 34-40 mm SL at three months and 50 mm SL at one year. They also determined total lengths (TL) for age groups to be 45-50 mm for YOY, 60-70 mm for yearlings, and 80 mm for gilts ending their third summer. Jenkins and Burkhead (1994) described gilts as being sexually mature at 50 mm SL. Measurements of preserved gilt darters (Clinch River 13 June 1992) were taken from specimens at the University of Tennessee research collection of fishes to estimate age group intervals. From these lengths, YOY ranged from 22-28 mm TL, juveniles ranged from 41-48 mm TL, and adults were all greater than 50 mm TL. The gilt darter age groups for the current study were classified according to these length values**.** YOY were classified as being 34 mm TL and below, juveniles were 35-50 mm TL, and adults as being greater than 50 mm TL. Underwater surveys may be biased because of magnification of specimens up to 1.33X, depending on the distance from the subject; this was taken into consideration during the surveys. Most gilt darters, especially the YOY, came within 30 cm of snorkelers during the surveys . Age classes and number of individuals found at each site are presented in Figure 11.

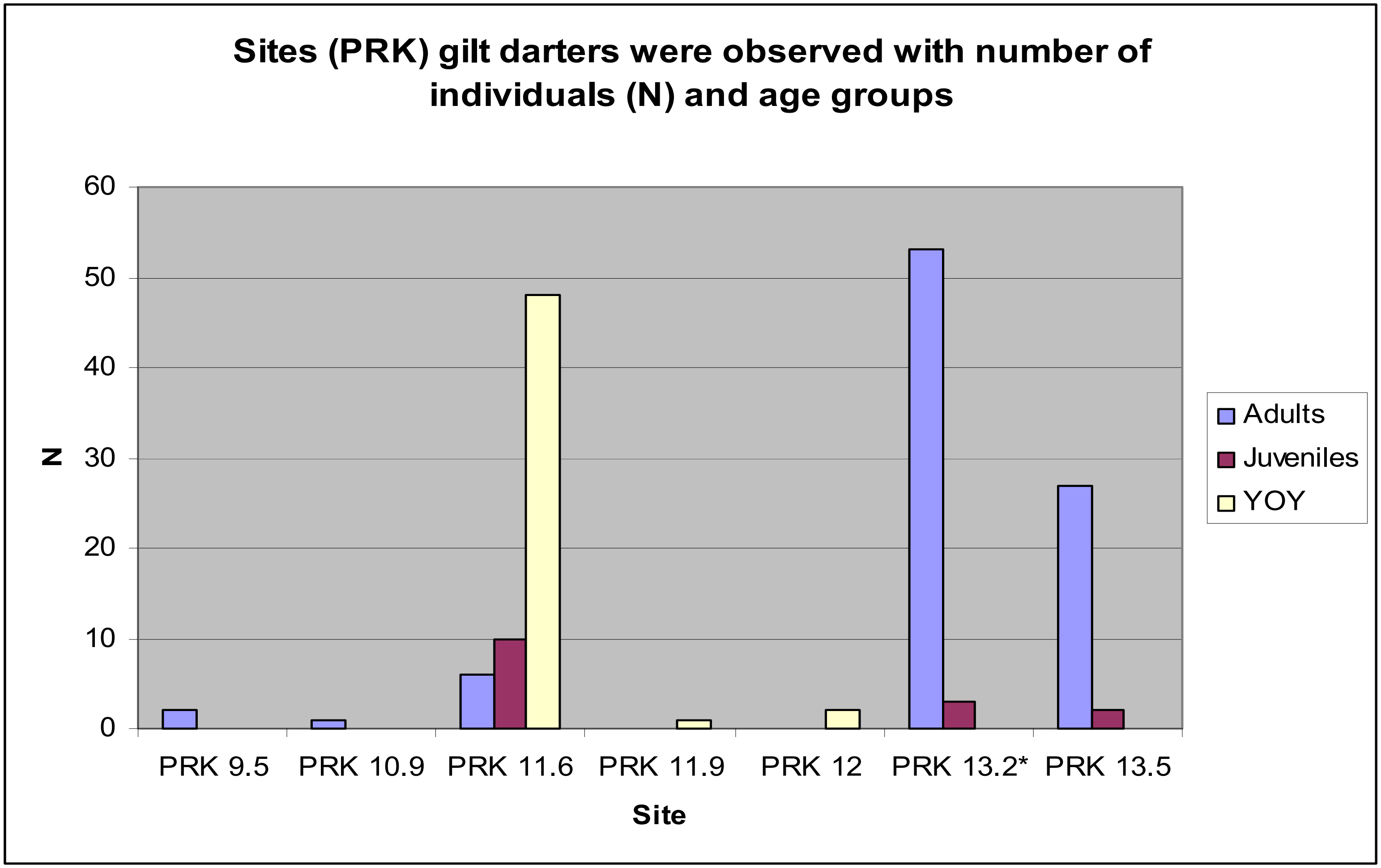

Figure 11. Relative number and age classes of gilt darters observed at seven sites (PRK) in the Pigeon River, TN, 2003. The asterisk (*) indicates the release site for all the gilt darters.

Most adult gilt darters remained at the release site (PRK 13.2) or moved upstream to PRK 13.5. These sites were comprised of 80% cobble, 15% boulder, and 5% sand/gravel. Of the 89 adults observed, 53 were found at the release site (PRK 13.2), and 27 were found upstream at PRK 13.5. Adults were also observed downstream at PRK 11.6, PRK 10.9, and PRK 9.5, but the number of individuals was low (6, 1, and 2, respectively). Few juveniles were observed in the population; only 15 were recorded. Juveniles can be difficult to classify because adult females are similar in appearance and in length to juveniles. The juveniles that were observed were at the release site (PRK 13.2), upstream at PRK 13.5, and downstream at PRK 11.6. The substrate characteristics observed where juveniles were seen included 80% cobble, 15% boulder, and 5% sand/gravel at PRK 13.2 and 13.5 and 80% cobble, 5% boulder, 5% sand/gravel, and 10% bedrock/slabrock at the downstream site, PRK 11.6.

Adult and juvenile fish movements may be the result of overpopulation. Exploratory individuals access alternative habitats when densities at an occupied habitat increase. Funk (1955), Smithson and Johnston (1999), and Schaefer (2003) all proposed that stream fish movement is determined by a large stationary group and a small, exploratory group. These exploratory individuals are the excess of the population and move to find new habitats and colonize there.

These earlier studies could provide the reason for gilt darter movements in the Pigeon River. The release site seems to be ideal habitat, so movement from that site could have been due to high densities creating competition. PRK 13.2 must be favored gilt darter habitat because they are remaining there and have successfully reproduced.

Another reason for downstream movement of adult and juvenile gilt darters could have been the unusually high rainfall in the spring and summer of 2003, causing high, fast flows in the river (Figure 12). The high flows could have swept these individuals downstream. Adult and juvenile gilt darters preferred 80-85% cobble, 5-15% boulder, and 5% sand/gravel. YOY fish, which were classified as being 34 mm TL or less, were found 0.8-1.6 km downstream of release site. Two were seen at PRK 12, one at PRK 11.9, and 48 at PRK 11.6 (Figure 13). The YOY were found over bedrock substrate. Only 6 of the 21 sample sites contained bedrock/slabrock and three of them had YOY gilt darters. YOY were found over substrate comprised of 80-85% cobble, 5% boulder, 5% sand/gravel, and 5-10% bedrock/slabrock. Of the 51 YOY that were found, 48 occupied the site (PRK 11.6) with 10% bedrock/slabrock and the fish were grouped over this substrate. This is because YOY gilt darters seem to prefer smooth surfaces (Pat Rakes, personal communication). Natsumeda (2003) explained that ". . . large, unembedded substrate (e.g., bedrock) often provides permanent safe refuges for stream fishes against floods and predators." YOY gilt darters were found exclusively over bedrock. Also, the 48 YOY were all grouped together at PRK 11.6. These were determined to be YOY because of their appearance and size, and because they differed in behavior and habitat locations from adult or juvenile gilt darters. YOY gilt darters most likely moved downstream due to drift. *Percina* larvae tend to be pelagic and drift passively downstream after hatching (David Etnier, personal communication). In 2003, precipitation was excessive and Pigeon River flows were well above normal. These increased flows probably also contributed to YOY movement downstream.

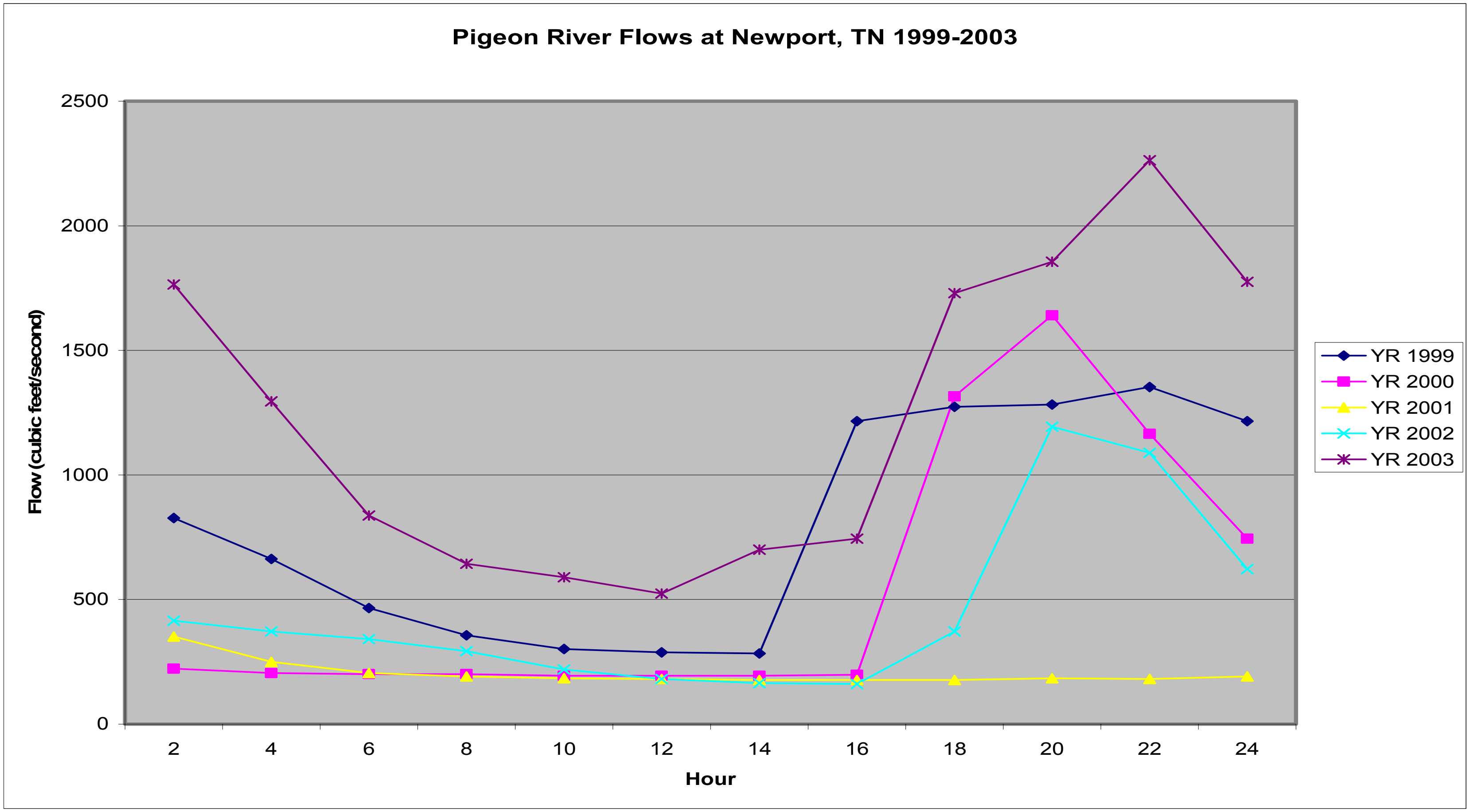

Figure 12. Pigeon River flows (cfs) on June 15, 1999-2003, at Newport, TN

Figure 13. PRK 11.6. The site where the lowest velocity (0.44 cfs) was recorded; 48 YOY gilt darters were seen over bedrock/slabrock at this location.

Harvey (1987) studied the effects of floods on downstream displacement of YOY fishes less than 25 mm TL in Brier Creek, Oklahoma. This study illustrated that drift was influenced by water velocity, turbulence, and light. The ability of fishes to withstand floods and avoid drift increased with fish size. Harvey determined that drift of larvae can be considerable even at base flow in lotic environments, and even more substantial at flood levels.

Natsumeda (2003) studied the movements of adult Japanese fluvial sculpins, *Cottus pollux*, in a Japanese mountain stream impacted by floods. Sculpins occupy the interstitial spaces of substrate, and floods fill the interstitial spaces with silt and gravel. Thus, sculpins are more vulnerable to flood disturbance than species that occupy the water column. Floods force sculpins to seek refuge elsewhere. Since gilt darters are also riffle-dwelling species, floods or excessive flows might affect them in a similar fashion.

White and Harvey (2003) studied the distribution and abundance of drifting embryonic and larval fish in northern California. This study indicated that the drift of larval fish is a crucial part of the ecology of stream fishes. Larval drift can act as population control by distributing fish species in streams and rivers. In the present study, YOY gilt darters were found downstream 0.3 km to 1.6 km from the release site in the Pigeon River (PRK 13.2). The majority were found at PRK 11.6, downstream of the release site (PRK 13.2).

The substrate composition at sites where no gilts were found was estimated to be less than 80% cobble, although there were exceptions. PRK 28.2, the furthest upstream of all sites had 95% cobble, 0 % boulder, and 5% sand/gravel in one area. This site was

15 km from the release site and only one site (PRK 13.5) between these two was considered preferred habitat. PRK 13.5 was inhabited by gilt darters, but they would most likely not travel 14.7 km to the extreme upstream site, since sites with suitable habitat were available nearby. PRK 28.2 contained more cobble and no boulder than occupied sites, so cobble ratios could be too high for ideal habitat and small amounts of boulder could be crucial. The other site exception was PRK 8.9, the release site for blueside darters. The substrate composition at this site is 80% cobble, 10% boulder, and 10 % sand/gravel. All sites with gilts had 5 % sand/gravel. More sand and gravel could have deterred them from this site. This site also contained some vegetation, and gilts prefer habitats free of vegetation (Etnier and Starnes 1993). The results of this study indicated that gilt darters preferred a substrate comprised of 80-85% cobble, 5-15% boulder, and 5% sand/gravel. YOY gilt darters also occupied these substrates but favored 10% bedrock/slabrock as well.

Velocities were recorded for sites where gilt darters were observed. The average velocity of these sites was 0.52 m/sec. The three sites where YOY were observed had slightly lower velocities than the other four sites. YOY would be expected to inhabit lower velocities because of their smaller size and limited swimming ability.

Fish community composition is important to know because certain species coexist with each other within riffles. Resource partitioning and habitat segregation allow riffle-dwelling species to coexist, forming groups with species that benefit each other (Chipps et al. 1993; Stauffer et al. 1996). Gilt darters were found with logperch, *Percina caprodes*; greenside darters, *Etheostoma blennioides*; snubnose darters, *E. simoterum*;

redline darters, *E. rufilineatum*; northern hogsuckers, *Hypentelium nigricans*; whitetail shiners, *Cyprinella galactura*; Tennessee shiners, *Notropis leuciodus*; central stonerollers, *Campostoma anomalum*; and banded sculpins, *Cottus carolinae* (Figure 14). The association of gilt darters with logperches is not surprising. Gilt darters have been known to form groups with other blotch-sided darters (Jenkins and Burkhead 1993). Etnier and Starnes (1993) observed gilt darters feeding in association with logperches, ". . . following them about as they engage in their stone-flipping behavior and rushing in to steal the food items revealed beneath." This behavior represents species co-existing and illustrates that gilt darters belong in this habitat in the Pigeon.

Generally, population pressure and habitat quality define fish movements (Mundahl and Ingersoll 1983), although other factors can contribute. Precipitation can influence fish movement. During the spring and summer of 2003, river flows were well above average. The movements of gilt darters in this study seemed to be influenced by population pressure, normal larval drift, and high flows.

Reproduction

The reproduction of re-introduced species is critical for survival and, therefore, for the success of re-introductions. A self-sustaining population must develop for re-introductions to be successful (Griffith et al. 1989). During the present study, reproduction was evident with the observance of YOY gilt darters. Also, darters without visible tags most likely indicated reproduction. Ninety-six gilt darters seen were without tags. Fifty-one of these were YOY and 15 were juveniles. Excluding the YOY and

a) 

b) 

c) 

d) 

Figure 14. Fish community associated with gilt darters: a)logperch; b)greenside darter; c) snubnose darter*;* d)redline darter; e)northern hogsucker; f)whitetail shiner; g) Tennessee shiner; h)central stoneroller; i)banded sculpin. Illustrations courtesy of Richard Bryant, Fishes of Tennessee (Etnier and Starnes 1993).

e)

f)

g)

h)

i)

Figure 14. (Continued)

juveniles, 30 of 89 adult fish were not tagged, indicating 26.7% of the adults observed resulted from reproduction of the 2001 stocking (Table 3).

Tag loss, or the inability to observe tags without a bluelight, could have been factors with observed "untagged" adults. Although Coombs (2003) reported 100 % tag retention in redline darters after 125 days, a few of these tags were difficult to see, especially the yellow tags. All tags fluoresce under a bluelight, but the bluelight was not used in field observations. Thus, some tags may not have been readily visible to the snorkelers. Also, tags are sometimes lost if the injection is placed too deep under the skin (Coombs 2003). During the current study, taggers were experienced and ensured that the needle could be seen just under the skin. Needle insertion could be deemed as correct and tags would remain visible if the needle could be seen under the skin. So, although untagged adult gilts were observed, some could have been a result of faded tag color. This portion of the population was probably small, since tag colors deemed more difficult to see were infrequently used.

Since adults without tags were observed, and juveniles and YOY were recognized, three successful reproductive seasons are likely for the gilt darters. Re-introductions for the gilt darter began in May of 2001. The breeding season begins in late April and ends in early July, so chronologically; the first re-introductions could have reproduced. That they did reproduce is suggested by the (27 %) untagged adults seen during snorkel surveys. The juveniles would represent successful reproduction from the summer of 2002, and the YOY from the summer of 2003. The juveniles occurring in the Pigeon River were probably about one year of age. They were larger than the YOY, but

Table 3. Distributions of gilt darters with survey date, site, age, and tag (if present).

DATE	SITE	ADULT TAGGED	ADULT NOT TAGGED	JUVENILE	YOY
6/24/2003	PRK 13.2	25	5		
6/24/2003	PRK 13.5	12	2		
7/17/2003	PRK 13.2	4	1		
9/10/2003	PRK 9.5	2			
9/16/2003	PRK 10.9		1		
9/30/2003	PRK 11.6		6	10	48
9/30/2003	PRK 11.9				1
9/30/2003	PRK 12.0				2
10/2/2003	PRK 13.5	5	8	2	
10/2/2003	PRK 13.2	11	7	3	

they were not yet sexually mature, as evidenced by their smaller size and less coloration (Etnier and Starnes 1993). Gilt darters reach sexual maturity when they are approximately 50 mm SL, i.e., approximately 55-60 mm TL (Etnier and Starnes 1993; Jenkins and Burkhead 1994). Not all gilt darters reach sexual maturity in their first breeding season, and some individuals do not mature until very late in the breeding season (Hatch 1982). The YOY were seen on 30 September 2003. Since the egg and larval stages are completed within two weeks (Etnier and Starnes 1993), the YOY could have been just over two months of age to approximately five months old. Gilt darters have been observed to be 34-40 mm SL at three months and 50 mm SL at one year (Etnier and Starnes 1993).

During snorkel surveys, the YOY were classified as 34 mm TL or less. This would suggest that the observed YOY were less than three months old and that they emerged late in the breeding season. High flows in the Pigeon during the summer of 2003 could have affected breeding season, i.e., the gilt darters may have waited until the flows subsided later in the season to breed. Floods and high flows have been shown to interrupt and decrease reproductive success. Unusually high river stages can limit the abundance of early spawning and even postpone the spawning of some darter species (Thomas 1970). Also, as stated earlier, some gilt darters do not sexually mature until very late in the breeding season, and observed YOY could have been produced by the late-spawning portion of the population. The YOY observed were very small and their size indicates that this late breeding season probably did occur.

During the summer of 2003, gilt darters successfully reproduced in the Pigeon River, as evidenced by the YOY observed. Three age groups were observed (Figure 15), suggesting three successful breeding seasons since their initial release in May 2001. The results of this study indicate that they have been successful in sustaining populations thus far**.** “Fish reproducing in the wild is the best ecosystemic indicator of an optimal stream ecosystem (Neumann 2002)”. Suitable habitat must have been present for this to occur, suggesting that the re-introduced gilt darters are in ideal habitat.

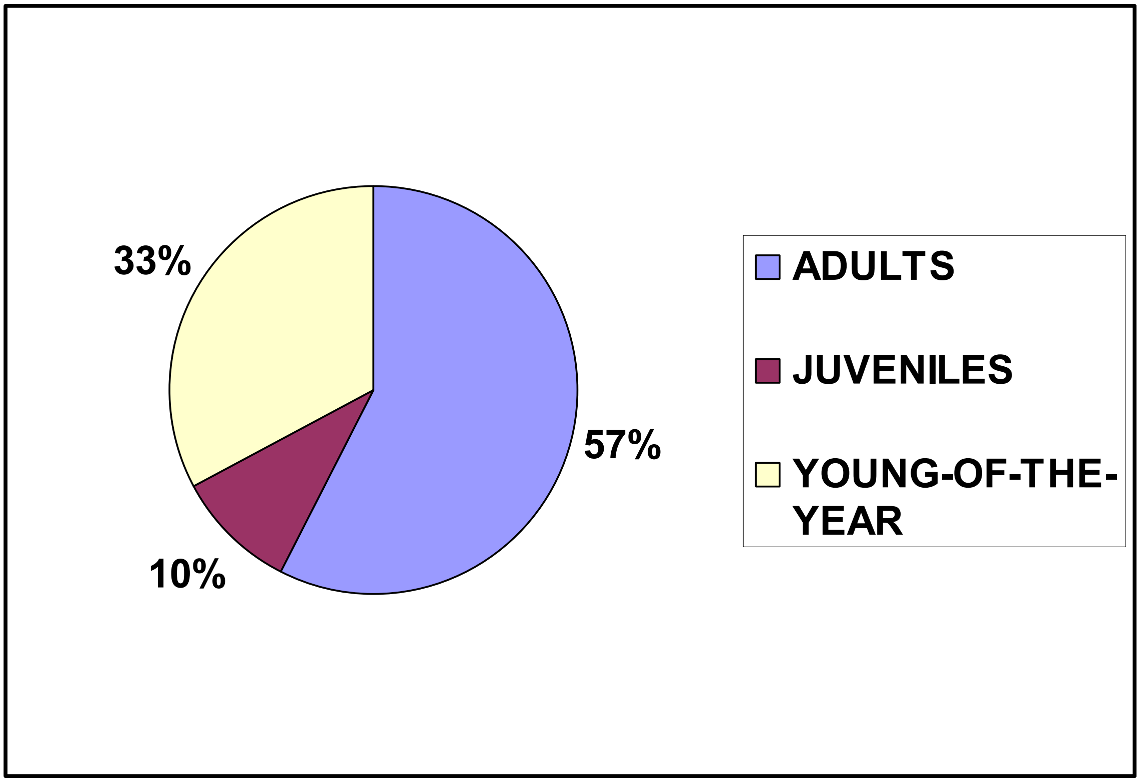

Figure 15. Age groups of gilt darters observed in snorkel surveys in 2003

CHAPTER V

Summary and Recommendations

Re-introductions of the gilt darter, *Percina evides*; bluebreast darter, *Etheostoma camurum*; and blueside darter; *E. jessiae*; were initiated in the summer of 2001 in a 19.5-km reach (PRK 8.7 to PRK 28.2) of the Pigeon River, Tennessee. Stripetail darter (*E. kennicotti*) re-introductions followed in the summer of 2003. The movements and the reproductive success of these species were documented by snorkel surveys at 21 designated sites both upstream and downstream of the re-introduction sites. Results of the study are as follows:

1. Bluebreast, blueside, and stripetail darters were not observed in the Pigeon River at any of the study sites. This was probably due to the fact that substantially fewer numbers of these species were re-introduced into the river than the number of gilt darters or that habitat requirements of these species differed from that of the gilt darters.
2. In 2003, three distinct age groups (adult, juvenile, YOY) of gilt darters were observed by snorkelers at six survey sites, indicating reproductive success in at least two separate years.
3. Adult gilt darters moved 0.3 km upstream (upstream site PRK 13.5) and 3.7 km downstream of the release site (PRK 9.5-PRK 12.0). Approximately 30% of adults moved upstream, 10% moved downstream, and the remainder stayed at the release site.

4. Assuming all reproduction occurred at the release site, juvenile gilt darters moved 0.3 km upstream and 1.6 km downstream; 13% of juveniles moved upstream, 67% moved downstream, and the remainder stayed at the release site.
5. YOY gilt darters moved 1.6 km downstream; there was no upstream movement by YOY.
6. Most of the gilt darters were found over substrates of 80-85% cobble, 5-15% boulder, and 5% gravel and sand. YOY utilized these substrates but were also found in association with an additional 5-10% bedrock.
7. Stream velocity values where gilt darters were observed ranged from 0.44 m/s to 0.70 m/s; the average velocity was 0.59 m/s. YOY were found in the slowest currents, i.e., 0.44, 0.58, and 0.46 m/s.
8. The fish community commonly associated with gilt darters included logperch, *Percina caprodes*; greenside darters, *E. blennioides*; snubnose darters, *E. simoterum*; redline darters, *E. rufilineatum*; northern hogsuckers, *Hypentelium nigricans*; whitetail shiners, *Cyprinella galactura*; Tennessee shiners, *Notropis leuciodus*; central stonerollers, *Campostoma anomalum*; and banded sculpins, *Cottus carolinae.*
9. Of the 155 total gilt darters observed during snorkel surveys, there were 89 adults (30 of these were not tagged), 15 juveniles, and 51 YOY. The 59 tagged adults indicated the VIE tag retention time of over 600 days.

It is recommended that re-introductions of bluebreast, blueside, and stripetail darters be continued until the numbers similar to gilt darter re-introductions are attained. Bluebreast darters are more difficult to find than gilt darters, and usually inhabit different habitats. These fish may be present in the river and even reproducing, but more surveys targeting bluebreasts will be needed to document their status. The blueside darters may have moved downstream from the release site (PRK 8.7) to find more suitable habitat. Those sites downstream of the release site were not surveyed due to inaccessibility by land; a river float is planned for the spring and/or summer of 2004 to survey those sites. Stripetail darters should continue to be re-introduced and surveys for them in shallow, pool areas should begin. Monitoring efforts should continue for all re-introduced darters.

The North Carolina portion of the Pigeon River downstream of the mill is currently being stocked with native fishes. The saffron shiner, *Notropis rubricroceus*, and the mirror shiner, *N. spectrunculus*, have already been re-introduced in this area. Brood stock specimens of the tangerine darter, *Percina aurantiaca*, have been obtained and captive propagation of this species is underway. They will be re-introduced into both the Tennessee and North Carolina portions of the Pigeon River

Although gilt darters are reproducing successfully in the river, monitoring efforts for this species should be continued. The number of gilt darters needed to establish permanent, viable populations in the Pigeon River has yet to be determined. There may be some threshold number of individuals in a re-introduced fish population that is necessary to reach before success is attained (Shute et al. 2003). Continued studies of the gilt darter and other re-introduced species in the Pigeon River may help to unravel these uncertainties.

Literature Cited

Literature Cited

Anonymous. 2003. Maptech Mapserver. http://mapserver.maptech.com/homepage/index.cfm (1 May 2003).

Bartlett, R.A. 1995. Troubled waters. University of Tennessee Press, Knoxville, TN. 329 pp.

Chipps, S.R., and S.A. Perry. 1993. Patterns of microhabitat use among four species of darters in three Appalachian streams. American Midland Naturalist 131: 175-180.

Coombs, J. A. 2003. Tag retention in re-introduced species of selected darters in the Pigeon River, TN. Masters thesis, University of Tennessee. 165 pp.

EA Engineering, Science and Technology. 2001. Balanced and indigenous species study for the Pigeon River; for Blue Ridge Paper Products, Inc.

Etnier, D.A., and W.C. Starnes. 1993. The fishes of Tennessee. University of Tennessee Press, Knoxville. 681 pp.

Freeman, M.C. 1995. Movements by two small fishes in a large stream. Copeia 1995:361-367.

Funk, J.L. 1957. Movement of stream fishes in Missouri. Transactions of the American Fisheries Society 85:39-57.

Griffith, B., J.M. Scott, J.W. Carpenter, and C. Reed. 1989. Translocations as a species conservation tool: status and strategy. Science Articles 245:477-480.

Harvey, B.C. 1987. Susceptibility of young-of-the-year fishes to downstream displacement by flooding. Transactions of the American Fisheries Society 116: 851-855.

Hatch, J.T. 1982. Life history of the gilt darter, *Percina evides* (Jordan and Copeland) in the Sunrise River, Minnesota. Doctoral dissertation, University of Minnesota, Minneapolis. 129 pp.

.

Jenkins, R.E., and N.M. Burkhead. 1994. Freshwater fishes of Virginia. American Fisheries Society, Bethesda, MD. 1079 pp.

Karr, J.R. 1981. Assessment of biotic integrity using fish communities. Fisheries 6:21-27.

Mattingly, H.T., and D.L. Galat. 2002. Distributional patterns of the threatened Niangua darter, *Etheostoma nianguae*, at three spacial scales, with implications for species conservation. Copeia 2002:573-585.

Mittelbach, G.G., A.M. Turner, D.J. Hall, and J.E. Retting. 1995. Perturbation and resilience: A long-term, whole-lake study of predator extinction and reintroduction. Journal of Ecology 76: 2347-2360.

Mundahl, N.D., and C.G. Ingersoll. 1983. Early autumn movements and densities of johnny (*Etheostoma nigrum*) and fantail (*E. flabellare*) darters in a southwestern Ohio stream. Ohio Journal of Science 83:103-108.

Murphy, B.R., and D.W. Willis, editors. 1996. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, MD. 732 pp.

Natsumeda, T. 2003. Effects of a severe flood on the movements of Japanese fluvial sculpin. Environmental Biology of Fishes 68: 417-424.

Neumann, D. 2002. Ecological Rehabilitation of a degraded large river system- considerations based on case studies of macrozoobenthos and fish in the lower Rhine and its catchment area. International Review of Hydrobiology. 87: 139-150.

Poly, W.J. 2002. Design and evaluation of a translocation strategy for the fringed darter (*Etheostoma crossopterum*) in Illinois. Journal of Biological Conservation 113: 13-22.

Page, L.M. 1983. The Handbook of Darters. T.F.H. Publications, Neptune City, NJ. 271 pp.

Rakes, P.L., J.R. Shute, and P.W. Shute. 1999. Reproductive behavior, captive breeding, and restoration ecology of endangered fishes. Environmental Biology of Fishes. 55: 31-42.

Rosenfeld, J. 2003. Assessing the habitat requirements of stream fishes: An overview and evaluation of different approaches. Transactions of the American Fisheries Society 132: 953-968.

Saylor, C.F., A.D. McKinney, and W.H. Schacher. 1993. Case study of the Pigeon river in the Tennessee River drainage. Pages 241-254 *in* Proceedings of the symposium on restoration planning for the rivers of the Mississippi River ecosystem, Larry W. Hessee, editor. Biological Report 19. U.S. Department of the Interior, National Biological Survey, Washington, D.C.

Scalet, C.G. 1973. Stream movements and population density of the orangebelly darter, *Etheostoma radiosum cyanorum* (Osteichthyes:Percidae). Southwestern Naturalist 17:381-387.

Schaefer, J.F., E. Marsh-Matthews, D.E. Spooner, K.B. Gido, and W.J. Matthews. 2003. Effects of barriers and thermal refugia on local movement of the threatened leopard darter, *Percina pantherina*. Environmental Biology of Fishes 66:391-400.

Shute, P.W., J.R. Shute, and P.L. Rakes. 2003. Unpublished report. Reintroduction of four imperiled Southeastern fishes in historic habitat in the Great Smoky Mountains National Park, USA. Tennessee Valley Authority.

Smithson, E.B., and C.E. Johnston. 1999. Movement patterns of stream fishes in a Ouachita Highlands stream: An examination of the restricted movement paradigm. Transactions of the American Fisheries Society 128:847-853.

Stauffer, J.R., J.M. Boltz, K.A. Kellogg, and E. S. van Snik. 1996. Microhabitat partitioning in a diverse assemblage of darters in the Allegheny River system. Environmental Biology of Fishes 46: 37-44.

Storck, T., and W.T. Momot. 1981. Movements of the creek chub in a small Ohio stream. Ohio Journal of Science 81:9-13.

Thomas, D.L. 1970. An ecological study of four darters of the genus *Percina* (Percidae) in the Kaskaskia River, Illinois. Illinois Natural History Survey. Biol. Notes 70: 1-19.

United States. Environmental Protection Agency. Clean Water Act. Washington: Government Printing Office, 1977.

White, J.L., and B.C. Harvey. 2003. Basin-scale patterns in the drift of embryonic and larval fishes and lamprey ammocoetes in two coastal rivers. Environmental Biology of Fishes 67: 369-378.

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