STATUS ASSESMENT OF A SHOAL BASS POPULATION

IN THE LOWER FLINT RIVER, GEORGIA

by

ANDREW THOMAS TAYLOR

(Under the Direction of Douglas L. Peterson)

ABSTRACT

The shoal bass (*Micropterus cataractae*) is a popular sport fish endemic to the Apalachicola-Chattahoochee-Flint Basin of Alabama, Georgia, and Florida. The species is in continual decline throughout its range, probably because of the negative effects of dams, non-native black basses (*Micropterus* spp.), and angling mortality. In this thesis, I present a thorough species review as well as two research chapters addressing the status and threats of a shoal bass population in the lower Flint River, Georgia. I estimated adult abundance within a spawning aggregation and also discovered that ~12% of sampled shoal bass were hybrids with non-native black basses. Mortality of shoal bass translocated during summer fishing tournaments seems relatively high (~33%), but population-level effects remain unclear. I concluded that the study population is facing several threats; therefore, diligent management of the fishery is warranted. Furthermore, similar status assessments are needed throughout the species range to inform future management and conservation efforts.

INDEX WORDS: Introgressive hybridization, Shoal bass, Spawning aggregation, Species review, Status assessment, Threats, Translocation

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DEDICATION

I dedicate this thesis to Mom, Dad, Anna, and Kaitlin. My mom, Teresa, and my dad, Tommy, instilled in me an appreciation for the outdoors that continues to bring joy and direction to my life. My sister Anna's unwavering encouragement kept me motivated in my scholarly and professional pursuits. My girlfriend, Kaitlin, revitalized my faith and happiness during stressful times. The completion of this thesis would not be possible without their constant love, understanding, and support.

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"This world, as a glorious apartment of the boundless palace of the sovereign Creator, is furnished with an infinite variety of animated scenes, inexpressibly beautiful and pleasing, equally free to the inspection and enjoyment of all his creatures."

―   William Bartram, 1791

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CHAPTER 1

BACKGROUND AND CHAPTER ORGANIZATION

Black basses (genus *Micropterus*) are freshwater teleosts belonging to family Centrarchidae. Fossil records indicate that the genus dates back to the Early Miocene and that the origin of the lineage likely evolved about 17 million years ago (Near et al. 2003). The French naturalist Lacépède (1802) described the first black bass, and over 200 years later the most recent species was described by Baker et al. (2008). Modern genetic analyses have revealed further diversity within the genus, and phylogenetic relationships continue to be revised (Johnson et al. 2001; Near et al. 2003; Oswald 2007).

Hook-and-line angling for black basses appears to date back as far as the mid-1700's. Naturalist William Bartram described how Seminole Indians caught warmwater 'trout'; he also noted the fish's sporting and food qualities. From these beginnings, recreational bass fishing in North America has expanded into a multi-billion dollar industry, and presently, black basses are the most pursued freshwater species (U.S. Fish and Wildlife Service [USFWS] 2006). Although increased angling mortality is associated with catch-and-release bass fishing tournaments (Wilde 1998), anglers and their organizations also contribute to large-scale conservation projects (USFWS 2006). Furthermore, many recreational fishing groups are beginning to emphasize the diversity and conservation needs of endemic black basses (Rabb 2009; Jones 2010).

At present, there are eight described species and many undescribed forms of black bass recognized among ichthyologists (National Fish and Wildlife Foundation [NFWF] 2010). Diversity among black basses is highest in the southeastern U.S., with six species endemic to the region (NFWF 2010). Diversity is highest in this region likely because sea level fluctuations from the Middle Miocene to the Pleistocene coincided with allopatric speciation events for black basses within the Gulf of Mexico drainages (Near et al. 2003). Only recently have many of these species been described, including the shoal bass, which was formally described in 1999 by Williams and Burgess. The shoal bass is endemic to the Apalachicola-Chattahoochee-Flint (ACF) Basin of Alabama, Florida, and Georgia (Williams and Burgess 1999) where it supports popular sport fisheries.

Unfortunately, threats to the long-term conservation of shoal bass have increased along with anthropogenic alteration of their habitats. Some of these threats are much older than others. Hydroelectric dams, in particular, were constructed throughout the species range beginning in the early 1900's (Stallings 2005). Recent threats include increased urbanization, increased water withdrawals, and introduction of non-native black basses (Long and Martin 2008; Stormer and Maceina 2008). Based on fisheries data available when the species was described, Williams and Burgess (1999) indicated that the shoal bass is in continual decline and called for comprehensive population and habitat assessments throughout the range.

Recent research efforts on shoal bass have focused largely on identifying habitat requirements for the species (Johnston and Kennon 2007; Stormer and Maceina 2009). This information allows managers to identify, protect, and restore critical habitats within the species range. However, population-specific data – such as estimates of abundance,

mortality, and introgressive hybridization rates – are necessary to assess the status of individual populations and further inform management and conservation efforts. These data are lacking throughout the range, and only one published study directly addresses shoal bass abundance (Stormer and Maceina 2008). Growing concerns over the conservation needs of the shoal bass, coupled with the lack of quantitative data, have created much debate among interest groups regarding the amount of protection needed to maintain recreational fisheries.

In this thesis, I present a current review of the available literature on the species, along with two separate studies that provide new, quantitative information on the status and potential threats to a shoal bass population in the lower Flint River, Georgia. In Chapter 2, I synthesize available literature on the species while highlighting threats and research needs. In Chapter 3, I present a status assessment of the shoal bass population in the lower Flint River, Georgia, between lakes Blackshear and Worth. This chapter includes estimates of spawning aggregation abundance and introgressive hybridization rates, along with a preliminary investigation of internal anchor tag retention. In Chapter 4, I present information on post-tournament survival and movement of shoal bass translocated from the lower Flint River into Lake Worth. Chapter 5 provides a conclusion to the thesis with a summary of key findings and implications from each chapter along with suggestions for future research. This thesis is intended to provide data and interpretations that will inform future management decisions for the study population, provide groundwork for future quantitative research on shoal bass populations, and ultimately provide insights into the status of the species.

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CHAPTER 2

SHOAL BASS LIFE HISTORY AND THREATS: A SYNTHESIS OF CURRENT

KNOWLEDGE OF A *MICROPTERUS* SPECIES[1]

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[1] Taylor, A. T. and D. L. Peterson. To be submitted to *Reviews in Fish Biology.*

Abstract

      The shoal bass (*Micropterus cataractae*) is a black bass species endemic to the Apalachicola-Chattahoochee-Flint Basin of Alabama, Florida, and Georgia. Damming in the basin has created extensive habitat loss; consequently, shoal bass have been extirpated from several areas of their native range. Early shoal bass research focused on age and growth, spawning habits, and distribution. The formal recognition of the species in 1999 increased interest in research and restoration. Recent research has described critical habitat, movements, and systematic information about shoal bass. As researchers continue to investigate the life history of the species, several threats have become apparent including habitat modification, interactions with non-native black basses, and the effects of angling. Currently, management needs included basic population assessments and investigation of factors causing population declines. Despite increased interest in the species, the outlook for the long-term conservation of the shoal bass is uncertain.

Introduction

      The shoal bass (*Micropterus cataractae*) is a black bass endemic to the Apalachicola-Chattahoochee-Flint (ACF) Basin of Alabama, Florida, and Georgia. Shoal bass are habitat specialists that occupy riverine 'shoal' areas that feature large rock outcrops and fast moving water (Williams and Burgess 1999). Upon formal description, Williams and Burgess (1999) attributed shoal bass declines to habitat losses resulting from dam construction and called for a thorough survey of populations and identification of microhabitat preferences. Several studies have since identified shoal bass habitat

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requirements (Johnston and Kennon 2007; Stormer and Maceina 2009) and additional

information on biology, ecology, and threats is available in the secondary literature.

Because of perceived threats to the persistence of shoal bass, the objective of this review

was to synthesize all pertinent information from peer-reviewed journals, conference

proceedings, gray literature, and popular articles regarding shoal bass biology and

management.

The shoal bass generates considerable interest from fisheries biologists,

conservation groups, and anglers because it is a sport fish that occurs in a relatively

restricted native range. The states of Alabama (Mirarchi et al. 2004) and Florida (Florida

Fish and Wildlife Conservation Commission 2009), as well as the American Fisheries

Society Endangered Species Committee (Williams et al. 1989), have listed shoal bass as a

Species of Special Concern because of declining populations throughout its native range.

Meanwhile, shoal bass have received national attention among bass anglers (Newell

2008) and associated popular media (Jones 2010). Because of debate regarding the level

of protection the shoal bass needs, this paper objectively synthesizes information for the

use of multiple interest groups.

Taxonomy and systematics

Shoal bass are a teleost fish belonging to order Perciformes. Within the family

Centrarchidae, shoal bass belong to genus *Micropterus*, commonly known as the black

basses (Boschung and Mayden 2004). Like all sunfishes, black basses are native only to

the freshwaters of North America. The earliest fossils of *Micropterus* date back to the

Early Miocene, and the origin of the lineage likely evolved about 17 million years ago

(Near et al. 2003). Although there are several theories for the mechanisms that lead to the speciation of black basses, Near et al.'s (2003) proposal is the most widely accepted. Near et al. (2003) reported that sea level fluctuations from the Middle Miocene to the Pleistocene coincide with allopatric speciation events for black basses in the Gulf of Mexico drainages.

Diversity of black basses is highest in the southeastern U.S. Hubbs and Bailey (1940) were the first to describe some of these endemic black basses, while also providing the first insights into the phylogenetic relationships within the genus based on morphological and meristic traits. Several authors have since used modern genetic analyses to show that shoal bass are closely related to Suwannee bass (*M. notius*) and redeye bass (*M. coosae*; Johnson et al. 2001; Near et al. 2003; Oswald 2007). Subsequent genetic studies by Oswald (2007) identified several genetically distinct populations of redeye bass and reported that shoal bass are most closely related to populations of redeye bass inhabiting the Altamaha, Apalachicola, and Savannah river basins. At present, eight black bass species have been described; however, at least three additional species or subspecies will likely be described as cryptic diversity within the genus is deciphered (Byron Freeman, Georgia Museum of Natural History, personal communication).

Morphology

Description of black bass species typically is based on morphological, meristic and coloration characteristics (Hubbs and Bailey 1940; Baker et al. 2008). Shoal bass morphology and internal anatomy are similar to that of other black basses. Early work by

Wright (1967) described the shoal bass as the "Flint River form of redeye bass" and highlighted differences between shoal bass and other black basses. Subsequent studies by Williams and Burgess (1999), however, showed that shoal bass morphology was substantially different from that of redeye bass. Based on their examination of 162 shoal bass from throughout the range, these authors reported external meristic traits including lateral line scale counts (61-87; mean 74), scale rows above the lateral line (8-10; mean 8.9), and scale rows below the lateral line (15-21; mean 18.5) that distinguished shoal bass from other black basses. The authors also noted that shoal bass exhibit a distinct 'tiger-striped' blotch pattern consisting of 10-15 vertical, mid-lateral and supra-lateral blotches (Figure 2-1).

Shoal bass are difficult to identify where they co-occur with similar black basses. Morphologically, shoal bass most closely resemble spotted bass (*M. punctulatus*; Williams and Burgess 1999). Unlike the spotted bass, the shoal bass does not have a tooth patch on the tongue (Figure 2-1; Williams and Burgess 1999). Shoal bass are also commonly confused with redeye bass (Williams and Burgess 1999), as both species often exhibit a blue-tinted throat and dark-red fins. Approximately 84% (136 of 162) of redeye bass specimens examined by Taylor et al. (unpublished data) possessed a tooth patch on the tongue, which suggests that this feature alone is not sufficient to distinguish redeye bass and shoal bass (Taylor et al., unpublished data). Instead, color characteristics such as the white margins on the anal and caudal fins of redeye bass should be used in conjunction with presence of a tooth patch presence to distinguish these species. Recent introduction of the smallmouth bass (*M. dolomieu*) into the ACF Basin may result in difficulty discerning this species from native shoal bass because the two species have

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similar coloration and scale counts (Wright 1967). The centrarchid key developed by Boschung and Mayden (2004) highlights a combination of scale counts that distinguishes the two species. Like many other centrarchid species, several of the black basses can interbreed to produce reproductively viable hybrids. Hybrid crosses of shoal bass, spotted bass, and Alabama bass (*M. henshalli*) are particularly difficult to distinguish from parent species. Ichthyologists have yet to reliably identify hybrids without the use of genetic analysis.

Distribution and legal status

Historically, shoal bass occurred throughout much of the ACF Basin of Alabama, Florida, and Georgia where shoal habitat existed (Figure 2-2). In Alabama, shoal bass are currently limited to four tributaries of the Chattahoochee River: the Wacoochee, Halawakee, Osanippa, and Little Uchee creeks (Stormer and Maceina 2008). Except for a small population at Moffit's Mill in Little Uchee Creek, abundances in these tributaries appear to be low (Stormer and Maceina 2008). In Florida, shoal bass inhabit the mainstem of the Apalachicola River from Jim Woodruff Dam to ~10 river kilometers (rkm) downstream (Williams and Burgess 1999). Shoal bass also occur in the Chipola River, Florida, where they are confined to about 50 rkm of the mainstem from Jackson County to Calhoun County (Parsons and Crittenden 1959; Ogilvie 1980).

In Georgia, shoal bass occur in the mainstems and a few of the larger tributaries of both the Chattahoochee and Flint rivers. Small populations are also scattered throughout the Chattahoochee River from the northern headwaters downstream to Walter F. George Reservoir (Williams and Burgess 1999; Straight et al. 2009). Shoal bass have

been extirpated from much of the Chattahoochee mainstem because they do not usually inhabit impounded waters (Williams and Burgess 1999). However, remnant populations still persist in shoal habitats immediately downstream from some impoundments (Sammons 2011). Limnetic coldwater releases have extirpated shoal bass from ~77 rkm of the Chattahoochee River below the Buford dam (Long and Martin 2008). Farther downstream, the 19-rkm reach below Morgan Falls Dam has been restored in recent years by stocking efforts coupled with a slight warming of waters caused by the gradual aging of the upstream reservoir (Long and Martin 2008). The most robust populations of shoal bass are currently found in the mainstem Flint River, where they are relatively common throughout except for the impounded waters of lakes Blackshear and Worth (Williams and Burgess 1999, Straight et al. 2009)

The Georgia Department of Game and Fish stocked shoal bass into the Ocmulgee River (Altamaha Basin) in the mid-1970's (Figure 2-2; Williams and Burgess 1999). In the mainstem and large tributaries of the Ocmulgee River, shoal bass can be found from the base of Lake Jackson Dam downstream to the confluence with the Oconee River (Figure 2-2) (Williams and Burgess 1999; Straight et al. 2009). Anecdotal reports from anglers suggest that shoal bass also have been introduced (illegally) above Lake Jackson into the Yellow, Alcovy, and South rivers.

Despite chronic declines in both abundance and range within the ACF Basin, the shoal bass has never been petitioned for listing under the endangered species act (Williams and Burgess 1999). At the state level, Alabama has listed and maintained listing of shoal bass as a species of special concern because of declining populations in the state's tributary waters of the Chattahoochee River (Mirarchi et al. 2004). The shoal

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bass is listed as threatened in Florida because of concerns over habitat loss (Gilbert 1992). The American Fisheries Society Endangered Species Committee and its affiliates have consistently recognized the shoal bass as "vulnerable" (Williams et al. 1989; Jelks et al. 2008) but no other state or federal listings have yet been adopted.

Life history and ecology

Aside from of several early investigations of growth and distribution, Wright (1967) provided the first comprehensive summary of shoal bass life history. Later, Williams and Burgess (1999) synthesized many of these studies into a single species description. In recent years, a few studies have focused on shoal bass habitat use in western Chattahoochee River tributaries (Johnston and Kennon 2007; Stormer and Maceina 2009), where populations persist at low levels. Several others studies have investigated various life history aspects including diet (Wheeler and Allen 2003), seasonal movements (Stormer and Maceina 2009), and interspecific interactions with other black basses (Goclowski 2010).

Spawning

Shoal bass reach sexual maturity at age three; the smallest mature female in the Flint River was 189 mm long in standard length (SL) and weight was 178 g (Wright 1967). In the same population, Wright (1967) reported that fecundity ranged with length and weight in females; egg counts and fish sizes ranged from 5,396 to 21,779 eggs for fish ranging in length from 314 mm to 442 mm SL and weight from 844 to 2,314 g. Because fecundity increases with size, there is an intrinsic value of larger shoal bass to reproductive success and natural recruitment.

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Spawning occurs from April to early June when water temperature is ~20 ºC (Wright 1967; Hurst 1969). Wright (1967) hypothesized that spawning is triggered by proper water temperature and relatively high, murky flows. Johnston and Kennon (2007) observed distinct size classes of fingerlings and suggested that shoal bass may have multiple spawning bouts within a season. Considering the variability of water temperatures and flows during the spawning season of shoal bass, an extended spawning season with multiple spawning bouts would be advantageous to natural reproduction.

Shoal bass spawning nests are rarely observed in the wild. Hurst (1969) observed a 46-cm diameter nest at a depth of 20 cm near the end of a pool, where eggs were adhering to small, rocky substrate. Wright (1967) observed an adult shoal bass hovering over a nest in ~46 cm of water. Although eggs or larvae were not observed, the nest was composed of coarse sand and was located in a shoal area about 6 m off of the river bank (Wright 1967). In shoals of the lower Flint River, dense spawning aggregations of shoal bass occupy certain shoal areas while other similar shoals may be unoccupied (Travis Ingram, Georgia Department of Natural Resources [GADNR], personal communication). The lack of knowledge about shoal bass spawning behavior warrants further investigation, especially when considering anthropogenic alteration of natural flow regimes may affect spawning behavior and reproductive success.

Age and growth

Johnston and Kennon (2007) delineated shoal bass life stages by the following total lengths (TL): larval fish are 0-50 mm TL, juveniles are 51-150 mm TL, and adults are > 150 mm TL (Ramsey and Smitherman 1972; Williams and Burgess 1999). Generally, shoal bass grow fastest during their first three years and slowest during their

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fifth, sixth, and seventh years (Parsons and Crittenden 1959; Wright 1967; Hurst 1969).

Parsons and Crittenden (1959) reported that shoal bass in the Chipola River, Florida, reach about 97 mm TL by the end of their first year. The maximum age of shoal bass is ~8 (Wright 1967) to 10 years (Dendy 1954). The world record shoal bass weighed 3.99 kg (8 lbs 12 oz) and was caught in the Apalachicola River in 1995 (International Game Fish Association 2010).

Parsons and Crittenden (1959) aged scales collected near the pectoral fins in an effort to avoid scales that were regenerated. They noted that scale annuli were distinct and false annuli were not found, but scales from the region used have an irregular shape that may make aging difficult. Wright (1967) could not account for the presence of false annuli in the scales of shoal bass from the Flint River. Wright (1967) noted that false annuli did not appear to coincide with periods of high flow and must be related to other environmental factors. Recently, both scales and sagittal otoliths have been used for aging shoal bass. Dakin et al. (2007) used scales to age young shoal bass in the Chattahoochee River, Georgia. They cautioned that scales tend to underestimate the age of older shoal bass because of regeneration, but scales are about as accurate as otoliths for aging younger fish. There has not been a comprehensive study to compare aging accuracy based on scales, otoliths, or other bony parts of the shoal bass.

Diet and foraging

Shoal bass prey primarily upon insects, fishes, and crayfishes (Wright 1967; Hurst 1969; Ogilvie 1980). Insects, especially mayflies (Ephemeroptera), appear to be important food items to smaller (40 – 120 mm SL) shoal bass (Wright 1967; Wheeler and Allen 2003). In the third year of life, shoal bass diet transitions from insects to crayfishes

and fishes (Wright 1967; Williams and Burgess 1999). Shoal bass prey upon a variety of

fishes including members of the orders Cypriniformes, Percifomes, and Silurifomes

(Wright 1967). Crayfish are the most important diet component of larger shoal bass;

fishes and insects are the second and third most important diet components, respectively

(Wright 1967; Hurst 1969; Wheeler and Allen 2003).

Little information exists about shoal bass foraging behaviors. Shoal bass were

observed foraging alone and in loose assemblages of three to five like-sized individuals

in the limestone shoals of Ichawaynochaway Creek, Georgia (Taylor and Peterson,

unpublished data). This information, along with anecdotal evidence from anglers,

suggests that shoal bass forage primarily in shoals.

Habitat use

Recent investigations suggest that shoal bass are shoal habitat specialists

(Johnston and Kennon 2007; and Stormer and Maceina 2009). In the shoal mesohabitat

of Little Uchee Creek, Alabama, shoal bass exhibit an ontogenetic shift in habitat use

(Johnston and Kennon 2007). Larval shoal bass appear to prefer boulder substrates in

deep water with low current velocities, but rapidly transition to shallow shoal habitats as

juveniles (Johnston and Kennon 2007). As adults, shoal bass prefer deeper habitats near

fast current with boulder and bedrock substrates adjacent (Johnston and Kennon 2007;

Stormer and Maceina 2009). Regardless of the specific microhabitats used, the species is

almost always associated with bedrock and boulder substrates (Stormer and Maceina

2009). Although adults can survive and reproduce in hatchery ponds, they are rarely

found in reservoirs (Williams and Burgess 1999).

Adult shoal bass habitat preferences appear to vary seasonally, with run and eddy macrohabitats preferred during winter and spring months, but deep pools preferred during summer and early fall months (Stormer and Maceina 2009). During extended droughts and low-water periods, adult shoal bass may depend on deep pool habitats as critical refugia, particularly when shoal habitats become dewatered (Johnston and Kennon 2007; Stormer and Maceina 2009). Habitat connectivity may be especially important for shoal bass during prolonged droughts when the fish may be forced to seek out deeper channel habitats with sufficient food and cover (Johnston and Kennon 2007). Hence, impoundment of shoal bass habitat is probably the single most important factor affecting the chronic decline of most remaining populations.

Although most biologists who study shoal bass agree that the species is a habitat specialist, recent studies document extensive use of pool habitats by shoal bass. In the summer and fall, Wheeler and Allen (2003) collected 46% of age-0 shoal bass and 76% of adult shoal bass from pool habitats in the Chipola River (Wheeler and Allen 2003). Likewise, Taylor and Peterson (unpublished data) regularly sampled adult shoal bass in deep pools over course limestone substrates in lower Flint River, Georgia. These data suggest that the species is more flexible than previously thought, especially in southerly portions of the range where drought conditions appear to be more common. Goclowski (2010) also reported that adult shoal bass in the upper Flint River often sought cover near large, woody debris with various substrate types. Considering all available habitat data, maintaining interconnected shoal and pool habitats within the native range of the shoal bass is imperative to the long-term conservation of the shoal bass.

Movement

Generally, movement and home range is highly variable among individuals and is unrelated to fish size (Stormer and Maceina 2009). Diel movement rates of shoal bass are similar between periods of daylight and darkness and appear to be directly related to water temperature (Goclowski 2010). Daily movement of shoal bass appears to be related to habitat connectivity. Daily movement averaged 403 m/d in an unimpounded section of the upper Flint River (Goclowski 2010), but only averaged 20 m/d in a short stretch of the Chattahoochee River between Riverview Dam and Bartletts Ferry Reservoir (Sammons 2011).

Shoal bass exhibit differences in movement in relation to season and seasonal variation in flow (Stormer and Maceina 2009). Shoal bass movement rates are typically highest during the spring months in association with the spawning season (Stormer and Maceina 2009; Goclowski 2010; Sammons 2011). Researchers have documented spawning-related migrations of adult shoal bass to large shoal areas (Goclowski 2010) and into tributaries (Sammons 2011), presumably to form dense spawning aggregations as documented on certain shoal complexes in the lower Flint River (Taylor and Peterson, unpublished data). Additionally, great numbers of adult shoal bass have be found immediately downstream of dams in early spring (Sammons 2011; Travis Ingram, GADNR, personal communication). This uninvestigated phenomenon may be because of increased foraging opportunities or attempts to migrate upstream to spawn.

Threats

Habitat

In the species description, Williams and Burgess (1999) recognized dams as a major cause of range-wide declines in shoal bass populations. Unfortunately, the ACF Basin is the second-most impounded watershed east of the Mississippi River with more than 1,400 individual impoundments (U.S. Army Corps of Engineers 2005 *in* Dakin et al. 2007). Although the proximate causes are unclear, dams fragment and destroy shoal bass habitats by inundating shallow high gradient shoal habitats (Williams and Burgess 1999). Furthermore, dams alter downstream habitats for shoal bass by modifying natural flow and temperature regimes (Williams and Burgess 1999; Long and Martin 2008). Flow alteration can be an especially severe problem below hydroelectric dams that are operated as hydropeaking facilities (Sammons 2011; Travis Ingram, GADNR, personal communication). A recent study suggested that populations that become isolated in small tributaries might become vulnerable to extirpation because of inbreeding depression (Dakin et al. 2007). Throughout their range, shoal bass are also vulnerable to a variety of other habitat threats including sedimentation, channelization, nutrient pollution, and diversion of ground water for both municipal and agricultural purposes (Ogilvie 1980; Johnston and Kennon 2007; Williams and Burgess 1999).

Non-native species

Introduction of non-native black basses into the ACF Basin confounds shoal bass conservation. Although shoal bass occur naturally and sympatrically with largemouth bass (*M. salmoides*) and redeye bass in the ACF Basin (Williams and Burgess 1999), non-native spotted bass, Alabama bass, and smallmouth bass all have been introduced

and established into regions of the ACF Basin (Table 2-1). Relative increases in non-native black basses and subsequent declines in shoal bass populations may suggest that non-native black basses have the ability to outcompete shoal bass, perhaps because these non-natives are better adapted to surviving in altered habitats than shoal bass (Stormer and Maceina 2008; Sammons and Maceina 2009). However, initial investigations have yet to provide conclusive evidence or identify mechanisms of potential interspecific competition between shoal bass and non-native black basses (Sammons and Maceina 2009; Goclowski 2010). Introgressive hybridization of shoal bass with Alabama bass and spotted bass poses a threat to the genetic integrity of shoal bass (Dakin et al. 2007). Several genetic studies are underway throughout the ACF Basin. Preliminary data from several lower Flint River populations indicate that hybridization is occurring at rates around 20% (Taylor and Peterson, unpublished data). The potential for competition and hybridization between shoal bass and non-native smallmouth bass that were recently introduced below Morgan Falls Dam in the Chattahoochee River has not been investigated.

Exploitation

Shoal bass populations in Georgia support a popular sport fishery, yet information on harvest rates and other the population-level effects are unknown. Because shoal bass are habitat specialists, knowledgeable anglers often target spawning aggregations during the spring months. Initial data from an ongoing GADNR tagging survey indicate that angling pressure is high – even in relatively remote portions of the lower Flint River (Travis Ingram, GADNR, personal communication). Although catch-and-release fishing for shoal bass is common, estimates of harvest and post-release mortality are lacking.

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The intentional displacement of large individuals from riverine to reservoir habitat is common practice among tournament anglers (Williams and Burgess 1999); however, post-release survival is unknown.

Management approaches

As is typical of many other black bass sport fisheries, management of shoal bass fisheries have consisted of harvest restrictions and stocking. In response to dwindling populations of shoal bass in Alabama, harvest of shoal bass was banned in state tributaries of the Chattahoochee River tributaries in 2006. Although Georgia fishing regulations still permit anglers to harvest up to 10 shoal bass per day in most of the state, the regulations were intended for all black bass species within the state. Although data necessary for population-specific regulations are not yet available, GADNR recently initiated an angler-based tagging survey on the lower Flint River to better understand the effects of the recreational fishery on that population.

Stocking of shoal bass fingerlings has also been used to supplement natural recruitment and aid in restoration efforts. From 2000 to 2007, GADNR stocked 12,000 - 20,000 marked fingerling shoal bass in the lower Flint River between lakes Blackshear and Worth (Travis Ingram, GADNR, personal communication) to supplement natural recruitment. Subsequent samples from the population showed that the stocked fish contributed 14-51% of year classes during this period (Travis Ingram, GADNR, personal communication). Shoal bass fingerlings were stocked in the Chattahoochee River below Morgan Falls Dam to restore a diminished native population (Long and Martin 2008), although stocking contribution has not yet been formally reported. A similar stocking

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effort to restore dwindling populations in several Alabama tributaries was also tested, but follow-up assessments suggested that few of the stocked fish survived (Sammons and Maceina 2009).

To manage against the threats of interspecific competition and introgressive hybridization posed by non-native black basses, biologists that study shoal bass are encouraging anglers to harvest non-native black basses caught in streams and rivers of the ACF Basin. Such harvesting approaches likely will have little affect on alleviating the potential negative interactions with non-native black basses in the ACF Basin because non-native spotted bass are considered a sport fish in certain areas of the ACF Basin, like Lake Lanier, Georgia. If introgressive hybridization with non-native black basses occurs at high rates, supplemental stocking of pure shoal bass may help maintain the genetic integrity of the shoal bass as a species. As such, identification and maintenance of pure shoal bass brood stock should be a priority. On a broader scale, emphasis on educating the public about the negative effects of introducing species is needed.

Knowledge of habitat requirements and conservation genetics of isolated populations suggests that restoration approaches focused on preserving and restoring shoal bass habitats may provide the best hope for maintaining and restoring populations throughout the range. For example, Dakin et al. (2007) reported that small, fragmented populations might be particularly vulnerable to the deleterious effects of low genetic diversity. Hence, preservation and enhancement of shoal habitats and in-stream connectivity should be priorities for management agencies concerned with the long-term conservation of the shoal bass.

Research needs

Several recent investigations have provided important information regarding shoal bass life history and the key factors likely responsible for population declines. Unfortunately, many populations already have been extirpated, which has led to a significantly diminished range. Identification and assessment of remaining populations – particularly those within the ACF Basin – should be a priority for management agencies, along with studies to identify mechanisms causing population declines. Development and implementation of population-specific management strategies along with subsequent monitoring within an adaptive management framework will be critical to ensuring long-term conservation of the species.

Future research efforts should focus on population-level status assessments and restoration efforts. The current lack of population dynamics and abundance data hinder advancement of management strategies for the species. Furthermore, monitoring hybridization rates is necessary to identify populations threatened by introgressive hybridization with non-native black basses. Many of these research needs are directly addressed in the Native Black Bass Keystone Initiative under the National Fish and Wildlife Foundation (NFWF; NFWF 2010). This initiative contains specific strategies to reduce threats and ensure persistence of shoal bass populations while providing coordination and adaptive management across management agencies and interest groups (NFWF 2010). While this initiative is recently underway, it has the potential to provide valuable new information that will aid management and long-term conservation of the species. Additionally, effective habitat and population restoration projects could counteract some of the range-wide decline in shoal bass populations.

Outlook

The outlook for the long-term conservation of the shoal bass is uncertain. Despite renewed interest in the species, increasing research efforts, and some progress in restoration, many populations have continued to decline during the past decade. Recent emphasis on understanding and preserving diversity of black bass species has prompted conservation groups and governmental agencies to focus conservation efforts on species such as shoal bass (NFWF 2010). However, efforts to restore habitat and populations may be diminished if further habitat fragmentation and loss occur – particularly within the ACF Basin where the most robust populations are currently found. Because of increasing demands for water, there is a renewed political interest in constructing dams along unimpounded portions of the ACF Basin, including the upper Flint River. As such, the long-term conservation of the shoal bass will be both a scientific as well as a political endeavor.

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Table 2-1. Names and current general distributions of native and non-native black basses (*Micropterus* spp.) within the Apalachicola-Chattahoochee-Flint (ACF) Basin of Alabama, Florida, and Georgia.

| Name | | ACF | |
Common	Scientific	Native	Distribution within ACF Basin
Shoal bass	*M. cataractae*	Yes	throughout
Largemouth bass	*M. salmoides*	Yes	throughout
Redeye bass	*M. coosae*	Yes	upper Chattahoochee and upper Flint
Spotted bass	*M. punctulatus*	No	Apalachicola, Chattahoochee, and Flint
Alabama bass	*M. henshalli*	No	upper Chattahoochee (and possibly upper Flint)
Smallmouth bass	*M. dolomieu*	No	Chattahoochee below Morgan Falls Dam
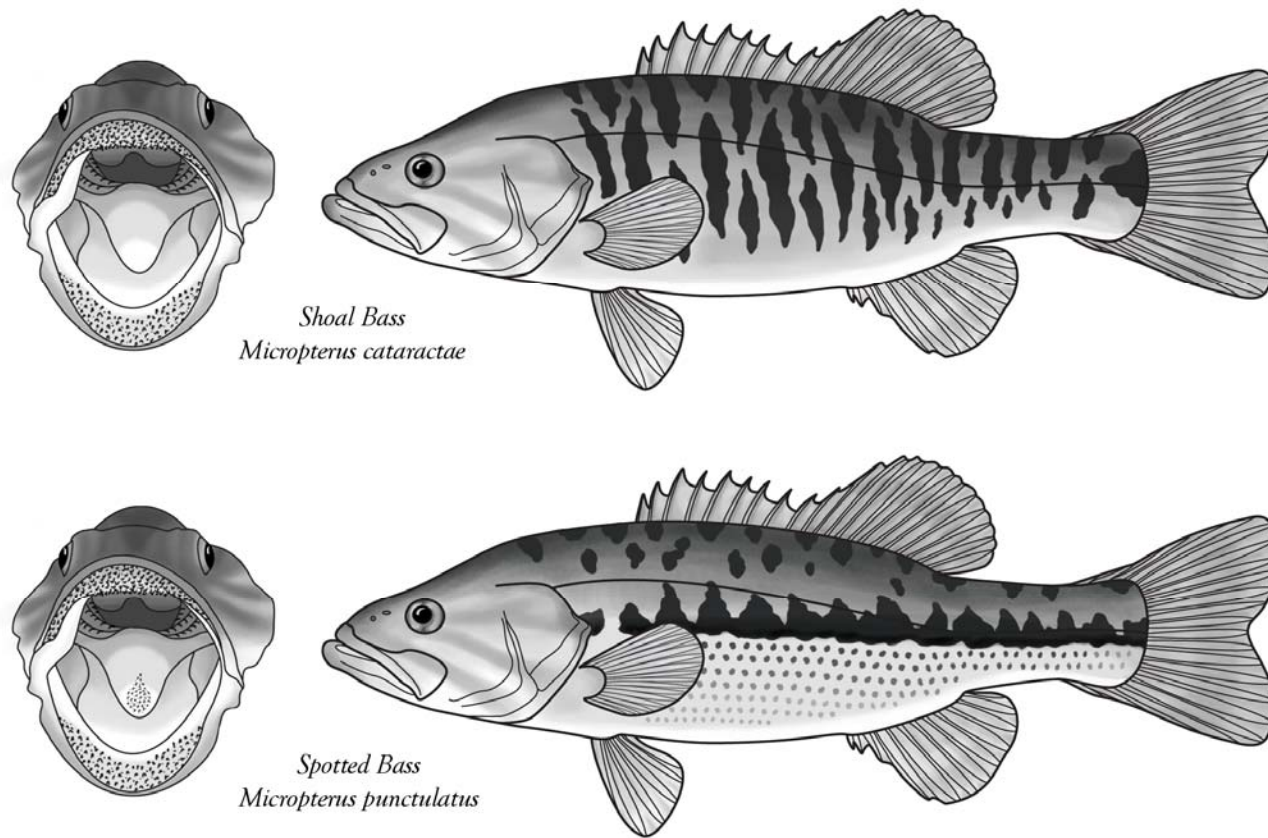
Illustration by Ami Flowers

Figure 2-1. A comparison of blotch patterns and tooth patch characteristics that distinguish shoal bass (*Micropterus cataractae*) from spotted bass (*M. punctulatus*). Spotted bass have been introduced throughout the native range of the shoal bass.
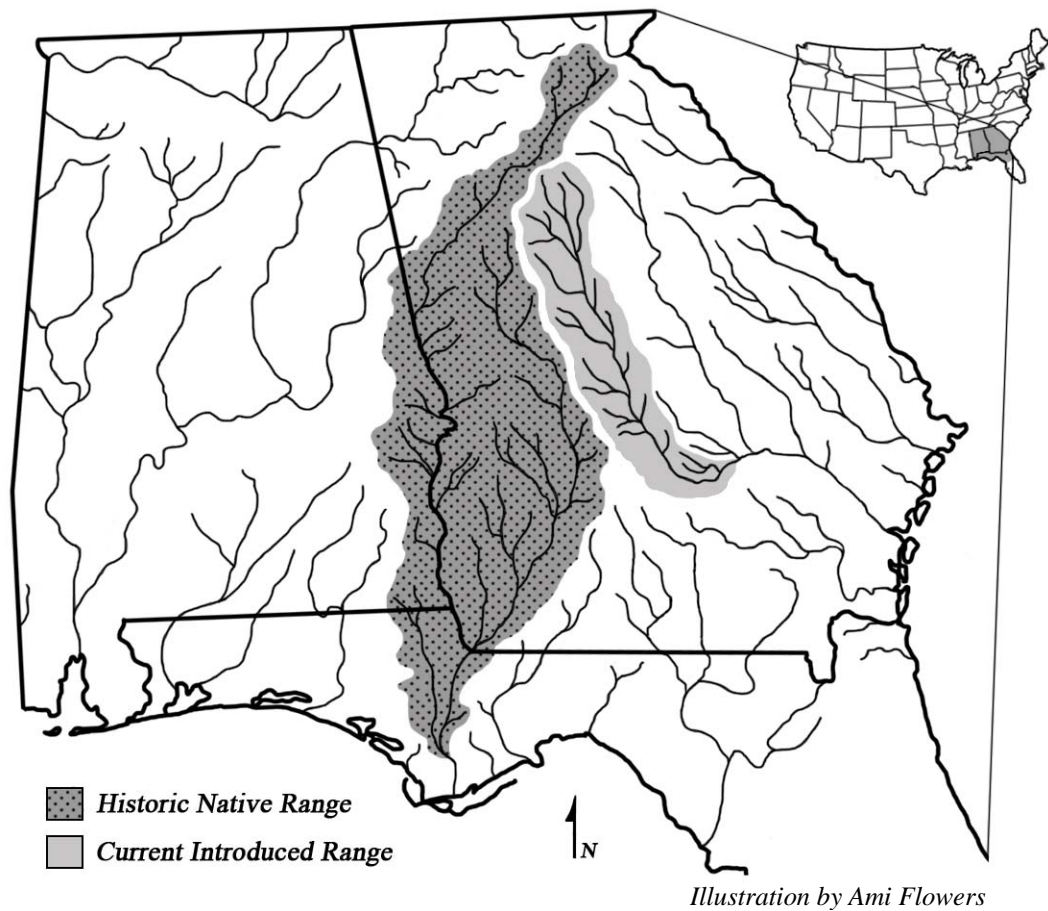
Figure 2-2. Historic native range and current introduced range of shoal bass (*Micropterus cataractae*). Shoal bass are endemic to the Apalachicola-Chattahoochee-Flint Basin of Alabama, Florida, and Georgia. They were introduced into the Ocmulgee River, Georgia, in the 1970's.

CHAPTER 3

STATUS ASSESSMENT OF THE SHOAL BASS POPULATION IN THE LOWER

FLINT RIVER, GEORGIA, BETWEEN LAKES BLACKSHEAR AND WORTH[2]

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[2] Taylor, A. T. and D. L. Peterson. To be submitted to *Transactions of the American Fisheries Society.*

Abstract

The shoal bass (*Micropterus cataractae*) is a popular sport fish endemic to the Apalachicola-Chattahoochee-Flint Basin of the southeastern U.S. The species faces a suite of threats, including the potential negative effects of dams, angling mortality, and introgressive hybridization with non-native black basses (*Micropterus* spp.). A lack of population-specific data has hindered management efforts. Our objectives were to: 1) estimate the abundance of harvestable adult shoal bass in a major spawning aggregation; and 2) evaluate the genetic "purity" of the population. A secondary objective was to determine if any internal anchor tags, used in mark-recapture studies of shoal bass, were lost over a short-term study. Our results revealed that 200-300 adults occupied a large shoal complex during the 2011 spawning season. Genetic analysis revealed that 18 of 152 (11.8%) shoal bass were hybrids with non-native black basses. We also documented loss of internal anchor tags in adult shoal bass. The abundance of adults in the spawning aggregation is difficult to place into context with other shoal bass populations; however, our results are indicative of the importance of shoal complexes as spawning habitat. Future studies should address estimating internal anchor tag loss over time so that tag loss can be accounted for in mark-recapture models. We suggest that long-term monitoring of shoal bass abundance and genetic integrity within an adaptive management framework will be critical in ensuring the continued viability of the population. Furthermore, until similar baseline data are available for all major populations, the long-term viability of recreational shoal bass fisheries seems uncertain.

Introduction

The shoal bass (*Micropterus cataractae*) is a black bass species endemic to the Apalachicola-Chattahoochee-Flint (ACF) Basin of the southeastern United States (Williams and Burgess 1999). Shoal bass inhabit riverine shoal areas characterized by swift currents and rocky substrates (Johnston and Kennon 2007). Adult shoal bass feed primarily on crayfish and small fishes (Wright 1967; Hurst 1969; Ogilvie 1980) and attain maximum sizes near 4.0 kg (International Game Fish Association 2010). Where they occur, shoal bass support popular recreational fisheries; however, a lack of population-specific data has hindered management efforts.

Recent concerns regarding conservation of the species have arisen because of several anthropogenic threats including habitat loss from dams (Williams and Burgess 1999), angling mortality, and introgressive hybridization with non-native black basses (*Micropterus* spp.; Sammons and Maceina 2009). Hydroelectric dams limit the amount of interconnected shoal habitat and may also affect natural reproduction of shoal bass by altering natural flow regimes (Sammons 2011). Despite their popularity as a sport fish, shoal bass have not been well studied. Although published studies examining the effects of recreational fishing mortality are lacking, recent tagging data from the Georgia Department of Natural Resources (GADNR) suggest that fishing pressure may threaten some populations (GADNR, unpublished data). Introductions of non-native spotted bass (*M. punctulatus*), Alabama bass (*M. henshalli*), and smallmouth bass (*M. dolomieu*) into the ACF Basin raise additional concerns about interspecific competition of shoal bass with non-native black basses and the genetic integrity of shoal bass populations. Introgressive hybridization has been documented in several populations, but how

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hybridization rates vary amongst non-native species, across populations, or over time is unknown.

Although anthropogenic disturbances have reduced shoal bass populations from historic levels in the Chattahoochee and Apalachicola rivers (Williams and Burgess 1999), the Flint River drainage in Georgia currently supports the healthiest remaining populations of shoal bass within the species' native range (Williams and Burgess 1999; Straight et al. 2009). Two mainstem impoundments, lakes Blackshear and Worth, occur along the lower Flint River prior to it reaching the confluence with the Chattahoochee River at Lake Seminole. An isolated population of shoal bass exists in the 50 river-kilometer (rkm) reach of the lower Flint River that lies between these two impoundments. Although this section of river is known among local anglers for producing trophy-sized shoal bass, little is known about the population and how a suite of anthropogenic disturbances may be affecting it.

In response to public concerns regarding shoal bass within this reach of the Flint, GADNR conducted supplemental stocking of shoal bass fingerlings from 2000-2007. Follow up surveys showed that the stocked fish contributed 14-51% of each age class during this period (Travis Ingram, GADNR, personal communication). Initial attempts to monitor recruitment of wild fish were unsuccessful (Taylor and Peterson, unpublished data) and given the hydrologic alteration and popularity of sport fishing in this reach, monitoring and management of the population is needed to help ensure the long-term health of the population. Further underscoring this need has been the recent spread of non-native black basses throughout the upper Flint River, upstream of Lake Blackshear. Although non-native spotted bass have been documented downstream of Lake Worth

since 1959 (Williams and Burgess 1999), non-native spotted bass and possibly Alabama bass were only recently documented in the upper Flint River above Lake Blackshear in 2005 (Goclowski 2010). GADNR sampling data suggest that the reach of the lower Flint River between lakes Blackshear and Worth may be the last mainstem Flint River population of shoal bass free of the potential negative effects posed by non-native black basses.

With these concerns in mind, the purpose of this study was to assess the status of the shoal bass population in the mainstem lower Flint River between lakes Blackshear and Worth. The specific objectives were to: 1) estimate abundance of harvestable adult shoal bass ($\geq$ 305 mm total length [TL]) in a major spawning aggregation; and 2) evaluate the genetic "purity" of the population. Because methodologies for shoal bass population studies are critical for future management, a secondary objective was to evaluate the shoal bass marking methods currently used in GADNR monitoring efforts. Information gained from this study will provide valuable baseline information on population status on which to base future management decisions and conservation efforts for the shoal bass population of interest.

Methods

Site description

The Flint River originates near Atlanta, Georgia and flows southerly as it traverses the Piedmont and Southeastern Plains ecoregions (Figure 3-1). While the upper Flint River flows unimpeded for approximately 350 river-kilometers (rkm), the lower Flint River features two mainstem hydroelectric impounds. Lake Blackshear is a

35.21 km^2 impoundment created in 1930 by the Crisp County Dam (CCD; Crisp County Power Commission 2011). Approximately 50 rkm downstream of CCD, the smaller 5.67 km^2 Lake Worth (also known as Lake Chehaw) impoundment is created by the Flint River Dam (FRD; Georgia Power 2011). Kinchafoonee and Muckalee creeks, two large tributaries of the lower Flint River, flow into the western side of Lake Worth. The lower Flint River then continues southward ~127 rkm before it enters into Lake Seminole, where it converges with the Chattahoochee River and forms the Apalachicola River downstream of Jim Woodruff Dam. Unlike the slow-moving, sandy streams characteristic of the Southeastern Plains ecoregion, numerous shoals with swift-moving water and rocky substrates characterize the lower Flint River. The lower Flint River traverses over Ocala Limestone formations typical of the Dougherty Plain district, thus the river channel features abundant limestone shoal habitat.

The study area encompassed 50 rkm of the lower Flint River, beginning upstream at the base of CCD and extending downstream to the headwaters of Lake Worth (Figure 3-1). The river channel in this area is typically about 70-m wide and 1-6 m deep. The area features two large shoal complexes – Philema Shoals (1.6 rkm long) and Abrams Shoals (1.9 rkm long) – as well as several smaller shoal areas. The dams and reservoirs at each end of the reach create physical barriers to shoal bass immigration and emigration (Williams and Burgess 1999). Though populations of shoal bass exist in both Kinchafoonee and Muckalee creeks (Straight et al. 1999), they are functionally isolated from the mainstem population by Lake Worth. Operation of CCD as a hydropeaking facility influences flow throughout the 50 rkm study area and has raised concerns that

alterations of natural flow regimes could affect the shoal bass population dynamics within the study reach.

Spawning aggregation abundance

To estimate abundance of the spawning aggregation at Philema Shoals, adult shoal bass were sampled on six separate occasions during the spawning season, which lasted from early April to early May 2011. All sampling was conducted using a pulsed-DC boat electrofisher, equipped with an aerated holding tank. During each sampling occasion, two electrofishing passes were made on the river. There was one on each side, beginning at the upstream extent of Philema Shoals and ending near the base of the shoals just downstream of the Georgia State Route 32 bridge. All adult shoal bass (≥ 305 mm TL) captured were kept in the aerated tank on board the vessel until the end of sampling run, after which they were marked with both PIT and internal anchor tags (described below) and released.

Analysis of the mark-recapture data was performed using the robust design model with closed captures and unequal primary sampling intervals (Kendall et al. 1995) and input into Program MARK version 6.0 (White and Burnham 1999). Because temporary immigration and emigration were not of interest in this study, all gamma' and gamma" parameters were fixed to zero during the analysis. As a result, the survival estimates generated between each primary period represent apparent survival, which accounts for immigration, emigration, and mortality. Abundance (N) was incorporated into all candidate models as varying in each primary period and apparent survival (S) was incorporated as varying between primary periods. An information-theoretic approach (Burnham and Anderson 2002) was used within Program MARK to evaluate the relative

plausibility of four candidate models. Candidate models were developed using the parameter index charts in Program MARK that incorporated capture (p) and recapture (c) probabilities as either constant, time-varying, and/or equal. Akaike's Information Criteria (AIC; Akaike 1973) with small-sample bias adjustment (AICc; Hurvich and Tsai 1989) was used to assess the relative fit of each candidate model as described by Burnham and Anderson (2002). Because candidate models of capture and recapture probabilities were used to describe binomial outcomes of capture and recapture probabilities, the use of model-averaging to generate a confidence set of models was deemed inappropriate. Thus, the model with the largest AICc weight was considered the best-fitting model. Real parameter estimates were taken from the best-fitting candidate model.

Hybridization

The entire study area was opportunistically sampled for shoal bass, non-native black basses, and their intergrades in summer 2010 and spring 2011. A sanitized pair of scissors was used to take a ~ 10 X 5 mm fin-clip was taken from the posterior margin of each fish captured. Tissue samples were stored in individually labeled microtubes filled with 95% ethanol. At the conclusion of each sampling season, all samples were shipped to Michael Tringali, Ph.D., with the Florida Fish and Wildlife Conservation Commission's Fish and Wildlife Research Institute (FWC-FWRI) for genetic analysis. There, microsatellite DNA loci were surveyed as described by Tringali et al. (2010) and alleles at each locus were assigned to a parent species by using the assignment algorithm within Program STRUCTURE (Pritchard et al. 2000). This information was used to estimate the genomic proportions of each individual analyzed as well as to assign

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individuals into categories (first filial generation of two different parental types [F1 hybrid], backcrosses to either species, and pure species).

Any shoal bass determined to contain ≥1.8% genomic proportion of non-native black bass alleles was considered to be a hybrid based on simulations that used reference genotypes (Alicia Alvarez, FWC-FWRI, personal communication). After all samples had been analyzed, a total hybridization rate was calculated by dividing the number of hybrids (including F1 and backcrossed individuals) sampled by the number of individual fish analyzed. Genomic proportions in hybridized individuals were examined to quantify the degree of introgressive hybridization present.

Tag retention

To evaluate the shoal bass marking methods currently used in GADNR monitoring efforts, a simple double marking experiment was used to compare the GADNR internal anchor tags (Floy FM-95W laminated) with PIT tags (Destron Fearing FISHID SST-1) – an internal tag which was found to have 100% retention over two years in largemouth bass (*M. salmoides*; Harvey and Campbell 1989). All shoal bass used in the tag retention study were captured on April 13th, 2011 from Philema Shoals using a standard boat electrofisher equipped with pulsed DC current. Captured fish were held in an aerated holding tank on board the vessel until the sampling run was completed, after which each fish was measured (TL; mm), weighed (g), and inspected for tags. Adult fish (≥ 305 mm TL) were double-tagged with one PIT tag and one internal anchor tag and released. Tagging was accomplished by first using a sterile scalpel to make a 15-mm incision through the skin ~40 mm posterior to the pectoral fin insertion. Using a 12-guage needle inserted under the lacerated skin, a PIT tag was injected into the body

cavity ~30 mm anterior to the incision. Immediately following the insertion of the PIT tag, the anchor portion of the internal anchor tag was placed into the incision just beneath the skin wall as described by Guy et al. (1996). Before each fish was released, both tag numbers were recorded, the anchor tag was given a slight tug to confirm that it was secure, and the PIT tag was scanned to ensure proper insertion and functionality. Several follow-up sampling events were conducted to document subsequent tag loss.

Results

Spawning aggregation abundance

Over the six separate electrofishing occasions, a total of 93 unique shoal bass were captured, 9 of which were recaptured on at least one occasion. Two of these fish were recaptured twice, yielding a total of 11 recaptures during the spawning season (Table 3-1). Estimates of spawning aggregation abundance (N), apparent survival (S), and capture probability (p) were obtained from the best-fitting robust design model that incorporated capture probability as constant over primary periods but varying within secondary sampling periods, with recapture probability constant and equal (Table 3-2).

From the best-fitting model, the spawning aggregation was estimated to contain 87 (95% C.I. 47 – 188) adults during April 5th and 6th, 181 (95% C.I. 101 – 374) adults during April 13th and 14th, and 136 (95% C.I. 75 – 285) adults during May 4th and 5th (Table 3-3). Apparent survival was estimated at 15.5% (95% C.I. 1.7% – 65.5%) from period 1-2, and 70.9% (95% C.I. 40.1% – 89.9%) from period 2-3 (Table 3-3). Capture probability during each sampling period varied from 0.11 (95% C.I. 0.05 – 0.22) to 0.15 (95% C.I. 0.07 – 0.29).

Hybridization

During sampling in summer 2010 and spring 2011, 152 unique tissue samples were obtained for microsatellite analysis. All fish included in the samples were identified in the field as shoal bass based on blotch pattern and the absence of an obvious tooth patch on the tongue (Taylor and Peterson, Chapter 2), and obvious non-native black basses were not sampled. Microsatellite analysis revealed that 18 of 152 (11.8%) fish identified as shoal bass in the field were actually a hybrid form with a non-native black bass, 17 of which were spotted bass x shoal bass hybrids that had backcrossed towards shoal bass and had spotted bass genomic proportions ranging 1.8-18.5% (Figure 3-2). One other hybrid had shoal bass, Alabama bass, and spotted bass alleles (Figure 3-2). The remaining genetic samples were considered pure shoal bass with genomic proportions > 0.982.

Tag retention

On April 13th, 2011, 24 adult shoal bass were double-tagged in Philema Shoals. The following day, three of these fish were recaptured and all three fish had retained both their PIT and internal anchor tags. Three other double-tagged fish were recaptured on May 4th, 2011, an interval of 21-d after initial tagging. All three of these fish had retained their PIT tags but had lost their internal anchor tags. No other recaptures of these double-tagged fish were made despite several additional sampling attempts.

Discussion

The estimates of abundance and apparent survival of adult shoal bass occupying the Philema Shoals spawning aggregation may provide some important insight into the

spawning behavior of shoal bass. Judging from our estimates of abundance, a maximum of about 181 adult shoal bass occupied the Philema Shoals complex during the 2011 spawning season. Such dense aggregations of shoal bass could make populations vulnerable to overharvest by recreational anglers, particularly during the spring spawning season. Between April 6th and April 14th, 2011, apparent survival within the study reach was estimated at 0.15, which suggests that few adult fish remained within the shoal complex during the first week of the spawning season. From April 14th to May 5th, 2011, however, apparent survival increased to 0.71, which indicates that as the spawn progressed the fish were much less likely to leave the area until spawning concluded. Although detailed telemetry studies are needed to better understand spawning movements and behaviors of adult shoal bass, our data suggest that adults move in and out of spawning areas in large groups during the early portion of the spawning season. This behavioral tendency may explain Johnston and Kennon's (2007) observation of different size classes of age-0 shoal bass within a tributary of the Chattahoochee River. Further studies are needed to assess the importance of large shoal complexes for shoal bass spawning and to determine if shoal bass spawning aggregations are unique within the genus.

Our genetic analysis revealed that in an area once thought to be "pure" of non-native black bass genetics, about 12% (18 of 152) of fish identified in the field as shoal bass were actually a hybrid form with a non-native black bass species. While no pure non-native black basses have been sampled from this area, our data provide the first evidence that non-native spotted bass and Alabama bass genes have infiltrated the shoal bass gene pool in the study area. This area has been traditionally used by GADNR to

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obtain genetically-pure shoal bass brood fish (Travis Ingram, GADNR, personal communication). Because two hydroelectric dams border the study area, the shoal bass population in our study area was the last segment of the mainstem Flint River to be polluted with non-native black bass genes. The low percentage of non-native alleles observed in hybridized individuals indicates that spotted bass and Alabama bass are probably not yet established within the study reach, and that the hybridization is probably occurring from hybrids that have passed downstream of CCD. Provided that these non-native black basses are not directly introduced into the study reach, further hybridization should be minimal; however, future monitoring will be critical to ensure the genetic integrity of the population, especially if brood fish are collected from this reach for future restoration efforts.

Whether non-native spotted bass pose a serious, long-term threat to shoal bass populations in the lower Flint River remains unclear. Within the *Micropterus* genus, many closely related species occur sympatrically with minimal hybridization. Introduction of non-native black basses, however, has caused local extirpations of native species through introgressive hybridization and interspecific competition. In the Savannah River for example, an endemic population of redeye bass (*M. coosae*) – a close relative to the shoal bass (Oswald 2007) – has been nearly extirpated from Lake Keowee following introduction of non-native Alabama bass (Barwick et al. 2006). In the lower Flint River however, spotted bass have been documented below the FRD since 1959 (Williams and Burgess 1999), yet hybridization rates with shoal bass are only ~20% (Taylor and Peterson, Chapter 2). Furthermore, lab studies by Goclowski (2010) suggested that life history differences between the two species will likely result in

resource partitioning that will allow the two species to coexist. Nonetheless, the numerous impoundments currently located within the Flint River Basin have dramatically altered flow regime while fragmenting gene flow in of the native population. Consequently, we suggest that long-term monitoring of shoal bass abundance and genetic integrity within an adaptive management framework will be critical in ensuring the continued viability of the population.

Based on a limited number of recaptures, our tag retention study indicated that some loss of internal anchor tags occurs within 21 days post-tagging. These results suggest that researchers using these internal anchor tags need to account for tag loss within their mark-recapture models. This may be especially critical in assessments of exploitation where tag loss may result in gross underestimation of angler harvest. Given the need for population dynamics research for shoal bass within the ACF Basin, directed studies are needed to estimate tag retention rates for PIT and internal anchor tags.

Upon describing the shoal bass, Williams and Burgess (1999) stated that the continued decline of the shoal bass illustrated the need for a thorough, range-wide survey. Although our study revealed important population status information in one key segment of the Flint River Basin, similar assessments are needed throughout the ACF Basin to identify potential threats and to develop population-specific management strategies. We suggest that a combination of angler tag-return studies, mark-recapture estimates, and genetic analysis be used in unison to establish and maintain a comprehensive conservation strategy for the species. In populations exposed to intensive angling, altered flow regimes, or other anthropogenic disturbances, use of robust design to assess adult spawning aggregations may be useful for monitoring long-term stability of population

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structure. Until baseline data are available for all major populations, the long-term

viability of recreational shoal bass fisheries seems uncertain.

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Table 3-1. Capture histories of adult shoal bass (≥ 305 mm TL) sampled in the spawning aggregation at Philema Shoals in the lower Flint River, Georgia, during the 2011 spawning season.

	Secondary Sampling Session Date					
4/5/11	4/6/11	4/13/11	4/14/11	5/4/11	5/5/11	Frequency
1	0	0	0	0	0	10
1	1	0	0	0	0	1
0	1	0	0	0	0	9
0	1	0	1	0	0	1
0	0	1	0	0	0	21
0	0	1	0	0	1	1
0	0	1	0	1	0	1
0	0	1	1	1	0	1
0	0	1	1	0	0	2
0	0	0	1	0	0	16
0	0	0	1	1	1	1
0	0	0	0	1	0	19
0	0	0	0	1	1	1
0	0	0	0	0	1	9

Table 3-2. Robust design analysis candidate models for the spring 2011 shoal bass spawning aggregation at Philema Shoals in the

lower Flint River, Georgia. All candidate models feature gamma parameters fixed to zero for apparent survival (S), and abundance

(N) is incorporated as varying in each primary period and apparent survival (S) as varying between primary periods. The model with

the largest AICc weight was considered the best-fitting model.

Model	AICc	Delta AICc	AICc Weights	Model Likelihood	Number of Parameters	Deviance
Capture probability constant over primary periods but varying within secondary sampling sessions, with recapture probability constant and equal	-276.0295	0.0000	0.53556	1.0000	7	0
Capture and recapture probabilities constant and equal	-275.4976	0.5319	0.41049	0.7665	6	0
Capture probability varying over primary period, with recapture probability varying over secondary sampling sessions	-270.9800	5.0495	0.04289	0.0801	8	0
Capture probability varying within each secondary session and also varying over primary period, with recapture probabilities varying over primary period	-268.2696	7.7599	0.01106	0.0207	11	0

Table 3-3. Parameter estimates, standard errors, and 95% confidence limits from the best-fitting robust design model for estimating abundance, apparent survival, and capture probability of the spring 2011 shoal bass spawning aggregation at Philema Shoals in the lower Flint River, Georgia.

Parameter	Estimate	Standard Error	95% Confidence Limits Lower	95% Confidence Limits Upper
S 1 and 2	0.1545	0.1561	0.0173	0.6554
S 2 and 3	0.7090	0.1359	0.4012	0.8986
Gamma" (fixed)	0.0000	0.0000	0.0000	0.0000
Gamma" (fixed)	0.0000	0.0000	0.0000	0.0000
Gamma' (fixed)	0.0000	0.0000	0.0000	0.0000
p Session 1	0.1495	0.0543	0.0707	0.2888
p Session 2	0.1096	0.0407	0.0515	0.2181
N Period 1	86.0203	33.0382	46.4162	187.3365
N Period 2	180.7824	64.5928	100.7690	373.5711
N Period 3	135.4615	49.5272	74.7354	284.5455
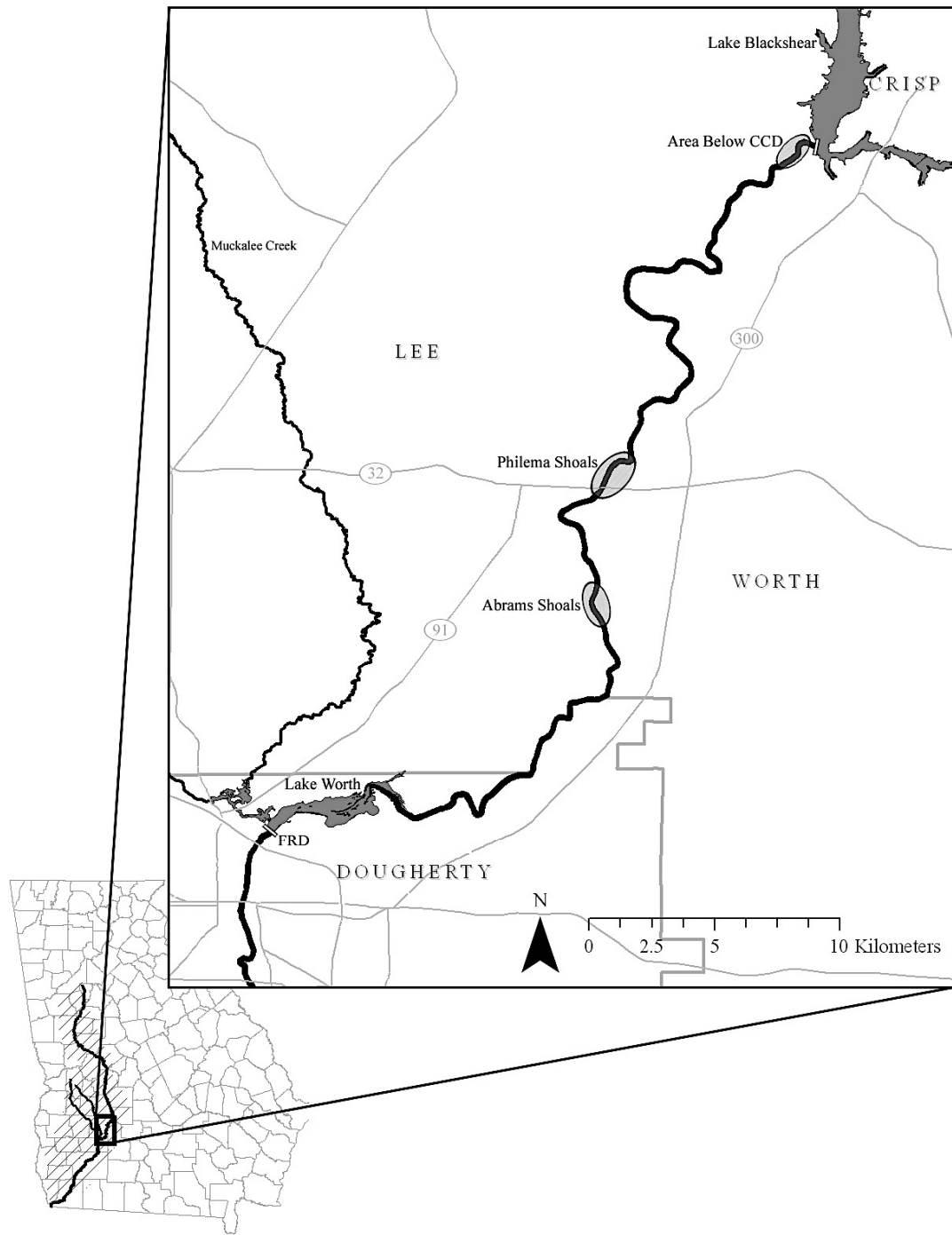
Figure 3-1. A map of the 50-rkm study reach of the lower Flint River, Georgia, between

Crisp County Dam and the Flint River Dam. Philema and Abrams shoals are the two

largest shoal complexes in the study area.
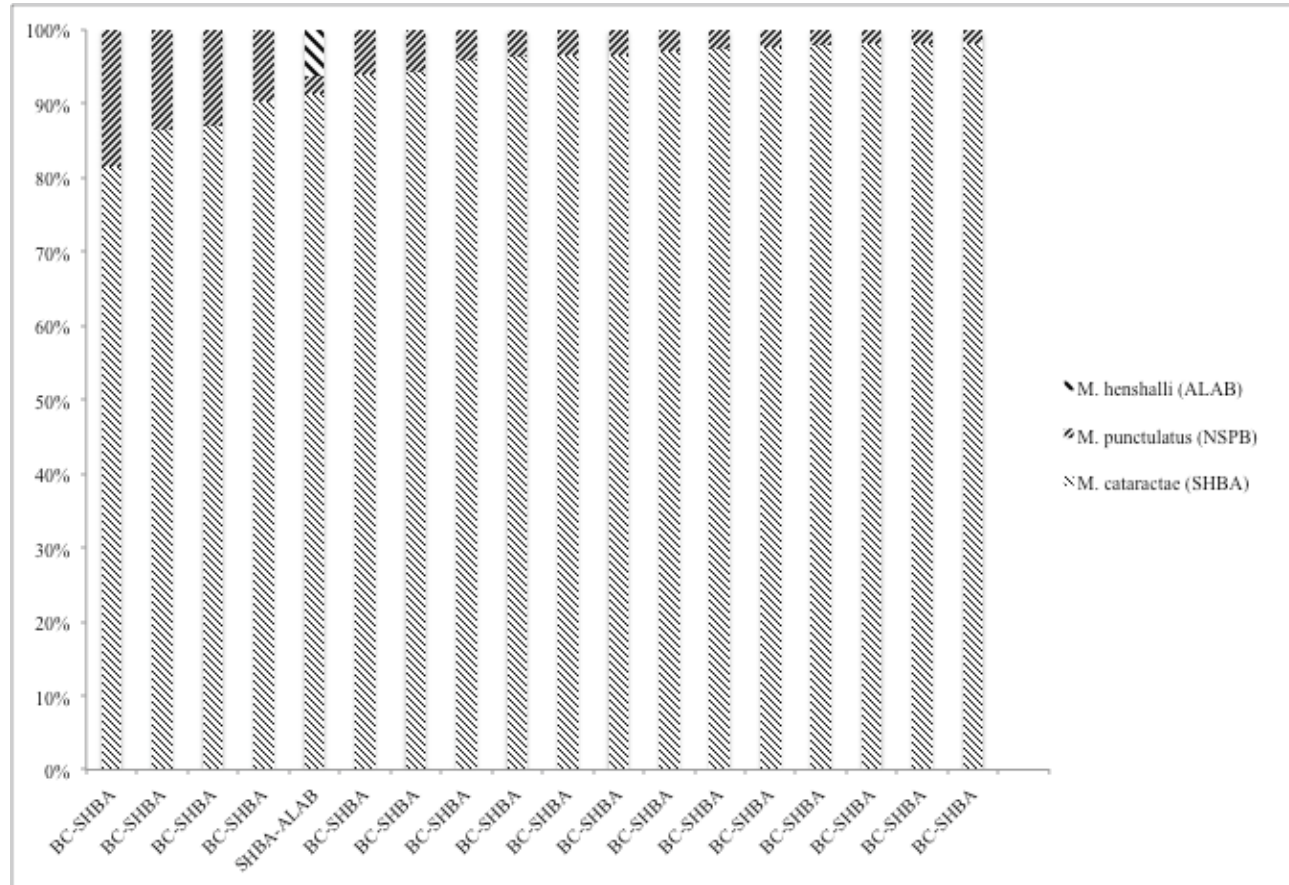
Figure 3-2. Genomic proportions of 18 hybrids discovered through microsatellite analysis of 152 individual black bass (excluding largemouth bass) sampled from the lower Flint River, Georgia, between Lakes Blackshear and Worth in 2010 and 2011. "BC" denotes backcrosses

CHAPTER 4

POST-TOURNAMENT MOVEMENT AND FATE OF SHOAL BASS

TRANSLOCATED FROM THE LOWER FLINT RIVER INTO LAKE WORTH,

GEORGIA[3]

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[3] Taylor, A. T. and D. L. Peterson. To be submitted to *Proceedings of the Southern Division of the American Fisheries Society's Black Bass Diversity Symposium.*

Abstract

The shoal bass (*Micropterus cataractae*) is a popular sport fish endemic to the
southeastern U.S. The species faces a suite of potential threats, including high angling
mortality. However, published studies have assessed the potential effects of angling-
related translocation of shoal bass into reservoirs – a common practice during fishing
tournaments. In this study, our objective was to evaluate survival and short-term
movement of tournament-captured shoal bass following translocation from riverine to
reservoir habitats. Results showed that 83% of telemetered shoal bass displaced in the
spring months returned to the river in an average of 21 d (SD = 8). Eventual fates of
telemetered fish and monitoring survival of tournament-caught shoal bass revealed that
the effects of translocation may vary seasonally, with mortality reaching approximately
33% during the summer months. We suggest that future studies investigating post-
release mortality and sub-lethal effects of translocated shoal bass are needed to better
understand the population-level effects of fishing tournament translocation.

Introduction

Shoal bass (*Micropterus cataractae*) comprise a regionally-popular recreational
fishery and are valued for their aggressive nature and willingness to strike artificial lures.
The species is endemic to the Apalachicola-Chattahoochee-Flint (ACF) Basin of
Alabama, Florida, and Georgia (Williams and Burgess 1999). During the mid-1970's,
the Georgia Department of Game and Fish introduced shoal bass into the Ocmulgee
River in central Georgia (Altamaha Basin; Williams and Burgess 1999) and the resulting
population is now well established. Shoal bass feed on aquatic insects, crayfish, and

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small fishes (Wright 1967; Hurst 1969; Ogilvie 1980) and are susceptible to conventional bass- and fly-fishing gear. Anglers participating in fishing tournaments often target shoal bass, as shoal bass can attain maximum sizes near 4.0 kg (International Game Fish Association 2010). Recently, shoal bass have garnered increased publicity for their role in several bass fishing tournaments and have been featured in popular fishing magazine articles (Newell 2008; Jones 2010).

As the popularity of shoal bass angling has increased, the need to assess the effects of angling on the species has become more evident. Growing concerns for the long-term conservation of the species include the negative effects of dams (Williams and Burgess 1999), interspecific interactions with non-native black basses (genus *Micropterus*; Stormer and Maceina 2008), and increased fishing mortality. Unfortunately, shoal bass population dynamics have not been well studied. Consequently, studies addressing the potential effects of recreational angling are needed for long-term management and conservation of the species.

Several aspects of shoal bass ecology make the species particularly vulnerable to excessive angling mortality. As a habitat specialist, shoal bass frequently congregate in large shoal complexes of warm-water rivers (Johnston and Kennon 2007) for both foraging and spawning. Because shoal bass can be caught all year long, experienced anglers have learned to target these shoal areas, particularly during the spring months when large adults are spawning. Although many of the fish caught by anglers are released, studies assessing fishing mortality or spawning success of exploited populations have not been attempted.

Another concern regarding the effects of shoal bass angling is the routine practice of translocating captured shoal bass from riverine to reservoir habitats at the conclusion of angling tournaments. Survival and movement of shoal bass released into impoundments have not been investigated, but the species does not typically inhabit or persist in lentic habitats (Williams and Burgess 1999). Considering that the increased handling associated with tournament translocation likely increases stress in translocated individuals, fishing mortality of shoal bass may be much higher than previously thought, especially where tournament anglers are targeting the species. Consequently, the objective of our study was to evaluate survival and short-term movement of tournament captured shoal bass after translocation from riverine to reservoir habitats. Information garnered through this research will yield insight into the effects of tournament-related translocation on shoal bass and may facilitate management of shoal bass fisheries where tournament translocation occurs.

Methods

Site description

The study was conducted on a 50 river-kilometer (rkm) reach of the Flint River, located in southeastern Georgia, between Lake Blackshear and Lake Worth (4-1). The Flint River originates near Atlanta and flows approximately 550 rkm southward through the Piedmont and Southeastern Plains ecoregions until its confluence with the Chattahoochee River at Lake Seminole. Although extensive anthropogenic alteration of the mainstem Chattahoochee River has reduced shoal bass population sizes from historic levels (Williams and Burgess 1999), the Flint River boasts some of the most robust

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populations of shoal bass within the ACF Basin. Situated in the Southeastern Plains

ecoregion, the lower Flint River is characterized by large shoal complexes that provide

critical habitat for all shoal bass life stages (Johnston and Kennon 2007). Unlike the free-

flowing upstream reaches and tributaries, the lower Flint has two mainstem hydroelectric

dams. The first of these is the Crisp County Dam (CCD), which forms Lake Blackshear

and is operated by the Crisp County Power Commission. Further downstream, the Flint

River Dam forms Lake Worth and is operated by Georgia Power. Fishing tournaments in

the area typically operate from early spring through early fall each year.

Sampling and analysis

To monitor post-release survival and movement of shoal bass translocated from

river to lake habitats by tournament anglers, 12 adult fish were sampled from the river on

February 16th and 17th, 2011. Fish were collected using a standard boat-mounted pulsed-

DC electrofishing unit. As each fish was captured, the time and location of each capture

were recorded with a handheld GPS unit. Captured fish were held in a recirculating,

aerated livewell on board the vessel while additional fish were collected. At the

conclusion of each sampling run, a radio transmitter (Advanced Telemetry Systems

Model F1840 or F1850) was surgically implanted into the body cavity of each fish with

procedures similar to those described by Maceina et al. (1999). These transmitters

weighed 20-25 g and weighed no more than approximately 2% of each fish's body

weight to ensure that movement and behavior of telemetered fish was unaffected by the

additional weight of the transmitter (Winter 1996). Fish were then placed back into the

aerated livewell and allowed to recover for ~30 mins. All fish were held ~2 hrs from

initial capture to their eventual release at the tournament weigh-in site at Cromartie Landing on Lake Worth.

A small boat equipped with a portable receiver (ATS R2000) and a hand-held directional antenna was used to monitor post-release movements of transmittered fish weekly from February 24th, 2011, to June 2nd, 2011. Depth (m) and visual habitat descriptions were recorded at each fish relocation. A stationary receiver array was positioned at the first shoal upstream of Lake Worth to determine how long each fish had remained in the lake before returning to riverine shoal habitats. Eventual fate of each telemetered shoal bass was determined at the end of July 2011 by an additional radio telemetry survey and several angler reports. Any fish that did not return to the river or that could not be located for more than two consecutive weeks were considered to have left the population. Likewise, any fish that remained stationary for more than three consecutive weeks was presumed dead.

At the conclusion of the study, daily movement rates of each fish were calculated by dividing the distance moved (m) between relocations by the amount of time (d) elapsed during the relocation interval (Colle et al. 1989; Wilkerson and Fisher 1997). Distance traveled between each subsequent relocation was calculated using the measure tool in ArcMap version 10 (ESRI 2011) and paths between points were assumed to follow the main river channel.

To estimate post-release survival of tournament-caught shoal bass, a floating net pen was anchored ~500 m from tournament weigh-in site at Cromartie Landing. The net pen, which measured 2.5 X 2.5 X 3.0 m, was constructed of a metal frame outfitted with floats and rigid plastic mesh. All shoal bass captured in five local tournaments conducted

between late June and late July 2011 were placed into the net pen at the conclusion of each tournament weigh-in. Fish were held in the net pen overnight and inspected ~12 hrs after being placed into the net pens. The number of dead shoal bass observed in the pens after 12 hrs was added to the total number of dead fish observed at the weigh-in to determine total mortality from the tournament as the total number of dead shoal bass divided by the total number of shoal bass weighed in.

Results

Radio transmitters were surgically implanted into three shoal bass from below CCD, six from Philema Shoals, and three from Abrams Shoals (Figure 4-1). Body weight of fish averaged 1267 g (range: 825 – 1903 g) prior to surgical implantation of transmitters, and total length (TL) averaged 414 mm (range: 367 – 480 mm; Table 4-1). Eventual fates analysis revealed that 5 out of 12 telemetered fish had left the population or were dead at the end of our study – two fish left the study area, two fish died after tournament translocation in June 2011, and one other died of unknown causes.

Following their translocation into Lake Worth, transmittered shoal bass seemed to experience three general phases: river re-entry, spawning, and post-spawn. Average daily movement rates peaked at 955 m/d (range: 16 – 1784 m/d) as 10 of 12 telemetered fish eventually returned to the river (Table 4-2). The 10 fish that returned to the river spent an average of 21 d (SD = 8) in Lake Worth (Table 4-1). Once telemetered shoal bass returned to the river, their movement rates appeared to vary seasonally. Between 35 and 72 d post-translocation (late March to early May 2011), other shoal bass sampled in the study area were observed with free-flowing sperm and eggs (Taylor and Peterson,

Chapter 3), and average movement rates of telemetered fish decreased noticeably. On

April 15th, 2011, near the middle of the spawning season, movement rates averaged 160

m/d (range: 19 – 434 m/d; Figure 4-2). During this time, 7 of 10 telemetered fish

remained in or near Philema Shoals. Between 72 and 103 d post-translocation (early

May through early June 2011), water levels dropped over a meter, and telemetered shoal

bass had average movement rates near 25 m/d (range: 1 – 51 m/d; Figure 4-2).

During the five summer tournaments observed, a total of 15 shoal bass were

weighed in (Table 4-3). Two shoal bass out of 15 (23%) were dead before weigh-in with

deaths attributed to hooking injuries. Of eight shoal bass observed in the net pen 12 hrs

after weigh-in, three were dead and five others were released alive; thus, the 12-hr post-

tournament mortality rate was estimated to be 38%. However, five other shoal bass

escaped the net pen overnight and whether the escapees survived the 12-hr period is

uncertain. The low number of shoal bass observed, coupled with a 38% escape rate from

the net pen, hindered our ability to estimate initial and 12-hr survival of tournament-

caught shoal bass. Because escaped fish had to jump ~5 cm over the top of the net pen,

they were assumed to survive the 12-hr observation period. Our limited observations

showed that at least 33% of shoal bass captured during summer tournaments died.

Discussion

The results of this study provide new information on both the lethal and sub-lethal

effects that catch-and-release tournaments may impose on shoal bass within the Flint

River Basin. Telemetry data showed that most (83%) of translocated fish returned to

riverine habitats within 3 weeks of their release, and 60% of these individuals returned to

their original capture sites. Two of the twelve fish translocated to Lake Worth passed downstream of FRD and subsequently took up residence in the downstream reach of the river. Thus, translocation by tournament anglers may facilitate a previously undocumented source of gene flow between the two populations. Likewise, emigration of translocated individuals could possibly help maintain gene flow among other adjacent populations inhabiting the Kinchafoonee and Muckalee creeks, both tributaries of Lake Worth. Unfortunately, translocation may also facilitate colonization of non-native black basses throughout the Flint River Basin.

Data from the stationary array showed that translocated shoal bass returned to the river after an average of 21 d (SD = 8) in the reservoir. Mean daily movement rates were highest during late March as the spawning season began, which suggests that the translocated fish may have had impetus to reach suitable spawning shoals. During the spawning period, which continued until early May, the majority of telemetered fish occupied Philema Shoals, a 2.5-rkm long shoal complex in the mainstem of the river. Concurrent sampling in Philema Shoals indicated that this area is a shoal bass spawning aggregation area (Taylor and Peterson, Chapter 3). During the spawning season, daily movement rates decreased to an average of about 150 m/d and some fish appeared to move between adjacent shoal complexes. As the spawn concluded and water levels in the river dropped over 1.5 m, daily movement rates averaged about 25 m/d and the majority of fish were observed moving slightly downstream into slightly deeper areas near the base of shoal complexes. Although causal mechanisms are unclear, shoal bass moved into deeper pools as water levels receded and stream flow declined (Stormer and Maceina 2009). Post-spawning movements of transmitted fish in our study were

similar, but further studies are needed to understand seasonal movements and habitat preferences of shoal bass in impounded rivers like the Flint.

The results of our translocation experiment documented that captured shoal bass quickly left the lentic environment where there were released and returned to the river. However, two of our transmittered fish were caught by tournament anglers in June 2011. Although these fish were released after the tournament weigh-in, they were subsequently found dead near the weigh-in site at Cromartie Landing. Throughout the course of our study, anglers frequently reported catching other transmittered shoal bass, but none of these fish were caught during a tournament, and hence, were released back to the river with limited handling time. Subsequent tracking of these fish showed that all of them survived and that they appeared to behave normally thereafter. Although we did not evaluate the effects of angler handling time on survival of released shoal bass in this study, previous studies on other black bass species have shown that handling time is positively related to post-release mortality (Wilde 1998; Edwards et al. 2004). Because tournament anglers in our study held their catches until the end of the tournament, we suspect that the extended handling time and translocation of tournament-caught shoal bass in this study may explain the relatively high mortality rates we observed.

Our findings suggest that the effects of translocation of shoal bass in bass tournaments may vary seasonally. Telemetry data from fish translocated during the spring showed that most fish quickly returned to the river; however, the effects imposed on individuals translocated during the summer months remains unclear. Furthermore, during the summer months, the total morality of tournament-caught shoal bass appears slightly higher than the 26-28% total mortality reported for other black basses (Wilde 1998).

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However, population-level effects of higher summer mortality are uncertain because tournament catches of shoal bass during summer months were relatively low. An average of three shoal bass was weighed in over five tournaments because low water levels restricted access to shoal habitats upstream of the lake throughout the summer. Future studies investigating post-release mortality and sub-lethal effects of translocated shoal bass are needed to better understand the population-level effects of fishing tournament translocation. Until such information is available, diligent management of the shoal bass fishery in our study area is warranted.

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    (Teleostei: Centrarchidae), from the Apalachicola River Basin in Alabama,
    Florida, and Georgia. *Bulletin of the Florida Museum of Natural History*
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Table 4-1. Capture location, total length (TL), weight, time required to re-enter the first shoal habitat upstream of Lake Worth, number of locations, overall average movement rate, and eventual fate and location of each telemetered fish translocated from the lower Flint River, Georgia, in early February, 2011.

Tag #	Capture Area	TL (mm)	Weight (g)	Time in Lake (d)	# of Relocations	Overall Avg. Mvmnt. (m/d)	Eventual Fate
701	Philema	386	1003	12	9	136	Alive
711	Philema	410	1174	17	11	76	Alive
721	Below CCD	457	1743	14	9	233	Alive
731	Philema	385	906	35	10	316	Dead
741	Abrams	376	825	20	13	220	Alive
751	Abrams	390	1092	19	10	375	Alive
761	Below CCD	458	1753	21	13	655	Dead
771	Philema	407	1185	15	11	306	Alive
781	Below CCD	367	962	33	11	318	Dead
791	Abrams	376	838	*	4	102	Left
820	Philema	480	1903	22	10	375	Alive
931	Philema	475	1821	*	2	111	Left

*Fish left study area after several weeks in Lake Worth and never re-entered the shoal habitats upstream of Lake Worth from where they were displaced.

Table 4-2. Summary of radio-telemetry data for 12 shoal bass that were captured from several locations in the lower Flint River, Georgia, and translocated into Lake Worth in early February, 2011.

Telemetry Obs. Dates in 2011	Time Since Translocation (d)	Number of Fish Locations	Min. Observed Mvmt. (m/d)	Max. Observed Mvmt. (m/d)	Avg. Observed Mvmt. (m/d)	Fish Moving Downstream (%)
24-Feb	*	11	66	327	150	18.2
3-Mar	15	11	22	1949	592	45.5
11-Mar	23	7	16	1784	955	0.0
16-Mar	28	7	44	2489	878	14.3
23-Mar	35	10	64	2072	730	0.0
1-Apr	44	10	19	1258	256	40.0
7-Apr	50	10	5	1513	242	40.0
15-Apr	58	9	19	434	160	55.6
20-Apr	63	8	17	559	181	62.5
29-Apr	72	9	0	562	106	55.6
18-May	88	8	1	51	26	87.5
26-May	96	7	0	50	23	71.4
2-Jun	103	6	1	83	20	50.0

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* 7 days for the fish translocated on February 17, 2011 from Philema and Abrams shoals and 8 days for fish translocated on February 16, 2011 from the area just downstream of Crisp County Dam (CCD).

Table 4-3. Observations of immediate and 12-hr post-tournament mortality of shoal bass caught and translocated into Lake Worth, Georgia during local fishing tournaments held in the summer months. Fish were held in a net pen to assess 12-hr, post-tournament survival.

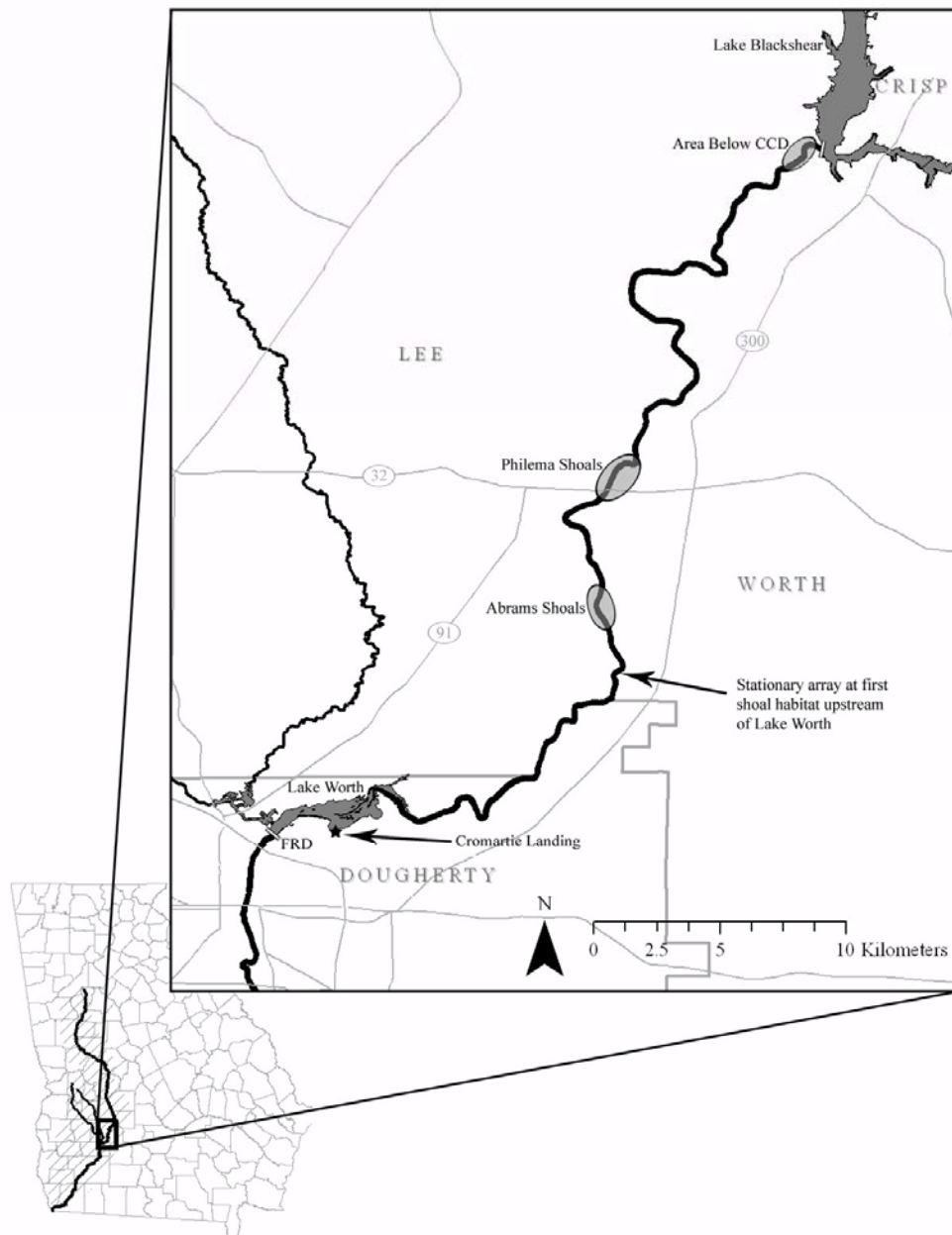|	Shoal Bass at Weigh-in		Shoal Bass in Net Pen (12-hr Survival)				
Date	Total	Dead	Held	Alive	Dead	Escaped	% Mortality
6/24/11	7	1	6	3	1	2	28.6
7/7/11	4	1	3	0	2	1	75.0
7/14/11	1	0	1	0	0	1	0.0
7/21/11	2	0	2	1	0	1	0.0
7/28/11	1	0	1	1	0	0	0.0
Total	15	2	13	5	3	5	33.3

Figure 4-1. A map of the study area that spanned of 50 river kilometers (rkm) of the lower Flint River, Georgia, from the base of Crisp County Dam (CCD) and included the entirety of Lake Worth. Circled areas indicate original capture locations of transmittered and translocated shoal bass.
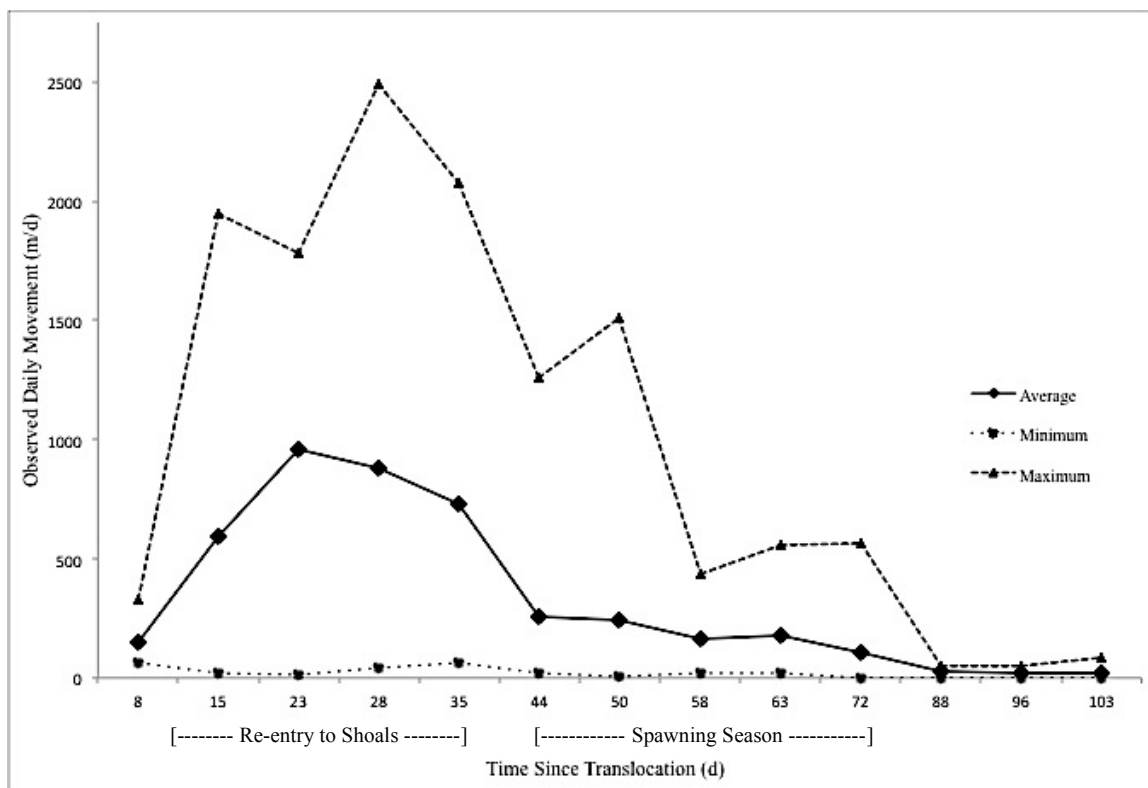
Figure 4-2. Daily movement rates of translocated shoal bass as they returned from Lake Worth to shoal habitats in the lower Flint River, Georgia, in spring and summer 2011.

CHAPTER 5

CONCLUSIONS

Within the native range of the shoal bass, Georgia's Flint River Basin supports some of the most robust remaining populations (Williams and Burgess 1999; Straight et al. 2009). My research focused on a population confined to 50 river-kilometer reach of the lower Flint River. Isolated by hydroelectric dams at either end, this particular river segment was previously thought to contain the last remaining mainstem population free of non-native spotted bass (Travis Ingram, Georgia Department of Natural Resources [GADNR], personal communication). Population isolation and habitat degradation are well-established threats to shoal bass inhabiting impounded rivers (Williams and Burgess 1999), yet my study area is well-known among shoal bass anglers as having one of the best populations in Georgia. Despite many recreational angling groups voicing concerns over the need for shoal bass conservation, many questions remain regarding the effects of angling mortality and angler translocation of shoal bass within the study area.

In Chapter 2, I synthesized all available literature on shoal bass life history, habitat needs, and current threats. Perhaps the most important of my conclusions was that long-term conservation efforts for the shoal bass must focus on maintaining interconnected shoal and pool habitats throughout the native range. I also emphasized that my study is a single example of the type of quantitative, population-specific assessments that are imperative for future management and conservation efforts. At

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present, the future of the species is somewhat uncertain because most populations have continued to decline despite renewed public interest.

In Chapter 3, I reported the results of a new and substantive population assessment in my study area. Mark-recapture estimates suggested that the only known spawning aggregation within the 50-rkm study area – within what is considered to be the stronghold of the species' range – may have contained as few as 181 (95% C.I. 101 – 374) adults during the "peak" of the spawning season. Although pure non-native black basses were not observed in any of my samples, genetic analysis of the tissue samples I collected revealed that ~12% of shoal bass collected during my study were actually hybrid backcrosses with non-native spotted bass (*M. punctulatus*). In the course of that assessment, I also evaluated the marking methods currently used in GADNR's annual survey of angling mortality. Based on a limited number of recaptures, my results indicated that some of the internal anchor tags were lost within 21 d post-tagging. Directed studies are needed to estimate tag retention longer periods so that tag loss can be accounted for in future mark-recapture assessments. Within the context of these findings, I suggest that abundance of spawning aggregations and hybridization rates should be monitored within an adaptive management framework. This will allow biologists to further assess the effects of potential threats while deriving optimal management strategies for the population.

In Chapter 4, I investigated short-term movement and survival of individual shoal bass that had been moved by anglers from the lower Flint River into Lake Worth. Although 83% of the fish translocated in early spring returned to the river after a few weeks, nearly 33% of shoal bass translocated during the summer months either died

within 12 hrs of tournament weigh-ins. Based on these results, I concluded that further studies are needed to better quantify population-level effects of translocation.

Although my study area is considered a prime destination for shoal bass angling, my findings suggest that diligent management, research, and monitoring should be incorporated into an adaptive management framework for the population. In total, the results and conclusions reported in this thesis underscore the need for range-wide population assessments, as well as the need for identification of at-risk populations. I hope the methods presented within this thesis provide a detailed framework for future efforts to address these needs. Until such work is completed, the conservation status of the shoal bass remains uncertain.

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