

**ASSESSMENT OF SMALLMOUTH BASS
MICROPTERUS DOLOMIEU AND ROCK BASS
AMBLOPLITES RUPESTRIS GROWTH AND
CONDITION IN THE LITTLE RIVER, TENNESSEE**

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ABSTRACT

The Little River in Blount County, Tennessee, is a popular tourist location and fishery. It originates inside the Great Smoky Mountains National Park (GSMNP) and has sustained few impacts due to the protection of the Park. Growth and condition of smallmouth bass *Micropterus dolomieu* and rock bass *Ambloplites rupestris* were evaluated in Little River, Tennessee, from April to August 2013 and related to populations from other rivers in East Tennessee. Samples were collected via boat and backpack electrofishing. Selective sampling techniques targeting five or more fish in each 25.4- mm class produced 97 smallmouth bass and 48 rock bass. Otoliths were extracted from all fish for age determination. Length and weight measurements along with sex of each fish were also recorded.

The von Bertalanffy growth function predicted smallmouth bass grew to 180 mm in 2.5 years, 305 mm in 5.1 years, and 356 mm in 6.7 years. Rock bass grew to 100 mm in 2.4 years, 180 mm in 5.2 years, and 230 mm in 8.3 years. When compared to other rivers in Eastern Tennessee, growth of smallmouth bass and rock bass in Little River was slow, although smallmouth bass grew faster in Little River outside the GSMNP. The maximum age of smallmouth bass and rock bass collected was 15.0 and 7.0 years, respectively. Mean relative weights (W_r) of smallmouth bass and rock bass were 84 and 89, respectively. Poor condition and slow growth was common in Little River fish and may be related to low temperature and productivity associated with the Park watershed or low abundance of food.

The results of this study enable fisheries managers to make informed decisions on how angling regulations and harvest may affect populations of smallmouth bass and rock bass in the Little River. The Little River has the potential to produce trophy size smallmouth bass and regulations on rock bass harvest could be reviewed by managers to enhance the fishery and promote larger and older fish.

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CHAPTER I

INTRODUCTION

Smallmouth bass *Micropterus dolomieu* and rock bass *Ambloplites rupestris* are sunfishes in the family Centrarchidae (Perciformes) and both species occur together throughout most of their ranges (Coble 1975; Etnier and Starnes 2001). Both species are popular among anglers of riverine systems (Weithman 1991; Mayers 2003) due to their ability to put up a hard fight and their excellent table fare (Etnier and Starnes 2001). Both species are important components of Little River's diversity and sport fishery. These aggressive predators are the dominant sport fish in Little River as largemouth bass *M. salmoides* and spotted bass *M. punctulatus* occur in such low numbers they are not considered a significant part of the fishery (Carter et al. 2013).

Smallmouth bass popularity as a sportfish has been documented as far back as the 19th century, when Henshall (1889) referred to the bass as "inch for inch and pound for pound, the gamest fish that swims." Smallmouth bass fisheries are ranked among the highest in economic and aesthetic values and can be worth millions of dollars annually (U.S. Department of the Interior 2002). The current Tennessee and world record smallmouth bass is from Dale Hollow Reservoir, although it was caught on the Kentucky side in 1955 (Etnier and Starnes 2001).

Angling pressure on a stream depends on fishing success, accessibility to fishing locations, and the density of humans around the stream and can include the aesthetic value or reputation of the region (Coble 1975). Carter et al. (2013) claim "excellent"

populations of smallmouth bass and rock bass are present in Little River, and rainbow trout *Oncorhynchus mykiss* are stocked in spring and fall as water temperatures allow. The lower portion of the river has many developed campgrounds and is a popular recreation destination for tourists and local anglers, creating the opportunity for an outstanding fishery (Carter et al. 2013). The Tennessee Wildlife Resources Agency (TWRA) is responsible for managing fish and wildlife throughout Tennessee and divides the state from west to east into Regions I-IV, respectively. The entire length of the Little River is located within Region IV.

The Little River is a 5th order stream that originates near Clingman's Dome in the GSMNP and flows northwest approximately 59 miles (95 km) through the towns of Townsend and Maryville. It joins the Tennessee River (Fort Loudoun Reservoir) near Tennessee River Mile (TRM) 635.6. The watershed drains approximately 379 mi² (982 km²) before reaching its confluence with the Tennessee River (Carter et al. 2013). The Little River begins in the Blue Ridge physiographic province in the GSMNP, and then flows into the Ridge and Valley province just outside the Park boundary near the town of Walland. The gradient is drastically reduced when leaving the Blue Ridge province and long deep pools and shallow shoals are created within the Ridge and Valley province.

Tennessee has the richest freshwater fish fauna in the United States (Etnier and Starnes 2001). The Little River is home to over 50 species of fish and provides critical habitat for four species listed federally (Carter et al. 2013). Carter et al. (2013) described Little River as “an outstanding resource in the quality of the water and the species that inhabit it.” Since approximately one-third of the Little River watershed is within the boundaries of GSMNP (Jett 2010), the river has sustained less human impacts due to the

protection of the Park. The portion of Little River within the GSMNP has been considered an Outstanding National Resource Water partially due to its outstanding biological diversity and naturally reproducing trout from Little River Mile (LRM) 33.0 to its origin (Denton et al. 2012). Downstream of the Park, the river supports a highly diverse fish fauna and has consistently scored an “excellent” rating on annual Index of Biotic Integrity (IBI) assessments by the TWRA since 2002 (Carter et al. 2013). IBI assessments often depend on a watershed with low human impacts and excellent biological integrity for use as a “reference” to assess conditions in nearby watersheds. Collection of basic population data on sport fish in Little River will assist in these future assessments since Little River serves as a “benchmark” for evaluating other similar rivers (Carter et al. 2013). Anglers can also benefit from understanding the natural growth and condition characteristics of popular sport fish within regional fisheries.

Impacts outside GSMNP are also minimal due to the mostly rural watershed. The city of Maryville has the largest population at 27,000 people. Impacts are still caused by row crop and livestock agriculture, which can introduce sedimentation, as well as, pesticides and fertilizer pollutants. These have been documented as factors in fish population declines (Lenat 1984; Scott et al. 1986; Mason et al. 1991).

There are three small impoundments on Little River: a low head dam at Rockford (LRM 6.8), Perry’s Mill dam (LRM 21.9) downstream of Walland, and a low head dam located in Townsend (LRM 33.6). Additionally, approximately 8.3 river miles (1.6 km) of the lower portion of Little River are impounded by Fort Loudoun dam on the Tennessee River. There is a decline of suitable habitat and quality of the fishery for rock bass and smallmouth bass below Perry’s Mill dam (Carter et al. 2013). In addition, the

mouth of the Little River is negatively influenced by the impoundment of Ft. Loudoun Reservoir (Jett 2010), and elevated levels of the toxin polychlorinated biphenyl (PCB) in fish tissue (TDEC 2008a).

Many factors influence abundance, mortality, recruitment, longevity, condition, and growth of riverine populations of smallmouth bass and rock bass. Flow regimes, food availability and abundance, physical habitat, stream size, water temperature and quality, and exploitation can greatly affect growth rates and other characteristics in fish populations (Coutant 1975; Shaffer 2004; Brown et al. 2009). Zorn et al. (2001) found larger streams have significantly higher abundance of smallmouth bass compared to smaller streams. Smaller streams lack physical factors, deep water habitats, and have highly variable flows and provide less optimal conditions compared to larger streams (Coutant 1975; Schlosser 1987).

Carter et al. (2012) noted the lack of age and growth information for smallmouth bass and rock bass populations in Little River and Fiss et al. (2001) expressed the need for more surveys of smallmouth bass in the rivers of Region IV to ensure adequate representation of those resources in statewide averages.

Therefore, the objectives of this study were to:

(1) Determine ages, growth rates, and relative weights for smallmouth bass and rock bass in Little River downstream of GSMNP and

(2) Relate these characteristics to historical data collected from Little River, and other relatively similar rivers in Region IV.

CHAPTER II

LITERATURE REVIEW

Target Species

Smallmouth Bass

The smallmouth bass *Micropterus dolomieu* (Figure 1), is a very popular sport fish and is targeted by anglers throughout its range. Due to this popularity, the smallmouth bass has been widely introduced outside its native range of the interior eastern North America west of the Appalachian Mountains (Etnier and Starnes 2001). The “*i*” was dropped from the end of the specific epithet *dolomieu* due to changes in the rules of zoological nomenclature (Bailey and Robins 1988).

Smallmouth bass utilize root wads, stumps, and other woody debris as well as coarse rocky substrate, boulders, and rock outcrops as cover (Coble 1975; Miller 1975; Probst et al. 1984; Rankin 1986; Todd and Rabeni 1989; Barrett and Maughan 1994). Klauda (1968) concluded that rough substrate helps brace and protect smallmouth from being swept downstream when they become lethargic as water temperatures drop near 4°C or below. They are attracted to areas of darkness (Haines and Butler 1969) with slow to moderate currents (Coble 1975; Rankin 1986; Sechnick et al. 1986; Leonard and Orth 1988; Barrett and Maughan 1994). Smallmouth bass have been documented to occupy the same pool for an entire season (Larimore 1952; Munther 1970) or make long distance movements in spring and fall (Henegar 2007).

The best rivers for smallmouth bass have been described as being mid-order, cool



Figure 1. Photograph of an adult smallmouth bass *Micropterus dolomieu* (355 mm TL).

and clear, with alternating riffles and pools (>50% pools), a moderate current and gradient (0.75 m/km-4.7 m/km), abundant shade and cover, and substrates of gravel and larger materials (Edwards et al. 1983; Armour 1993; Lasenby and Kerr 2000). Non-turbid water is preferred since the smallmouth bass is a predator that depends highly on vision to effectively find prey (Armour 1993; Sweka and Hartman 2003).

Smallmouth bass spawn at water temperatures between 12.5 and 23.5°C (Coble 1975; Edwards et al. 1983; Graham and Orth 1986) with maximum survival of eggs between 15 and 27°C (Shuter et al. 1980). Hubbs and Bailey (1938) noted the spawn often occurs at 15-18°C between April and early May in the southeastern United States. Reproductive maturity is reached in males at ages 2 to 4 and ages 3 to 5 for females (Coble 1975).

During spawning, the male selects a nest site in a calm area near large structure such as stumps or boulders in shallow water (<1 m deep) (Coble 1975). The nest substrate is usually sand, gravel, or rubble and is cleared out by a sweeping of the tail by the male (Hubbs and Bailey 1938; Latta 1963; Mraz 1964; Pflieger 1966). Once the male fertilizes the eggs, he remains with them to aggressively guard them, although there is

some debate whether the male fans the nest to provide oxygen and remove silt deposition. Several authors claim the male does not fan the nest (Hubbs and Bailey 1938; Pflieger 1966; Coble 1975); however others have noted this observation in their findings (Emig 1966; Schneberger 1972; Reynolds and O'Bara 1991). Females may renest and respawn with or without a successful first spawn (Pflieger 1966), though not all mature smallmouth spawn each spring (Raffetto et al. 1990).

The primary diet of the smallmouth bass consists of fish, crayfish, aquatic insects, and microcrustaceans (Hubert 1977; Probst et al. 1984; Shaffer 2004). They will also eat frogs, tadpoles, fish eggs, terrestrial insects (ants, grasshoppers) and plant material where available (Keating 1970; Scott and Crossman 1973). Younger fish begin feeding on microcrustaceans (Copepods, Cladocera) and aquatic insects and move to feeding primarily on crayfish and larger fish as they grow in size (Coble 1975; Etnier and Starnes 2001). Their diet is greatly influenced by availability and abundance of prey (Paragamian 1973).

It is well documented that males and females grow at the same rate (Bennett 1938; Westman and Westman 1949; Webster 1954; Latta 1963; Dunlop et al. 2005), though Henderson and Foster (1956) did discover females grew larger than males in Columbia River, Washington. Smallmouth bass can live up to 18 years in Canada, but are unlikely to live more than 15 years in the South (Coble 1975; Etnier and Starnes 2001). Fajen (1959) and Coble (1975) reported an average life expectancy of 9-11 years.

A synopsis of smallmouth bass by Coble (1975) stated smallmouth bass average 279 mm and 323 mm total length (TL) by ages 4 and 5, respectively, though studies conducted in Tennessee have shown much variation (Cathey 1973; Gwinner 1973; Fiss et

al. 2001; Shaffer 2004). Gwinner (1973) found smallmouth bass averaged only 165 mm and 200 mm at ages 4 and 5 respectively in a small, cold stream, whereas Cathey (1973) saw growth of 435 mm by age 5 in larger and warmer streams. Fiss et al. (2001) reported smallmouth bass averaged 261 mm and 298 mm at ages 4 and 5 in a statewide analysis. In Region IV, these same age classes averaged 256 mm and 298 mm, respectively. Shaffer (2004) saw ages 4 and 5 smallmouth bass grow to 210 mm and 245 mm in Little River within the GSMNP and 237 mm and 269 mm in Abrams Creek, respectively.

Compared to lotic systems, mean growth was greater for impounded smallmouth bass due to higher temperatures, low flow rates, low turbidity, longer growing season, and higher food availability (King et al. 1991; Etnier and Starnes 2001). Smallmouth bass reached sizes of 404 and 440 mm by ages 4 and 5 in Norris Reservoir, Tennessee (Eschmeyer 1940; Stroud 1948) during the highly productive period after impoundment. Recent TWRA unpublished data (J. Negus, TWRA, personal communication) found smallmouth bass in Norris Reservoir grew to 425 mm and 489 mm by ages 4 and 5, respectively.

Rock Bass

Rock bass *Ambloplites rupestris* (Figure 2), are native to the Mississippi River, Great Lakes, southern Hudson Bay basins, and the Connecticut through Delaware River drainages on the Atlantic Coast. They have been introduced outside their native range, but are absent from the Coastal Plain and Conasauga River system in Tennessee (Scott and Crossman 1973; Pflieger 1975; Trautman 1981; Jenkins and Burkhead 1994;



Figure 2. Photograph of an adult rock bass *Ambloplites rupestris* (198 mm TL).

Etnier and Starnes 2001).

Rock bass prefer clear water and are intolerant of turbidity and siltation (Robison and Buchanan 1988; Bunt et al. 2004). In Tennessee, rock bass inhabit lower reaches of trout streams to warmwater streams (Etnier and Starnes 2001) and are mostly associated with rootwads, rocks, woody debris, aquatic vegetation, sheltered pools and other types of cover (Pflieger 1975; Trautman 1981; Probst et al. 1984; McClendon and Rabeni 1987; Leonard and Orth 1988; Jenkins and Burkhead 1994).

Spawning occurs from April to June (Pflieger 1975) at temperatures ranging from 15.6 to 27°C (Neill and Magnusen 1974; Gross and Nowell 1980; Tin 1982). The male fans out a nest in sand and gravel substrate at the bottom of a moderately flowing pool. After spawning, female rock bass leave and males are solely responsible for protecting the offspring (Gross and Nowell, 1980). Rock bass may spawn multiple times per year with earlier spawns increasing the opportunity for more spawning (Noltie and

Keenleyside 1987). Noltie and Keenleyside (1987) also saw asynchronous nesting and spawning over several weeks in riverine rock bass populations in Canadian systems, in contrast with lacustrine populations where nesting and spawning was synchronous over a two day period. Stearns (1976) and Noltie and Keenleyside (1987) both concluded that unstable and unpredictable environmental conditions in riverine systems led to reduced growth and adult survival, therefore maturity and reproduction occur earlier compared to more stable lacustrine environments. Rock bass exhibit sexual dimorphism in growth with males being larger than females of the same age (Breder 1936; Eddy and Carlander 1942; Beckman 1945). This has potentially evolved to facilitate nest defense (Hubbs and Cooper 1935).

Rock bass have been studied several times in other Tennessee streams (Speir 1969; Cathey 1973; Gwinner 1973). Gwinner (1973) and Cathey (1973) found rock bass grew to an average of 45 mm TL in year 1 and 80, 155, 160, 195, and 200 mm TL for years 2-6, respectively. More recent TWRA unpublished data (F. Fiss, TWRA, personal communication) indicate rock bass grew to a mean TL of 64, 101, 136, and 148 mm at ages 1 to 4 respectively and 198 mm by age-6 in Little River, Tennessee. Carlander (1977) reported growth of 120 mm TL by the end of their second year in some southern streams.

Both sexes reach maturity by the beginning of year 3 (Carlander 1977). Maximum life span was estimated at about 8 years (Redmon and Krumholz 1978). Carlander (1977) reported a 13-year-old Wisconsin rock bass, but also noted most southern fish do not live past 8 years. Funk (1955) classified the rock bass as “sedentary” due to little mobility within the stream.

The diet of the rock bass primarily consists of small fish, crayfish, snails, and aquatic insects (Elrod et al. 1981; Probst et al. 1984). Amphipods, copepods, and aquatic insects are an important food source for juvenile rock bass (George and Hadley 1979). Other fish are a major food source for adult rock bass (Pflieger 1975, Schlosser 1982, Probst et al. 1984, Keast 1985, Leonard and Orth 1988, Jenkins and Burkhead 1994) and become more important in the diet as the fish grows (Elrod et al. 1981). Unlike smallmouth bass, rock bass in northern streams were found to grow at nearly the same rate as those in lakes and were in better condition than lake dwelling rock bass (Noltie 1988), though higher mortality rates have been documented (Carlander, 1977; Covington et al. 1983).

Fishery Characteristics

While research has been conducted on darters in the Little River (Greenburg 1991; Heacock 1995; Jett 2010), there is no known extensive assessment on smallmouth bass or rock bass age and growth outside of the GSMNP. Shaffer (2004) evaluated smallmouth bass populations in Abrams Creek and Little River within the GSMNP beginning at LRM 35.0. Cathey (1973) and Gwinner (1973) studied age, growth, and length-weight relationships of smallmouth bass and rock bass in Roaring River and Spring Creek, Tennessee, respectively. Although these studies were beneficial, the TWRA desired better sport fish growth data on the Little River outside of GSMNP, due to the popularity of the fishery.

Before 1995, the TWRA realized they were lacking basic data on riverine smallmouth bass in Tennessee, such as population characteristics and creel data. These data were necessary to evaluate potential regulations and to make informed management decision for Tennessee fisheries. They conducted a study over several years of riverine smallmouth bass populations across the state of Tennessee. The report by Fiss et al. (2001) stated the objectives were to describe the size structure, growth, annual mortality, and recruitment of riverine smallmouth populations and predict how the populations would respond to various length restrictions using modeling software. Some 72 populations were sampled over a six-year period and were estimated to represent approximately 75% of river populations and 20% of stream populations statewide.

A total of 1,564 smallmouth bass from 22 populations were collected from various streams and rivers in Region IV for age determination. Growth for Little River fish was classified as “slow” for ages 3 (<232 mm) and 4 (<263 mm) due to mean total lengths in the 25th percentile. Fiss et al. (2001) reported that Tennessee smallmouth bass populations required 7.0 years statewide and 6.7 years in Region IV to attain the preferred size (Gabelhouse 1984) of 356 mm. Smallmouth bass in Region III exhibited slower growth, taking 8.3 years to reach the preferred size. Shaffer (2004) predicted it would take smallmouth bass 8.1 years to reach 305 mm in the GSMNP, and found the smallmouth bass populations in Little River to be comprised of mostly young fish ($\leq$ age 4). Shaffer (2004) recorded Little River temperatures of 18.2-18.6°C during July and August 2002-03. Those summer temperatures were below the optimum range of 21-27°C

for adult smallmouth bass (Edwards et al. 1983) and may account for the slower growth compared to the mean length-at-age of other populations within the region.

For Region IV smallmouth bass populations, proportional stock density (PSD) ranged from 16 to 50 (Fiss et al. 2001). Shaffer (2004) reported PSD range of 13 ± 8.6 for smallmouth bass in Little River inside the Park. The PSD values in Little River surveys by TWRA (Carter et al. 2012) were 22.9 and 22.7 for smallmouth bass and rock bass respectively. Those PSD values were all well below the balanced value of 30-60% (Anderson and Weithman 1978), and may suggest slow growth, poor recruitment, or high mortality. Fiss et al. (2001) noted other rivers in TN as having low PSDs, such as the French Broad (16%) and Buffalo (14%). Fiss et al. (2001) did not calculate PSD for Little River due to the lack of age-2 and older smallmouth bass from an anecdotal sample which included only 21 smallmouth bass.

In 2009, TWRA placed a protected length range (PLR) regulation on smallmouth bass in Little River from Rockford Dam (LRM 6.8) to the GSMNP boundary (LRM 35.0) (Carter et al. 2013). The PLR prohibits harvest of smallmouth bass on Little River between 330 mm and 432 mm TL and only one of the five fish daily creel to exceed 432 mm. An angler use and harvest survey has been implemented by TWRA (Bart Carter, TWRA, personal communication) to gauge the popularity of the regulation and assist with evaluating population effects.

Length restrictions, (e.g. a PLR), can have beneficial long-term effects when used properly and success depends upon angler participation, enforcement, growth rates, and natural and hooking mortality (Coble 1975; Roell and DiStefano 2010). Length restrictions have shown changing the age and size structure of exploited smallmouth bass

and rock bass populations has the potential to increase the average size and age of fish in the population. In turn, the average catch sizes should increase (Coble 1975; Roell and DiStefano 2010).

CHAPTER III

METHODS

Sampling

Sample Area

Smallmouth bass were collected between April and August 2013 and rock bass between April and July 2013 from the Little River in Blount County, Tennessee. The study area covered the reach of river from LRM 9.2 to LRM 32.1 (Table A1, Figure 3) and individual collection efforts ranged from 0.1 to 5.6 river miles in length. All collection efforts were conducted upstream of the low head dam at Rockford (LRM 6.8) and downstream of the low head dam at Townsend (LRM 33.6) (Figure 3).

The study areas were chosen to maximize the likelihood of capturing smallmouth bass based on prime habitat, electrofishing conditions, boat access, and discharge rates. Collecting samples in April was preferred due to the difficulty of boat access and navigation during low summer discharges that previously made collections difficult for TWRA. All sample sites were located within Blount County, although Little River does begin and end in Sevier and Knox Counties, respectively. Site location coordinates were recorded with a Garmin global positioning system (GPS) handheld unit at the farthest upstream and downstream point of active sample collection (Table A1).

Sample Collection

Fish were netted and a total length (TL) measurement was taken to obtain size classification. Five fish were targeted from each 25.4-mm (1-inch) size classes which

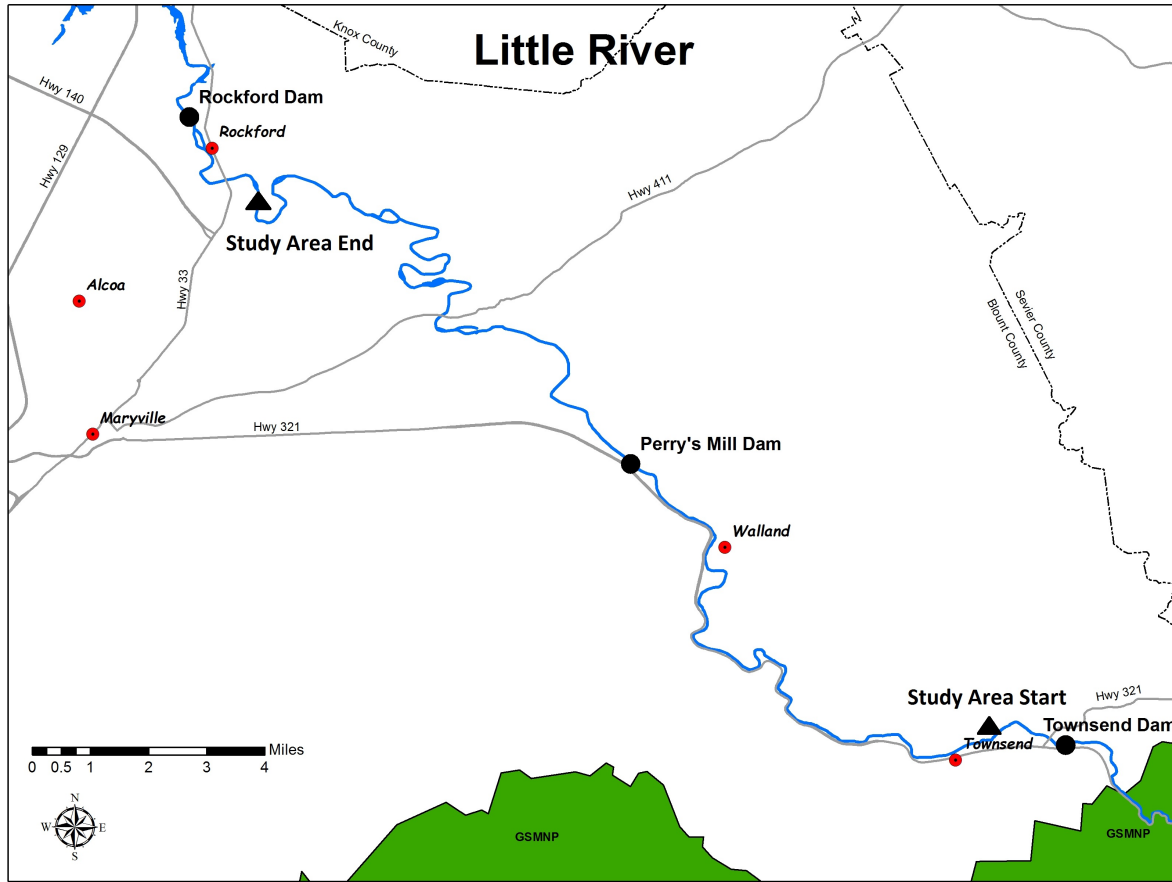


Figure 3. Map of the sample collection area on Little River, Blount County, Tennessee.

were rounded to: 0-, 25-, 51-, 76-, 102-, 127-, 152-, 178-, 203-, 229-, 254-, 279-, 305-, 330-, 356-, 381-, 406-, 432-, 457-, 483-, and 508- mm in length. Efforts were made to collect fish from the range of size classes for both target species expected to occur in Little River (1-533 mm for smallmouth bass and 1-279 mm for rock bass). Once a size class sample minimum was reached, fish in that size class were no longer collected, with some exceptions to provide a more accurate mean. Total length (mm), weight (g), and sex were recorded and otoliths were removed from each fish. Sex was recorded as male (M), female (F), or unknown (U) if not sexually mature. Sampling methods were designed to collect a sufficient number of fish to provide an accurate assessment of

growth and condition across age classes, while preventing “over-collection” and possibly damaging the popular fishery that existed in the river.

Boat electrofishing was conducted with typical generator-powered systems producing pulsed DC current through a control box to drop cables in the water. The systems produced 120 pulses-per-second and were adjusted to produce an output of at least 2-4 amps. The boat was launched upstream at the beginning of the site and was floated downstream. When habitat for the target species was encountered, the boat operator would engage the electrofishing pedal and release it when the habitat was thoroughly sampled. This process continued until the end of the site was reached.

Where the water was too shallow or inaccessible for boat access or when targeting smaller fish, backpack electrofishers were utilized and operated between 200 and 250 volts AC depending on conductivity. The operator would wade along shorelines and electrofish areas where the target species were likely to be present (i.e., under rootwads or woody debris). Multiple angling attempts were also made to obtain fish in larger size classes of both species, but no fish were collected via this method.

Otoliths

Otolith ages have been used to determine growth, survival, recruitment, mortality, and impacts of environmental change, assess stock structure, measure effects of fishing, and guide resource management decisions and policies (Jones 1992). Otoliths have been shown to be the most reliable structure for aging fish (LaBay and Lauer 2006), especially for smallmouth bass (Long and Fisher 2001). Scales are not reliable for age

determination for smallmouth bass (Beamish and McFarlane 1987) and are subject to resorption in times of stress (Jones 1992).

Drawbacks to otolith aging are that the fish must be sacrificed, and proper training of personnel is necessary. Three pairs of otoliths (lapilli, sagittae, asterisci) occur in teleosts and differ in many ways such as size and shape. The sagittae is the largest, easiest to remove and handle, and contains the widest increments (Secor et al. 1991), therefore it was selected as the best option for this study.

Two sagittal otoliths were extracted from each fish in the field using the “up through the gills” method described by Secor et al. (1991). This method consisted of the following steps: cutting through the isthmus, bending the head backwards away from the body, scraping the tissue away from the neurocranium (braincase), cutting slightly into the bulla with a knife to crack it open, and grasping the two exposed sagittal otoliths to remove. Once removed, the otoliths were placed in plastic vials and numbered incrementally. After the otoliths were allowed to dry completely (Butler 1992), the vials were sealed for storage.

Otoliths with easily identifiable annuli were read in the whole form. All others were manually split into sections along the transverse axis (Secor et al. 1991) with a thumbnail and index finger. Long and Fisher (2001) claimed that sectioned otoliths remove reader bias regardless of reader experience. The innermost side of sectioned otoliths was prepared using an electric rotary tool with a polishing wheel attachment, progressively wet sanded with 600 and 1000-grit sandpaper, and then polished with a rotary felt wheel attachment until smooth. Some otoliths that were more difficult to read were lightly charred with a flame and rebuffed to provide more defined annuli.

Once polishing was complete, the otolith was placed in a petri dish containing black electrical putty molded into a bowl. Water was poured into the putty bowl and petri dish to completely inundate the otolith and putty. The otolith was forced into the putty, inner side up, to reduce movement, and illuminated using a fiberoptic light source. Each annulus was equal to one year of growth. The outside edge or “margin” of the otolith was considered an annulus due to collection during the breeding season for both smallmouth bass and rock bass.

All otoliths were read two times each by Reader 1 (author) and Reader 2 (B. Carter, TWRA). Any otoliths with differing age estimates between Readers 1 and 2 were read by an independent party, Reader 3 (J. Brian Alford, University of Tennessee). Final age estimates were determined after consultation between all readers. All individuals read otoliths without knowledge of prior age estimates to remove bias.

Statistical Analyses

Growth

Growth rates were predicted length-at-time (L_t) following the von Bertalanffy growth equation (von Bertalanffy 1938):

$$L_t = L_{\infty} (1 - e^{-K(t-t_0)})$$

where L_{∞} = the maximum theoretical attainable length, K = the growth coefficient, t_0 = the time (years) when length is theoretically zero, t = age in years, and e = exponent for natural logarithms.

Due to spawning time similarities in the month of April for both target species, that month was used as the beginning of the growth year for samples collected in this study. Ages were adjusted to account for additional growth as suggested by Haddon (2011). For example, if a one-year-old fish was collected in July, the age was considered to be 1.25 years, or one-quarter of one year of additional growth. All ages of fish from TWRA unpublished data were calculated without additional growth time adjustments, due to the inability of the von Bertalanffy growth function to predict a t_0 . In addition to the model prediction for maximum theoretical attainable length (L_∞), it was fixed at 292 mm for rock bass and 559 mm for smallmouth bass to assess potential differences in growth estimates, based on maximum total length each species is likely to reach in the Little River.

Growth for both target species in Little River was compared to five other popular riverine fisheries in Eastern Tennessee where anglers target smallmouth bass and rock bass (Pigeon, Nolichucky, Powell, North Fork Holston, and Clinch). The time (years) to reach a specified length (mm) was predicted via von Bertalanffy growth curves among these rivers using TWRA's raw data from 1996 and 1997 that was part of the Agency's smallmouth bass report (Fiss et al. 2001).

Relative Weight

Relative weight (W_r) is an improvement of the relative condition factor (K_n) (Wege and Anderson 1978), and attempts to describe the shape of a fish in good condition (Anderson and Neumann 1996). The values were calculated using the relative weight equation by Neumann et al. (2012):

$$W_r = W/W_s \times 100$$

with the standard weight (W_s) equation:

$$\log_{10}(W_s) = a' + b[\log_{10}(\text{TL})],$$

where W = weight of an individual (g), a' = intercept, b = slope of the $\log_{10}(\text{weight})$ and $\log_{10}(\text{length})$ regression equation, TL = total length of an individual (mm), and (W_s) is the length specific standard weight predicted by a weight-length regression developed for a species. W_r is a percentage, but is displayed without the symbol. Smallmouth bass ($a' = 5.329$, $b = 3.2$) and rock bass ($a' = -4.827$, $b = 3.074$) have different proposed parameter values for intercept and slope. Minimum length recommended for application for smallmouth bass (150 mm) and rock bass (80 mm) were utilized since younger fish weights tend to be variable. Smallmouth bass and rock bass slope, intercept, and minimum length values reported by Neumann et al. (2012) were used to calculate relative weights.

Frequency-at-age of smallmouth bass was estimated from graphs produced by Shaffer (2004). All analyses were calculated utilizing the Microsoft Excel add-in program including the data analysis tool packaged with the software program Fishery Analysis and Modeling Simulator (FAMS) developed by Slipke and Maceina (2010).

CHAPTER IV

RESULTS

Ninety-seven smallmouth bass and 48 rock bass were collected from April to August 2013 from Little River, Blount County, Tennessee (Table A2). Both target species were more abundant and easier to collect between Perry's Mill dam and the Townsend dam. Higher than usual precipitation levels resulted in samples being collected in July and August instead of only April and May as originally intended. Most fish were collected in April and May with one rock bass collected in July, and four smallmouth bass collected in August.

Otoliths were removed and read from all fish collected (n=145). Otolith age estimates were in agreement between Readers 1 and 2 for 131 fish (90%) and discrepancies were resolved by Reader 3. All age estimates (n = 145) were finalized after consultation between all readers.

At least five smallmouth bass were collected in size classes 51- mm to 547- mm and four fish from the 406- mm and 547- mm classes. No fish were observed or collected from the 0- mm, 25- mm, 483- mm, or 508- mm classes. The maximum age of smallmouth bass observed was 15.0 years (Table A2, Figure 4).

At least five rock bass were collected in the 25- mm to 203- mm size classes, and two fish in the 229- mm class. No fish were observed or collected from the 0- mm or 254- mm classes. The maximum age of rock bass observed was 7.0 years (Table A2, Figure 5). No age-4 rock bass and only two age-2 smallmouth bass were present.

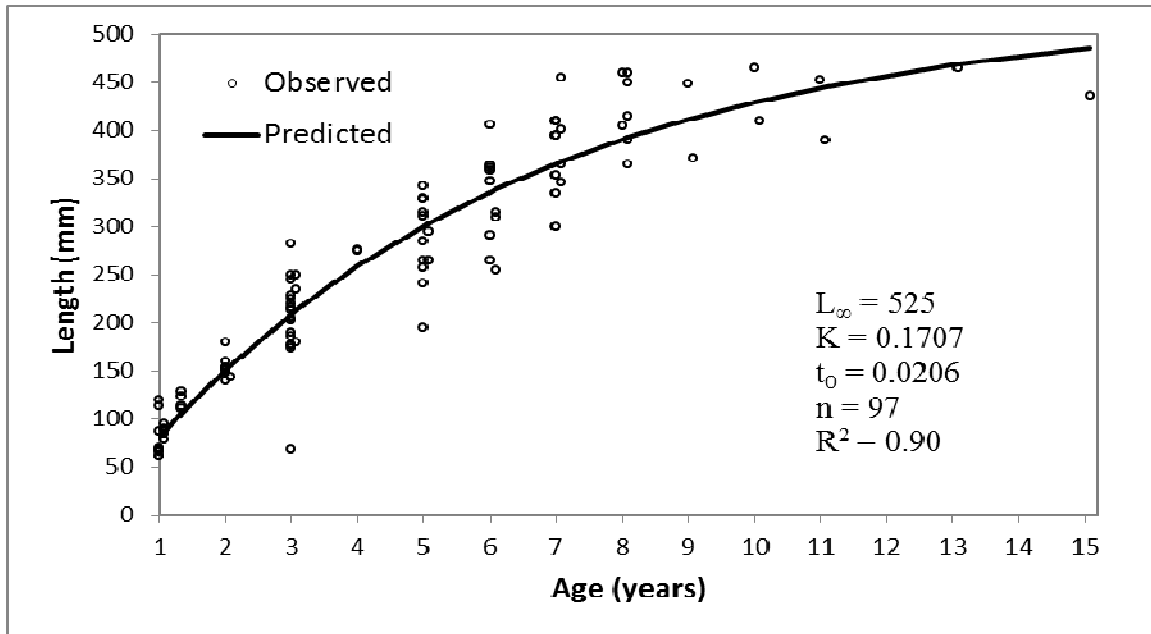


Figure 4. von Bertalanffy growth curve predicting length-at-age for smallmouth bass in Little River, Blount County, Tennessee, from April to August 2013.

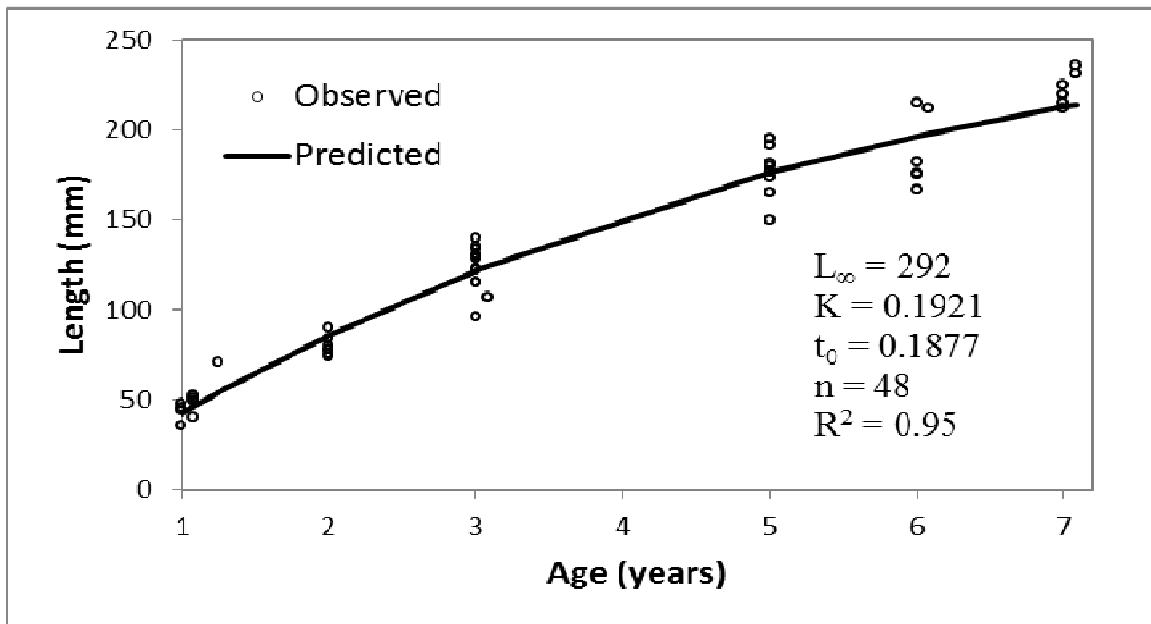


Figure 5. von Bertalanffy growth curve predicting length-at-age for rock bass in Little River, Blount County, Tennessee, from April to July 2013.

The von Bertalanffy growth function predicted smallmouth bass in Little River would take 2.5 years to grow to the stock size of 180 mm, 5.1 years to reach 305 mm, and 6.7 years to reach the preferred size of 356 mm, with an L_{∞} of 525 mm (Table A3, Figure 4). Time to reach 305 mm was described due to reference to that specific length in other studies (Austen and Orth 1988; Shaffer 2004).

Rock bass in Little River were predicted to take 2.4 years to grow to the stock size of 100 mm, 5.2 years to reach the quality size of 180 mm, and 8.3 years to reach the preferred size of 230 mm, with an L_{∞} fixed at 292 mm (Table A3, Figure 5). The model predicted an L_{∞} of 341 mm, which was unrealistic, therefore was adjusted to a more appropriate maximum theoretical length. The stock, quality, and preferred general length categories were proposed by Gabelhouse (1984).

Overall growth rates of smallmouth bass in Eastern Tennessee rivers ranged from 1.5 to 2.5 years (mean = 1.9) to reach 180 mm and 5.6 to 6.8 years (mean = 6.3) to reach 356 mm (Table A3, Figure 6). The L_{∞} was fixed at 559 mm for the Nolichucky, Powell, North Fork Holston, and Clinch Rivers due to unrealistic L_{∞} predictions by the model. Growth rates of rock bass in Eastern Tennessee rivers ranged from 1.1 to 2.4 years (mean = 1.5) to reach 100 mm and 3.7 to 5.2 years (mean = 4.4) to reach 180 mm, and 6.2 to 8.7 years (mean = 7.6) to reach 230 mm (Table A3, Figure 7). All L_{∞} values were fixed at 292 mm due to unrealistic L_{∞} predictions. Using TWRA unpublished data from 1996 and 1997, the model predicted Little River smallmouth bass would take 2.2 years to reach 180 mm, 4.6 years to reach 305 mm, and 6.1 years to reach 356 mm, with an L_{∞} fixed at 525 mm. Using the same TWRA data, rock bass took 2.0 years to reach 100 mm, 5.3 years to reach 180 mm, and 9.0 years to reach 230 mm, with L_{∞} fixed at 292 mm.

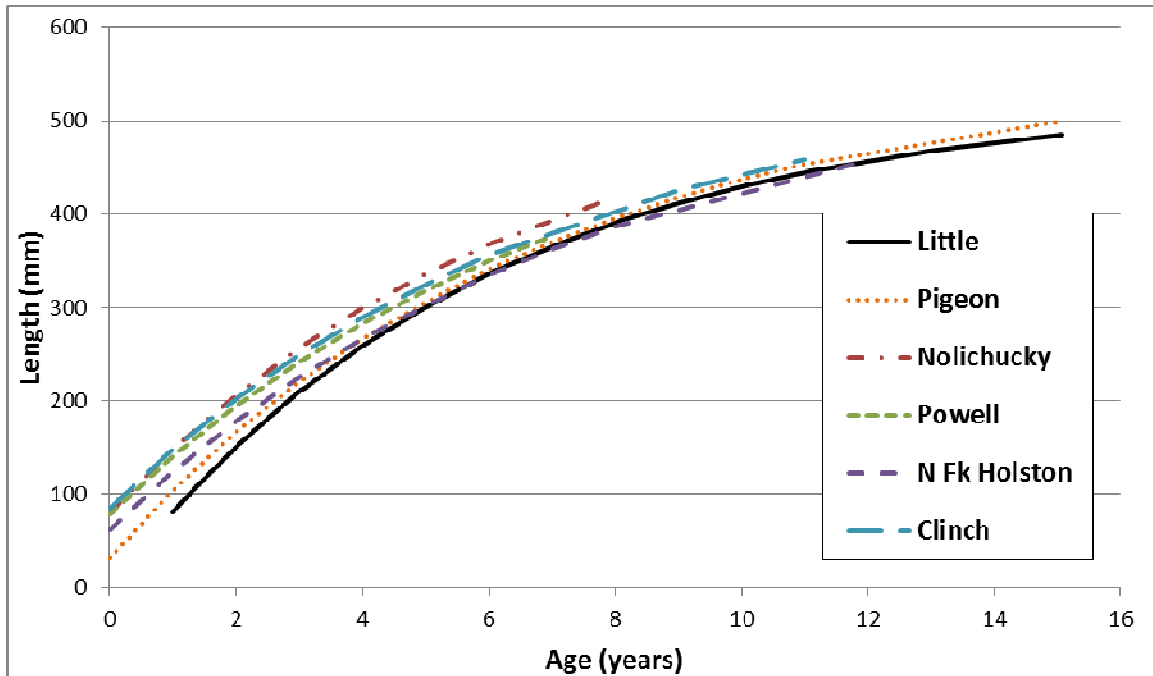


Figure 6. von Bertalanffy growth curves predicting length-at-age for smallmouth bass in Little River and other popular riverine fisheries in Eastern Tennessee.

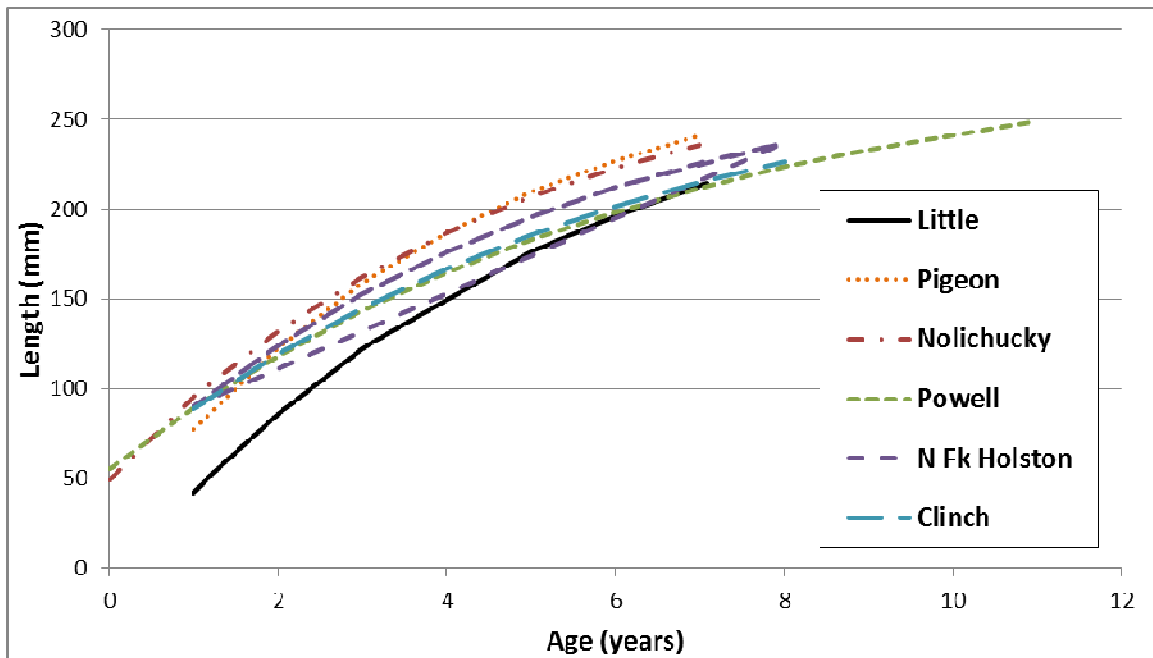


Figure 7. von Bertalanffy growth curves predicting length-at-age for rock bass in Little River and other popular riverine fisheries in Eastern Tennessee.

Relative weight (W_r) for smallmouth bass ranged from 64 to 102 (mean = 84) (Table A4, Figure 8). One erroneous value was omitted from calculations. Rock bass relative weight ranged from 70 to 124 (mean = 89) (Table A4, Figure 9). The condition of both smallmouth bass and rock bass increased as total length increased. Using TWRA unpublished data from 1996 and 1997, smallmouth bass had a mean W_r of 85. Shaffer (2004) reported a mean W_r of 87 from Little River and 84 from Abrams Creek inside the Park. The mean W_r of rock bass in Little River in 1996 was 85. Condition of both species decreased as total length increased based on data from Shaffer (2004) and TWRA. Although collection methods between Shaffer (2004) and TWRA's unpublished data were not directly comparable with the present study, there were some obvious age class distinctions between fish collected. Shaffer (2004) used block nets and a backpack electrofisher to create a closed system and TWRA's collection methods utilized a timed boat and backpack electrofishing efforts; both involved collecting all fish without regard to specified sizes. The present study used boat and backpack electrofishing equipment in a selective catch type effort to target fish in all size classes including upper age classes. Shaffer's (2004) age frequency distributions for Little River smallmouth bass indicated that 0.5% ($n = 1$) of fish were > age 7. Using TWRA's unpublished data, only 5% ($n = 1$) of smallmouth bass were > age 7. During the present study, 16% ($n = 15$) of smallmouth bass were > age 7 (Table A2). The TWRA unpublished data had only 3% ($n = 1$) of rock bass > age 4. During the present study, 42% ($n=20$) of rock bass were > age-4 (Table A2).

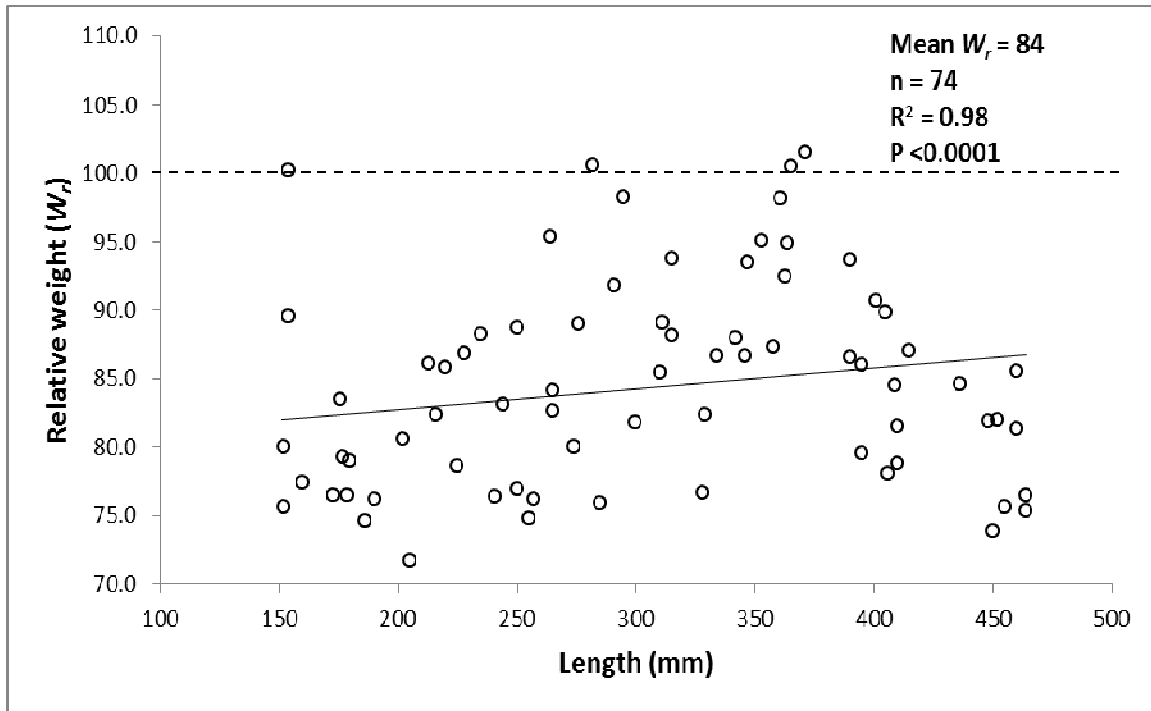


Figure 8. Relative weights (W_r) of smallmouth bass collected in Little River, Blount County, Tennessee, from April to August 2013.

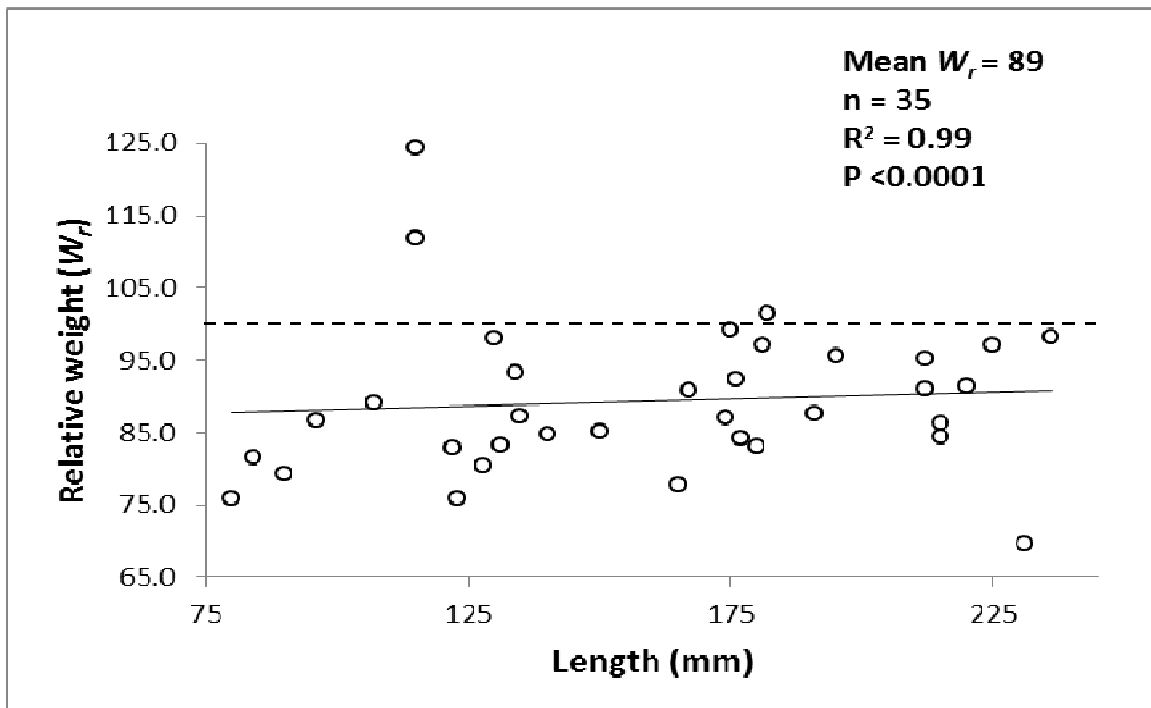


Figure 9. Relative weights (W_r) of rock bass collected in Little River, Blount County, Tennessee, from April to July 2013.

CHAPTER V

DISCUSSION

The Little River in Blount County, Tennessee, is a popular fishery and has sustained relatively low impacts, in part, due to the protection of the GSMNP. Both target species were more abundant between Perry's Mill dam and the Townsend dam. Jett (2010) also reported this observation for darters and concluded this central section of the river is extremely important to the fishes of Little River and that Perry's Mill dam serves as an impediment to the upstream movement of fish. Collection of smallmouth bass and rock bass throughout the reach between LRM 9.2 and LRM 32.1 was considered representative of the population within the river.

The maximum age of smallmouth bass observed was 15.0 years which aligns with the reported maximum age estimate by Coble (1975). A 15-year-old smallmouth bass was also collected in the Pigeon River (Fiss et al. 2001). The maximum age of rock bass observed was 7.0 years. The maximum life span for rock bass has been estimated at about 8 years (Carlander 1977; Redmon and Krumholz 1978), but TWRA unpublished data revealed a 13-year-old fish from the Elk River (TWRA Region II) and several other rock bass exceeding age 8 have been collected in Tennessee rivers and streams.

Above-average precipitation in 2009 (USGS 2009, Jett 2010) may have disrupted the 2009 year class of both rock bass and smallmouth bass due to the scarcity of age-4 fish collected. Craven et al. (2010) reported flashy discharge patterns during the spawning period can affect spawning success. Increased flows during a spawn may have

affected Little River fish more than other local rivers due to the Little River's lack of hydropower and flood control structures that control flows.

Smallmouth bass in Little River grew more slowly than in other rivers in Region IV. Growth rates were most similar to the North Fork Holston and Pigeon Rivers which also have length restrictions on harvest (Carter et al. 2012). Smallmouth bass exceeding 500 mm have been observed in the Little River survey by TWRA in 2008 (Carter et al. 2012). Therefore, the von Bertalanffy growth function L_{∞} prediction of 525 mm was considered realistic as a maximum theoretical attainable length and suggested smallmouth bass in the Little River are capable of attaining memorable (430 mm) and even trophy (510 mm) lengths. Fiss et al. (2001) considered Little River in their slow category, but data from the present study align more closely with their medium growth category for age-4 smallmouth bass. Smallmouth bass populations requiring ≥ 6 years to grow to 305 mm were also considered slow by studies in Virginia, Missouri, and Oklahoma (Covington et al. 1983; Orth et al. 1983; Austen and Orth 1988; Reed and Rabeni 1989).

Growth rates, survival, and abundance of black bass and other species are greatly influenced by temperature, food supply, and flow rates (Coble 1975; Coutant 1975; Oliver et al. 1979; Serns 1982; Paragamian and Wiley 1987). Shaffer (2004) reported smallmouth bass in Little River grew to 305 mm in 8.1 years inside the Park. Although not reported, using the parameters from that study, those fish would take 15.3 years to reach 356 mm. He concluded the slow growth rate is probably due to low prey abundance or variable discharge in Little River and high density, variable discharge, and increased turbidity in Abrams Creek. These factors may also affect fish growth outside

of the Park especially below Perry's Mill dam where reduced habitat availability occurs (Carter et al. 2012) and has been attributed as a factor in reduced growth rates (Paragamian and Wiley 1987). Low flows can also reduce available habitat for predator and prey and increase competition, therefore reducing growth (Paragamian and Wiley 1987). Little River is susceptible to low flows such as in 2007, when the lowest flow ever recorded on the river by the United States Geological Survey ($30 \text{ ft}^3/\text{s}$) occurred (Carter et al. 2012).

Rock bass in Little River grew more slowly than other rivers in Region IV and take longer to reach a quality size (180 mm). The predicted L_{∞} by the von Bertalanffy growth function for rock bass was unrealistic for that species in Little River. Possible explanations are a low sample size or the missing age class (age 4). Rock bass can probably attain memorable (280 mm) size in Little River since Carter et al. (2012) collected a $> 275 \text{ mm}$ rock bass in a 2005 survey.

Rock bass can be sensitive to fishing mortality and exploited populations have shown size distributions leaning toward smaller fish due to over-harvest of larger fish ($< 150 \text{ mm}$) (Roell and DiStefano 2010). That can have an effect on long-term management strategies for the fishery. Roell and DiStefano (2010) reported protections of rock bass can have positive effects on growth rates and can increase abundance of larger fish since rock bass are usually harvested when caught, unlike smallmouth bass which are most often released by anglers. The length restrictions placed on rock bass in their study had high angler support, stable angler catch rates with reduced harvest, and increased abundance of larger rock bass ($\geq 180 \text{ mm}$), while not reducing prey (crayfish and fish) abundance. The restrictions also indirectly increased larger smallmouth bass

abundance and decreased mortality from incidental catch by rock bass anglers.

Restrictions on rock bass could be considered for Little River to increase larger and older fish (> age 7) not observed in the present study. Of rivers in Region IV, rock bass were most similar to the Powell and Clinch Rivers. These rivers could potentially benefit from rock bass length restrictions as well due to few fish collected > age 7 by TWRA in the 1996 unpublished data. Currently rock bass regulations allow a creel of 20 fish per day with no minimum length limits.

Mean relative weight (W_r), or condition, of both smallmouth bass (84) and rock bass (89) were low and condition increased as total length increased. Smallmouth bass in Little River were poorly conditioned and considered emaciated (Slipke and Maceina 2010) during this study. Rock bass mean W_r was in the acceptable range, but not close to 100 that is considered physiologically and ecologically optimal (Anderson and Neumann 1996). Shaffer (2004) also reported poor condition of smallmouth bass from Little River and Abrams Creek inside the Park, though condition decreased as length increased in both streams. He attributed the poor condition to prey bases being adequate, but not abundant, in Little River and high density of fish increasing competition in Abrams Creek, as well as variable flows and cooler water temperatures. Relative weights were low and varied between 73 and 83 in exploited populations in the New River in Virginia and West Virginia (Austen and Orth 1988). Slipke et al. (1998) reported smallmouth bass condition increased as total length increased in Alabama with high mean W_r (95-104) and attributed it to a plentiful prey base. TWRA unpublished data for smallmouth bass collected from Little River in 1996 and 1997 and rock bass in 1996 suggested those fish were poorly conditioned as well and condition decreased as total length increased for

both species. The decreasing condition with the increase in length is likely attributed to low numbers of larger fish in the TWRA sample for both species and an overall low sample size.

In the present study, increasing condition with length observed in both species, suggested more efficient utilization of prey resources as the fish grows. Smallmouth bass prefer more crayfish as they grow (Probst et al. 1984; Shaffer 2004) and rock bass prefer more fish (Elrod et al. 1981). Limited abundance of these food bases along with variable flow rates would most likely affect condition (McClendon and Rabeni 1987) and growth rates. Without examination of stomach contents, the forage abundance is unknown. Condition can vary seasonally (Pope and Willis 1996) and should be used as a long term assessment for management opportunities and not limited to one season (Anderson and Neumann 1996).

By utilizing a selective collection method in this study, it is believed that the von Bertalanffy growth function produced more accurate growth estimates for older fish based on observed fish instead of strictly theoretical estimates based on mathematically equations. Any future studies focused on age and growth of older fish may consider selecting for upper size classes from their target species to obtain observable lengths-at-age and therefore more accurate predictions.

CHAPTER VI

SUMMARY AND RECOMMENDATIONS

The Little River in Blount County, Tennessee, is a popular tourist location and fishery. The assessment of growth and condition of smallmouth bass and rock bass in Little River, Tennessee, from April to August 2013 via boat and backpack electrofishing produced the following information:

- The maximum observed age of 7.0 years for rock bass collected suggested that older fish in the population may be scarce.
- The smallmouth bass and rock bass in Little River grew slower than most other popular riverine fisheries in Region IV, but faster than Little River within GSMNP.
- Smallmouth bass growth was most similar to that of the North Fork Holston and Pigeon Rivers and rock bass to the Powell and Clinch Rivers.
- Both smallmouth bass and rock bass were more abundant between Perry's Mill and Townsend dams.
- Smallmouth bass and rock bass in Little River are capable of attaining "trophy" and "memorable" sizes, respectively.
- Mean relative weight (W_r) of rock bass was low, but in the acceptable range, but smallmouth bass were considered emaciated.

- Utilizing a selective sampling method is believed to allow for more confident estimates of predicted lengths-at-age for older fish by using observed data instead of predictions based exclusively on mathematical equations.

The following management recommendations could be considered:

- Consider reducing harvest of rock bass in Little River from Rockford dam to the GSMNP boundary. Current rock bass regulations allow a creel of 20 fish per day with no minimum length limits. Such a liberal regulation may allow exploitation of larger rock bass that grow slowly in Little River.
- The growth rates from this study can be combined with information collected during the future angler use and harvest surveys and periodic stock assessments by the TWRA to make informed management decisions.
- The W_r in this study only provides the condition for the target species for the year 2013, and could be used for long term monitoring of smallmouth bass and rock bass of Little River by the TWRA.

Any future studies conducted on growth and condition could benefit from collecting all samples within the same month. That will allow more closely related length-at-age estimates without factoring in additional growth time. Collecting samples during the spring allowed easier boat access, but could hinder backpack electrofishing efforts due to high flows. It could also alter the W_r estimates since energy resources are placed into reproduction during April and May and do not represent the normal condition of the fish. These factors should be taken into account in future growth and condition studies.

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APPENDIX

Table A1. Sampling locations, dates, and GPS coordinates from the study area. Coordinates are in decimal degrees. Range and length are in Little River Miles (LRM).

Date	Range	Sample Length	Latitude/Longitude Start		Latitude/Longitude End	
10-Apr-13	26.5-23.5	3.0	35.702546	-83.814625	35.734347	-83.818592
17-Apr-13	21.9-16.3	5.6	35.748979	-83.836804	35.794749	-83.881015
10-May-13	32.1-26.5	5.6	35.680611	-83.748694	35.702546	-83.814625
15-May-13	29.6-26.5	3.1	35.682333	-83.788048	35.702546	-83.814625
31-May-13	10.2-9.2	1.0	35.813864	-83.922292	35.814577	-83.928629
1-Jul-13	26.6-26.4	0.2	35.701973	-83.813175	35.703049	-83.816892
5-Aug-13	20.3-20.1	0.2	35.765719	-83.856393	35.768151	-83.854754
6-Aug-13	29.8-29.9	0.1	35.680026	-83.784295	35.680828	-83.785448

Table A2. Minimum, mean, and maximum observed lengths-at-age of smallmouth bass (n=97) and rock bass (n=48) collected in Little River, Blount County, Tennessee, in 2013.

Age	Minimum Length	Mean Length	Maximum Length	n
Smallmouth Bass				
1	61	91	129	18
2	140	154	152	10
3	69	206	282	19
4	274	275	276	2
5	195	286	342	12
6	255	327	406	10
7	300	378	455	11
8	365	421	460	7
9	371	410	448	2
10	410	437	464	2
11	390	421	452	2
12				
13	464	464	464	1
14				
15	436	436	436	1
Rock Bass				
1	35	48	71	9
2	74	80	90	7
3	96	123	140	12
4				
5	150	177	195	8
6	167	188	215	6
7	212	223	236	6

Table A3. von Bertalanffy growth function predicted time (years) to reach a specified length (mm) for smallmouth bass and rock bass in the Little River and other popular fisheries in Eastern Tennessee.

River	Rock Bass			Length (mm)	Smallmouth Bass	
	100	180	230		180	356
Little*	2.4	5.2	8.3		2.5	6.7
Pigeon	1.5	3.7	6.2		2.2	6.5
Nolichucky	1.1	3.7	6.5		1.5	5.6
Powell	1.4	4.8	8.7		1.7	6.2
N. Fk. Holston	1.3	4.2	7.4		2.1	6.8
Clinch	1.4	4.7	8.4		1.6	6.0

*Smallmouth bass took 5.1 years to reach 305 mm

Table A4. Estimated length-weight relationship parameters and standard error ($\pm$) for smallmouth bass and rock bass collected in Little River, Blount County, Tennessee, in 2013, logarithmically transformed.

Species	a'	b	P	R²	n	Mean W_r
Smallmouth bass	-5.0971 $\pm$ 0.1108	3.0765 $\pm$ 0.0469	<0.0001	0.98	74	84.3
Rock bass	-4.8911 $\pm$ 0.0828	3.0801 $\pm$ 0.0399	<0.0001	0.99	35	89.4

VITA

Justin Robert Wolbert was born November 1, 1983. He graduated from Union High School in Rimersburg, Pennsylvania, in 2002. He joined the United States Air Force in 2002 and was honorably discharged in 2008. He received an Associate of Applied Science degree from the Community College of the Air Force in 2008. After moving to Knoxville with his wife Jessica, he enrolled in the University of Tennessee as an undergraduate in 2009. Upon graduation in 2012 with a Bachelor of Science degree in Wildlife and Fisheries Science, Justin continued at the University of Tennessee as a graduate student. In June of 2012, he was accepted as a candidate for a Master of Science degree in Wildlife and Fisheries Science. He graduated in August 2014.