

AN ABSTRACT OF A THESIS

EVALUATION OF SMALLMOUTH BASS IN ABRAMS CREEK AND LITTLE RIVER WITHIN GREAT SMOKY MOUNTAINS NATIONAL PARK

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Master of Science in Biology

Smallmouth bass *Micropterus dolomieu* were sampled during Summers 2002 and 2003 from two streams within Great Smoky Mountains National Park (GSMNP), Little River (freestone stream) and Abrams Creek (limestone stream), to determine age and growth, size structure, abundance, mortality, and recruitment for smallmouth bass within GSMNP. Smallmouth bass were sampled using visual observation and electrofishing. Growth rates in Abrams Creek and Little River were significantly different ($P < 0.05$). von Bertalanffy growth curves predicted smallmouth bass in Abrams Creek would reach 305 mm (12 inches) in 6.7 years, and reach the same length in Little River in 8.1 years. Proportional stock densities of smallmouth bass in Abrams Creek and Little River were 10% and 13%, respectively. Summer 2003 population estimates averaged 250 bass/ha (22.5 kg/ha) in Abrams Creek and 46 bass/ha (4.5 kg/ha) in Little River. Total annual mortality for ages II to VII was 43% in the Abrams Creek population and 28% in Little River's population. Recruitment variability was 47% and 94% in Abrams Creek and Little River, respectively. When compared to other streams in Tennessee, smallmouth bass in Abrams Creek and Little River exhibited slower growth and possessed a lower abundance of preferred size and larger bass, yet had similar mortality and recruitment rates.

Distribution and habitat utilization of smallmouth bass in Abrams, Hazel, and Eagle Creeks, and Little River were determined using underwater observation. Upstream distribution of smallmouth bass in Abrams Creek and Little River was stopped by large cascades, while smallmouth bass in Hazel and Eagle Creek were halted by a loss of suitable habitat. Amount of run and riffle habitat, discharge, and surface area of site were significant variables when predicting smallmouth bass abundance in Abrams Creek and Little River.

Using the population dynamics, distribution, and habitat utilization, a sampling protocol was developed for GSMNP fisheries biologists. Smallmouth bass should be sampled during low discharge periods. The sampling technique used should be based on management objectives set by GSMNP biologists. Assuming low discharge during sampling, electrofishing should be used if length-weight data is desired; however, snorkeling should be employed if population estimates are desired.

**EVALUATION OF SMALLMOUTH BASS IN ABRAMS CREEK AND LITTLE
RIVER WITHIN GREAT SMOKY MOUNTAINS NATIONAL PARK**

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CERTIFICATE OF APPROVAL OF THESIS

**EVALUATION OF SMALLMOUTH BASS IN ABRAMS CREEK AND LITTLE
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TABLE OF CONTENTS

	Page
LIST OF TABLES.....	vii
LIST OF FIGURES.....	viii
CHAPTER 1: INTRODUCTION.....	1
CHAPTER 2: DESCRIPTION OF STUDY AREA.....	5
Abrams Creek.....	5
Little River.....	6
Hazel Creek.....	7
Eagle Creek.....	7
CHAPTER 3: METHODS AND MATERIALS.....	8
Population Dynamics.....	8
Distribution and Habitat Utilization.....	15
Sampling Protocol.....	17
CHAPTER 4: RESULTS.....	18
Population Dynamics.....	18
Distribution and Habitat Utilization.....	21
Sampling Protocol.....	22
CHAPTER 5: DISCUSSION.....	23
Population Dynamics.....	23
Distribution and Habitat Utilization.....	28
Sampling Protocol.....	30

Management Recommendations.....	31
LITERATURE CITED.....	33
TABLES.....	40
FIGURES.....	45
VITA.....	54

LIST OF TABLES

Table	Page
1. Physical and chemical water quality parameters of Abrams Creek and Little River, Blount County, Tennessee from July through August 2002 and 2003.....	39
2. Coordinates (degrees, minutes, seconds) of sample reaches on Abrams Creek and Little River, Blount County, Tennessee, in WGS 84 datum.....	39
3. Percentage of habitat type and area (m ²) by site in Abrams Creek and Little River, Blount County, Tennessee.....	39
4. Proportional stock densities (PSD), mean relative weight (W_r), estimated annual mortality (AM), and recruitment variability estimates ($REC-CV$) for smallmouth bass collected from Abrams Creek and Little River, Blount County, Tennessee from July through August 2002 using electrofishing.....	40
5. Length-weight relationship parameters and standard error ($\pm$) of smallmouth bass collected from Abrams Creek ($n=252$) and Little River ($n=214$) from July through August 2002 using electrofishing following the general equation: $\log_{10}(W) = a + b[\log_{10}(TL)]$, where W is weight (g), TL (mm) is total length....	40
6. Mean total lengths at age for smallmouth bass collected in Abrams Creek and Little River, Blount County, Tennessee, during summer 2002.....	40
7. Estimated parameters and standard error of von Bertalanffy growth model for smallmouth bass collected from July through August 2002 in Abrams Creek ($n=176$) and Little River ($n=112$), Blount County, Tennessee using electrofishing, where K is the Brody growth coefficient, L_{∞} is theoretical maximum length a fish can attain, and t_0 is the time when length would theoretically be zero.....	41
8. Mortality and recruitment variability estimates of smallmouth bass collected from Abrams Creek and Little River, Blount County, Tennessee from July through August 2002.....	41
9. Numbers and percentages of smallmouth bass examined for stomach contents (crayfish, fish, or insects) collected from Abrams Creek ($n=181$) and Little River ($n=117$), Blount County, Tennessee from July through August 2002 using electrofishing.....	41

10. Significance levels (<i>P</i> -values) of logistic models using total lengths to predict the presence of crayfish, fish, and insects in stomachs of smallmouth bass collected from Abrams Creek and Little River, Blount County, Tennessee from July through August 2002.....	42
11. Estimated numbers and standing stock of smallmouth bass collected from Abrams Creek and Little River, Blount County, Tennessee from July through August 2003 using an electric seine and backpack electrofishing units.....	42
12. Coordinates (WGS 84 datum) of upper limits and stream kilometers of smallmouth bass distributions in Abrams Creek, Little River, Hazel Creek, and Eagle Creek within GSMNP sampled in July 2003 using underwater observation.....	43

LIST OF FIGURES

Figure	Page
1. Map depicting study site locations on Abrams Creek and Little River, Blount County, Tennessee.....	44
2. Length frequency distributions of smallmouth bass collected from Abrams Creek and Little River, Blount County, TN from July through August 2002....	45
3. Relative weight (W_r) of smallmouth bass collected from Abrams Creek and Little River, Blount County, Tennessee from July through August 2002. Dashed line represents average W_r of 100.....	46
4. Linear relationship ($\log_{10}$ transformed) between total length (mm) and weight (g) of smallmouth bass collected from Abrams Creek and Little River, Blount County, Tennessee from July through August 2002.....	47
5. Age frequency distribution of smallmouth bass collected from Abrams Creek and Little River, Blount County, Tennessee from July through August 2002...	48
6. von Bertalanffy growth curves for smallmouth bass collected from Abrams Creek and Little River, Blount County, Tennessee, from July through August 2002. Corresponding growth parameters are listed in Table 5.....	49
7. Linearized catch curves of smallmouth bass collected from Abrams Creek and Little River, Blount County, Tennessee, from July through August 2002.....	50
8. Residuals from a catch curve of smallmouth bass caught in Little River versus mean daily discharge of Little River for winter (December-February), spring (March-May), and June-July discharges. Data points are identified by corresponding smallmouth bass year-classes. Data points above the zero reference line indicate relatively strong year-classes, and those below the reference line indicate relatively weak year-classes.....	51
9. Logistic curves modeling the probability of insects and crayfish being found in stomachs of smallmouth bass in Little River, Blount County, Tennessee.....	52

CHAPTER 1

INTRODUCTION

The smallmouth bass *Micropterus dolomieu* has been the subject of extensive research, due in large part to its popularity among anglers. As a result, information has been compiled on the life history and biology of this fish species. Smallmouth bass have been widely introduced beyond their native waters of interior eastern North America west of the Appalachians Mountains (Etnier and Starnes 1993), and now inhabit streams, rivers, lakes, and reservoirs across the United States.

Smallmouth bass often occupy clear water lakes over 40 hectares in area and more than 9 meters deep (Coble 1975). Lake- and reservoir-dwelling smallmouth bass utilize habitats with clean rock or gravel substrate (Brown et al. 2000), woody structure (Hubert and Lackey 1980; Brown et al. 2000), adequate cover, and abundant food (Brown et al. 2000). Smallmouth bass inhabit rivers and streams with coarse, rocky substrate (Coble 1975; Miller 1975; Rankin 1986; Barrett and Maughan 1994), root wads, woody debris, and boulders (Rankin 1986; Todd and Rabeni 1989). They generally occupy deep pools with slow currents (Rankin 1986; Sechnick et al. 1986; Leonard and Orth 1988; Barrett and Maughan 1994) and areas of low light (Coble 1975; Miller 1975).

Factors such as water temperature, habitat suitability, food availability, stream flow, water quality, and exploitation result in wide variations in age, growth, mortality, recruitment, and population abundance among stream smallmouth bass

populations in the United States. On average, these fish reach a total length of 305 mm (12 inches) between ages 3 and 5 (Austen and Orth 1985; Etnier and Starnes 1993), and have a life expectancy of 9-11 years (Fajen 1959; Coble 1975). Young-of-the-year and juvenile smallmouth bass primarily feed on aquatic invertebrates and zooplankton, while adults forage on crayfish and other fish species (George and Hadley 1979; Probst et al. 1984; Rankin 1986; Livingstone and Rabeni 1991). Smallmouth bass exhibit little movement in streams except during spawning months of April to June (Montgomery et al. 1980; Langhurst and Schoenike 1990). Spawning occurs at mean daily water temperatures ranging from 12.5 to 23.5°C (Coble 1975; Graham and Orth 1986) and increased photoperiod duration (Cantin and Bromage 1991). Typically, male smallmouth bass construct nests in gravel substrate with slow current, and females spawn once or several times. Males guard the nest, fanning with their tails to prevent sediment and debris build-up, until the fry disperse (Coble 1975).

Population characteristics of smallmouth bass have been studied in streams of Alabama (Weathers and Bain 1991; Slipke et al. 1998), Arkansas (Filipek et al. 1995; Kilambi et al. 1997), Missouri (Fajen 1972, 1975b; Funk 1975; Covington et al. 1983; McClendon and Rabeni 1987; Reed and Rabeni 1989), Oklahoma (Orth et al. 1983), Tennessee (Fiss et al. 2001), and Wisconsin (Paragamian and Coble 1975; Forbes 1989; Lyons et al. 1996). Paragamian (1984) studied smallmouth bass population characteristics in five Iowa streams and used these characteristics to recommend a management plan to the Iowa Conservation Commission. Smallmouth bass in Alabama, Missouri, and Tennessee required 3 to 7 years to reach 305 mm (12

in). Annual mortality of a stream smallmouth bass population in Oklahoma was 61%, while smallmouth bass from an Arkansas stream exhibited annual mortality of 36%. Proportional stock indices (PSD) of smallmouth bass populations in Iowa and Wisconsin were 25% and 27%, respectively.

Fiss et al. (2001) studied population characteristics of riverine smallmouth bass populations across Tennessee. They expressed the need for more research on riverine smallmouth bass in Tennessee Wildlife Resource Agency (TWRA) Regions 3 and 4 to ensure adequate representation in statewide averages. Abrams Creek and Little River, of the GSMNP, are located in Blount County, TWRA Region 4. Smallmouth bass populations in Region 4 were found by Fiss et al. (2001) to require 6.7 years to reach the preferred size of 356 mm (14 inches). For samples containing at least 30 age 2+ smallmouth bass, proportional stock density (PSD) values ranged from 16 to 50, annual mortality was 14.7 to 39.4%, and recruitment variability was 21.6 to 105.0%. Fiss et al. (2001) used the population characteristics of these smallmouth bass to evaluate possible length restrictions in an attempt to improve fisheries. With the exception of the aforementioned study, no other research has been conducted on population dynamics of riverine smallmouth bass in Tennessee. Other studies have been conducted on riverine smallmouth bass in Tennessee; however, these studies concentrated on age and growth, length-weight relationships (Cathey 1973; Gwinner 1973), and hybridization (Pipas and Bulow 1998).

Great Smoky Mountains National Park (GSMNP) fisheries biologists annually monitor populations of native brook trout *Salvelinus fontinalis*, and nonnative rainbow trout *Oncorhynchus mykiss* and brown trout *Salmo trutta*. However, many

watersheds within the GSMNP of eastern Tennessee and western North Carolina contain populations of smallmouth bass, which became established in larger, cool-water streams prior to the Park's establishment. Due to the nature of these large streams (e.g., deep water, inaccessibility), GSMNP fisheries biologists have not sampled smallmouth bass populations, and therefore, do not know distributions and population structures. Knowledge of the dynamics and distribution of a fish population is critical in establishing and implementing beneficial management plans (Orth and White 1999). Population dynamics describe variations in abundance, responses to instream and surrounding habitat disturbances, and other components vital to proper fish management (Van Den Avyle and Hayward 1999). Anthropogenic inputs (e.g., heavy exploitation, non-point source pollution, dams) place ever-increasing strains on smallmouth bass populations. Therefore, smallmouth bass management is more critical now than ever before.

The objectives of this study were to:

- (1) Compare population dynamics (age and growth, abundance, mortality, and recruitment) of smallmouth bass in Little River, a freestone stream, and Abrams Creek, a limestone bedrock stream;
- (2) Describe the distribution and habitat utilization of smallmouth bass within Abrams Creek, Little River, and other GSMNP streams; and
- (3) Develop a sampling protocol for smallmouth bass populations within the GSMNP.

CHAPTER 2

DESCRIPTION OF STUDY AREA

Abrams Creek and Little River, in GSMNP, were sampled during this study. These streams differed geologically, with Abrams Creek characterized by limestone bedrock, and Little River as a freestone stream. In addition, Hazel and Eagle Creeks were sampled only for distribution of smallmouth bass.

Abrams Creek

Abrams Creek, located in Blount County, Tennessee, lies within the western section of the GSMNP. The Abrams Creek watershed is composed of approximately 348 km of streams (Parker and Pipes 1990). Smallmouth bass occur within the lower 27.4 km, where the stream possesses an average width of 18 m and an average gradient of 3.5% (Table 1). This section of Abrams Creek is extremely remote. Long, deep pools and runs are common throughout this reach.

Abrams Creek flows over and through large depressions of limestone, cuts through grazed cattle fields, and ultimately drains into Chilhowee Reservoir of the Little Tennessee River system. Conductivity and pH are high due to high amounts of dissolved calcium from the limestone (Nelson and McPherson 1987; Lindsey et al. 1998). Typically, conductivity and pH range from 55 to 87 μS and 6.7 to 7.2, respectively (GSMNP data 1999). The stream's unique limestone properties and contributions of fecal bacteria and nutrients result in a highly productive aquatic ecosystem.

From July through August 2002 and 2003, Abrams Creek's instream temperatures and conductivity ranged from 20.2 to 22.2°C and 48.7 to 62.7 μS , respectively. Stream

discharge averaged 0.45-2.2 m³/s, but fluctuated in response to precipitation events.

Predominant substrates were bedrock and cobble (Table 1).

Sample reaches were uniformly distributed throughout Abrams Creek's 27 km study area. Each sample reach consisted of run, riffle, pool, and complex habitats. Site 1, the downstream-most site, was located approximately 2 km upstream from the Chilhowee Reservoir impoundment. Long, deep pools and runs were the dominant habitat units within Site 1. Site 2 was located approximately 10 km upstream and was dominated by runs. Located upstream approximately 17 km from Site 2, Site 3 contained more complex and riffle habitats than did Sites 1 and 2 (Table 2; Table 3; Figure 1).

Little River

Little River is located in Blount County, Tennessee, on the northwestern section of the GSMNP. Within GSMNP, the Little River watershed drains approximately 283 km of streams (Parker and Pipes 1990). Smallmouth bass occur in 13.7 km of Little River in GSMNP; however, the population extends outside GSMNP boundaries. A highly traveled roadway follows this entire reach of Little River within GSMNP allowing easy access for anglers, swimmers, and tubers.

Unlike Abrams Creek, Little River is a freestone stream. Freestone streams are typical in the GSMNP (GSMNP data 1996), having low dissolved calcium concentrations and, therefore, are characterized by low conductivity and pH (Nelson and McPherson 1987; Lindsey et al. 1998). Typical measurements of conductivity range from 18 to 23 μ S, while pH ranges from 6.0 to 6.3 (GSMNP data 1999).

From July through August 2002 and 2003, instream water temperatures within sample reaches ranged from 18.2 to 18.6°C, and conductivity ranged from 17.2 to 17.7 µS. Stream discharge ranged from 0.94 to 2.9 m³/s, but fluctuated greatly in response to precipitation events. Mean width and depth were 15.9 and 2.7 m, respectively, while average gradient was 1.5% (Table 1). Predominant substrates were cobble and boulder.

Sample reaches in Little River were consistently dispersed throughout the 14 km study area. Site 1 was located approximately 1 km upstream of the GSMNP boundary, and consisted mostly of long, deep runs. Positioned approximately 5 km upstream of Site 1, Site 2 was dominated by runs and pools. Site 3 was located approximately 2 km upstream of Site 2 in the gorge section of Little River. Mean width was less at Site 3 and this reach consisted mostly of long runs (Table 2; Table 3; Figure 1).

Hazel Creek

Hazel Creek is a tributary to Fontana Reservoir (Little Tennessee River) located in the southern section of GSMNP in Swain County, North Carolina. The Hazel Creek watershed drains approximately 183 km of streams (Parker and Pipes 1990).

Eagle Creek

Located in Swain County, North Carolina, Eagle Creek lies within the southern section of GSMNP. Eagle Creek is located one watershed east of Hazel Creek and drains approximately 85 km of streams (Parker and Pipes 1990).

CHAPTER 3

MATERIALS AND METHODS

Population Dynamics

Three 200-m sites were selected within each stream (Little River and Abrams Creek) based on their inclusion of representative habitat types (riffles, runs, pools), ability to be effectively sampled, and accessibility. Sample reaches were located such that natural “breaks” (e.g., cascades, riffle heads) occurred at the upper end, and when coupled with a downstream block net, created a closed system during sampling. Each sample site was marked with aluminum tags and surveyor’s flagging on the upper and lower ends for easy recognition. A Garmin eTrex Legend global positioning system (GPS) was used to record sample site locations. Conductivity (μS) and temperature ($^{\circ}\text{C}$) were documented within reaches containing smallmouth bass using a Yellow Springs Instrument Model 85 meter.

Stream width (m), depth (m), total length (m), surface area (m^2), and discharge (m^3/s) were measured and recorded at each sample site. Wetted widths were recorded every 20 meters using a 100-m tape measure, and then averaged to calculate mean stream width within each sample reach. Depths were measured at three equidistant points across each 20-m transect using a calibrated PVC depth staff. Mean depth for a transect was calculated by dividing the total of the three depths by four. Mean depths at each transect were totaled and divided by the number of transects to obtain mean depth within the sample reach. Total length was measured from lower to upper ends using a 100-m tape measure. Surface area of the sample

reach was the product of total length and mean stream width. Stream discharge was calculated using a velocity-area method as outlined by McMahon et al. (1996). A tape measure was set perpendicular to flow across a section of stream possessing a uniform, bowl-shaped channel bed. A Marsh-McBirney Flo-Mate model 2000 portable flowmeter and top-setting wading rod were used to measure discharge at 60% of the stream depth. Beginning at one edge of the stream, measurements of depth and discharge were taken alternately every 0.5 m until the opposite wetted edge was reached. Water quality and habitat parameters were measured once per site due to sampling on consecutive days.

Percentage of habitat type was calculated for each sample reach and measured using a hip chain. Habitat was characterized as run, riffle, pool, or complex (Overton et al. 1997). Runs were defined as deep and fast water habitat with a defined thalweg and little surface agitation. Riffles were fast water habitats with surface agitation. Pools were slow water habitats scoured by water that formed nonuniform depressions in channel beds. Complex habitats were defined as any combination of run, riffle, or pool habitats.

From July through August 2002, smallmouth bass were collected from Little River and Abrams Creek using 110-volt AC backpack electrofishing gear. Total length (mm) and weight (g) were recorded for each fish collected. Sagittal otoliths were removed in the field from all smallmouth bass for age determination. Long and Fisher (2001) compared the precision of age estimates for three species of black bass, as derived from scales and otoliths, and found that otolith analysis was the most accurate method for age estimation. Scales were found to be inaccurate when

estimating age of smallmouth bass in Illinois (Beamish and McFarlane 1987). Otoliths were removed using the “Up Through the Gills” method as outlined by Secor et al. (1992). The gill isthmus was cut and gill arches removed exposing the prootic bullae. The bulla was cracked open with a scalpel and sagittal otoliths were removed using forceps. Otoliths were dried and stored in sealed plastic vials. A transverse section was made through the otolith’s core. Using water and 400-grit sandpaper, the internal surface of the sectioned otolith was polished. Polished otoliths were embedded into a water- and putty-filled dish with the internal surface facing up. A fiber-optic light source was used to illuminate the sectioned otolith revealing the annuli. Each annulus represented one year of growth. A second reader observed a sub-sample of 25 otoliths from each stream to verify ages of smallmouth bass.

Stomach contents were removed from sacrificed fish by dissection, identified as fish, crayfish, or insect, and enumerated (Bowen 1996). Comparisons of size structure, age and growth, recruitment, and mortality between the two streams were performed using smallmouth bass collected in 2002. Abundance was determined using catch per unit effort.

Smallmouth bass were collected from July through August 2003 using a 10-meter AC electric seine and 110-volt AC backpack electrofishing gear. Higher water levels in 2003, as compared to 2002, prohibited using only backpack electrofishing units to collect smallmouth bass. Smallmouth bass collected in 2003 were used to estimate population size.

The electric seine was powered by a 5-horsepower, 2500-watt, 120-volt Honda generator. Voltage was regulated to achieve approximately 2.5 –3.0 amps using a 1.5 KVA Smith-Root electrofisher control box. Twelve 1.5-meter metal droppers were spaced evenly along the width of the electric seine creating a consistent electric field. Spacers constructed from PVC pipe were fixed between droppers to prevent contact of two adjacent droppers. A rope was connected along the length of the electric seine, allowing for instream control. Floats, 13-cm in diameter, were positioned along the length of the electric seine to maintain buoyancy.

A large block net, extending the width of the stream, was placed at the lower end of each site to minimize immigration, emigration, or fish escapement during sampling. The electric seine was stretched out across the top of the site and floated downstream until the block net was reached. Pulling the electric seine upstream in high current prevented droppers from maintaining perpendicular alignment with the stream bottom. Therefore, the electric seine was floated downstream to allow vertical orientation of droppers, whereby, maximizing electric current throughout the entire water column. Two backpack electrofishing units were positioned on each end of the electric seine when stream widths exceeded 10 m. The generator, control box, and switch were floated behind the electric seine in a tractor tire inner tube. Netters were positioned upstream and downstream of the electric seine to capture stunned fish. Long-handled dip nets were used to collect fish from deep pools. A “herding” effect was created as fish were pushed downstream and collected at the block net. Walsh et al. (2002) and Angermeier et al. (1991) found high capture efficiency of stream fish using electric seines at depths less than 0.55 and 1.25 m, respectively.

Snorkeling was used to determine if smallmouth bass larger than those collected in 2002 with backpack electrofishing units occurred in deep, unwadeable pools. Larger fish were present in these deeper pools; therefore, the electric seine was constructed to sample the deeper pools insuring representative sampling of all sizes of smallmouth bass. Since accessibility to streams was limited, snorkeling was compared to electrofishing to determine if precise population estimates could be obtained using snorkeling. In 2002 and 2003, sample reaches were snorkeled to estimate smallmouth bass abundance using the bounded counts method as outlined by Reiger and Robson (1967). A PVC wrist lanyard and wax pencil were used to record numbers of observed smallmouth bass. Pezold et al. (1997) enumerated and determined relative sizes of smallmouth bass in two headwater streams of west-central Arkansas using underwater observation. Numbers of smallmouth bass counted during snorkeling were compared to those captured during electrofishing using a two-sample *t*-test with significance determined at $\alpha=0.05$.

Population estimates from 2003 were determined using mark-recapture analysis. Paragamian (1984) used a mark-recapture method to determine population estimates of smallmouth bass in Iowa. Schnabel's (1938) multiple-census method was used to increase accuracy of population estimates. Variance and confidence intervals were estimated for population estimates by treating the number of recaptures as a Poisson-distributed variable (Ricker 1975). Schnabel's method does not allow for mortality in the study. Van Den Avyle and Hayward (1999) suggested spacing the sampling periods close together to minimize the effects of mortality on the results. Therefore, each reach was sampled three times over consecutive days,

keeping sample periods close together, yet giving fish ample time for recovery. However, Site 3 on Abrams Creek was sampled only twice. High water during the third sampling period, heavy equipment, and a 3-km hike to the site deterred completion of a third sampling period on this Abrams Creek site. During the first and second sample periods, smallmouth bass were marked with right and left pelvic fin clips, respectively. Each unmarked smallmouth bass captured was weighed (g) and measured for total length (mm). After each capture, fish were released within the same site. Fajen (1962) studied stream stability on homing behavior of stream smallmouth bass in Missouri and found them to be “comparatively sedentary.” He recaptured 70% of smallmouth bass in the stable pools from which they had been previously captured. Also, Todd and Rabeni (1989) found Missouri smallmouth bass to be sedentary in a study addressing movement and habitat use. Another requirement of Schnabel’s method is that there are no additions to the population during the study (Van Den Avyle and Hayward 1999). An upstream “break” and a downstream block net were assumed to create a closed system, which satisfied this requirement.

Length frequency distributions were constructed for determination of size structure and PSD of the populations. PSD quantified the population’s ability to sustain a balance or equilibrium between size and numbers of fish leaving the population due to angler harvest or natural mortality, and those entering through recruitment (Ney 1999; Slipke and Maceina 2000). PSD was estimated for each sample using the equation:

$$\text{PSD}(\%) = \frac{\# \text{ fish } \geq 180 \text{ mm}}{\# \text{ fish } \geq 280 \text{ mm}} \times 100 .$$

Confidence intervals (95%) were estimated using the equation:

$$CI = t_{(\alpha, N-1)} \left\{ \left[\frac{P(1-P)}{N-1} \times \frac{N_T - N}{N_T} \right]^{0.5} + \frac{1}{2N} \right\},$$

where CI= confidence interval estimate (upper or lower) as a decimal fraction, P = estimated PSD as a decimal fraction, N = number of stock-length fish in sample, N_T = total number of stock-length fish in the population being sampled, and t = Student's t for α confidence level with $N-1$ degrees of freedom (two-tailed) (Gustafson 1988). Significant differences between PSD values for each stream was determined based on whether or not overlap of confidence intervals occurred. Condition (W_r) was evaluated using the relative weight equation for smallmouth bass as presented by Anderson and Neumann (1996):

$$W_r = \frac{W}{W_s} \times 100,$$

where the standard weight (W_s) equation was

$$\log_{10}(W_s) = -5.329 + 3.2[\log_{10}(TL)].$$

Standard weight (W_s) values from Kolander et al. (1993) were used. A minimum total length of 150 mm was designated because weight measurements of young fish tend to be variable (Anderson and Neumann 1996). Relative weights were compared between streams using the non-parametric Wilcoxon Rank Sum test ($\alpha=0.05$). Simple linear regression was used to predict $\log_{10}(\text{weight})$ from $\log_{10}(\text{total length})$, and the interaction term was used to determine if slopes differed at $\alpha=0.05$. Growth rates were calculated using von Bertalanffy growth equations (von Bertalanffy 1938), and compared between streams using 95% confidence limits of K and t_0 .

Mortality was estimated using catch curve analysis. Recruitment (*REC-CV*) was quantified using the equation:

$$REC - CV = 32 + 0.864(AgeRange) - 129.3(r^2) + 66.8(\log_{10}(AM)),$$

where *Age Range* was the range in years used in the catch curve regression, r^2 was the coefficient of determination for the catch curve regression line, and *AM* was estimated total annual mortality for the regression (Maceina and Slipke, in preparation). Logistic regression was used to model for the presence of fish, crayfish, or insects in smallmouth bass stomachs. Fisheries Analyses and Simulation Tools (FAST) software was used to calculate mortality and recruitment rates. The FAST modeling software had many advantages over previous modeling programs including user-friendliness and compatibility with the Windows operating system (Slipke and Maceina 2000).

Distribution and Habitat Utilization

Distribution and habitat utilization of smallmouth bass were determined by visual observation (snorkeling). Sampling by visual observation has proven to be more accurate than electrofishing for satisfying this objective (McClendon and Rabeni 1986; Mullner et al. 1998). Habitat utilization (Barrett and Maughan 1994), abundance, and distribution (Pezold et al. 1997) of smallmouth bass have been determined using underwater observations. All snorkeling was performed from June through August 2003. In Abrams Creek and Little River, distribution and habitat utilization were described using information obtained during 2002 and 2003 sampling. In addition, smallmouth

bass populations in Eagle Creek and Hazel Creek were observed to determine distribution and habitat utilization of smallmouth bass populations from tributaries of Fontana Reservoir (Little Tennessee River) in the southern section of GSMNP. Upper limits of smallmouth bass distributions were declared when no fish were observed for 250 m. A PVC wrist lanyard and wax pencil were used to record numbers of smallmouth bass and the habitats they occupied. Areas snorkeled were determined and densities (number/unit area) were calculated for each stream sampled for distributions. Densities were compared between streams using a two-sample *t*-test. Habitat units utilized by smallmouth bass were also quantified in each stream sampled (Peterson and Rabeni 2001). Various habitat variables (i.e., run, pool, riffle, and complex habitat; temperature; conductivity; discharge; mean width; mean depth; and surface area) were modeled to explain smallmouth bass abundance in Abrams Creek and Little River. Multiple linear regression analysis was used to determine which habitat features were important to smallmouth bass in GSMNP streams. Significance for all analyses was determined at $\alpha=0.05$.

Sampling Protocol

Population characteristics, distribution, and habitat utilization of smallmouth bass in GSMNP were required to develop a sampling protocol for GSMNP biologists. Optimum sampling conditions and collection techniques were determined by comparing catch rates and densities between 2002 and 2003, in which discharge was low and high, respectively. Comparisons were performed using a two-sample *t*-test; significance was determined at $\alpha=0.05$.

CHAPTER 4

RESULTS

Population Dynamics

From July through August 2002, 252 smallmouth bass were collected from Abrams Creek, while 214 were collected from Little River. However, smallmouth bass were not collected within the six sample reaches established for 2003 sampling.

Length frequency distributions indicated few (8%) smallmouth bass were larger than 254 mm (10 in) in total length, with most (93%) adult fish being 100 to 280 mm (Figure 2). Proportional stock indices (PSD) of $10 \pm 6.8\%$ and $13 \pm 8.6\%$ for Abrams Creek and Little River, respectively, reflected this indication. Overlapping confidence intervals of PSD estimates indicated no significant differences between Abrams Creek and Little River (Table 4). Relative weights (W_r) of smallmouth bass from Abrams Creek ranged from 65.7 to 102.7 (mean 84), while those of smallmouth bass from Little River ranged from 73.4 to 111.4 (mean 87; Table 4). Significant negative relationships existed for each population when relative weight (W_r) was regressed against total length ($P < 0.003$; Figure 3).

The linear relationships predicting weight from total length were significant ($P < 0.0001$, $r^2 = 0.99$; Table 5; Figure 4). However, the interaction term was not significant, which indicated slopes of the length-weight regression lines were not significantly different ($P = 0.28$).

The maximum age of smallmouth bass collected from Abrams Creek was 10 years, while the oldest fish collected from Little River was 9 years (Table 6). Smallmouth bass

from Abrams Creek exhibited a more stable age structure than that of Little River, as evidenced with the decline of number at age with increasing age (Figure 5). von Bertalanffy growth curves predicted smallmouth bass would reach 305 mm (12 in) in 6.7 and 8.1 years in Abrams Creek and Little River, respectively (Table 6; Figure 6). There was no overlap between 95% confidence limits of the growth curve parameters indicating growth differed for the Abrams Creek and Little River populations (Table 7).

Ages 2-7 were used in the catch curve analysis for smallmouth bass from Abrams Creek and Little River. Catch curve regression for smallmouth bass in Abrams Creek was significant ($P=0.03$), while that from Little River was not significant ($P=0.21$). Deviation from the catch curve regression line was greater for Little River's smallmouth bass ($r^2=0.30$) than smallmouth bass from Abrams Creek ($r^2=0.75$; Figure 7). Based on catch curve analysis for ages 2-7 in each population, annual mortality (AM) estimates were 41.3% and 27.5% for Abrams Creek and Little River, respectively (Figure 7). Slopes of the catch curve regression lines were not significantly different ($P=0.48$; Figure 7). Recruitment variability ($REC-CV$) was 46.5 and 93.8 for Abrams Creek and Little River, respectively. Trends in year-class strength were similar between streams; strong year-classes were produced in 1998 and 1995, while year-class strength was weak in 1997 (Figure 7). No significant relationships existed when residuals associated with each year in the catch curve analysis were plotted against the respective mean winter (December-February), spring (March-May), and June-July discharges (Figure 8).

Total sampling effort for Abrams Creek and Little River was 19.8 h. The catch rate of smallmouth bass from Abrams Creek was 52.4 bass/hr, while the catch rate of smallmouth bass from Little River was 14.8 bass/hr. Catch per unit effort between

Abrams Creek and Little River in 2002 was not significantly different ($P=0.09$).

Densities, as estimated using visual observation, were 338 and 241 bass/ha from Abrams Creek and Little River, respectively, and were not significantly different ($P=0.50$).

Stomach analysis was performed on 181 smallmouth bass from Abrams Creek and 117 smallmouth bass from Little River, most of which were Age 1 and older. Stomach analysis revealed 110 (61%) smallmouth bass examined for gut contents from Abrams Creek and 85 (73%) smallmouth bass from Little River contained crayfish, fish, or insects (Table 9). Seventy-six (42%) smallmouth bass stomachs collected from Abrams Creek were empty upon inspection, whereas, 37 (32%) smallmouth bass from Little River had no stomach contents. Of the smallmouth bass stomachs that had contents, most contained crayfish (25% in Abrams Creek, 31% in Little River; Table 9). The presence of crayfish ($P=0.002$, $X^2=0.664$) and insects ($P=0.0004$, $X^2=0.978$) in stomachs of smallmouth bass was significantly predicted using total lengths of smallmouth bass in Little River (Table 10; Figure 9). Total length was not a good predictor of the presence of fish in smallmouth bass stomachs from Little River ($P=0.96$). No significant relationships existed when smallmouth bass from Abrams Creek were modeled ($P>0.05$; Table 10).

From July through August 2003, 131 smallmouth bass were collected from Abrams Creek for population estimation, while 30 were collected from Little River. Density estimates for smallmouth bass in Abrams Creek and Little River were 249 and 46 bass/ha, respectively (Table 11). When compared between streams, density estimates were not considered different ($P=0.17$). The standing stock of smallmouth bass in Abrams Creek was 22.5 kg/ha, while that of Little River was 5.4 kg/ha (Table 11).

Standing stock estimates were significantly different between Abrams Creek and Little River ($P=0.04$). Population estimates calculated using snorkeling were 60 and 30 bass/ha in Abrams Creek and Little River, respectively, and were not significantly different ($P=0.40$). The catch rate of smallmouth bass in Abrams Creek was 25.5 bass/hr, while that of Little River smallmouth bass was 5.9 bass/hr. Catch rates from Abrams Creek and Little River were significantly different ($P=0.008$).

Distribution and Habitat Utilization

The distribution of smallmouth bass on Abrams Creek and Little River ended with large upstream barriers, Abrams Falls (N35°36'30.3" W83°52'46.6") and The Sinks (N35° 40'9.3" W83°39'42.6"), respectively. The smallmouth bass distribution in Hazel Creek was believed to extend further upstream than observed (S. Moore, National Park Service, personal communication). All suitable habitat 300 m upstream of the last sighting of smallmouth bass was extensively snorkeled, yet no smallmouth bass were observed. The Eagle Creek distribution of smallmouth bass ceased because of loss of suitable habitat due to shallow channel braiding (Table 12).

Habitat utilization analysis for Hazel Creek and Eagle Creek could not be performed due to low sample size. One smallmouth bass was observed in Hazel Creek above the impoundment of Fontana Reservoir, where substrate consisted of small and large cobble. However, six smallmouth bass were observed where Hazel Creek becomes impounded. The substrate here consisted of sand and large boulder. In Eagle Creek, seven smallmouth bass were observed in three pools upstream of the impoundment;

however, Eagle Creek became braided and shallow above these pools. Substrate within these pools consisted of large cobble and small and large boulder.

The following model, constructed using data from Abrams Creek and Little River, was significant and explained a large amount of variation ($P=0.0003$; $r^2=0.94$),

$$Abundance = 2.13(Run) + 22.5(Riffle) - 2.62(Discharge) - 0.09(Area) + 86.7.$$

Independent variables were not significantly correlated. Amount of pool and complex habitat, temperature, conductivity, mean width, and mean depth were removed from the model using the stepwise procedure in SAS (SAS 1998). These variables were removed because they were not significant ($P>0.05$) predictors of smallmouth bass abundance in Abrams Creek and Little River.

Sampling Protocol

Discharges of Abrams Creek and Little River were significantly different when compared between summer 2002 (mean $0.68 \text{ m}^3/\text{s}$) and 2003 (mean $89.8 \text{ m}^3/\text{s}$) ($P<0.0001$). Population estimates from Abrams Creek were significantly higher in 2002 than 2003 ($P=0.03$), as were those from Little River ($P=0.05$). However, densities in each stream were not significantly different between years ($P>0.05$). When comparing between years, catch rates of smallmouth bass in Abrams Creek were similar ($P=0.33$), but those from Little River were different ($P=0.05$). When comparing densities of smallmouth bass obtained using electrofishing and underwater observation, no significant difference was detected ($P=0.16$). A sampling protocol, based on the aforementioned results, is outlined in Chapter 5.

CHAPTER 5

DISCUSSION

Population Dynamics

To allow for comparisons of population dynamics between Abrams Creek and Little River, the study section of Little River (within GSMNP) was considered representative, even though it is the upper limit of the smallmouth bass distribution. However, the smallmouth bass distribution extends downstream outside of GSMNP. Fiss et al. (2001) collected smallmouth bass from Little River outside of GSMNP and classified Little River as slow growing. However, their sample size was low. Therefore, until further research can be conducted on smallmouth bass outside GSMNP, caution should be exercised when making conclusions about the smallmouth bass population in Little River based on data collected within GSMNP.

The smallmouth bass populations of Abrams Creek and Little River were composed primarily of young fish ($\leq$ Age 4). Anderson and Weithman (1978) suggested balanced populations of smallmouth bass would exhibit PSD ranges of 30-60%. The PSD's for smallmouth bass in Abrams Creek (10%) and Little River (13%) were below this suggested range. Low PSD values can be a result of slow growth, high mortality, or poor recruitment (Anderson and Weithman 1978). Smallmouth bass from Abrams Creek and Little River exhibited slow growth and variable recruitment, which resulted in low PSD estimates. Similar PSD's were observed for smallmouth bass from the Buffalo (14%), Red (13%), and French Broad Rivers (16%), Tennessee (Fiss et al. 2001) and Glover Creek, Oklahoma (19%) (Orth et al. 1983). Austen and Orth (1988) observed PSD

values of 2-5% for smallmouth bass populations in New River of Virginia and West Virginia. High mortality rates of smallmouth bass in the New (76-98%) and Buffalo Rivers (55%), and Glover Creek (61%), and highly variable recruitment (105%) for smallmouth bass in the French Broad River, resulted in low PSD values.

In Abrams Creek and Little River, as smallmouth bass increased in total length, condition (W_r) decreased. However, Slipke et al. (1998) found W_r increased as total length increased in the Tennessee River, Alabama, and attributed this finding to an overabundance of food. McClendon and Rabeni (1987) found a two-year mean W_r of 86 in a Missouri Ozark stream; in their study, condition was best predicted by temperature and crayfish abundance. In the Jacks Fork and Current Rivers, Missouri, smallmouth bass condition was greatest where the density was lowest suggesting an intraspecific influence (Covington et al. 1983). Conversely, mean W_r values of smallmouth bass in Abrams Creek and Little River remained similar as densities decreased from summer 2002 to summer 2003. If condition of smallmouth bass in Little River was density-dependent, mean W_r values would be expected to increase, rather than remain constant. Therefore, condition of smallmouth bass in Little River was probably not density-dependent, and more likely was related to other factors such as variable flows and temperatures, or prey abundance. In Abrams Creek, higher densities most likely influenced the condition of smallmouth bass. The summer 2003 density estimate for Abrams Creek, obtained using electrofishing, was 249 bass/ha. The decrease in densities from summer 2002 to summer 2003 was minimal so no changes would be expected in W_r values.

Crayfish were most abundant, by frequency of occurrence, in stomachs of smallmouth bass in Abrams Creek and Little River. Probst et al. (1984) used a prey-importance index and found crayfish to be energetically more important to smallmouth bass than fish or insects; however, Kilambi et al. (1997) found insects were most abundant in stomachs of smallmouth bass in the Buffalo River, Arkansas. Nearly half of smallmouth bass examined from Abrams Creek and a third from Little River did not have stomach contents. As reflected by the borderline low condition (W_r values) of smallmouth bass in Abrams Creek and Little River, the high occurrence of empty stomachs suggest prey bases are adequate to support the population, but are not overabundant. With few exceptions, stomachs of young-of-the-year smallmouth bass from Abrams Creek and Little River were not examined. Gape-limitations restrict young-of-the-year smallmouth bass to a diet of insects and zooplankton (Clark and Mancini 1980). Therefore, it was assumed that stomach contents of young-of-the-year smallmouth bass consisted of insects. The few that were examined contained insects or were empty. In Little River, immature smallmouth bass tended to feed on insects, while adult smallmouth bass fed primarily on crayfish. Fish were prey for a wide size range of smallmouth bass in Little River (111-348 mm), and therefore, were not significantly predicted to be in stomachs of smallmouth bass in Little River when analyzing using total lengths. Austen and Orth (1985) found similar results, as fish were prey for immature and adult smallmouth bass alike. Smallmouth bass in Abrams Creek were more opportunistic in feeding, as the frequency of occurrence of crayfish, fish, and insects were similar for immature and adult smallmouth bass.

Smallmouth bass in Abrams Creek and Little River grew slower than other stream populations across the United States. Smallmouth bass populations considered slow-growing in Tennessee, Missouri, Oklahoma, and Virginia required approximately 6 growing seasons to reach 305 mm in total length (Covington et al. 1983; Orth et al. 1983; Austen and Orth 1988; Reed and Rabeni 1989; Fiss et al. 2001). Possible explanations for slow growth in Abrams Creek could include resource competition due to high density, variable discharge, or increased turbidity levels. Slow growth of smallmouth bass in Little River may be attributed to low prey abundance or variable discharge. Low flows can reduce available habitat for prey production and concentrate smallmouth bass in a restricted environment, increasing competition for food, whereby, slowing growth (Paragamian and Wiley 1987). Exceptionally high flows have been found to reduce invertebrate populations by scouring (Powell 1958). Anderson et al. (1970) found an inverse relationship between growth of smallmouth bass and turbidity. Turbidity was not measured in Abrams Creek and Little River; however, higher turbidity in Abrams Creek reduced visibility during underwater observation. Abrams Creek is known for having higher turbidity levels than Little River.

Total annual mortality in Abrams Creek and Little River were comparable to those of exploited riverine populations in Tennessee (Fiss et al. 2001), Arkansas (Kilambi et al. 1997), and Iowa (Paragamian 1984). Reed and Rabeni (1989) found total annual mortality to be 16% in an unexploited Missouri stream population, while total annual mortality of smallmouth bass in exploited streams usually exceeds 50% (Orth et al. 1983; Paragamian 1984). The contribution of fishing mortality could not be determined due to a lack of exploitation data for Abrams Creek and Little River. The estimate of total

annual mortality for smallmouth bass in Little River should be viewed skeptically due to the insignificance of the catch curve regression and the large amount of deviation about the regression line. If recruitment is highly variable, consecutive years of catch curve data can be pooled together minimizing the fluctuation about the catch curve regression line. An alternate method of mortality estimation is cohort analysis, which analyzes one cohort through time; however, this would require additional years of sampling.

Estimates of recruitment variability are supported by the age structure histograms and catch curves for each study stream. Seasonal variations in stream discharge are believed to influence recruitment of smallmouth bass in Abrams Creek and Little River. However, regression analysis of catch curve residuals indicated no relationship between smallmouth bass year-class strength and the respective winter, spring, or June-July discharge. Slipke et al. (1998) found a negative relationship existed between year-class strength and mean daily discharge through Wilson Dam from April through July in the Shoals Reach of the Tennessee River. On the other hand, Swenson et al. (2002) and Sallee et al. (1991) found winter discharge to be a strong negative predictor of year-class strength of smallmouth bass in the Upper Mississippi River and the highly channelized Kankakee River, Illinois, respectively. More years of data may be needed before a significant relationship is observed between smallmouth bass year-class strength and discharge in Abrams Creek and Little River.

Densities of smallmouth bass from Abrams Creek and Little River were significantly different. Due to the limestone bedrock, Abrams Creek is more productive than Little River and is able to support larger numbers of smallmouth bass and their prey. Density was positively correlated with conductivity in Abrams Creek and Little River.

The density estimate for Abrams Creek was greater than other estimates reported for stream smallmouth bass populations. Mean density of an unexploited population in Missouri was 138 bass/ha, while densities of heavily exploited stream or riverine populations in Missouri, Oklahoma, Iowa, and Wisconsin ranged from 30-132 bass/ha (Reed and Rabeni 1989). Densities were significantly higher in 2002 when discharge was lower than it was in 2003. Also, a significant negative correlation existed between discharge and density in Abrams Creek and Little River. Discharge in 2003 may have exceeded that which smallmouth bass have been found to prefer (Sechnick et al. 1986; Todd and Rabeni 1989) causing them to move downstream to wider areas with lower flow.

Distribution and Habitat Utilization

Distributions of smallmouth bass in summer 2003 in Abrams Creek, Little River, Hazel Creek, and Eagle Creek were limited due to unsuitable habitat conditions. Large cascades physically blocked upstream smallmouth bass movement in Abrams Creek and Little River. The large cascades on Abrams Creek and Little River represent a major habitat change in these two streams. Above these cascades, the streams become shallower with higher gradient and flow. Smallmouth bass in Hazel Creek were not observed where they have been historically. Above average flows during sampling may have pushed smallmouth bass downstream to wider areas with slower flow. Multiple smallmouth bass were observed where the stream becomes impounded indicating preference for this habitat type at the time of sampling. In Eagle Creek, lack of deep pools and shallow braiding of the stream (i.e., loss of suitable habitat) was an obstacle to

upstream movement of smallmouth bass. Smallmouth bass typically occupy deep pools with low flow (Rankin 1986); observations of smallmouth bass at the impoundment and in the three deep pools below the shallow braiding confirm this finding.

Habitat preference results could not be obtained using the data collected during this study. To obtain habitat preference data, various habitat measurements should be recorded at each location a smallmouth bass is observed. Barrett and Maughn (1994) used this method and found adult smallmouth bass in a central Arizona stream utilized low velocity, middepth, sandy areas with cover, while juveniles preferred low velocity, shallow, gravelly substrate areas adjacent to instream cover. However, a highly significant model was constructed using site and abundance data from Abrams Creek and Little River, which predicted density using amount of run and riffle habitat, discharge, and area of the site. The significance of this model suggests these four variables are important in predicting smallmouth bass abundance in Abrams Creek and Little River. Smallmouth bass use run and riffle habitat because prey species such as crayfish and fish also utilize this habitat type. Also, currents in run and riffle habitats drift invertebrates to smallmouth bass. Smallmouth bass prefer slower discharge, which explains the negative correlation between discharge and abundance in the model. The reason for surface area of a site being significant in the model is uncertain. Accuracy of this model should be determined to evaluate its possible use as a future management tool. Lyons (1991) modeled smallmouth bass in Wisconsin and did not find any habitat variable or combination of variables that significantly predicted smallmouth bass abundance; however, amount of rocky substrate had the best correlation with smallmouth bass

abundance. Other studies have found rocky substrate, or some component of it, as being essential to good smallmouth bass habitat (Rankin 1986; McClendon and Rabeni 1987).

Sampling Protocol

Smallmouth bass should be sampled during low discharge periods. Densities and catch rates were significantly higher in summer 2002 when mean discharge was $0.68 \text{ m}^3/\text{s}$ than in summer 2003 when mean discharge was $2.54 \text{ m}^3/\text{s}$. Larger sample sizes provide more precise estimates and a better overall assessment of the target population.

If it is assumed that sampling will be performed during low discharge periods, the technique GSMNP biologists use should depend on the objectives of their research. Summer 2003 density estimates obtained using electrofishing were similar to those obtained using snorkeling in Little River; however, density estimates were significantly different between techniques in Abrams Creek. This difference in Abrams Creek can be explained with the increased turbidity during summer 2003 sampling. Underwater visibility was low, which resulted in a low estimate. The density estimate for Abrams Creek obtained using snorkeling (60 bass/ha) should be closer to the electrofishing estimate (249 bass/ha).

If population estimates are desired, then underwater observation should be used. This technique requires less overall effort and manpower than electrofishing. Snorkeling would be ideal for Abrams Creek, which has few access points where smallmouth bass occur. However, if GSMNP biologists want length/weight data, then electrofishing is the technique that should be employed. Although electrofishing requires much more effort

and manpower, more information can be obtained about the overall population using this data type. Backpack electrofishing would be effective for a major portion of the stream; however, deeper, unwadeable sections of stream should be snorkeled prior to electrofishing to verify the presence or absence of larger, older fish. The electric seine was constructed during this study to sample the deeper sections of stream. However, the effort required to carry the electric seine into Abrams Creek far outweighs the information that can be obtained from its use, and therefore, would not be practical. The electric seine can be used efficiently on Little River since access is much greater; although, the same sampling technique should be used among streams to statistically compare smallmouth bass populations within GSMNP.

Abrams Creek and Little River are open to smallmouth bass fishing; however, exploitation rates are not known for these populations. Current regulations for smallmouth bass in GSMNP are 5 fish, at least 7 inches (178 mm) in length. With the population dynamics obtained from this study and creel information, it can be determined if possible regulation changes are needed to enhance smallmouth bass populations within GSMNP.

Management Recommendations

As a result of the information gained in this study, the following management recommendations should be considered by GSMNP fisheries biologists:

- Monitor smallmouth bass populations during low discharge periods on an annual basis.
- Select sample sites based on accessibility and the inclusion of ideal smallmouth bass habitat (Coble 1975).

- For length/weight data, collect smallmouth bass using backpack electrofishing gear.
- Assess smallmouth bass abundance using a mark-recapture technique.
- If only population estimates are desired, sample smallmouth bass using underwater observation.
- If using snorkeling to evaluate electrofishing efficiency, snorkel the sample site before electrofishing.
- Study food habits of smallmouth bass and prey abundance to better understand the sub-average growth and condition.
- Conduct creel studies to assess effects of exploitation.
- Estimate total annual mortality using cohort analysis.
- Conduct habitat preference studies on smallmouth bass for future site establishment and to target possible areas in need of habitat improvement.
- Conduct studies on seasonal movement of smallmouth bass between Abrams Creek and Chilhowee Reservoir, and on streams containing smallmouth bass which flow into Fontana Reservoir.
- Since growth and density are different between Abrams Creek and Little River, consider separate regulations for each stream

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TABLES

Table 1. Physical and chemical water quality parameters of Abrams Creek and Little River, Blount County, Tennessee from July through August 2002 and 2003.

Parameter	Stream	
	Abrams Creek	Little River
Mean width	18.1 m	15.9 m
Mean depth	2.1 m	2.7 m
Gradient	3.5 %	1.5 %
Discharge	0.45-2.2 m ³ /s	0.94-2.9 m ³ /s
Temperature	21.3 °C	18.4 °C
Conductivity	54.1 µS	17.4 µS

Table 2. Coordinates (degrees, minutes, seconds) of sample reaches of Abrams Creek and Little River, Blount County, Tennessee, in WGS 84 datum.

Stream	County	Site	Latitude	Longitude
Abrams Creek	Blount	1	N 35° 34' 22.8"	W 83° 59' 07"
		2	N 35° 35' 13.2"	W 83° 56' 55"
		3	N 35° 36' 42.0"	W 83° 54' 20"
Little River	Blount	1	N 35° 39' 40.0"	W 83° 42' 26"
		2	N 35° 39' 53.8"	W 83° 41' 42.8"
		3	N 35° 40' 5.7"	W 83° 40' 58.5"

Table 3. Percentage of habitat type and area (m²) by site in Abrams Creek and Little River, Blount County, Tennessee.

Stream	Site	Area	Percentage of each			
			Run	Pool	Riffle	Complex
Abrams Creek	1	3691	45	38	7	9
	2	2149	59	26	8	6
	3	2855	31	52	7	10
Little River	1	4041	55	22	6	17
	2	3096	54	29	5	12
	3	2352	85	8	3	3

Table 4. Proportional stock densities (PSD), mean relative weight (W_r), estimated annual mortality (AM), and recruitment variability estimates ($REC-CV$) for smallmouth bass collected from Abrams Creek and Little River, Blount County, Tennessee from July through August 2002 using electrofishing.

Stream	PSD (%)	Mean W_r	AM (%)	$REC-CV$
Abrams Creek	10±6.8	84.3	41.3	46.5
Little River	13±8.6	87.0	27.5	93.8

Table 5. Length-weight relationship parameters and standard error ($\pm$) of smallmouth bass collected from Abrams Creek ($n=252$) and Little River ($n=214$) from July through August 2002 using electrofishing following the general equation: $\log_{10}(W) = a + b[\log_{10}(TL)]$, where W is weight (g), TL (mm) is total length.

Stream	a	b	P	r^2
Abrams Creek	-4.3021 $\pm$ 0.084	2.7261 $\pm$ 0.038	<0.0001	0.99
Little River	-4.3619 $\pm$ 0.154	2.7543 $\pm$ 0.064	<0.0001	0.99

Table 6. Mean total lengths at age for smallmouth bass collected in Abrams Creek and Little River, Blount County, Tennessee, during summer 2002.

Stream	Length at age (mm)										
	0	1	2	3	4	5	6	7	8	9	10
Abrams Creek	54	130	179	222	237	269	293	304			440
Little River	46	119	155	204	210	245	279	278		314	

Table 7. Estimated parameters and standard error of von Bertalanffy growth model for smallmouth bass collected from July through August 2002 in Abrams Creek ($n=176$) and Little River ($n=112$), Blount County, Tennessee using electrofishing, where K is the Brody growth coefficient, L_{∞} is theoretical maximum length a fish can attain, and t_0 is the time when length would theoretically be zero.

Stream	K	L_{∞} (mm)	t_0 (yr)
Abrams Creek	0.135 ± 0.0009	450	-1.665 ± 0.015
Little River	0.183 ± 0.0009	375	-1.035 ± 0.012

Table 8. Mortality and recruitment variability estimates of smallmouth bass collected from Abrams Creek and Little River, Blount County, Tennessee from July through August 2002.

Stream	Mortality	Recruitment variability
Abrams Creek	41.3	46.5
Little River	27.5	93.8

Table 9. Numbers and percentages of smallmouth bass examined for stomach contents (crayfish, fish, or insects) collected from Abrams Creek ($n=181$) and Little River ($n=117$), Blount County, Tennessee from July through August 2002 using electrofishing.

Stream	Crayfish	Fish	Insects	Combination	Empty
Abrams Creek	46 (25%)	37 (20%)	17 (9%)	10 (6%)	76 (42%)
Little River	36 (31%)	26 (22%)	21 (18%)	2 (2%)	37 (32%)

Table 10. Significance levels (*P*-values) of logistic models using total lengths to predict the presence of crayfish, fish, and insects in stomachs of smallmouth bass collected from Abrams Creek and Little River, Blount County, Tennessee from July through August 2002.

Stream	Presence of		
	Crayfish	Fish	Insects
Abrams Creek	0.2680	0.4910	0.6667
Little River	0.0020	0.0960	0.0004

Table 11. Estimated numbers and standing stock of smallmouth bass collected from Abrams Creek and Little River, Blount County, Tennessee from July through August 2003 using an electric seine and backpack electrofishing units.

Stream	Site	Population estimate	95% C.I.	Number per ha	Standing stock (kg/ha)
Abrams Creek	1	90	47-224	202	19.9
	2	141	75-288	436	32.3
	3	40	24-69	113	15.3
			Mean	249	22.5
Little River	1	13	5-31	35	4.2
	2	22	8-54	72	10.2
	3	9	3-23	30	1.9
			Mean	46	5.4

Table 12. Coordinates (WGS 84 datum) of upper limits and stream kilometers of smallmouth bass distributions in Abrams Creek, Little River, Hazel Creek, and Eagle Creek within GSMNP sampled in July 2003 using underwater observation.

Stream	County, State	Upper limit coordinates		Stream km
Abrams Creek	Blount, TN	N 35° 36' 30.3"	W 83° 52' 46.6"	27.4
Little River	Blount, TN	N 35° 40' 9.3"	W 83° 39' 42.6"	13.7
Hazel Creek	Swain, NC	N 35° 28' 51"	W 83° 42' 58"	10.3
Eagle Creek	Swain, NC	N 35° 29' 2.8"	W 83° 46' 26.7"	4.3

FIGURES

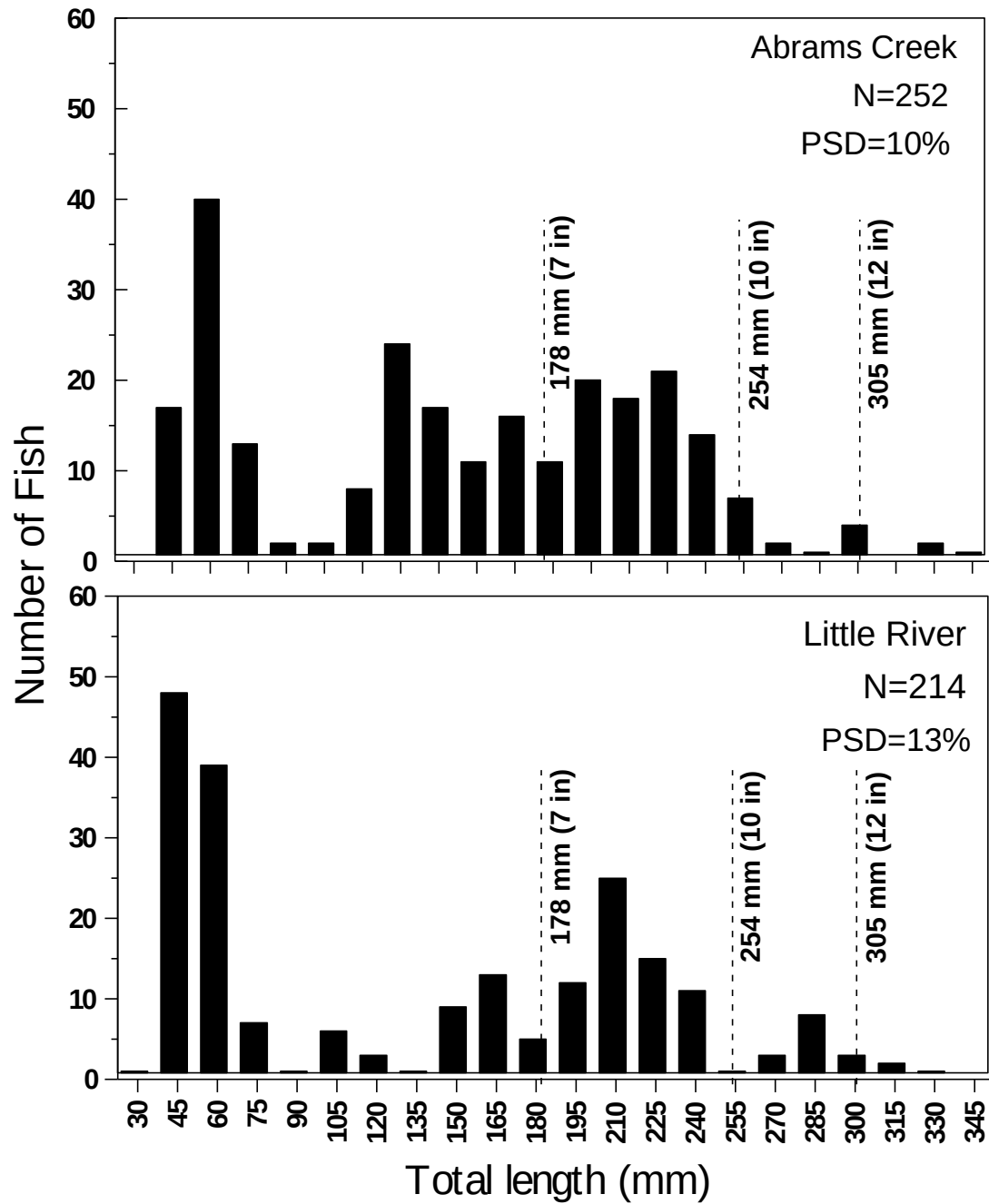


Figure 2. Length frequency distributions of smallmouth bass collected from Abrams Creek and Little River, Blount County, TN from July through August 2002.

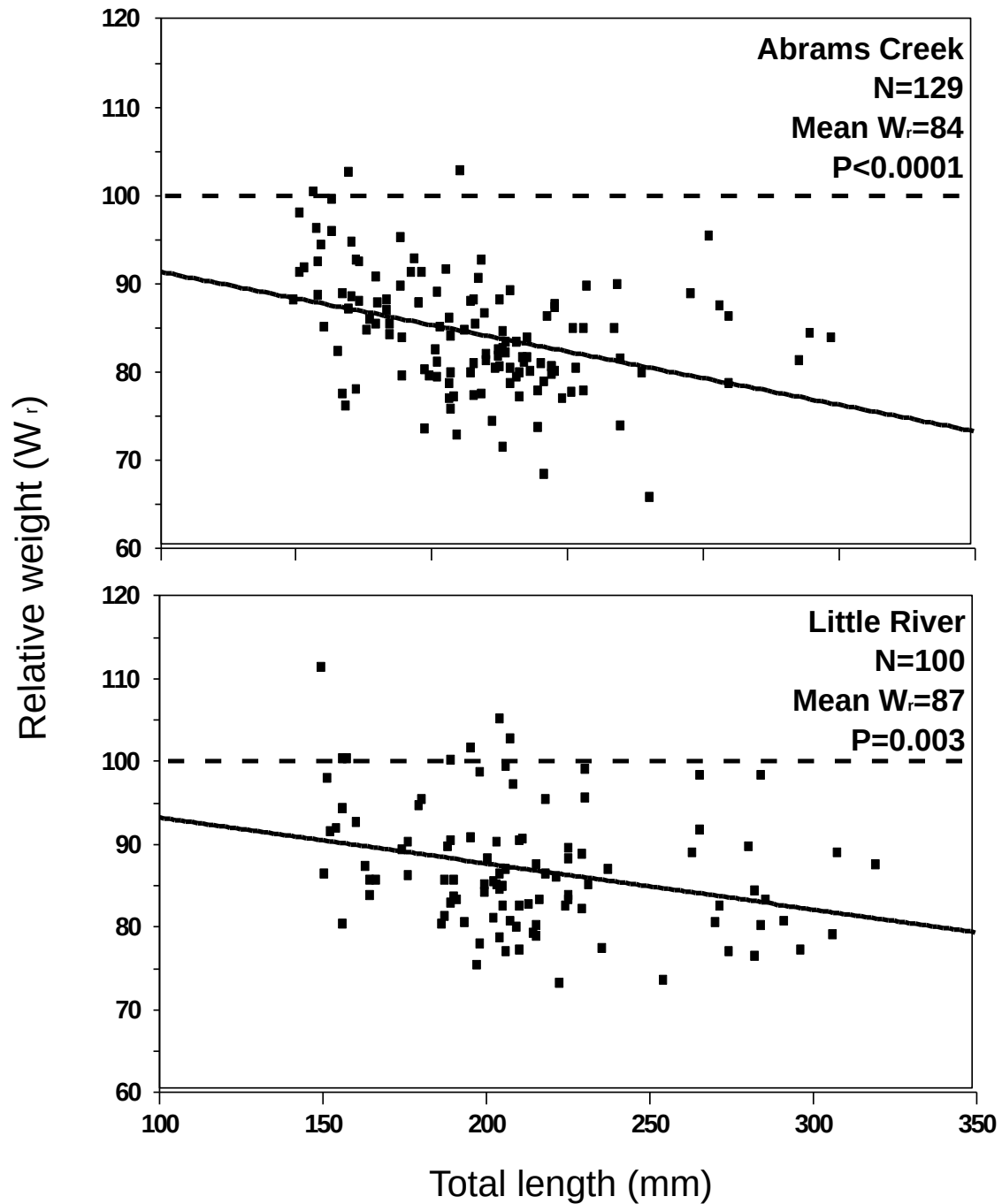


Figure 3. Relative weight (W_r) of smallmouth bass collected from Abrams Creek and Little River, Blount County, Tennessee from July through August 2002. Dashed line represents average W_r of 100.

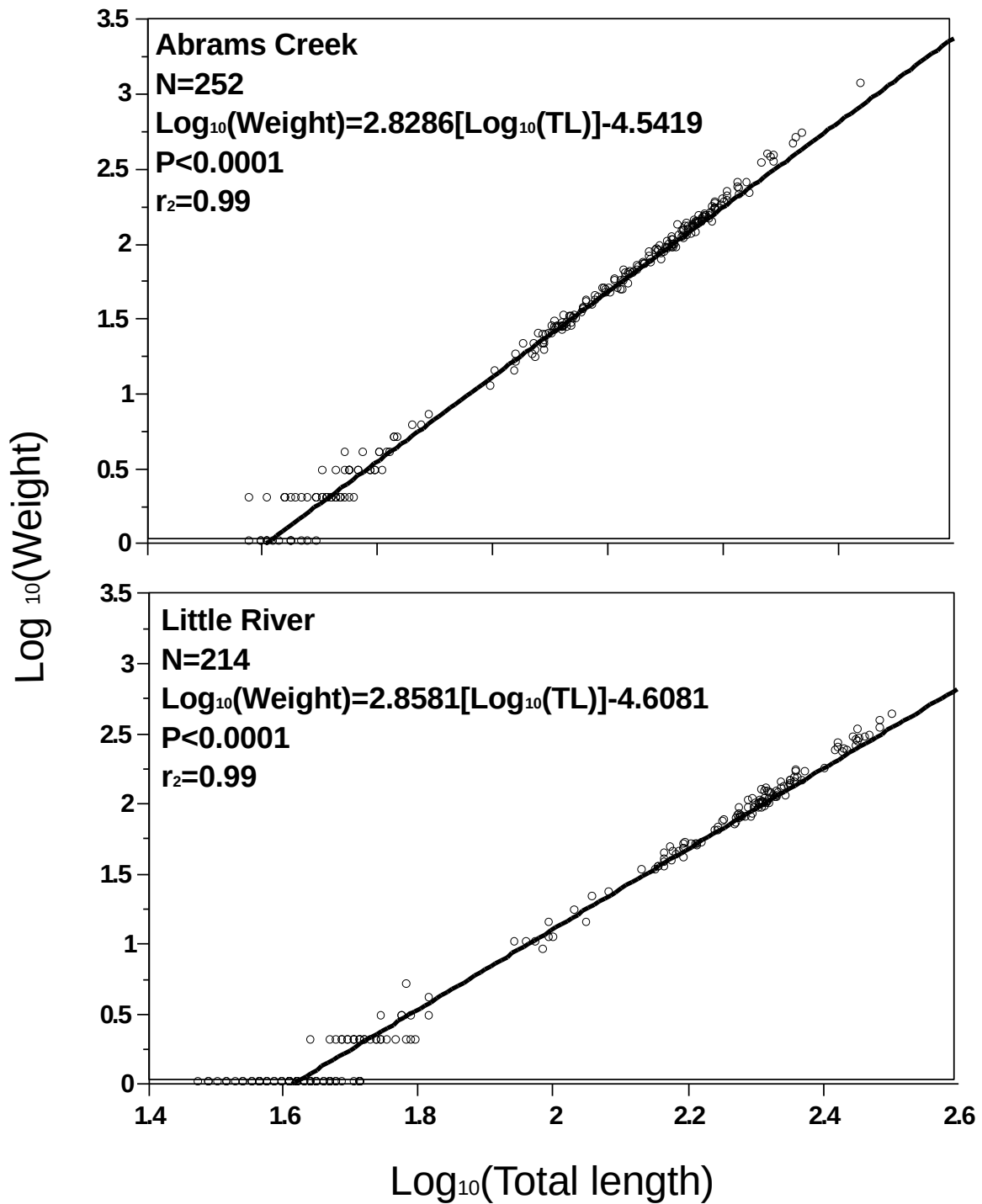


Figure 4. Linear relationship (log₁₀ transformed) between total length (mm) and weight (g) of smallmouth bass collected from Abrams Creek and Little River, Blount County, Tennessee from July through August 2002.

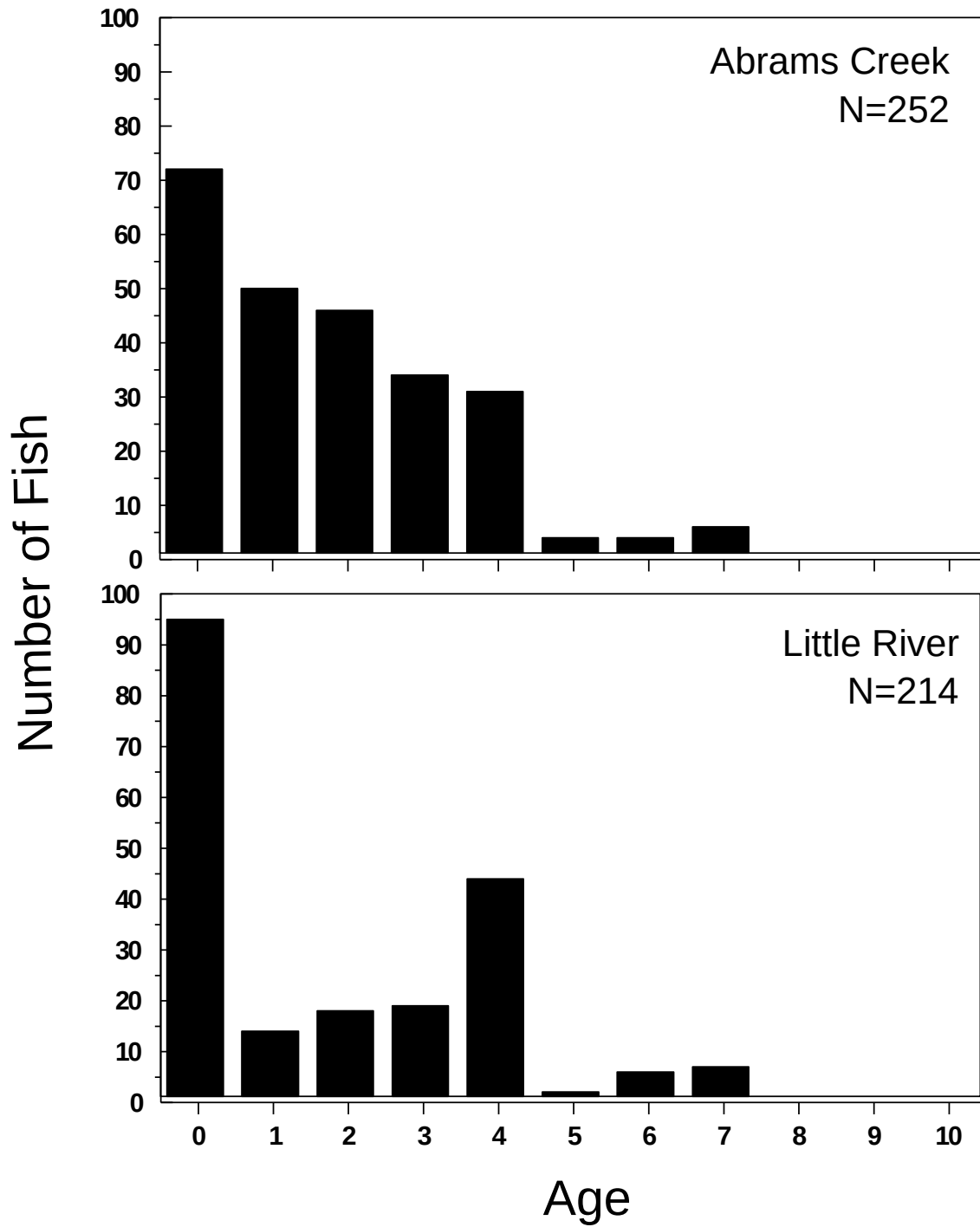


Figure 5. Age frequency distribution of smallmouth bass collected from Abrams Creek and Little River, Blount County, Tennessee from July through August 2002.

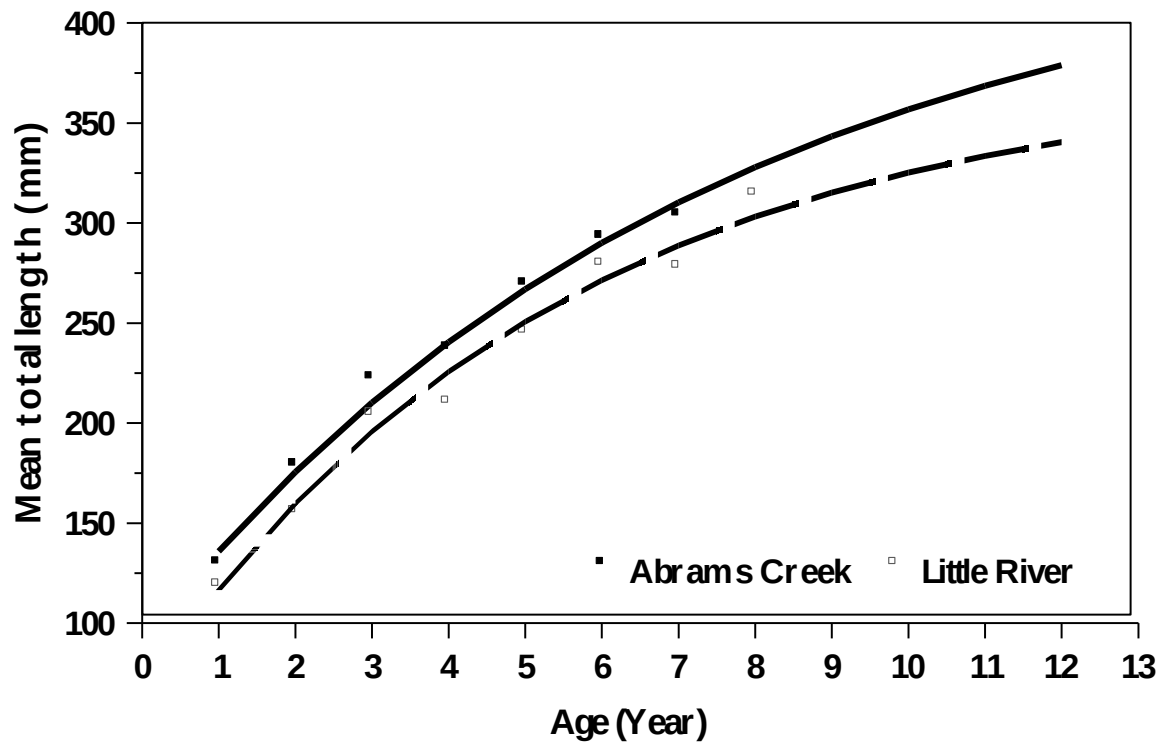


Figure 6. von Bertalanffy growth curves for smallmouth bass collected from Abrams Creek and Little River, Blount County, Tennessee, from July through August 2002. Corresponding growth parameters are listed in Table 5.

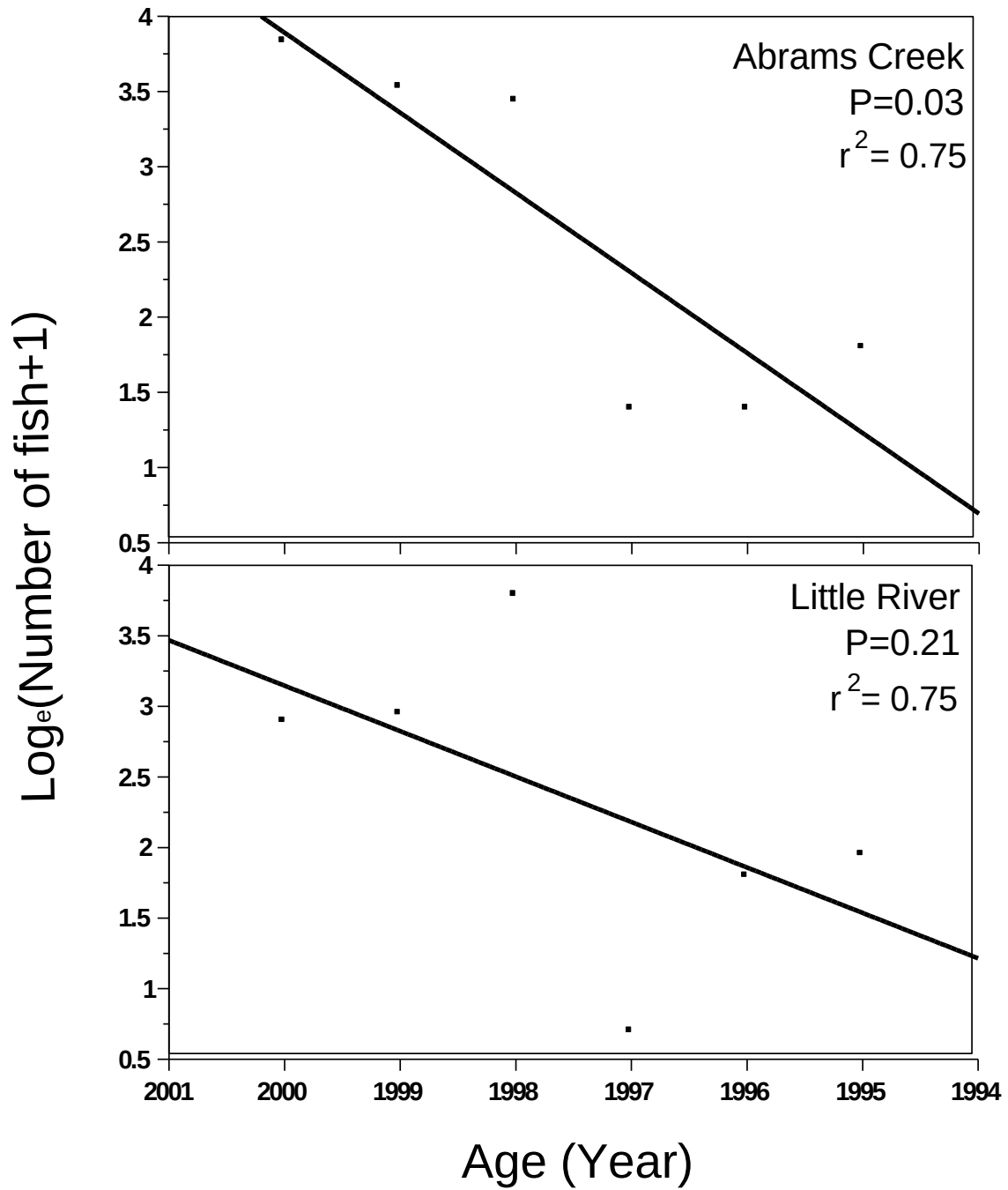


Figure 7. Linearized catch curves of smallmouth bass collected from Abrams Creek and Little River, Blount County, Tennessee, from July through August 2002.

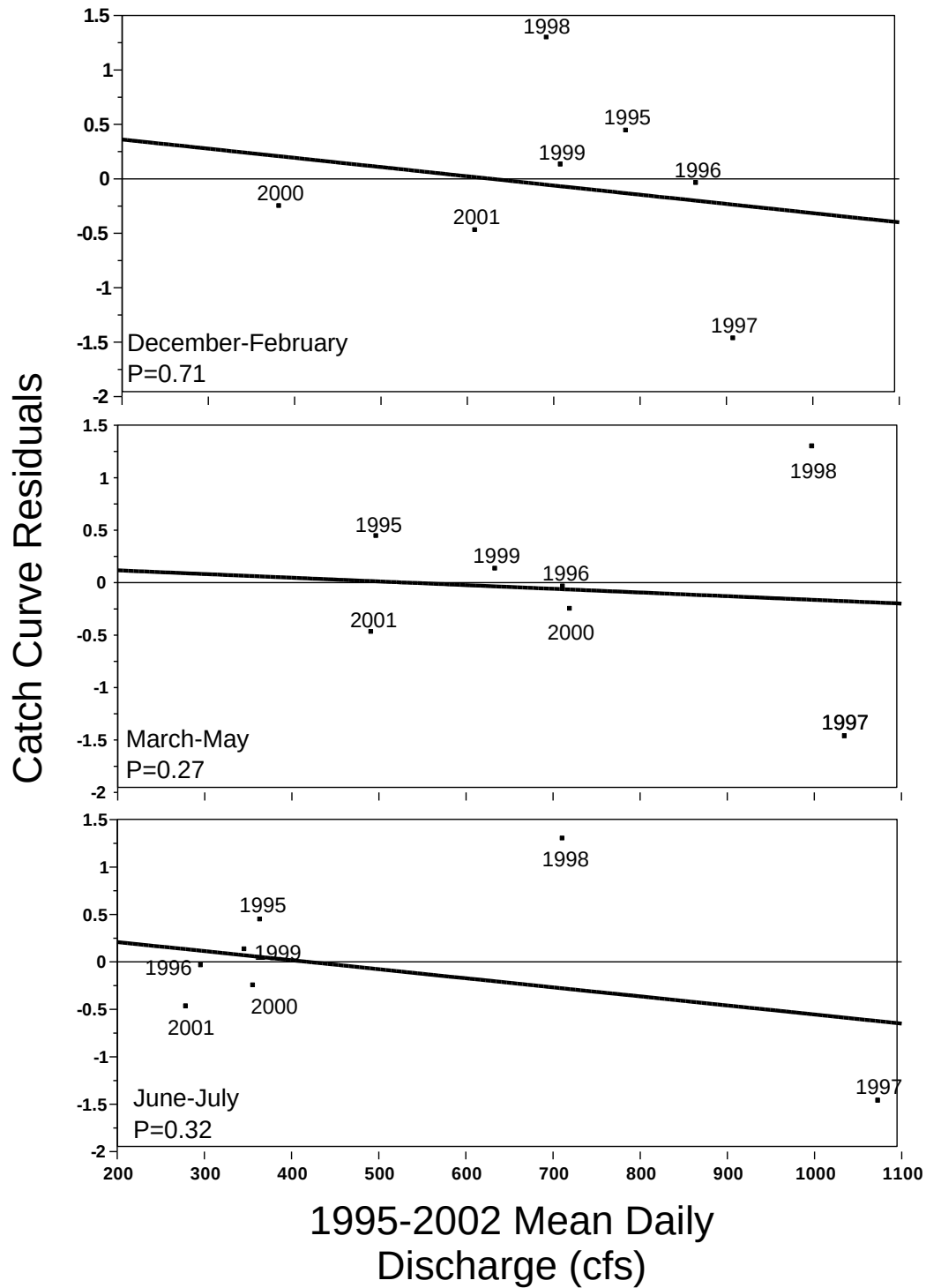


Figure 8. Residuals from a catch curve of smallmouth bass caught in Little River versus mean daily discharge of Little River for winter (December-February), spring (March-May), and June-July discharges. Data points are identified by corresponding smallmouth bass year-classes. Data points above the zero reference line indicate relatively strong year-classes, and those below the reference line indicate relatively weak year-classes.

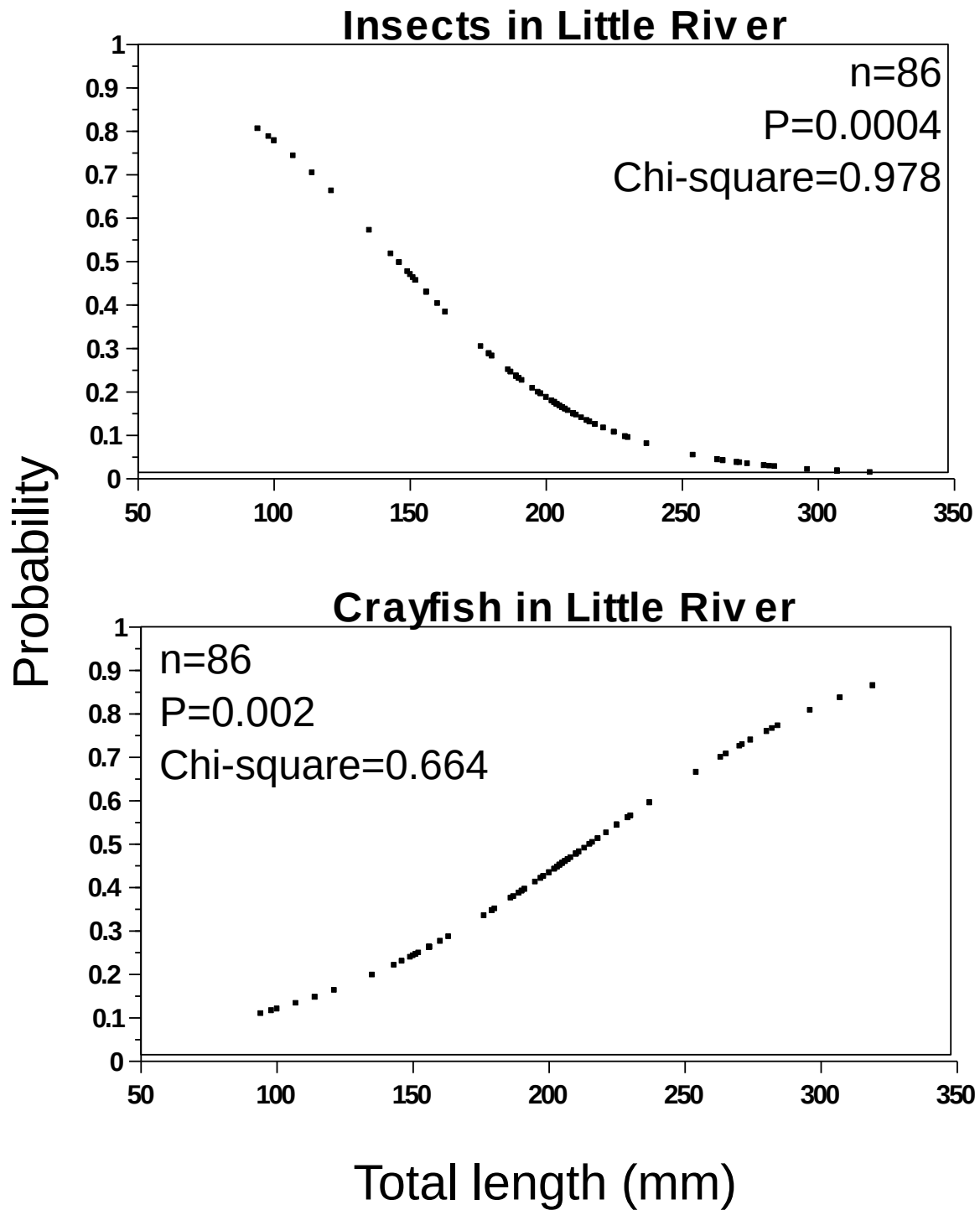


Figure 9. Logistic curves modeling the probability of insects and crayfish being found in stomachs of smallmouth bass in Little River, Blount County, Tennessee.

VITA

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