Conservation status of shoal bass in Alabama: distribution, abundance, stocking efficacy, and possible effects of sympatric congeneric black bass in selected tributaries of the Chattahoochee River, Alabama

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EXECUTIVE SUMMARY

Shoal bass *Micropterus cataractae* are native only to the Apalachicola drainage, with an original distribution that included most of the Chattahoochee and Flint river basins. Shoal bass appear to be habitat specialists, generally found in shallow, rocky riffles and shoals in medium- to large-sized streams and rivers and are intolerant of reservoir conditions. Much of the riverine habitat favored by shoal bass has been destroyed by impoundment in the Chattahoochee River drainage; remaining shoal bass populations continue to suffer loss of habitat from increased sedimentation from changing land use and altered hydrology from changing water uses. This species has recently been classified as a species of High Conservation Concern in Alabama, and stream surveys in 2005-2006 by Auburn University found only one healthy shoal bass population remaining in Alabama. In addition, shoal bass have largely disappeared from the main channel of the Chattahoochee River along the Alabama-Georgia state line, as that river has been impounded from West Point, Georgia downstream to its confluence with the Flint River in Lake Seminole. Many areas in which shoal bass been collected historically now appear to be dominated by spotted bass *Micropterus punctulatus*, which have been found to prefer the same type of habitat used by shoal bass. Thus, the possible mechanisms of spotted bass-shoal bass relations must be examined to determine the nature of the threat posed by spotted bass to shoal bass and guide future conservation efforts.

<u>Black Bass Species Compositions and Habitat Associations</u>

For this project, fish and habitat surveys were conducted from selected reaches of Osanippa, Halawakee, Wacoochee, and Little Uchee creeks, Alabama to examine the black bass community present in each stream and to evaluate habitat associations for each species. In addition, samples of the black bass community were collected below Langdale, Riverview, Bartletts Ferry, Goat Rock, Oliver, North Highlands, and Eagle Phenix dams on the Chattahoochee River. Findings of this portion of the study include:

1) Most reaches of Alabama streams and areas below dams in the Chattahoochee River were dominated by non-native spotted bass. Shoal bass only dominated the black bass community in the Moffits Mill shoal of Little Uchee Creek. Only two unstocked shoal bass were collected in the other three streams during this study.

2) Catch rates of all three black bass species was highest in shoal habitat, indicating that these habitats constitute important areas for black bass in these streams. The relatively scarcity of large shoal complexes in these Alabama streams may increase the likelihood of competitive interactions among black bass, especially between the introduced spotted bass and the native shoal bass.

3) The last known Alabama shoal bass population at the Moffits Mill shoal on Little Uchee Creek exhibited some signs of recovery in fall 2008, but many of these fish were lost downstream due to high water flows in the spring 2009. As of May 2009, this population

had not recovered from the droughts of previous years and its persistence remains in jeopardy.

4) Shoal bass populations were found below all dams on the Chattahoochee River except Bartletts Ferry; however, most populations were characterized by low abundance and showed evidence of poor recruitment. The overall effect of dams in the Chattahoochee River may have been to reduce a continuous metapopulation of shoal bass into a series of isolated populations of limited genetic diversity and low effective population size, with an increased likelihood of extinction.

5) Results from this study confirm that Alabama populations of shoal bass remain in great danger of extinction. These populations can likely only be recovered with rapid and decisive management actions. Until some recovery of other Alabama populations are observed, the last remaining population of wild shoal bass in Alabama at Moffits Mill shoal must be protected at all costs. If drastic actions are not taken rapidly, it is only a matter of time before wild shoal bass are gone from Alabama's waterways.

<u>Shoal Bass Stocking Evaluation</u>

Shoal bass are a popular game fish in many river systems in Georgia, and are supported by a supplemental stocking program in some river sections where natural recruitment has been chronically low. These stocking programs have generally been very successful, with the contribution of stocked fish to the year class approaching 50% in some years. Alabama Department of Wildlife and Freshwater Fisheries biologists stocked over 300 shoal bass in selected reaches of Halawakee, Osanippa, and Wacoochee creeks in January 2008 in an attempt to restore the species to these streams. These fish were sampled from stocked stream reaches over three seasons covering a 18-month period to assess stocking contribution and relative stocking success. Findings include:

1) Relatively few fish were recaptured during surveys in 2008 and 2009; only 21 of the 314 stocked fish were ever recaptured, and recovery rates ranged between 4-8 percent among the stream reaches. Significant movement was detected for three fish stocked into the upper Halawakee reach; all three fish traveled > 2 km downstream from their stocking sites, moving over the Beans Mill Dam in the process.

2) Stocking failed to appreciably change the species composition of the black bass community by the end of the project in all stream reaches but Wacoochee Creek, where the proportion of shoal bass increased nearly 10-fold over pre-stocking conditions. However, few black bass of any species were collected in Wacoochee Creek during these surveys, and only one stocked fish was collected in the last sample.

3) Shoal habitat where the last Alabama population of shoal bass is found (Moffits Mill shoal on Little Uchee Creek) differed from major shoal complexes on Halawakee and Wacoochee creeks, but was more similar to shoal complexes on Osanippa Creek.

4) Despite proceeding on the best available science regarding available shoal habitat and shoal bass densities in Alabama streams, the reintroduction of shoal bass into Halawakee, Osanippa, and Wacoochee creeks was generally unsuccessful. Reasons for this failure were not fully investigated, but likely included a depauperate prey fish community present in these streams due to several years of drought prior to stocking, wild congenerics such as spotted bass being better adapted to handle adverse conditions than newly stocked fish, and potential movement of stocked fish outside of the study area.

5) Results of this study should allow Alabama Division of Wildlife and Freshwater Fisheries biologists to move forward with new stocking strategies in an attempt to restore shoal bass to their former range in Alabama. Future shoal bass stockings should be of small juvenile (fingerling) fish, which has been shown to be successful in two Georgia rivers. Furthermore, because the shoal habitat on Osanippa Creek most closely approximates that found at the Moffits Mill site on Little Uchee Creek, initial restoration efforts should be concentrated there to maximize the chances of success.

<u>Competition Between Shoal Bass and Spotted Bass in Laboratory Systems</u>

Because available evidence suggested possible competitive interactions between native shoal bass and nonnative spotted bass, an investigation of these relationships was undertaken. Shoal bass and spotted bass were collected from the wild using various electrofishing gears and held in tanks in order to observe possible competitive interactions between the two species. Tanks were modified with cobble- to boulder-sized rock to simulate natural shoal habitats. Black bass were stocked into one of three treatment groups: 1) a conspecific group of six shoal bass, 2) conspecific group of six spotted bass, and 3) a heterospecific group of three shoal bass and three spotted bass. A total of three trials were made; trials lasted for 60 or 90 d. Growth of bass was estimated at the end of the period and compared between treatments.

1) All trials conducted during this study were plagued by high mortality of fishes, especially during periods of high water temperatures, resulting in high variability that limited our ability to analyze these data. Growth of subject fish was also extremely variable among treatments within each treatment group; variance was often an order of magnitude greater than the mean for both length and weight.

2) Not surprisingly, no significant differences were detected among treatments for either species of fish or in any trial for absolute growth in length, weight, or instantaneous growth rates (t-test; $t < |1.75|$; $P > 0.10$). However, length increases of shoal bass appeared to be greater in the conspecific treatment than the heterospecific treatment in all three trials; whereas, spotted bass length increases appeared to be greater in the heterospecific treatment than in the conspecific treatment in the second and third trials, but not the first.

3) Despite the difficulties encountered during this study, there was some indication that spotted bass can negatively affect the growth of shoal bass when they are found in close proximity to each other. Supporting this is the fact that a concurrent study on the Flint

River, Georgia, found that diets of shoal bass and introduced spotted bass were more similar than between native shoal bass and largemouth bass, especially at small sizes.

4) Given the fact that shoal habitats in Alabama streams appear to be heavily used by both shoal bass and spotted bass, it seems obvious that competition between these species is very likely in these Alabama streams and may have contributed to the decline of shoal bass observed in Alabama streams. However, further research is necessary to understand and predict the effects of black bass introductions into new watersheds.

ACKNOWLEDGMENTS

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INTRODUCTION AND BACKGROUND

Shoal bass *Micropterus cataractae* are native only to the Apalachicola drainage, with an original distribution that included most of the Chattahoochee and Flint river basins (Williams and Burgess 1999). Shoal bass appear to be habitat specialists, generally found in shallow, rocky riffles and shoals in medium- to large-sized streams and rivers and are intolerant of reservoir conditions (Wheeler and Allen 2003; Boschung and Mayden 2004). Much of the riverine habitat favored by shoal bass has been destroyed by impoundment in the Chattahoochee River drainage; however, healthy populations remain in the mainstem and large tributaries of the Flint River, Georgia (J. Evans, Georgia Department of Natural Resources [GDNR], unpublished data). Additionally, the species was stocked into the Ocmulgee River, a tributary of the Altamaha River, by GDNR in the mid 1970s, which currently supports a popular fishery (J. Evans, GDNR, personal communication).

The role of habitat alteration in the imperilment of freshwater fishes is well established (Warren et al. 2000), and remaining shoal bass populations continue to suffer loss of habitat from increased sedimentation from changing land use and altered hydrology from changing water uses (Walser and Bart 1999). The conservation status of shoal bass has been reviewed by biologists in Alabama, Florida, and Georgia several times in the last 40 years (Williams and Burgess 1999). This species has been assigned a status of Special Concern by the American Fisheries Society Endangered Species Committee (Williams et al. 1989), and has recently been classified as a species of High Conservation Concern in Alabama (Mirarchi et al. 2004). Shoal bass have largely disappeared from the main channel of the Chattahoochee River along the Alabama-Georgia state line, as that river has been impounded from West Point, Georgia downstream to its confluence with the Flint River in Lake Seminole (Williams and Burgess 1999). However, a few relict populations still exist in shoals found from immediately downstream from these dams to the headwaters of the downstream reservoirs (B. Hess, GDNR, personal communication).

In Alabama, shoal bass historically occurred in the Osanippa, Halawakee, Wachoochee, and Uchee river systems in the east-central region of the state. However, recent extensive surveys conducted by Auburn University of those streams found only one viable population of shoal bass remaining in the Moffits Mill section of Little Uchee Creek in Lee County (Stormer and Maceina 2008). Only 10 shoal bass were collected outside that population during the two-year survey. Shoal bass populations in Alabama have suffered large declines in abundance over the last 30 years, and the future persistence of this species in Alabama may be precarious.

Many areas in which shoal bass been collected historically now appear to be dominated by spotted bass *Micropterus punctulatus*, which have been found to prefer the same type of habitat used by shoal bass (Hurst et al. 1975; Layher et al. 1987; Tillma et al. 1998). Spotted bass may be more of a habitat generalist than shoal bass (Vogele 1975; Sammons and Bettoli 1999), and may be able to outcompete shoal bass when the two are found sympatrically (Miller 1975; Smitherman 1975). Many river systems in the range of shoal bass are being degraded due to changes in land use and increased demand for water supplies (Williams and Burgess 1999), and degradation of habitat in systems where both species are found may favor spotted bass over shoal bass, due to their greater adaptability.

Spotted bass and shoal bass were collected in approximately equal numbers from Halawakee Creek in 1968-69 (Hurst 1969); however, by 2005-06, only 3 shoal bass were collected from the same reach, compared to 53 spotted bass (Stormer 2007). The spotted bass in Halawakee Creek in the late 1960s were considered to be the northern subspecies *M. p. punctulatus* by Smitherman and Ramsey (1972), and these fish were introduced to the upper Chattahoochee drainage sometime after 1941 (Williams and Burgess 1999). However, a more recent invader to the system has been the Alabama subspecies of spotted bass *M. p. henshalli*, which was first found in the Chattahoochee River in 1970 upstream of Atlanta, Georgia (Williams and Burgess 1999). Introduced Alabama spotted bass were found to hybridize with native smallmouth bass *Micropterus dolomieu* in Lake Chatuge, Georgia, resulting in the almost complete loss of pure smallmouth bass in that system (Pierce and VanDenAvyle 1997). That same survey found that all the spotted bass collected in Lake Lanier, Georgia, on the upper Chattahoochee River, were the Alabama subspecies. Spotted bass abundance has been increasing in Lake Eufaula, on the Chattahoochee River since the early 1990s (GDNR, unpublished data). Since Lake Eufaula lies downstream of the streams where shoal bass are found in Alabama, it is likely that abundance of spotted bass has also increased in the areas where these streams empty into the Chattahoochee River, thus providing a vector for invasion.

No genetic work has been done on the spotted bass found in these areas; however, it is possible that the observed increases of spotted bass over the last 10-15 years have been caused by Alabama spotted bass spreading through the system.

Regardless of the subspecies, spotted bass appear to be replacing shoal bass in many of the streams in Alabama. Lending further support for this hypothesis is the fact that the only viable shoal bass population found in the Auburn University 2005-06 survey was above a natural barrier, a vertical 3- to 5-m drop into a plunge pool on Little Uchee Creek, which may have impeded upstream migration of fishes in most years. Few spotted bass were collected by electrofishing in the areas with shoal bass above this plunge pool; however, the majority of black bass collected by angling below it were spotted bass. Furthermore, the section of Halawakee Creek above where Hurst (1969) sampled in 1968-69 is isolated from the downstream sections by a mill dam, and only largemouth bass *Micropterus salmoides* were collected above the dam in 2005-06; whereas, spotted bass were commonly collected below the dam (Stormer and Maceina 2008). Genetic analysis of suspected hybrid black bass in Halawakee and Osanippa creeks found two shoal bass-spotted bass hybrids in Osanippa Creek and one largemouth bass-spotted bass hybrid in Halawakee Creek (Stormer 2007). Therefore, some hybridization has occurred on in these systems, which could jeopardize the future of shoal bass in Alabama, as has been observed for Guadalupe bass *Micropterus treculi* in Texas (Morizot et al. 1991). Thus, the possible mechanisms of spotted bass-shoal bass relations must be examined to determine the nature of the threat posed by spotted bass to shoal bass and guide future conservation efforts.

Shoal bass are a popular game fish in many river systems in Georgia (J. Evans, GDNR, personal communication), and are supported by a supplemental stocking program in some river sections where natural recruitment has been chronically low (R. Weller, GDNR, personal communication). These stocking programs have generally been very successful, with the contribution of stocked fish to the year class approaching 50% in some years. Alabama Department of Wildlife and Freshwater Fisheries (ADWFF) has become interested in using supplemental stocking as a method to restore shoal bass to some areas where populations are currently low or nonexistent (S. Rider, ADWFF, personal communication). Many factors can affect the efficacy of supplemental stocking programs, such as stocking procedures, predation, and natural year-class strength (Isermann et al. 2002). Thus, evaluation of any stocking program of shoal bass is required to assess its success and cost-effectiveness.

The objectives of this study were to 1) determine habitat use of shoal bass, spotted bass, and largemouth bass in selected Chattahoochee River tributaries in Alabama, and to describe species composition of the black bass community below selected Chattahoochee River dams between West Point Dam and Columbus, Georgia, 2) evaluate contribution of stocked shoal bass to year-class strength of the species in selected Alabama streams, 3) examine possible competition of spotted bass and shoal bass in a laboratory environment, and 4) examine the genetics of black bass in selected Chattahoochee River tributaries in Alabama and Georgia, as well as in the mainstem Chattahoochee River in selected unimpounded reaches between West Point Dam and Columbus, Georgia. This report covers the first three objectives of this study; Objective 4 will be presented in a separate report by University of Alabama biologists. Specific fish sent to University of Alabama for genetic analyses are listed in the Appendix.

CHAPTER ONE

Habitat Associations and Population Characteristics of Black Bass Collected in Four Alabama Streams and Selected Tailwaters of Chattahoochee River Dams

ABSTRACT

Fish and habitat surveys were conducted from selected reaches of Osanippa, Halawakee, Wacoochee, and Little Uchee creeks, Alabama, to examine the black bass community present in each stream and to evaluate habitat associations for each species. In addition, samples of the black bass community were collected below Langdale, Riverview, Bartletts Ferry, Goat Rock, Oliver, North Highlands, and Eagle Phenix dams on the Chattahoochee River. Most reaches of Alabama streams and areas below dams in the Chattahoochee River were dominated by non-native spotted bass. Shoal bass only dominated the black bass community in the Moffits Mill shoal of Little Uchee Creek. Only two unstocked shoal bass were collected in the other three streams. Catch rates of all three black bass species were highest in shoal habitat, indicating that these habitats constitute important areas for black bass in these streams. The relatively scarcity of large shoal complexes in these Alabama streams may increase the likelihood of competitive interactions among black bass, especially between the introduced spotted bass and the native shoal bass. The last known Alabama shoal bass population at the Moffits Mill shoal on Little Uchee Creek exhibited some signs of recovery in fall 2008, but many of these fish were lost downstream due to high water flows in the spring 2009. As of May 2009, this population had not recovered from the droughts of previous years and its persistence remains in jeopardy. Shoal bass populations were found below all dams on the Chattahoochee River except Bartletts Ferry; however, most populations were characterized by low abundance and showed evidence of poor recruitment. The overall effect of dams in the Chattahoochee River may have been to reduce a continuous metapopulation of shoal bass into a series of isolated populations of limited genetic diversity and low effective population size, with an increased likelihood of extinction. Results from this study confirm that Alabama populations of shoal bass remain in great danger of extinction. These populations can likely only be recovered with rapid and decisive management actions. Until some recovery of other Alabama populations are observed, the last remaining population of wild shoal bass in Alabama at Moffits Mill shoal must be protected at all costs. If drastic actions are not taken rapidly, it is only a matter of time before wild shoal bass are gone from Alabama's waterways.

INTRODUCTION

Collectively, black bass *Micropterus* spp. constitute one of the most popular and economically important freshwater fisheries in North America. In 2006, an estimated 10 million anglers spent 161 million days fishing for black bass in the U.S., representing approximately 40% of all anglers and angling effort in freshwater other than the Great Lakes (FWS and USBOC 2008). Although the majority of this effort was likely directed towards largemouth bass *M. salmoides* and smallmouth bass *M. dolomieu*, popularity of some of the less-widespread black bass has increased, possibly in response to higher rates of user competition that has been observed to alter angler behavior in some southeastern U.S. reservoirs (Yow et al. 2008). As a consequence, the importance of these fisheries continues to increase over time; however, little is known about the biology of these black bass species, which may hinder efforts to manage them.

Shoal bass *Micropterus cataractae* is a species endemic to the Apalachicola drainage and, in Alabama, is found only in the Chattahoochee River drainage. Although shoal bass are one of the most recently described black bass species (Williams and Burgess 1999), very little information exists on the biology of this species. However, shoal bass are thought to be declining in abundance in many localities within its native range (Williams and Burgess 1999; Boschung and Mayden 2004). Shoal bass are habitat specialists, generally found in shallow, rocky riffles and shoals in medium- to large-sized streams and rivers and are intolerant of reservoir conditions (Wheeler and Allen 2003; Boschung and Mayden 2004).

In Alabama, shoal bass were historically found in only a few Chattahoochee River tributaries, mostly located above the Fall Line (Boshung and Mayden 2004). Extensive surveys conducted by Auburn University in 2005-2006 on four of these Alabama streams found only one viable population of shoal bass, in the Moffits Mill section of Little Uchee Creek in Lee County (Stormer and Maceina 2008). Only ten shoal bass were collected outside that population during the two-year survey. Also, a severe drought in 2006 appeared to have drastically reduced the shoal bass population at Moffits Mill (Stormer and Maceina 2008). Alabama shoal bass populations have likely suffered large declines in abundance over the last 30 years, and the future persistence of this species in Alabama is in jeopardy. Furthermore, extensive impounding of the Chattahoochee River has resulted in a few disjunct relict populations of shoal bass remaining in the main river channel, isolated by large pools of relatively standing water. Many of the Alabama streams that formerly held shoal bass populations now flow into these impoundments; whereas, they formerly flowed into the Fall Line area of the Chattahoochee River. Thus, shoal bass populations in the entire Chattahoochee River basin below West Point Dam appear to be at risk of extirpation.

Habitat use of black bass in lotic systems is poorly understood, and this is especially true of shoal bass. Largemouth bass and shoal bass are not commonly found in the same habitat in streams. While shoal bass are commonly found in shallow riffle areas and fast current, largemouth bass more typically occur in pools and slower runs (Hurst 1969; Wheeler and Allen 2003). However, shoal bass have been commonly collected in run and even pool habitats (J. Evans, Georgia Department of Natural Resources [GDNR], and C. Paxton, Florida Wildlife Commission, personal communications). Unlike the native congeneric largemouth bass, spotted bass commonly use habitats similar to shoal bass, including both woody and rocky cover found near areas of higher current velocity (Hurst et al. 1975; Layher et al. 1987; Tillma et al. 1998). In Alabama, many streams in which shoal bass been collected historically now appear to be dominated by spotted bass (Stormer and Maceina 2008), thus there is a need to better delineate habitats used by the three black bass species found in these Chattahoochee River tributaries.

The objectives of this portion of this study were to 1) determine habitat selection and use of shoal bass, spotted bass, and largemouth bass in selected Chattahoochee River tributaries in Alabama, and 2) to describe species composition of the black bass community below selected Chattahoochee River dams between West Point Dam and Columbus, Georgia, henceforth referred to the Middle Chattahoochee Area (MCA).

Study Areas

This study was conducted in selected reaches of Osanippa, Halawakee, Wacoochee, and Little Uchee creeks (Figure 1-1) where shoal bass have been found during previous surveys (Hurst et al. 1975; Maceina and Stormer 2008), or in areas where shoal bass were stocked for another portion of this study (Chapter 2). In addition, samples of the black bass community were collected below Langdale, Riverview, Bartletts Ferry, Goat Rock, Oliver, North Highlands, and Eagle Phenix dams on the Chattahoochee River (Figure 1-1).

METHODS

Selected reaches of streams were sampled for habitat and black bass. Each reach was approximately 40 mean stream widths (MSW) long; MSW was determined by measuring bankfull stream width at 5-8 transects along the reach (Tillma et al. 1998). Habitat use of each black bass species collected in streams were investigated by examination of relative abundance of each species by mesohabitat (shoal, riffle, run, pool). Mesohabitat units within each sampling station were determined by habitat measurements taken along transects placed approximately every 2 MSW apart along the entire length of the station (Simonson et al. 1994). Percent instream woody cover and rocky substrate were estimated for each mesohabitat. Stream width (bankfull and current [wetted] flow), water depth and velocity, substrate characteristics (% sand, gravel, cobble, boulder, bedrock), were measured along each transect. Water depth, velocity, and substrate particle size were measured at five equidistant points along each transect; velocity was measured at 0.6 times the depth if depth was < 0.75 m, otherwise, it was measured at 0.2 and 0.8 times depth and averaged (Tillma et al. 1998). Substrate particle size was classified according to a modified Wentworth scale (Cummins 1962). Black bass were sampled from each mesohabitat within the sampled reach using a Smith Root backpack electrofisher. All black bass collected were identified, measured (total length [TL]), and weighed (g).

Black bass catch per effort (CPE; number/h) was compared to the measured habitat features to assess habitat use of each species (Layher et al. 1987; Tillma et al. 1998). Multiple regression analysis was used to assess relationships among stream habitat data and black bass catch rate in each stream reach and across all stream reaches (Maceina 1992), using a generalized regression model:

$$\text{Black Bass CPE} = b_o \pm b_1(\text{HABITAT}_1) \pm b_2(\text{HABITAT}_2)... \pm b_i(\text{HABITAT}_i)$$

where b_o, b_1, b_2, and b_i were the regression coefficients for the intercept and slope coefficients, and HABITAT was either a single or multiple measures of habitat. In each case, the candidate models were chosen based on Akaike's Information Criteria (AIC) and Mallows' (1973) Cp statistic (Burnham and Anderson 2002; SAS Institute 2004). Variance Inflation and Condition indices were used to choose the best model from among the candidate models, defined as the model that explained the greatest amount of variation in black bass CPE with the fewest number of independent variables. Significance for these models was set at $P \leq 0.05$.

Relations among habitat variables and among black bass CPE were assessed using Pearson correlations (SAS Institute 2004). Differences in mean bank-full width, depth, and velocity among mesohabitats were examined in each stream and across all four streams using a Generalized Linear Model (SAS Institute 2004). Similarly, relations among black bass CPE across all streams were examined with Pearson correlations, and differences in black bass CPE was examined among mesohabitats across all streams using a Generalized Linear Model. Due to relatively low power expected due to low sample sizes, significance for these tests was set at $P \leq 0.10$.

Population size of shoal bass > 150 mm TL was estimated at the Moffits Mill shoal complex in the spring of 2009 using a Lincoln-Peterson mark-recapture model with the Chapman modification (Ricker 1975). The entire shoal was sampled using a Smith Root backpack electrofisher, shoal bass > 150 mm TL were tagged with a Passive Integrated Responder (PIT) tag and released. One week later the shoal was sampled again using similar techniques and all shoal bass were examined for a PIT tag. Population estimates were calculated with 90% confidence intervals using the software package Ecological Methodology (Krebs 2003), and compared to previous estimates of this population calculated in a previous study (Stormer and Maceina 2008) to assess relative abundance of shoal bass at Moffits Mill through time.

Black bass were sampled below selected dams on the Chattahoochee River to examine species composition and size structure. Fish were sampled using a boom-mounted electrofishing boat for one hour of pedal time below each dam. During sampling, the boat was maneuvered so that all cover, substrate, and flows present below the dam were sampled; however, preference was given to areas expected to hold shoal bass (e.g., rocky areas characterized by fast flows). All black bass were collected, measured (TL), weighed (g), and released. Species composition and size structure were compared among species and among dams to identify potential relict populations of shoal bass and recruitment patterns of each species.

RESULTS

A total of 237 largemouth bass, 117 shoal bass, and 430 spotted bass were collected during this study (Table 1-1); specific latitude and longitude coordinates for each sample area may be found in the Appendix. Spotted bass dominated the black bass community in Osanippa and lower Halawakee creeks; whereas, largemouth bass were the most commonly found black bass species in Halawakee Creek above the Beans Mill Dam (Table 1-1). Shoal bass only dominated the black bass community in the Moffits Mill shoal of Little Uchee Creek (Table 1-1). The majority of shoal bass collected in Osanippa, Halawakee, and Wacoochee creeks were stocked fish (Chapter 2); however, one wild fish was collected in the lower Halawakee Creek shoals and another in the Wacoochee Creek shoal areas in spring 2009.

Shoal bass were collected below all dams on the Chattahoochee River but Bartletts Ferry, but spotted bass composed the majority of each black bass sample (Table 1-1). Shoal bass populations below most Chattahoochee River dams appeared to be dominated by large adults (Figures 1-2, 1-3, and 1-4); however, shoal bass size distributions were more balanced below Langdale and Riverview dams (Figure 1-2). In contrast, length distributions of largemouth bass and spotted bass appeared to be well-balanced below all Chattahoochee River dams, with juveniles commonly collected (Figures 1-2, 1-3, and 1-4).

Habitat was measured in reaches of four Alabama streams: the Beans Mill area of Halawakee Creek, the Moffits Mill area of Little Uchee Creek, the area of Osanippa Creek adjoining property owned by Travis Carter, and the portion of Wacoochee Creek running through the Goat Rock Hunt Club. Mesohabitats visually delineated as shoal, run, riffle, or pool habitat exhibited differences in measured variables such as stream width, depth, and water flow. Specific habitat measurements taken in each mesohabitat in each streams may be found in the Appendix.

Habitat variables generally showed weak or no correlations among each other across all streams (Table 1-2). Visual estimates of percent woody debris and rock were inversely correlated, meaning that mesohabitats with high amounts of rock usually had less woody habitat and vice versa. However, percent woody debris was not correlated to any other habitat variable.

Percent rock habitat was weakly correlated to flow velocity and percent bedrock substrate, and inversely related to percent sand substrate (Table 1-2). Mesohabitats with wider stream widths tended to be less likely to contain cobble substrate and more likely to contain bedrock substrate. Not surprisingly, higher amounts of bedrock substrate were associated with less percentages of cobble, boulder, and sand substrates; whereas, percent boulder and sand substrates were positively correlated. However, no other correlations were detected among substrate measurements.

In the Beans Mill area of Halawakee Creek, shoal habitats were characterized by wider bank-full stream widths and faster water flows than the other mesohabitats; but shoal and pool habitats were deeper than riffle and run habitats (Figure 1-5). Substrate of shoal habitats was entirely bedrock; whereas, substrate of the other three mesohabitats were dominated by cobble (Figure 1-6). Similarly, shoal habitats in the Travis Carter area of Osanippa Creek were characterized by wider stream widths and faster water flows than either run or pool habitats; however, unlike Halawakee Creek, shoal habitats were also shallower than other mesohabitats (Figure 1-7). No riffle habitats were found in the Travis Carter area of Osanippa Creek. Also, unlike Halawakee Creek, the majority of the substrate found in all three mesohabitats in Osanippa Creek were dominated by bedrock (Figure 1-8). However, similar to Halawakee Creek, shoal habitats consisted entirely of bedrock; whereas, substrates of the other two mesohabitats measured in Osanippa Creek contained boulder and sand substrates. Mesohabitats were more homogenous in the Goat Rock Hunt Club area of Wacoochee Creek, particularly shoal and run habitats; however, shoal habitats were shallower than the other habitats (Figure 1-9). Similar to the Travis Carter area of Osanippa Creek, no riffle mesohabitats were found in this section of Wacoochee Creek. Substrate of all three mesohabitats in this section of Wacoochee Creek were dominated by bedrock to an even greater degree than what was found in Osanippa Creek (Figure 1-10).

No riffle or pool habitats were found in the Moffits Mill area of Little Uchee Creek; however the patterns in habitat characteristics between the remaining two mesohabitat types were consistent with what was found in the other three streams. Shoal habitat in this section of Little Uchee Creek was characterized by wider stream widths, shallower depths, and faster current than was run habitats (Figure 1-11). Substrate of both mesohabitats was dominated by bedrock; however, bedrock composed a greater percentage of shoal habitat than run habitat (Figure 1-12).

Differences among habitat variables across all streams followed a similar pattern to that observed in each of the four streams. Shoal habitat was characterized by wider stream widths than the other mesohabitats (Figure 1-13). Riffle and shoal habitats had faster current velocities than the other habitats, and riffle habitat had the shallowest depths, followed by shoal and run habitats, with pool habitats characterized by the greatest depths (Figure 1-13). Shoal habitat was heavily dominated by bedrock substrate and riffle habitat consisted entirely of cobble across all streams; however, substrate composition of the other two mesohabitats was more variable (Figure 1-14). Run habitat was also dominated by bedrock substrate, but cobble was also common. In contrast, substrate in pool habitat was evenly apportioned among bedrock, cobble, and sand or boulders, likely due to specific differences among streams (Figure 1-14).

Catch rates of black bass were variable and not different among mesohabitats across all streams (Figure 1-15). However, high catch rates of all three species were observed in shoal habitats; whereas, only largemouth bass were collected in pool habitats and only spotted bass were collected in riffle habitats. All three species were collected in run habitats, but catch rates of shoal bass and spotted bass appeared to be lower in run habitats than other habitat types, while largemouth bass catch rates were similar and high in shoal and run habitats (Figure 1-15). However, catch rates were not different among species within any mesohabitat ($F \leq 1.05$; $P \geq 0.36$), likely due to the relatively low power of these analyses. Similarly, catch rates of black bass across all mesohabitat and stream combinations were not correlated with each other (Figure 1-16). Although there appeared to be a weak pattern of largemouth bass and spotted bass to be using different mesohabitats (i.e., high largemouth bass CPE and low spotted bass CPE and vice versa), no such pattern was evident between shoal bass and either of the other bass species (Figure 1-16).

Largemouth bass and spotted bass CPE was not correlated with any habitat measurement across mesohabitats; however, shoal bass CPE was correlated with water flow and percent boulder substrate (Table 1-3). Regression analyses found a few significant models predicting black bass catch rates from habitat variables, either for specific streams or across all streams. Percent boulder and percent bedrock substrate explained 87% of the variation in largemouth bass

CPE in Osanippa Creek; whereas, spotted bass CPE in Osanippa Creek was best explained by water flow (Table 1-4). Shoal bass had the greatest number of significant models explaining catch, and all but the model for Halawakee Creek indicated that higher flows were associated with higher CPE (Table 1-4). Over all streams, shoal bass CPE was best explained by high water flows and a greater percentage of boulder substrate.

Numerous shoal bass over a wide range of sizes were collected from the Moffits Mill shoal on Little Uchee during the habitat and fish surveys in fall 2008 (Figure 1-17). However, sampling of this area in spring 2009 found very few shoal bass present in the area (Figure 1-17), and the subsequent population estimate of shoal bass > 150 mm TL indicated that the population had not recovered from the 2007 levels (Figure 1-18).

DISCUSSION

Spotted bass continued to dominate the black bass community in virtually all Alabama tributary streams and lotic areas of the MCA. Prior to the introduction of spotted bass in the 1940s (William and Burgess 1999), largemouth bass and shoal bass were the only two black bass found in these systems. Largemouth bass were commonly collected from all areas we sampled, but wild, unstocked shoal bass shoal bass were rarely collected outside of the Moffits Mill shoal on Little Uchee Creek. Relict populations of shoal bass were found below most dams on the Chattahoochee River in the MCA; however, in general population abundance appeared to be low with inconsistent recruitment.

Other than stocked fish (Chapter 2), few shoal bass were collected in Halawakee Creek, Osanippa Creek, and Wacoochee Creek, confirming observations made in 2005-2006 by Stormer (2007). Although the present study was not designed to conduct a stream-wide survey for shoal bass, most of the sampling in these streams was conducted in habitats known to be used by shoal bass, especially juvenile fish (S.Sammons, unpublished data). Thus, the failure to collect more than a few wild shoal bass in these areas likely indicated that shoal bass have been virtually eliminated from these streams, and appears to have been replaced by non-native spotted bass. Shoal bass and spotted bass are known to use pool habitats during certain parts of the year

(Tillma et al. 1998; Wheeler and Allen 2003; Stormer and Maceina 2009), and thus some shoal bass may have been found in these refuges from our sampling effort. However, the lack of age-0 shoal bass, but not largemouth bass or spotted bass, in our samples offered further proof that shoal bass abundance was likely extremely low in these streams.

Habitat use was surprisingly similar among black bass species in these Alabama streams. Not surprisingly, catch rates of shoal bass were typically higher in areas with faster water flows and rocky substrate. Catch rates of the other two species were more variable, but, similar to shoal bass, were usually higher in shoal habitat. Obviously these areas are important habitat for black bass in these streams. Many of the fish collected were age-0 or juvenile fish, indicating that shoal habitat was an important spawning area for all three species, which has also been found in the Flint River, Georgia (M. Goclowski, Auburn University, unpublished data). Only largemouth bass were collected in pool habitat, which has been identified as preferred habitat for this species in lotic waters (Hurst 1969; Wheeler and Allen 2003). However, much of the deeper pool habitats found in these streams was unaccessible to the gear used during this study, and species abundance could not be estimated in these habitats.

Shoal habitat in these streams was typically found in areas of large elevation changes, where the stream transitioned from the Piedmont to the Coastal Plain physiographic provinces. These areas were characterized by wide stream widths, shallow water depths, fast water flows, and high proportions of rocky substrate. Because of their locations near or at the Fall Line of streams, abundance of shoal habitat in the MCA is necessarily low compared to their obvious importance to black bass populations. The fact that these habitats are in relatively short supply in these streams may increase the opportunities for black bass species to have negative interactions, compared to larger systems such as the Ocmulgee or Flint rivers in Georgia, where largemouth bass, spotted bass, and shoal bass apparently coexist peaceably (J. Evans, GDNR, personal communication).

Diet of largemouth bass, spotted bass, and shoal bass in rivers may be relatively similar, consisting of fish, aquatic insects, and crayfish (Vogele 1975; Scott and Angermeier 1998; Wheeler and Allen 2003). Wheeler and Allen (2003) found that diets of shoal bass and largemouth bass were relatively similar in the Chipola River, Florida. Hurst (1969) found little difference between diets of shoal bass and spotted bass in Halawakee Creek, Alabama, with both species feeding heavily on fishes and crayfishes. Diets of largemouth bass and shoal bass in the Flint River, Georgia, exhibited clear evidence of resource partitioning, with low occurrence of overlap between their diets (S. Sammons, unpublished data). However, diets of introduced spotted bass in the Flint River was more similar to shoal bass diets, with high diet overlap observed 50% of the time. Thus, shoal bass may not only compete with other black bass species for space but also food, if supplies are limiting.

The population of wild shoal bass at Moffits Mill shoal on Little Uchee Creek suffered a catastrophic decline during the drought of 2006-2007 (Stormer and Maceina 2008). Our results indicated that this population had begun to recover in the fall 2008, with 34 fish collected representing at least 3 age groups. However, by the following spring, the population of fish > 150 mm TL had fallen to 2007 levels. High stream discharge resulting from storm events in March 2009 may have contributed to this loss of fish. Downstream of this area is a natural barrier, a vertical 3- to 5-m drop that inhibits fish upstream fish movement at most water levels (Stormer 2007). Flows on the Uchee Creek gauge (USGS gauge 02342500, http://waterdata.usgs.gov/nwis/nwisman/?site_no=02342500) reached 10,000 cfs in late March 2009, which was more than 10 times greater than mean daily flow for this stream during this time of year. Shoal bass have been found to move long distances in the Flint River, Georgia, particularly in the spring (S. Sammons, unpublished data), and thus this high-water event may have afforded these fish an opportunity to move downstream away from this shoal complex. Regardless of the reason, the last wild shoal bass population in Alabama remains at a dangerously low abundance and is vulnerable to further declines caused by outside disturbances such as land-use changes or increased angling pressure.

MANAGEMENT IMPLICATIONS

Human population has shown a dramatic increase in the southeastern U.S. over the last half of the 20th century, and these rates appear to be increasing even more in the 21st century. This population growth has resulted in rapid rates of development and associated land use changes, including increases in impermeable surfaces, which has been shown to greatly affect hydrology of streams in surrounding watersheds. In the Halawakee and Osanippa creek watersheds, Johnston and Maceina (2009) documented a change in land use over the same 30-year period in which shoal bass disappeared from these systems. In both cases, the natural pine-hardwood forest cover declined 32-51% while pine mono-culture increased more than three-fold. While this study revealed little change in urban or residential uses, many new homes have been constructed along Halawakee Creek since the last land-use survey (2001) used in the Johnston and Maceina (2009) study, and land use continues to change rapidly in these watersheds. Associated with these land-use changes was a concomitant decrease in flows, which can be attributed to the 69% increase in the human population in the surrounding area over the same time frame (Johnston and Maceina 2009). Thus, changes in the land use in these watersheds may be decreasing the quality of shoal habitat available to black bass, by increasing runoff and siltation, as well as decreasing flows and increasing the deleterious effects of natural droughts. As quality habitat declines in these stream, the potential for displacement of the specialist shoal bass by the generalist spotted bass likewise increases.

Lotic fishes are often distributed across large spatial scales as metapopulations, defined simply as a set of local populations that undergo exchange of individuals (Hanski et al. 1995; Jager et al. 2001). Habitat specialists, such as shoal bass, are more likely to form a metapopulation structure across large spatial scales, since they commonly are found in and around shoal habitat. Thus, each shoal complex in a river may be thought of as a patch, separated from other patches by various lengths of non-preferred habitat (i.e., pools). Individual exchange among patches is likely mediated by migration patterns and distance between patches. Persistence of shoal bass populations in each patch is likely affected by the extent of migration exhibited by shoal bass individuals (Hanski et al. 1995). Within the same river, spatial dynamics of metapopulations may take the form of patchy-population dynamics among nearby patches; however, within a main channel-tributary system, where patches are farther apart, spatial dynamics may be more similar to a core-satellite model, where the main river populations are more stable (the core population), and tributary populations are more ephemeral (the satellite population) (Schlosser and Angermeier 1995). In these cases, the core population acts as a source for the satellite populations, replenishing their numbers when the populations are severely reduced by environmental disturbance such as droughts.

Fragmentation of riverine habitat by dams is a common, world-wide phenomena, and has been shown to adversely affect fishes, especially those with high migration rates (Jager et al. 2001). Construction of dams was rampant across the southeastern U.S. during the first half of the 20th century (Miranda 1996). Dam construction leads to river fragmentation and isolation of fish populations, and can reduce genetic diversity and recruitment of river fishes (Martinez et al. 1994; Jager et al 2001; Jaeger et al. 2005). In the early 20th century, large mainstem dams were constructed on the Chattahoochee River near the cities of Atlanta and Columbus, Georgia, further restricting fish movement and inundating shoal habitat (Dakin et al. 2007). Currently, shoal bass in much of the MCA exist in small isolated populations found immediately downstream of dams and in shoals of large tributaries. Since shoal bass do not tolerate impoundment (Williams and Burgess 1999), the tributary populations have been effectively cut off from mainstem shoal habitats by dams and reservoirs, and are likewise isolated. Lower migrations rates make local populations more vulnerable to environmental perturbations, leading to less stability and increase the likelihood of local extinctions (Hanski et al. 1995; Jager et al. 2001). The overall effect of dams in the Chattahoochee River may have been to reduce a continuous metapopulation of shoal bass into a series of isolated populations of limited genetic diversity and low effective population size, with an increased likelihood of extinction (Dakin et al. 2007).

Shoal bass in the Ocmulgee and Flint River systems in Georgia appear to spawn in large shoal complexes, often moving long distances to reach these habitats (S. Sammons, unpublished data). After spawning, some of these fish, particularly the larger individuals, leave the shoals and disperse throughout the river; however, many fish remain in shoal habitat for most of the year. In addition, Johnston and Kennon (2007) reported an ontogenetic shift in shoal bass habitat use in the Moffits Mill shoal in Little Uchee Creek, Alabama, with larval, juveniles, and adults using distinct microhabitats within shoals. Furthermore, these habitat associations changed in response to droughts, which has been commonly reported for other lotic fishes (Matthews and Marsh-Matthews 2003). Stormer and Maceina (2009) found that shoal bass in the Moffits Mill shoals continued to prefer run and eddy habitat as water levels decreased, even when these mesohabitats constituted less than 20% of available habitat. Shoal bass were only found using pool habitats in late summer and fall, when shoal habitats were virtually dewatered. Also, the shoal bass population suffered high mortality during that drought event, resulting in an 80% decline in population size (Stormer and Maceina 2008), and had not recovered as of spring 2009. Thus, shoal bass in tributary systems appear to be highly vulnerable to droughts and the resulting loss of connectivity to mainstem systems (Matthews and Marsh-Matthews 2003), which may be exacerbated by the presence of mainstem dams and impounding of historic shoal bass habitats (Dakin et al. 2007). It appears that shoal bass populations in the MCA are at a high risk of extirpation, which may have already taken place in at least three Alabama streams.

Results from this study confirm that the future of the Alabama populations of shoal bass remain in jeopardy. These populations can likely only be recovered with rapid and decisive management actions such as complete protection of riparian zones in these streams, active removal of introduced spotted bass, and continued stocking of shoal bass. We furthermore recommend that the last remaining population of wild shoal bass in Alabama at Moffits Mill shoal on Little Uchee Creek be protected from angling by immediate closure of this area to fishing until some recovery of shoal bass is observed in other streams. If drastic actions are not taken rapidly, it is only a matter of time before wild shoal bass are gone from Alabama's waterways.

Table 1-1. Number of black bass collected in Alabama streams and Chattahoochee River reaches during 2008-2009.

Stream/Area	Largemouth Bass	Shoal Bass	Spotted Bass
Halawakee/Upper	19	5	0
Halawakee/Mill Pond	28	0	0
Halawakee/Below Beans Mill	13	3	5
Halawakee/Lower	4	7	51
Little Uchee/Griffins Mill	7	0	0
Little Uchee/Moffits Mill	22	44	1
Osanippa/Travis Carter	3	4	21
Osanippa/Below Travis Carter	1	1	12
Wacoochee/Goat Rock Hunt Club	10	9	2
Chattahoochee River/Langdale	16	10	18
Chattahoochee River/Riverview	2	6	24
Chattahoochee River/Bartletts Ferry	35	0	70
Chattahoochee River/Goat Rock	42	7	90
Chattahoochee River/Oliver	13	5	97
Chattahoochee River/North Highlands	15	10	25
Chattahoochee River/Eagle Phenix	7	6	14

Table 1-2. Pearson correlation coefficients among habitat variables measured in four Alabama streams. Coefficients followed by a single asterisk were significant at P ≤ 0.10, those followed by a double asterisk were significant at P ≤ 0.01.

	% RK	BF WID	DEP	VEL	% COB	% BD	% SD	% BR
% WD	-0.54**	-0.13	0.08	-0.25	0.12	-0.02	0.26	-0.24
% RK	-	0.12	-0.23	0.36*	-0.07	-0.11	-0.70**	0.45**
BF WID	-	-	0.02	0.05	-0.44**	-0.16	0.04	0.40*
DEP	-	-	-	-0.43	-0.23	0.06	0.28	0.06
VEL	-	-	-	-	0.05	0.05	-0.29	0.07
% COB	-	-	-	-	-	-0.02	-0.02	-0.75**
% BD	-	-	-	-	-	-	0.40*	-0.51**
% SD	-	-	-	-	-	-	-	-0.56**

Table 1-3. Pearson correlation coefficients among black bass catch rates (fish/hr) and habitat variables measured in four Alabama streams. Coefficients followed by a single asterisk were significant at P ≤ 0.10, those followed by a double asterisk were significant at P ≤ 0.01.

	% WD	% RK	BF WID	DEP	VEL	% COB	% BD	% SD	% BR
LMB	0.10	-0.26	0.03	0.06	0.09	-0.19	0.11	0.05	0.11
SPB	-0.28	0.34	0.13	-0.23	0.17	-0.08	-0.19	-0.22	0.22
SHB	-0.19	0.16	0.05	-0.18	0.67**	-0.17	0.35*	-0.11	0.04

Table 1-4. Results of multiple regression analyses determining the relation of black bass catch per effort (CPE, Number/hr) to various measures of habitat for four Alabama streams. Only significant models are presented; the best model for each species and stream combination was chosen using AIC, BIC, variance inflation, and condition index criteria as described in the methods. PBD = percent boulder, PBR = percent bedrock, VEL = stream velocity.

Species	Stream	Equation	R^2 (P-value)
LMB	Osanippa	CPE = -3.56 + 0.16 (PBD) + 0.04 (PBR)	0.87 (< 0.01)
SPB	Osanippa	CPE = 1.23 + 141.19 (VEL)	0.37 (0.05)
SHB	Halawakee	CPE = 0.17 + 0.12 (PBR)	0.97 (< 0.01)
SHB	Osanippa	CPE = -0.06 + 26.52 (VEL)	0.36 (0.05)
SHB	Little Uchee	CPE = -1.86 + 110.72 (VEL)	0.95 (< 0.01)
SHB	All Streams	CPE = -1.31 + 46.04 (VEL) + 0.11 (PBD)	0.55 (< 0.01)

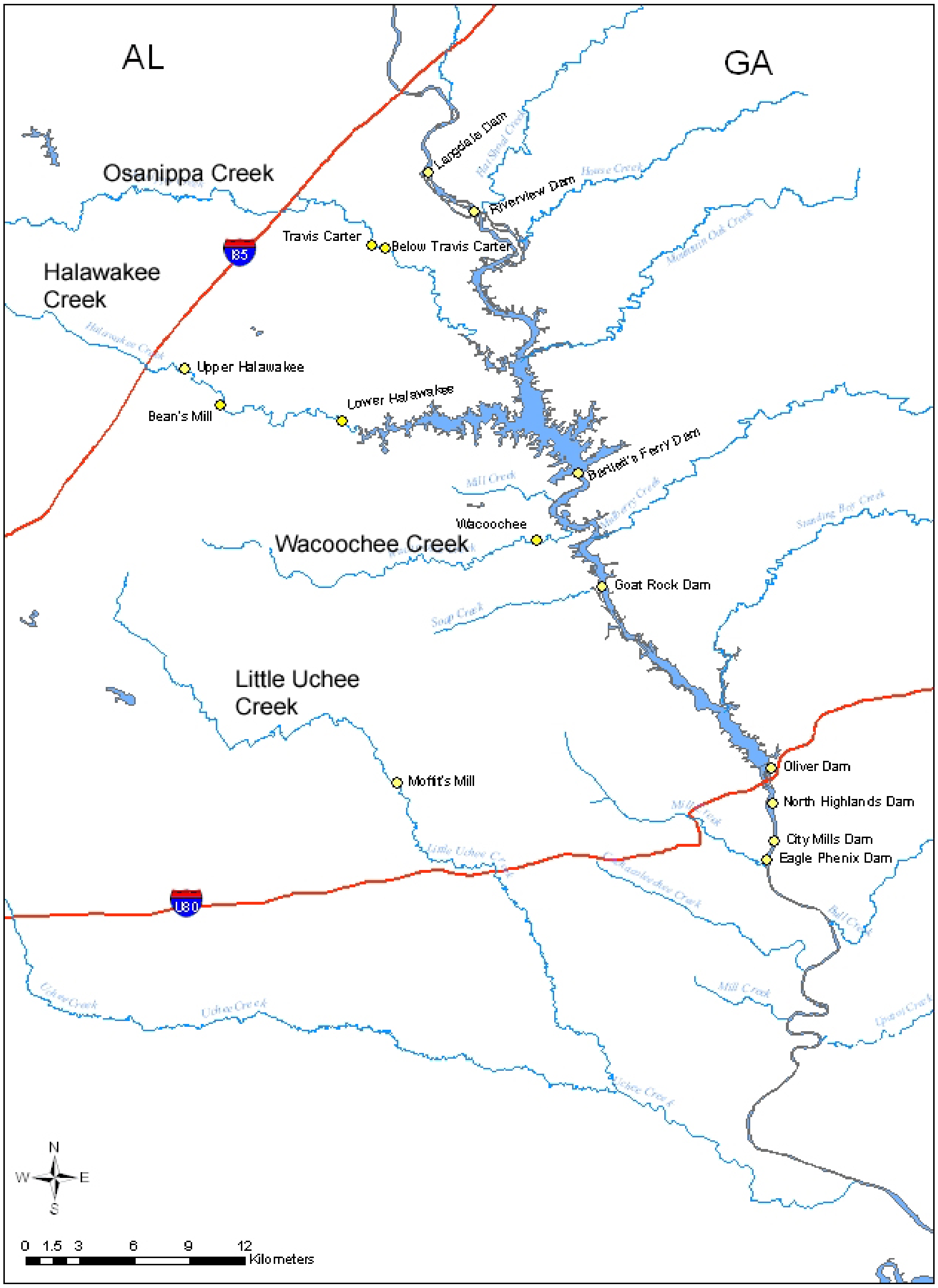

Figure 1-1. Study areas sampled for black bass and habitat during 2008-2009 in this study.

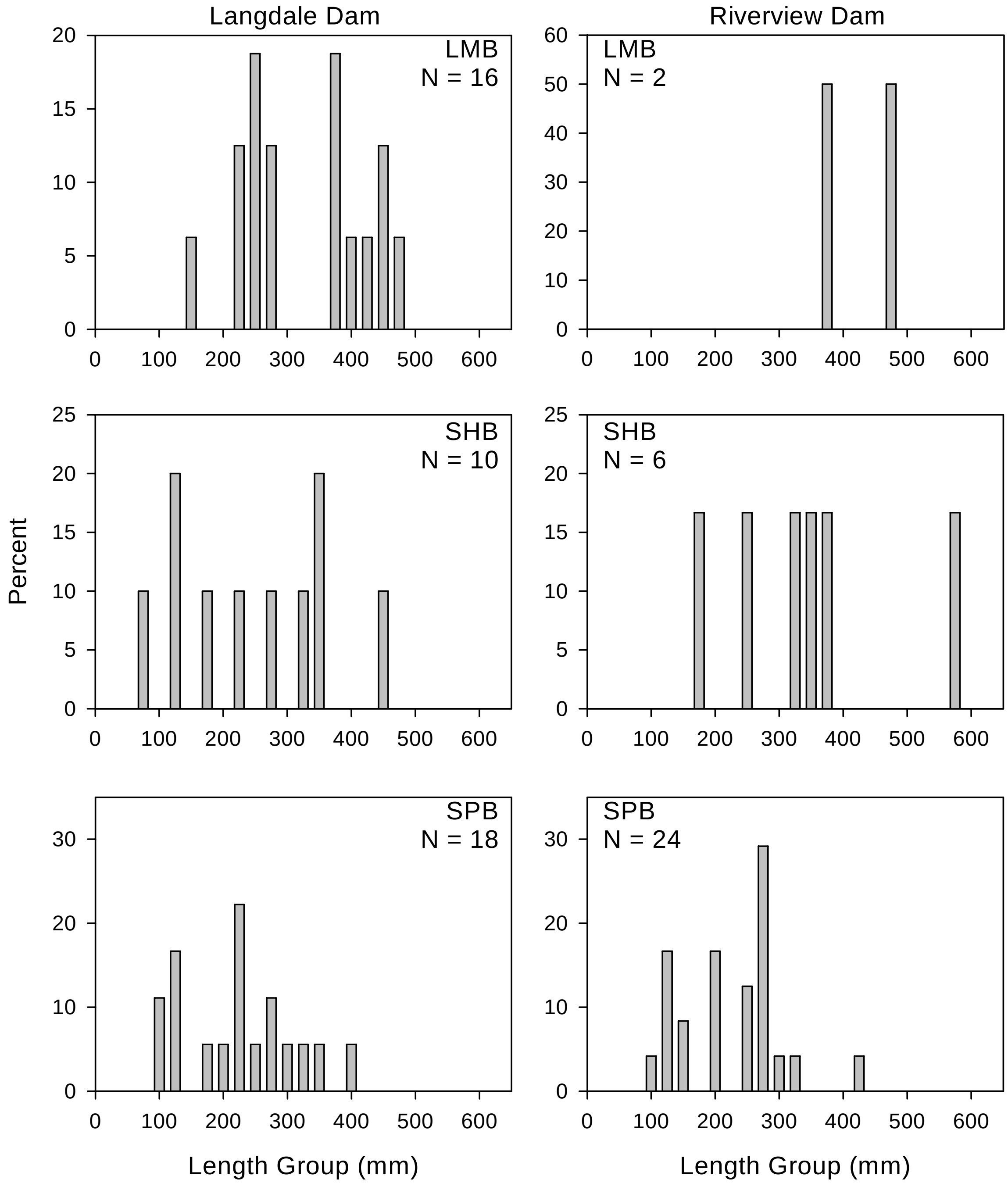

Figure 1-2. Length frequencies (25-mm length groups) of black bass collected below two dams on the Chattahoochee River during the summers of 2008 and 2009. Note the different y-axes among panels.

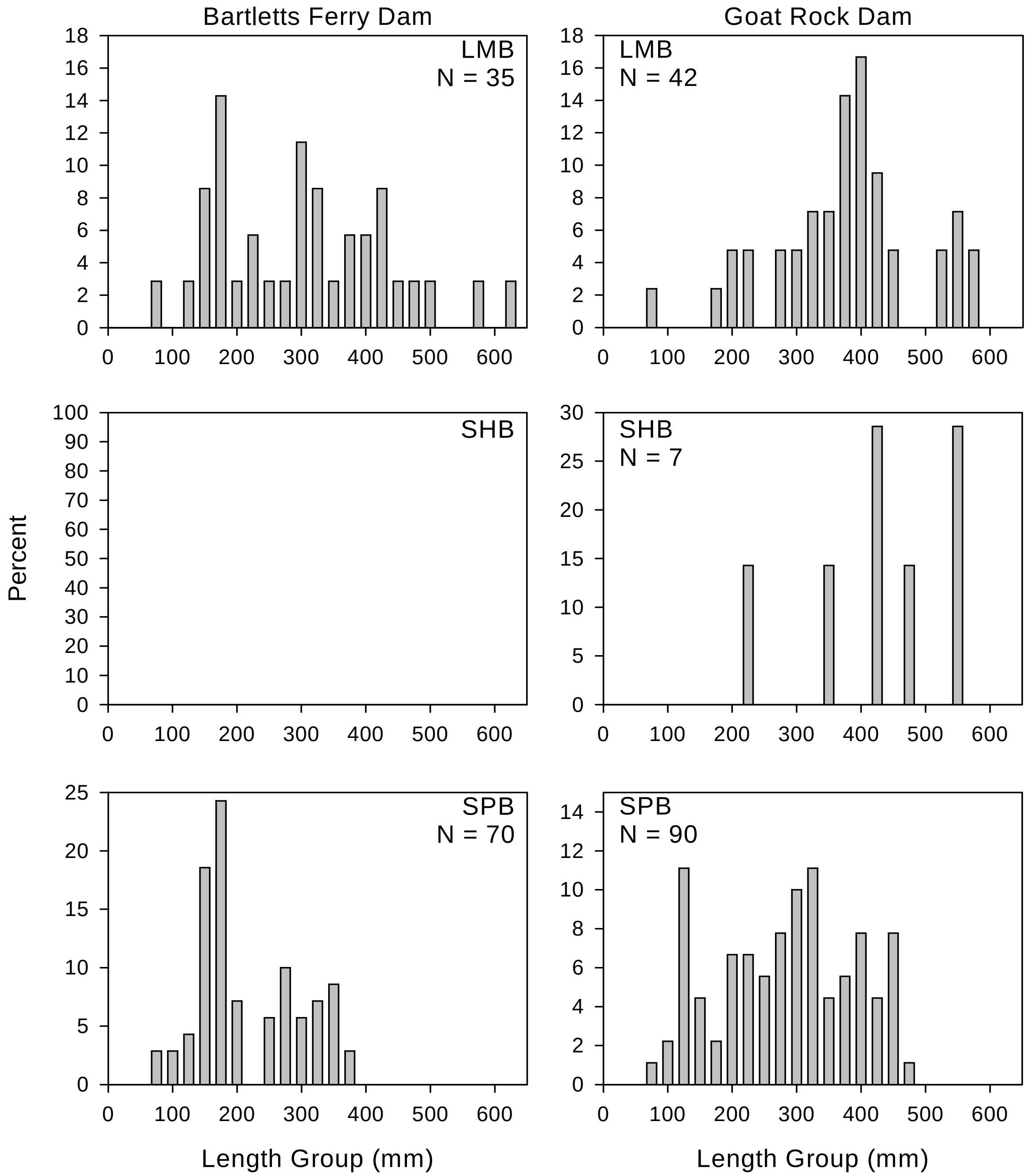

Figure 1-3. Length frequencies (25-mm length groups) of black bass collected below two dams on the Chattahoochee River during the summers of 2008 and 2009. No shoal bass were collected below Bartletts Ferry Dam in either year. Note the different y-axes among panels.

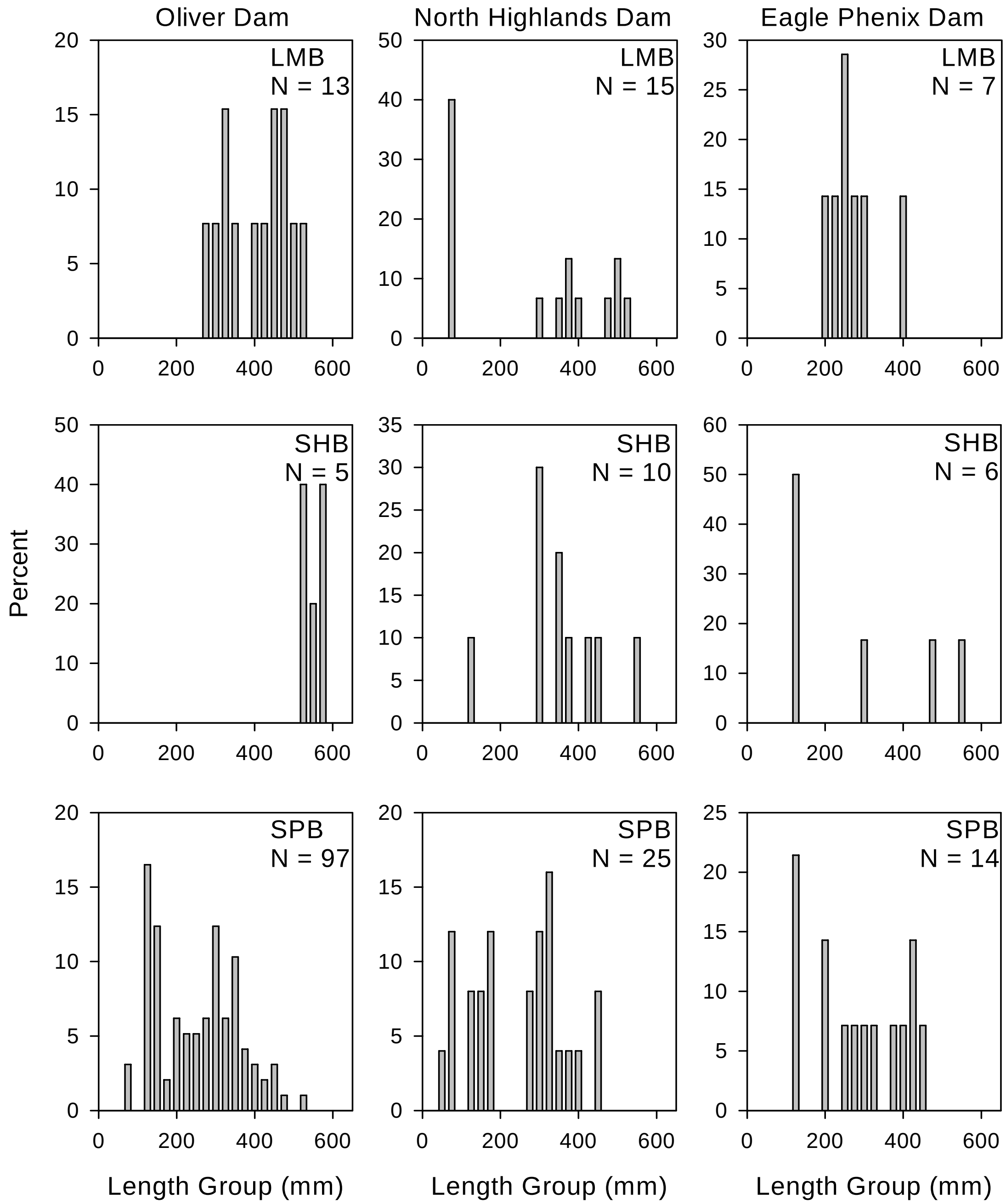

Figure 1-4. Length frequencies (25-mm length groups) of black bass collected below three dams on the Chattahoochee River during the summer of 2009. Note the different y-axes among panels.

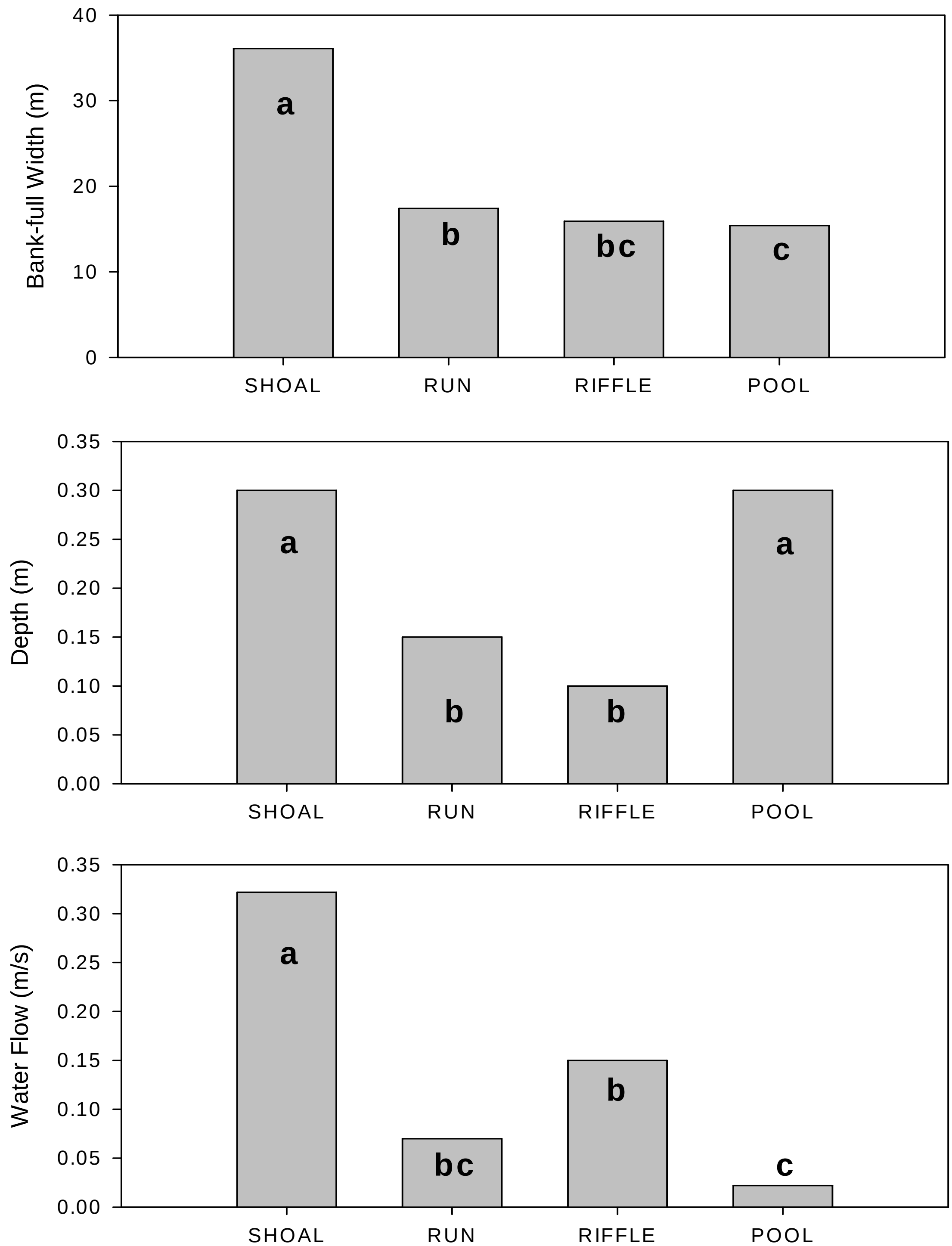

Figure 1-5. Mean habitat values measured across four mesohabitats from the Beans Mill area of Halawakee Creek, Alabama. Means with the same letter were not different among mesohabitats (Fisher's LSD Test; P > 0.10). Note different y-axes among panels.

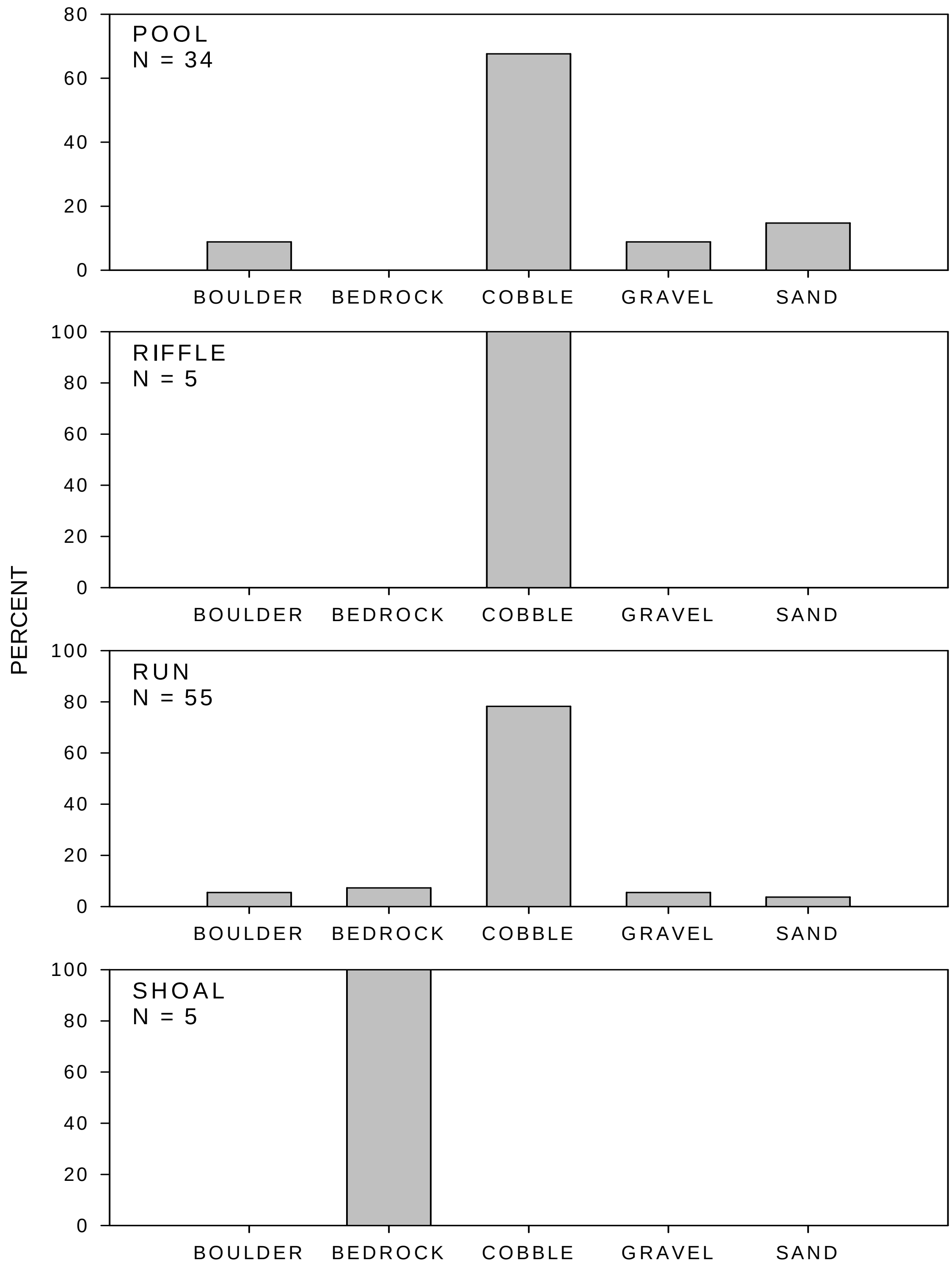

Figure 1-6. Substrate composition measured across four mesohabitats from the Beans Mill area of Halawakee Creek, Alabama. Note the different y-axes among panels.

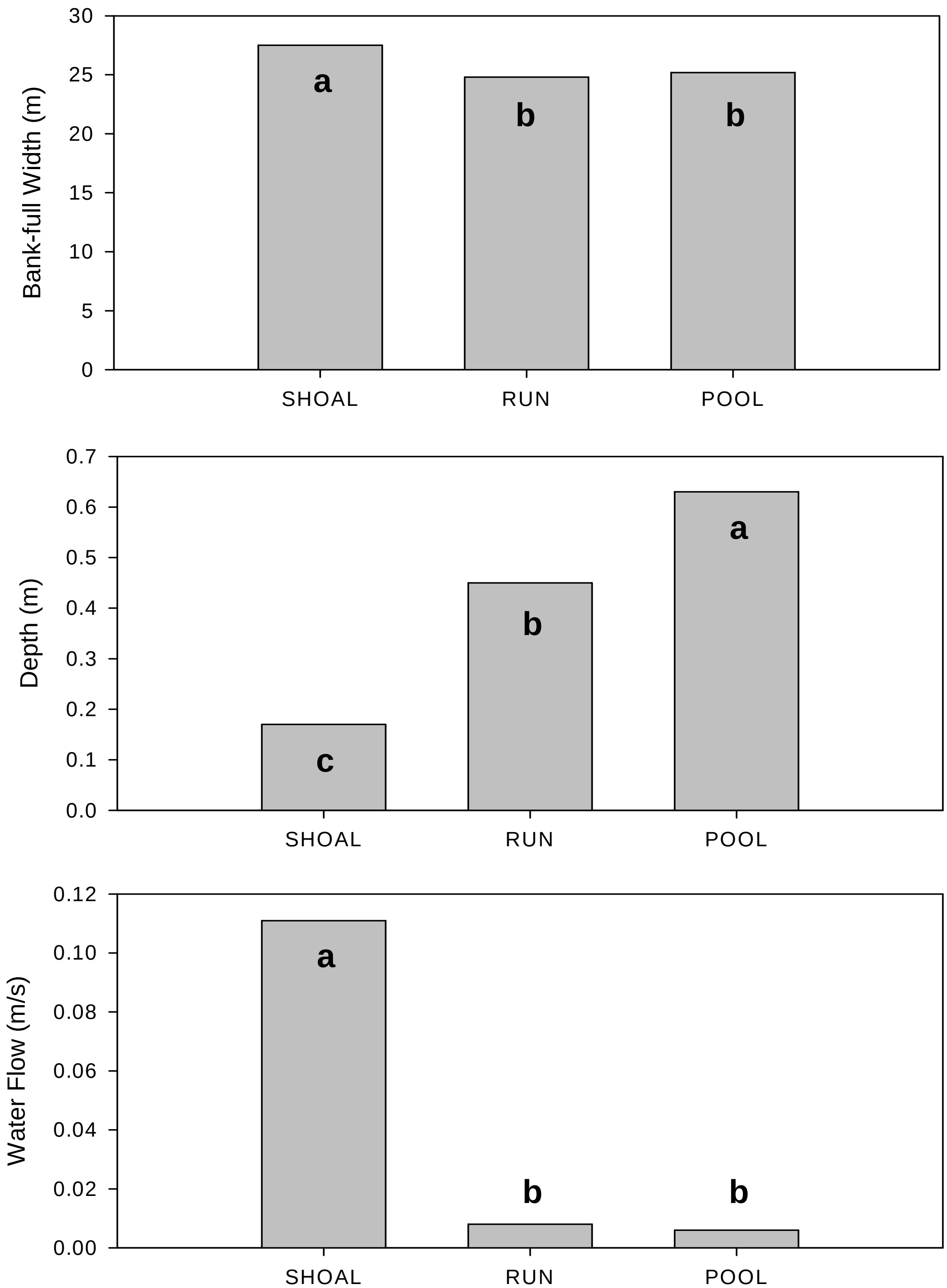

Figure 1-7. Mean habitat values measured across three mesohabitats from the Travis Carter area of Osanippa Creek, Alabama. Means with the same letter were not different among mesohabitats (Fisher's LSD Test; $P > 0.10$). Note different y-axes among panels.

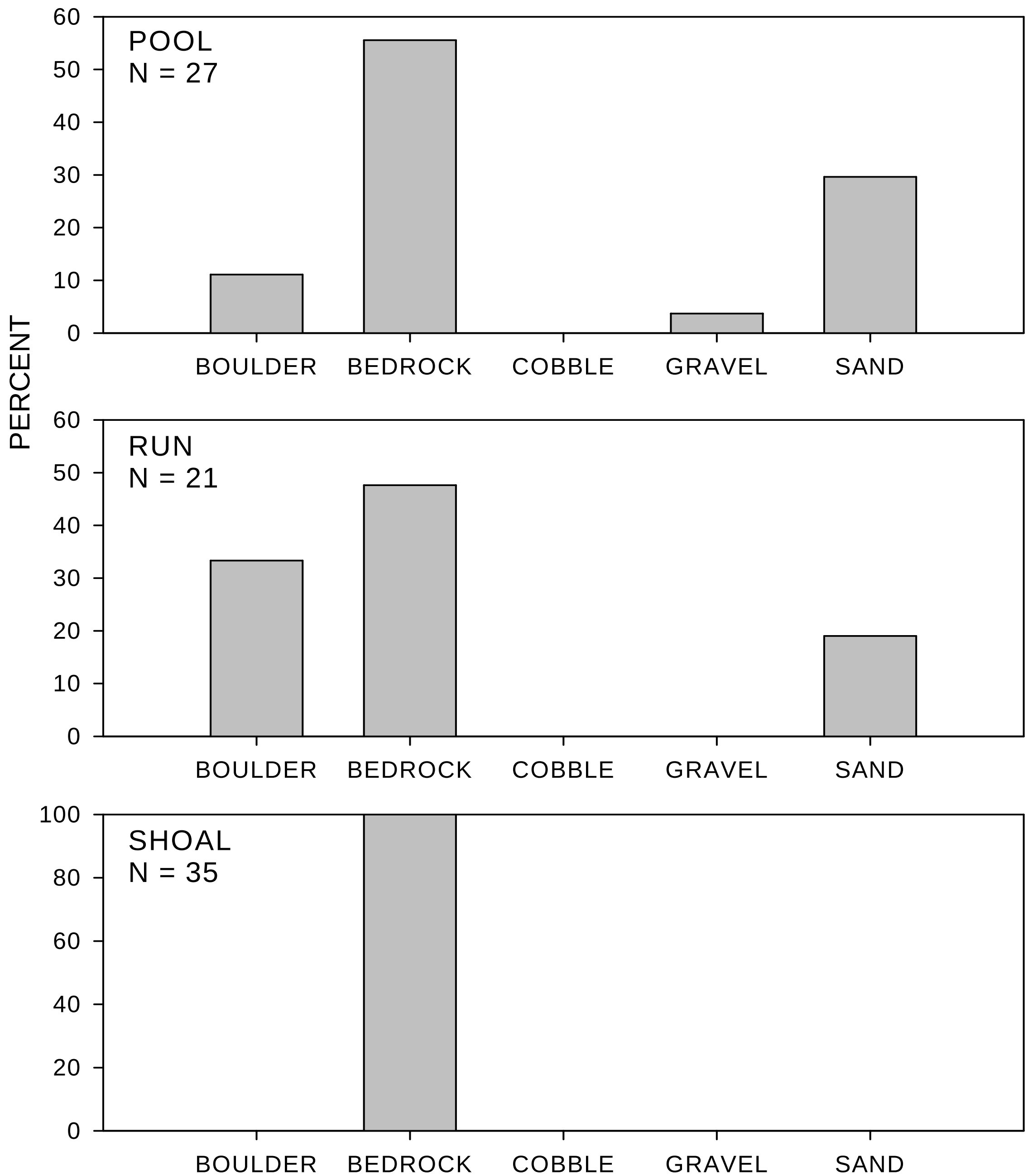

Figure 1-8. Substrate composition measured across three mesohabitats from the Travis Carter area of Osanippa Creek, Alabama. Note the different y-axes among panels.

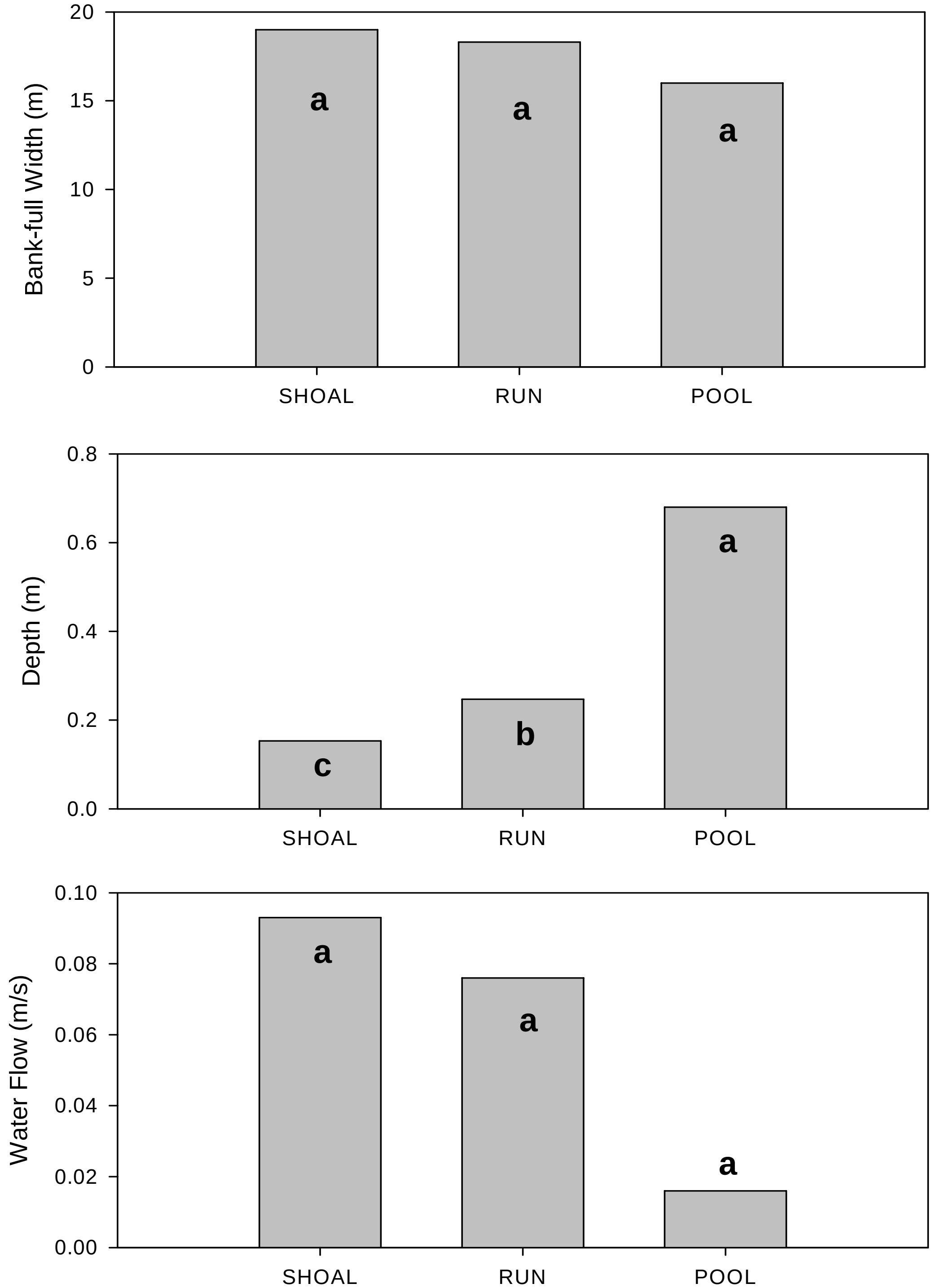

Figure 1-9. Mean habitat values measured across three mesohabitats from the Goat Rock Hunt Club area of Wacoochee Creek, Alabama. Means with the same letter were not different among mesohabitats (Fisher's LSD Test; $P > 0.10$). Note different y-axes among panels.

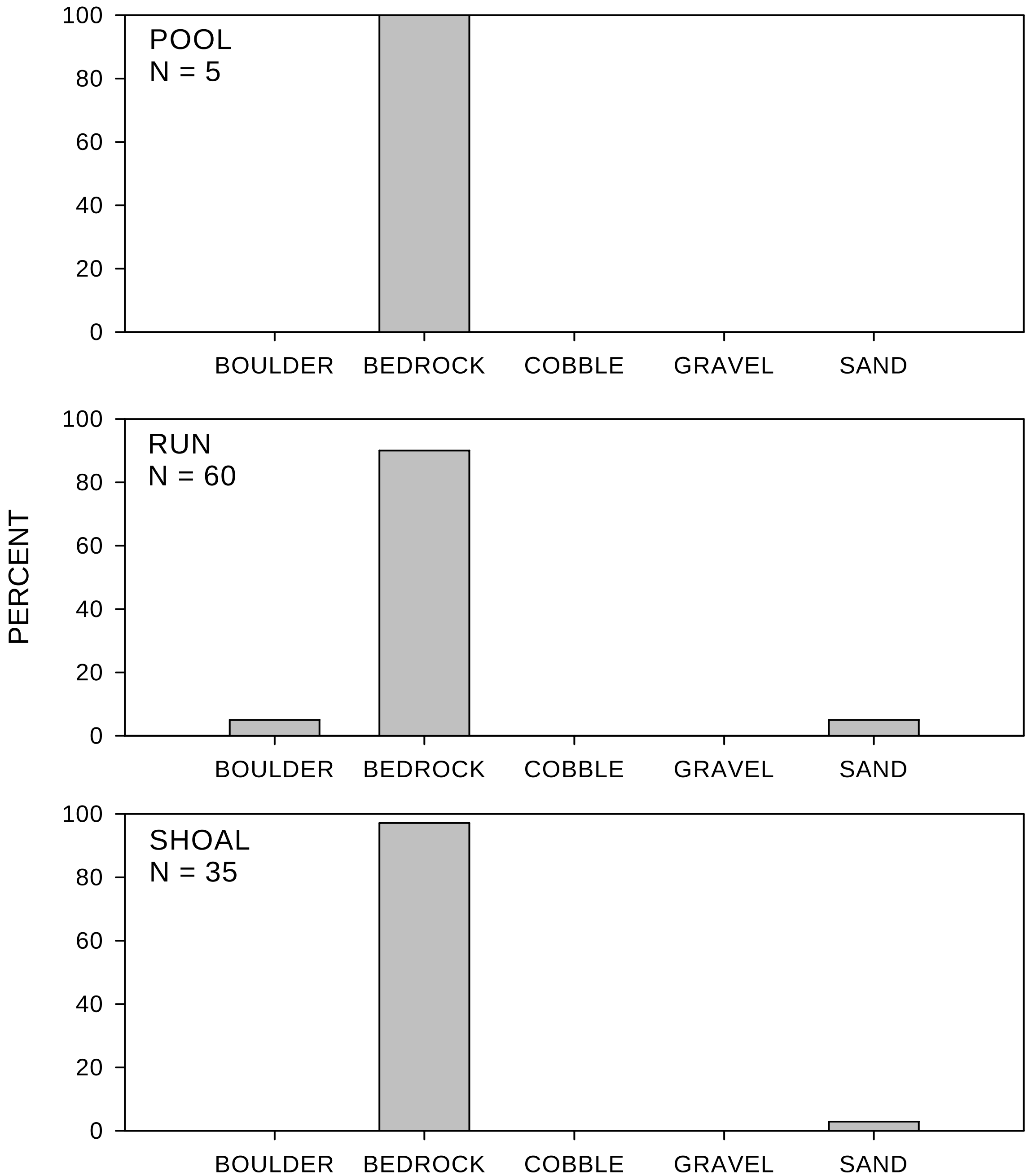

Figure 1-10. Substrate composition measured across three mesohabitats from the Goat Rock Hunt Club area of Wacoochee Creek, Alabama. Note the different y-axes among panels.

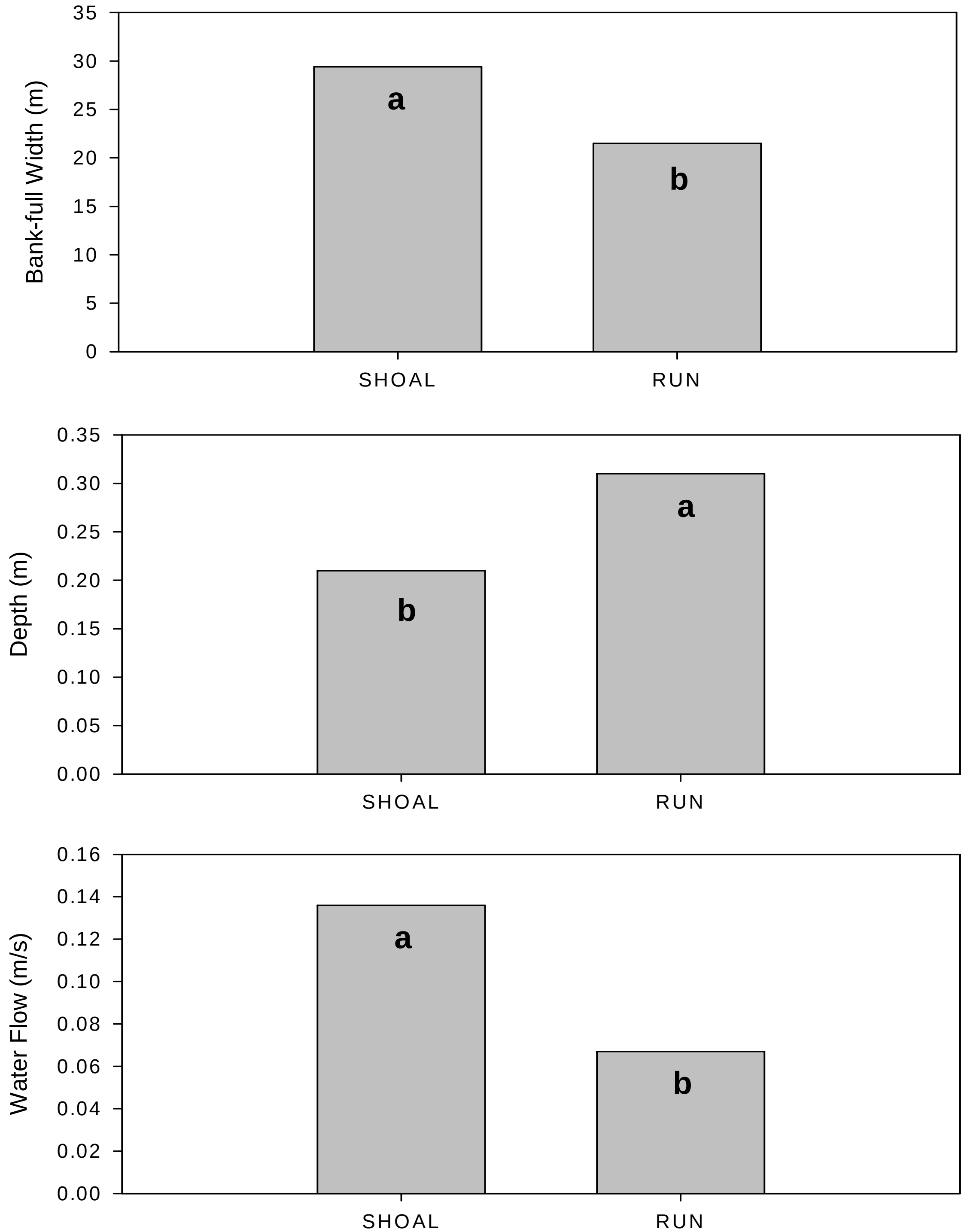

Figure 1-11. Mean habitat values measured across two mesohabitats from the Moffits Mill area of Little Uchee Creek, Alabama. Means with the same letter were not different among mesohabitats (Fisher's LSD Test; P > 0.10). Note different y-axes among panels.

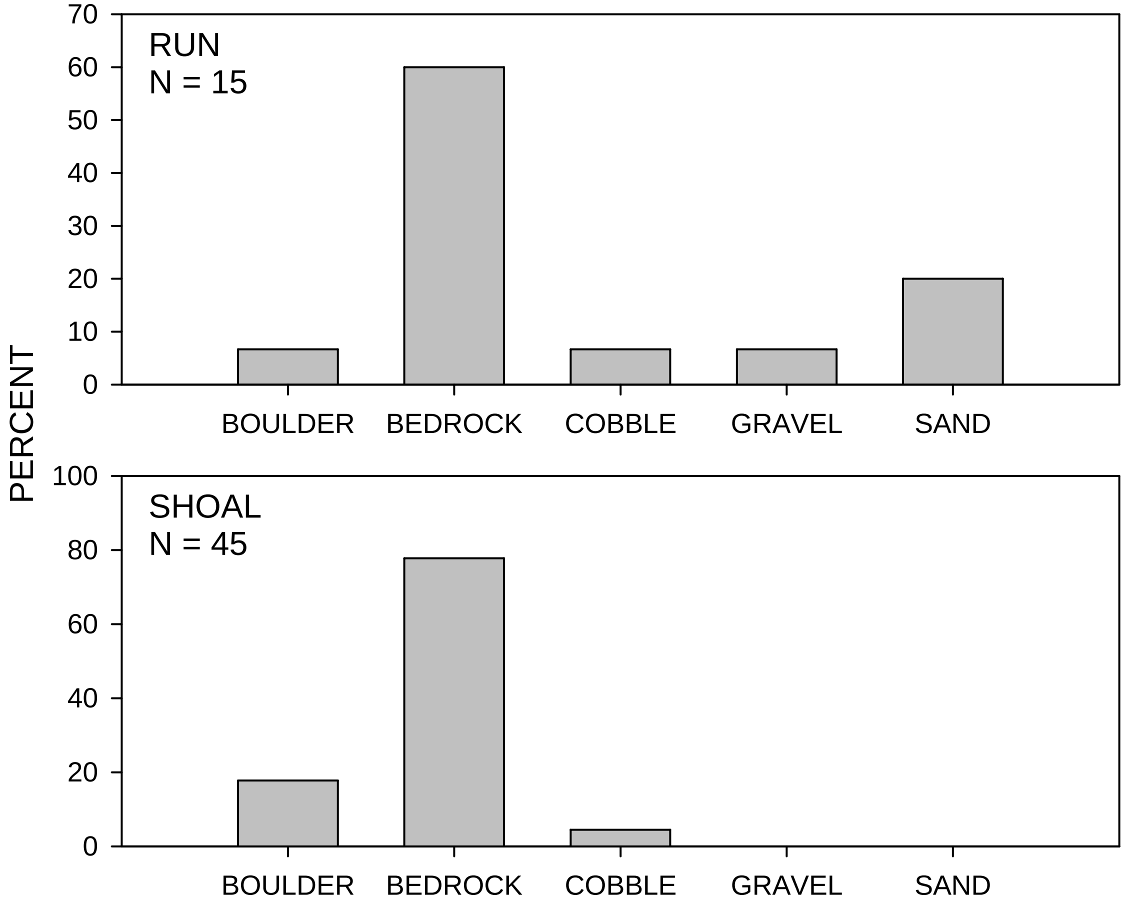

Figure 1-12. Substrate composition measured across two mesohabitats from the Moffits Mill area of Little Uchee Creek, Alabama. Note the different y-axes among panels.

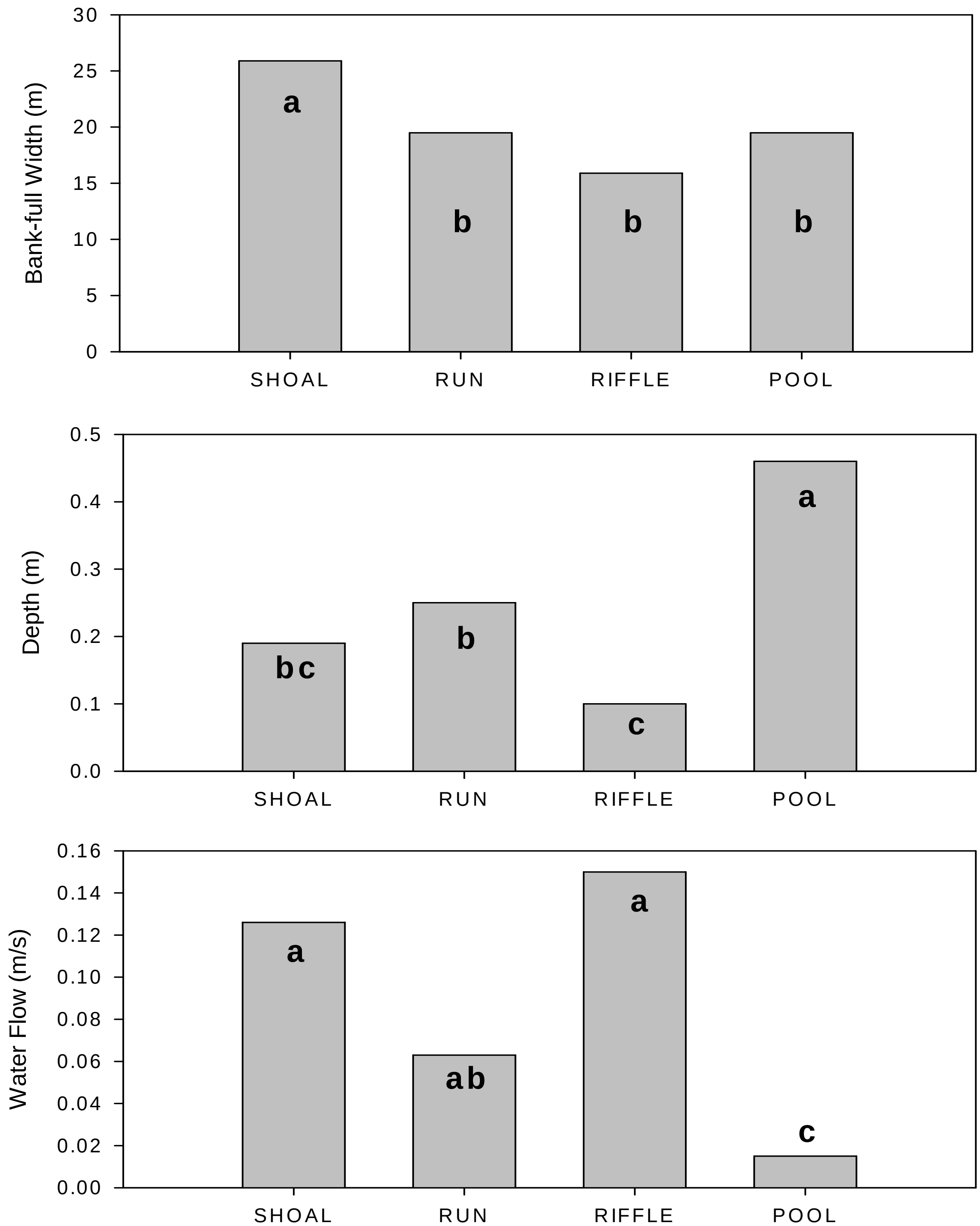

Figure 1-13. Mean habitat values measured across four mesohabitats from areas of four Alabama streams (342 observations). Means with the same letter were not different among mesohabitats (Fisher's LSD Test; P > 0.10). Note different y-axes among panels.

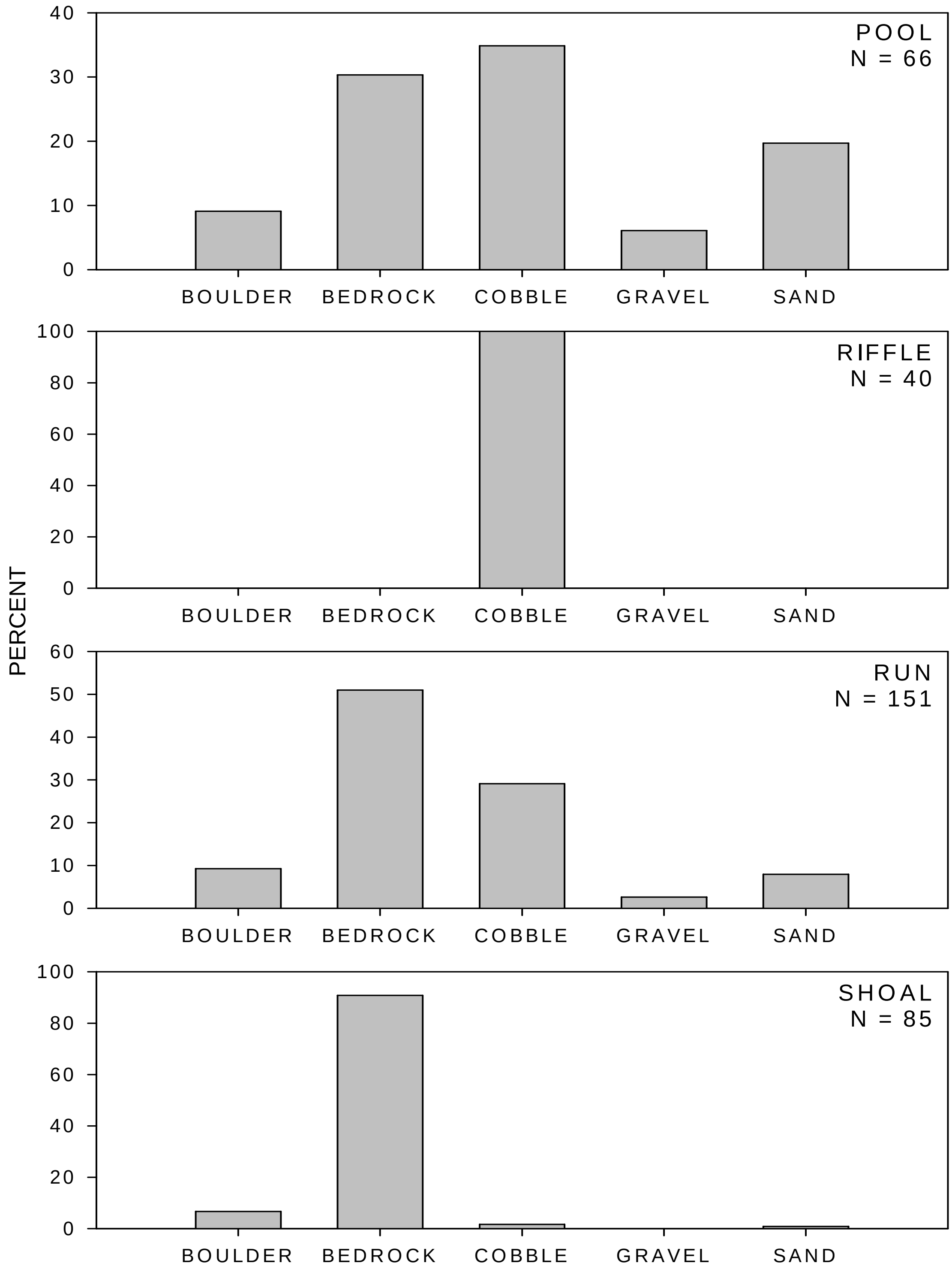

Figure 1-14. Substrate composition measured across four mesohabitats from areas of four Alabama streams. Note the different y-axes among panels.

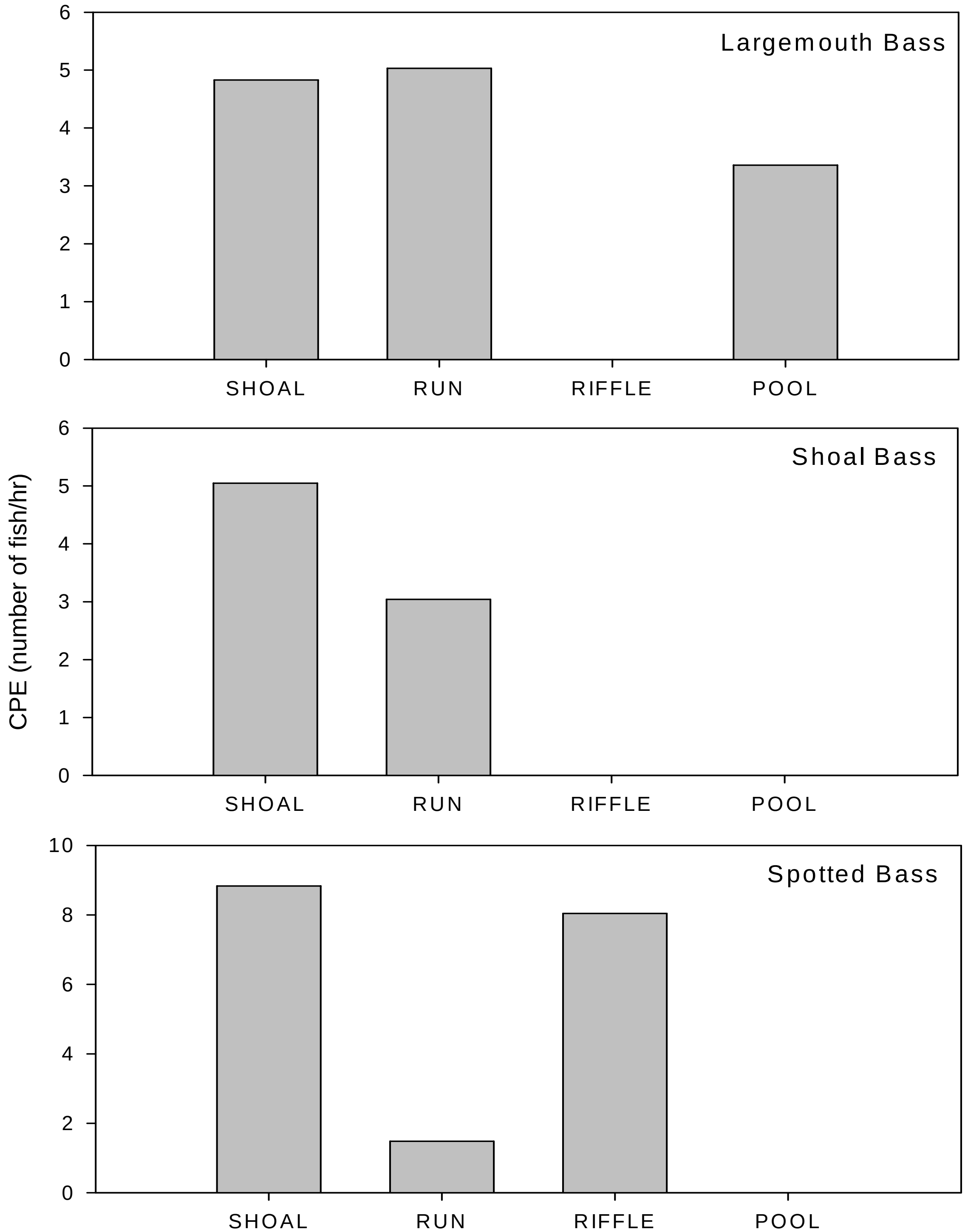

Figure 1-15. Mean catch-per-effort (CPE) of three species of black bass across four mesohabitats from areas of four Alabama streams. Catch was not different among mesohabitats for any species (Fisher's LSD Test; $P > 0.10$).

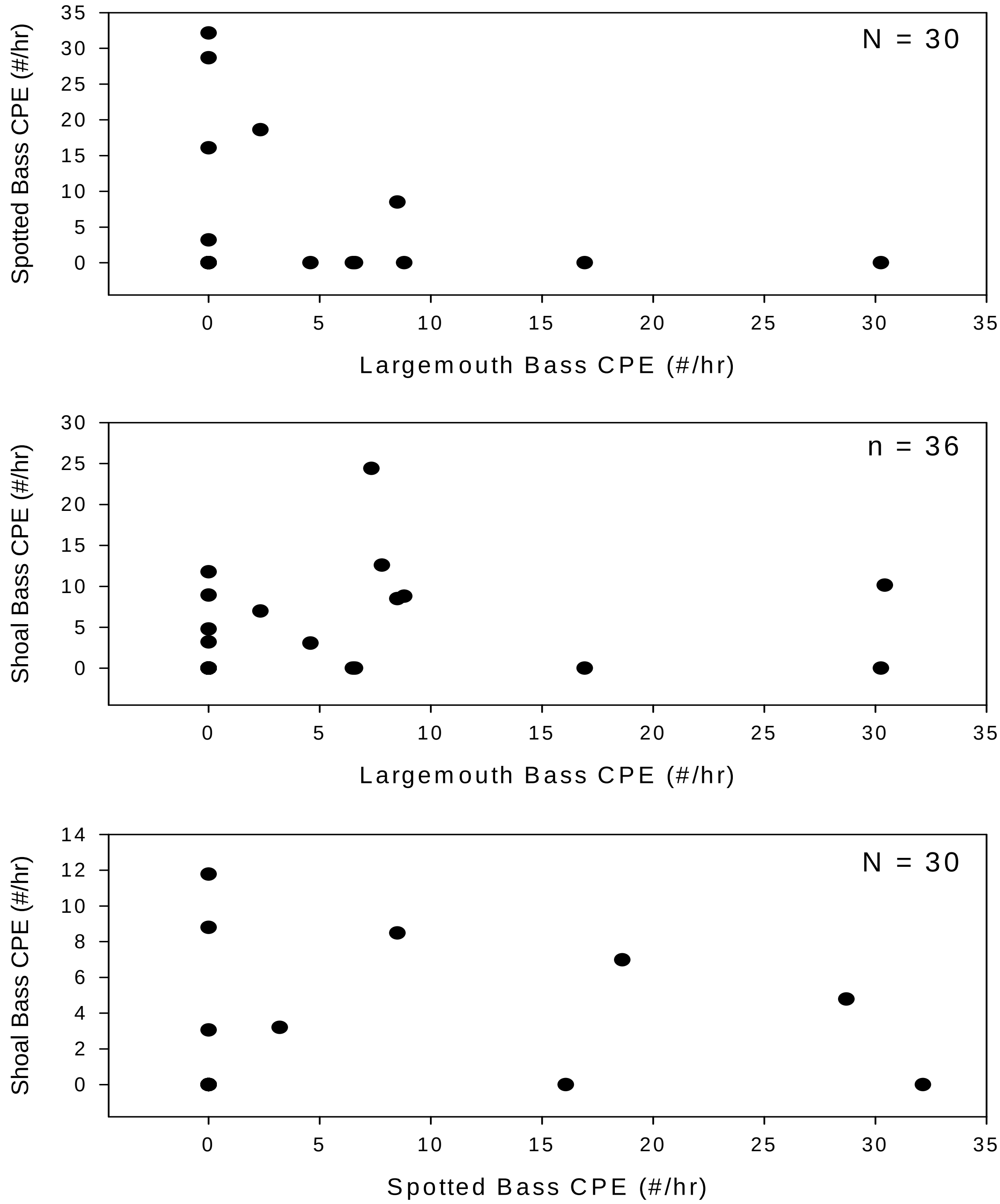

Figure 1-16. Correlations of catch per effort (CPE) of black bass collected across mesohabitats in four Alabama streams. No spotted bass were collected from Little Uchee Creek mesohabitats, thus the difference in sample size in top and bottom panels. None of the correlations were significant (P > 0.10).

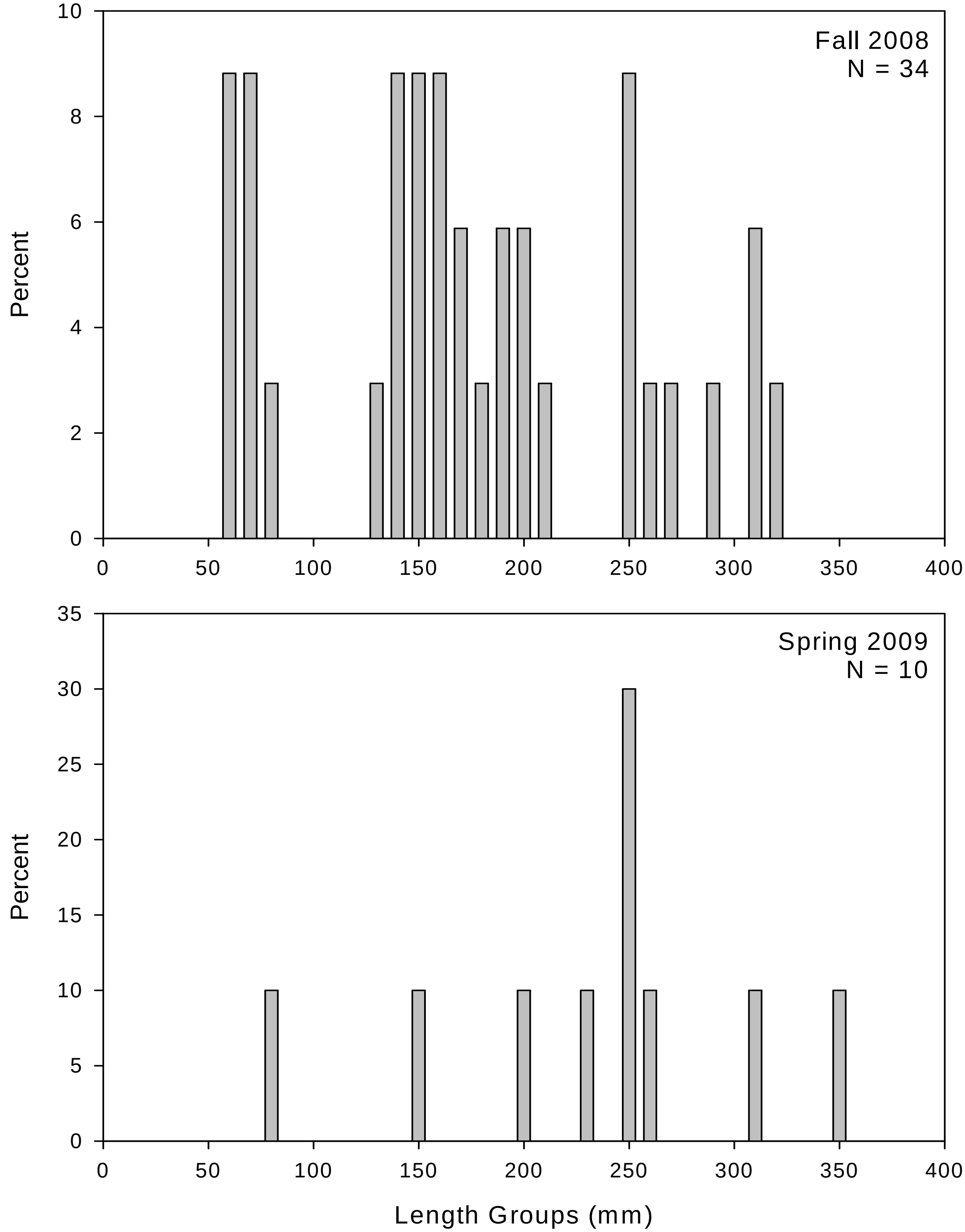

Figure 1-17. Length frequencies (25-mm length groups) of shoal bass collected from the Moffits Mill shoal of Little Uchee Creek during two sampling periods. Note the different y-axes among panels.

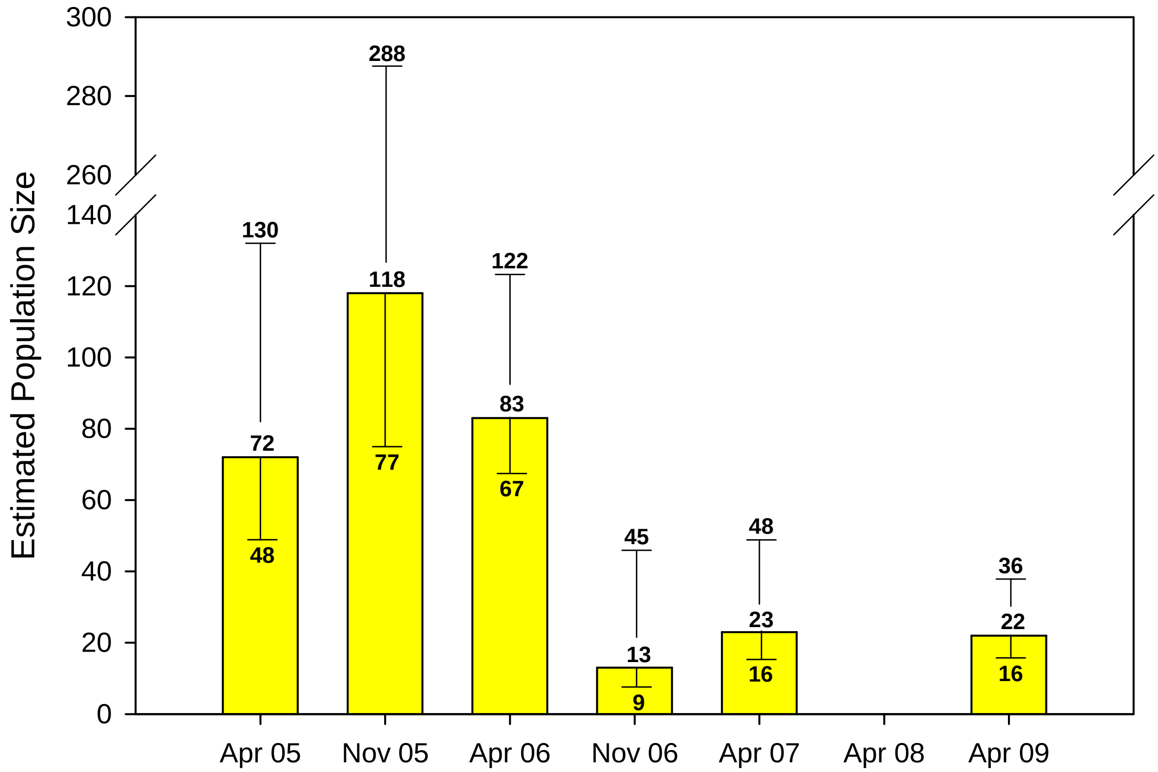

Figure 1-18. Population estimates of shoal bass at Moffits Mill from 2005-2009 and corresponding 90% confidence intervals.

CHAPTER TWO

Fate and Dispersal of Shoal Bass Stocked Into Three Alabama Streams

ABSTRACT

Over 300 shoal bass were stocked in selected reaches of Halawakee, Osanippa, and Wacoochee Creek in January 2008 in an attempt to restore the species to these streams. These fish were sampled from stocked stream reaches over three seasons covering a 18-month period to assess stocking contribution and relative stocking success. Relatively few fish were recaptured during surveys in 2008 and 2009; only 21 of the 314 stocked fish were ever recaptured, and recovery rates ranged between 4-8 percent among the stream reaches. Significant movement was detected for three fish stocked into the upper Halawakee reach; all three fish traveled > 2 km downstream from their stocking sites, moving over the Beans Mill Dam in the process. Stocking failed to appreciably change the species composition of the black bass community by the end of the project in all stream reaches but Wacoochee Creek, where the proportion of shoal bass increased nearly 10-fold over pre-stocking conditions. Since only one shoal area in Alabama streams (Moffits Mill shoal on Little Uchee Creek) continued to support a wild population of shoal bass (Chapter 1), habitat was measured in that area and compared to habitat measured in the largest shoal areas into which shoal bass were stocked in the other three streams to assess any differences among them. Shoal habitat at the Moffits Mill shoal on Little Uchee Creek differed from major shoal complexes found on Halawakee and Wacoochee creeks, but was more similar to shoal complexes found on Osanippa Creek. Despite proceeding on the best available science regarding available shoal habitat and shoal bass densities in Alabama streams, the reintroduction of shoal bass into Halawakee, Osanippa, and Wacoochee creeks was generally unsuccessful. Reasons for this failure were not fully investigated, but likely included a depauperate prey fish community present in these streams due to several years of drought prior to stocking, wild congenerics such as spotted bass being better adapted to handle adverse conditions than newly stocked fish, and potential movement of stocked fish outside of the study area. Results of this study should allow Alabama Division of Wildlife and Freshwater Fisheries biologists to move forward with new stocking strategies in an attempt to restore shoal bass to their former range in Alabama. Future shoal bass stockings should be of small, juvenile (fingerling) fish, which has been shown to be successful in two Georgia rivers. Furthermore, because the shoal habitat on Osanippa Creek most closely approximates that found at the Moffits Mill site on Little Uchee Creek, initial restoration efforts should be concentrated there to maximize the chances of success.

INTRODUCTION

Shoal bass *Micropterus cataractae* have been recently listed as a priority conservation species for Alabama by an expert panel, and the survey work conducted by Auburn University in 2005-06 (Maceina and Stormer 2008) revealed that their persistence in Alabama may be more precarious than first thought. Only one substantial shoal bass population was detected in Alabama, in one 650-m shoal on Little Uchee Creek. Thus conservation measures are needed to maintain and enhance shoal bass in Alabama streams. Reasons for the decline of this species are not known, but proposed impacts include habitat degradation, caused by practices such as poor land use and water withdrawals for irrigation, and interactions with congeneric black bass species, most notably spotted bass *Micropterus punctulatus*. It is not known whether spotted bass have directly outcompeted shoal bass or are more adaptable to habitat change; however, clearly spotted bass have been replacing shoal bass in many of the streams in Alabama.

Shoal bass are a popular game fish in many river systems in Georgia (J. Evans, Georgia Department of Natural Resources [GDNR], personal communication), and are supported by a supplemental stocking program in some river sections where natural recruitment has been chronically low (R. Weller, GDNR, personal communication). These stocking programs have generally been very successful, with the contribution of stocked fish to the year class approaching 50% in some years. Alabama Department of Wildlife and Freshwater Fisheries (ADWFF) has become interested in using supplemental stocking as a method to restore shoal bass to some areas where populations are currently low or nonexistent (S. Rider, ADWFF, personal communication). Many factors can affect the efficacy of supplemental stocking programs, such as stocking procedures, predation, and natural year-class strength (Isermann et al. 2002). Evaluation of any stocking program of shoal bass is required to assess its success and cost-effectiveness. Thus, the objective of this portion of this study was to evaluate contribution of stocked shoal bass to year-class strength of the species in selected Alabama streams.

METHODS

Shoal bass were stocked in selected reaches of Halawakee, Osanippa, and Wacoochee Creek in January 2008 by ADWFF biologists (Figure 2-1). Before stocking, all shoal bass were tagged with a Passive Integrated Transponder (PIT) tag that had a unique code to identify specific individuals. Shoal bass were stocked into these streams at a rate of 10 fish/100 m of available shoal habitat. This rate was developed using the population estimates of the wild shoal bass population at the Moffits Mill shoal at Little Uchee Creek before the decline of that population due to the drought (Stormer and Maceina 2008). The amount of shoal habitat present in each stream was calculated from the surveys conducted by Stormer (2007). Shoal bass were measured (mm, total length [TL]), tagged, and released directly into the shoal habitat by biologists. These fish were sampled from stocked stream reaches by a Smith Root backpack electrofishing unit in spring 2008, fall 2008, and spring 2009 to assess stocking contribution and relative stocking success. Each shoal bass collected was scanned for the presence of a PIT tag. Stocking contribution was determined as 1) the percent of shoal bass recovered from each cohort that were stocked into the stream, and 2) change in the species composition of the black bass community in each stream, using the species composition reported by Stormer (2007) as the baseline estimate. Growth of stocked shoal bass was evaluated by calculating instantaneous growth rates (G; Isely and Grabowski 2007) for individual fish; comparisons among streams were made using an ANOVA (Sas Institute 2004).

Since only one shoal area in Alabama streams (Moffits Mill shoal on Little Uchee Creek) continues to support a wild population of shoal bass (Chapter 1), habitat was measured in that area and compared to habitat measured in the largest shoal areas into which shoal bass were stocked in the other three streams to assess any differences among them. For each stream, habitat was measured in a manner similar to that described in Chapter 1, except the measurements only took place in shoal complexes and transects were spaced 20 m apart. Shoal complexes measured were the largest complexes found during earlier surveys by Stormer (2007) and included the last shoal above Lake Harding on Halawakee Creek, the shoal complex adjoining property owned by Travis Carter on Osanippa Creek, the next shoal complex located downstream of Travis Carter's property on Osanippa Creek, and the shoal complex located at the Goat Rock Hunt Club on Wacoochee Creek. Mean bank-full width, depth, and velocity were compared between these shoal complexes and the Moffits Mill shoal complex using t-tests (SAS Institute 2004). Substrate composition (percent boulder, bedrock, cobble, gravel, and sand) were compared between Moffits Mill and the other shoal complexes using Z-tests (Steel and Torrie 1980). Significance for all statistical tests was set at P = 0.05.

RESULTS

A total of 314 shoal bass were stocked into four stream reaches in early January 2008; a wide variation of sizes were available due to differences in hatchery production ponds (Figure 2-2). Mean TL of fish stocked into the stream reaches were different ($F = 211.78$; $df = 3. 310$; $P < 0.0001$); largest fish were stocked into the upper Halawakee Creek (mean TL = 241 mm), next largest into Osanippa Creek (mean TL = 217 mm), and smallest fish were stocked into Wacoochee Creek (mean TL = 180 mm) and lower Halawakee Creek (mean TL = 178 mm) (Figure 2-2). Relatively few fish were recaptured during surveys in 2008 and 2009; only 21 of the 314 stocked fish were ever recaptured, and recovery rates ranged between 4-8 percent among the stream reaches (Figure 2-3). Shoal bass were not able to be sampled in Osanippa Creek in 2009, due to high water conditions persisting throughout the year. Recapture rate of stocked shoal bass declined over time in all sections but lower Halawakee Creek, where recovery rate was uniformly low through time (Table 2-1). Significant movement was detected for three fish stocked into the upper Halawakee reach; all three fish traveled > 2 km downstream from their stocking sites, moving over the Beans Mill Dam in the process (Figure 2-4). Only 2 of the 21 fish were recaptured twice, and none were recaptured three or more time. Stocking failed to appreciably change the species composition of the black bass community by the end of the project in all stream reaches but Wacoochee Creek, where the proportion of shoal bass increased nearly 10-fold over pre-stocking conditions (Figure 2-5). Initially, shoal bass composition increased from 0 to 40% of the black bass community in the Upper Halawakee, but by the end of the project, no shoal bass were collected above Beans Mill Dam (Figure 2-5). Despite the lack of contribution, stocked shoal bass that were collected appeared to be in good health, and displayed average to good growth rates (Table 2-2). Growth of stocked fish was greater in Wacoochee Creek than in either Halawakee or Osanippa creeks ($F = 5.68$; $df = 2, 18$; $P = 0.0123$), and was inversely correlated to the initial size of fish stocked ($r = -0.74$; $P < 0.0001$).

Shoal habitat variables differed between the Moffits Mill shoal on Little Uchee Creek and major shoals on the other three streams. Moffits Mill shoal habitat was narrower with higher water flows than the last shoals on Halawakee Creek (Table 2-3, Figure 2-6); depth distribution was not different (Figure 2-6), but mean depth was greater in the Halawakee Creek shoals than the Moffits Mill shoals (Table 2-3). Bedrock and cobble substrate composed a greater proportion of shoal habitat at Moffits Mill than in the last shoal of Halawakee Creek, where gravel and sand was more dominant than at Moffits Mill (Figure 2-6). In contrast, mean stream width and stream flow velocity was similar between shoal habitats at Moffits Mill and the lower shoals and upper shoals on Osanippa Creek (Table 2-3). Distribution of stream flows was also similar between the Moffits Mill shoals and both Osanippa Creek shoals, but stream width was different, skewing towards wider stream widths at Moffits Mill compared to both Osanippa Creek shoals (Figures 2-7 and 2-8). Mean depths and depth distributions were greater in both Osanippa Creek shoals than the Moffits Mill shoal (Table 2-3; Figures 2-7 and 2-8). Bedrock and gravel composed a greater proportion of shoal habitat substrate in the lower Osanippa Creek shoal than the Moffits Mill shoal, but boulder and cobble composed a greater proportion of shoal substrate at Moffits Mill than at the lower shoal at Osanippa Creek (Figure 2-7). Substrate was more similar between the Moffits Mill and the upper Osanippa Creek shoals (Figure 2-8). Wacoochee Creek shoal habitat was narrower and had less water flows than the Moffits Mill shoals; however, depths were more similar between the shoals (Table 2-3; Figure 2-9). Bedrock and cobble substrates composed greater proportions of shoal substrate in Moffits Mill than in Wacoochee Creek; whereas, shoal substrates were composed of greater proportions of gravel and sand substrates in Wacoochee Creek than in the Moffits Mill shoal (Figure 2-9).

DISCUSSION

Despite proceeding on the best available science regarding available shoal habitat and shoal bass densities in Alabama streams, the reintroduction of shoal bass into Halawakee, Osanippa, and Wacoochee creeks was generally unsuccessful. Only 6.7% of these fish were ever recaptured, and most of those were recaptured < 6 months post-stocking. Less than 2% were found 9-18 months post-stocking. Furthermore, species composition of the black bass community was virtually unchanged from pre-stocking conditions by the end of the project in Halawakee and Osanippa creeks. Although shoal bass did represent a progressively greater proportion of the black bass community in Wacoochee Creek, black bass density was very low in that stream throughout the project, and only a total of 7 stocked shoal bass were ever recaptured in this stream. The final sample, in Spring 2009, consisted of four black bass, including two shoal bass, only one of which was stocked.

The low recapture rates of stocked shoal bass were likely the result of several mediating factors. Shoal bass were stocked into streams that were currently in the midst of one of the worst droughts on record; mean May-October flows at the Uchee Creek stream gauge (USGS gauge 02342500, http://waterdata.usgs.gov/nwis/nwisman/?site_no=02342500) were 87% and 93% lower than the 50-year mean in 2006 and 2007, respectively (Figure 2-10). Flows remained low in 2008 until late August, when the first of several rain events fell in the watershed, increasing flows greatly, and higher rainfall and stream flows persisted throughout 2009. Droughts are well-known to cause massive perturbations in lotic fish communities (Tramer 1977; Kelsch 1994; Matthews and Marsh-Matthews 2003). Black bass catch rates fell 32-68% from 2005-2006 to 2008 in Halawakee and Osanippa creeks (Table 2-4), and it is likely that other species of fish living in these systems suffered similar population declines. Therefore, shoal bass were stocked into aquatic systems that were likely ravaged by a two-year drought, resulting in depauperate fish communities. Thus, these systems were not conducive to high survival rates of stocked fish, which have been shown to be less capable of adapting to natural conditions than naturally-reproduced fishes (Bettinger and Bettoli 2002; Hoffman and Bettoli 2005).

Food availability is often a significant factor in determining stocking success (Moore et al. 1991; Bauer 2002), and likely was also a major contributing factor in the lack of stocking success observed in this study. As noted above, drought conditions that persisted for almost seven months post-stocking almost certainly reduced the abundance of fish prey for the newly stocked shoal bass. Furthermore, shoal bass were stocked at large sizes in an attempt to increase survival, as has been shown in other studies (Santucci and Wahl 1993; Buynak et al. 1999; Brooks et al. 2002). However, this likely increased the predatory demand on systems that were already characterized by low prey availability, which may have decreased survival of stocked shoal bass. Finally, shoal bass stocked into these Alabama streams were raised in ponds over one growing season and fed a diet of fathead minnows *Pimephales promelas* to increase their growth and survival rates (S. Rider, ADWFF, personal communication). Thus, these fish were highly piscivorus at the time of stocking. However, subsequent research on the Flint River, Georgia, has documented that wild shoal bass are highly insectivorous at sizes < 300 mm TL (S. Sammons, unpublished data). Similar diets were observed for spotted bass in the Flint River. Thus, wild fish of both species may have been better adapted to withstand low fish prey abundance than the shoal bass stocked into these streams.

Stocked shoal bass did exhibit movement among shoals in Halawakee Creek, and it is possible that at least some stocked fish survived by moving away from stocking sites in these streams. Concomitantly, a large reduction of wild shoal bass was observed in the Moffits Mill shoal of Little Uchee Creek during this study, which was attributed to high flow events in the spring of 2009 (Chapter 1). However, shoal bass were stocked into the only suitable shoal bass habitat in these streams, as identified by Stormer (2007), and these same shoals were sampled repeatedly throughout this project. Although shoal bass are known to use habitats other shoals during the course of the year (Wheeler and Allen 2003; Stormer and Maceina 2009), it is not likely that the majority of the stocked fish would have been able to evade our sampling gear throughout the entire project. Also, shoal bass in the Flint and Ocmulgee rivers in Georgia have been observed to congregate in shoal areas during the spring (M. Goclowski, Auburn University, and J. Evans, GDNR, unpublished data), and the failure to collect more than two stocked shoal bass during spring 2009 in suitable shoal habitat offers further proof that stocking success was uniformly low across streams.

The shoal habitat found at Moffits Mill on Little Uchee Creek supports the last known wild population of shoal bass in Alabama (Chapter 1). This study demonstrated that the shoal habitat at this site is generally distinct from most other major shoal complexes found in these streams. It is likely that the Moffits Mill shoals offer almost ideal conditions for the persistence of shoal bass, which may explain how the species has managed to persist there while the other populations have largely disappeared. The Moffits Mill shoal habitat offers a unique combination of moderate stream width, shallow depths, and fast current that shoal bass have been found to favor in Alabama streams (Stormer and Maceina 2009; Chapter 1). However, shoal bass have been found to use a wide range of habitats in the Flint River (M. Goclowski, Auburn University, unpublished data), and thus there is no reason to assume that these other shoal habitats cannot support shoal bass in the future. Based the results of the habitat surveys, the shoals on Osanippa Creek adjacent to the property of Travis Carter are more similar to the Moffits Mill shoal complex on Little Uchee Creek than the major shoal complexes in either Halawakee or Wacoochee creeks.

Shoal bass appear to prefer moderate to large-sized rivers and streams, and are rarely found in small streams. Wacoochee Creek may be too small to offer long-term persistence of shoal bass, despite having the highest recapture rate of stocked shoal bass. This may also be true of the upper reaches of Halawakee Creek above Beans Mill Dam, which may explain the observed downstream displacement of stocked shoal bass. Low-order streams are more vulnerable to the effects of droughts (Matthews and Marsh-Matthews 2003), and thus avoidance of small streams may be an adaptation to reduce the risk of drought, or may be due to the fact that populations in small streams are more unstable and likely to experience local extinction. In contrast, the last shoal complex on Halawakee Creek is wider and deeper than the other shoal complexes, but has less flow than Moffits Mill. Furthermore, directly below this shoal Halawakee Creek flows into Lake Harding, which may artificially increase the abundance of competing species such as spotted bass or white bass *Morone chrysops* in these areas, making it less suitable for shoal bass recovery efforts.

MANAGEMENT IMPLICATIONS

Stocking efforts of black bass are often met with limited success (Boxrucker 1986; Ryan et al. 1998; Hoffman and Bettoli 2005; Diana and Wahl 2008). The results of this study adds to the growing list of black bass stocking efforts that did not work out as planned. However, shoal bass have been stocked for years on the Flint River, Georgia, below Lake Blackshear to supplement recruitment, often with high contribution to year-class strength (T. Ingram, GDNR, personal communication). Similarly, a 5-year stocking effort on the Chattahoochee River in Atlanta has led to the creation of a sport fishery, which had been eliminated due to altered temperature regimes from Buford Dam (J. Long, Oklahoma State University, unpublished data). Thus, it is highly likely that the stocking failure of shoal bass in these Alabama streams was caused by an unfortunate combination of extreme environmental conditions and stocking decisions that were made before more complete biological data were available for shoal bass. Results of this study, combined with concurrent research on shoal bass on the Flint River, Georgia, should allow ADWFF biologists to move forward with new stocking strategies in an attempt to restore shoal bass to their former range in Alabama. We suggest that future shoal bass stockings should be of small juvenile (fingerling) fish, which has been shown to be successful in two Georgia rivers. Furthermore, we suggest that shoal bass restoration should be initially performed in and around the shoal complexes adjoining Travis Carter's property on Osanippa Creek. Because the shoal habitat there most closely approximates that found at the Moffits Mill site on Little Uchee Creek, it seems likely that shoal bass restoration would be most easily achieved at this site.

Table 2-1. Recaptures of shoal bass stocked into Alabama streams through time. Number in parentheses is the number stocked into each stream reach.

Stream	Spring 2008	Summer 2008	Fall 2008	Spring 2009
Upper Halawakee (94)	6*	1**	1**	0
Lower Halawakee (75)	1	1	0	1
Osanippa (67)	-	5	0	-
Wacoochee (78)	4	-	2	1

* one of these fish was in the lowest shoal in the Lower Halawakee section

** collected below Beans Mill Dam in the Lower Halawakee section

Table 2-2. Lengths and growth rate (absolute growth rate (mm/d) and instantaneous growth rate [G]) of recaptured stocked shoal bass in three Alabama streams. If fish were recaptured more than once, only the first recapture is presented here and used for the growth analyses.

Stream	Stock Date	Recap Date	Days at Large	Initial Length (mm)	Recapture Length (mm)	Growth Rate (mm/d)	G
Hal	01/08/08	11/06/08	303	240	277	0.097	0.000473
Hal	01/08/08	05/14/08	127	249	258	0.071	0.000280
Hal	01/08/08	05/14/08	127	231	241	0.079	0.000334
Hal	01/09/08	08/22/08	226	178	215	0.164	0.000836
Hal	01/08/08	05/14/08	127	225	234	0.071	0.000309
Hal	01/08/08	08/22/08	227	248	273	0.110	0.000423
Hal	01/08/08	06/06/08	150	239	254	0.100	0.000406
Hal	01/08/08	05/14/08	127	236	242	0.047	0.000198
Hal	01/09/08	06/06/08	149	172	183	0.074	0.000416
Hal	01/09/08	05/06/09	483	182	257	0.155	0.000714
					Mean:	**0.0968**	**0.000439**
Osa	01/10/08	07/22/08	194	260	273	0.067	0.000252
Osa	01/10/08	07/22/08	194	174	193	0.098	0.000534
Osa	01/10/08	07/22/08	194	248	250	0.010	0.000041
Osa	01/10/08	07/22/08	194	239	252	0.067	0.000273
Osa	01/10/08	07/22/08	194	202	223	0.108	0.000513
					Mean:	**0.070**	**0.000323**
Wac	01/11/08	05/15/08	125	192	207	0.120	0.000602
Wac	01/11/08	10/22/08	285	174	235	0.214	0.001054
Wac	01/11/08	05/15/08	125	174	189	0.120	0.000662
Wac	01/11/08	10/22/08	285	164	250	0.302	0.001479
Wac	01/11/08	05/15/08	125	211	222	0.088	0.000407
Wac	01/11/08	05/05/09	480	188	264	0.158	0.000707
					Mean:	**0.167**	**0.000819**

Table 2-3. Mean bank-full width, depth, and velocity measured on four large shoal complexes on three Alabama streams. In each case, means were compared against those measured on Little Uchee Creek, in the shoal complex containing the last known Alabama shoal bass population. P-values greater than 0.05 were considered to be non-significant.

Stream	Bank-full width (m)	Depth (m)	Velocity (m/s)
Halawakee	36.9	0.35	0.174
Little Uchee	26.6	0.24	0.302
t value (P-value)	10.21 (< 0.01)	3.35 (< 0.01)	-3.16 (< 0.01)
Lower Osanippa	26.3	0.32	0.235
Little Uchee	26.6	0.24	0.302
t value (P-value)	-0.27 (> 0.05)	3.27 (< 0.01)	-1.73 (> 0.05)
Upper Osanippa	26.8	0.32	0.239
Little Uchee	26.6	0.24	0.302
t value (P-value)	-0.17 (> 0.05)	-2.56 (0.01)	1.57 (> 0.05)
Wacoochee	18.5	0.21	0.113
Little Uchee	26.6	0.24	0.302
t value (P-value)	8.30 (< 0.01)	1.25 (> 0.05)	5.41 (< 0.01)

Table 2-4. Catch rate (number/hr) of black bass in three reaches of Alabama streams before and after the drought of 2007. Data from 2005-2006 were taken from Stormer (2007).

Stream	2005/2006	2008	Decline
Upper Halawakee	6.84	3.60	47%
Lower Halawakee	15.25	10.43	32%
Osanippa	10.10	3.20	68%

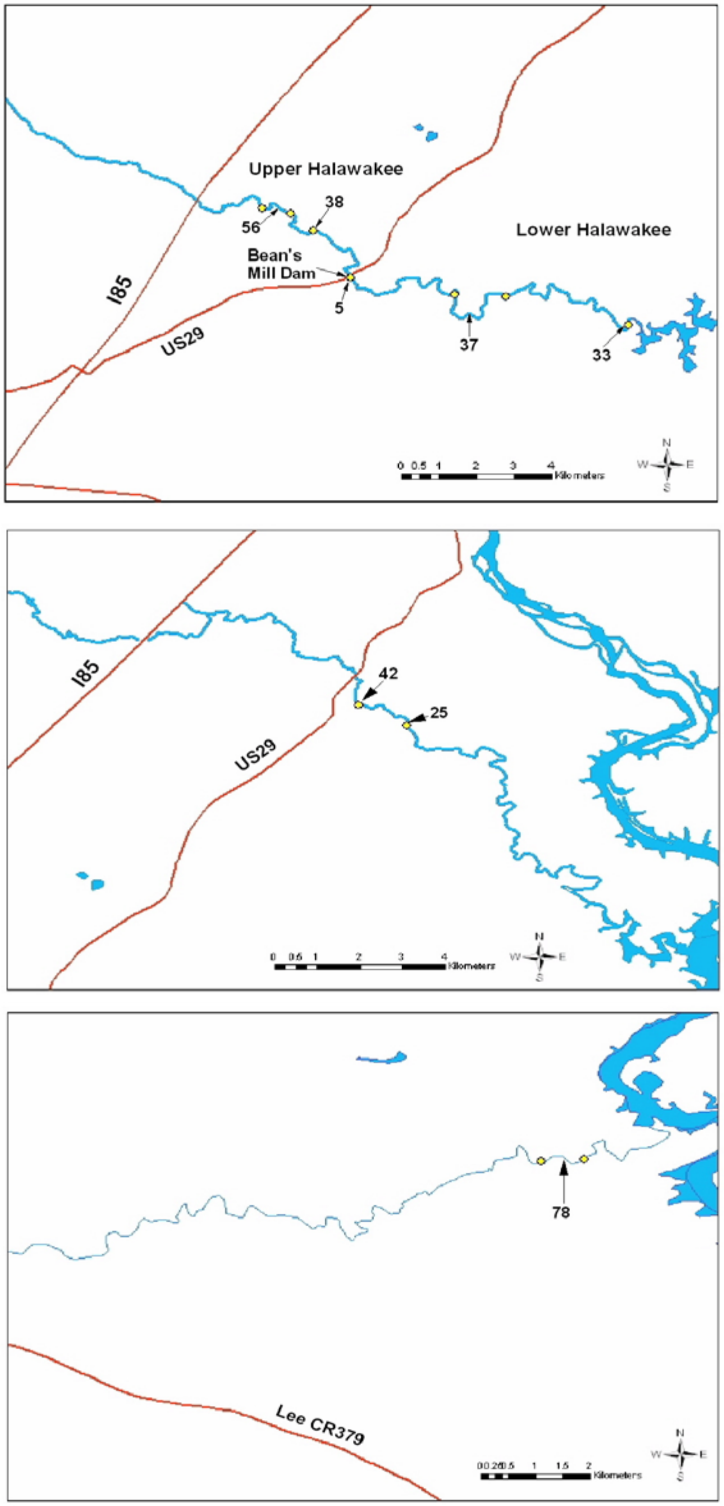

Figure 2-1. Stocking sites and number of shoal bass stocked at each site in Halawakee (top), Osanippa (middle) and Wacoochee (bottom) creeks, Alabama. Arrows pointing between two points indicate that fish were stocked in several shoals between those sites.

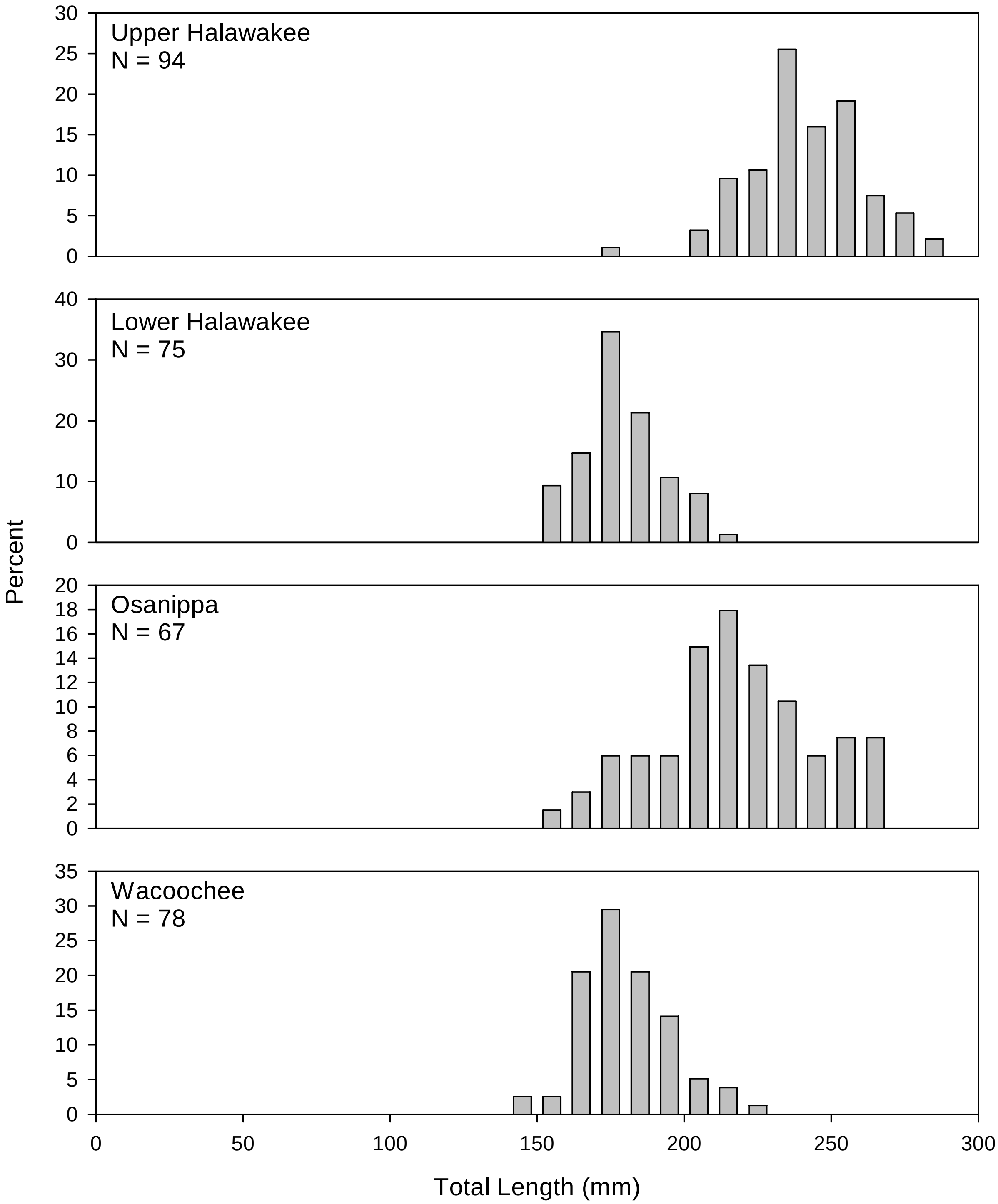

Figure 2-2. Length-frequencies (5-mm length groups) of shoal bass stocked into three Alabama streams in January 2008.

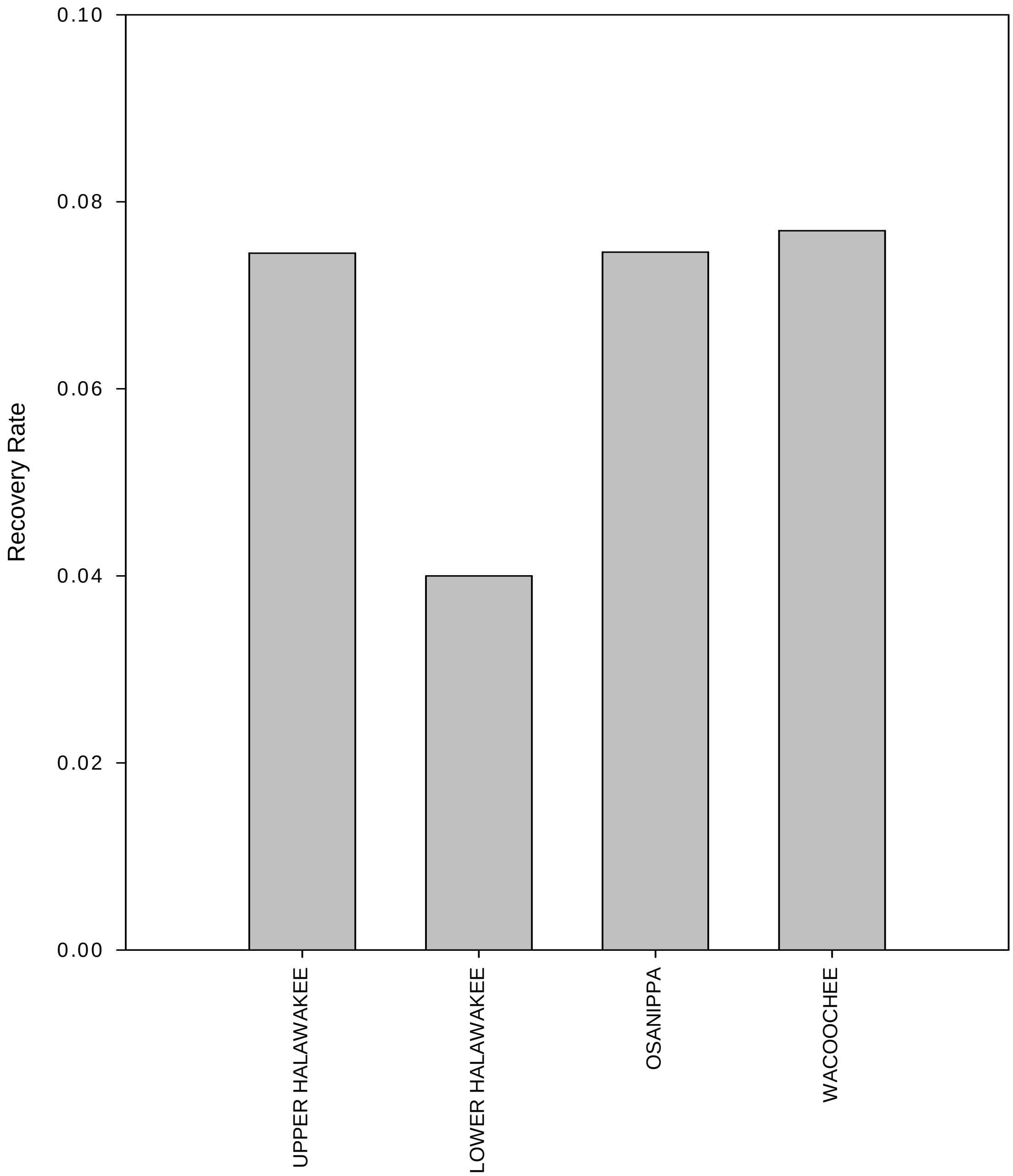

Figure 2-3. Recovery rates of stocked shoal bass from three Alabama streams. Recovery rates are expressed as proportion of individual stocked fish collected in the stream 4-18 months after stocking.

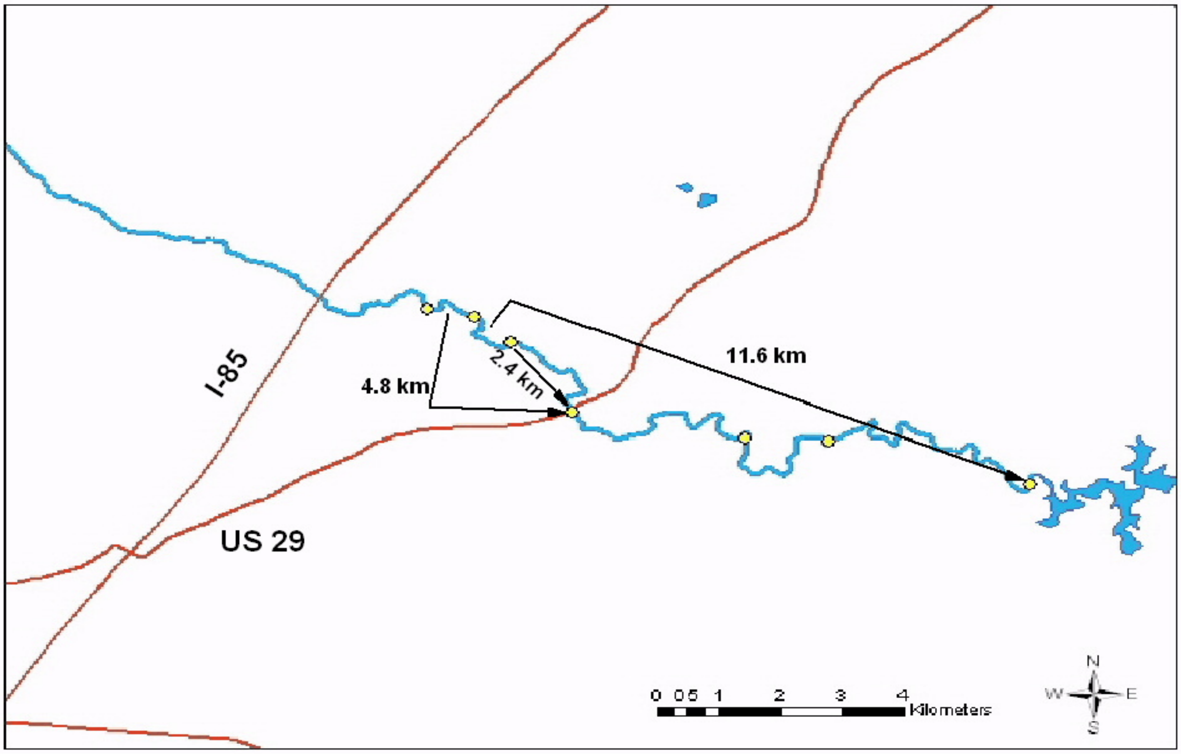

Figure 2-4. Movement of three stocked shoal bass in Halawakee Creek, Alabama. Stocking sites are denoted by circles. Beans Mill Dam is located where US 29 crosses Halawakee Creek, and a stocking site was located directly below the dam.

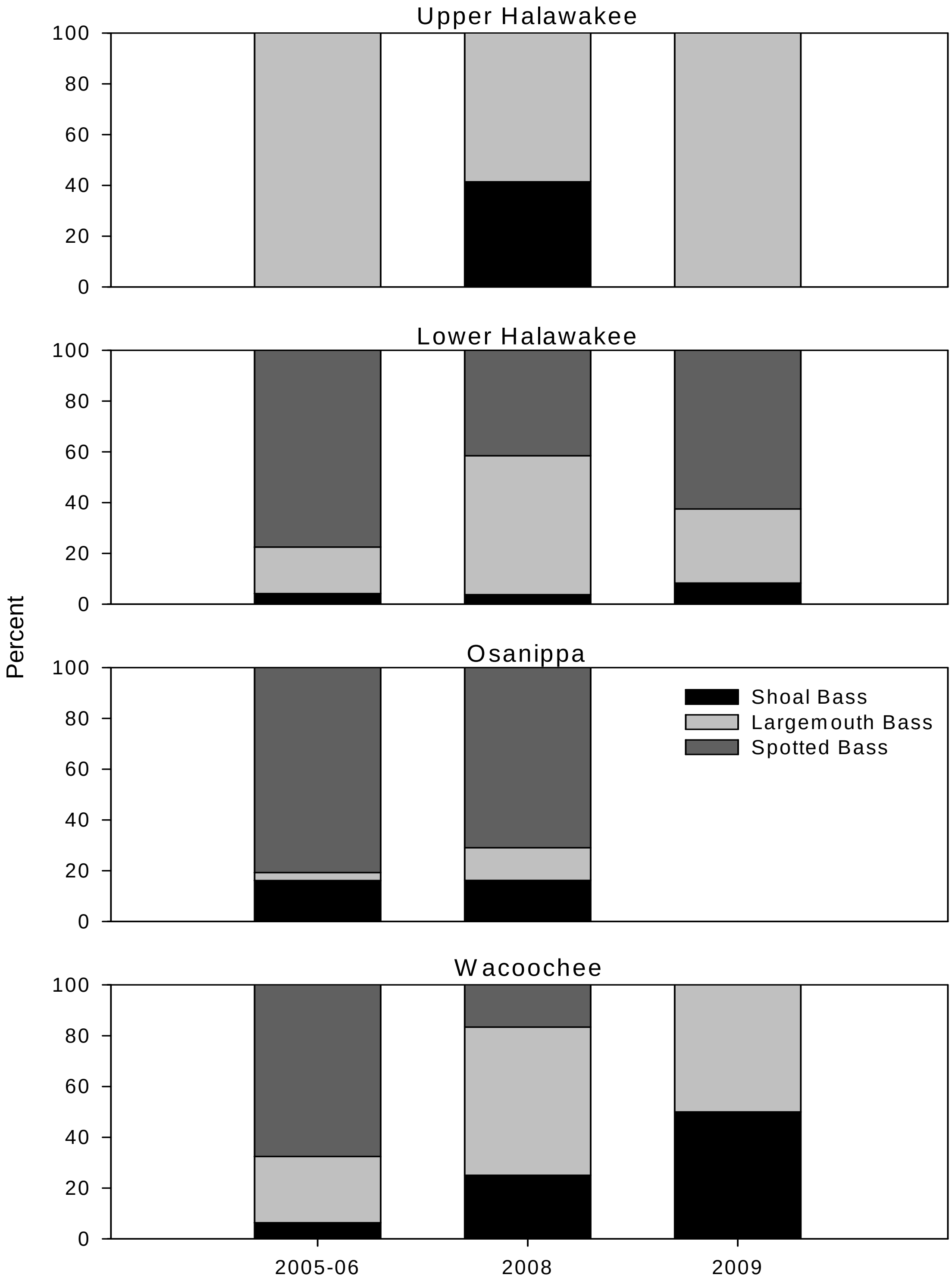

Figure 2-5. Species composition of the black bass community in three Alabama streams before and after stocking of shoal bass in January 2008. Data from 2005-06 were taken from Stormer (2007); Osanippa Creek was not sampled in 2009.

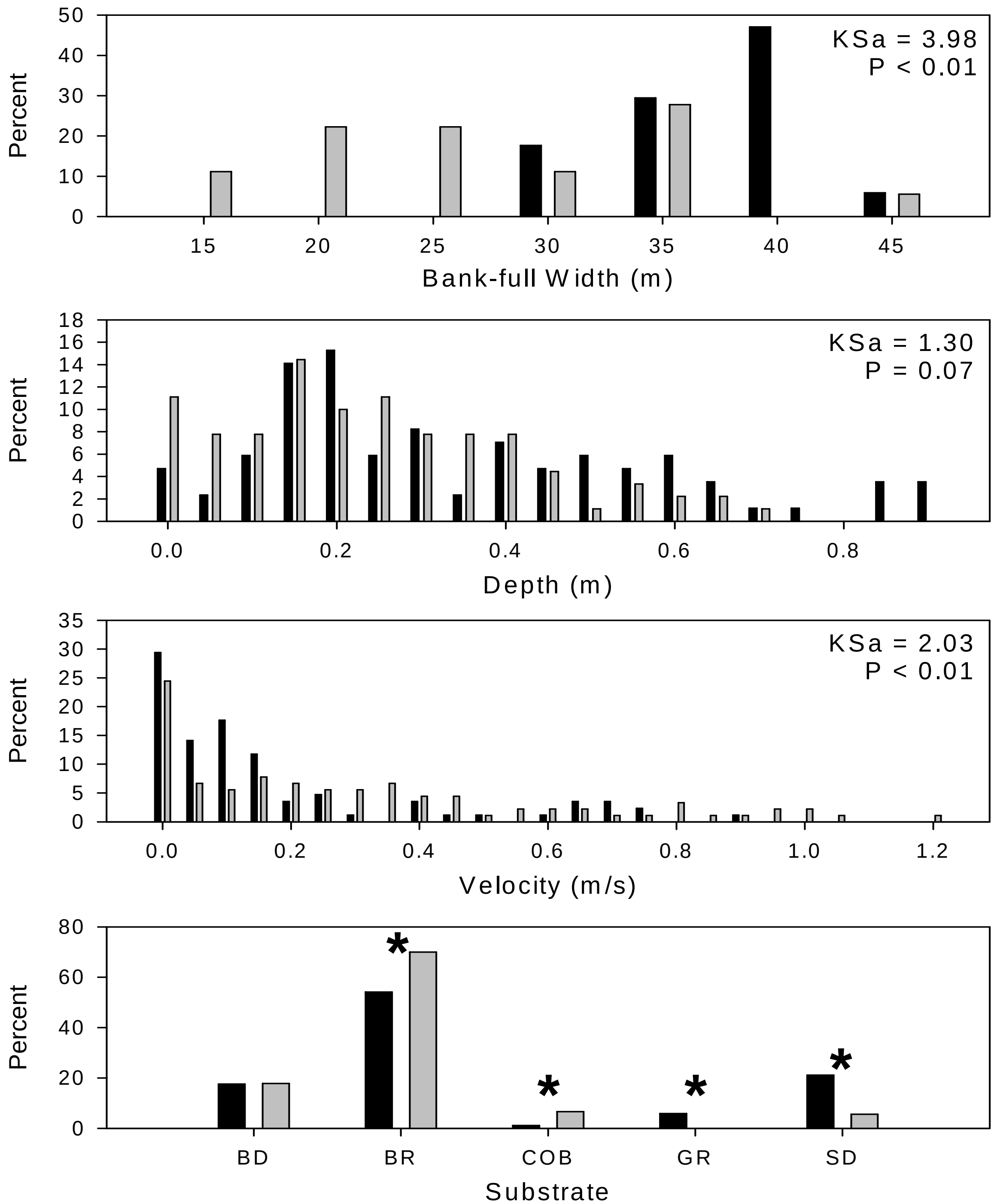

Figure 2-6. Habitat characteristics of the last shoal on Halawakee Creek (black bars) compared to the shoals at Moffits Mill on Little Uchee Creek (gray bars). Differences in distribution of bank-full width, depth, and flow velocity were assessed between sites using a Kolmogorov-Smirnov two-sample test. Differences between substrate proportions were assessed using Z-tests; significant differences (P < 0.05) are indicated by an asterisk.

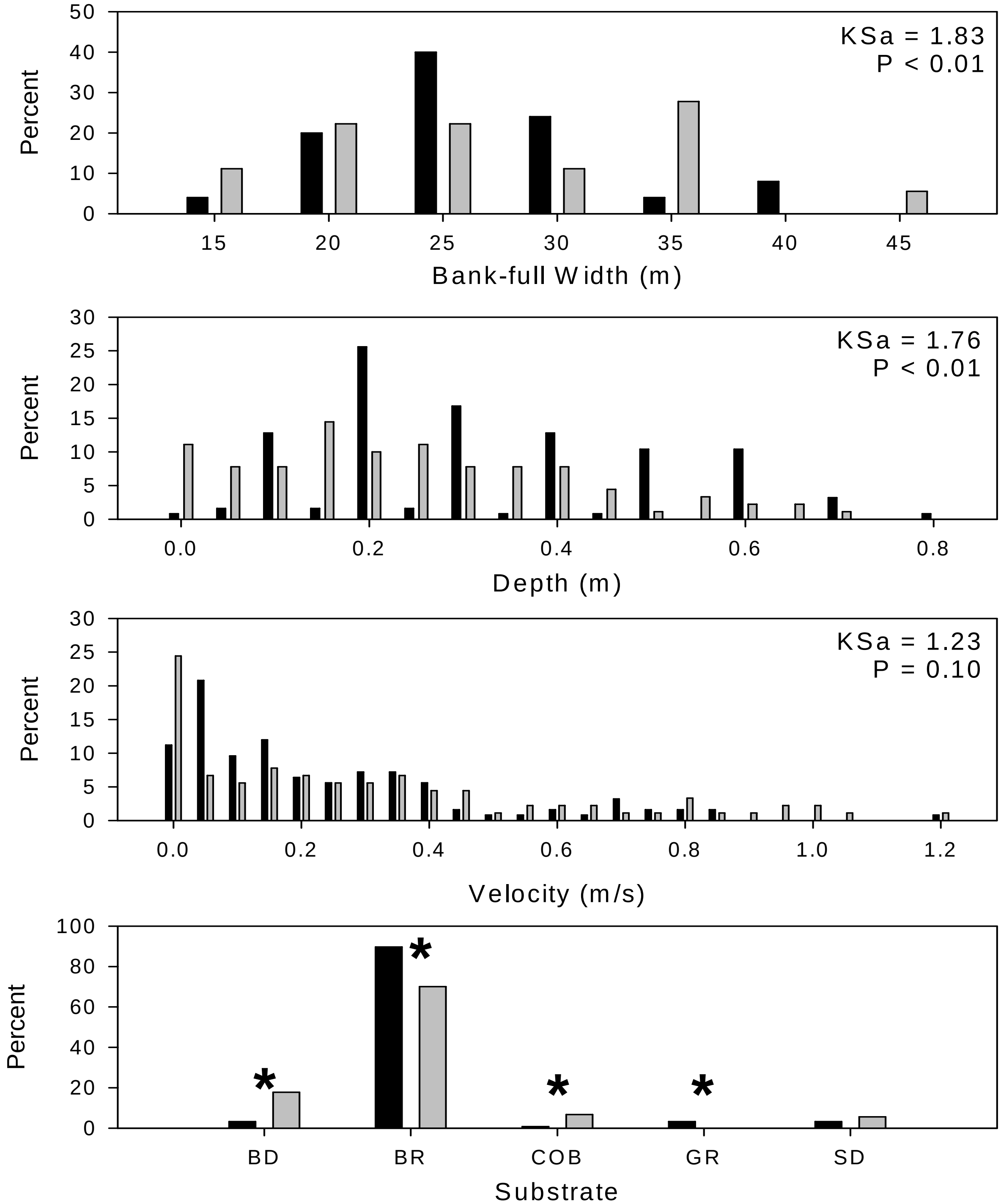

Figure 2-7. Habitat characteristics of the lower shoal on Travis Carter's property on Osanippa Creek (black bars) compared to the shoals at Moffits Mill on Little Uchee Creek (gray bars). Differences in distribution of bank-full width, depth, and flow velocity were assessed between sites using a Kolmogorov-Smirnov two-sample test. Differences between substrate proportions were assessed using Z-tests; significant differences ($P < 0.05$) are indicated by an asterisk.

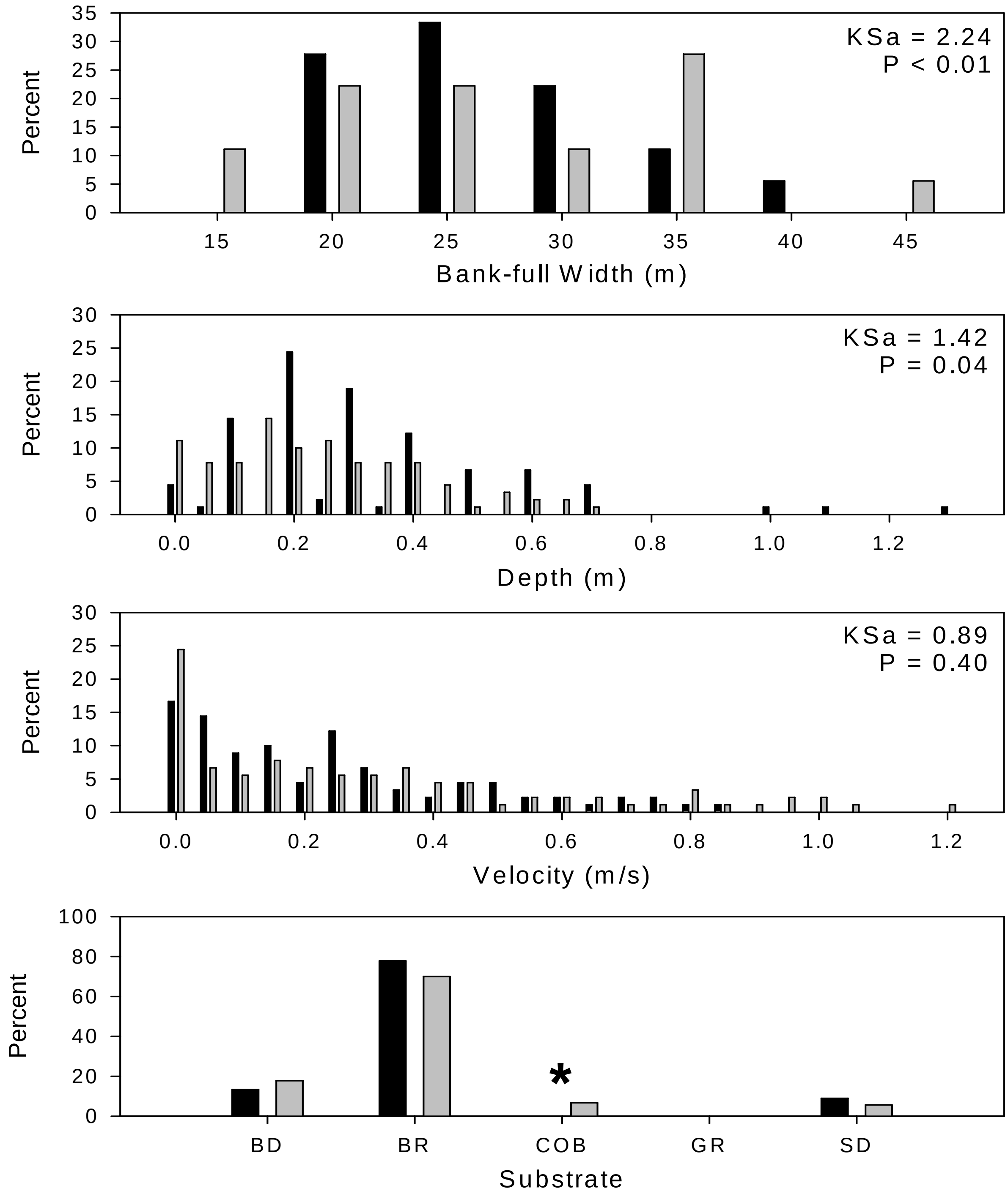

Figure 2-8. Habitat characteristics of the upper shoal on Travis Carter's property on Osanippa Creek (black bars) compared to the shoals at Moffits Mill on Little Uchee Creek (gray bars). Differences in distribution of bank-full width, depth, and flow velocity were assessed between sites using a Kolmogorov-Smirnov two-sample test. Differences between substrate proportions were assessed using Z-tests; significant differences ($P < 0.05$) are indicated by an asterisk.

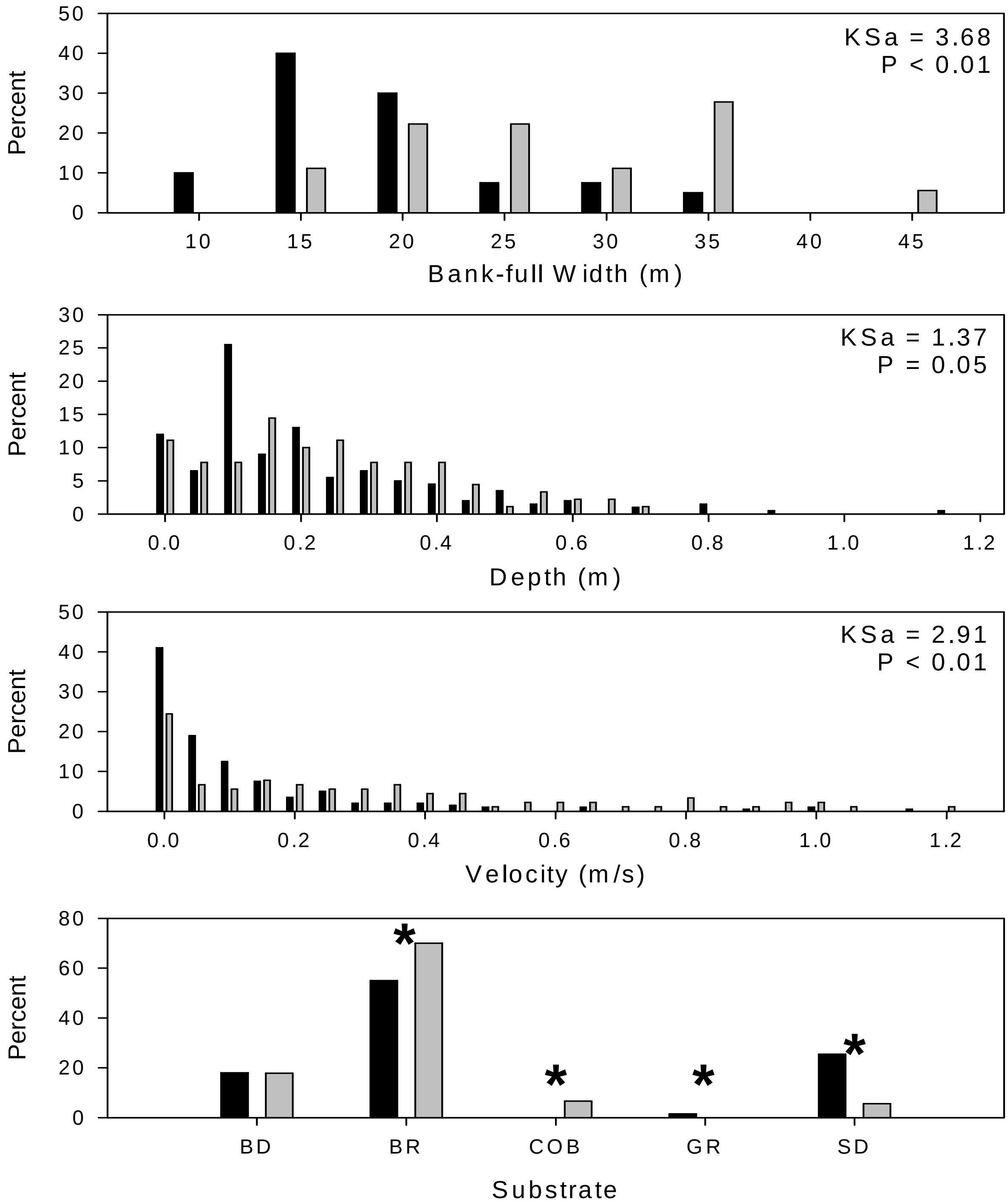

Figure 2-9. Habitat characteristics of the lowest shoal on Wacoochee Creek (black bars) compared to the shoals at Moffits Mill on Little Uchee Creek (gray bars). Differences in distribution of bank-full width, depth, and flow velocity were assessed between sites using a Kolmogorov- Smirnov two-sample test. Differences between substrate proportions were assessed using Z-tests; significant differences ($P < 0.05$) are indicated by an asterisk.

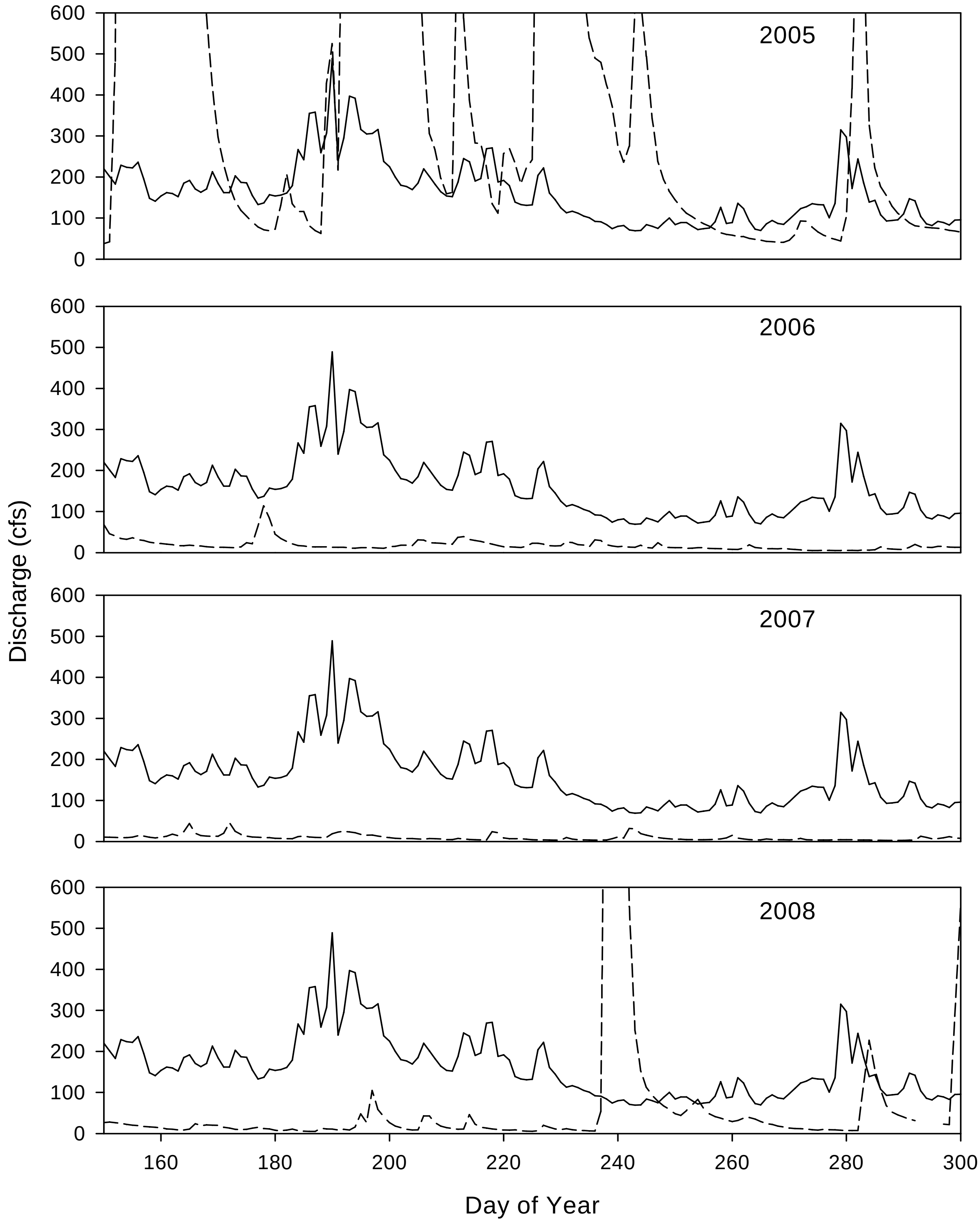

Figure 2-10. Mean daily discharge (dotted lines) and the 50-year average discharge (solid line) at the USGS gauge on Uchee Creek from May-October over a four-year period.

CHAPTER THREE

Competition Between Laboratory-Housed Spotted Bass and Shoal Bass

ABSTRACT

Shoal bass and spotted bass were collected from the wild using various electrofishing gears and held in tanks in order to observe possible competitive interactions between the two species. Tanks were modified with cobble- to boulder-sized rock to simulate natural shoal habitats. Black bass were stocked into one of three treatment groups: 1) a conspecific group of six shoal bass, 2) conspecific group of six spotted bass, and 3) a heterospecific group of three shoal bass and three spotted bass. A total of three trials were made; trials lasted for 60 or 90 d. For all three trials, black bass were measured for total length (mm), weighed to the nearest 0.1g, and marked with fin clips or tagged with PIT tags prior to introduction into the experimental streams. Each treatment group was given approximately equal amounts (rate of about 3% of total biomass/day) of similar-sized prey (minnows and crayfish) every 48 hours. At the end of each trial, the raceways or tanks were drained, black bass were removed, measured for total length (mm), weighed to the nearest 0.1g, and identified using fin clips or PIT tags. All trials conducted during this study were plagued by high mortality of fishes, especially during periods of high water temperatures, resulting in high variability that limited our ability to analyze these data. Growth of subject fish was also extremely variable among treatments within each treatment group; variance was often an order of magnitude greater than the mean for both length and weight. Not surprisingly, no significant differences were detected among treatments for either species of fish or in any trial for absolute growth in length, weight, or instantaneous growth rates (t-test; $t \leq |1.75|$; $P \geq 0.10$*). However, length increases of shoal bass appeared to be greater in the conspecific treatment than the heterospecific treatment in all three trials; whereas, spotted bass length increases appeared to be greater in the heterospecific treatment than in the conspecific treatment in the second and third trials, but not the first. Despite the difficulties encountered during this study, there was some indication that spotted bass can negatively affect the growth of shoal bass when they are in close proximity to each other. Given the fact that shoal habitats in Alabama streams appear to be heavily used by both shoal bass and spotted bass (Chapter 1), it seems obvious that competition between these species is likely in these Alabama streams and may have contributed to the decline of shoal bass observed in Alabama streams. However, further research is necessary to understand and predict the effects of black bass introductions into new watersheds.*

INTRODUCTION

Shoal bass *Micropterus cataractae*, a species native to the Apalachicola basin, has been declining throughout its native range, including Alabama (Williams and Burgess 1999; Stormer and Maceina 2008). Historically, the only congeneric black bass that occurred in sympatry with shoal bass were native stocks of largemouth bass *Micropterus salmoides*. Largemouth bass and shoal bass are rarely found in the same habitat in streams. While shoal bass are commonly found in shallow riffle areas and fast current, largemouth bass more typically occur in pools and slower runs (Hurst 1969; Wheeler and Allen 2003). However, spotted bass *Micropterus punctulatus* were first found in the Apalachicola basin in the 1940s and had spread above the Fall Line by the 1960s (Williams and Burgess 1999). Recently, anglers have been illegally introducing spotted bass into systems across the range of shoal bass that formerly contained only largemouth bass and shoal bass.

Unlike the native congeneric largemouth bass, spotted bass commonly use habitats similar to shoal bass. In Alabama, many streams in which shoal bass been collected historically now appear to be dominated by spotted bass (Stormer and Maceina 2008), which have been found to prefer the same type of habitat used by shoal bass (Vogele 1975; Hurst et al. 1975; Layher et al. 1987; Tillma et al. 1998). Spotted bass appear to be more of a habitat generalist than shoal bass (Vogele 1975; Sammons and Bettoli 1999), and may be able to outcompete shoal bass when the two are found sympatrically (Miller 1975; Smitherman 1975). Growth and survival of spotted bass were found to be less influenced by intraspecific and total fish density than largemouth bass in Oklahoma ponds (Clady and Luker 1982), and thus may be more resilient to reduced food availability than congeneric black bass.

Fishes of the family Centrarchidae are known to be very adaptable, able to modify habitat and food use to fill available niches and coexist with other congenerics (Werner et al. 1977; Scott and Angermeir 1998; Sammons and Bettoli 1999; Long and Fisher 2000). However, many of these studies have been conducted either on native species assemblages, or in novel environments such as reservoirs, where all fish species have had to adapt to new conditions. Over the last ten years the illegal introduction of spotted bass outside their native range has reached epidemic proportions. Spotted bass are now found in almost every river system in Georgia and many in South Carolina and North Carolina. The effects of these introductions have not been fully documented; however, evidence exists to suggest that they may be able to hybridize with or outcompete some of the endemic black bass species found in the southeastern U.S., especially those that are obligate lotic species, such as shoal bass.

Food habits of spotted bass and shoal bass were found to be more similar than diets of largemouth bass and shoal bass (S. Sammons, unpublished data). Thus, the potential for interspecific competition favoring spotted bass over shoal bass exists in these Alabama streams where a decline of shoal bass have been observed. Therefore, the objective of this study was to examine possible competition of spotted bass and shoal bass in a laboratory environment.

METHODS

Shoal bass and spotted bass were collected from the wild using various electrofishing gears and held in tanks in order to observe possible competitive interactions between the two species. A total of three trials were conducted. For the first trial, six concrete raceways (6.25 m x 1.2 m) at the E. W. Shell Fisheries Center at Auburn University were modified with cobble- to boulder-sized rock to simulate natural shoal habitats. Water was released into one end of the tank, flowed in a unidirectional direction over the substrate, and drained out the other end of the raceway. Each raceway was stocked with six black bass and held for a trial period of 60 d. Black bass were stocked into one of three treatment groups: 1) a conspecific group of six shoal bass, 2) conspecific group of six spotted bass, and 3) a heterospecific group of three shoal bass and three spotted bass. Two raceways were used for each treatment group for a total of six treatments per period. In the heterospecific group, individuals of each species were size matched by total length (Winemiller and Taylor 1987).

Because other fish production needs at the E. W. Shell Center required the use of the concrete raceways, the other two trials were conducted in circular aquaculture tanks (filled to approximately 0.9 m^3). As in the first trial, the tanks were modified to resemble stream habitat; however, flow was set up in a circular motion to approximate unidirectional flow before draining out of the center of the tank. Approximately 200 g of size-matched black bass (between 2 and 6 fish per tank; biomass/volume approximately equal to that in raceways) were placed in each tank. Fish were placed into the same treatment groups described above. The second trial consisted of six heterospecific replicates, four conspecific shoal bass replicates, and three conspecific spotted bass replicates. The third trial consisted of nine treatment replications, three replicates of each treatment.

For all three trials, black bass were measured for total length (mm), weighed to the nearest 0.1g, and marked with fin clips or tagged with PIT tags prior to introduction into the experimental streams. Each treatment group was given approximately equal amounts (rate of about 3% of total biomass/day) of similar-sized prey (minnows and crayfish) every 48 hours. Prey was introduced into the raceways after dark and close to cover to minimize initial predation on newly introduced prey items. Water temperature was monitored for the duration of each trial with Hobo Water Temp Pro v2 data loggers. At the end of each trial, the raceways or tanks were drained, black bass were removed, measured for total length (mm), weighed to the nearest 0.1g, and identified using fin clips or PIT tags. Trials lasted for 60 or 90 d; trial 1 was conducted from April 25, 2008 until June 25, 2008, trial 2 was conducted from November 4, 2008 until February 2, 2009, and trial 3 was conducted from March 12, 2009 until May 11, 2009. Further trials were attempted throughout the study, but were discontinued due to excessive fish mortality.

Growth of black bass in each treatment was determined by examining changes in length and weight from the beginning to the end of each trial. Mean changes in absolute growth (length and weight) as well as differences in instantaneous growth rate (G; Isely and Grabowski 2007) of each species were compared among treatments for each trial using an ANOVA (SAS Institute 2004). If no interaction between replicates and treatment were observed, means were compared using t-tests. Significance for all tests was set at $P \leq 0.05$.

RESULTS

All trials conducted during this study were plagued by high mortality of fishes, especially during periods of high water temperatures. Spotted bass experienced higher rates of mortality than shoal bass. This had the two-fold effect of decreasing both the number of successful treatment replicates completed and the number of fish surviving until the end of the trials in each replicate. The end result was high variability that limited our ability to analyze these data. Growth of subject fish was also extremely variable among treatments within each treatment group; variance was often an order of magnitude greater than the mean for both length and weight (Tables 3-1, 3-2, and 3-3).

Due to differences among trials, each trial had to be analyzed separately. The third trial in particular was characterized by excessive fish mortality that caused almost every treatment replicate to consist of a single fish (Table 3-3). Not surprisingly, no significant differences in absolute growth in length or weight, or in instantaneous growth rates were detected among treatments for either species of fish in any trial (t-test; $t \leq |1.75|$; $P \geq 0.10$). However, length increases of shoal bass appeared to be greater in the conspecific treatment than the heterospecific treatment in all three trials; whereas, spotted bass length increases appeared to be greater in the heterospecific treatment than in the conspecific treatment in the second and third trials, but not the first (Figure 3-1). Changes in weight was more variable among treatments and trials for each species, but spotted bass appeared to gain more weight (or lose less weight) in the conspecific treatment than the conspecific treatment in the first and third trials (Figure 3-2). However, weight gain of spotted bass appeared greater in the heterospecific treatment than the conspecific treatment in trial 2. Shoal bass weight gain appeared more similar among treatments than spotted bass, and only in trial 1 was any difference apparent between treatments, where shoal bass seemed to gain more weight in the heterospecific group (Figure 3-2).

DISCUSSION

Low sample size due to excessive mortality of fish subjects, especially spotted bass, resulted in high variability in growth patterns among treatment replicates. This hampered our ability to draw firm conclusions regarding the potential for competition between spotted bass and shoal bass in this study. The inability of spotted bass in particular to survive confinement in our experimental units was unexpected, given their apparent high adaptability to various natural habitats (Tillma et al. 1998; Scott and Angermeir 1998; Sammons and Bettoli 1999). However, spotted bass exhibited higher rates of initial mortality than largemouth bass after being caught, weighed in, and released during fishing tournaments on Lake Martin, Alabama (Ricks 2006). The disparity in mortality between largemouth bass and spotted bass was especially great during periods of high water temperatures. Based on our experiences from this project, it appears that spotted bass are also less able to withstand handling and confinement stress than shoal bass, especially during the summer. Future studies of this nature will have to design innovative ways to overcome this obstacle.

Despite the difficulties encountered during this study, there was some indication that spotted bass can negatively affect the growth of shoal bass when they are found in close proximity to each other. Shoal bass consistently grew more in length in conspecific treatments than in heterospecific treatments in all three trials. Spotted bass response was more variable, but a corresponding increase in growth in heterospecific treatments vs conspecific treatments was observed in 2 of 3 trials. This implies that spotted bass prospered more in the presence of shoal bass than they did in the presence of conspecifics; whereas, shoal bass prospered more in the presence of conspecifics than with spotted bass. However, given the nature of these data and the limitations discussed above, this can only be viewed as inference, not fact. At best, it indicates that competition between these species may be a possible scenario that requires further study.

Likewise, the potential for trophic competition between these species appears to be high in natural systems. Diets of the introduced spotted bass appeared to occupy an intermediate position between the native largemouth bass and shoal bass in the Flint River, Georgia, but was generally more similar to shoal bass (S. Sammons, unpublished data). Like shoal bass, diets of juvenile spotted bass were dominated by insects, except in winter, when fish became more important. Spotted bass commonly appear to be insectivores in lotic environments (Smith and Page 1969; Ryan et al. 1970; Scott and Angermeier 1998); likely, in their native range they fill a niche similar to that of shoal bass. Also like shoal bass, spotted bass diet in the Flint River was extremely diverse, particularly for fish < 300 mm (S. Sammons, unpublished data). High diversity in spotted bass diet has been reported by other researchers working in lotic environments (Smith and Page 1969; Ryan et al. 1970; Scalet 1977; Scott and Angermeier 1998), and appears to be characteristic of this species. Despite the high diversity observed in spotted bass and shoal bass diets in the Flint River, Georgia, significant overlap between these two species was common, occurring in 5 of 10 comparisons across size groups and seasons. In contrast, diet overlap between spotted bass and largemouth bass was only observed in 3 of 10 comparisons, which was still a greater percentage than what was observed between the two native species.

Given the results of this study, along with that of concurrent research conducted on the Flint River, Georgia, and the fact that shoal habitats in Alabama streams appear to be heavily used by both shoal bass and spotted bass (Chapter 1), it seems obvious that competition between these species is very likely in these Alabama streams and may have contributed to the decline of shoal bass observed in Alabama streams (Stormer and Maceina 2008). Competition is known to be a major driving force structuring fish communities (Fausch and White 1981; Stein et al. 1995). While most native fish assemblages have evolved mechanisms to reduce competition for food and space (Werner et al. 1977; Harmelin-Vivien et al. 1989), the introduction of a new species that has not evolved with the native fishes creates an opportunity for conflict, which may result in negative effects on native species (Huckins et al. 2000; Moyle et al. 2003; Blanchet et al. 2007). Transfers of black bass from their native range into new areas has been occurring for a long time, but we are only now beginning to realize the ecological consequences of these actions. Research such as this study is vital to understand and predict the effects of further black bass introductions into new watersheds.

Table 3-1. Results of the first trial of the shoal bass - spotted bass competition study, conducted from April 25, 2008 to June 25, 2008 (60-d trial). Three treatments were used: heterospecific groups of both species, conspecific groups of shoal bass, and conspecific groups of spotted bass. Growth is reported as the difference between ending and beginning lengths and weights. Fish that died during the trial are not reported.

				Total Length (mm)		Weight (g)	
Tank	Treatment	Species	Number	Growth	Variance	Growth	Variance
1A	Hetero	Shoal	4	13.0	148.7	29.3	782.9
		Spotted	1	-6.0	-	-6.0	-
1B	Hetero	Shoal	3	13.7	21.3	34.0	387.0
		Spotted	3	-1.7	2.3	-6.7	101.3
2A	Con	Shoal	5	4.8	80.7	15.0	431.5
2B	Con	Shoal	5	8.4	90.3	16.2	229.2
3A	Con	Spotted	5	3.8	80.2	10.8	832.2
3B	Con	Spotted	4	0.75	12.9	15.25	80.9

Table 3-2. Results of the second trial of the shoal bass - spotted bass competition study, conducted from November 4, 2008 to February 2, 2009 (90-d trial). Three treatments were used: heterospecific groups of both species, conspecific groups of shoal bass, and conspecific groups of spotted bass. Growth is reported as the mean difference between ending and beginning lengths and weights. Fish that died during the trial are not reported.

				Total Length (mm)		Weight (g)	
Tank	Treatment	Species	Number	Growth	Variance	Growth	Variance
1B	Hetero	Shoal	1	0.0	-	6.2	-
		Spotted	1	1.0	-	10.8	-
2A	Hetero	Shoal	1	1.0	-	14.9	-
		Spotted	1	2.0	-	15.8	-
2B	Hetero	Shoal	1	2.0	-	5.8	-
		Spotted	2	5.0	2.0	2.3	45.1
3A*	Hetero	Shoal	1	2.0	-	12	-
4A	Hetero	Shoal	3	2.0	4.0	2.8	3.8
		Spotted	2	2.0	8.0	1.9	17.4
4B*	Hetero	Shoal	1	2.0	-	15.1	-
1C	Con	Shoal	5	0.4	1.8	2.6	5.2
2C	Con	Shoal	2	0.5	4.5	11.8	75.7
4C	Con	Shoal	2	13.0	392.0	19.9	505.6
5B	Con	Shoal	1	-1.0	-	3.6	-
3B	Con	Spotted	4	0.0	24.7	1.5	5.0
3C	Con	Spotted	1	0.0	-	3.6	-
5C	Con	Spotted	4	0.5	1.7	1.9	1.6

* all spotted bass died before the end of the trial and these tanks were not used for analyses

Table 3-3. Results of the third trial of the shoal bass - spotted bass competition study, conducted from March 12, 2009 to May 11, 2009 (60-d trial). Three treatments were used: heterospecific groups of both species, conspecific groups of shoal bass, and conspecific groups of spotted bass. Growth is reported as the difference between ending and beginning lengths and weights. Fish that died during the trial are not reported.

				Total Length (mm)		Weight (g)	
Tank	Treatment	Species	Number	Growth	Variance	Growth	Variance
1C	Hetero	Shoal	1	0.0	-	4.2	-
		Spotted	1	5.0	-	-6.0	-
2C	Hetero	Shoal	1	-7.0	-	-2.1	-
		Spotted	1	-3.0	-	0.3	-
2B	Con	Shoal	1	2.0	-	6.7	-
3A	Con	Shoal	1	-1.0	-	-4.8	-
3C	Con	Spotted	1	-1.0	-	2.1	-
3B	Con	Spotted	2	-2.5	12.5	-2.4	165.6

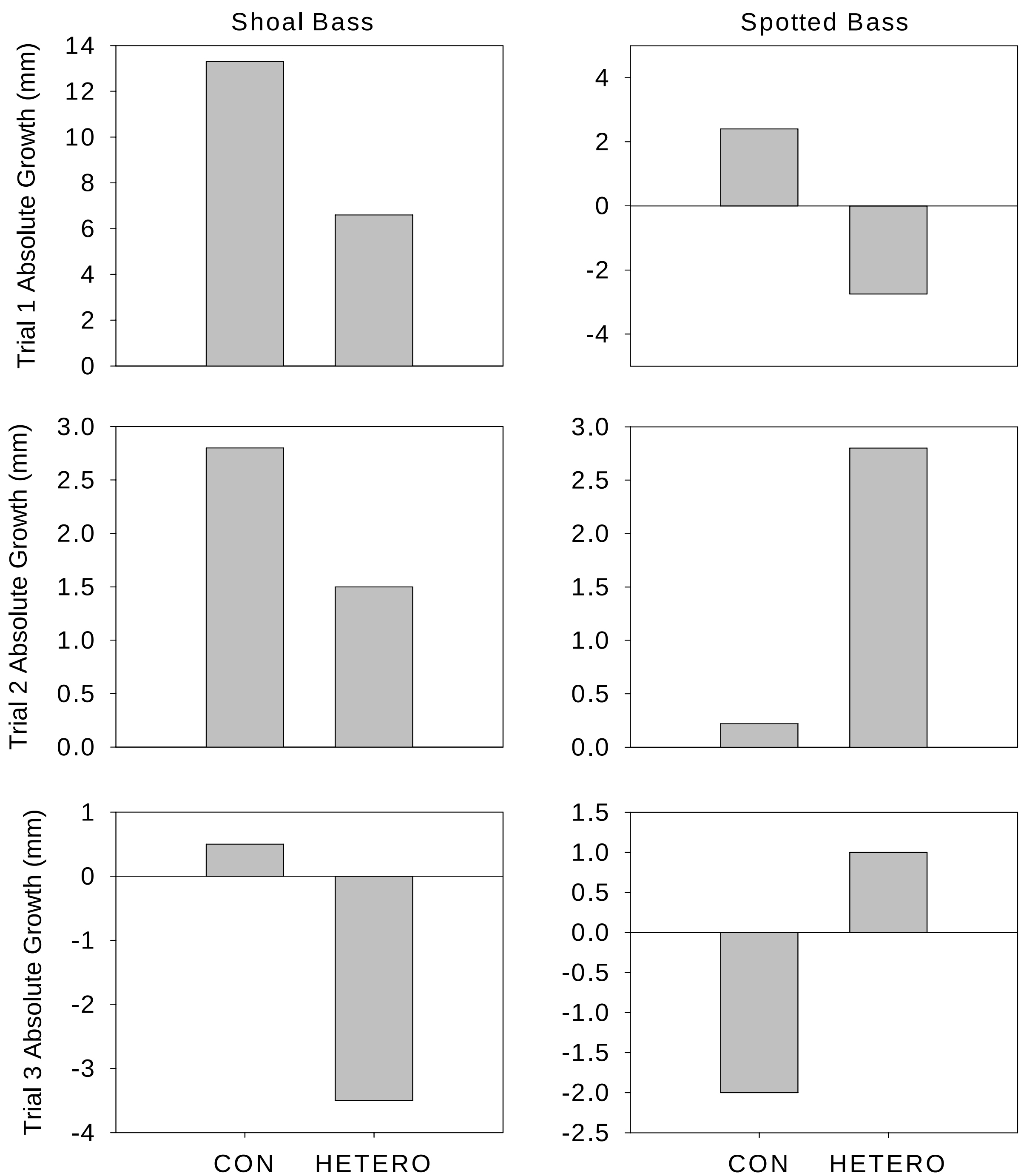

Figure 3-1. Mean absolute growth in total length of shoal bass and spotted bass stocked into outdoor tanks. Tanks were either conspecific (CON) or heterospecific (HETERO) treatments. Three trials were conducted; Trials 1 and 3 were 60-d trials and Trial 2 was 90 d. Mean growth was not different among treatments for any species and trial combination (t-test, $P > 0.05$). Note different Y-axes.

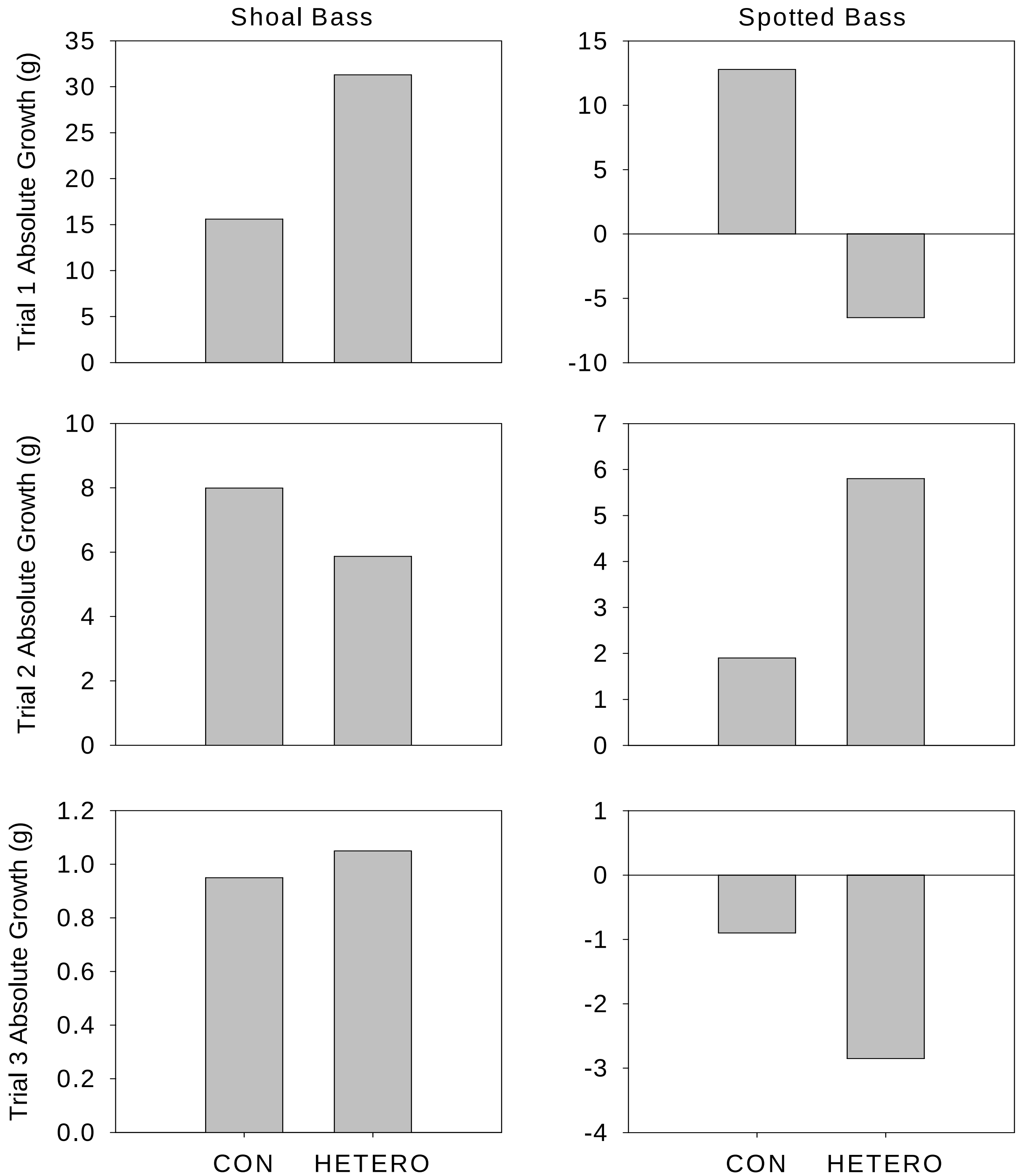

Figure 3-2. Mean absolute growth in weight of shoal bass and spotted bass stocked into outdoor tanks. Tanks were either conspecific (CON) or heterospecific (HETERO) treatments. Three trials were conducted; Trials 1 and 3 were 60-d trials and Trial 2 was 90 d. Mean growth was not different among treatments for any species and trial combination (t-test, $P > 0.05$). Note different Y-axes.

REFERENCES

Bauer, D. L. 2002. White bass population differences in Nebraska reservoirs with gizzard shad or alewife prey bases. North American Journal of Fisheries Management 22: 665-670.

Bettinger, J. M. and P. W. Bettoli. 2002. Fate, dispersal, and persistence of recently stocked and resident rainbow trout in a Tennessee tailwater. North American Journal of Fisheries Management 22: 425-432.

Blanchet, S., G. Loot, G. Grenouillet, and S. Brosse. 2007. Competitive interactions between native and exotic salmonids: a combined field and laboratory demonstration. Ecology of Freshwater Fish 16: 133-143.

Boschung, H. T., and R. L. Mayden. 2004. Fishes of Alabama. Smithsonian Books, Washington, D.C.

Boxrucker, J. 1986. Evaluation of supplemental stocking of largemouth bass as a management tool in small impoundments. North American Journal of Fisheries Management 6: 391-396.

Brooks, R. C., R. C. Heidinger, R. J. H. Hoxmeier, and D. H. Wahl. 2002. Relative survival of three sizes of walleyes stocked into Illinois lakes. North American Journal of Fisheries Management 22: 995-1006.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference, a practical information-theoretical approach, 2nd edition. Springer Science and Business Media, LLC, New York, NY.

Buynak, G. L., B. Mitchell, D. Michaelson, and K. Frey. 1999. Stocking subadult largemouth bass to meet angler expectations at Carr Creek Lake, Kentucky. North American Journal of Fisheries Management 19: 1017-1027.

Clady, M. D., and G. W. Luker. 1982. Competition between spotted and largemouth bass in variable pond ecosystems. Transactions of the American Fisheries Society 111: 665-674.

Cummins, K. W. 1962. An evaluation of some techniques for the collection and analysis of benthic samples with special emphasis on lotic waters. American Midland Naturalist 67: 477-504.

Dakin, E. E., B. A. Porter, B. J. Freeman, and J. M. Long. 2007. Genetic integrity of an isolated population of shoal bass (*Micropterus cataractae*) in the upper Chattahoochee River basin. Natural Resource Technical Report NPS/NRWRD/NRTR - 2007/366. National Park Service, Water Resources Division, Fort Collins, Colorado.

Diana, M. J., and D. H. Wahl. 2008. Long-term stocking success of largemouth bass and the relationship to natural populations. Pages 413-426 *in* M. S. Allen, S. M. Sammons, and M. J. Maceina, editors. Balancing fisheries management and water uses for impounded river systems. American Fisheries Society Symposium 62, Bethesda, Maryland.

Fausch, K. D., and R. J. White. 1981. Competition between brook trout (*Salvelinus fontinalis*) and brown trout (*Salmo trutta*) for positions in a Michigan stream. Canadian Journal of Fisheries and Aquatic Sciences 38: 1220-1227.

Hanski, I., T. Pakkala, M. Kuussaari, and G. Lei. 1995. Metapopulation persistence of an endangered butterfly in a fragmented landscape. Oikos 72: 21-28.

Harmelin-Vivien, M. L., R. A. Kaim-Malka, M. Ledoyer, and S. S. Jacob-Abraham. 1989. Food partitioning among scorpaenid fishes in Mediterranean seagrass beds._ Journal of Fish Biology 34: 715-734.

Hoffman, K. J., and P. W. Bettoli. 2005. Growth, dispersal, mortality, and contribution of largemouth bass stocked into Chickamauga Lake, Tennessee. North American Journal of Fisheries Management 25: 1518-1527.

Huckins, C. J. F., C. W. Osenberg, G. G. Mittelbach. 2000. Species introductions and their ecological consequences: An example with congeneric sunfish. Ecological Applications 10: 612-625.

Hurst, H. N. 1969. Comparative life history of the redeye bass, *Micropterus coosae* (Hubbs and Bailey), and the spotted bass, *Micropterus p. punctulatus* (Rafinesque), in Halawakee Creek, Alabama. M.S. Thesis, Auburn University, Alabama.

Hurst, H. N., G. Bass, and C. Hubbs. 1975. The biology of the Guadalupe, Suwannee, and redeye basses. Pages 47-53 *in* R. H. Stroud and H. Clepper, editors. Black Bass Biology and Management. Sport Fishing Institute, Washington D.C., USA.

Isely, J. J., and T. B. Grabowski. 2007. Age and Growth. Pages 187-228 *in* C. S. Guy and M. L. Brown, editors. Analysis and interpretation of freshwater fisheries data. American Fisheries Society, Bethesda, Maryland.

Isermann, D.A., P.W. Bettoli, S.M. Sammons, and T. N. Churchill. 2002. Initial post-stocking mortality, oxytetracycline marking, and year-class contribution of black-nosed crappies stocked into Tennessee reservoirs. North American Journal of Fisheries Management 22: 699-708.

Jaeger, M. E., A. V. Zale, T. E McMahon, and B. J. Schmitz. 2005. Seasonal movements, habitat use, aggregation, exploitation, and entrainment of saugers in the Lower Yellowstone River: An empirical assessment of factors affecting population recovery. North American Journal of Fisheries Management 25: 1550-1568.

Jager, H. I., J. A. Chandler, K. B. Lepla, and W. Van Winkle. 2001. A theoretical study of river fragmentation by dams and its effects on white sturgeon populations. Environmental Biology of Fishes 60: 347-361.

Johnston, C. E. and R. A. Kennon. 2007. Habitat use of the shoal bass, Micropterus cataractae, in an Alabama stream. Journal of Freshwater Ecology 22: 493-498.

Johnston, C. E. and M. J. Maceina. 2009. Fish assemblage shifts and species declines in Alabama, USA streams. Ecology of Freshwater Fish 18: 33-40.

Kelsch, S. W. 1994. Lotic Fish-Community Structure Following Transition from Severe Drought to High Discharge. Journal of Freshwater Ecology 9: 331-341.

Krebs, C. J. 2003. Programs for Ecological Methodology, version 6.1.1. University of British Columbia, Vancouver.

Layher, W. G., O. E. Maughan, and W. D. Warde. 1987. Spotted bass habitat suitability related to fish occurrence and biomass and measurements of physicochemical variables. North American Journal of Fisheries Management 7: 238-251.

Long, J. M., and W. L. Fisher. 2000. Inter-annual and size-related differences in the diets of three sympatric black bass in an Oklahoma reservoir. Journal of Freshwater Ecology 15: 465-474.

Maceina, M. J. 1992. A simple regression model to assess environmental effects on fish growth. Journal of Fish Biology 41**:** 557-565.

Mallows, C. L. 1973. Some comments on Cp. Technometrics 15: 661-675.

Martinez, P. J., T. E. Chart, M. A. Trammell, J. G. Wullschleger, and E. P. Bergersen. 1994. Fish Species Composition before and after Construction of a Main Stem Reservoir on the White River, Colorado. Environmental Biology of Fishes 40: 227-239.

Matthews, W. J. and E. Marsh-Matthews. 2003. Effects of drought on fish across axes of space, time and ecological complexity. Freshwater Biology 48: 1232-1253.

Miller, R. J. 1975. Comparative behavior of Centrarchid basses. Pages 85-94 in R. H. Stroud and H. Clepper, editors. Black Bass Biology and Management. Sport Fishing Institute, Washington D.C., USA.

Miranda, L. E. 1996. Development of reservoir fisheries management paradigms in the Twentieth Century. Pages 3-11 *in* L. E. Miranda and D. R. DeVries, editors. Multidimensional approaches to reservoir fisheries management. American Fisheries Society, Bethesda, Maryland.

Mirarchi, R.E., J. T. Garner, M. F. Mettee, and P. E. O'Neil (eds). 2004. Alabama wildlife, volume two: imperiled aquatic mollusks and fishes. The University of Alabama Press, Montgomery.

Moore, C. M., R. J. Neves, and J. J. Ney. 1991. Survival and abundance of stocked striped bass in Smith Mountain Lake, Virginia. North American Journal of Fisheries Management 11: 393-399.

Morizot, D. C., S. W. Calhoun, L. L. Clepper, M. E. Schmidt, J. H. Williamson, and G. J. Carmichael. 1991. Multispecies hybridization among native and introduced Centrarchid basses in Central Texas. Transactions of the American Fisheries Society 120: 283-289.

Moyle, P. B., P. K. Crain, K. Whitener, and J. F. Mount. 2003. Alien fishes in natural streams: fish distribution, assemblage structure, and conservation in the Consumnes River, California, U.S.A. Environmental Biology of Fishes 68: 143-162.

Pierce, P. C., and M. J. VanDenAvyle. 1997. Hybridization between introduced spotted bass and smallmouth bass in reservoirs. Transactions of the American Fisheries Society 126: 939-947.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Fisheries Research Board of Canada Bulletin 191.

Ricks, B. R. 2006. Effects of tournament fishing on dispersal and population characteristics of black bass in Lake Martin, Alabama. M. S. Thesis, Auburn University, Alabama.

Ryan, M. J., M. A. Webb, and L. T. Fries. 1998. Contribution of largemouth bass reared in nursery ponds to year classes in two Texas reservoirs. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 50(1996): 131-138.

Ryan, P. W., J. W. Avault, and R. O. Smitherman. 1970. Food habits and spawning of spotted bass in Tchefuncte River, southeastern Louisiana. Progressive Fish-Culturist 32: 162-167.

Sammons, S.M. and P.W. Bettoli. 1999. Spatial and temporal variation in electrofishing catch rates of three black bass species from Normandy Reservoir, Tennessee. North American Journal of Fisheries Management 19:454-461.

Santucci, V. J. and D. H. Wahl. 1993. Factors influencing survival and growth of stocked walleye (*Stizostedion vitreum*) in a centrarchid-dominated impoundment. Canadian Journal of Fisheries and Aquatic Sciences 50: 1548-1558.

SAS Institute, Inc. 2004. SAS system for linear models. Release 9.1. Cary, North Carolina.

Scalet, C. G. 1977. Summer food habits of sympatric stream populations of spotted bass, *Micropterus punctulatus*, and largemouth bass, M. salmoides, (Osteichthyes: Centrarchidae). The Southwest Naturalist 21: 493-501.

Schlosser, I. J., and P. L. Angermeier. 1995. Spatial variation in demographic processes of lotic fishes: conceptual models, empirical evidence, and implications for conservation. Pages 392-401 *in* J. L. Nielsen, editor. Evolution and the Aquatic Ecosystem: Defining Unique Units in Population Conservation. American Fisheries Society, Bethesda, Maryland.

Scott, M. C., and P. L. Angermeier. 1998. Resource use of two sympatric black basses in impounded and riverine sections of the New River, Virginia. North American Journal of Fisheries Management 18: 221-235.

Simonson, T. D., J. Lyons, and P. D. Kanehl. 1994. Quantifying fish habitat in streams: Transect spacing, sample size, and a proposed framework. North American Journal of Fisheries Management 14: 607-615.

Smith, P. W., and L. M. Page. 1969. Food of spotted bass in streams of the Wabash River drainage. Transactions of the American Fisheries Society 98: 647-651.

Smitherman, R. O. 1975. Experimental species associations of basses in Alabama ponds. Pages 76-84 in R. H. Stroud and H. Clepper, editors. Black Bass Biology and Management. Sport Fishing Institute, Washington D.C., USA.

Smitherman, R. O., and J. S. Ramsey. 1972. Observations on spawning and growth of four species of basses (*Micropterus*) in ponds. Proceedings of the Associated Fish and Wildlife Agencies 25 (1971): 357-365.

Steel, R. G. D., and J. H. Torrie. 1980. Principles and procedures of statistics. 2nd edition. McGraw-Hill Publishing Company, New York.

Stein, R. A., D. R. DeVries, and J. M. Dettmers. 1995. Food-web regulation by a planktivore: Exploring the generality of the trophic cascade hypothesis. Canadian Journal of Fisheries and Aquatic Sciences 52: 2518-2526.

Stormer, D. G. 2007. Distribution, abundance, and population characteristics of shoal bass in tributaries of the Chattahoochee River, Alabama. M. S. Thesis, Auburn University, Auburn.

Stormer, D. G., and M. J. Maceina. 2008. Relative abundance, distribution, and population metrics of shoal bass in Alabama. Journal of Freshwater Ecology 23: 651-661.

Stormer, D. G., and M. J. Maceina. 2009. Habitat use, home range, and movement of shoal bass in Alabama. North American Journal of Fisheries Management 29: 604-613.

Tillma, J. S., C. S. Guy, and C. S. Mammoliti. 1998. Relations among habitat and population characteristics of spotted bass in Kansas streams. North American Journal of Fisheries Management 18: 886-893.

Tramer, E. J. 1977. Catastrophic mortality of stream fishes trapped in shrinking pools. American Midland Naturalist 97: 469-478.

U. S. Fish and Wildlife Service and U. S. Bureau of the Census. 2008. 2006 national survey of fishing, hunting, and wildlife-associated recreation. U. S. Government Printing Office, Washington, D.C.

Vogele, L. E. 1975. The spotted bass. Pages 34-45 *in* R. H. Stroud and H. Clepper, editors. Black Bass Biology and Management. Sport Fishing Institute, Washington D.C., USA.

Walser, C. A., and H. L. Bart. 1999. Influence of agriculture on in-stream habitat and fish community structure in Piedmont watersheds of the Chattahoochee River System. Ecology of Freshwater Fish 8: 237-246.

Warren, M. L., and 11 coauthors. 2000. Diversity, distribution, and conservation status of the native freshwater fishes of the southern United States. Fisheries 25: 7-31.

Werner, E. E., D. J. Hall, D. R. Laughlin, D. J. Wagner, L. A. Wilsmann, and Funk, F. C. 1977. Habitat partitioning in a freshwater fish community. Journal of the Fisheries Research Board of Canada 34: 360-370.

Wheeler, A. P., and M. S. Allen. 2003. Habitat and diet partitioning between shoal bass and largemouth bass in the Chipola River, Florida. Transactions of the American Fisheries Society 132: 438-449.

Williams, J. D., and G. H. Burgess. 1999. A new species of bass, *Micropterus cataractae* (Teleostei: Centrarchidae), from the Apalachicola River Basin in Alabama, Florida, and Georgia. Bulletin of the Florida Museum of Natural History 42(2): 81-114.

Winemiller, K. O., and D. H. Taylor. 1987. Predatory behavior and competition among laboratory-housed largemouth and smallmouth bass. The American Midland Naturalist 117: 148-166.

Williams, J. E., and 7 coauthors. 1989. Fishes of North America endangered, threatened, or of special concern: 1989. Fisheries 14: 2-20.

Yow, D. L., K. B. Hodges, A. P. Wheeler, and J. M. Rash. 2008. Crowding and response: Angler perceptions on western North Carolina reservoirs. Pages 231-245 *in* M. S. Allen, S. M. Sammons, and M. J. Maceina, editors. Balancing fisheries management and water uses for impounded river systems. American Fisheries Society Symposium 62, Bethesda, Maryland.

APPENDIX TABLES

Appendix Table 1. Mean habitat values measured in four types of mesohabitats (pool [PL], riffle [RF], run [RN], and shoal [SH]) from the Beans Mill area of Halawakee Creek in August 2008. Habitat values were percent woody debris (%W), percent rock cover (%RK), bankfull stream width (BF WID), current, wetted stream width (CUR WID), depth (DEP), stream flow (VEL), and percent boulder (% BD), bedrock (% BR), cobble (% COB), gravel (% GR), and sand (%SD) substrate.

MESO	% WD	% RK	BF WID	CUR WID	DEP	VEL	% BD	% BR	% COB	% GR	% SD
PL1	5.0	80.0	16.7	16.3	0.2	0.015	0.0	0.0	90.0	0.0	10.0
PL2	10.0	85.0	13.8	12.9	0.4	0.012	30.0	0.0	60.0	0.0	10.0
PL3	5.0	75.0	20.9	13.3	0.5	0.040	0.0	0.0	75.0	0.0	25.0
PL4	20.0	50.0	13.7	11.4	0.2	0.031	0.0	0.0	50.0	30.0	20.0
RF1	5.0	100.0	15.9	8.1	0.1	0.150	0.0	0.0	100.0	0.0	0.0
RF2	1.0	100.0	15.9	8.1	0.1	0.150	0.0	0.0	100.0	0.0	0.0
RN1	0.0	95.0	17.5	16.7	0.1	0.086	2.9	8.6	80.0	2.9	5.7
RN2	5.0	85.0	17.1	13.3	0.2	0.42	10.0	5.0	75.0	10.0	0.0
SH1	5.0	100.0	36.1	29.1	0.3	0.322	0.0	100.0	0.0	0.0	0.0

Appendix Table 2. Mean habitat values measured in two types of mesohabitats (run [RN] and shoal [SH]) from the Moffits Mill area of Little Uchee Creek in September 2008. Habitat values were percent woody debris (%W), percent rock cover (%RK), bankfull stream width (BF WID), current, wetted stream width (CUR WID), depth (DEP), stream flow (VEL), and percent boulder (% BD), bedrock (% BR), cobble (% COB), gravel (% GR), and sand (%SD) substrate.

MESO	% WD	% RK	BF WID	CUR WID	DEP	VEL	% BD	% BR	% COB	% GR	% SD
RN1	5.0	100.0	24.4	24.4	0.4	0.022	0.0	100.0	0.0	0.0	0.0
RN2	10.0	70.0	25.5	23.1	0.2	0.096	0.0	80.0	0.0	0.0	20.0
RN3	5.0	40.0	14.7	12.8	0.3	0.084	20.0	0.0	20.0	20.0	40.0
SH1	0.0	100.0	40.5	38.0	0.1	0.046	0.0	100.0	0.0	0.0	0.0
SH2	0.0	100.0	32.5	25.2	0.2	0.109	3.0	97.0	0.0	0.0	0.0
SH3	0.0	100.0	14.55	8.3	0.2	0.250	70.0	10.0	20.0	0.0	0.0

Appendix Table 3. Mean habitat values measured in three types of mesohabitats (pool [PL], run [RN], and shoal [SH]) from the Travis Carter area of Osanippa Creek in July 2008. Habitat values were percent woody debris (%W), percent rock cover (%RK), bankfull stream width (BF WID), current, wetted stream width (CUR WID), depth (DEP), stream flow (VEL), and percent boulder (% BD), bedrock (% BR), cobble (% COB), gravel (% GR), and sand (%SD) substrate.

MESO	% WD	% RK	BF WID	CUR WID	DEP	VEL	% BD	% BR	% COB	% GR	% SD
PL1	10.0	85.0	21.0	19.5	0.6	0.004	0.0	100.0	0.0	0.0	0.0
PL2	10.0	50.0	.	.	.	.	.	.	.	.	.
PL3	5.0	60.0	27.0	26.0	0.8	0.006	20.0	0.0	0.0	0.0	80.0
PL4	5.0	100.0	21.0	8.0	1.3	0.010	0.0	100.0	0.0	0.0	0.0
PL5	10.0	50.0	30.1	22.3	0.4	0.006	22.0	22.0	0.0	11.0	44.0
RN1	0.0	90.0	22.0	20.0	0.6	0.007	0.0	100.0	0.0	0.0	0.0
RN2	5.0	90.0	23.6	18.5	0.4	0.006	64.0	0.0	0.0	0.0	36.0
RN3	1.0	100.0	30.0	26.0	0.5	0.013	0.0	100.0	0.0	0.0	0.0
SH1	0.0	100.0	22.0	15.0	0.2	0.110	0.0	100.0	0.0	0.0	0.0
SH2	1.0	100.0	25.6	20.4	0.2	0.040	0.0	100.0	0.0	0.0	0.0
SH3	0.0	100.0	25.9	19.6	0.2	0.103	0.0	100.0	0.0	0.0	0.0
SH4	0.0	100.0	30.1	23.5	0.2	0.159	0.0	100.0	0.0	0.0	0.0

Appendix Table 4. Mean habitat values measured in three types of mesohabitats (pool [PL], run [RN], and shoal [SH]) from the Goat Rock Hunt Club area of Wacoochee Creek in October 2008. Habitat values were percent woody debris (%W), percent rock cover (%RK), bankfull stream width (BF WID), current, wetted stream width (CUR WID), depth (DEP), stream flow (VEL), and percent boulder (% BD), bedrock (% BR), cobble (% COB), gravel (% GR), and sand (%SD) substrate.

MESO	% WD	% RK	BF WID	CUR WID	DEP	VEL	% BD	% BR	% COB	% GR	% SD
PL1	0.0	70.0	16.0	15.4	0.7	0.016	0.0	100.0	0.0	0.0	0.0
RN1	10.0	90.0	21.2	20.5	0.2	0.066	0.0	100.0	0.0	0.0	0.0
RN2	0.0	100.0	17.0	17.0	0.4	0.045	0.0	100.0	0.0	0.0	0.0
RN3	5.0	100.0	17.4	16.0	0.2	0.251	0.0	100.0	0.0	0.0	0.0
RN4	5.0	90.0	19.5	15.0	0.3	0.025	0.0	95.0	0.0	0.0	5.0
RN5	0.0	95.0	17.3	12.8	0.3	0.022	30.0	50.0	0.0	0.0	20.0
SH1	15.0	90.0	18.5	18.0	0.2	0.030	0.0	100.0	0.0	0.0	0.0
SH2	0.0	100.0	12.3	11.0	0.2	0.090	0.0	100.0	0.0	0.0	0.0
SH3	5.0	80.0	30.0	30.0	0.1	0.038	0.0	100.0	0.0	0.0	0.0
SH4	0.0	75.0	16.8	12.1	0.2	0.115	0.0	95.0	0.0	0.0	5.0

Appendix Table 5. Fish sampled from the lowest shoal on Halawakee Creek, Alabama, for fin clips for genetic analyses. Fin clips were sent to Dr. Phillip M. Harris, results are presented in a separate report.

Sample Date	ID	Field ID	TL	WT
June 3, 2008	Hal 1	Spotted Bass	214	113
	Hal 2	Spotted Bass	147	35
	Hal 3	Spotted Bass	134	25
	Hal 4	Spotted Bass	121	-
	Hal 5	Spotted Bass	115	-
	Hal 6	Spotted Bass	317	438
June 6, 2008	Hal 7	Spotted Bass	320	298
	Hal 8	Spotted Bass	227	111
	Hal 9	Spotted Bass	158	41
	Hal 10	Spotted Bass	186	64
	Hal 11	Spotted Bass	114	13
	Hal 12	Spotted Bass	277	225
	Hal 13	Spotted Bass	285	202
	Hal 14	Spotted Bass	120	16
	Hal 15	Spotted Bass	206	100
	Hal 16	Spotted Bass	278	245
	Hal 17	Spotted Bass	94	-
	Hal 18	Spotted Bass	104	-
	Hal 19	Hybrid	120	-
	Hal 20	Spotted Bass	336	442
	Hal 21	Spotted Bass	129	22
	Hal 22	Spotted Bass	212	94

Appendix Table 6. Fish sampled below Goat Rock Dam on the Chattahoochee River for fin clips for genetic analyses. Fin clips were sent to Dr. Phillip M. Harris, results are presented in a separate report.

Sample Date	ID	Field ID	TL	WT
June 26, 2008	GR 1	Spotted Bass	342	429
	GR 2	Spotted Bass	362	552
	GR 3	Spotted Bass	331	420
	GR 4	Spotted Bass	407	824
	GR 5	Spotted Bass	274	228
	GR 6	Spotted Bass	257	197
	GR 7	Spotted Bass	304	280
	GR 8	Spotted Bass	146	34
	GR 9	Spotted Bass	54	-
	GR 10	Spotted Bass	76	-
	GR 11	Spotted Bass	305	330
	GR 12	Spotted Bass	141	31
	GR 13	Spotted Bass	131	24
	GR 14	Spotted Bass	116	-
	GR 15	Spotted Bass	132	29
	GR 16	Shoal Bass	544	-
	GR 17	Hybrid	400	1025

Appendix Table 7. Fish sampled below Bartletts Ferry Dam on the Chattahoochee River for fin clips for genetic analyses. Fin clips were sent to Dr. Phillip M. Harris, results are presented in a separate report.

Sample Date	ID	Field ID	TL	WT
August 1, 2008	BF 1	Spotted Bass	146	31
	BF 2	Spotted Bass	261	259
	BF 3	Spotted Bass	335	506
	BF 4	Spotted Bass	277	313
	BF 5	Spotted Bass	295	287
	BF 6	Spotted Bass	146	41
	BF 7	Spotted Bass	75	4
	BF 8	Spotted Bass	55	-
	BF 9	Spotted Bass	247	164
	BF 10	Spotted Bass	244	182
	BF 11	Spotted Bass	284	267
	BF 12	Spotted Bass	138	26
	BF 13	Spotted Bass	142	29
	BF 14	Spotted Bass	155	42
	BF 15	Spotted Bass	56	-
	BF 16	Spotted Bass	145	33
	BF 17	Spotted Bass	181	68

Appendix Table 8. Fish sampled at Travis Carter's property on Osanippa Creek, Alabama, for fin clips for genetic analyses. Fin clips were sent to Dr. Phillip M. Harris, results are presented in a separate report.

Sample Date	ID	Field ID	TL	WT
July 22, 2008	OSA 1	Spotted Bass	53	-
	OSA 2	Spotted Bass	143	28
	OSA 3	Spotted Bass	142	29
	OSA 4	Spotted Bass	114	-
	OSA 5	Spotted Bass	209	99
	OSA 6	Spotted Bass	130	21
	OSA 7	Spotted Bass	54	-
	OSA 8	Spotted Bass	75	4
	OSA 9	Spotted Bass	108	-
	OSA 10	Spotted Bass	129	26
	OSA 11	Spotted Bass	67	-
	OSA 12	Spotted Bass	122	19
	OSA 13	Spotted Bass	127	19
	OSA 14	Spotted Bass	195	73
	OSA 15	Spotted Bass	126	17
	OSA 16	Spotted Bass	110	-
	OSA 17	Spotted Bass	67	-
	OSA 18	Spotted Bass	124	20
	OSA 19	Spotted Bass	117	16
	OSA 20	Spotted Bass	237	145
	OSA 21	Spotted Bass	179	52

Appendix Table 9. Fish sampled at the Moffits Mill shoal on Little Uchee Creek, Alabama, for fin clips for genetic analyses. Fin clips were sent to Dr. Phillip M. Harris, results are presented in a separate report.

Sample Date	ID	Field ID	TL	WT
September 3, 2008	LU 1	Shoal Bass	169	54
	LU 2	Shoal Bass	178	53
	LU 3	Shoal Bass	65	-
	LU 4	Shoal Bass	77	-
	LU 5	Shoal Bass	69	-
	LU 6	Shoal Bass	72	-
	LU 7	Shoal Bass	135	-
	LU 8	Shoal Bass	169	46
	LU 9	Shoal Bass	83	-
	LU 10	Shoal Bass	186	64
	LU 11	Shoal Bass	215	103
	LU 12	Shoal Bass	67	-
	LU 13	Shoal Bass	142	27
	LU 14	Shoal Bass	157	37
	LU 15	Shoal Bass	75	-
	LU 16	Shoal Bass	155	39
	LU 17	Shoal Bass	207	88
	LU 18	Shoal Bass	319	354
	LU 19	Shoal Bass	209	96
	LU 20	Shoal Bass	158	40
	LU 21	Shoal Bass	311	405
	LU 22	Shoal Bass	256	192
	LU 23	Shoal Bass	141	27
	LU 24	Shoal Bass	278	248
	LU 25	Shoal Bass	147	34

Appendix Table 10. Latitude and longitude of sample sites on Alabama streams and Chattahoochee River reaches sampled for black bass during 2008-2009.

Stream/Area	Latitude	Longitude
Halawakee/Upper	32.715760	85.285500
Halawakee/Mill Pond	32.699969	85.266275
Halawakee/Below Beans Mill	32.697080	85.266810
Halawakee/Lower	32.684600	85.203346
Little Uchee/Griffins Mill	32.526710	85.264450
Little Uchee/Moffits Mill	32.506830	85.180030
Osanippa/Travis Carter	32.778410	85.193310
Osanippa/Below Travis Carter	32.775070	85.185390
Wacoochee/Goat Rock Hunt Club	32.628500	85.111030
Chattahoochee River/Langdale	32.814200	85.164550
Chattahoochee River/Riverview	32.794528	85.141564
Chattahoochee River/Bartletts Ferry	32.661000	85.090494
Chattahoochee River/Goat Rock	32.605722	85.078806
Chattahoochee River/Oliver	32.513919	84.995825
Chattahoochee River/North Highlands	32.496658	84.995114
Chattahoochee River/Eagle Phenix	32.467769	84.997530