DISTRIBUTION, ABUNDANCE, AND POPULATION CHARACTERISTICS OF

SHOAL BASS IN TRIBUTARIES OF THE CHATTAHOOCHEE

RIVER, ALABAMA

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DISTRIBUTION, ABUNDANCE, AND POPULATION CHARACTERISTICS OF SHOAL BASS IN TRIBUTARIES OF THE CHATTAHOOCHEE RIVER, ALABAMA

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THESIS ABSTRACT

DISTRIBUTION, ABUNDANCE, AND POPULATION CHARACTERISTICS OF SHOAL BASS IN TRIBUTARIES OF THE CHATTAHOOCHEE RIVER, ALABAMA

David G. Stormer

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The shoal bass *Micropterus cataractae* is the most recently described black bass species and in east-central Alabama, this fish only occurs in streams that flow into the Chattahoochee River. Recently, shoal bass were listed as a species of special concern in Alabama. Shoal bass are considered habitat specialists and prefer shoals, but little information exists on the current status, habitat use, movement, and home range size. Fifty km of 4 tributaries (Wacoochee, Halawakee, Little Uchee, and Osanippa) of the Chattahoochee River were surveyed and about 6 km of shoal bass habitat were found. Only one substantial population of shoal bass was found (Moffits Mill on Little Uchee

Creek). On the three other streams, these fish were infrequently collected or rare.

A multiple census mark-recapture study in April 2005 estimated a population size of 72 shoal bass (90% CI = 48, 130) with a density and biomass of 42 fish/ha and 11.7 kg/ha of shoal bass ($\geq$ 150 mm TL) residing in the Moffits Mill shoal. Estimates of shoal bass population size were similar in November 2005 (N = 107) and April 2006 (N = 69), but declined dramatically in November 2006 (N = 13) and April 2007 (N = 23) due to mortality and some migration from the shoal as this site dewatered in summer-fall 2006. From November 2005 to April 2006, survival was 82% based on mortality sensors in radio telemetered fish, but declined to 22% over a 6-month period after this time.

Radio telemetry of 24 shoal bass revealed that these fish exhibited relatively sedentary behavior with little movement outside of the shoal. However, as dry conditions persisted through summer and fall 2006, movement increased and 3 individuals moved to a refuge area just downstream of the dewatered shoal. Shoal bass were strongly associated with boulder substrate, lower-than-available current velocity ($\leq$0.10 m/s), and average available depth (0.30 m - 0.50 m). Home range analysis revealed that 92 % of radio tagged shoal bass remained within the total area of the Moffits Mill shoal and indicated that these fish primarily used the shoal throughout the year.

Eighty-seven shoal bass ($\geq$150 mm TL) were collected from the Moffits Mill shoal between April 2005 and April 2007 to describe the weight:length relationship ($\log_{10}(Wt) = -5.490 + 3.235*\log_{10}(TL)$). Shoal bass from the Flint River, Georgia were in better condition and exhibited greater growth rates in total length (mm) and weight (g) than for fish from Moffits Mill.

Based on anecdotal evidence, shoal bass have likely declined (except for 1 population) in Chattahoochee River tributaries in Alabama. Land use changes, population fragmentation, and habitat changes may have caused this decline. Possible conservation strategies include protection of the upper and middle Little Uchee Creek basin, water withdrawal protection within watersheds of the 4 tributaries I sampled, and stocking shoal bass in the 3 other tributaries. A moratorium of shoal bass harvest in Alabama was put into effect on 1 October, 2006 in an attempt to protect this population.

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INTRODUCTION

Alabama contains a diverse aquatic fauna in North America as more than a third of all North American freshwater fishes reside in its waters (Lydeard and Mayden 1995). The faunal richness observed in Alabama may be attributed to the 23,000 km of streams and rivers that traverse numerous distinct physiographic regions, and several distinct drainages, eventually draining into the Gulf of Mexico and Tennessee River.

The Chattahoochee River, which borders sections of Alabama and Georgia, is particularly distinct from other Alabama rivers and the faunal community is unique and greatly contributes to regional aquatic diversity. In Alabama, tributaries of the Chattahoochee River drain regions both above and below the physiographic fall line. The number of unique species includes fishes exclusive to upland and lowland habitats. While these systems are relatively small and restricted to a limited portion of the state, many species are native only to the streams in the Chattahoochee drainage (Lydeard and Mayden 1995).

Ten species native to the Chattahoochee River drainage in Alabama are currently considered species of special concern in Alabama (Mirarchi et al. 2004). These species may be vulnerable to reduced abundance or even extirpation as a result of limited or altered adequate habitat while other species have limited range (Johnston and Farmer

2004). One of the rare and potentially vulnerable species native to the Chattahoochee drainage of Alabama is the shoal bass *Micropterus cataractae*. The shoal bass is the most recently described species of black bass, but has been recognized as a distinct black bass species for many years (Williams and Burgess 1999). Shoal bass have often been confused with or historically referred to as a type of redeye bass *M. coosae*. Morphologically, shoal bass most closely resemble spotted bass *M. punctulatus* and these two species are known to occur in the same river drainages in Alabama, Georgia and Florida (Williams and Burgess 1999). In the Apalachicola basin, the shoal bass occurs sympatrically with redeye bass, spotted bass, and largemouth bass *M. salmoides*. In Alabama, however, the shoal bass is only found in the Chattahoochee River drainage (Ramsey 1975; Williams and Burgess 1999).

Williams and Burgess (1999) suggested the distribution and abundance of shoal bass may be declining in Alabama. Among the possible reasons for the decline in shoal bass include habitat loss from impoundment of the Chattahoochee River and its tributaries (Williams and Burgess 1999). Evidence has suggested that shoal bass stocked in ponds may initially survive, but are not likely to persist over time (Smitherman 1975). Smitherman and Ramsey (1972) also found that the shoal bass experienced the highest mortality of four stream dwelling black basses (*M. coosae, M. cataractae, M. punctulatus, M. dolomieu, M. notius*) after stocked into the same pond with fathead minnows *Pimephales promelas*. Shoal bass likely do not survive over time in impoundments due to habitat alteration and/or competitive interactions with other black bass species (Williams and Burgess 1999). Additional causes for the decline in range and abundance of shoal bass may include pollution, poor land use (leading to increased siltation) and deterioration of water quality which contributes to habitat degradation (Ramsey 1975; Ogilvie 1980). Williams and Burgess (1999) suggested a thorough survey of the Chattahoochee River and its tributaries to describe the current status of shoal bass within this unique system.

Typically, examination of black bass habitat associations focused on populations from natural lakes, reservoirs, and small impoundments (Tillma et al. 1998). However, black basses are distributed throughout the United States and all of these species are known to occur in lotic systems. Quantifying habitat requirements and preferences for stream-dwelling black basses is an essential component in determining management plans and restorative procedures for populations that are in decline (Paragamian 1981). Although shoal bass are considered habitat specialists (Ramsey 1975; Williams and Burgess 1999), there is a paucity of information regarding habitat use for this species. Wheeler and Allen (2003) investigated macrohabitat and microhabitat use of sympatric shoal bass and largemouth bass in a section of the Chipola River, Florida. These fish exhibited habitat partitioning, possibly to minimize interspecific competition. These results indicated that shoal bass preferred shoal habitat and rocky substrate while largemouth bass favored pools with sand bottom (Wheeler and Allen 2003).

Currently, no information exists regarding movement or home range size for shoal bass. Movement and behavior have been examined for other centrarchids, which has improved management and conservation efforts. Variability in black bass movement patterns in lotic systems has been associated with fluctuations in temperature, flow, and depth, as well as differences in substrate, cover, and habitat type (Barrett and Maughan 1994; Buynak and Mitchell 2002; Rankin 1986: Sowa and Rabeni 1995; Todd and Rabeni 1989). Lyons and Kanehl (2002) reported significantly different seasonal movement patterns and habitat associations between northern and mid-western stream-dwelling smallmouth bass populations. Spotted bass movement was significantly higher during spring and fall than summer and winter in Otter Creek, Kansas (Horton and Guy 2002). The description of seasonal movement and diel activity along with quantifying habitat associations for spotted bass in this stream assisted in generating recommendations for restorative procedures (Horton and Guy 2002). In the Pend Orielle River, Idaho, largemouth bass migrated as much as 16 km to two warm water overwintering areas in late fall as a result of flood control drawdowns and re-distributed throughout the river and its tributaries in the spring (Karchesky and Bennett 2004). Understanding and quantifying movement patterns and habitat use by stream-dwelling black basses offer insights into the potential implications of restricting movement by stream alteration or habitat modification.

Relative abundance and distribution of shoal bass in Alabama is not known and should be examined to determine its current status. Identifying habitat requirements for shoal bass in Alabama is also important as it could lead to the designation of critical habitat necessary to maintain this species, and to restore habitats that have been altered or degraded.

Of particular interest is the potential movement of shoal bass among shoal habitats within a stream and isolation among populations. Isolated populations that are low in abundance, are at a greater risk of extirpation (Morita and Yokota 2002). Information including home range size and movement patterns of shoal bass will provide a better understanding of the behavior of this species and could lead to improved implementation of conservation measures.

In this study, I estimated the amount of available shoal habitat and assessed distribution and relative abundance of shoal bass in four tributaries of the Chattahoochee River. In one of these tributaries, radio telemetry was used to describe seasonal movement, home range, and habitat use by shoal bass at a single site (Moffits Mill on Little Uchee Creek). Population metrics including abundance, growth, the weight:length relationship, survival, and the length-frequency distribution were also estimated for shoal bass at Moffits Mill.

STUDY SITES

Portions of four tributaries located within the Chattahoochee River drainage in Alabama were selected for investigating distribution and relative abundance of shoal bass. Selected streams were chosen based on historic collections of shoal bass from Halawakee, Wacoochee, and Little Uchee creeks (Williams and Burgess 1999), and accounts of shoal bass presence in Osanippa Creek (Figure 1). These streams are found within the Southern Piedmont Upland physiographic region and are characterized by alternating gravel and bedrock riffles and sand-bottomed pools. The selected streams are relatively shallow (< 2 m) and have variable current (Gilbert 1969). Pine and hardwood forests dominate the watersheds for these streams, but some areas have been cleared and developed in the last several years.

Halawakee Creek originates in Chambers County and flows for approximately 29 km in a southeasterly direction to its confluence with the Chattahoochee River at Lake Harding (Figure 1). The Halawakee Creek watershed drains approximately 225 km^2 of land in Lee County. Wacoochee Creek is about 25 km long and joins the mainstem of the Chattahoochee River of the impounded Goat Rock Lake in Lee County. The Wacoochee Creek watershed drains 85 km^2 of land. Osanippa Creek originates in Chambers County and extends approximately 36 km southeast through Lee County and drains approximately 320 km^2 of land. The Osanippa Creek eventually drains into the northern portion of Lake Harding. Little Uchee Creek drains 371 km^2 of land. Little Uchee Creek originates in Lee County and flows for approximately 60 km before its confluence with the Uchee Creek in Russell County.

Movement, home range, and habitat use of shoal bass were described at the Moffits Mill shoal (hereafter "Moffits Mill") in Little Uchee Creek. The shoal at Moffits Mill is approximately 650 m in length and 1.7 hectares (ha) in area. Moffits Mill is dominated by a boulder/bedrock substrate and intermittent flow and depth regimes. A large water fall (elevation = 3 m) separates the Moffits Mill shoal from the shoals upstream. Another water fall (elevation = 4 m) is located approximately 1.15 km downstream of the Moffits Mill water fall. Between the lower end of the Moffits Mill shoal and the downstream water fall is an area of slack-water, approximately 500 m in length. This area maintains minimal flow during periods of high discharge, but exhibits negligible flow during the rest of the year. Sand and mud dominate the substrate of the slack-water area and this area maintains measurable water depth throughout the year.

METHODS

Distribution and abundance of shoal bass

Lengths (m) and locations of available shoal habitat were estimated by sampling representative reaches on Little Uchee, Halawakee, Wacoochee, and Osanippa Creeks. These streams were surveyed by canoe and lengths of all shoal habitats within each reach were recorded with a GPS unit. Lengths of shoals were imported into ARC View GIS 3.2 (ESRI 1999) and measured. Streams were surveyed during spring, summer, and fall of both 2005 and 2006. In addition, all four streams were surveyed with a fixed winged aircraft to search for shoal habitat.

Distribution and relative abundance of shoal bass were assessed by sampling representative sites on these streams where I suspected the habitat could support shoal bass inhabitation. Sites were sampled during spring, summer and fall of both 2005 and 2006. Fish were collected by electrofishing with a Smith-Root LR-24 backpack electrofisher. All shoal bass greater than 150 mm total length (TL) were implanted with Biomark TX1411L, 12mm, glass encapsulated, Passive Integrated Transponder (PIT) tags. Shoal bass less than 150 mm TL were measured and released. PIT tags were implanted with a 12 gauge hypodermic syringe into the peritoneal cavity just posterior and slightly dorsal to the pelvic girdle as described by Prentice et al. (1990). After tagging was completed, individuals were scanned (Biomark PIT tag pocket reader, 125khz) to determine if the tag was retained and readable. Each shoal bass was weighed (g), measured (mm TL), and released at the site of capture. Electrofishing effort was recorded in sec as measured by the backpack electrofisher.

Population size, density and biomass of shoal bass ($\geq$ 150 mm TL) were estimated by capture-mark-recapture at Moffits Mill on Little Uchee Creek. Three sampling passes were performed weekly during 14 - 28 April 2005. Each shoal bass collected was scanned to detect a PIT tag then weighed, measured, and released. Untagged shoal bass were implanted with a PIT tag, then weighed, measured, and released. A multiple-census population estimate technique was used to estimate population size with 90% confidence intervals (Schnabel 1938). Density (N/ha) was calculated by dividing the population estimate by the total area (ha) of the Moffits Mill shoal. Biomass (kg/ha) was calculated by multiplying the average weight (g) of shoal bass (> 150 mm TL) by the estimated population size, then dividing that number by the total area (ha) of Moffits Mill.

Four additional population estimates were computed for shoal bass at Moffits Mill using a two-pass technique from the formula (Seber 1982):

$$N = \frac{(M + 1)(C + 1)}{(R + 1)} - 1$$

where (M) is the number of individuals marked in the first sample, (C) is the total number of individuals collected in the second sample, and (R) is the number of recaptured individuals in the second sample. Population estimates performed during the radio tagging events on 16 November 2005 and 13 April 2006 were calculated after one pass with the total number of PIT tagged and radio tagged shoal bass from the preceding estimates considered the number of marked (M) individuals and the number of recaptures from those estimates used as the denominator (R) in the equation. I assumed migration did not occur from the Moffits Mill shoal complex during these time periods. An estimate of survival was computed for the 16 November 2005 and 13 April 2006 population estimates, and multiplied by (M) because I assumed that not all PIT tagged and radio tagged fish survived to be available for recapture (Krebs 1999). For the population estimates during 1 - 10 November 2006 and 12 - 19 April 2007, two pass capture-mark-recapture methods were performed. Recaptured PIT tagged and radio tagged shoal bass from all of the preceding events were considered as marked (M) fish in the equation if collected during the first pass. Ninety percent confidence intervals (Krebs 1999) were computed for the estimates of population size. During all passes for every estimate, untagged shoal bass (≥ 150 mm) were implanted with a PIT tag, weighed, measured, and released.

Habitat use, movement, and home range

To determine habitat use, home range, and seasonal movement of shoal bass at Moffits Mill, 12 fish were fitted with 3.6 g internal radio transmitters (Advanced Telemetry Systems model F1580) with a minimum battery life of 140 d on 13 November 2005 and an additional 12 fish were implanted on 16 April 2006. Internal radio transmitters were chosen because less abnormal behavior has been observed in stream-dwelling fish than with externally attached transmitters (Tyus et al. 1984). Shoal bass 180 g were collected with backpack electrofishing and the weight of the transmitter did not exceed 2% of the fish's weight (Winter 1996).

Radio transmitters were implanted using a similar surgical procedure as described by Maceina et al. (1999). After collection, each fish was anaesthetized in a solution of 150 mg/L tricane methanesulfonate. Prior to and between surgeries, radio transmitters and surgical instruments were placed in a solution of Nolvasan medical scrub to prevent contamination. The surgical procedure began with a 1-2 cm incision slightly lateral to the midventral line just posterior to the pelvic girdle. The antenna was pulled through the body wall from within the peritoneal cavity using a cruciate needle approximately 2 cm posterior to the incision. The radio transmitter was placed in the body cavity and the incision was closed with 2 monofilament nonabsorbable sutures (2-0 Ethilon). Once closed, a solution of betadine antiseptic was applied to the incision to help prevent infection. Each surgery lasted less than 5 minutes. Weight and total length were recorded and each fish was scanned (Biomark pocket reader) for a pit tag. After each procedure was completed, fish were returned to a holding tank until equilibrium was attained and subsequently released at the site of capture.

Beginning on 18 November 2005, each radio tagged shoal bass was tracked until the fish died, shed the transmitter, or the tag failed. To assess seasonal movements, fish locations were recorded weekly using an Advanced Telemetry Systems signal receiver (Model R2000, 150mHz) and a four element directional yagi antenna. The location of each fish was recorded by walking along the stream bank until the direction of the signal was perpendicular to the recorder. The recorder waded into the stream on this perpendicular line until reaching a location where the signal was the strongest. The point at which the signal was the strongest was recorded as the location of the fish. This method was of tracking was employed to minimize disturbance to the stream and reduce the chances of startling tagged fish. The location of each fish, date and time of day were recorded with a GPS unit. When radio tagged shoal bass were unable to be located by walking along the stream bank, upstream and downstream reaches were paddled twice by canoe until the fish was located. If radio tagged shoal bass were unable to be located by walking, or by canoe, a fixed wing aircraft with two wing mounted four element directional yagi antennae was used on two occasions to search for fish in the Chattahoochee River watershed.

For each fish location, the following habitat parameters were recorded: mesohabitat type (McMahon et al. 1996) was classified at each location as pool (area of stream channel with nearly flat water surface, and deeper than average channel depth located in shoal or in slack-water area between shoals), run (relatively laminar flow with moderate depth, moderate to swift current, and generally dominated by bedrock or boulder substrate), riffle (turbulent flow, shallow depth, moderate to swift current, and dominated by gravel or cobble substrate), or eddy (area of circular flow formed by boulders and/or bedrock within riffle or run). Microhabitat variables at each fish location were measured including water temperature at bottom and depth (m) was measured with a depth pole. Water current velocity (m/s) was determined at 60% of depth using a Marsh-

McBirney model 201M portable water current meter. Dominant substrate type was also recorded visually at each contact point similar to the modified Wentworth classification (McMahon et al. 1996). Dominant substrate was classified either as vegetation, or by substrate size (diameter) as sand-silt (<0.2 cm), gravel (0.2-0.6 cm), cobble (7.5-30.0 cm), boulder (≥ 31.0 cm), and bedrock (relatively unbroken stream bottom). Shoal bass locations were entered into a database, and imported into ArcView Version 3.2 for analysis (Esri 1999). Occurrences of fish in each habitat category were used to characterize habitat use.

The study site at Moffits Mill was mapped once per season to describe habitat available to shoal bass. Transect lengths were made perpendicular to flow at 20 m intervals and the starting point for each transect was recorded with a GPS. Sampling stations along each transect were approximately 10 m apart. Habitat type, substrate, cover type, depth, and water velocity at 60% of depth were recorded at each station.

Data were grouped into four seasons based on water temperature and time of year: winter (temperature < 12 °C, mean = 9 °C; 18 November 2005-24 February 2006), spring (temperature 13-24 °C increasing, mean = 19 °C; 03 March 2006-26 May 2006), summer (temperature > 25 °C, mean = 29 °C; 02 June 2006-28 August 2006), and fall (temperature 14-32 °C decreasing, mean = 26 °C; 04 September 2006-10 November 2006). Percent occurrence of fish in each habitat category were compared among seasons. Categorical data (including mesohabitat, substrate, and cover use frequency distributions) were compared with goodness-of-fit χ^2 tests (SAS 2003). Differences in depth and velocity distributions used by shoal bass among seasons were compared using the Kolmogorov-Smirnov test (SAS 2003). When significant differences were detected ($P < 0.05$) among seasons, nonparametric multiple comparisons were used to determine which seasons differed in velocity and depth associations (SAS 2003).

Flow measurements were not available at Little Uchee Creek at Moffits Mill, but were available at a United States Geological Survey hydrologic station (USGS site number 02343500) downstream of Moffits Mill on Uchee Creek near Fort Mitchell, Alabama. Although this site was about 40 km from Moffits Mill, I assumed these daily readings were approximate of flow fluctuations in Little Uchee Creek at Moffits Mill. These data were used to examine differences in shoal bass movement, home range size, and population density over time.

To determine habitat preference, the electivity index (D) of Jacobs (1974) was employed:

$$D = (r - p)(r + p - 2rp)^{-1}$$

where (r) is the proportion of a habitat variable or interval used by the individuals observed and (p) is the proportion of the same habitat variable or interval that is available. Values for the index range from -1 to +1, where -1 indicates complete avoidance and +1 indicates total preference.

Locations of individual fish were used to describe seasonal movement and home range. Seasonal minimum movement was determined by measuring the distance (m) traveled (one week intervals) by each radio tagged shoal bass and calculating meters moved per day (m/d):

$$\text{Movement (m/d)} = \frac{\text{distance moved from previous location (m)}}{\text{days lapsed between observations (d)}}$$

Movement was recorded as the minimum distance traveled from the previous location. Movement patterns were compared among the 4 seasonal periods as defined above.

Differences in seasonal movement were tested with a repeated measures mixed model that included random and fixed effects (SAS 2003). Individual fish represented the random effects and seasons represented fixed effects in the analysis. Restricted maximum likelihood (REML) was used to estimate variance components using mixed model analysis (SAS 2003) by minimizing the likelihood of residuals from fitting the fixed effects portion of the model (Littell et al. 2006). First-order autoregressive (AR(1)) covariance was designated for this analysis because I assumed observations taken closer together in time were more highly correlated than observations taken farther apart in time. When differences were detected by the repeated measures ANOVA, a least squares multiple range comparison procedure with a Bonferroni correction ($\propto$ = 0.05 / N tests) was used to determine which seasons differed in movement. The Bonferroni correction was used to control for the Type I multiple comparison error rate associated with simultaneous inferences.

Home ranges were calculated for 21 of the 24 radio tagged shoal bass using a kernel estimator similar to the procedure described by Seamen and Powell (1996). Only fish that were at large for a minimum of 20 weekly observations were used for analysis and not enough locations were obtained for 3 of the 24 fish. Fifty percent and 95% kernel home ranges were calculated with the Animal Movement Analysis Extension (Hooge et al. 1997) for ARC View GIS 3.2 (ESRI 1999). Fifty percent kernel home ranges were considered the portion of the stream of core activity and 95% kernel home ranges were regarded as the total area of the stream used by the fish (Hooge et al. 2001). The Wilcoxon rank-sum test was used to test for differences in 50% and 95% kernel home range areas between fish tagged in November 2005 and April 2006. The Wilcoxon rank sum test was used for analysis because of small sample size and home range sizes were not normally distributed. Fifty percent and 95% kernel home range areas were compared among seasons using a Kruskal-Wallis analysis of variance (ANOVA; SAS 2003).

Population metrics

A length-frequency distribution was obtained from all non-recaptured shoal bass collected at Moffits Mill. The length(TL):weight(WT) relationship was described by:

$$\log_{10}(\text{WT (g)}) = -b_0 + b_1 * \log_{10}(\text{TL (mm)})$$

Fulton's coefficient of condition ($K = \text{weight}*100{,}000/\text{TL}^3$) was computed for shoal bass collected from Moffits Mill and fish were placed in two length groups (200 - 299 and 300

- 399 mm TL). Condition of shoal bass were compared using t-tests to fish of similar length collected from the Flint River, Georgia, which also represented an endemic population. Data for 85 shoal bass were obtained from the Georgia Department of Natural Resources (J. Evans, unpublished data) from August to November 2005 using DC boat electrofishing. Upon collection of fish from the Flint River, total lengths (mm) and weights (g) were recorded and sagital otoliths were removed.

To assess and compare growth rates of shoal bass collected from Little Uchee Creek at Moffits Mill, I analyzed growth data of shoal bass collected from the Flint River. Instantaneous annual rates of growth for length and weight of shoal bass collected from Moffit's Mill were obtained from 21 recaptures of PIT and radio tagged fish. The number of days between recaptures was not the same for all shoal bass used in the analysis so the differences in length and weight were divided by time (d/365) between the initial and final recapture date. The equations to compute instantaneous annual growth (G) for length (L) and weight (W) were:

$$G_L = \frac{\ln(TL_{recap}(mm)) - \ln(TL_{initial}(mm))}{time}$$

$$G_W = \frac{\ln(WT_{recap}(g)) - \ln(WT_{initial}(g))}{time}$$

Age of shoal bass collected from the Flint River was determined according to the procedures of Hoyer et al. (1985) and Maceina (1988). To account for differences in growth due to time of collection and growth after annuli were formed, annual increments of 0.25, 0.33, 0.42, and 0.50 years were added to the ages of fish collected from August through November 2005. A Von Bertalanffy (1938) growth equation was fit to the total length-to-age data to predict lengths at age. Weight at age was estimated from predicted lengths by regressing $\log_{10}$(weight) against $\log_{10}$(length) for the 85 fish that were collected. Instantaneous growth in length and weight were computed similar to the equations presented for fish collected from Moffits Mill except that predicted lengths and weights were used and G was estimated by subtracting each years previous growth for the year. Hence, each G represented annual instantaneous rates and scaled similar to those computed for fish from Moffits Mill. Instantaneous growth for length and weight were plotted against the respective midpoints for length and weight for each population and compared graphically.

Estimates of finite survival rate (S) were computed for radio tagged shoal bass between November 2005 - April 2006 and April 2006 - November 2006 from the formula (Pollock et al. 1989):

$$S_k = \prod_{i=1}^{n} \left[1 - (d_i/r_i) \right]$$

where (S_k) is the Kaplan-Meier estimate of finite survival rate for each weekly time period, (d_i) is the number of deaths recorded at time i, (r_i) is the number of individuals alive and at risk at time i, and (n) is the number of time checks for possible deaths. A

95% CI was derived for each survival estimate from the variance and standard error components of the Kaplan-Meier estimate as described by Pollock et al. (1989). The Kaplan-Meier estimated accounts for lost fish by adjusting the number of individuals at risk (Krebs 1999). Radio tagged shoal bass were considered dead if one of three assumptions were met: (1) the radio tag and/or fish was retrieved from the stream bed; (2) the signal was repeatedly located under a boulder in a dewatered area; (3) or the signal was repeatedly located in the nearby forest.

RESULTS

Distribution and abundance

On Wacoochee Creek, approximately 4.8 km were traversed and one large shoal (800 m) was found on the lower end of this stream, 1.5 km from confluence with the Chattahoochee River (Figure 2). Three sampling trips with 250 min of electrofishing effort yielded only one shoal bass (179 mm TL) at this location (Figure 2). Sixteen spotted bass, and 6 largemouth bass were collected from this stream.

Eighteen km of Halawakee Creek were traversed and I found 1.64 km of shoal habitat (Figure 3). Nine hundred m of shoal habitat were located in a set of shoals above Beans Mill dam. The additional shoals totaling 740 m were located downstream of Beans Mill dam terminating at the confluence with Lake Harding. Spotted bass comprised the majority of black bass collected (N = 53) from Halawakee Creek, followed by largemouth bass (N = 22). Three shoal bass (mean = 260 mm TL) were collected over 3 sampling trips (472 min), all at the farthest downstream shoal site below Beans Mill Dam (Figure 3).

On Osanippa Creek, 6.5 km were traversed by canoe. Beginning just downstream of the US 29 bridge crossing, 1.10 km (Figure 4) of shoal habitat was measured. Six shoal bass (mean = 65 mm TL) were collected on this stream over 4 sampling trips with

500 min of effort (Figure 4). Twenty-four spotted bass, and 1 largemouth bass were collected from Osanippa Creek.

Twenty one km of Little Uchee Creek were traversed by canoe and 1.95 km of shoals were measured (Figure 5). Approximately 1.25 km of the total available shoal habitat were located over a set of 10 shoals beginning at Meadows Mill and terminating just upstream from Moffits Mill. The remaining 700 m of shoal habitat were distributed between the Moffits Mill shoal (650 m) and another downstream shoal (50 m). Ninety seven shoal bass (mean = 238 mm TL; Figure 6) were collected from the Little Uchee Creek during 6 sampling trips in 2005 and 2006 (1297 min). Fewer spotted bass (N = 7), and a greater number of largemouth bass (N = 31) were collected from Little Uchee Creek than from the 3 other streams surveyed.

Estimates of population size, density and biomass at Moffits Mill, Little Uchee Creek

In April 2005, an adequate number of recaptures were obtained after 3 passes to estimate a population size of 72 (90% CI = 48, 130) shoal bass (≥150 mm TL; mean weight = 267 g) at Moffits Mill (Table 1). The calculated area (ha) of the Moffits Mill shoal was 1.7 ha; thus 42 fish/ha with a biomass of 11.7 kg/ha inhabited this shoal. In November 2005, 31% of the shoal bass collected were recaptures from April 2005. An estimated survival rate of 91% was multiplied to the number of marked (M) shoal bass and the estimated population size was 107 (90% CI = 70, 258; Figure 7). Between April 2005 and April 2006, the estimated survival rate was 82%, and in April 2006, the recapture rate was 57% for radio and PIT tagged shoal bass at Moffits Mill. A population estimate of 69 (90% CI = 55, 99) was computed (Figure 7). In November

2006, the estimated population size was only 13 (90% CI = 9, 31; Figure 7) fish, and by April 2007, the estimated population size increased slightly to 23 (90% CI = 16, 48; Figure 7).

Seasonal habitat use and preference

A total of 705 locations were recorded for 23 of 24 radio tagged shoal bass from 16 November 2005 to 10 November 2006 to describe seasonal habitat use at Moffits Mill (Table 2). The tag for 1 of the 24 shoal bass was collected on the stream bed shortly after tagging and not used in the analysis.

Mesohabitat Use and Preference

Chi-square analysis showed that seasonal meso-habitat use by shoal bass at Moffits Mill was not homogenous ($\chi^2 = 208.2$; df = 6; $P < 0.0001$; Figure 8). In winter 2005 - 2006 as flow increased (Figure 9), runs were used by shoal bass 44% of the time, followed by eddies (30%), and pools (26%). In spring 2006, runs (42%) continued to dominate mesohabitat use by shoal bass while eddies were used 33% of the time and pools made up the remainder of associations (Figure 8). Electivivty indices showed that shoal bass preferred runs and eddies during winter 2005 - 2006, and spring 2006, while pools were modestly avoided (Figure 10). When flow began to decline and water temperatures reached summer maximums in 2006, shoal bass shifted from the use of runs and eddies to pools. Pools contributed 68% of the habitat used by shoal bass, followed by eddies (26%), while runs were used least (6%) during summer 2006 (Figure 8). However, shoal bass continued to exhibit preference for runs and eddies even as they contributed to less than 20% of the available habitat (Figure 10). Low flow conditions persisted into fall 2006, and the majority of available habitat was located in a downstream deep water refuge (Figure 10). Pools contributed about 90% of the habitat shoal bass used, and a shift in habitat preference was observed as shoal bass preferred pools over all other habitat types (Figure 10). The remaining 10% of the mesohabitat used by shoal bass during fall 2006 was distributed between eddies and runs (Figure 8), and these habitat types were modestly avoided (Figure 10). Shoal bass completely avoided riffle habitat in all seasons.

Substrate Use and Preference

Although differences existed in seasonal distributions of substrate associations ($\chi^2 = 74.01$; df = 9; $P < 0.0001$), boulders contributed the dominant (54%) substrate type used (Figure 11) and preferred (Figure 12) during all seasons. In winter 2005 - 2006, shoal bass were found over boulders 63% of the time, and bedrock 23% of the time, while sand contributed only 10% of the substrate used by shoal bass (Figure 11). Boulders were the only preferred substrate type throughout winter 2005 - 2006 (Figure 12). During spring and summer 2006, boulders continued to be the preferred substrate type while sand was selected in proportion to its availability (Figure 12). Shoal bass used bedrock substrate only 14% of the time in spring 2006 followed by a slight increase in summer 2006 (Figure 11). As low flow conditions persisted through late summer and into fall 2006, sand (44%) became the dominant substrate available to shoal bass (Figure 12). However, boulders contributed over half of the shoal bass substrate associations and were the only preferred bottom type (Figure 12). Shoal bass used cobble, and gravel less than 5% of time and exhibited avoidance of these substrate types in all seasons.

Cover Use and Preference

Shoal bass use of cover types differed among seasons ($\chi^2 = 19.46$; df = 6; P = 0.004), but boulders were the dominant cover type used (Figure 13) and preferred (Figure 14) during all seasons. Conversely, shoal bass displayed avoidance for open water, wood, and aquatic vegetation cover types in every season, even as open water pools became the dominant habitat type available (Figure 14). In winter 2005 - 2006, boulders made up 72% of cover associations while bedrock contributed only 13% , and open water was used only 15% of the time (Figure 13). Pairwise comparisons revealed that cover use did not vary between winter 2005 - 2006 and spring or summer 2006 ($P > 0.10$). However, as discharge continued to decline through late summer and into fall 2006, shoal bass used a higher proportion of open water and a lower proportion of bedrock ledges (Figure 13) . Significant differences in cover use were evident between fall 2006 and all other seasons ($P < 0.01$). By fall 2006, shoal bass were found in open water 30% of the time, but exhibited relatively strong avoidance of open water, and continued to prefer boulder cover (Figure 14). The use of bedrock by shoal bass was almost nil, while boulders continued to contribute about 2/3 of cover associations by the end of autumn 2006 (Figure 13). Woody debris and aquatic vegetation were the least abundant cover types in winter 2005 - 2006, spring, and summer 2006, and shoal bass avoided these cover types in all seasons (Figure 14).

Depth Use and Preference

Seasonal differences in depth associations were evident for shoal bass at Moffits Mill (*Ksa* = 4.40; $P < 0.0001$). Depths tended to exhibit bimodal distributions in every season except for winter 2005 - 2006 (Figure 15). One mode was evident at a depth of approximately 0.50 m and another at depths greater than 1.20 m with few locations between 0.80 and 1.00 m. Shoal bass used shallower depths most often during winter (mean = 0.45 m), while use of deeper water occurred during fall (mean = 0.89 m; Figure 15), and appeared to be inversely related to flow. In winter, shoal bass preferred depths of 0.40-0.60 m and displayed neutral selection for depths of 0.80-1.00 m (Figure 16). Depths greater than 1.00 m were generally avoided by shoal bass during winter 2005 - 2006 (Figure 16). During spring 2006, shoal bass exhibited preference for depths ranging from 0.40-0.80 m, while modest avoidance for depths of 1.00-1.20 m was evident, and depths greater than 1.30 m were selected in proportion to availability (Figure 16). The bimodal distribution in shoal bass depth use and preference was most evident in summer and fall 2006 as depths of 0.40-0.60 m and greater than 1.3 m were preferred while depths of 0.80-1.00 were avoided (Figure 16). In all seasons, the shallowest depths were avoided by shoal bass.

Velocity Use and Preference

Velocities that shoal bass used differed among seasons (Ksa = 6.07; $P < 0.0001$; Figure 17) and ranged from 0.00-0.70 m/s. Velocities used by shoal bass during winter 2005-2006 and spring 2006 were approximately 5 times greater than summer and fall (Figure 17), reflecting the variation in flow observed over the study period (Figure 9).

Although a measurable rate of velocity was associated with 70% of all observations, fish were most often found where velocities were less than 0.10 m/s in every season (Figure 17). During winter 2005-2006, shoal bass preferred water velocities of 0.10-0.30 m/s while velocities below 0.10 m/s, above 0.70 m/s, and between 0.40-0.50 m/s were avoided (Figure 18). In spring 2006, the greatest velocities available to shoal bass at Moffits Mill were around 1.0 m/s, but shoal bass preferred water velocities of 0.00-0.30 m/s and generally avoided velocities greater 0.35 m/s (Figure 18). In summer 2006, velocities available to shoal bass ranged from 0.00-0.40 m/s. Shoal bass exhibited neutral selection for water velocity of 0.00 m/s, although this velocity comprised 88% of the available flow throughout summer 2006 (Figure 18). By summer and fall 2006, shoal bass inhabited areas with water velocities $\leq$ 0.10 m/s, as areas with higher water velocities were rare (Figure 18).

<u>Estimates of home range size</u>

Eleven of 12 shoal bass tagged on 16 November 2005 and 10 of 12 fish tagged on 13 April 2006 were tracked for a minimum of 20 weeks and had a sufficient number of observations (median = 30 locations/fish) to be used to estimate home range (Table 2). Of the three fish not used in home range analysis, one fish was consumed by a great blue heron *Ardea herodias*, another was consumed by a water moccasin *Ancistrodon piscivorus* , and one died shortly after tracking commenced.

For shoal bass tagged in November 2005, 50% kernel home range areas ranged from 60-1,684 m^2 (mean = 466; Figure 19) and 95% kernel home range areas ranged from 155-5,886 m^2 (mean = 1,983; Figure 20). For fish tagged in April 2006, 50% kernel home range areas ranged from 48-7,746 m^2 (mean = 1,877; Figure 19) and 95% kernel home range areas ranged from 122-22,517 m^2 (mean = 7,674; Figure 20).

Fifty and 95% home range areas were similar between fish tagged in November 2005 and April 2006 (one sided Z = 1.16, P = 0.12) based on a Wilcoxon rank-sum test and were pooled for the remainder of the analysis. For all fish pooled, 50% kernel home range areas were highly variable and ranged from 60-7,746 m^2 (mean = 1,138 m^2). Similarly, 95% kernel home range areas varied greatly and ranged from 155-22,517 m^2 (mean = 4,693 m^2). Although the shoal at Moffits Mill was 1.7 ha, 50 and 95% kernel home range areas averaged only 7 and 28% of the entire shoal reach (Figures 19 and 20).

Core (50%) and 95% home range areas were largest in spring and smallest in winter, but did not differ statistically among seasons ($P > 0.10$; Table 3). Core use area and 95% home range size varied more than an order of magnitude among individual fish within each season. No relationship was detected between shoal bass total length (mm) and either 50% ($r^2 = 0.40$, P = 0.07) or 95% ($r^2 = 0.28$, P = 0.22) home range areas.

<u>Seasonal Movement</u>

Mixed model analysis showed that movement rates of radio tagged shoal bass differed among seasons at Moffits Mill (F = 4.33; df = 3,45; P = 0.009). However, movement was skewed toward lower rates throughout the study period, and ranged from 0-66 m/d (mean = 3.2 m/d). Shoal bass moved less than 3 m/d in 80% of weekly observations, and exhibited no measurable movement in approximately 40% of weekly observations in every season (Figure 21). Radio tagged shoal bass did not emigrate outside of the 1.15 km Moffits Mill shoal/pool complex.

Shoal bass exhibited little movement during winter 2005-2006 (mean = 2.3 m/d; water temperature mean = 9 °C). Throughout the entire winter 2005-2006 season, all radio tagged shoal bass were located in the Moffits Mill shoal (Figure 23). Movement of shoal bass appeared to increase during spring 2006 (mean = 3.9 m/d), although not significantly ($P > 0.10$), as flow and water temperature continued to increase (Figure 9). Shoal bass movement throughout spring 2006 was restricted to within the shoal (Figure 23). Sixty five percent of radio tagged shoal bass were located slightly upstream from the original tagging location during the spring (Figures 24 and 25). However, on 26 May 2006, as flow continued to decline, the first shoal bass migrated away from the shoal (Figure 25). This individual moved to a downstream pool, approximately 350 m from its previous location. By the end of May 2006, 95% of radio tagged shoal bass were located in the Moffits Mill shoal.

Movement appeared to decline in June and July 2006 (mean 2.7 m/d), but not significantly ($P > 0.10$), as discharge continued to decline and water temperatures exceeded 30°C (mean = 29 °C; Figure 22). By 11 August 2006, 17 of 19 (90%) radio tagged shoal bass were located in the Moffits Mill shoal. Two additional shoal bass migrated to the downstream deep water refuge during summer 2006 (Figure 23).

In fall 2006, as dry conditions persisted, movement rates increased (mean = 3.7 m/d), but movement was largely between the downstream water fall and the dewatered lower end of the Moffits Mill shoal (Figure 25). Daily movement was significantly higher in fall 2006 ($P < 0.06$) compared to winter 2005-2006 and spring 2006. By November 2006, the deep water refuge had no appreciable water velocity and water depths were greater than 1.2 m. Throughout the duration of the study, no radio tagged shoal bass were located below the downstream water fall and when the study terminated, the 3 remaining individuals were monitored just downstream from the lower end of the Moffits Mill shoal (Figure 23). At the end of the study period, 1 fish was still alive and located above the falls upstream of Moffits Mill and I believe it was transplanted to this location by an angler.

Population Metrics

Excluding recaptures, 87 shoal bass ($\geq$ 150 mm TL) were collected from the Moffits Mill shoal between April 2005 and April 2007. The weight to length relationship (Figure 26) was:

$$\log_{10}(Wt) = -5.490 + 3.235*\log_{10}(TL).$$

Flint River shoal bass were in better condition than Little Uchee fish in the 200-299 mm TL ($t = 4.68$; $P < 0.0001$) and 300-399 mm TL ($t = 5.08$; $P < 0.001$) groups based on Fulton's coefficient of condition (Table 4). Graphical analysis showed that predicted instantaneous annual growth rates (Wt) for Flint River shoal bass were greater than for the 21 shoal bass collected from Moffits Mill (Figure 27). Only 1 shoal bass recaptured from Moffits Mill displayed greater instantaneous annual growth (Wt) than what was predicted for Flint River fish, and 86% of shoal bass from Moffits Mill exhibited lower growth in length (mm TL) than the predicted values for Flint River fish (Figure 27). During the first 6 months of radio tracking, only 1 shoal bass died (bird predation). After the second radio tagging event, 15 fish died, 3 signals terminated, 1 signal was lost, and 4 fish were alive. The finite survival rate (S) for radio tagged shoal bass at Moffits Mill was 0.82 (95% CI, 0.59 - 1.00) between November 2005 and April 2006, and 0.22 (95% CI, 0.07 - 0.37) between April 2006 and November 2006.

DISCUSSION

Distribution and abundance

With the exception of 1 site, shoal bass abundance and occurrence were limited and low in 4 tributaries of the Chattahoochee River surveyed in Alabama. Similar lengths of shoal habitat exists on each of the 4 tributaries and based on my radio telemetry data, shoal bass prefer shoal habitat. The only substantial population of shoal bass was observed at Moffits Mill in Little Uchee Creek. Hurst (1969) collected 68 shoal bass in Halawakee Creek from Beans Mill Dam to the confluence with Lake Harding, and Gilbert (1969) reported shoal bass were more prevalent than largemouth bass and spotted bass in the shoals of Wacoochee and Halawakee creeks. In this study, only 4 shoal bass were collected from the same areas of these two streams while 97 largemouth bass and spotted bass were collected. In Osanippa Creek, efforts to collect black bass either have not been attempted or reported. Comparative data for black bass abundance is also unavailable for Little Uchee Creek.

The decline in shoal bass could be due to habitat alteration or loss of suitable habitat from impoundments and poor land use (Williams and Burgess1999). Stream fragmentation from impoundments has been shown to favor habitat generalists such as largemouth bass over fluvial specialists like smallmouth bass (Guenther and Spacie 2006). Shoal bass are considered fluvial specialists due to their inability to persist in lentic systems (Smitherman 1975). Halawakee Creek has been fragmented by Beans Mill Dam upstream and altered downstream by an impoundment of the Chattahoochee River at Lake Harding. In this study, largemouth bass were the only black bass species collected from Halawakee Creek above Beans Mill dam, while only three shoal bass were collected at the farthest shoal downstream of Beans Mill Dam. On Wacoochee Creek, the shoals in the lower reach possibly have become disconnected from the Chattahoochee River as a result of heavy sediment loading and only 1 shoal bass was collected from this stream. The presumed larger population of shoal bass that previously existed in the Wacoochee Creek shoal could have experienced population decline if mortality was high during extreme dry periods, and connectivity to the Chattahoochee River was lost.

Impoundments may also act as barriers to movement by fluvial specialists and prevent recolonization of preferred habitat after an episodic disturbance (Guenther and Spacie 2006; Herbert and Gelwick 2003). Williams and Burgess (1999) indicated that shoal bass were intolerant of reservoir conditions. If the Chattahoochee River once acted as a source of shoal bass to recolonize Alabama tributaries, impoundments may have dramatically disrupted the presence of shoal bass founder populations. The construction of 5 dams along the Chattachoochee River, beginning with Bartletts Ferry (Lake Harding) upstream and Eagle-Phenix downstream, likely extirpated shoal bass as a source population for recolonizing the Osanippa, Halawakee, and Wacochee shoals. Annual sampling of Lake Harding since the late 1980's has produced only a single shoal bass (Alabama Division of Wildlife and Freshwater Fisheries, unpublished data). Alternatively, the shoals on Little Uchee Creek at Moffits Mill are approximately 40 km upstream of the confluence with the Chattahoochee River and likely, the shoal bass population at this location has been able to persist without recolonization from the Chattahoochee River.

In 3 of the 4 streams that I sampled, presence and abundance of spotted bass may be deleterious to shoal bass. Competition and predation have been implicated in the decline of fluvial specialists in favor of habitat generalists in streams where habitat has been altered or degraded (Guenther and Spacie 2006). Spotted bass are considered habitat generalists due to their ability to survive in a variety of habitats in impoundments as well as in large rivers and streams. Spotted bass have been found to inhabit the same stream reaches as shoal bass (Gilbert 1969) and may outcompete shoal bass for resources. Smitherman and Ramsey (1972) reported higher survival rates for shoal bass than for three other stream dwelling black basses, including spotted bass, when stocked into separate systems. However, spotted bass exhibited greater growth rates and higher survival after stocked into the same small impoundment with shoal bass (Smitherman and Ramsey 1972).

In the 3 streams where shoal bass abundance was low, spotted bass were relatively plentiful. In Halawakee Creek, the ratio of spotted bass to shoal bass was 18 to 1. In Wacoochee Creek, spotted bass outnumbered shoal bass 16 to 1, and in Osanippa Creek, 24 spotted bass and 6 shoal bass were collected. The only stream surveyed in this study where shoal bass abundance was greater than spotted bass was Little Uchee Creek (97 to 7). All but 1 shoal bass from Little Uchee Creek were collected upstream of a large natural barrier (4 m waterfall), which may have obstructed upstream migration of spotted bass. The majority of black bass collected below the barrier were spotted bass. Partitioning of resources has been observed between shoal bass and largemouth bass (Wheeler and Allen 2003), but competitive interactions between shoal bass and spotted bass in streams have not been examined.

Habitat preference, home range and seasonal movement of shoal bass at Moffits Mill

Although seasonal differences were evident among the distributions of mesohabitats, shoal bass in the Moffits Mill shoal preferred bedrock and boulder substrate and cover throughout the year. Seasonal differences in habitat use appeared to be related to the environmental conditions during the study period. In a previous study, age-0 and adult shoal bass used areas with high proportions of rocky substrate, and deeper than average depth in the shoals of the Chipola River, Florida (Wheeler and Allen 2003). Preferences for rocky substrate and cover have been reported for smallmouth bass inhabiting lotic systems (George and Hadley 1979), but smallmouth bass have also been associated with vegetation, and woody structure (Probst et al. 1984). Tillma et al. (1998) concluded that the amount of woody rootwads and undercut bank cover were the best predictors of spotted bass density in Kansas streams. I found shoal bass avoided woody structure and aquatic vegetation.

Shoal bass were strongly associated with moderate to deep areas of Moffits Mill, and a strong seasonal component was evident for depth preferences. However, I could not effectively record the deepest areas in the pools for both habitat and shoal bass use. Therefore, observations of shoal bass in the deepest areas were included in the deepest interval (> 1.30 m). In winter 2005-2006 and spring 2006, moderate depths (0.40-0.60 m) were preferred, while deeper areas (>1.30 m) were preferred in summer and fall 2006. The shallowest areas (<0.20 m) were consistently avoided throughout the study period. Shoal bass were associated with deeper-than-average areas in the shoals of the Chipola River, Florida (Wheeler and Allen 2003). Similar results were reported for stream-dwelling smallmouth bass (Rankin 1986; Todd and Rabeni 1989).

Velocity associations for shoal bass at Moffits Mill were lower-than-average in all seasons, and preferred velocities were less than 0.35 m/s throughout the year. Todd and Rabeni (1989) observed similar behavior of smallmouth bass in a Missouri stream. Smallmouth bass introduced into an Arizona stream preferred velocities below 0.20 m/s (Barrett and Maughan 1994). Wheeler and Allen (2003) found that shoal bass were associated with higher-than-average current velocities in the Chipola River, Florida. However, extremely low flows were observed in this study during late summer and fall 2006, and during these seasons areas with measurable current velocities were too shallow to be inhabited by shoal bass.

Similar to Wheeler and Allen (2003), I observed shoal bass in pools and shoals, but a seasonal component was evident in habitat associations. Shoal bass displayed preference for eddies and runs in every season except for fall 2006, when discharge was almost nil and pools were the most abundant habitat type available. Wheeler and Allen (2003) indicated that shoal bass may be more macrohabitat generalists then previously assumed, and this may be the case for shoal bass in a larger system like the Chipola River, Florida (length = 201 km; watershed area = 3,124 km^2). I found that shoal bass in

Little Uchee Creek (length = 60 km; watershed area = 371 km^2) were habitat specialists that displayed great fidelity to shoal habitat, but may require refuge areas during periods of extremely low flow and high water temperature to escape increased risk of mortality.

My results indicated that shoal bass at Moffits Mill exhibited relatively sedentary behavior throughout the year. Smallmouth bass in the Flat River, Michigan, spent 50%-60% of the time inactive (Rankin 1986), and Klauda (1975) reported that adult smallmouth bass in a "semi-natural" stream held the same position 80% of the time. In this study, during winter 2005 - 2006, no radio tagged shoal bass abandoned the Moffits Mill shoal. Movement patterns displayed little variation until late spring when water temperatures reached 25 °C and the shoal began to dewater. Movement rates have increased during spring for other black bass populations in streams and have been related to spawning (Todd and Rabeni 1989) as well as abiotic factors (Langhurst and Schoenike 1990). In this study, only 13% of radio tagged shoal bass migrated away from the shoal to a downtream refuge area and the remainder of movement patterns were restricted to within the shoal. The high recapture rates (range = 22 - 57%) observed during the five population estimates between April 2005 and April 2007 also provided supporting evidence of limited movement by shoal bass at Moffits Mill.

Fish that disappear during a movement study possibly move outside of the study site and can bias results (Gowan 1994). However, the study ended with only one (4%) radio tagged shoal bass designated as lost due to its disappearance prior to the expired battery life and the tag was not recovered. I speculate that it was unlikely that this individual emigrated out of the study area as it exhibited the smallest core home range size and exhaustive attempts were undertaken to locate this fish by canoe and airplane. Possible causes for the disappearance of this shoal bass include tag failure, natural mortality, or angler harvest.

Migratory behavior can be triggered by unfavorable climate conditions, limited food or space resources, competition, and predation (Bell 1991). The dry period at Moffits Mill persisted into fall 2006, and by the end of the study period, small isolated pools dominated the habitat available to shoal bass that did not migrate out of the shoal. Differences in individual movement may be attributable to the physical environment in which the population resides. Shoal bass that migrated downstream displayed behavior that differed from the fish that remained in the shoal. Large differences in movement patterns have been observed in individuals of other stream-dwelling species during periods of abiotic stress (Matthews 1998; Aparicio and Desostoa 1999).

Excluding radio tag signals that were lost or expired (N = 4), the mortality rate for shoal bass remaining in the shoal during the summer and fall 2006 was 100%. Abiotic induced migratory behavior may have allowed for a better chance of survival and subsequent recolonization of the shoal after the extended dry period observed at Moffits Mill. Although none of the 3 radio tagged shoal bass moved back up into the shoal by the end of the tracking period (November 2006), these fish were disconnected from the shoal by a dry riffle bed that extended greater than 100 m. These individuals made frequent movements between an area just below the dry riffle bed and the downstream waterfall, but were not located in the 500 m reach between these two areas in any observation. This slack water area was composed of habitat largely avoided by shoal bass throughout the study period. Possibly, these individuals were displaying a type of searching behavior in an attempt to either move back up into the shoal or find another area of preferred habitat.

Population Metrics

At Moffits Mill, population estimates in April 2005, November 2005, and April 2006 were relatively similar, while lower estimates were computed in November 2006 and April 2007 which was attributed to mortality associated with the drought that persisted through fall 2006. Between April 2005 and April 2006, I estimated 69-107 shoal bass (≥ 150 mm) inhabited this site and was associated with high survival (S = 0.82). As Moffits Mill became dewatered in summer and fall 2006, abundance declined to 13 and 23 fish respectively, and was associated with a much lower survival rate (S = 0.22). However, the dry conditions in 2006 may have led to strong recruitment as 41% of the total catch during November 2006 were juvenile shoal bass (< 150 mm). Conversely, less than 5% of the total catch were juveniles during the preceding estimates in April 2005, November 2005, and April 2006 estimates.

The length-to-weight relationship computed for shoal bass at Moffits Mill was similar to the length-weight regressions for other black bass species (Wege and Anderson 1978; Kolander et al. 1993; Weins et al. 1996). All 21 PIT tagged shoal bass from Moffits Mill exhibited positive growth between capture and recapture. Lower growth rates were observed for shoal bass at Moffits Mill compared to fish from the Flint River. Similarly, body condition of shoal bass from Moffits Mill was lower than for fish from the Flint River. The difference in size between the Flint River and Little Uchee Creek might explain the disparity in growth and body condition observed between these two populations. The Flint River drains approximately 21,911 km^2 of land and has an average annual discharge of 114 m^3/s, compared to a watershed area of 3,124 km^2 and an average annual discharge of approximately 12 m^3/s for Uchee Creek (USGS Uchee Creek gage near Ft. Mitchell, Alabama). Increased growth rates have been observed for Atlantic salmon *Salmo salar* parr in larger lacustrine systems then smaller fluvial systems (Halvorsen and Svenning 2000; Dempson et al. 2004), and Kwak et al. (2006) reported faster growth rates of flathead catfish *Polydictis olivaris* in the largest of 3 North Carolina rivers studied. Similar comparisons appear to be absent in the literature for intraspecific black bass populations inhabiting rivers and streams.

Petty and Grossman (2004) suggested that periods of low flow could negatively affect growth due to increased physiological stress from increased water temperature, and reduced wetted area for foraging. Hakala and Hartman (2004) observed a reduction in body condition of brook trout during pre- compared to post-drought conditions. In 2006, Uchee Creek suffered its 5th lowest average annual discharge in the last 60 years and dry conditions were quite severe at Moffits Mill.

Survival rates of radio tagged shoal bass at Moffits Mill decreased dramatically after May 2006 and reflected the low flow conditions that persisted from summer into fall 2006. Initial mortality from the tagging procedure was not evident as I observed 100% survival of radio tagged shoal bass from November 2005 through February 2006 and only one fish died (bird predation) by the second radio tagging event in April 2006. The tag was recovered about 8 km from Moffits Mill in a swamp, not contiguous to Little Uchee

Creek, below a Great Blue Heron nest. Thus, I assumed this shoal bass was consumed by this bird. The high survival rates observed during this time period corresponded to higher population estimates in November 2005 and April 2006. Monthly survival estimates declined precipitously from mid-summer into fall 2006 and by the end of the November 2006, all radio tagged shoal bass located in the shoal were assumed dead. In seven northern Appalachian streams, brook trout density decreased by approximately 60% from pre- to post-drought population sampling (Hakala and Hartman 2004). In this study, the lowest of five shoal bass population estimates was computed in November 2006, corresponding to the lowest survival estimate for radio tagged fish.

Management and conservation strategies

Anecdotal evidence (Gilbert 1969; Hurst 1969) indicated shoal bass were more common in tributaries of the Chattahoochee River in Alabama, but currently these fish are in low abundance (except the population at Moffits Mill) in isolated populations with little or no connections to other shoal bass populations. Dam construction on the Chattahoochee River, and poor land use practices on the mainstem of the Chattahoochee River and its tributaries where shoal bass are known to inhabit may have reduced the amount and quality of suitable shoal habitat and affected the potential for recolonization. My results stress the importance of preserving suitable shoal habitat in the tributaries surveyed to conserve existing shoal bass populations. Possibly, stocking shoal bass could be used to augment populations that are currently at critically low levels and include populations in Osanippa, Halawakee, and Wacoochee Creeks.

Droughts are natural disturbances in streams and can play a major role in re-structuring lotic communities (Magoulick and Kobza 2003). Periods of low flow can favor large piscivores such as shoal bass by increasing foraging efficiency and allowing for better recruitment. However, prolonged dry periods resulting in the desiccation of a stream reach may have negative effects on sportfish communities through increased risk of predation, starvation, and angler harvest (Adams and Warren 2005). Normal periods of low flow may be exacerbated upstream by water draw-downs or poor land use practices and alter the impacts that dry periods impart on fish populations. I recommend a comprehensive investigation into the current water and land use practices along the riparian zones of the four tributaries surveyed in this study and assess impacts to local hydrology compared to historic levels. Finally, the Alabama Division of Wildlife and Freshwater Fisheries placed a moratorium on harvest of shoal bass in Alabama on 1 October 2006 in attempt to prevent further decline.

TABLES

Table 1. Data collected for the multiple census mark-recapture estimate of shoal bass ($\geq$150 mm TL) population size at Moffits Mill on Little Uchee Creek, Alabama during 14 - 28 April 2005.

Pass	Total catch (C)	Marked at large (M)	Recaptures (R)
1	19	0	0
2	17	19	4
3	19	32	9
Total	55	51	13

Table 2. Tagging date, tag number, TL (mm), Wt (g), days at large, and fate of radio tagged shoal bass at Moffits Mill. Fates represented by (*) indicate predation by *Ardea herodias* and (**) indicates predation by *Ancistrodon piscivorus*.

Tagging group	Tag ID	TL (mm)	Wt (g)	Days at large	Number of locations	Fate
Nov. 05	684	420	1004	158	21	Died
	702	254	197	335	47	Died
	722	310	329	153	23	Battery expired
	742	272	209	98	19	Died*
	761	344	538	245	35	Died
	782	374	657	311	44	Died
	803	368	600	311	44	Died
	822	356	575	311	44	Died
	843	332	423	335	47	Died
	861	291	254	251	36	Died
	882	261	205	335	47	Battery expired
	903	361	577	297	42	Battery expired
Apr. 06	014	349	553	182	24	Died
	043	283	309	182	24	Died
	063	281	250	204	27	Died
	083	308	372	120	20	Lost
	102	390	772	211	28	Study ended
	123	503	2125	165	22	Died
	144	372	656	211	28	Study ended
	163	277	266	144	20	Died
	182	368	665	211	28	Study ended
	202	357	658	211	23	Transplanted
	222	287	316	105	14	Died
	244	308	349	29	4	Died**

Table 3. Fifty percent and 95% home range areas (m^2) of 21 radio tagged shoal bass at Moffits Mill between November 2005 and November 2006.

Season	Mean	SE	Range (min.- max.)
50% home range			
Winter	201	61	26 - 763
Spring	1,423	468	10 - 6,571
Summer	1,140	368	7 - 5,013
Fall	1,261	663	10 - 8,347
95% home range			
Winter	984	187	249 - 2,447
Spring	3,550	898	45 - 13,109
Summer	3,165	841	55 - 12,833
Fall	2,908	1,473	45 - 20,089

Table 4. Fulton's coefficient of condition [$K = (Wt*100000)/TL^3$)] for shoal bass collected from the Flint River and Little Uchee Creek. Numbers in parentheses represent standard deviations.

	Size groups (mm TL)	
River	200-299	300-399
Flint	1.31 (0.10)	1.38 (0.10)
Little Uchee	1.17 (0.12)	1.25 (0.09)

FIGURES

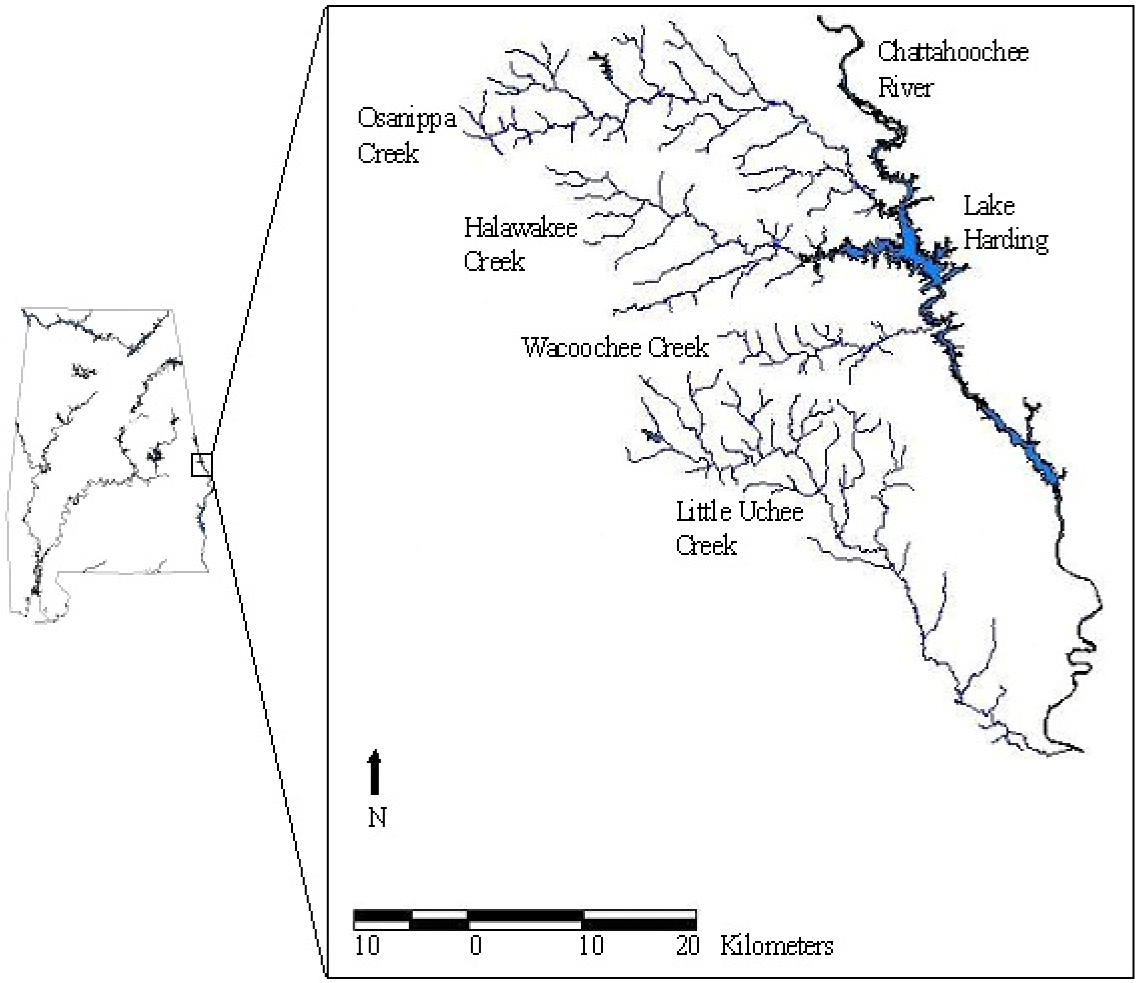

Figure 1. Map of the four streams selected for assessing distribution and abundance of shoal bass in Alabama.

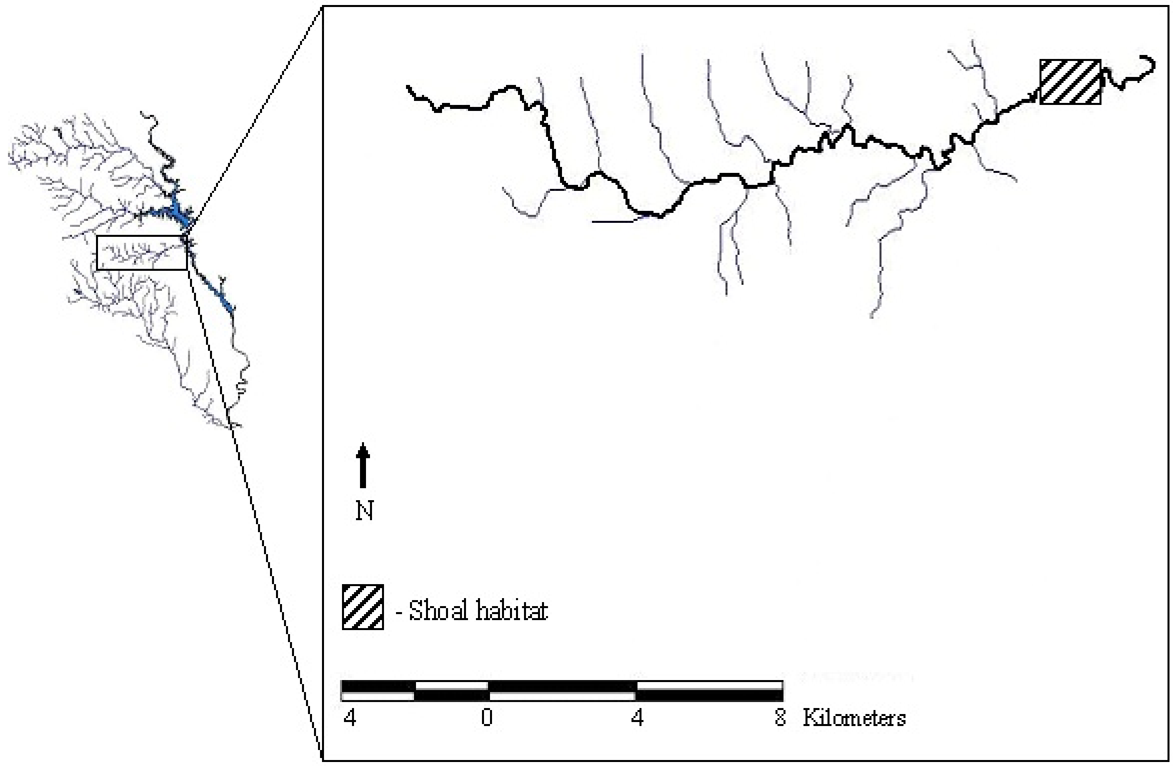

Figure 2. Map of Wacoochee Creek and location of shoal habitat (shaded areas).

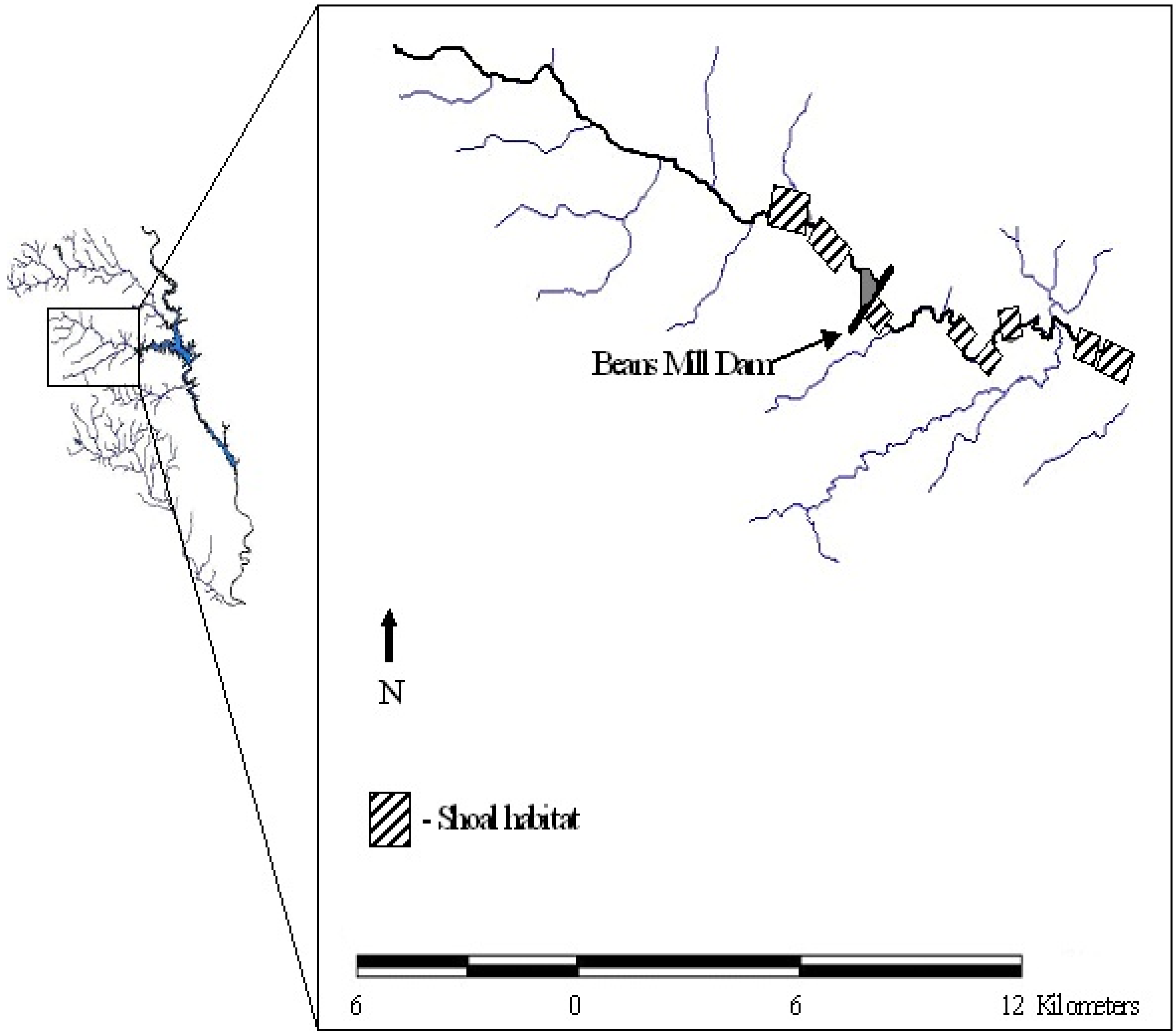

Figure 3. Map of Halawakee Creek and locations of shoal habitat (shaded areas).

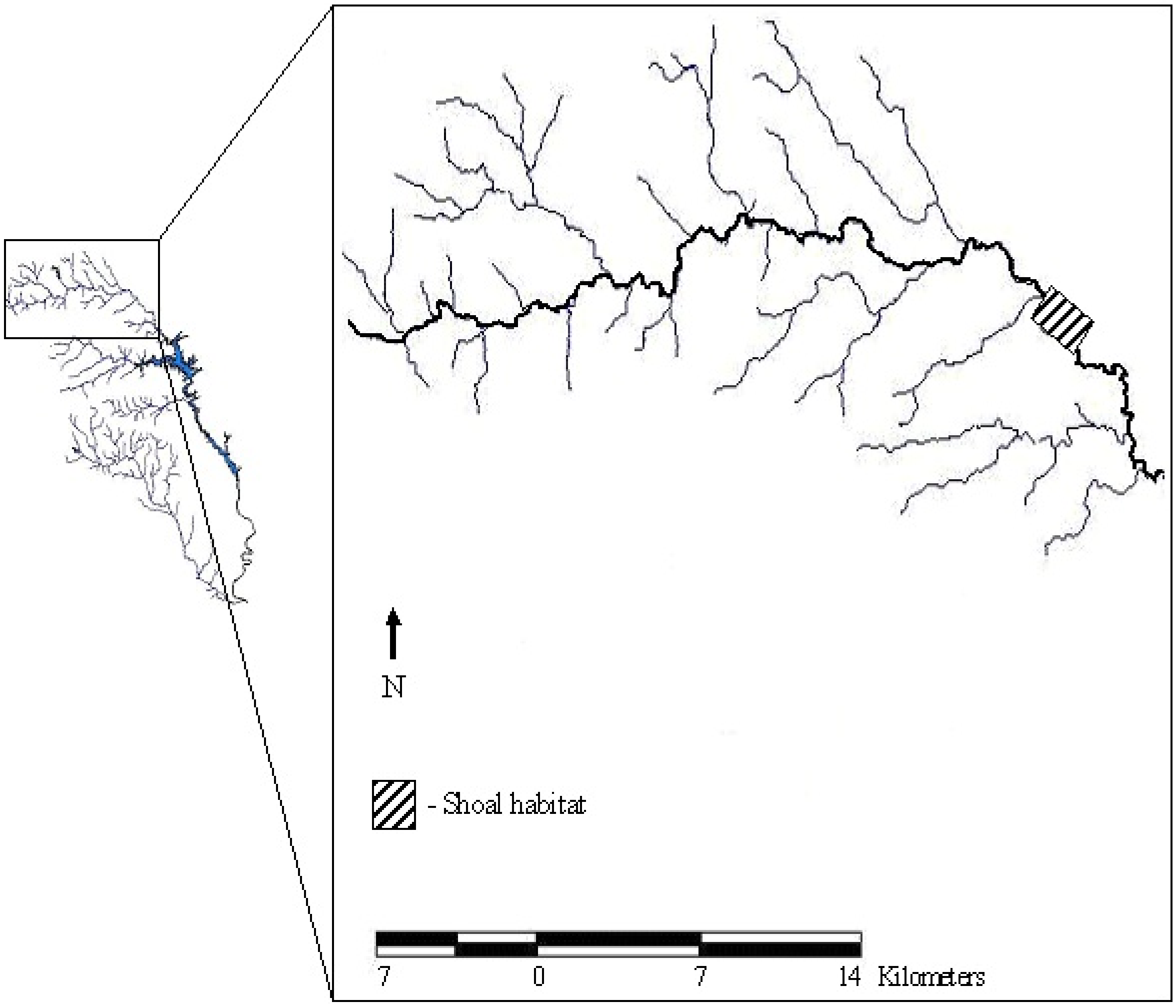

Figure 4. Map of Osanippa Creek and location shoal habitat (shaded areas).

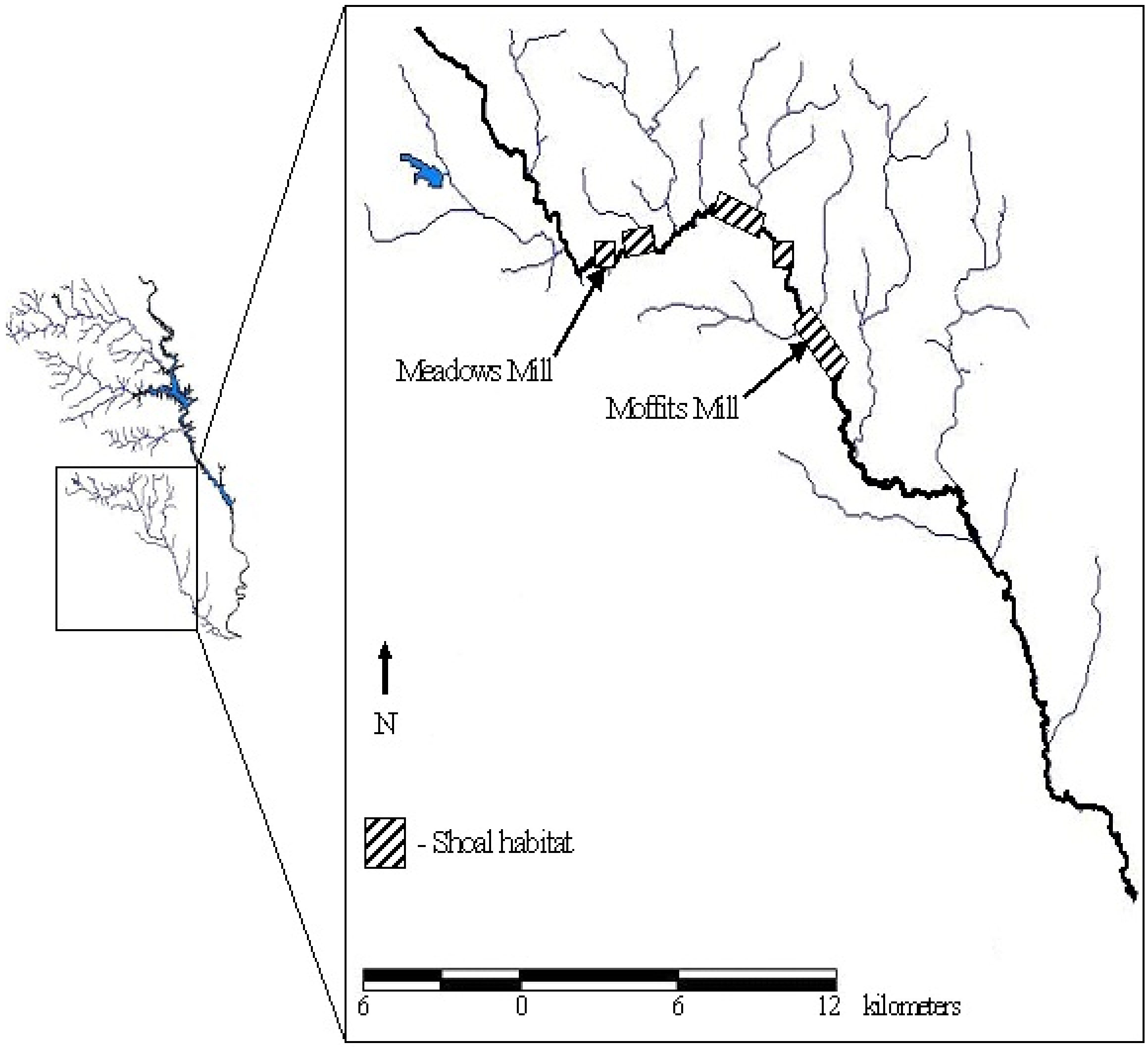

Figure 5. Map of Little Uchee Creek and the locations of shoal habitat.

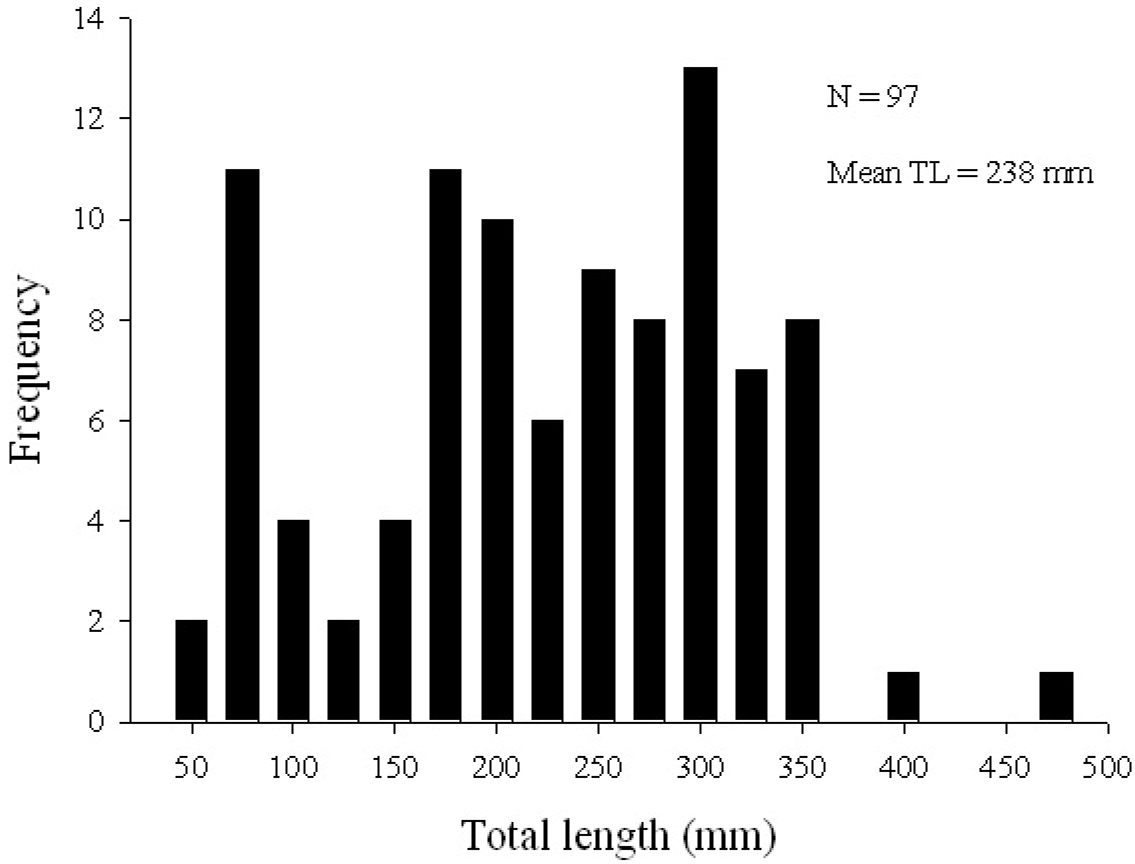

Figure 6. Length-frequency distribution of shoal bass collected from the Little Uchee Creek, Alabama during 6 sampling trips during spring, summer, and fall of both 2005 and 2006.

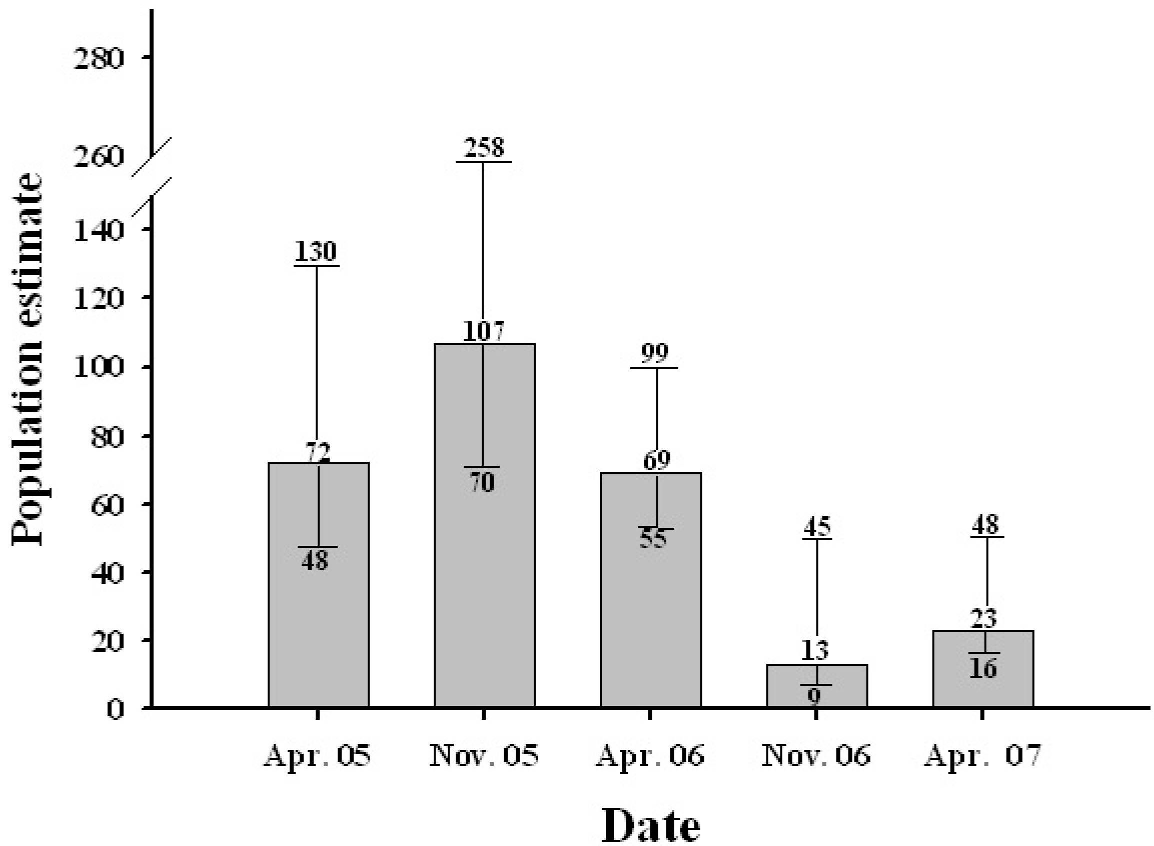

Figure 7. Estimates of shoal bass population size at Moffits Mill. Values on top of frequency bars represent population estimates for each sampling period. Values above and below error bars indicate upper and lower bounds of 90% confidence interval.

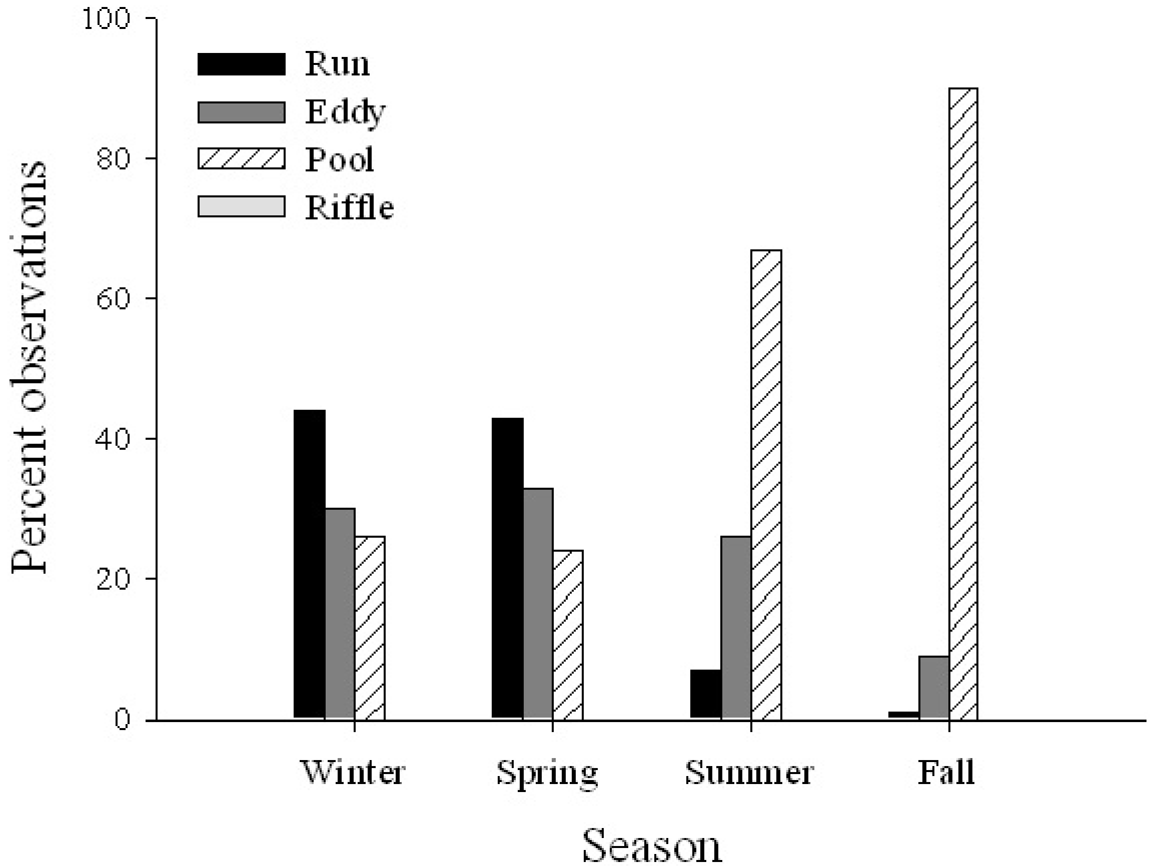

Figure 8. Frequency distribution of mesohabitat use by shoal bass tracked over four seasons at Moffits Mill.

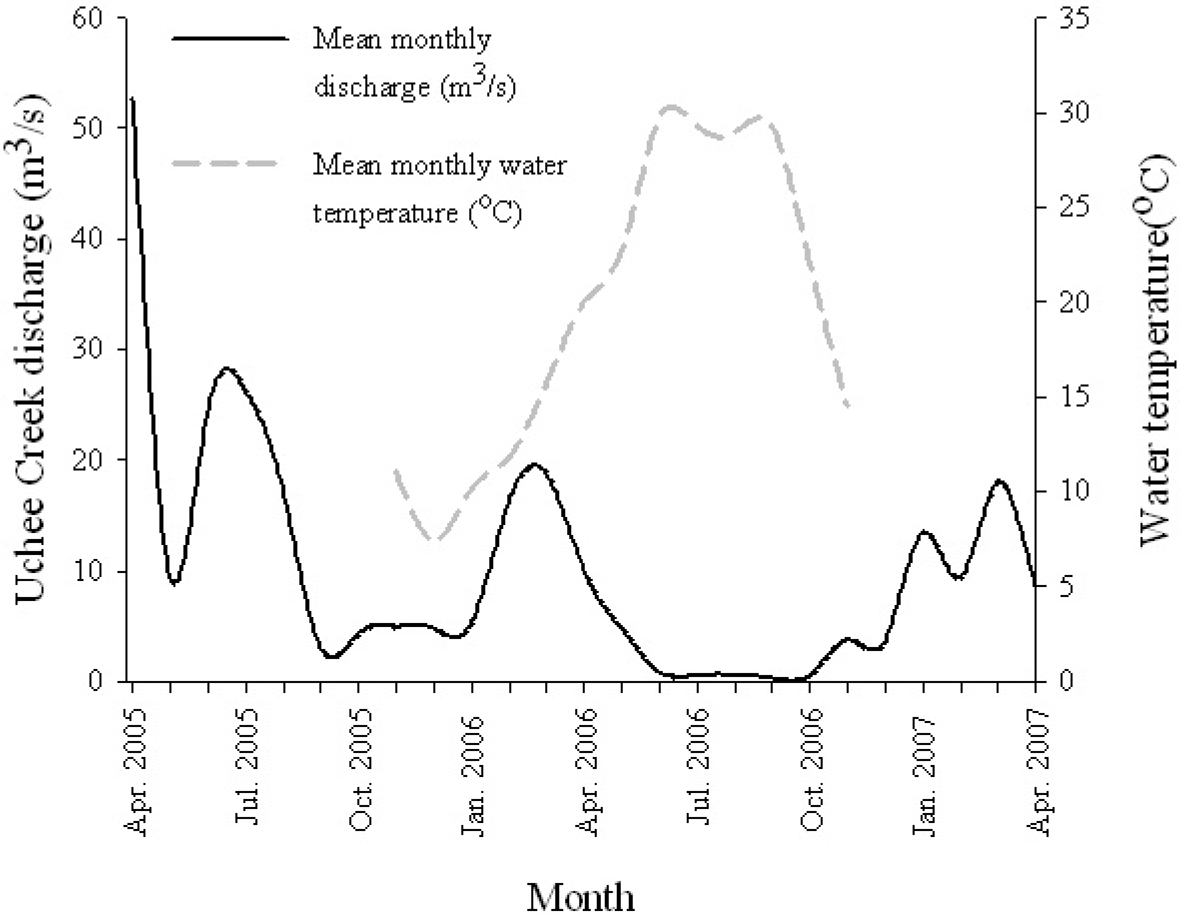

Figure 9. Mean monthly discharge (m^3/s) at Uchee Creek station (near Ft. Mitchell, Alabama) throughout the entire study period and bottom water temperature (°C) at Moffits Mill for the habitat use and movement portion of the study.

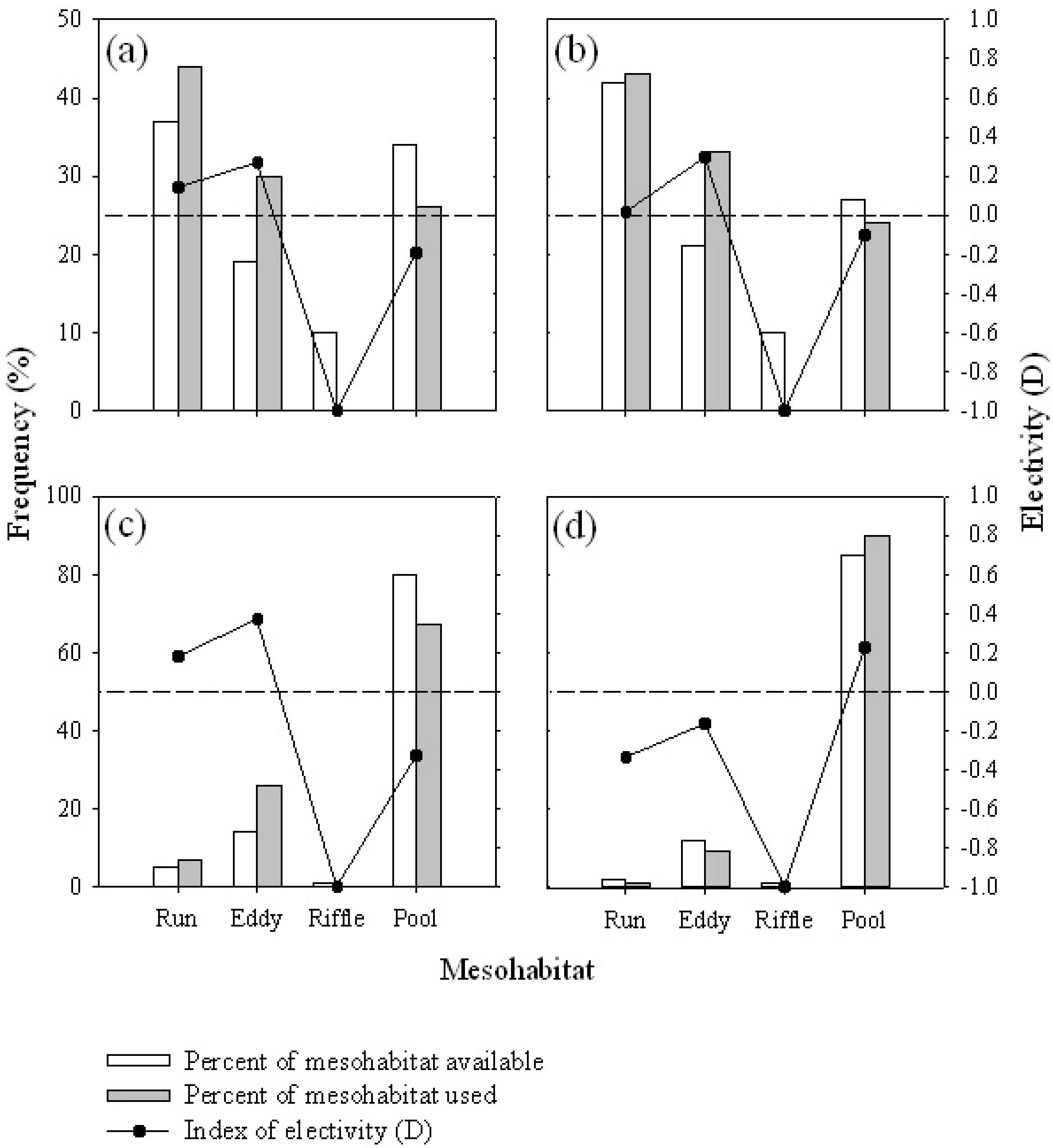

Figure 10. Frequency distributions of mesohabitat types used and available to shoal bass at Moffits Mill in: (a) winter, (b) spring, (c) summer, and (d) fall. Positive electivity (Jacobs 1974) values indicate preference and negative values indicate avoidance.

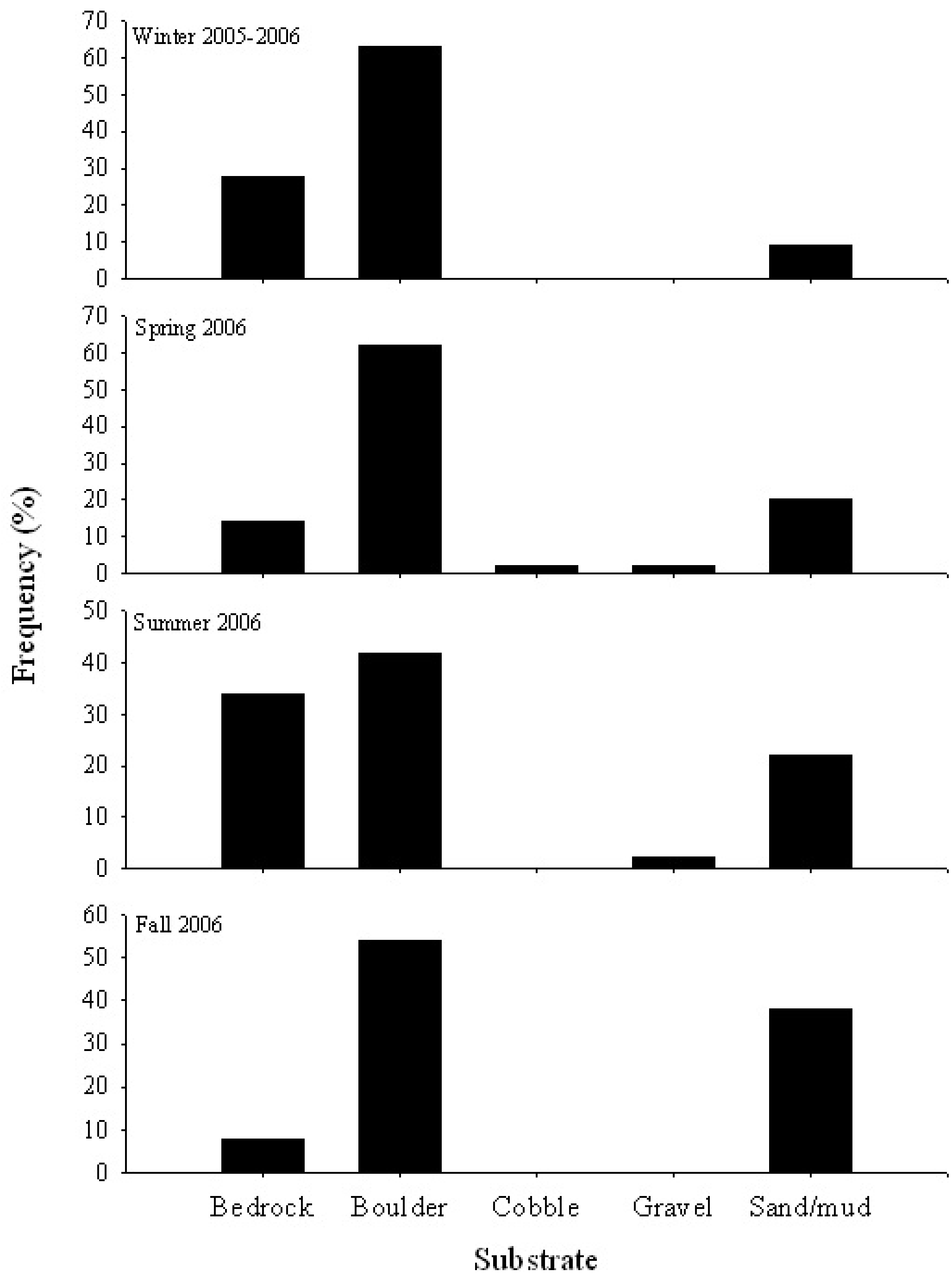

Figure 11. Frequency distribution of substrate use by radio tagged shoal bass tracked over four seasons at Moffits Mill.

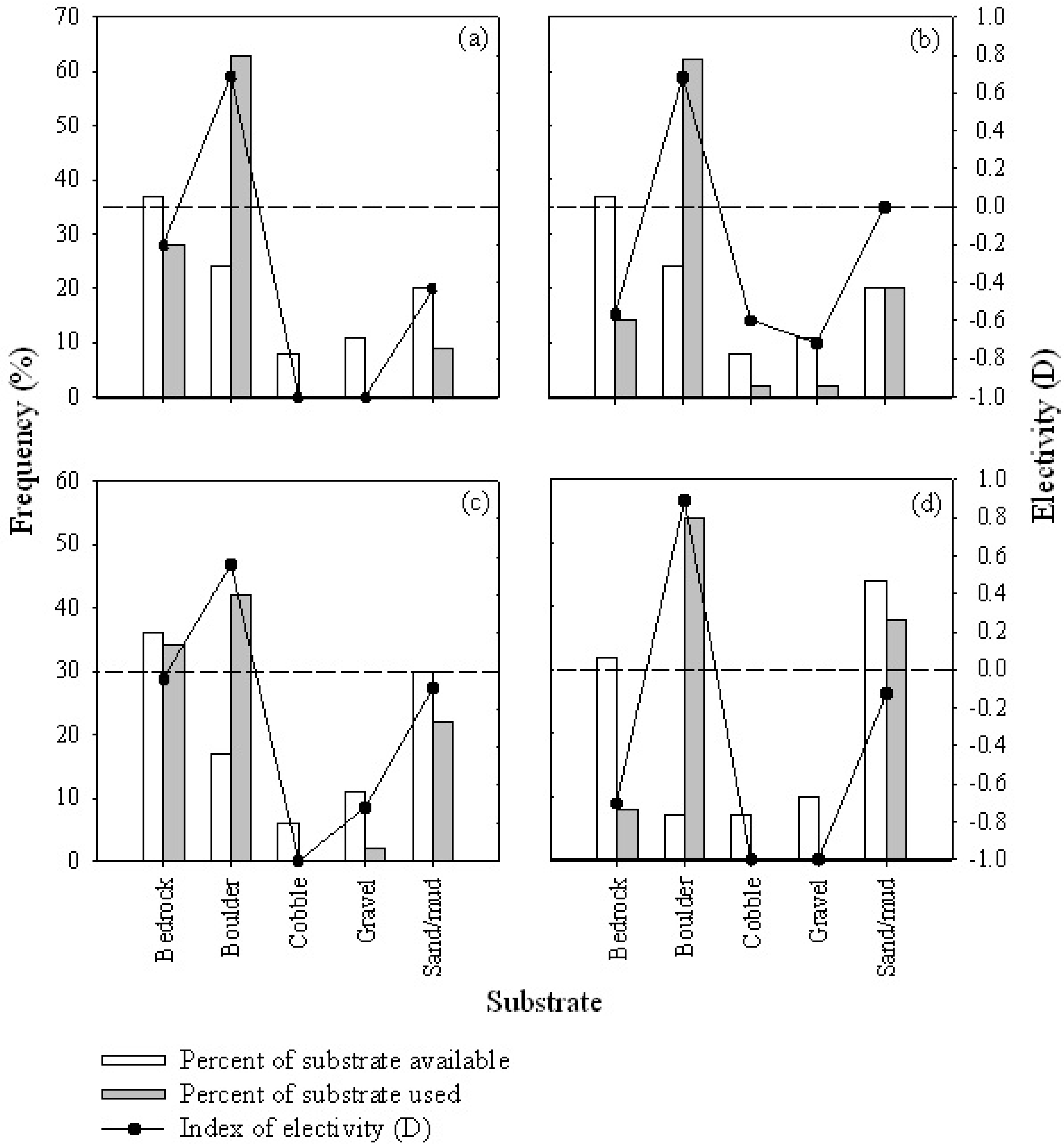

Figure 12. Frequency distributions of substrate types used and available to shoal bass at Moffits Mill in: (a) winter, (b) spring, (c) summer, and (d) fall. Positive electivity (Jacobs 1974) values indicate preference and negative values indicate avoidance.

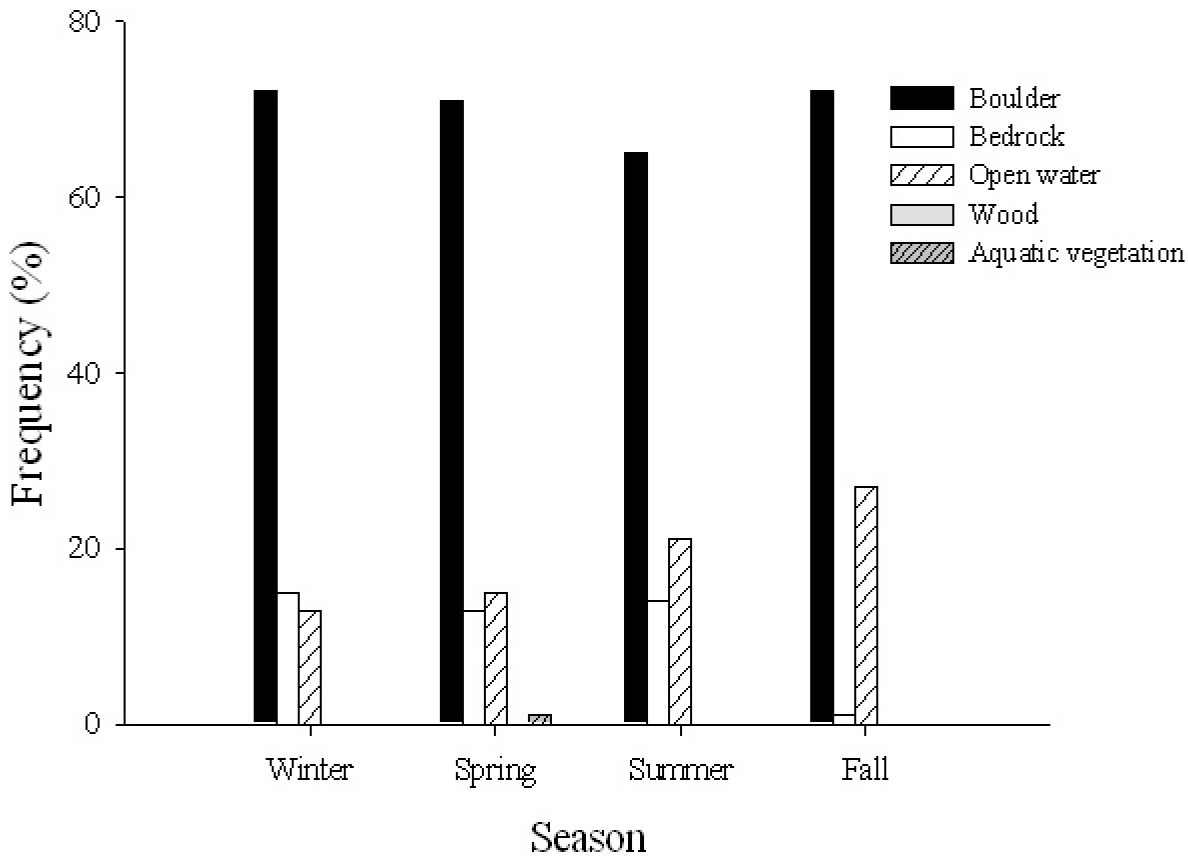

Figure 13. Frequency distribution of cover use by radio tagged shoal bass tracked over four seasons at Moffits Mill.

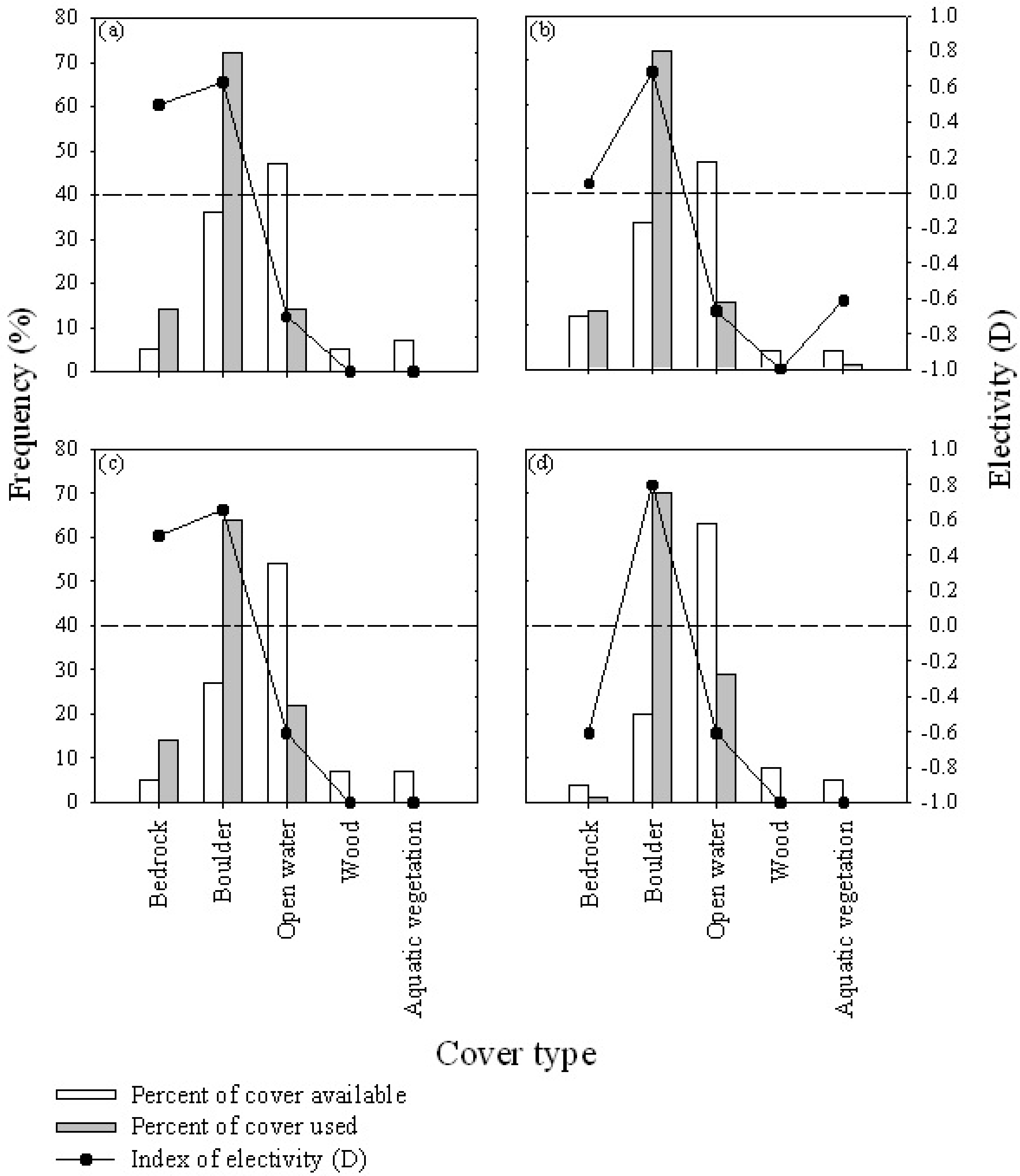

Figure 14. Frequency distributions of cover types used and available to shoal bass at Moffits Mill in: (a) winter, (b) spring, (c) summer, and (d) fall. Positive electivity (Jacobs 1974) values indicate preference and negative values indicate avoidance.

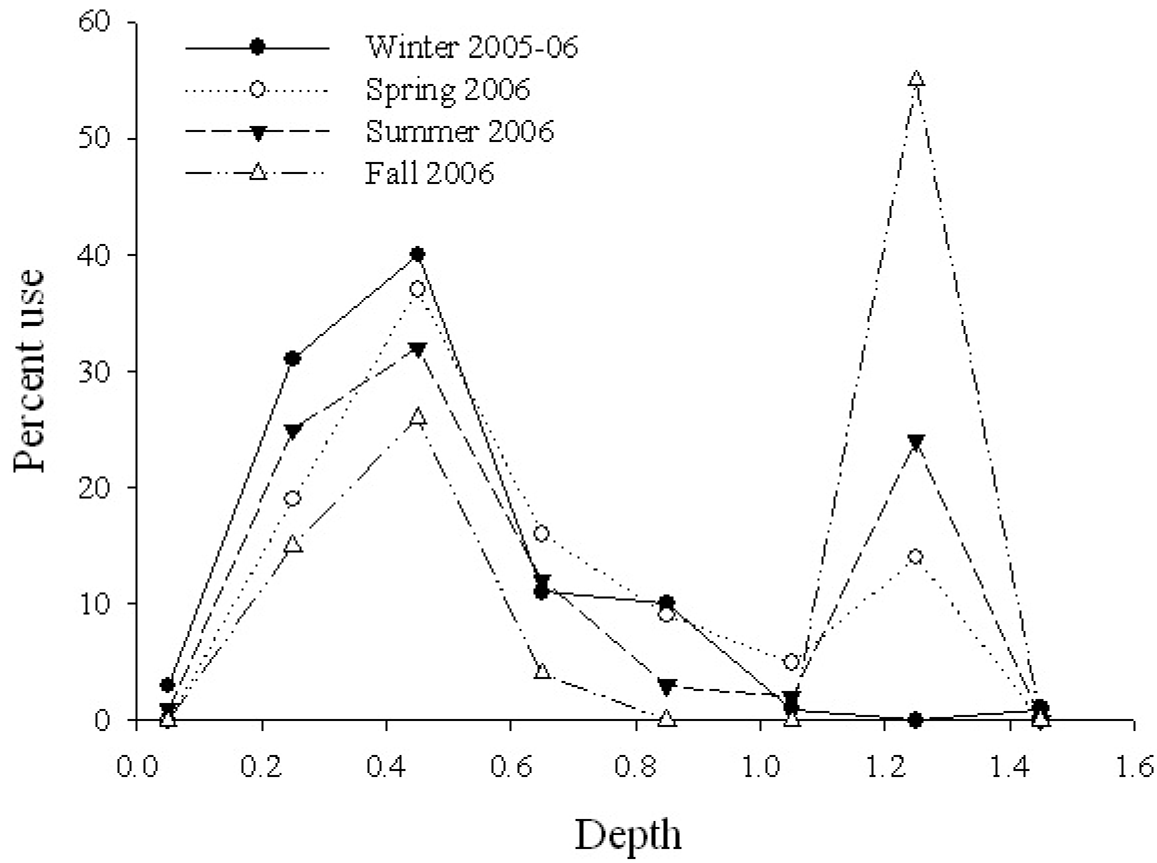

Figure 15. Depth (0.20 m groups) associations for shoal bass tracked over four seasons at Moffits Mill.

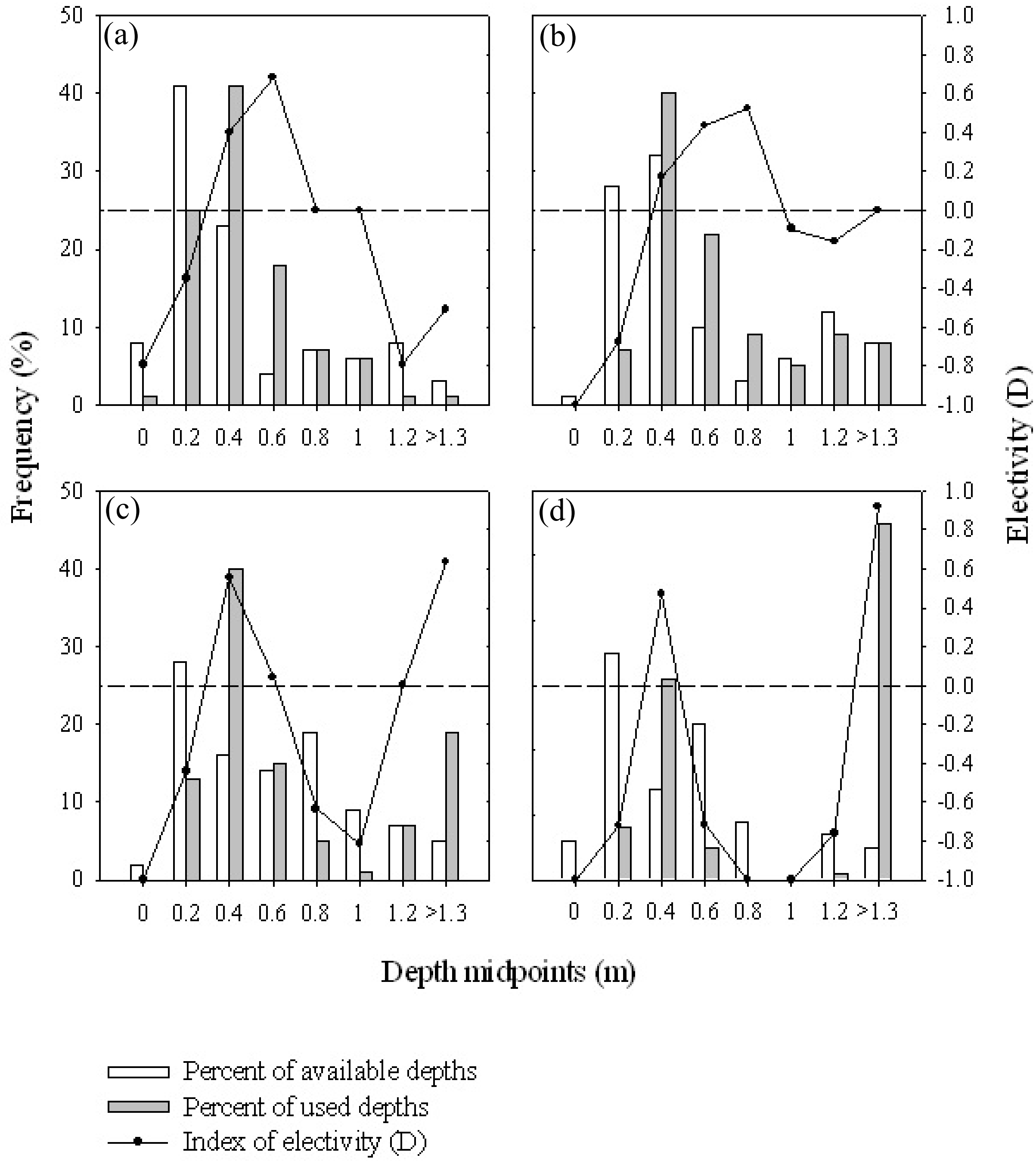

Figure 16. Frequency distributions of depths used and available to shoal bass at Moffits Mill in: (a) winter, (b) spring, (c) summer, and (d) fall. Positive electivity (Jacobs 1974) values indicate preference for each interval and negative values indicate avoidance.

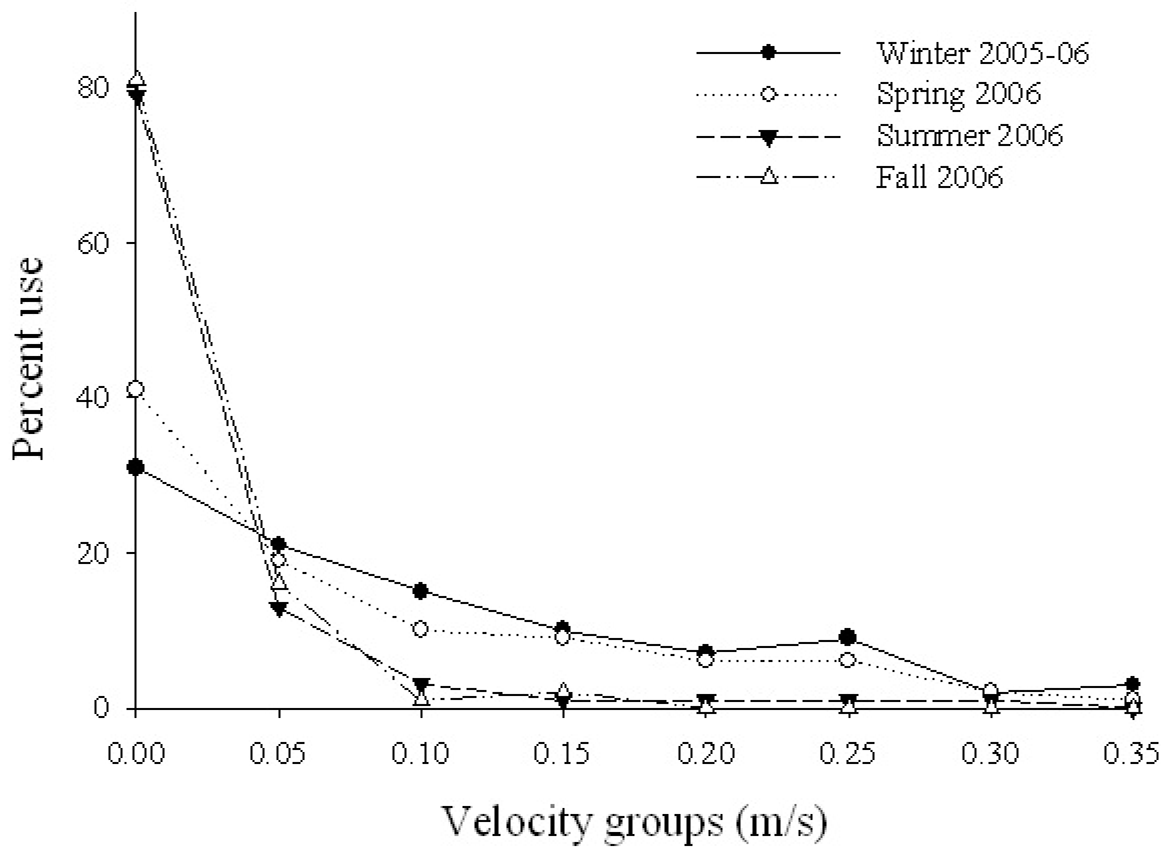

Figure 17. Velocity (0.05 m/s groups) associations for shoal bass tracked over four seasons at Moffits Mill.

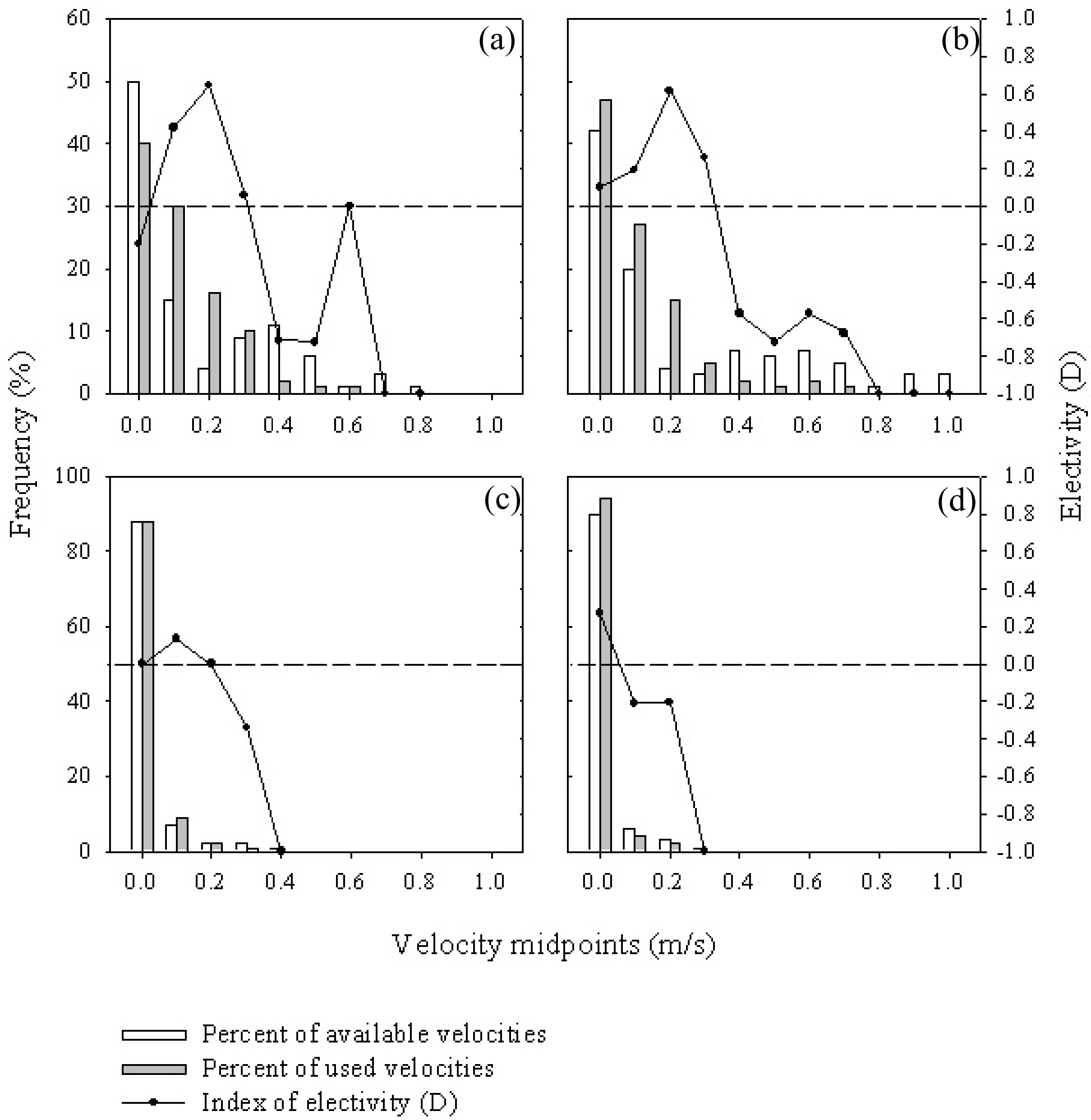

Figure 18 . Frequency distributions of velocity groups used and available to shoal bass at Moffits Mill in: (a) winter, (b) spring, (c) summer, and (d) fall. Positive electivity (Jacobs 1974) values indicate preference for each interval and negative values indicate avoidance.

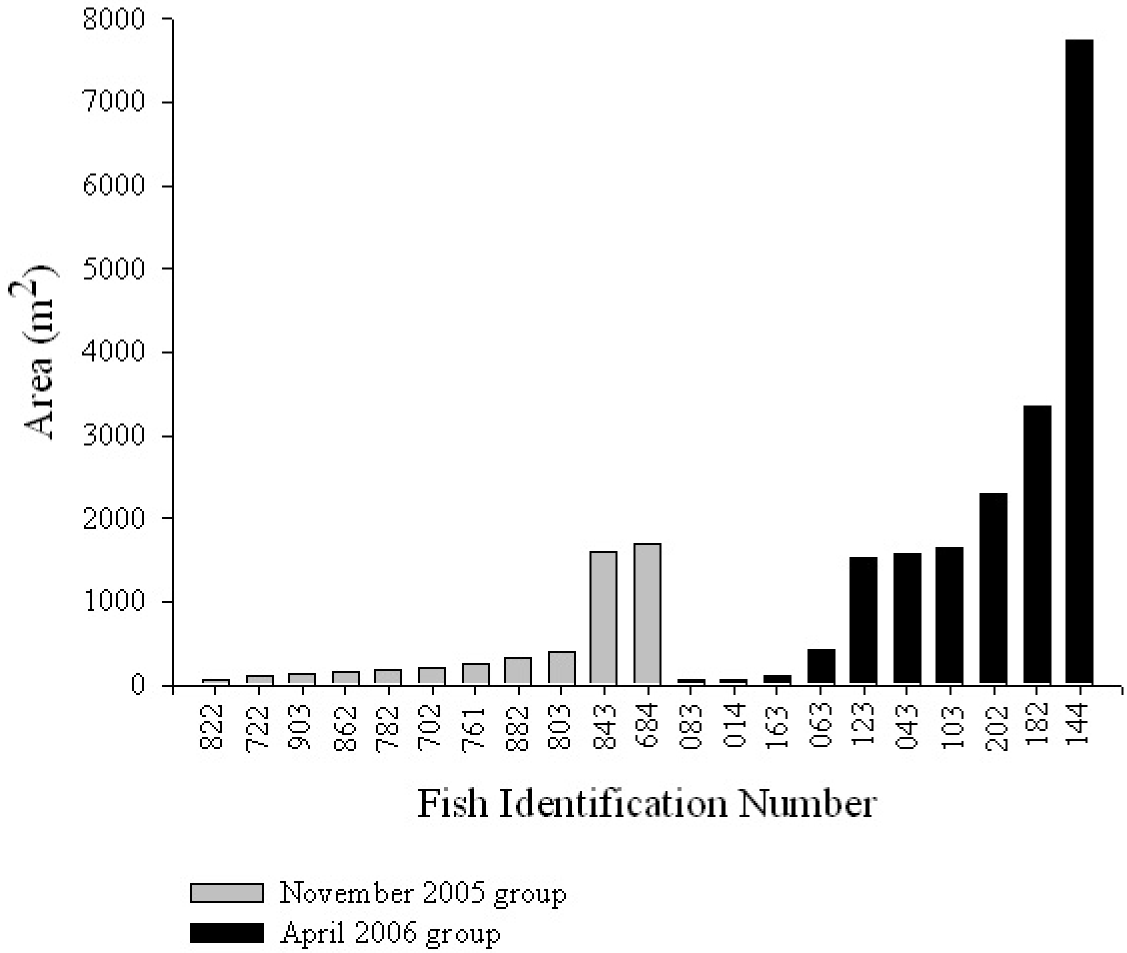

Figure 19. Fifty percent (core) kernel home range areas (m^2) for radio tagged shoal bass at Moffits Mill.

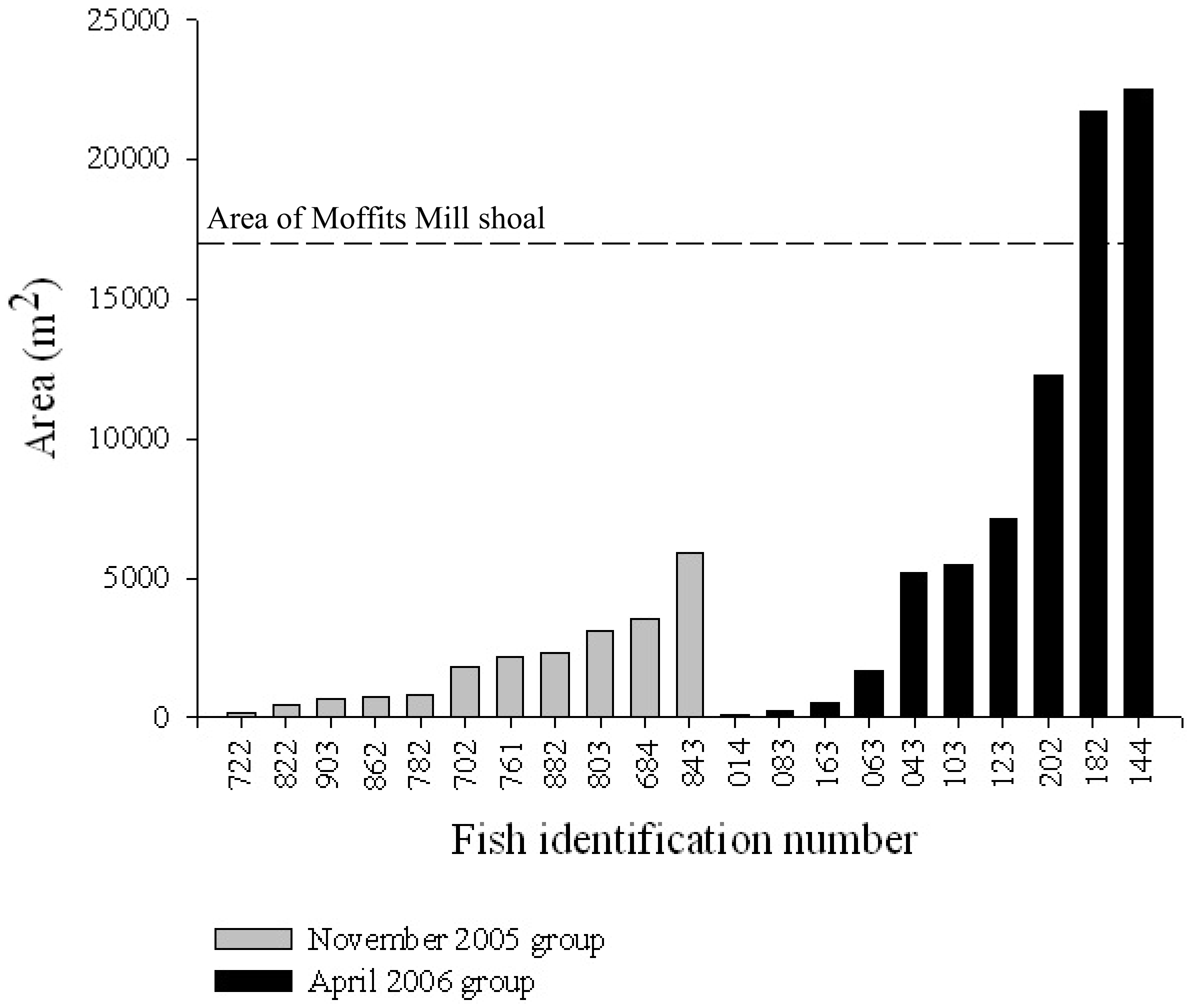

Figure 20. Ninety five percent kernel home range areas (m^2) for radio tagged shoal bass at Moffits Mill. The horizontal dashed line represents the area (17,000 m^2) of the Moffits Mill shoal.

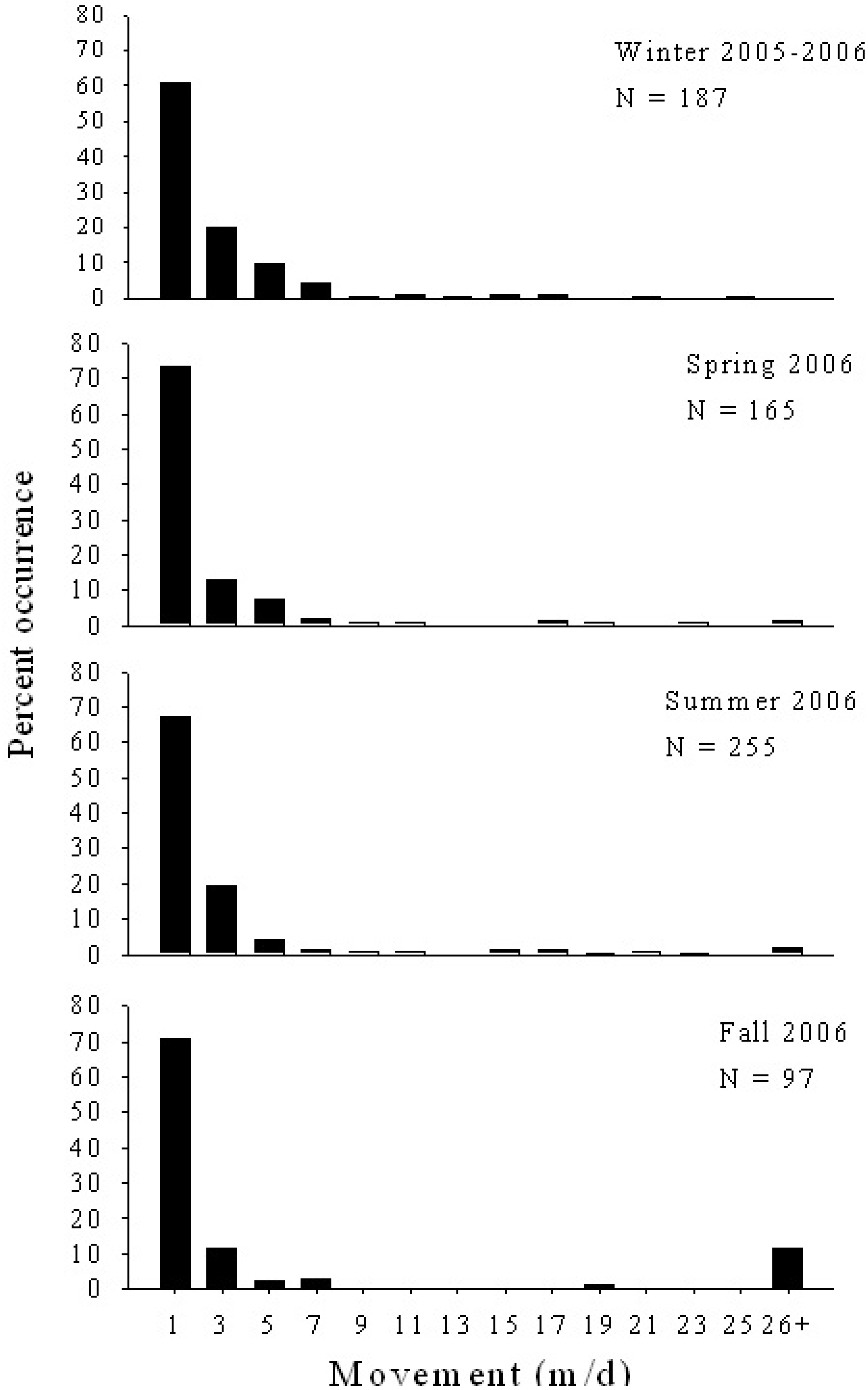

Figure 21. Movement distributions of radio tagged shoal bass tracked in all four seasons at Moffits Mill.

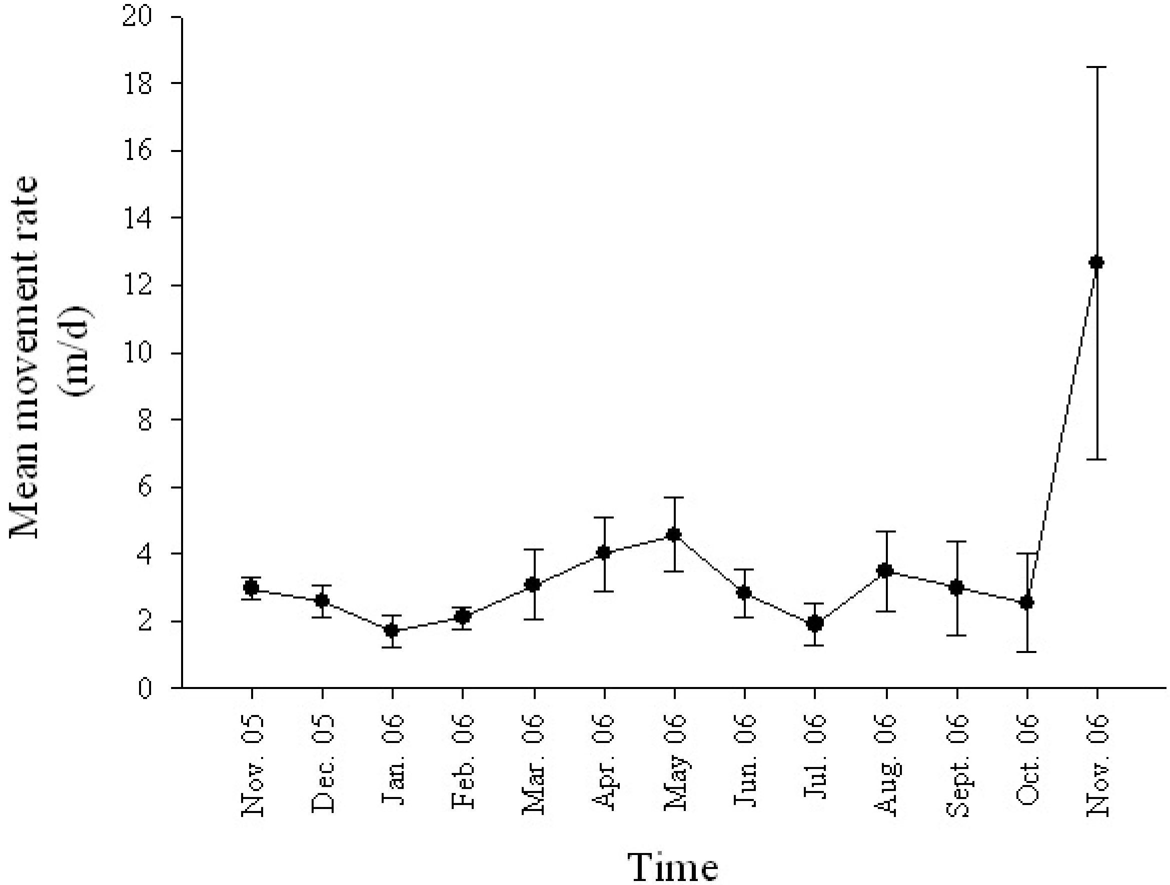

Figure 22. Mean movement rates by month for radio tagged shoal bass at Moffits Mill. Error bars represent ± 1 standard error.

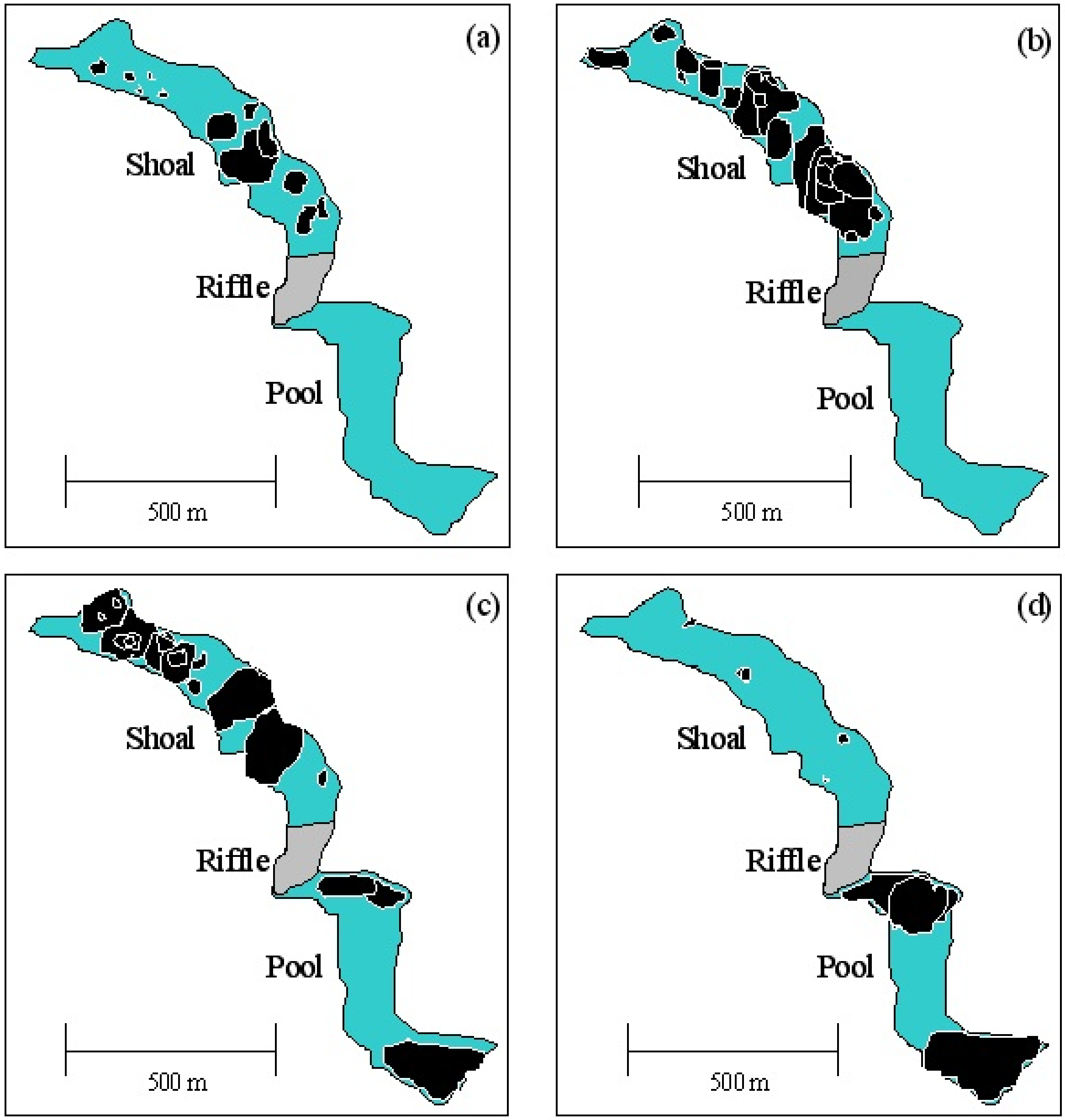

Figure 23. Fifty percent (core) home ranges of radio tagged shoal bass at the Moffits Mill study site in (a) winter 2005-06, (b) spring 2006, (c) summer 2006, and (d) fall 2006. Home ranges are represented by the black images bordered in white.

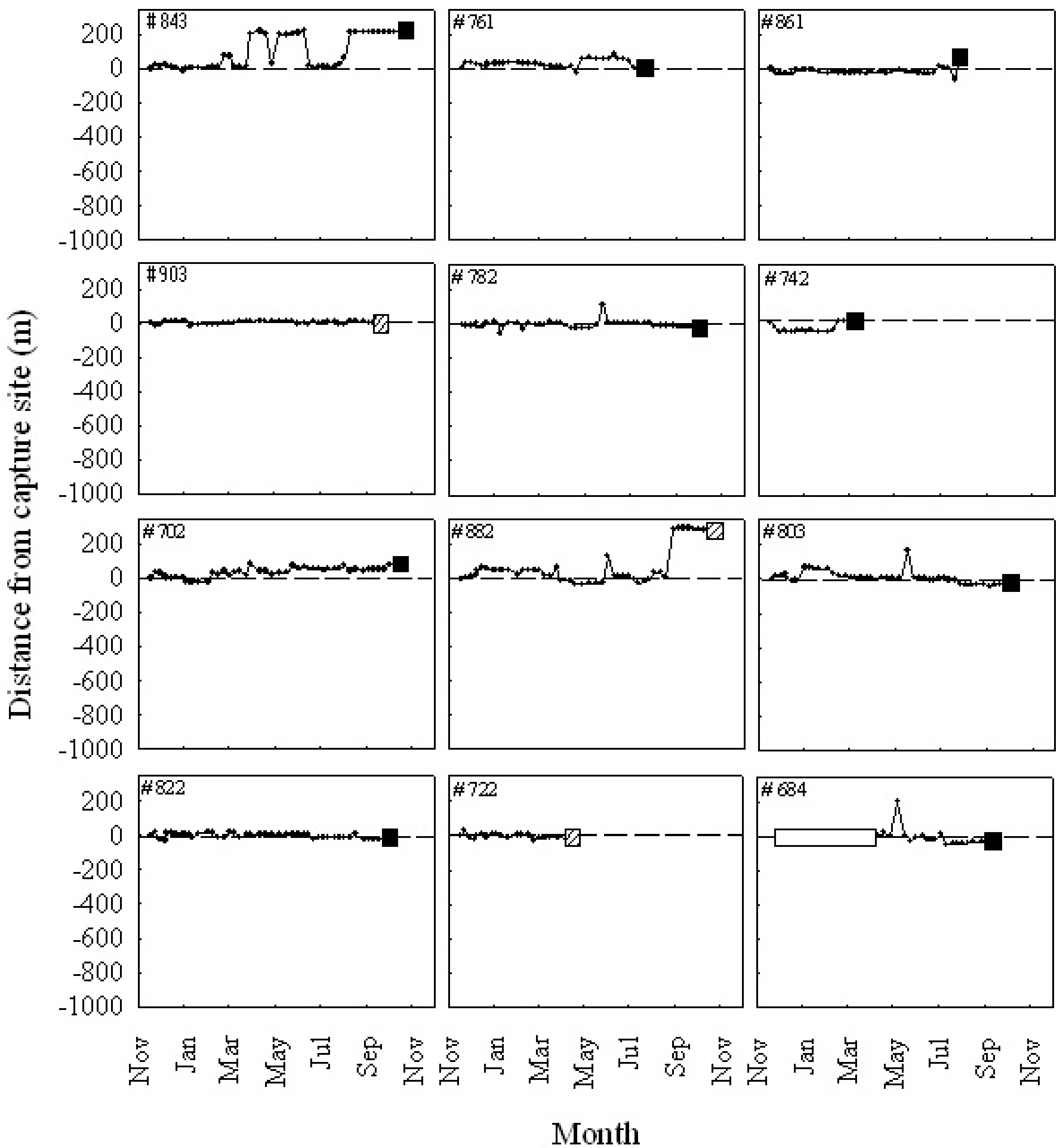

Figure 24. Weekly locations of radio tagged shoal bass (November 2005 group) relative to their capture site (0 m) at Moffits Mill. Positive values are distances moved upstream, and negative values are distances moved downstream from the site of tagging, for each fish. Boxes with diagonal lines indicate a tag expiration. Black boxes indicate mortality.

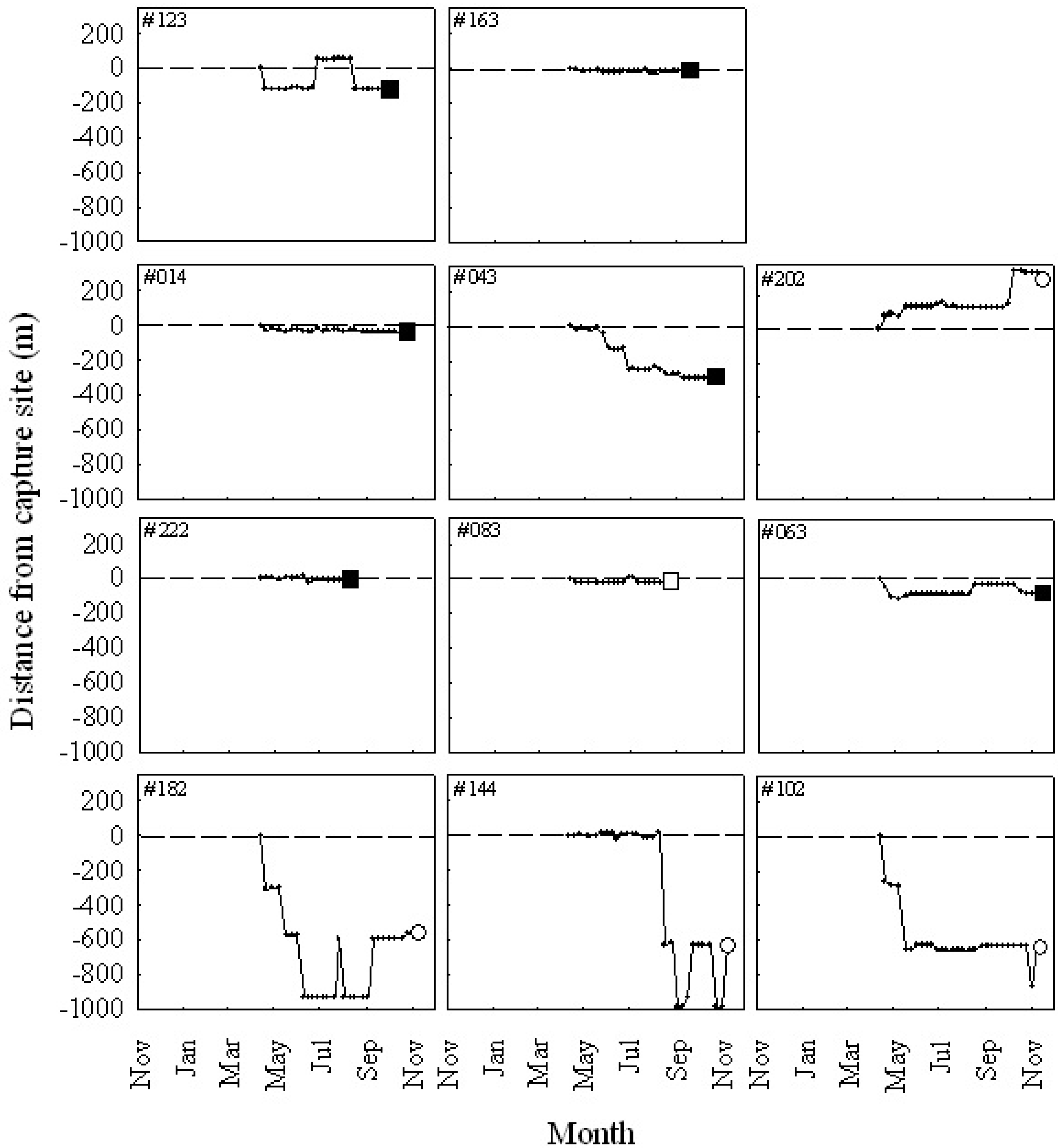

Figure 25. Weekly locations of radio tagged shoal bass (April 2006 group) relative to their capture site (0 m) at Moffits Mill. Positive values are distances moved upstream, and negative values are distances moved downstream from the site of tagging for each fish. Black boxes indicate mortality. White boxes indicate a lost signal. White circles indicate the end of the study period.

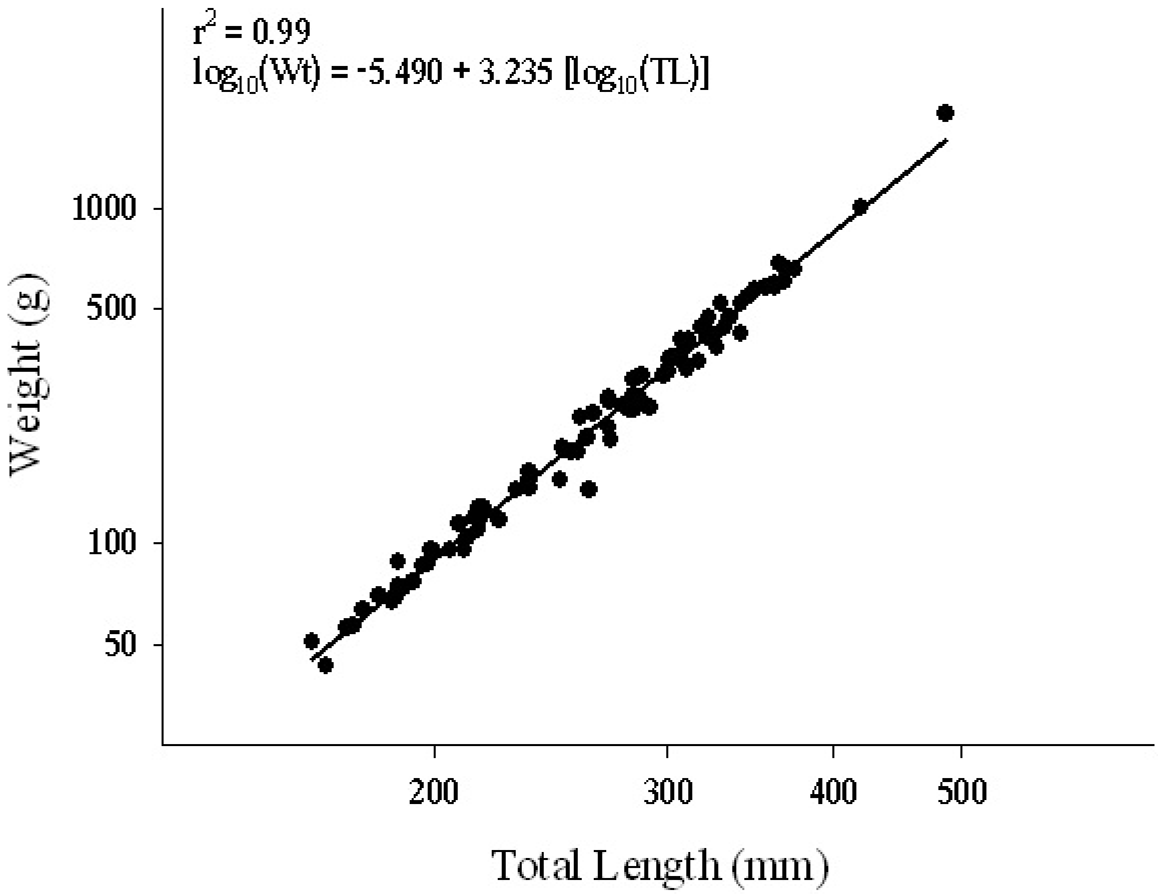

Figure 26. Weight to length regression for shoal bass (≥150 mm TL) collected at Moffits Mill.

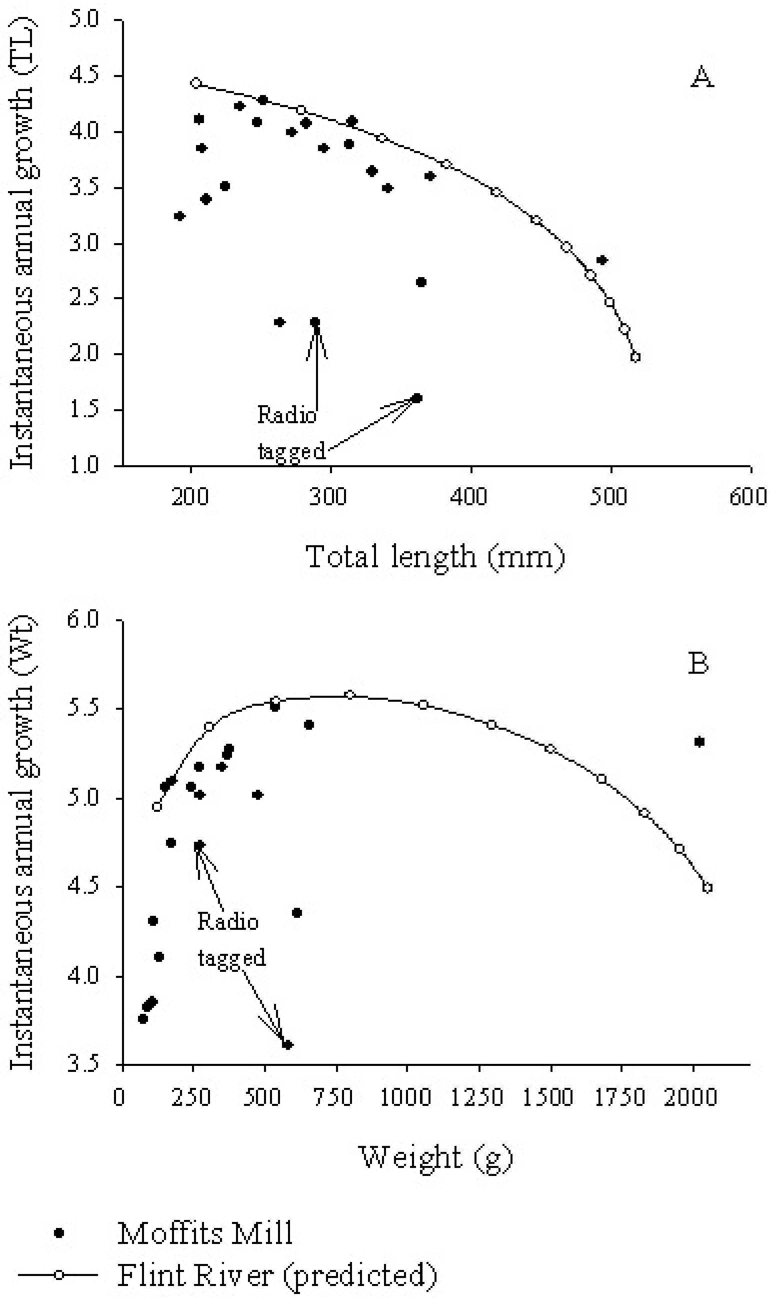

Figure 27. Instantaneous annual growth rates in total length (mm) and weight (g) for recaptured shoal bass from Moffits Mill compared to shoal bass collected from the Flint River, Georgia.

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