Habitat Use of Suwannee Bass and Largemouth Bass in the Withlacoochee River, Florida

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Abstract: We investigated the microhabitat selection of largemouth bass (*Micropterus salmoides*) and Suwannee bass (*M. notius*) using multivariate logistic regression modeling. Relative use probabilities for cover types were similar among juvenile and adult bass of both species with minor differential use. However, the water velocity and depth selection functions between juveniles were associated with slow and shallow locations, while the selection functions between adults were associated with intermediate speeds and depths. The predictive abilities of the habitat selection models significantly differed between juvenile and adult bass of both species, between adult largemouth bass and Suwannee bass, but not between juvenile largemouth bass and Suwannee bass.

The Suwannee bass (*Micropterus notius*) is a species of black bass that was first described in the Ichetucknee River, Florida (Bailey and Hubbs 1949). This species, which inhabits the Suwannee River and Ochlockonee River drainages of Florida and Georgia (Hellier 1967, Bass and Hitt 1973, Bass 1974, MacCrimmon and Robbins 1975, Keefer and Ober 1977), has the smallest natural range of the black basses (Koppleman and Garret 2002). Recently, Suwannee bass were discovered in the Wacissa (Cailteux et al. 2002a), St. Marks, and Wakulla rivers in northwest Florida, although these populations may have been introduced (Cailteux et al. 2002b). Due to their relatively small range, Suwannee bass are considered a species of special concern in Florida (Florida Administrative Code 68A-27.005) and rare in Georgia (Georgia Administrative Code 391-4-10-.09).

Suwannee bass share their narrow range with the widespread (MacCrimmon and Robbins 1975) largemouth bass (*M. salmoides)*. The biology and ecology of largemouth bass have been extensively studied, and they are commonly considered habitat and forage generalists. Conversely, studies pertaining to Suwannee bass are few, and are limited to their distribution (Bass and Hitt 1973, Bass 1974, Keefer and Ober 1977, Schramm and Maceina 1986, Cailteux et al. 2002a, Cailteux et al. 2002b), food habits (Hurst et al. 1975, Schramm and Maceina 1986, Cailteux et al. 2002a), age and growth (Smitherman and Ramsey 1972, Bonvechio et al. 2005) and habitat use (Schramm and Maceina 1986, Strong et al. 2010). The study by Schramm and Maceina (1986) in the Santa Fe River, Florida, contains the only information that compares the habitats used by Suwannee bass and largemouth bass in the same system. The authors concluded that habitat segregation between the species was not evident based on comparisons of relative abundance in six macrohabitats.

As management agencies develop conservation efforts for Suwannee bass (FFWCC 2005), as well as water conservation rules that consider fish and wildlife habitats (Subsection 373.042 (2), Florida Statutes; Chapter 62-40.473, FAC), studies pertaining to habitat use have become increasingly important. Deviation from the natural flow regime (Poff et al. 1997) has been shown to affect fish community composition (Bain et al. 1988, Marchetti and Moyle 2001) and generally benefits species with wider environmental and chemical tolerances (Copp 1990). Thus, the generalist tendencies of largemouth bass may allow this species to more easily adjust to long-term changes in the natural flow regime. Conversely, the restricted range of Suwannee bass may suggest life-stage-specific habitat preferences that limit their distribution, and less of an ability to adjust to habitat changes associated with stream flow alteration.

Differential resource selection is one of the principal relationships that permit species to coexist when resources are limiting (Rosenzweig 1981). Resource selection is influenced by a variety of factors including spatial and temporal scales (Abrams 2000, Schmidt et al. 2000, Wheeler and Allen 2003, Godvik et al. 2009), population densities (Rosenzweig 1981, Greene and Stamps 2001, Lindberg et al. 2006), competition (Rummel and Roughgarden 1985, Young 2004), predation (Werner et al. 1983, Power 1987), and evolutionary processes (Connell 1980, Lawlor 1980). Because

largemouth bass are sympatric throughout the entire range of Suwannee bass, habitat resources may be partitioned to facilitate coexistence due to one or several of these factors. Therefore, we investigated the microhabitat use of Suwannee bass and largemouth bass in a lotic system. The objectives of this study were to test (1) whether habitat parameters used by largemouth bass and Suwannee bass juveniles and adults differed from available (random) habitat parameters, and (2) whether the predictive ability of habitat models resulting from Objective 1 differed between bass species and life stages.

Methods
Study Area

The Withlacoochee River originates in southern Georgia near the cities of Tifton and Moultrie, and drains approximately 6,035 km² of mostly agricultural lands in Georgia and Florida (Hand et al. 1996). The study area was located approximately 1 km downstream of Florida State Route (SR) 6 highway to the confluence with the Suwannee River near Ellaville, Florida (Madison and Hamilton counties) (Figure 1).

Fish Collections

We used boat-electrofishing equipped with a Smith-Root 5.0 GPP to collect Suwannee bass and largemouth bass within the study area depicted in Figure 1. The study area was partitioned into six river segments, based on six shoals which limited boating access between segments during periods of low discharge. Consequently, river segments were unequal in length. Because black bass are often associated with areas containing structure, 200-m transects were located parallel to the riparian zone, where the majority of cover existed in the form of overhanging terrestrial vegetation, tree roots, limerock outcroppings, and snags. Sampling occurred seasonally for two years during winter (January–March), spring (April–June), summer (July–September), and fall (October–December) months to account for temporal shifts in habitat use. We generally sampled 15 transects within each season, with a goal of collecting 50 individuals per species and life stage. Transects were predominantly located within run mesohabitats. Thus, we normally avoided sampling outside river bends where water depth and clarity limited the electrofishing efficiency, and riffle habitats where water velocity was too great to effectively capture stunned fishes. Additionally, effort was made to plan collection trips during low river discharges in each season to minimize stunned-fish drift during electrofishing, and maximize water clarity to more accurately determine the fish's original location and assess the associated microhabitat features.

Prior to fish sampling, five numbered buoys were deployed within each 200-m transect to obtain a sample of the available
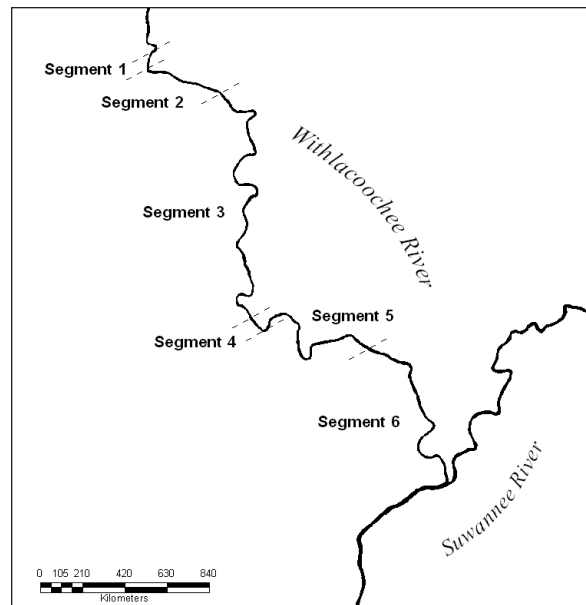
Figure 1. Location of the Withlacoochee River, Florida, and sampling segments (dashed lines).

microhabitat parameters. This was accomplished by the buoy deployer facing away from the shoreline transect and deploying the buoys within the sample area. These available locations were spatially separated, but were otherwise not systematically placed. After these five buoys were deployed, fish sampling within the transect commenced. During fish sampling, a numbered buoy was deployed over the location where each black bass was encountered to measure the used microhabitat parameters. The dip-netter announced the buoy number to the data recorder, and the data recorder identified the species, and recorded the total length (mm) prior to placing the bass into a livewell. Buoys were not deployed if the original location of the bass species was uncertain. Subsequent to fish sampling, microhabitat measurements were recorded at each buoy corresponding to either available or used locations. Water velocity (m sec⁻¹) was recorded at 60% of the depth in the water column using a Marsh-McBirney Flo-mate 2000 portable velocity meter. Water column depth (cm) was measured using a 2-m pole marked in centimeter increments, or a Speedtech Depthmate if the depth exceeded 2 m. Cover type was qualitatively described from the boat and was assigned to one of nine categories listed in Table 1. One measurement of water velocity and depth was taken at the buoy location, whereas cover type was described within a 0.91-m radius of the buoy location.

Table 1. Cover type categories and descriptions assigned to each available and used microhabitat assessment in the Withlacoochee River, Florida.

Cover type	Description
Bedrock no cover	Bedrock substrate with no cover present. Includes cobble and gravel.
Sand no cover	Sand substrates with no cover present.
Roots/knees	Exposed roots of riparian trees and knee projections of cypress trees *Taxodium* spp.
Snag	Large woody debris, typically resting on the river bottom.
Organic debris pack	Includes fine woody debris and leaf litter.
Boulder/rock outcrops	Bedrock forms of cover including boulders, rock overhangs, rock ledges and rock crevices.
Falldown	Trees fallen into stream, typically occupying the majority of the water column, and composed of multiple branches (and occasionally leaves) of different sizes.
Vegetation	Aquatic submersed, emergent, and floating macrophytes, including filamentous algae mats. Terrestrial vegetation hanging over and into the stream.
Undercut bank	A bank in which the profundal portion has eroded away by the water action.

Microhabitat Analyses

Length frequency histograms were constructed for Suwannee bass and largemouth bass from each sampling season to identify the length break between juvenile and adult fishes. We assumed that all size classes that comprised the first mode in the distribution represented juveniles as either age 0 in the summer and fall collections, or age 1 in the winter and spring collections. The remaining fishes larger than those in the first mode were considered adults.

We used retrospective logistic regression (McCullagh and Nelder 1989, Agresti 2002), to model the probabilities that microhabitat variables were associated with used locations as opposed to available locations. In retrospective logistic analysis, observations are chosen on the basis of their response condition, and potential explanatory variables are then observed. In our case, sample location (used locations vs. available locations) was treated as the response in the following binary pairs: largemouth bass adult vs. available, largemouth bass juvenile vs. available, Suwannee bass adult vs. available, and Suwannee bass juvenile vs. available. Explanatory variables examined for fixed predictor effects included cover type, sample period, water velocity, and water depth. The former two variables were categorical, and the latter two continuous. Observations for each response pair were modeled under the assumption that they were independent. Main effects for the four predictor variables were included in all models regardless of significance. All interactions were evaluated, and the models were compared by AICc. If the ΔAICc between two models was <2, then the model with fewer parameters was favored (Burnham and Anderson 2002). Logistic modeling was performed primar-

ily with SAS PROC GLIMMIX assuming a binary conditional response distribution and logit link function (SAS Institute 2010a). SAS PROC LOGISTIC (SAS Institute 2010b), and S-PLUS Design library functions (lrm, rcs, plot.Design, and residual.Design; Harrell 2003 a) were also applied as checks or supplements.

Improvements to model fit were checked after including random effects of river segment and nonlinear effects of the continuous predictors water depth and water velocity. The LaPlace estimation method of PROC GLIMMIX was used with random effects. Harrell's (2004) restricted cubic spline macro DASPLINE was used to compute 3- and 4- knot spline terms for water velocity and depth to transform these predictors to non-linear forms. Models with interactions between the spline terms and the other variables were examined. Model averaging was not employed because our interest was primarily in model structure, and nonlinear effects make parameter averaging inappropriate (Burnham and Anderson 2002). Because the models were exploratory and power considerations were paramount, *P*-values were not adjusted for multiple tests (Roback and Askins 2005).

Effects of the predictors were evaluated by type III F tests and summarized by probability plots. For continuous predictors (velocity and depth), we modeled the probability that a sampled location at any point on the predictor scale was one used by a fish rather than one randomly available with S-PLUS plot.Design's option "fun = function(x)1/(1+exp(x)." This transforms a prediction from the logit scale to probability scale (Harrell, 2003 b). These plotted probabilities were adjusted to the median value of the continuous variable whose effect is not shown and to the most frequent level of the categorical variables cover type and sample period. For the categorical cover predictor (cover), the modeled probabilities that a location was used by a fish were plotted as values output by SAS GLIMMIX LSMEANS statements with the ILINK option, which also transforms from the logit scale to probability scale (SAS Institute 2010b). The LSMEANS statement estimates means for categorical variable levels at the means of continuous covariates and as if the categorical classes were balanced. For both continuous and categorical predictors, a probability near 1 would indicate that variable was almost certainly associated with a used location rather than with an available location, and a probability near 0 would indicate that variable was almost certainly associated with an available location rather than a used location.

The final models were checked for global goodness of fit by le Cessie-van Houwelingen-Copas-Hosmer unweighted sum of squares (CHCHUSS) tests (computed with S-PLUS Design library function 'residuals.lrm'; Harrell 2003 c). *P* values >0.05 for these goodness-of-fit tests indicate acceptable fit. Predictive ability of the models was summarized by determining the area under the corre-

sponding "receiver operating characteristic" (ROC) curves. These areas were computed using SAS PROC LOGISTIC and Gönen's (2007) ROC macro with leave-one-out cross validation; standard errors estimated by this macro correspond to those computed asymptotically from Somers' D statistic (Gönen 2007). Receiver operating characteristic curves plot cross validated rank-ordered proportions of true positives (fish locations predicted to be fish locations) versus proportions of false positives (random locations predicted to be fish locations). When ROC area equals 0.5, the model is useless for prediction, and indicates no selectivity on the part of the fish. When ROC area = 1.0, the model predicts perfectly. Pairwise differences in ROC areas were also tested by computing $Z = |\text{Area1} - \text{Area2}|/(SE^2_{area1} + SE^2_{area2})^{0.5}$ and applying a two-tailed test with a = 0.05 that Z differed significantly from 0 (GraphPad Software 2009). This test assumes that the data for the two ROC curves are uncorrelated, an assumption that is partially violated by use of the same (or similar) data for random locations in different models. Such correlation makes this test conservative (Hanley and McNeil 1983). Significant differences in ROC area were taken to indicate differences in overall habitat selectivity (or at least differential use) implied by the fitted models.

Results

We measured microhabitat variables at 1,885 locations during eight seasonal sampling periods, and the number of sample locations varied by season, year, species, and life stage (Table 2). Observations of fish at the available locations were rare: 9 largemouth bass adults (1.53%), 11 largemouth bass juveniles (1.9%), 19 Suwannee bass adults (3.23 %), and 2 Suwannee bass juveniles (0.34%). Juveniles of both species had poor recruitment in 2005 based on the number of used locations, which affected the seasonal sample size (Table 2). This was likely due to poor survival of juveniles following a spring flood in 2005 that increased the river discharge by 9,000 cfs and the stage by 7.6 m.
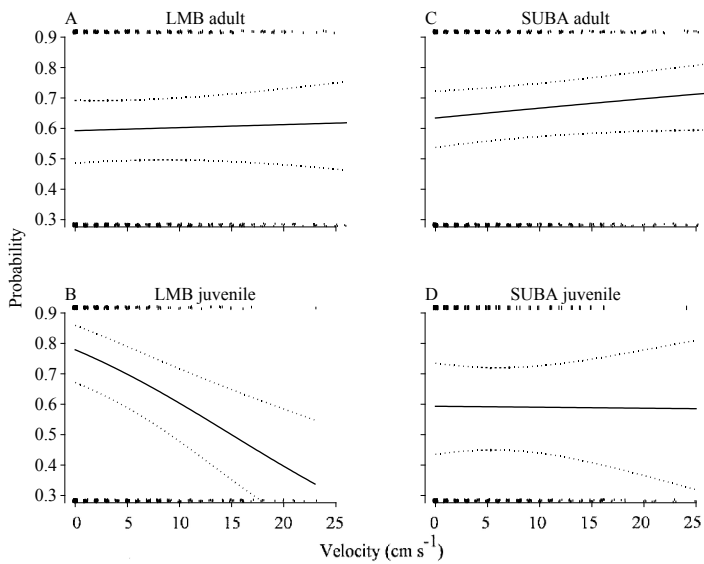
In the model chosen for largemouth bass adults (CHCHUSS Z = 0.067, P = 0.946), all variables except water velocity provided some significant predictive discrimination between used locations and available locations (Table 3, Figure 2A). Depth was best trans-

Table 2. The number of available sample locations, and the number of used sample locations for adult and juvenile largemouth and Suwannee bass during each sample period on the Withlacoochee River, Florida. LMB = largemouth bass and SUBA = Suwannee bass. WI = winter, SP = spring, SU = summer, FA = fall. NS = no sample was not collected.

| | 2005 | 2006 | | | | 2007 | | | | |
	FA	WI	SP	SU	FA	WI	SP	SU	FA	Total
Available	92	76	76	65	NS	71	74	75	60	589
LMB adult	14	20	50	25	NS	31	61	63	92	356
LMB juvenile	0	1	8	112	NS	100	26	69	27	343
SUBA adult	77	39	82	40	NS	14	51	90	56	449
SUBA juvenile	4	0	0	38	NS	28	45	19	14	148

Table 3. Fixed effect type III tests of logistic models for adult and juvenile largemouth and Suwannee bass. The F statistic is expressed with numerator and denominator degrees of freedom in subscript parentheses, and *P*-value underneath. The Depth (1) and Depth (2) variables represent the 3-knot and 4-knot restricted cubic spline terms, respectively. Model predictive ability was measured by the area under the corresponding "receiver operating characteristic" (ROC), with associated standard error. Similar letters under the significance grouping indicates no difference (*P* > 0.05) in model predictive abilities by the species/stages. LMB = largemouth bass, SUBA = Suwannee bass, -a = adult, and -j = juvenile. The model presented for LMB-j is without fixed effect interactions.
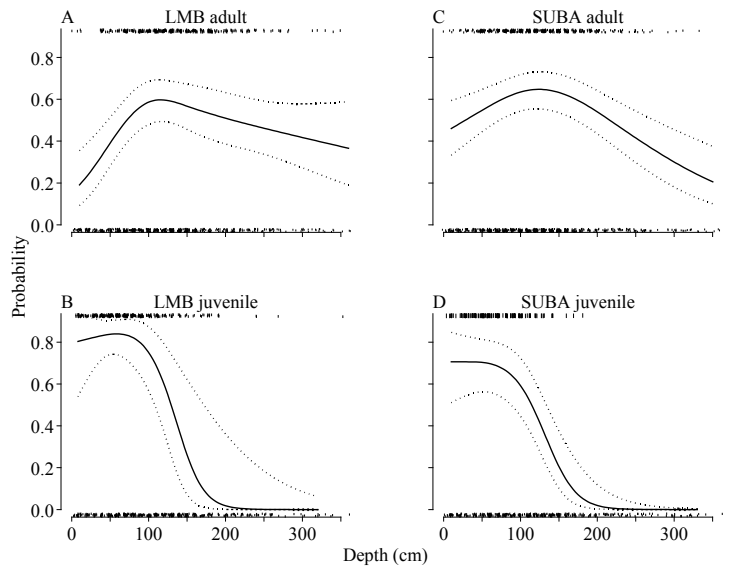
| | Effect | | | | | | Predictive ability |
	Velocity	Depth	Depth (1)	Depth (2)	Cover	Sample period	ROC area ±SE Significance grouping
LMB-a	$0.13_{(1,841)}$ 0.7215	$16.52_{(1,841)}$ <0.0001	$9.17_{(1,841)}$ 0.0025	$6.04_{(1,841)}$ 0.0142	$8.96_{(7,841)}$ <0.0001	$4.23_{(7,841)}$ 0.0001	0.7233 ± 0.0177 A
LMB-j	$15.09_{(1,681)}$ 0.0001	$4.28_{(1,681)}$ 0.0389	$11.58_{(1,681)}$ 0.0007	$11.53_{(1,681)}$ 0.0007	$3.23_{(7,681)}$ 0.0023	$11.78_{(5,681)}$ <0.0001	0.7725 ± 0.0175 B
SUBA-a	$2.34_{(1,959)}$ 0.1268	$11.61_{(1,959)}$ 0.0007	$20.05_{(1,959)}$ <0.0001	NA NA	$7.03_{(7,959)}$ <0.0001	$3.80_{(7,959)}$ 0.0004	0.6719 ± 0.0171 C
SUBA-j	$0.02_{(1,524)}$ 0.9011	$0.08_{(1,524)}$ 0.7832	$9.06_{(1,524)}$ 0.0027	NA NA	$3.05_{(7,524)}$ 0.0037	$4.62_{(5,524)}$ 0.0004	0.7957 ± 0.0199 B

Figure 2. Velocity logistic regression models (solid line) for adult and juvenile largemouth bass and Suwannee bass. The y-axis values indicate the probability that a given velocity was associated with a used location rather than an available location. Dotted lines represent the 95% confidence intervals around the function. The jittered marks at the top of the graph represent the frequency of used locations, and the jittered marks on the x-axis represent the frequency of available locations.

Figure 3. Depth logistic regression models (solid line) for adult and juvenile largemouth bass and Suwannee bass. The y-axis values indicate the probability that a given depth was associated with a used location rather than an available location. Dotted lines represent the 95% confidence intervals around the function. The jittered marks at the top of the graph represent the frequency of used locations, and the jittered marks on the x-axis represent the frequency of available locations. Graph B is presented with no interactions.

formed as a 4-knot spline, and the estimated probability that depth was associated with a used location rather than a random location peaked at around 100 cm (Figure 3A). The probability that locations were used in depths greater than 100 cm declined more slowly than the probabilities associated with depths less than 100 cm. Least squares mean probabilities of locations associated with largemouth bass adults rather than available locations were greatest with falldown, snag, and vegetation cover types (Figure 4A).

The logistic model for juvenile largemouth bass with lowest AICc was one containing interactions between 3-knot spline terms for depth and cover type as well as between depth and sample period. However, such effects are difficult to summarize concisely and may not represent practically useful patterns. Alternatively, the best model lacking interactions was one including 4-knot spline effects for depth. Although much inferior to the best model by AICc (ΔAICc @ 20), its practical predictive ability as judged by cross validated ROC was not significantly lower (0.7866 vs. 0.7725, Z = 0.7=576, *P* = 0.564), and the CHCHUSS test indicated acceptable fit (Z = 0.567, *P* = 0.571). Although the models are not quite nested because of their difference in spline terms, this seems a case where a less than best model can be profitably used despite omitting some fine scale effects (Burnham and Anderson 2002). Consequently, the alternative depth probability function was highest at depths less than 100 cm, and then decreased steadily until a depth of 200 cm (Figure 3B). Beyond 200 cm, probability of use
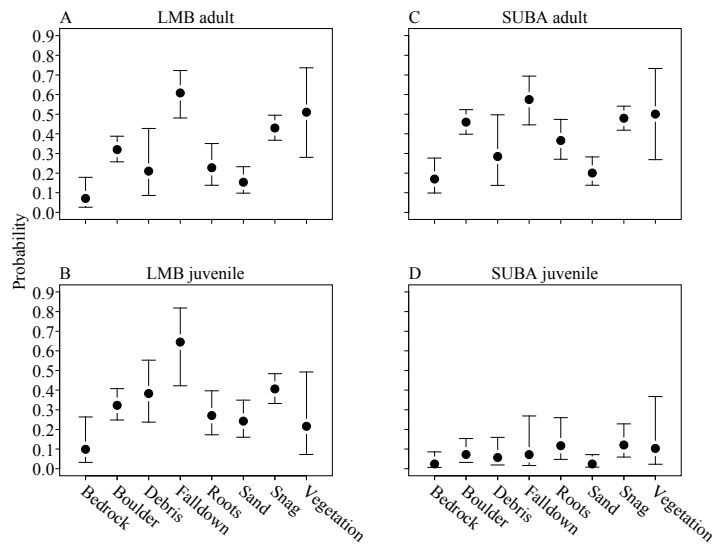
Figure 4. Cover least square mean probabilities (solid dots) for adult and juvenile largemouth bass and Suwannee bass. The y-axis values indicate the probability that a given cover was associated with a used location rather than an available location. Vertical lines represent the 95% confidence interval around the mean.

was minimal. Water velocity showed a significant negative main effect (Table 3), and maximum use probability occurred at low velocities, and decreased thereafter (Figure 2B). Least squares mean probabilities for cover types were greatest with falldown, snag, and debris (Figure 4B).

The logistic model for Suwannee bass adults was similar to that of largemouth adults and provided an acceptable fit (CHCHUSS $Z = 0.381$, $P = 0.704$). Cover type and sample period had significant main effects, and a 3-knot spline was best for depth, whereas water velocity was not a significant factor. (Table 3, Figure 2C). Similar to largemouth bass adults, the depth function for Suwannee bass adults showed the highest probabilities around 100 cm (Figure 3C). However, the probabilities were greater at depths less than 100 cm, and the probabilities decreased more abruptly in depths greater than 100 cm when compared to largemouth bass adults. The cover probabilities associated with Suwannee bass adult locations were greatest for falldown, snag, and vegetation (Figure 4C). Suwannee bass adults also had a relatively higher probability value for boulder and root cover types than for largemouth bass.

In the logistic model chosen for juvenile Suwannee bass (CHCHUSS $Z = -1.693$ $P = 0.090$), water velocity showed no significant effect (Figure 2D), whereas cover, sample period, and a 3-knot spline for depth were significant (Table 3). The depth probability function was greatest at depths less than 100 cm, and declined to a depth of 200 cm, beyond which probability of use was minimal (Figure 3D). Snags, roots, and vegetation cover types were more highly associated with Suwannee bass juveniles (Figure 4D).

The models developed showed acceptable goodness of fit and moderate indexes of predictive ability, with greatest predictability for Suwannee bass juveniles (highest ROC area) and least for Suwannee bass adults (lowest ROC area), (Table 3). Thus, juvenile bass seemed to use habitats more selectively, largemouth bass adults less so, and Suwannee bass adults least so. Additionally, pairwise differences in predictive abilities of the models were nominally significant, except for that between the two juvenile species.

Discussion

Juvenile and adult Suwannee bass and largemouth bass were found in a range of water velocities, depths, and cover types, indicating that both species and life stages are generalists to some extent in their microhabitat associations. However, the logistic regressions varied somewhat among species and life stages in their predictive abilities (except between juvenile bass) and implied varying degrees of selection among the habitat variables measured. Habitat partitioning was most evident between juvenile and adult bass. The water velocity and depth selection functions of juveniles were associated with slow and shallow locations, while the selection functions of adults were associated with intermediate speeds and depths. Ontogenetic shifts in habitat use have been observed in various lotic fishes, and have been explained by biotic interactions associated with competition (Freeman and Stouder 1989)

and predation avoidance (Power 1987, Schlosser 1987). Other studies have shown that the physical effect of current velocity can influence fish endurance, foraging success (Schaefer et al. 1999) and swimming performance (Deegan et al. 2005), particularly with juvenile fishes regardless of body shape. In the only study that has examined the habitat use of these two species, Schramm and Maceina (1986) did not find any evidence of size-specific habitat partitioning among six macrohabitats in the Santa Fe River, Florida. Nonetheless, largemouth bass <150 mm were not collected in rock riffle or vegetated riffle habitats in their study, and Suwannee bass <150 mm were infrequently collected in these habitats, suggesting uncommon use of swift currents by juveniles relative to the other macrohabitats examined by Schramm and Maceina (1986).

The microhabitat use also differed between adult Suwannee bass and largemouth bass. Suwannee bass adults showed a greater affinity to shallower depths, boulder and root cover types, and greater water velocities than largemouth bass adults. This is contrary to the conclusions of Schramm and Maceina (1986), who could not discern any differences in the relative abundance estimates between Suwannee bass and largemouth bass among macrohabitats in the Santa Fe River, Florida. However, some supporting information from their study may be gleaned by examining the relative abundances of the intermediate size group (150–299 mm) associated with macrohabitats, since this was the size group most frequently collected during their study. Suwannee bass were most frequently collected in brushpile habitats, followed by deep rock and vegetated riffle habitats, in order of relative abundance. By comparison, largemouth bass were most frequently collected in sand bank habitats, followed by brushpile and deep rock habitats. Therefore, although we found the habitat selection models to differ between adult Suwannee bass and largemouth bass, differential use of microhabitats appears to be minor due to a substantial amount of habitat-use overlap observed in this study and by Schramm and Maceina (1986).

Use of logistic models to quantify resource selection has been the focus of much interest and some disagreement (Boyce et al, 2002, Manly et al. 2002, Keating and Cherry 2004, Johnson et al. 2006). How logistic regression is applied, interpreted, and evaluated in the context of resource selection depends in part on the sampling scheme employed. Our sampling approach was developed following the "use-availability" model. With such an approach, the random "available" sample is expected to include a potentially unknown mixture of used and unused locations, which complicates the model's evaluation of predictive ability. For our random available sample, use could be evaluated and was found to be extremely low. Because of the low number of used cases in the available sample, the available sample was practically one of "unused" locations.

Interpretive methods appropriate to "case-control, used-unused" studies were therefore applied.

A potential bias to our habitat results was the sampling limitation to river runs. This decision was necessary to best determine the fish's location during electrofishing, and to stay within reasonable limitations of the gear. With the exception of six major shoal and riffle habitats, fast water macrohabitats are relatively sparse in the Withlacoochee River and are best characterized by low gradient riffles and glides (Arend 1999) lacking substantial cover. It is unlikely that inclusion of these habitats would have affected the outcome of our results given that bedrock and sand substrates with no cover were infrequently associated with used bass locations. Another potential bias to our results is that electrofishing efficiency is known to decrease with depth (Henry et al. 2001), and is selective towards larger individuals (Reynolds 1996). Both of these circumstances can lead to skewed depth selection functions. Eighteen percent of the available locations and 3% of the used locations in our dataset exceeded 2 m. It is possible that black bass located in depths greater than 2 m were not fully vulnerable to the electrofishing current, and that the detection of juvenile fish decreased with increasing depth. Consequently, the resource selection functions presented are mostly indicative of run habitats within a 2-m depth constraint.

This study helps to fill needed information gaps regarding the resource use of a lesser studied black bass, and complements prey partitioning observations by Schramm and Maceina (1986) between Suwannee bass and largemouth bass, and observations of spawning-site characteristics of Suwannee bass by Strong et al. (2010). Although we found considerable overlap between the selection functions of Suwannee bass and largemouth bass, minor differences in habitat selection may be important for the conservation and management strategies of Suwannee bass. For example, Warren and Nagid (2008) concluded that simulated river flow reductions (>40%) in the Withlacoochee River resulted in greater habitat loss estimates for Suwannee bass than for largemouth bass, potentially causing an ecological shift benefiting largemouth bass. The findings of this analysis suggest that conservation efforts for Suwannee bass through water management should focus on river flows that inundate the majority of large woody debris, boulder, and root cover types in depths less than 2 m. However, the maintenance of seasonal flood events and a wooded shoreline are necessary to ensure the regular recruitment and inundation of such habitats occurs.

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