HABITAT RELATIONSHIPS FOR SPOTTED SUNFISH AT THE ANCLOTE, LITTLE MANATEE, AND MANATEE RIVERS, FLORIDA

By

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This thesis is dedicated to the preservation and sustainable management of Florida’s aquatic resources.

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Establishing river minimum flow and level (MFL) regulations to maintain ecosystem health is a top priority for Florida's management agencies due to expanding human population size and water demand. The spotted sunfish *Lepomis punctatus* is sensitive to changes in river water levels and could potentially serve as an indicator for ecosystem health, within the context of water level fluctuation and management.

I measured characteristics of habitat (i.e., current velocity, depth, substrate, cover abundance) utilized by spotted sunfish and compared them to overall available habitat within the stream margin environment to identify patterns of habitat selection at three southwestern Florida Rivers (Anclote, Little Manatee, and Manatee). Multivariate Analysis of Variance (MANOVA) was used to test whether habitat metrics collectively differed between available and utilized habitats. I assessed how fluctuations in river stage and flow could influence spotted sunfish habitat availability. I also assessed fish community richness and diversity patterns among the predominant habitat types within each system. All sampling occurred from November 2004 to March 2006 during fall and spring seasons.

Overall, spotted sunfish tended to select habitat having greater structural complexity than the average available habitat. In many instances, spotted sunfish appeared to select large and fine woody debris habitats. However, I collected spotted sunfish from a variety of habitat types through the study, indicating that the species was somewhat general in its habitat associations. I found few significant differences in habitat measures between juvenile and adult fish, suggesting that habitat associations were similar between the life stages.

My simulations indicated that 0.3-meter reductions in average daily stage could reduce habitat availability for spotted sunfish by up to 20% across systems. Overall, habitats utilized by spotted sunfish were more resilient to stage declines due to fish utilization of areas with deeper depths and more complex habitat than the average conditions. I found that fish richness tended to vary among habitat types at all systems, and relatively complex habitat such as woody debris and aquatic plants frequently exhibited higher fish richness than less complex habitats such as sandbars.

I conclude that the inundation of complex habitat types is likely important for spotted sunfish, and even minor changes in the average daily stage during fall and spring seasons could substantially reduce overall availability of these habitat types. Habitats utilized by spotted sunfish also exhibited high total fish richness, suggesting that protection of complex habitats will benefit the fish communities of southwest Florida Rivers. Results of this study can serve to inform resource managers responsible for setting MFL regulations to aid in the protection of habitat for freshwater fishes.

CHAPTER 1
INTRODUCTION

Background

Water allocation and the ability to reach a balance between the needs of society and the natural environment are growing concerns among water resource managers and stakeholders, especially within the state of Florida. One critical step in the protection of Florida's water resources is the implementation of Minimum Flows and Levels (MFL) for priority water bodies (373.042, Florida Statutes). The MFL policies facilitate the regulation of surface water diversion and ground water withdrawal such that variation in streamflow and surface water levels can sustain the ecological integrity of each water body (373.042, Florida Statutes).

Fisheries managers have noted that maintaining high quality river fisheries in light of increases in human population and land development would be a major challenge (Peters 1982; Bass and Cox 1985; Tyus 1990). Anthropogenic modifications in streamflow and resulting habitat alteration can strongly influence the abundance and composition of aquatic fauna (Cushman 1985; Irvine 1985; Schlosser 1985; Bain et al. 1988; Kinsolving and Bain 1993; Travnichek et al. 1995; Power et al. 1999). Stream fish community metrics and population dynamics have been correlated with water level and streamflow changes (Kelsch 1994; Raibley et al. 1997; Weyers et al. 2003). Bonvechio and Allen (2005) linked year-class strength of several Centrarchid species to seasonal variation in flow/stage for four Florida Rivers.

The spotted sunfish *Lepomis punctatus*, a member of the Centrarchidae family, is one of the most abundant species in native stream fish assemblages of Florida rivers (Hubbs and Allen 1943; Bailey et al. 1954; McLane 1955), and has been shown to exhibit population responses to fluctuating flow and stage (Rogers et al. 2005). Rogers et al. (2005) found that spotted sunfish abundance was low following persistently low flow and stage conditions during the year prior to sampling at the Ocklawaha River, Florida. They believed that spotted sunfish could serve as an indicator species for MFL regulation due to the apparent population responses to changing streamflow and stage.

However, habitat associations of the spotted sunfish remain largely uninvestigated. Studies have shown that structurally complex cover, such as woody debris (Anderson et al. 1978; Angermeier and Karr 1984; Benke et al. 1985; Lobb and Orth 1991) and aquatic macrophytes (Rozas and Odum 1988; VanderKooy et al. 2000) provide important forage and refuge locations for stream fish communities. Spotted sunfish have been observed to utilize dense vegetation and fallen trees along stream margins (McLane 1955), and diet analyses indicate that spotted sunfish feed on invertebrates associated with aquatic vegetation (VanderKooy et al. 2000) and submerged snags (Benke et at. 1985). The inundation and availability of these habitat types, often characteristic of stream margins and important to stream fish communities, can be strongly influenced by fluctuations in flow and stage (Bain et al. 1988).

Objectives

My objectives were to

1) identify habitat associations for juvenile and adult spotted sunfish relative to available habitat at the Anclote, Little Manatee, and Manatee Rivers,

2) predict how changes in river stage/flow for each system would influence habitat availability for spotted sunfish, and

3) identify habitat-specific fish community composition for each river system.

Findings will help guide the establishment of MFL regulations for each river, so habitats for spotted sunfish and the broader fish community can be protected.

Study Locations

This study included the Anclote, Little Manatee, and Manatee Rivers of the central Gulf Coast of Florida (Figure 1). The Anclote River flows generally east to west and discharges into the Gulf of Mexico between the towns of Holiday and Tarpon Springs, Florida. The Little Manatee River discharges into Hillsborough Bay, the westernmost portion of Tampa Bay, whereas the Manatee River discharges into the Gulf of Mexico at the southern region of Tampa Bay. Similar to the Anclote River, the Manatee and Little Manatee Rivers also flow from east to west, with all rivers having relatively short distances (i.e., 20-40 km) between headwaters and river mouths. All rivers exhibit a sinuous, meandering channel typical of low gradient streams (Figure 1).

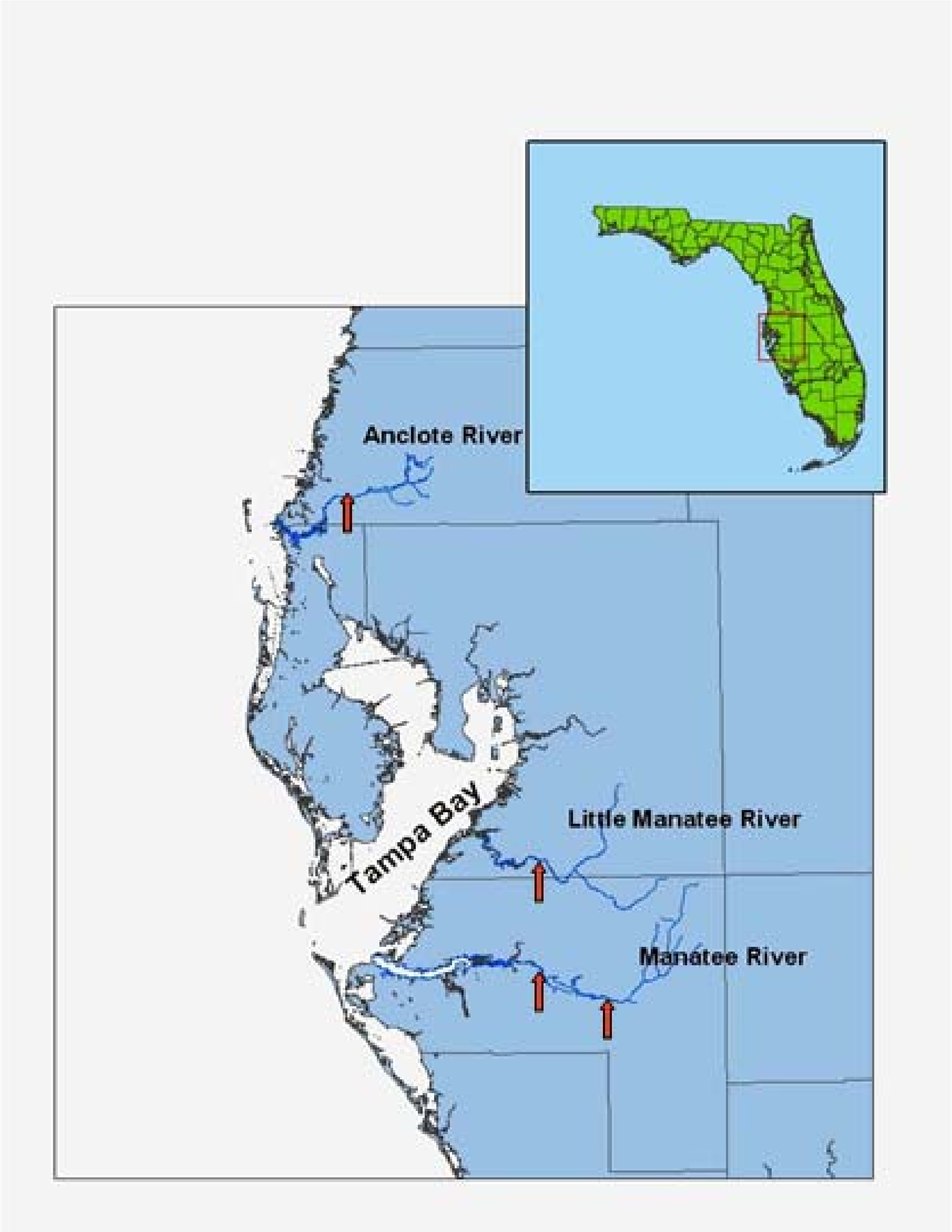

Figure 1. Locations of the Anclote, Little Manatee, and Manatee Rivers in relation to Tampa Bay along the Gulf Coast of Florida. Approximate locations of sample sites in each river are indicated by red arrows. Specific latitude and longitude coordinates of sampling site boundaries are provided in Table 5 of the Appendix.

CHAPTER 2
METHODS

Approach and Sampling Units

Habitat selection has been defined many ways in the literature, and it was important in this study to clearly define "habitat selection" as used here. Rosenfeld (2003, p. 954) advocated that

> [h]abitat selection (i.e., differential occupancy) occurs when an organism avoids a particular habitat (negative selection) or uses a habitat in greater proportion than its availability in the environment (positive selection). Habitat selection can be demonstrated if fish occur at higher densities in particular habitats, or if fish occur at higher frequencies in particular microhabitats to relative frequency of that microhabitat in the environment.

My use of the term "habitat selection" refers to the differential utilization of habitat relative to its availability within the environment. Thus, the overall approach of my study was to evaluate the habitat selection of spotted sunfish by characterizing the overall available habitat conditions within study locations and then to compare these data to habitat characteristics from which spotted sunfish were collected.

During pilot sampling at each river, I observed available habitat types (e.g., woody debris, overhanging root wads, and aquatic macrophytes) interspersed throughout each river system. As the mix of habitat types typically occurs across a relatively small longitudinal stream distance (< 500 m), cluster sampling was determined to be an appropriate sampling strategy (Schaeffer et al. 1990). Cluster sampling entails selecting replicate sample areas that include all available habitat types, so that variation among sample areas (i.e., clusters) is relatively small, but variation among systems (i.e., rivers) is relatively large. Within each river system, I utilized longitudinal sections of river channel, referred to as a river reach, as my sampling replicate. River reaches were 500 m in length at each river, because this size included all available habitat types present in each system. Three reaches were selected for sampling on the Anclote and Manatee Rivers, whereas at the Little Manatee River, I selected five reaches for sampling. During pilot sampling on the Little Manatee River I encountered two distinct 'zones' of channel morphology. Within the upper zone of the sampling region, I found that the channel width typically ranged between 15 - 20 m. The downstream zone of the sampling region had a wider channel, typically between 30 – 50 m, and it tended to support a greater abundance of rooted aquatic vegetation along banks, presumably due to a lesser degree of shading by the adjacent riparian overstory. Therefore, for Little Manatee River I selected three reaches within the upper zone and two reaches within the downstream zone of the sampling region to more fully characterize the habitat types available within this system.

I sampled spotted sunfish and stream fish communities at two geographically disparate locations on Manatee River. During the first year of the study, I sampled within reaches located upstream of Lake Manatee, whereas sampling during the second year was conducted below the Lake Manatee dam. The appendix (Table 5) provides the latitude and longitude coordinates of all sampling reaches. River stage and discharge (when available) for the study period were obtained for each system from T. Carson, U. S. Geological Survey.

Spotted Sunfish Sampling

Spotted sunfish were sampled between November 2004 and March 2006, with an emphasis placed on fall and spring sampling. Typically, spring and fall seasons along the central Gulf Coast of Florida have relatively low rainfall compared to summer. Thus, streamflows within this region are likely to be near base flow conditions during spring and fall. My sampling during spring (March-May) and fall (November-December) was designed to evaluate habitat associations for spotted sunfish during relatively stable and low flow conditions.

I sampled the Anclote and Little Manatee Rivers once each during fall and spring seasons from November 2004 to March 2006. In total, there were two fall samples and two spring samples for each of these rivers. The Manatee River upstream samples were collected during fall 2004 and spring 2005, whereas, the Manatee River downstream samples were collected during fall 2005 and spring 2006.

Spotted sunfish were collected using boat electrofishing gear that consisted of a 4.6-m aluminum jon boat powered by a 50-horsepower outboard motor with bow mounted anode probes. I used electrical power output of 5-8 Amps pulsed DC current regulated through a model VI-A Smith-Root pulsator. Power was supplied by a Honda 5000-watt AC generator.

My method of operating the electrofishing boat utilized two field personnel, one to operate the boat and pulsator located near the stern, and a second, located on the bow, to identify, collect, and measure spotted sunfish. For each reach, there were essentially two electrofishing transects, one conducted along each bank for the entire 500-m. Field personnel operated the electrofishing boat along each bank at a slow, but consistent speed to ensure that all portions of each bank regardless of available habitat received equal effort. All electrofishing samples were conducted during daylight hours, approximately between 7:00 am and 5:00 pm.

Following visual identification of a spotted sunfish, the location of each individual was marked, as precisely as possible, with either a bright orange flag, when proximity to shore or water depth permitted, or a bright orange buoy tethered to an anchor. I made efforts to locate spotted sunfish intervals at the point where an individual was first seen within the electromagnetic field. If I suspected that substantial electrotaxis or drifting had occurred by an individual, it was not used for habitat data collection. I measured each spotted sunfish to nearest mm total length and classified individuals as adult (≥ 60 mm TL) or juvenile (< 60 mm TL) (Caldwell et al. 1957; Carlander 1977). In the case that two or more individuals were located within a 0.5-m radius of one another, I marked the multiple locations as at the most central point.

Habitat Measurement

For this study, a habitat interval refers to a cylindrical volume of water horizontally defined by a 1 meter radius centered on a marked spotted sunfish location, spanning the vertical distance from water surface to substrate. My goal was to quantitatively describe the habitat characteristics present within each interval. Habitat measurements included depth, distance from bank, predominant substrate type, current velocity at 60% depth, large woody debris size category and abundance, aquatic macrophyte type and density, and cover penetration to the substrate (see below for explanation of terms). Depth, distance from bank, and cover penetration were measured to the nearest decimeter. Current velocity was measured with a Model 2000 Marsh-McBurney Flowmate flowmeter. I used a Woody Debris Index (WDI), very similar to that outlined by Dolloff et al. (1993), to quantify aggregations of large woody debris within habitat intervals. Pieces of large woody debris were categorized by cross-sectional diameter and counted. Large woody debris size categories were: (I) 5-10 cm in diameter, and (II) greater than 10 cm in diameter. A single WDI score was calculated for each interval using the following equation

$$WDI = WD1 + 2(WD2) \qquad (1)$$

where WD1 = count of woody debris size (I), and WD2 = count of woody debris size (II). Pieces of woody debris having a cross-sectional diameter less than 5 cm were categorized as fine woody debris (FWD), and abundance of FWD was estimated visually as the percentage of the interval volume occupied (PVO). The category FWD included overhanging terrestrial brush, root wads, and other small diameter woody structure. Aquatic macrophyte abundance was also estimated visually as percentage of the interval volume inhabited (PVI).

To form a less specific descriptor of habitat cover complexity, I formulated a Habitat Complexity Index (HCI). The HCI combines proportions of large woody debris counts, FWD abundance, and aquatic macrophyte abundance for each interval. I standardized the habitat metrics as a proportion of the maximum value for each parameter across all rivers and sampling dates. The standardized metrics were combined to create the HCI for each interval as

$$HCI = \left(\frac{WD1}{10}\right)\cdot\left(\frac{WD2}{8}\right)\cdot\left(\frac{PlantPVI}{90}\right)\cdot\left(\frac{FWDPVO}{80}\right) \qquad (2)$$

where WD1 = count of woody debris size (I), WD2 = count of woody debris size (II), PlantPVI = percent of interval inhabited by aquatic macrophytes, and FWDPVO = percent of interval occupied by fine woody debris. The denominators in equation 2 represented the maximum values across all systems and intervals, for standardization to proportions.

Cover penetration (P) was measured as the percentage of interval depth occupied by all combined habitat metrics in relation to the stream surface. For example, plants and woody debris that reached to a depth of 1 m within a 2-m deep interval were assigned a penetration value of 50%. Penetration values were used to estimate loss of spotted sunfish habitat with decline in river stage (below).

Available habitat was measured along equally spaced transects perpendicular to streamflow within each stream reach, similar to methods proposed by Simonson et al. (1994) and implemented by Wheeler and Allen (2003). For each habitat sampling event, the location of the first transect was located downstream from the upstream boundary of a stream reach at a randomly generated distance between 0 and 100 m. Thereafter, each transect was progressively located 100 m downstream from the previous transect until a total of five habitat availability transects were completed for each sampling reach. Two habitat availability intervals, centered one meter from each stream bank, were located along each transect line, and habitat parameters were measured in the same manner as for intervals utilized by spotted sunfish. Thus, available and utilized habitats were measured at the same spatial scale.

I used the habitat characteristics sampled from each river to predict how reductions in average river stage would influence habitat availability for spotted sunfish. I surmised that habitat availability and resiliency to changing water levels could be described by

$$HA = [(D \cdot P) - L] \cdot HCI \tag{3}$$

where HA is the habitat availability for the interval, D is the water depth in m, L is a simulated incremental decline in average stage in meters, HCI is the habitat complexity index, and P is the cover penetration. I simulated values of L ranging from 0 to 2 meters with 0.1-m increments. For each incremental decline in L, I estimated the proportion of habitat intervals P(HA) where HA would decline to zero. Thus, the value 1-P(HA) depicted the proportion of habitat intervals where some portion of cover remained inundated following each incremental 0.1-m decline in river stage (L). I obtained values of 1-P(HA) separately for utilized and available habitat intervals for each system, which assessed how habitats used by spotted sunfish varied from the random habitat intervals regarding potential habitat loss.

Habitat-Specific Community Assessment

To address my third objective, I sampled fish communities at each river. I conducted habitat-specific community electrofishing at the Anclote and Little Manatee Rivers during April and December 2005. For the Manatee River, community sampling was conducted once at the upstream site during April 2005, and once at the downstream site during December 2005. My goals were to document species richness and diversity and identify potential differences in these community metrics with respect to differences in predominant habitat types, similar to Lobb and Orth (1991). To formulate diversity values, I used Shannon-Wiener's index of biological diversity:

$$H' = -\sum_{i=1}^{s} (p_i) \cdot (\log_2 p_i)$$

where H' = Shannon-Wiener index of biological diversity, s = number of species, and p_i = proportion of total sample belonging to ith species. I used the same areas within each river for community sampling as with spotted sunfish sampling. The same boat mounted electrofishing gear was used for community sampling as for spotted sunfish sampling. I used 300-second electrofishing transects as sample replicates for each habitat type. During each transect, the electrofishing boat was maneuvered such that the electromagnetic field was maintained only near a single habitat type. I then progressively moved the boat from one patch of selected habitat to another of the same type, and this technique was continued throughout the duration of each transect. A minimum of four transects were collected for each habitat type at each river and community sampling event (i.e., season). All fish collected were identified to species, tallied, and measured to the nearest millimeter total length on site. Any unidentifiable individuals were preserved on ice and later keyed to species in the laboratory.

Statistical Analyses

Habitat variables measured at each interval were highly non-normal due to the proportional and categorical scales of the data (e.g., PVI, WDI). I transformed all habitat values to the ranks in order to construct non-parametric multivariate analyses of variance (MANOVA). The MANOVA's tested the null hypothesis that the mean ranked habitat variables (flow, depth, WDI, FWD, PlantPVI) collectively did not differ between utilized and available habitat intervals. The MANOVAs were constructed separately for each river with the following fixed effects: interval type (available vs. utilized), season, year, and the interactions of these values. The effect reach(river) was used as a block effect to account for any variation explained among reaches, which was expected to be low due to the cluster sampling design. The MANOVA analyses were repeated for three levels of interval type (adult, juvenile, and available) to assess differences in habitat utilization between adult and juvenile life stages. I analyzed data from each river separately for a total of eight MANOVA tests (four total sampling areas in the Anclote, Little Manatee, and Manatee upstream and downstream, two MANOVA each). For the Manatee River sections, the year effect was not possible to evaluate because I sampled each section (upstream and downstream) in only one fall and spring, resulting in interval type and season as fixed effects. When significant effects were detected with the MANOVAs, the least squares means procedure (SAS 2002) was used to identify the effects that contributed to the differences.

I used three-way analysis of variance (ANOVA) to test for differences in mean HCI scores between utilized and available habitat intervals at Anclote and Little Manatee Rivers. Fixed effects were interval type, year, and season as described above. I used a two-way ANOVA to test for differences in mean HCI scores at Manatee River upstream and downstream locations with interval type and season serving as the fixed effects. Because I sampled Manatee River upstream and downstream reaches each during a single year, there was no fixed effect of year.

To test for differences in mean species richness and diversity among predominant habitat types at Anclote and Little Manatee Rivers, I use two-way ANOVA. Fixed effects included habitat type and season. I used one-way ANOVA to test for differences in mean species richness and diversity among habitat types at both Manatee River sampling locations. Community samples were conducted once at each location on the Manatee River. Thus, habitat type was the only fixed effect.

CHAPTER 3
RESULTS

Spotted Sunfish Habitat Utilization

I collected habitat parameter measurements at a total of 470 available and 915 utilized habitat intervals across all sampling locations. At Anclote River, I characterized 120 available intervals and 292 utilized intervals. With regard to the utilized intervals at Anclote River, 178 were occupied adults and 114 by juveniles. At Little Manatee River, I characterized 210 available intervals and 473 utilized (329 adult and 144 juvenile) habitat intervals. At the Manatee River downstream site, I characterized 60 available and 72 utilized (60 adult and 12 juvenile) habitat intervals, and at the Manatee River upstream site, I characterized 80 available and 78 utilized (52 adult and 26 juvenile) habitat intervals.

The MANOVA analyses testing for differences in collective habitat variables between utilized and available intervals were significant for all rivers, but some river-specific differences occurred. For the Anclote and Manatee downstream site, there were no significant interactions (all $P > 0.25$) , but the interval effect was significant indicating that habitat variables where spotted sunfish were collected differed from the available interval habitat variables (Table 1). Spotted sunfish were collected from areas with higher WDI and FWD than the available intervals at both systems (Table 1). Water depth was greater for utilized than available intervals at the Anclote River (Table 1). The MANOVA for habitat data from the Manatee River upstream site indicated a significant two-way interaction ($P = 0.034$) between interval types (available vs. utilized) and season. This interaction was due to significant differences in utilized habitat WDIs between seasons and was of little importance for comparisons between interval types.

For the Little Manatee River, I found a significant three-way interaction between interval type (utilized vs. available), season (spring and fall), and year (first and second) ($P < 0.0001$). This interaction occurred because significant relationships among interval types were not consistent for either season, between years (Table 2). For example, utilized versus available habitat variables differed for depth, WDI, and FWD in the spring of 2006, whereas only depth differed between interval types in fall 2004 (Table 2). All other statistical tests did not indicate significant interactions between interval types and season or year (all $P > 0.379$).

Generally, adult and juvenile size-classes of spotted sunfish displayed similar habitat use patterns, and both size classes were associated with structurally complex habitat. For the Anclote River and the Manatee River downstream site, the MANOVA exhibited a significant interval effect (both $P < 0.0001$) without any significant interactions (all $P > 0.109$). Both adult and juvenile spotted sunfish utilized areas with high WDI and FWD relative to available intervals. However, intervals occupied by juveniles had significantly greater plant densities than intervals occupied by adults or available intervals (both $P < 0.057$) at the Manatee River downstream site (Table 3). No differences were detected between life stages at the Manatee upstream site (Table 3).

Similar to the combined life stage analysis, I found a three-way interaction among interval type (juvenile, adult, available), season, and year at the Little Manatee River (Table 4) ($P < 0.0001$). This interaction occurred because juvenile spotted sunfish occurred in habitats that were intermediate between adult and available intervals, and these effects were most apparent in spring 2006 (Table 4). For example, adults were collected from intervals with deeper depths and higher WDI and FWD than the available intervals in spring 2006, but habitat where juveniles occurred during directed sampling was intermediate to the these values for the spring 2006. The depth variable also differed between adult and available habitat intervals during fall 2004, with depth being intermediate for habitats occupied by juveniles (Table 4). Thus, the relationships of utilized and available habitat for juveniles and adults generally mirrored the relationships I observed when size-classes were aggregated.

My use of the HCI score indicated that spotted sunfish were usually associated with physical habitat having greater structural complexity relative to that of the representative available habitat. The mean HCI scores for utilized versus available habitat were significantly greater ($P < 0.0001$) at the Anclote (0.47 versus 0.27), and the Manatee River downstream site (0.65 versus 0.20). The Manatee River upstream site showed an opposite relationship with HCI scores being higher for available (0.48) versus utilized (0.34) intervals ($P < 0.0001$). Similar to the MANOVA for collective habitat variables, the three-way ANOVA for HCI scores showed a significant three-way interaction at the Little Manatee River ($P < 0.0001$), where HCI scores were higher for utilized than available intervals in the fall 2004 (0.47 versus 0.33) and spring 2006 (0.44 versus 0.26, both $P < 0.045$). Thus, the use of HCI showed the same relationships as the MANOVA using all habitat variables, where spotted sunfish utilized locations with higher habitat complexity than the more general available conditions within most systems. The Manatee River upstream site differed from the other systems and showed some opposite patterns, but this likely occurred because of the more homogenous nature of the habitat conditions at this site.

Effects of Altered Stage/Flow on Habitat Availability

My study rivers are located in Southwest Florida, where rainfall patterns consist of a summer wet season with a relatively dry spring, winter, and fall (Kelly et al. 2005). My study design sampled these rivers in spring and fall during periods when river flow and stage are relatively low. Water levels during our sampling were similar between years (Figure 2) and representative of the average, relatively low flow conditions expected during these seasons. However, all of my study reaches except the Manatee River upstream were tidally influenced and exhibited stage variation of about 0.3 meters throughout the day. Flow direction varied from downstream to occasionally upstream with outgoing and incoming tides. Nevertheless, all of the study sites had low salinity (< 5 ppt) throughout this study as indicated by my collection of obligate freshwater fishes on all sampling events and the ability to use a freshwater electrofishing arrangement as the sampling gear.

Simulations of HA indicated that average stage declines of 0.3 m could result in 0 to 20% habitat loss for spotted sunfish across systems (Figure 3). The Southwest Florida Water Management District has used a criterion of 15% habitat loss as significant for coastal rivers (Kelly et al. 2005), and my simulations indicated that this degree of habitat loss would occur with average stage declines of 0.3 m or less in three of four systems. The largest decline in available habitat occurred at the Manatee River downstream site and the smallest at the Manatee River upstream site (Figure 3). The Anclote and Little Manatee Rivers exhibited about 20% losses in habitat availability with a 0.3 m reduction in average stage, and 40-50% habitat loss with a 0.6 m reduction. The Manatee River upstream site was characterized by relatively steep banks and abundant aquatic plants (primarily Maidencane *Panicum hemitomon*) extending out to 1-2 m water depths, which made habitat loss less susceptible to changes in water levels. For the other three systems, a 0.3 m decline in average stage was predicted to reduce available habitat by 15-20% (Figure 3).

Spotted sunfish utilized habitat intervals that were more resilient to changes in river stage than the average condition at all rivers except the Manatee River upstream site. Utilized habitat intervals exhibited more gradual declines in habitat availability with incremental declines in average stage at the Anclote, Little Manatee, and Manatee River downstream site (Figure 3). This occurred because spotted sunfish utilized intervals that were deeper and had more complex habitat than the available habitat intervals at each system. The Manatee River upstream site exhibited little difference in habitat availability between utilized and available intervals, and slightly lower habitat loss for available intervals at a 0.6 m average stage decline (Figure 3). Because this site was located above the impoundment, the habitat conditions (e.g., flow, stage, HCI) were likely influenced by the dam, resulting in habitat relationships that were not similar to our other study sites or other southwest Florida streams. All other stream sites in this study exhibited relatively rapid habitat loss with declines in average stage.

Habitat-Specific Fish Community Analysis

Over the course of this study, I collected 23 fish species at the Anclote River, 26 at the Little Manatee River, 12 at the Manatee River upstream and 21 species at the Manatee River downstream. Collectively, there were 26 species collected from the Manatee River system. Thus, overall fish species richness was similar among river systems and ranged from 23 to 26. Individual fish species and the habitats from which they were collected within each river are shown in the Appendix (Table 6). The family Centrarchidae was the most common family with eight species (Appendix, Table 6). As expected for these coastal systems, fish taxa represented a range of obligate freshwater (e.g., Centrarchidae) to estuarine species (e.g., common snook *Centropomus undecimalis*, Appendix, Table 6).

I found seasonal patterns in species richness at the Anclote and Little Manatee Rivers, and diversity varied with season at the Anclote River. At both rivers, the season and habitat effects were significant (all $P < 0.05$) for species richness, and the interaction of season and habitat was not significant (both $P > 0.13$), allowing evaluation of only the main effects. Mean richness was higher in the fall (6.3 and 6.3 species per transect) than in the spring (3.3 and 3.7 species per transect) at the Anclote and Little Manatee Rivers, respectively (all $P < 0.05$). Mean diversity was higher in the fall (2.13) than in the spring (1.38) at the Anclote River. However, mean diversity did not vary between seasons at the Little Manatee River ($P = 0.17$).

I also detected differences in richness among habitats at two of the three river systems. For the Anclote River, overhanging terrestrial brush, exposed root-wads, and large woody debris had greater mean species richness (all $P < 0.1$, Figure 4) and diversity than sandbar habitat (all $P < 0.1$, Figure 4). Thus, it appeared that all complex habitat types contained higher richness and diversity than sandbar habitats at the Anclote River. At the Little Manatee River, aquatic plants contained higher mean richness than large woody debris and overhanging terrestrial brush (both $P < 0.02$, Figure 4), but the other habitat types did not differ with regard to richness. Fish diversity at the Little Manatee River did not differ among habitat types ($P = 0.29$, Figure 5).

For the Manatee River, I found no differences in fish richness or diversity among habitat types at the Manatee River upstream site (Figures 4 and 5, both $P > 0.6$), but species richness was higher in large woody debris than the other habitats for the Manatee River downstream site ($P = 0.04$, Figure 4). Fish diversity did not differ among habitat types at either Manatee River site (both $P > 0.51$, Figure 5).

My habitat-specific electrofishing revealed several differences in fish richness, whereas fish diversity varied with habitat only at the Anclote River. In general, relatively complex habitat such as large woody debris and plants frequently harbored higher fish richness than less complex habitats such as sandbars. The nearly homogeneous habitat characteristics at the Manatee River upstream site probably contributed to the lack of significant differences for this system.

Table 1. Mean and standard deviation (SD) of habitat parameters for utilized and available habitat intervals at Anclote River and Manatee River downstream and upstream sites. Depth is stream depth in m, Current is current velocity in m/s, WDI is woody debris index, FWD is percent of interval volume occupied by fine woody debris, and Plant is percent of interval volume inhabited by aquatic macrophytes. Shaded blocks denote significant differences, as indicated by MANOVA testing and comparison of least squares means, between utilized and available habitat intervals for the corresponding habitat parameter (All $P < 0.1$).

River	Parameter	Utilized $\bar{x}$ (SD)	Available $\bar{x}$ (SD)
Anclote	Depth	1.00(0.57)	0.83(0.45)
	Current	0.01(0.01)	0.01(0.02)
	WDI	3.22(3.16)	1.60(2.50)
	FWD	17.84(13.59)	11.08(10.67)
	Plant	0.89(3.19)	1.58(6.22)
Manatee downstream	Depth	0.71(0.30)	0.67(0.31)
	Current	0.00(0.00)	0.00(0.00)
	WDI	5.94(5.14)	1.15(2.51)
	FWD	13.19(7.28)	7.00(5.61)
	Plant	1.53(3.99)	1.50(5.77)
Manatee upstream	Depth	1.67(0.71)	1.69(0.70)
	Current	0.00(0.00)	0.00(0.00)
	WDI	0.64(1.46)	0.60(1.28)
	FWD	6.92(7.78)	9.88(13.64)
	Plant	18.46(13.96)	27.75(23.87)

Table 2. Mean and standard deviation (SD) of habitat parameters for utilized and available habitat intervals per season and year for Little Manatee River. Depth is stream depth in m, Current is current velocity in m/s, WDI is woody debris index, FWD is percent of interval volume occupied by fine woody debris, and Plant is percent of interval volume inhabited by aquatic macrophytes. Shaded blocks denote significant differences, as indicated by MANOVA testing and comparison of least squares means, between utilized and available habitat intervals for the corresponding habitat parameter (All $P < 0.1$).

	First				Second			
	Fall		Spring		Fall		Spring	
Parameter	Utilized $\bar{x}$ (SD)	Available $\bar{x}$ (SD)	Utilized $\bar{x}$ (SD)	Available $\bar{x}$ (SD)	Utilized $\bar{x}$ (SD)	Available $\bar{x}$ (SD)	Utilized $\bar{x}$ (SD)	Available $\bar{x}$ (SD)
Depth	0.89(0.47)	0.65(0.44)	0.88(0.51)	0.86(0.48)	0.75(0.41)	0.73(0.52)	0.76(0.37)	0.55(0.33)
Current	0.04(0.05)	0.03(0.05)	0.06(0.07)	0.05(0.06)	0.04(0.04)	0.04(0.04)	0.01(0.02)	0.01(0.02)
WDI	2.49(3.54)	1.28(2.08)	1.39(1.92)	1.24(1.84)	1.69(2.64)	0.88(1.35)	2.76(3.50)	1.00(1.48)
FWD	16.37(18.27)	10.75(13.09)	13.51(13.09)	12.14(11.66)	10.09(12.01)	10.00(9.69)	14.26(12.92)	9.80(12.86)
Plants	6.59(13.39)	8.25(18.10)	5.64(8.50)	6.29(14.26)	8.32(11.76)	3.80(6.97)	4.56(10.03)	5.00(10.93)

Table 3. Mean and standard deviation (SD) of habitat parameters for adult, juvenile, and available habitat intervals at Anclote River and Manatee River downstream and upstream sites. Depth is stream depth in m, Current is current velocity in m/s, WDI is woody debris index, FWD is percent of interval volume occupied by fine woody debris, and Plant is percent of interval volume inhabited by aquatic macrophytes. Shaded blocks and differing letters denote significant differences, as indicated by MANOVA testing and comparison of least squares means, among interval types (All P < 0.1).

River	Parameter	Adult $\bar{x}$ (SD)	Juvenile $\bar{x}$ (SD)	Available $\bar{x}$ (SD)
Anclote	Depth (m)	A	A	B
		1.04(0.58)	0.95(0.55)	0.83(0.45)
	Current (m/s)	A	BC	AC
		0.011(0.02)	0.006(0.01)	0.011(0.02)
	WDI	A	B	C
		3.43(3.23)	2.89(3.04)	1.60(2.50)
	FWD (PVI)	A	A	B
		17.30(13.72)	18.68(13.40)	11.08(10.67)
	Plant (PVI)	A	A	A
		(0.67)2.51	(1.23)4.02	1.58(6.22)
Manatee downstream	Depth (m)	A	A	A
		0.73(0.30)	0.64(0.25)	0.67(0.32)
	Current (m/s)	A	A	A
		0.00(0.00)	0.00(0.00)	0.00(0.00)
	WDI	A	A	B
		6.05(5.05)	5.42(5.78)	1.15(2.51)
	FWD (PVI)	A	A	B
		13.50(7.32)	11.67(7.18)	7.00(5.61)
	Plant (PVI)	A	B	A
		1.00(3.03)	4.17(6.69)	1.50(5.77)
Manatee upstream	Depth (m)	A	A	A
		1.57(0.66)	1.86(0.79)	1.69(0.70)
	Current (m/s)	A	A	A
		0.00(0.00)	0.00(0.00)	0.00(0.00)
	WDI	A	A	A
		0.77(1.60)	0.38(1.10)	0.60(1.28)
	FWD (PVI)	A	A	A
		8.08(8.41)	4.62(5.82)	9.88(13.64)
	Plant (PVI)	A	A	A
		16.92(13.07)	21.54(15.41)	27.75(23.87)

Table 4. Mean and standard deviation (SD) of habitat parameters for adult, juvenile, and available habitat intervals per season and year at Little Manatee River. Depth is stream depth in m, Current is current velocity in m/s, WDI is woody debris index, FWD is percent of interval volume occupied by fine woody debris, and Plant is percent of interval volume inhabited by aquatic macrophytes. Shaded blocks and differing letters denote significant differences, as indicated by MANOVA testing and comparison of least squares means, among interval types (All P < 0.1).

	First						Second					
	Fall			Spring			Fall			Spring		
	Adult $\bar{x}$ (SD)	Juvenile $\bar{x}$ (SD)	Available $\bar{x}$ (SD)	Adult $\bar{x}$ (SD)	Juvenile $\bar{x}$ (SD)	Available $\bar{x}$ (SD)	Adult $\bar{x}$ (SD)	Juvenile $\bar{x}$ (SD)	Available $\bar{x}$ (SD)	Adult $\bar{x}$ (SD)	Juvenile $\bar{x}$ (SD)	Available $\bar{x}$ (SD)
Depth	A	AB	B							A	AB	B
	0.92(0.47)	0.80(0.47)	0.65(0.44)	0.93(0.53)	0.75(0.43)	0.86(0.48)	0.73(0.43)	0.80(0.33)	0.73(0.52)	0.82(0.39)	0.68(0.33)	0.55(0.33)
Current												
	0.04(0.05)	0.03(0.04)	0.03(0.05)	0.06(0.07)	0.06(0.06)	0.05(0.06)	0.03(0.03)	0.06(0.05)	0.04(0.05)	0.02(0.02)	0.01(0.02)	0.01(0.02)
WDI										A	AB	B
	2.62(3.78)	2.06(2.61)	1.28(2.08)	1.60(2.06)	0.85(1.41)	1.24(1.84)	1.80(2.71)	1.27(2.37)	0.88(1.35)	3.17(3.49)	2.31(3.49)	1.00(1.48)
FWD										A	AB	B
	17.67(18.95)	12.19(15.39)	10.75(13.09)	13.68(12.57)	13.08(14.63)	12.14(11.66)	10.24(12.72)	9.55(8.99)	10.00(9.69)	15.83(13.81)	12.50(11.68)	9.80(12.86)
Plant												
	6.02(13.46)	8.44(13.22)	8.25(18.10)	4.71(7.62)	8.08(10.21)	6.29(14.62)	8.71(12.42)	6.82(8.94)	3.80(6.97)	4.03(9.59)	5.16(10.54)	5.00(10.93)

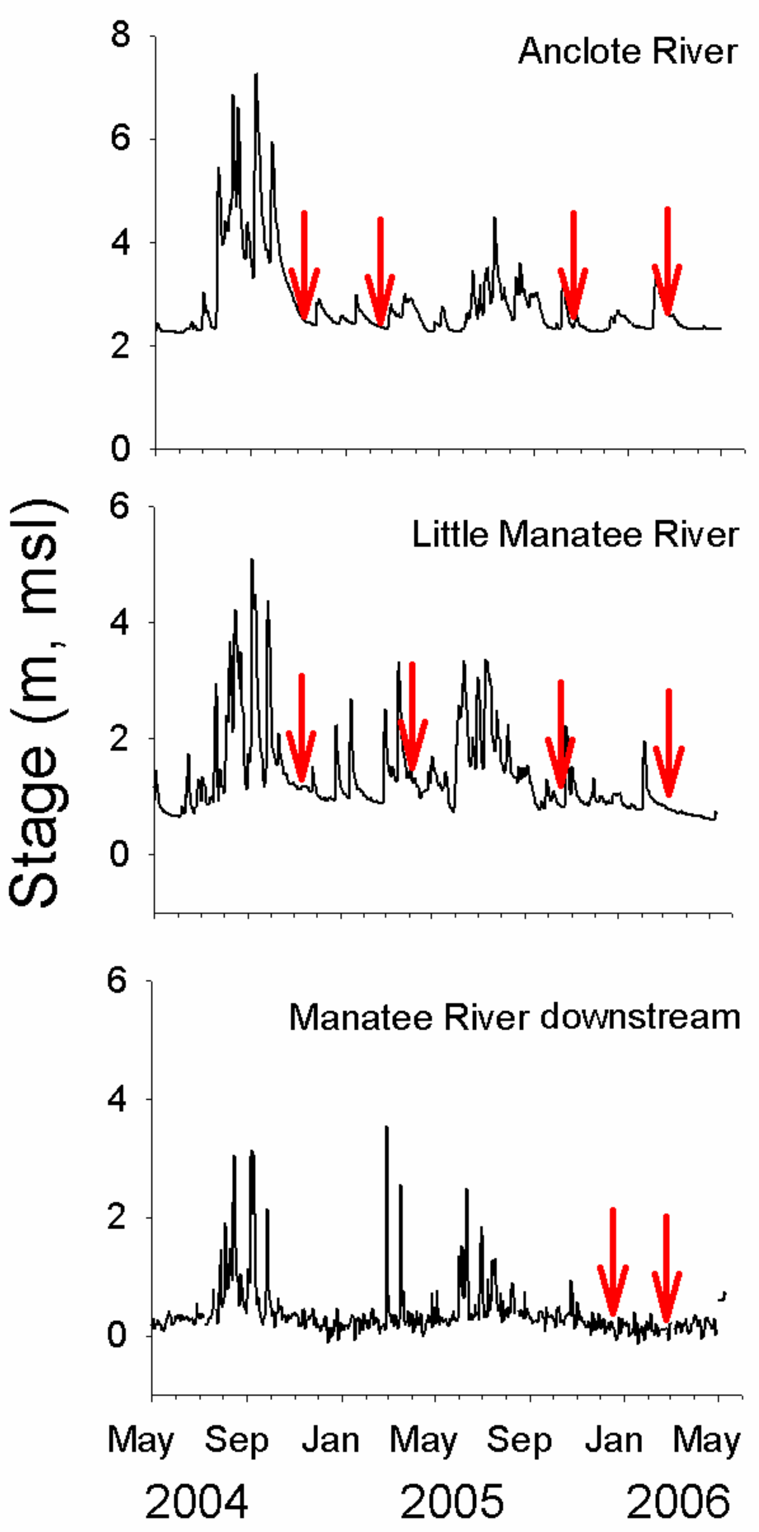

Figure 2. Hydrographs representing average daily stage (meters, mean sea level) data for the Anclote, Little Manatee, and Manatee River downstream sites during the two-year study period. Sampling periods at each system are indicated by red arrows. Stage data were provide by T. Carson, U. S. Geological Survey.

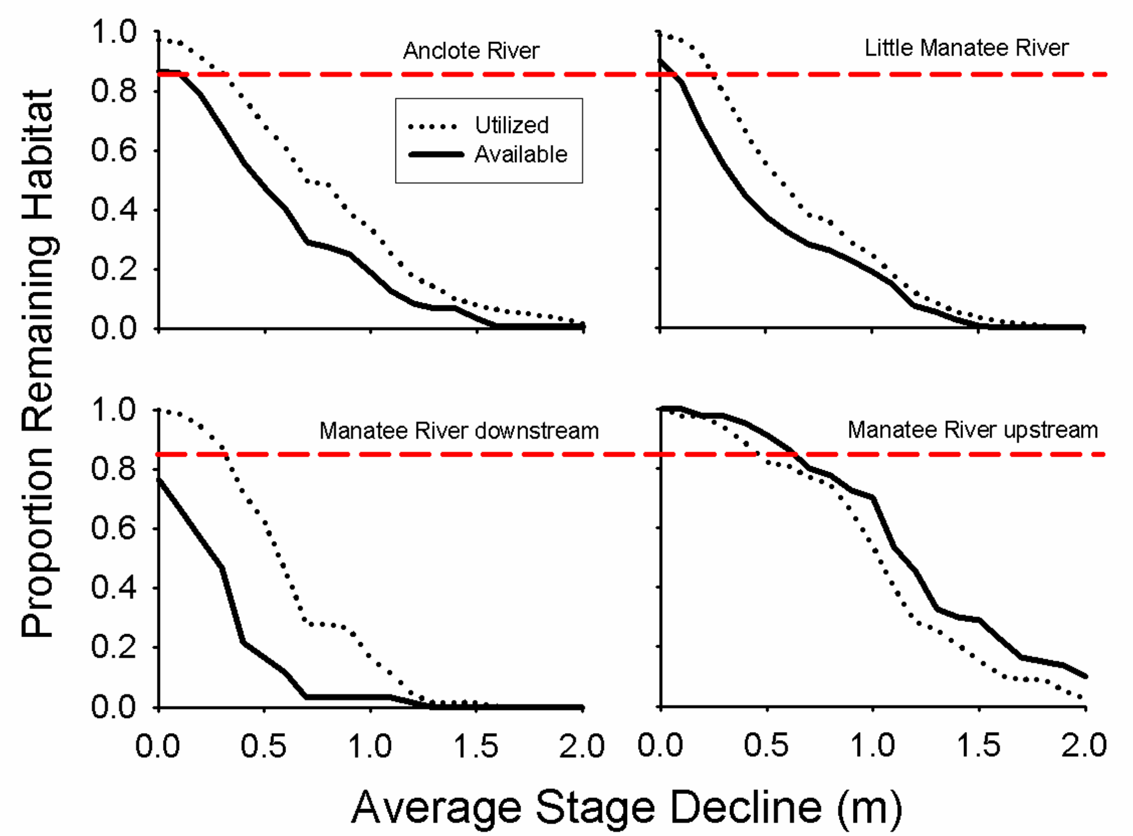

Figure 3. Proportion of total habitat intervals per river with habitat remaining inundated (y axis) with incremental decline in average river stage (m, x axis). Dotted lines show habitat intervals utilized by spotted sunfish, and solid lines show randomly located intervals representing overall available habitat. The dashed red line signifies the 15% habitat loss value at each system

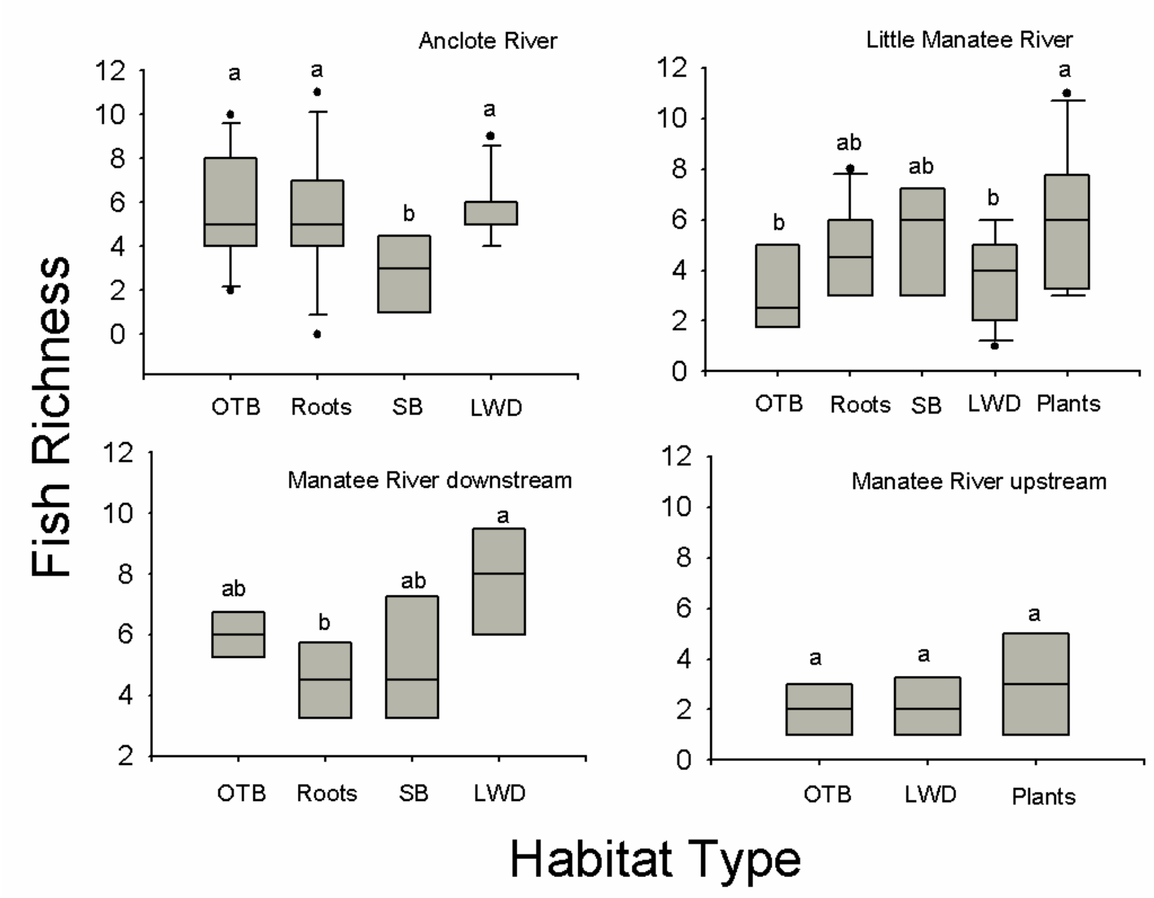

Figure 4. Box plots of fish species richness (y axis) for each system. Habitat types including overhanging terrestrial brush (OTB), roots, sandbars (SB), large woody debris (LWD), and aquatic plants (Plants) are shown (x axis). Observations are from habitat-specific electrofishing transects. Differential lettering denotes significant difference in group means, as indicated by ANOVA testing and comparison of least squares means, among habitat types (All $P < 0.1$). Median values are denoted by the horizontal mid-line within the shaded region of each box. Upper and lower bounding horizontal lines of the shaded region of each box denote the 75th and 25th percentile values. Upper and lower box plot whiskers denote the 90th and 10th percentile values. Dots lying beyond box plot whiskers denote the 95th and 5th percentile values.

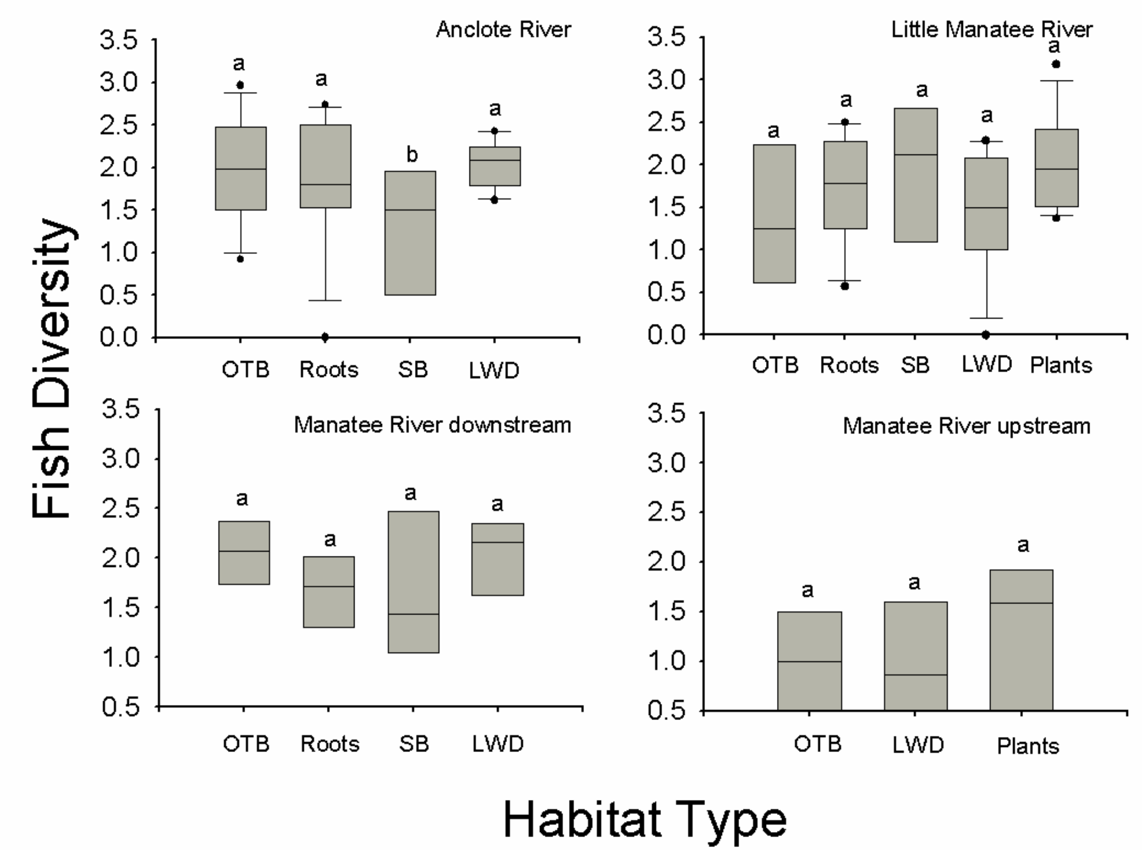

Figure 5. Box plots of fish diversity (y axis) for each system. Habitat types including overhanging terrestrial brush (OTB), roots, sandbars (SB), large woody debris (LWD), and aquatic plants (Plants) are shown (x axis). Observations are from habitat-specific electrofishing transects. Differential lettering denotes significant difference in group means, as indicated by ANOVA testing and comparison of least squares means, among habitat types (All $P < 0.1$). Median values are denoted by the horizontal mid-line within the shaded region of each box. Upper and lower bounding horizontal lines of the shaded region of each box denote the 75th and 25th percentile values. Upper and lower box plot whiskers denote the 90th and 10th percentile values. Dots lying beyond box plot whiskers denote the 95th and 5th percentile values.

CHAPTER 4
DISCUSSION

Spotted sunfish generally selected habitats with greater habitat complexity compared to overall available habitat conditions. Woody debris habitats were frequently selected by spotted sunfish, and the association with these habitats was the most common of any of the habitat relationships that I measured. I also found spotted sunfish utilizing aquatic plants as a habitat when plants were present and one instance of juveniles selecting habitats of greater plant abundance relative to adults. Overall, spotted sunfish appeared to be habitat generalists, with fish selecting areas of more complex habitat than the available intervals (i.e., woody debris and/or aquatic plants). This generalist use of habitat corresponds to several anecdotal reports that associate spotted sunfish with a variety of habitats within Florida streams (Chable 1947; Kilby 1955; McLane 1955; Caldwell et al.1957) and is evident among other ecologically similar Florida Centrarchid species. Hill and Cichra (2005) noted that the congeners such as warmouth sunfish *L. gulosus*, redbreast sunfish *L. auritus*, and dollar sunfish *L. marginatus* have been historically collected from a variety of lotic environments, and they described all of these species as having been associated with woody debris, aquatic vegetation, and other structurally complex habitat types.

Numerous investigators have noted the importance of woody debris habitats to fish in lotic environments (Todd and Rabeni 1989; Fausch and Northcote 1992; Everett and Ruiz 1993; Koehn et al. 1994; Flebbe and Dolloff 1995; Crook and Robertson 1999; Horan et al. 2000; Dolloff and Warren 2003). Woody debris habitat offers refuge from current velocity (McMahon and Hartman 1989; Shirvell 1990) and predators (Koehn et al. 1994), and provides foraging (Benke et al. 1984; Smock et al. 1985) and ambush locations for stream fishes (Matthews 1998). The current velocity measurements that I recorded throughout the study were generally very low (range: 0 – 0.4 m/s), indicating that refuge from flow velocity would likely have been a minor factor in spotted sunfish habitat use. The body form and mouth morphology of spotted sunfish suggest that the species is most suited to feeding on small prey items attached to substrate or drifting within the water column (Carrol et al. 2004). Thus, it is much more likely that the association of spotted sunfish with woody debris and complex habitats was attributable to their use of these habitat types as foraging areas and refuge from predation rather than as velocity refuge. However, during higher flows they may utilize woody debris as velocity refuge.

Previous work surrounding the feeding ecology of spotted sunfish provides a functional linkage between the species and complex habitats such as woody debris and aquatic vegetation. As implied by their general morphology and relatively small size, spotted sunfish feed primarily on aquatic insects and other invertebrates (Chable 1947; McLane 1955; Caldwell et al.1957). Chable (1947) and McLane (1955) found 100% and 85% of their spotted sunfish diet samples, respectively, to contain insects. Prey taxa frequently observed among spotted sunfish diet items include chironomidae, coleoptera, trichoptera, ephemeroptera, and amphipoda (Chable 1947; McLane 1955; Caldwell et al.1957), all of which have been shown to be associated with complex habitats in Florida streams (Warren et al. 2000; Steigerwalt 2005).

Across nearly all lotic environments, woody debris has been shown to provide important habitat for aquatic invertebrates (Braccia and Batzer 2001; Benke and Wallace 2003). However, because of the general instability of sand and mud substrates in these systems, the relative value of woody debris, root wad, and submerged vegetation to stream ecosystems appears to increase in lowland rivers where these habitats offer the most stable attachment sites for invertebrates (Benke et al. 1984; Smock et al. 1985. Benke et al. (1985) showed that invertebrate communities derived from snag habitat were a valuable source of prey items for *Lepomis* spp. and other stream fishes at Satilla River, Georgia, and noted that snag fauna comprised at least 60% of diet composition for all *Lepomis* spp., including spotted sunfish. Kelly et al. (2005) noted a similar linkage between snag and root habitat derived invertebrate communities and redbreast sunfish diet composition at the Alafia River, Florida. Caldwell et al. (1957) found large quantities of periphyton among spotted sunfish stomachs and indicated that it was representative of the attached algal community growing on leaves of locally abundant *Sagittaria* at the Silver River, Florida. They suggested that the periphyton were most likely incidentally consumed while feeding on attached invertebrates among these vegetation beds. McLane (1955) also found filamentous algae to be a large component (26.9 % by occurrence) of spotted sunfish diet at the St. Johns River, Florida.

Complex habitat such as woody debris and aquatic vegetation also provides refuge from predators for juvenile or small bodied fishes such as *Lepomis* spp. (Savino and Stein 1982; Everett and Ruiz 1993; Crook and Robertson 1999; Dolloff and Warren 2003). Juvenile bluegill sunfish tend to select complex habitats (i.e., aquatic plants or artificial aquatic plants) in the presence of potential predators and this behavior often results in reduced predation success (Savino and Stein 1982; Werner et al.1983; Gotceitas and Colgan 1987; Johnson et al.1988). Because the coastal rivers of Florida contain a variety of freshwater and marine piscivores, and spotted sunfish remain relatively small even as adults, the availability of complex habitat is probably important as refuge from predation. Largemouth bass and/or common snook were abundant in all our sample rivers, and loss of complex habitat would likely expose spotted sunfish to higher mortality rates via predation (e.g., Savino and Stein 1982).

Habitat requirements of adults and juveniles of a species often differ (Larkin 1978; Werner and Gilliam 1984; Halpern et al. 2005). Ontogenetic shifts in habitat utilization have been observed among various lotic fishes, such as Roanoke logperch *Percina rex* (Rosenberger and Angermeier 2003), river blackfish *Gadopsis marmoratus* (Koehn et al. 1994), creek chub *Semotilus atromaculatus* (Magnan and FitzGerald 1984), and several Salmonid species (Moore and Gregory 1988; McMahon and Hartman 1989; Nickelson et al. 1992). I identified one instance of juvenile spotted sunfish using greater aquatic plant densities relative to adults. However, the general pattern was that adult and juvenile spotted sunfish occupied similar habitat types, and I found few significant differences between habitat parameters collected for adult and juvenile lifestages. The overall similarity in adult and juvenile spotted sunfish habitat utilization patterns corresponded to McMahon's (1984) description of habitat use of a congener, warmouth sunfish. Mittlebach (1984) noted that pumpkinseed sunfish *L. gibbosus* tend to occupy similar habitat types throughout their ontongeny, but overall few studies have specifically addressed comparisons of habitat utilization between adult and juvenile lifestages of *Lepomis* spp. (see Hill and Cichra 2005).

Although it represents a single occurrence in my results, the use of higher plant densities by juveniles relative to adults is not surprising. Lobb and Orth (1991) also found associations of juvenile stream fish species with in-stream vegetation. Similarly, Hellier (1966) observed a pattern in use of vegetation by juvenile redbreast sunfish in a Florida river. Juvenile bluegill sunfish have been observed using complex habitats that offer abundant and relatively small interstitial spaces, much like those created by dense aquatic vegetation, as a refuge from predation (Savino and Stein 1982; Werner et al. 1983; Gotceitas and Colgan 1987; Johnson et al. 1988).

At Anclote and Little Manatee Rivers, I found that habitat intervals occupied by spotted sunfish exhibited greater depth values relative to the available habitat intervals. The outer edge of stream bends typically corresponded to areas of greater depth found in close proximity to the bank, and these locations may provide an important component of spotted sunfish habitat. These areas would be subjected to greater substrate erosion during periods of increased streamflow; thus, creating localized abundances of exposed root-wads and fallen woody debris. Deeper areas along the bank may also be more resilient to fluctuations in river stage, thus, providing habitat that remains inundated throughout daily tidal changes.

My identification of spotted sunfish habitat selection was likely largely dependent on changes in density of the species across habitat types. Van Horne (1983) stressed that the assumption that greater density of a species within a particular habitat type translates into greater quality of that habitat type may not always hold true. Evaluation of habitat quality should consider spatial changes in species density, but it must also consider comparisons of survival and reproductive contribution by individuals occupying differing habitats (Van Horne 1983). For example, social interactions among individuals of a species may create instances where subdominant individuals, exhibiting reduced survival and reproductive output relative to dominant individuals, occupy sub-optimal habitats at high densities (population sink). In this situation, sustenance of the local population may be reliant upon a few dominant individuals, exhibiting high survival rate and reproductive output, that occupy the best habitat (population source) at a relatively low density. Thus, relying solely on abundance as an indicator of habitat quality may lead to erroneous conclusions in the identification of quality habitats (Van Horne 1983). My study addressed patterns in habitat use and selection by spotted sunfish in Florida Rivers, but I did not investigate demographic patterns such as individual survival rates or reproductive contribution in relation to stream habitat types. Thus, although my identification of utilized and selected habitat characteristics may be representative of important or required spotted sunfish habitat, the habitat associations revealed here may not infer differences in fish survival and growth had these habitats been lost from the system. Experimental manipulations would be required to elucidate the impacts of habitat change on fish vital rates.

Rogers et al. (2005) found that spotted sunfish abundance was positively related to river stage at the Ocklawaha River, Florida, with high fish abundances in years following high stage the previous year. I did not evaluate inter-annual trends in spotted sunfish abundance in this study, but the habitat use and selections patterns that I identified help explain the mechanisms for the relationship reported by Rogers et al. (2005). High water levels inundate complex habitats, likely providing food and refuge for spotted sunfish. Conversely, years with low water levels would reduce habitat availability possibly leading to lower spotted sunfish abundance via food limitation, predation, or a combination of these factors. Bonvechio and Allen (2005) found that redbreast sunfish year class strength was also positively related to river flows in Florida, and the relationship for *Lepomis* spp. may extend across several members of the genus.

My simulations indicated that relatively small decreases in river stage (e.g., average 0.30 m decline) below base-flow conditions could result in up to 20% reduction in habitat availability. Kelly et al. (2005) identified MFL strategies for the Alafia River, Florida, based on periods of varying seasonal flows through the year. My samples were conducted during their Blocks 1 and 3, which represent the spring and fall seasons typically exhibiting relatively low flows and stage. Water levels and flows during my sampling events were relatively low at about base-flow conditions (refer to Figure 2). My habitat measurements suggested that relatively minor declines in average river stage at base flow conditions could reduce overall habitat availability beyond the 15% benchmark used by the Southwest Florida Water Management District to signify undesirable resource loss (Kelly et al. 2005). However, these habitat loss simulations may not accurately reflect changes in shoreline habitat availability during long term (multi-year) stage and streamflow declines. Long term decreases in flow regime would redefine stream margins in response to new water level trends, and riparian vegetation would colonize newly exposed banks, thus, allowing for continued recruitment of complex habitats derived from terrestrial sources. Furthermore, long term changes in river stage and steamflow trends may provide conditions conducive to aquatic plant colonization, also creating new complex habitats for stream fishes. Considering these limitations, I advocate that my simulations are likely best suited to estimate habitat loss during short-term (< 1-2 years) declines in average daily stage.

I did not evaluate the potential effect of low river flow and stage on habitat loss via saltwater intrusion. Stream channel elevation was relatively low within all of my sampling reaches, and with the exception of those on the Manatee River upstream of the Lake Manatee Dam, many of my sampling reaches were at least somewhat tidally influenced. It is possible, under conditions of persistent low freshwater discharge, that water level in my study areas would remain stable if saline water from the downstream estuary encroached upstream, resulting in a different form of habitat loss for freshwater fish communities than I measured. Catalano et al. (2006) found saltwater intrusion to significantly reduce available habitat for freshwater fishes in the Lower Hillsborough River, Florida when flows declined. Estevez and Marshall (1994) noted changes in historical isohaline and vegetation patterns in the Manatee River estuary following implementation of flow regulation via a dam on the Manatee River, Florida. I did not find high salinity waters in the Anclote, Little Manatee, or Manatee downstream sites during this study, with freshwater fishes present during all sampling events. However, location and movement of isohalines within the shallow bays and lagoons of the Gulf of Mexico are considered especially susceptible to the effects of fluctuating freshwater flow inputs (Sklar and Browder 1998). Therefore, saltwater intrusion should be considered as another potential form of habitat loss for freshwater/oligohaline fishes in these coastal river systems, and defining the extent of potential saltwater intrusion is needed for these systems.

My sampling design incorporated sampling along the bank of each river, and it is possible that mid-channel habitat could have influenced habitat availability for spotted sunfish. However, these rivers are relatively shallow (< 2 meters) and narrow (i.e., < 50 meters wide) with shifting of sediments occurring during high flood events. The mid channel areas of the rivers were largely devoid of woody debris and aquatic plants. Nevertheless, my evaluation of habitat availability for spotted sunfish should be viewed as conservative, as not all sections of the rivers were sampled for habitat availability and fish occurrence.

My habitat-specific community sampling indicated that not only are complex habitat types selected for by spotted sunfish but that they tend to harbor greater species richness relative to other habitat types as well. Fish species richness varied among habitat types for all sampling rivers except the Manatee River upstream site. The specific habitat types that contained the highest fish richness varied among rivers, but fish richness was generally highest in either large woody debris (Anclote River and Manatee River downstream) or plant habitats (Little Manatee River). These results were similar to those of Lobb and Orth (1991), who found highest stream fish densities in and adjacent to snags relative to other habitats in a warmwater Virginia stream. Rogers et al. (2005) found that spotted sunfish abundance was related to fish richness across years at the Ocklawaha River, Florida. The habitat relationships I identified supported this relationship because both spotted sunfish occurrence and total richness were highest in the complex habitats at each system. I was unable to detect differences in fish diversity among habitat types in most cases, suggesting that fish diversity may be a less effective metric for detecting change in fish communities than species richness.

I acknowledge that my use of electrofishing as a sampling technique may introduce some inherent biases into data collected for spotted sunfish habitat intervals (e.g., Bain and Finn 1991). Efficacy of electrofishing is inversely related to depth and complexity of some habitat types (i.e., dense vegetation) (Bayley and Austen, 2002). These tendencies may have biased locations of spotted sunfish toward areas of shallower depth and away from areas of dense aquatic plants or overhanging brush. However, I directed sampling effort along river banks to minimize the effects of depth on capture efficiency. When subjected to an electromagnetic field, fish may exhibit varied responses. Of some concern were positive electrotaxis, the movement of a fish toward the electrofisher anode, negative electrotaxis, and fright response, the latter two of which would result in movements of a fish away from the electrofisher electromagnetic field (Bain and Finn 1991; Reynolds 1996). Any of these results could have affected the spatial accuracy of spotted sunfish habitat intervals. However, I made efforts to locate spotted sunfish intervals at the point where an individual was first seen within the electromagnetic field. If I suspected that substantial electrotaxis had occurred by an individual, it was not used for habitat data collection. Additionally, I felt that use of a one meter radius for habitat intervals provided sufficient volume of measured habitat that it would remain representative of an individual’s true habitat occurrence if limited electrotaxis did occur. Electrofishing efficiency also increases with fish size (Reynolds 1996), suggesting that juvenile spotted sunfish were likely not collected as efficiently as adults. However, because my goal was to measure the habitat associations, the relative comparisons among habitat types at each system were meaningful.

In summary, I identified habitat use and selection patterns for spotted sunfish but found them to be fairly general in their habitat associations. Few differences were found between adult and juvenile habitat use patterns, indicating that the generalist use of habitats likely persists throughout spotted sunfish ontongeny. My results suggest that seemly minor changes in the average stage during fall and spring seasons may substantially reduce the availability of habitats used by spotted sunfish. Spotted sunfish appeared to be a good indicator of fish richness differences among habitat types, suggesting that protection of complex habitats will also benefit the whole fish community in southwest Florida Rivers.

APPENDIX
SAMPLING LOCATIONS AND COMMUNITY SUMMARY

Table 5. Latitude and longitude coordinates for spotted sunfish sampling reaches at Anclote, Little Manatee, and Manatee Rivers, Florida. Upstream refers to upstream reach boundaries and Downstream refers to downstream reach boundaries.

River	Reach	Upstream	Downstream
Anclote	1	N 28°12.382’ W 82°42.527’	N 28°12.311’ W 82°42.656’
	2	N 28°12.270’ W 82°42.660’	N 28°12.199’ W 82°42.803’
	3	N 28°12.167’ W 82°42.806’	N 28°11.946’ W 82°42.826’
Little Manatee	1	N 27°40.531’ W 82°22.523’	N 27°40.673’ W 82°22.768’
	2	N 27°40.569’ W 82°22.787’	N 27°40.569’ W 82°23.010’
	3	N 27°40.536’ W 82°23.012’	N 27°40.435’ W 82°23.214’
	4	N 27°40.097’ W 82°23.411’	N 27°39.956’ W 82°23.350’
	5	N 27°39.898’ W 82°23.430’	N 27°39.888’ W 82°23.691’
Manatee upstream	1	N 27°27.887’ W 82°14.973’	N 27°27.997’ W 82°15.171’
	2	N 27°27.987’ W 82°15.186’	N 27°28.077’ W 82°15.468’
	3	N 27°28.089’ W 82°15.490’	N 27°28.109’ W 82°15.666’
Manatee downstream	1	N 27°29.779’ W 82°21.431’	N 27°29.964’ W 82°21.546’
	2	N 27°30.023’ W 82°21.631’	N 27°30.275’ W 82°21.679’
	3	N 27°30.323’ W 82°21.637’	N 27°30.563’ W 82°21.683’

Table 6. Habitat-specific list of fish species collected from the Anclote (A), Little Manatee (L), Manatee upstream (U) and Mantee downstream (D) rivers.

		Roots			Snags				Overhanging Brush				Plants		Sandbars		
Family	Species	A	L	D	A	L	U	D	A	L	U	D	L	U	A	L	D
Lepisosteidae	Florida gar *Lepisosteus platyrincus*	x		x	x	x	x	x	x	x	x	x	x	x			
	Longnose gar *L. osseus*		x	x	x	x		x		x		x	x				
Amiidae	Bowfin *Amia calva*	x			x				x		x			x	x		
Anquillidae	American eel *Anguilla rostrata*		x	x						x						x	
Synbranchidae	Asian swamp eel *Monopterus albus*		x										x				
Cyprinidae	Golden shiner *Notemegonus crysoleucas*				x				x		x			x			
	Taillight shiner *Notropis maculatus*							x				x	x				x
	Coastal shiner *N. petersoni*	x	x	x	x	x		x	x	x		x	x		x	x	x
Catostomidae	Lake chubsucker *Erimyzon sucetta*	x									x			x			
Ictaluridae	Channel catfish *Ictalurus punctatus*							x						x			
	Brown bullhead *Ameiurus nebulosus*					x								x			
Clariidae	Walking catfish *Clarias batrachus*										x						
Fundulidae	Bluefin killifish *Lucania goodei*	x							x				x		x	x	
	Rainwater killifish *L. parva*												x				
	Golden topminnow *Fundulus chrysotus*				x												
	Seminole Killifish *F. seminolis*												x			x	x

		Roots			Snags				Overhanging Brush				Plants		Sandbars		
Family	Species	A	L	D	A	L	U	D	A	L	U	D	L	U	A	L	D
Poeciliidae	*Gambusia* sp.	x	x	x	x				x	x		x	x	x	x	x	x
	Sailfin molly *Poecilia latipinna*											x	x		x	x	x
Ellasomatidae	Banded pygmy sunfish *Ellasoma zonatum*		x														
	Everglades pygmy sunfish *E. evergladei*	x															
Centrarchidae	Largemouth bass *Micropterus salmoides*	x	x	x	x	x	x	x	x	x	x	x	x	x		x	
	Bluegill sunfish *Lepomis macrochirus*	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x
	Dollar sunfish *L. marginatus*	x	x		x				x								
	Redbreast sunfish *L. auritus*															x	
	Redear sunfish *L. microlophus*	x			x	x	x	x	x		x	x	x	x	x	x	
	Spotted sunfish *L. punctatus*	x	x	x	x	x		x	x	x		x	x		x	x	
	Warmouth sunfish *L. gulosus*	x	x		x			x	x					x			
	Bluespotted sunfish *Enneacanthus gloriosus*		x						x								
Cichlidae	Black acara *Cichlasoma bimaculatum*	x															
	Blue tilapia *Oreochromis aurea*							x									
Atherinopsidae	Brook silverside *Labidesthes sicculus*							x	x								
	Inland silverside *Menidia beryllina*																x
Mugillidae	Striped mullet *Mugil cephalus*		x		x	x		x	x			x				x	

		Roots			Snags				Overhanging Brush				Plants		Sandbars		
Family	Species	A	L	D	A	L	U	D	A	L	U	D	L	U	A	L	D
Gobiidae	Naked goby *Gobiosoma bosc*					x										x	
	River goby *Awaous banana*															x	
Achiridae	Hogchoker *Trinectes maculatus*		x			x		x	x			x	x		x	x	x
Eleotridae	Fat sleeper *Dormitator maculatus*	x															
Centropomidae	Common snook *Centropomus undecimalis*		x	x		x		x		x			x				
Lutjanidae	Mangrove snapper *Lutjanus griseus*							x									

LIST OF REFERENCES

Anderson, N. H., J. R. Sedell, L. M. Roberst, and F. J. Triska. 1978. The role of aquatic invertebrates in processing of wood debris in coniferous forest streams. American Midland Naturalist 100:64-82.

Angermeier, P. L., and J. R. Karr. 1984. Relationshipes between woody debris and fish habitat in a small warmwater stream. Transactions of the American Fisheries Society 113:716-726.

Bailey, R. M., H. E. Winn, and C. L. Smith. 1954. Fishes from the Escambia River, Alabama and Florida. Proceedings of the Academy of Natural Sciences of Philadelphia 106:109-164.

Bain, M. B., and J. T. Finn. 1991. Analysis of microhabitat of fish: investigator effect and investigator bias. Rivers 2(1):57-65.

Bain, M. B., J. T. Finn, and H. E. Brooke. 1988. Streamflow regulation and fish community structure. Ecology 69:382-392.

Bass, D. G., and D. T. Cox. 1985. River habitat and fishery resources of Florida. Pages 122-188 *in* W. Seaman Jr., editor. Florida aquatic habitat and fishery resources. American Fisheries Society, Florida Chapter, Eustis, Florida.

Bayley, P. B., and D. J. Austen. 2002. Capture efficiency of a boat electrofisher. Transactions of the American Fisheries Society 131: 435-451.

Benke, A. C., R. L. Henry, III, D. M. Gillespie, and R. J. Hunter. 1985. Importance of snag habitat for animal production in southeastern streams. Fisheries 10(5):8-13.

Benke, A. C., T. C. Van Arsdall, Jr., D. M. Gillespie, and F. K. Parrish. 1984. Invertebrate productivity in a subtropical blackwater river: the importance of habitat and life history. Ecological Monographs 54: 25-63.

Benke, A. C., and J. B. Wallace. 2003. Influence of wood on invertebrate communities in streams and rivers. Pages 149-177 *in* S. Gregory, K. Boyer, and A. Gurnell, editors. The ecology and management of wood in world rivers. American Fisheries Society, Bethesda, Maryland.

Bonvechio, T. F., and M. S. Allen. 2005. Relations between hydrological variables and year-class strength of sportfish in eight Florida waterbodies. Hydrobiologia 532:193-207.

Braccia, A., and D. P. Batzer. 2001. Invertebrates associated with woody debris in a Southeastern U. S. forested floodplain wetland. Wetlands 21:18-31.

Caldwell, D. K., H. T. Odum, T. R. Hellier, Jr., and F. H. Berry. 1957. Populations of spotted sunfish and Florida largemouth bass in a constant-temperature spring. Transactions of the American Fisheries Society 85:120-134.

Carlander, K. D. 1977. Handbook of freshwater fishery biology, Volume 2. Iowa State University Press, Ames, Iowa.

Carrol, A. M., P. C. Wainwright, S. H. Huskey, D. C. Collar, and R. G. Turingan. 2004. Morphology predicts suction feeding performance in centrarchid fishes. The Journal of Experimental Biology 207:3873-3881.

Catalano, M. J., M. S. Allen, and D. J. Murie. 2006. Effects of variable flows on water chemistry gradients and fish communities at Hillsborough River, Florida. North American Journal of Fisheries Management 26:108-118.

Chable, A. C. 1947. A study of the food habits and ecological relationships of the sunfishes of northern Florida. Master's thesis. The University of Florida, Gainesville, Florida.

Crook, D. A., and A. I. Robertson. 1999. Relationships between riverine fish and woody debris: implications for lowland rivers. Marine and Freshwater Research 50:941-953.

Cushman, R. M. 1985. Review of ecological effects of rapidly varying flows downstream of hydroelectric facilities. North American Journal of Fisheries Management 5:330-339.

Dolloff, D. A., D. G. Hankin, and G. H. Reeves. 1993. Basinwide estimation of habitat and fish populations in streams. U. S. Forest Service. General Technical Report SE-83. Asheville, North Carolina.

Dolloff, C. A., and M. L. Warren, Jr. 2003. Fish relationships with large wood in small streams. Pages 179-193 *in* S. Gregory, K. Boyer, and A. Gurnell, editors. The ecology and management of wood in world rivers. American Fisheries Society, Bethesda, Maryland.

Estevez, E. D., and M. J. Marshall. 1994. Impact of flow variation in the Manatee River, section 2. Biological assessment of pre- and post-alterations. Flows and salinities. Tampa Bay National Estuary Program Technial Pbulication 09-94. Prepared by Mote Marine Laboratory for Dames and Moore, Inc., Tampa Bay National Estuary Program.

Evertt, R. A., and G. M. Ruiz. 1993. Coarse woody debris as a refuge from predation in aquatic communities. Oecologia 93:475-486.

Fausch, K. D., and T. G. Northcote. 1992. Large woody debris and Salmonid habitat in a small coastal British Columbia stream. Canadian Journal of Fisheries and Aquatic Sciences 49:682-693.

Flebbe, P. A., and C. A. Dolloff. 1995. Trout use of woody debris and habitat in Appalachian wilderness streams of North Carolina. North American Journal of Fisheries Management 15:579-590.

Gotceitas, V., and Colgan, P. 1987. Selection between densities of artificial vegetation by young bluegills avoiding predation. Transactions of the American Fisheries Society 116:40-49.

Halpern, B. S., S. D. Gaines, and R. R. Warner. 2005. Habitat size, recruitment, and longevity as factors limiting population size in stage-structured species. The American Naturalist 165:82-94.

Hellier, T. R., Jr. 1966. Fishes of the Santa Fe River system. Bulletin of the Florida State Museum 11:1-46.

Hill, J. E., and C. E. Cichra. 2005. Biological synopsis of five selected Florida Centrarchid fishes with an emphasis on the effects of water level fluctuations. St. Johns Water Management District. Special Publication SJ2005-SP3. Palatka, Florida.

Horan, D. L., J. L. Kershner, C. P. Hawkins, and T. A. Crowl. 2000. Effects of habitat area and complexity on Colorado River cutthroat trout density in Uinta Mountains streams. Transactions of the American Fisheries Society 129:1250-1263.

Hubbs, C. L., and E. R. Allen. 1943. Fishes of Silver Springs, Florida. Proceedings Florida Academy of Sciences 6:110-130.

Irvine, J. R. 1985. Effects of successive flow perturbations on stream invertebrates. Canadian Journal of Fisheries and Aquatic Sciences 42:1922-1927.

Johnson, D. L., R. A. Beaumier, and W. E. Lynch, Jr. 1988. Selection of habitat structure interstice size by bluegills and largemouth bass in ponds. Transactions of the American Fisheries Society 117:171-179.

Kelly, M., A. Munson, J. Morales, and D. Leeper. 2005. Alafia River flows and levels; freshwater segment. Final Report, Southwest Florida Water Management District, Brooksville, Florida.

Kelsch, S. W. 1994. Lotic fish-community structure following transition from severe drought to high discharge. Journal of Freshwater Ecology. 9:331-341.

Kilby, J. D. 1955. The fishes of two Gulf Coast marsh areas of Florida. Tulane Studies in Zoology 2:175-247.

Kinsolving, A. D., and M. B. Bain. 1993. Fish assemblage recovery along a riverine disturbance gradient. Ecological Applications 3:531-544.

Koehn, J. D., N. A. O'Connor, and P. D. Jackson. 1994. Seasonal and size-related variation in microhabitat use by a southern Victorian stream fish assemblage. Australian Journal of Freshwater Research 45:1353-1366.

Larkin, P. A. 1978. Fisheries management – an essay for ecologists. Annual Review of Ecology and Systematics 9:57-73.

Lobb, M. D., and D. J. Orth. 1991. Habitat use by an assemblage of fish in a large warmwater stream. Transactions of the American Fisheries Society 120:65-78.

Magnan, P., and G. J. FitzGerald. 1984. Ontogenetic changes in diel activity, food habits, and spatial distribution of juvenile and adult creek chub, *Semotilus atromaculatus*. Environmental Biology of Fishes 11:301-307.

Matthews, W. J. 1998. Patterns in freshwater fish ecology. Chapman and Hall, New York, New York.

McLane, W. M. 1955. The Fishes of the St. Johns River system. Doctoral dissertation. The University of Florida, Gainesville, Florida.

McMahon, T. E., G. Gebhart, O. E. Maughan, and P. C. Nelson. 1984. Habitat suitability index models and instream flow suitability curves: warmouth. FWS/OBS-82.10.67. U. S. Fish and Wildlife Service, Washington, D.C.

McMahon, T. E., and G. F. Hartman. 1989. Influence of cover complexity and current velocity on winter habitat use by juvenile coho salmon (*Oncorhynchus kisutch*). Canadian Journal of Fisheries and Aquatic Sciences 46:1551-1557.

Mittelbach, G. G. 1984. Predation and resource partitioning in two sunfishes (Centrarchidae). Ecology 65:499-513.

Moore, K. M. S., and S. V. Gregory. 1988. Summer habitat utilization and ecology of cutthroat trout fry (*Salmo clarki*) in Cascade Mountain streams. Canadian Journal of Fisheries and Aquatic Sciences 45:1921-1930.

Nickelson, T. E., J. D. Rodgers, S. L. Johnson, and M. F. Solazzi. 1992. Seasonal changes in habitat use juvenile coho salmon (Oncorhyncus kisutch) in Oregon coastal streams. Canadian Journal of Fisheries and Aquatic Sciences 49:783-789.

Peters, J. C. 1982. Effects of river and streamflow alteration on fishery resources. Fisheries 7(2):20-22.

Power, G., R. S. Brown, and J. G. Imhof. 1999. Groundwater and fish – insights from northern North America. Hydrological Processes 13:401-422.

Raibley, P. T., T. M. O'Hara, K. S. Irons, K. D. Blodgett, and R. E. Sparks. 1997. Largemouth bass size distributions under varying annual hydrological regimes in the Illinois River. Transactions of the American Fisheries Society 126:850-856.

Reynolds, J. B. 1996. Electrofishing. Pages 221-253 *in* B. R. Murphy and D. W. Willis, editors. Fisheries Techniques, 2nd Edition. American Fisheries Society, Bethesda, Maryland.

Rogers, M. W., M. S. Allen, and M. D. Jones. 2005. Relationships between river surface levels and fish assemblages in the Ocklawaha River, Florida. River Research and Applications 21:501-511.

Rosenberger, A., and P. L. Angermeier. 2003. Ontogenetic shifts in habitat use by the endangered Roanoke logperch (*Percina rex*). Freshwater Biology 48:1563-1577.

Rosenfeld, J. 2003. Assessing the habitat requirements of stream fishes: an overview and evaluation of different approaches. Transactions of the American Fisheries Society 132:953-968.

Rozas, L. P., and W. E. Odum. 1988. Occupation of submerged aquatic vegetation by fishes: testing the roles of food and refuge. Oecologia 77:101-106.

SAS Institute. 2002. SAS Users Guide: Statistics, Version 8, 4th edition. SAS Institute, Cary, North Carolina.

Savino, J. F., and R. A. Stein. 1982. Predator-prey interaction between largemouth bass and bluegills as influenced by simulated submersed vegetation. Transactions of the American Fisheries Society 111:255-266.

Scheaffer, R. L., W. Mendenhall, and L. Ott. 1990. Elementary survey sampling, 4th edition. PWS-KENT, Boston, Massachusetts.

Schlosser, I. J. 1985. Flow regime, juvenile abundance, and the assemblage structure of stream fishes. Ecology 66:1484-1490.

Shirvell, C. S. 1990. Role of insteam rootwads as juvenile coho salmon (*Oncorhyncus kisutch*) and steelhead trout (*O. mykiss*) cover habitat under varying steamflows. Canadian Journal of Fisheries and Aquatic Sciences 47:852-861.

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

Sklar, F. H., and J. A. Browder. 1998. Coastal environmental impacts brought about by alterations to freshwater flow in the Gulf of Mexico. Environmental Management 22:547-562.

Smock, L. A., E. Gilinsky, and D. L. Stoneburner. 1985. Macroinvertebrate production in a southeastern United States blackwater stream. Ecology 66: 1491-1503.

Steigerwalt, N. M. 2005. Environmental factors affecting aquatic invertebrate community structure on snags in the Ichetucknee River, Florida. Master's thesis. The University of Florida, Gainesville, Florida.

Todd, B. L., and C. F. Rabeni. 1989. Movement and habitat use by stream-dwelling smallmouth bass. Transactions of the American Fisheries Society 118:229-242.

Travnichek, V. H., M. B. Bain, and M. J. Maceina. 1995. Recovery of a warmwater fish assemblage after the initiation of a minimum-flow release downstream from a hydroelectric dam. Transactions of the American Fisheries Society 124:836-844.

Tyus, H. M. 1990. Effects of altered streamflows on fishery resources. Fisheries 15(3):18-20.

Van Horne, B. 1983. Density as a misleading indicator of habitat quality. Journal of Wildlife Management 47:893-901.

VanderKooy, K. E., C. F. Rakocinski, and R. W. Heard. 2000. Trophic relationships of three sunfishes (*Lepomis* spp.) in an estuarine bayou. Estuaries 23:621-632.

Warren, G. L., D. A. Holt, C. Cichra, and D. VanGenecten. 2000. Fish and aquatic invertebrate communities of the Wekiva and Little Wekiva Rivers: a baseline evaluation in the context of Florida's minimum flows and levels statues. St. Johns River Water Management District Special Publication SJ2000-SP4, Palatka, Florida.

Werner, E. E., and J. F. Gilliam. 1984. The ontogenetic niche and species interactions in size-structured populations. Annual Reviews in Ecology and Systematics 15:393-425.

Werner, E. E., J. F. Gilliam, D. J. Hall, and G. G. Mittelbach. 1983. An experimental test of the effects of predation risk on habitat use in fish. Ecology 64:1540-1548.

Weyers, R. S., C. A. Jennings, and M. C. Freeman. 2003. Effects of pulsed, high-velocity water flow on larval robust redhorse and v-lip redhorse. Transactions of the American Fisheries Society 132:84-91.

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

BIOGRAPHICAL SKETCH

Andrew (Drew) Carl Dutterer was born on October 17, 1979, in Athens, Georgia. In 1984 he and his family relocated to the North Carolina foothills, just outside of the small town of Dallas. Drew enrolled at North Carolina State University following graduation from high school in 1998. While attending N.C. State, Drew received a bachelor's degree in environmental sciences, with an emphasis in ecology. In 2004, Drew enrolled at the University of Florida to pursue a Master of Science degree, while conducting research through the Department of Fisheries and Aquatic Sciences. He completed his graduate studies with the University of Florida in the summer of 2006. Drew is a washed-up artist, closet musician, incompetent outboard mechanic, swell cook, and fair biologist. First and foremost, however, he is an avid outdoorsman and for most of his life fishing has been a passion, presenting that insatiable itch to scratch.