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Fish assemblages found in tidal-creek and seagrass habitats in the Suwannee River estuary

Troy D. Tuckey
Florida Fish and Wildlife Conservation Commission
Florida Wildlife Research Institute
Apalachicola Field Laboratory
East Point, Florida 32328
Present address: School of Marine Science
Virginia Institute of Marine Science
College of William and Mary
P.O. Box 1346, Route 1208 Greate Road
Gloucester Point, Virginia, 23062
E-mail address: tuckey@vims.edu

Mark Dehaven
Department of Agriculture and Consumer Services
Division of Aquaculture
11350 SW 153rd Ct.
Cedar Key, Florida 32625

Abstract—Fish assemblages were investigated in tidal-creek and seagrass habitats in the Suwannee River estuary, Florida. A total of 91,571 fish representing 43 families were collected in monthly seine samples from January 1997 to December 1999. Tidal creeks supported greater densities of fish (3.89 fish/m^2; 83% of total) than did seagrass habitats (0.93 fish/m^2). We identified three distinct fish assemblages in each habitat: winter–spring, summer, and fall. Pinfish (*Lagodon rhomboides*), pigfish (*Orthopristis chrysoptera*), and syngnathids characterized seagrass assemblages, whereas spot (*Leiostomus xanthurus*), bay anchovy (*Anchoa mitchilli*), silversides (*Menidia* spp.), mojarras (*Eucinostomus* spp.), and fundulids characterized tidal-creek habitats. Important recreational and commercial species such as striped mullet (*Mugil cephalus*) and red drum (*Sciaenops ocellatus*) were found primarily in tidal creeks and were among the top 13 taxa in the fish assemblages found in the tidal-creek habitats. Tidal-creek and seagrass habitats in the Suwannee River estuary were found to support diverse fish assemblages. Seasonal patterns in occurrence, which were found to be associated with recruitment of early-life-history stages, were observed for many of the fish species.

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The Suwannee River estuary, located on the gulf coast of Florida, is relatively pristine and supports commercial and recreational fisheries. It is an unusual estuary, with an orientation along the open coastal shoreline, and its habitats include oyster bars, mudflats, seagrasses, tidal creeks, and an extensive salt marsh (Comp and Seaman, 1985). In other estuaries of the United States, fish assemblages, species abundance, and habitat associations within estuaries have been studied extensively. Particular attention has focused on estuaries as nursery habitats for young-of-the-year (YOY) fishes that use seagrasses, tidal-creeks, and marshes during their early-life stages (Shenker and Dean, 1979; Bozeman and Dean, 1980; Livingston, 1984; Cowan and Birdsong, 1985; Gilmore, 1988; McGovern and Wenner, 1990; Baltz et al., 1993; Peterson and Turner, 1994; Rooker et al., 1998). In addition, comparisons between different habitats within estuarine systems have been conducted to evaluate the value of each habitat as a nursery (Weinstein and Brooks, 1983; Sogard and Able, 1991; Rozas and Minello, 1998; Paperno et al., 2001). Aside from basic species-composition studies of marsh fishes (Kilby, 1955; Nordlie, 2000) and fishes that inhabit shallow waters near Cedar Key (Reid, 1954), only one recent study (Tsou and Matheson, 2002) has investigated the distribution patterns of fishes in the Suwannee River estuary. Tsou and Matheson (2002) found that the nekton community structure for the Suwannee River estuary had a strong seasonal pattern that was consistent among years and followed patterns for water temperature and river discharge. They found assemblages that were associated with warm and cold seasons, and wet and dry seasons, but they did not examine habitat specific assemblages (Tsou and Matheson, 2002). For proper management of fishery resources, it is beneficial to have detailed, current information concerning the status of all life-history stages and associated habitats of species that reside in the area, as well as information concerning species interactions and associated food webs. Although human development in the Suwannee River estuary is not a current threat, the potential withdrawal of freshwater from the Suwannee River for human consumption is a possibility and could impact fish assemblages found in the estuary (Tsou and Matheson, 2002).

This article describes habitat-specific assemblages by examining the fish fauna collected in seagrass habi-

tats with those collected in tidal-creek habitats in the Suwannee River estuary. We performed comparisons of monthly collections of fish found along tidal-creek shorelines and those found in seagrass habitats to define fish assemblages and incorporated abiotic parameters as potential factors influencing the assemblages. We also compared length distributions of species in each habitat to examine the success of YOY recruitment and the subsequent influence of YOY recruitment on fish assemblages in order to understand the nursery function of each habitat.

Methods

Study location

This study took place in the Suwannee River estuary, which lies along the gulf coast of Florida, extending from just north of the Suwannee River to Cedar Key (Fig. 1). The Suwannee River empties directly into the Gulf of Mexico forming an unusual open estuary that stretches 13 kilometers north of the river mouth, southeastward to the islands of Cedar Key, and extends approximately 8 kilometers offshore (Leadon[1]). The Suwannee River estuary is shallow (water depth <2.2 m below mean sea level), and has semidiurnal tides with a tidal range of 0.7 m. The shoreline is relatively undeveloped; the city of Cedar Key (pop. 898) along the southeastern edge of the estuary and the small town of Suwannee approximately 4.8 kilometers inland along the Suwannee River are the only populated areas. The remainder of the coastline, consisting of the Lower Suwannee and Cedar Keys National Wildlife Refuges and the Cedar Key State Preserve, is owned by the public.

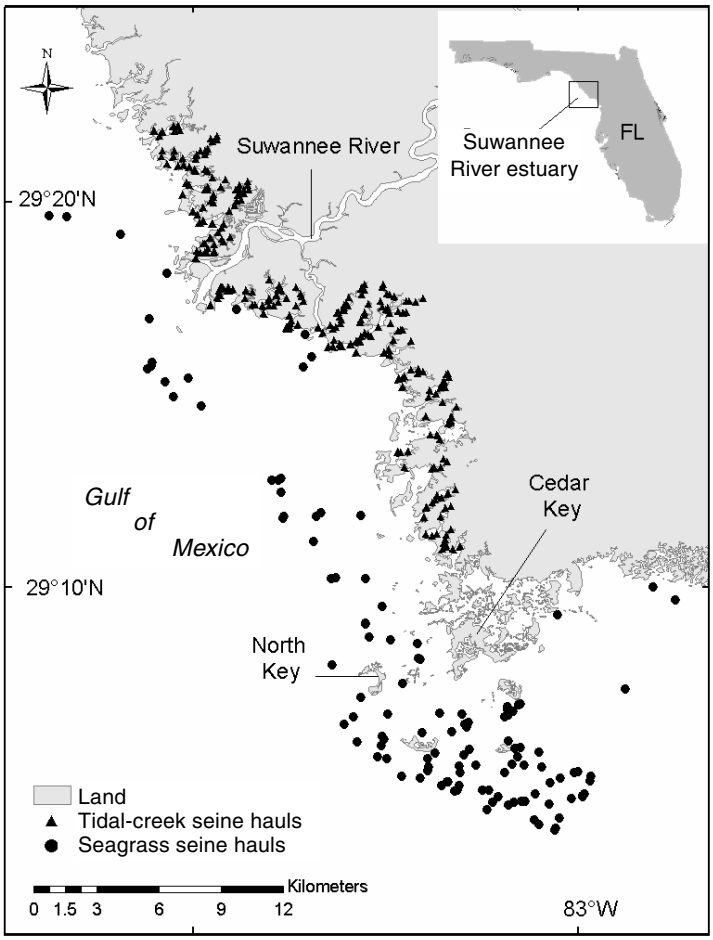

Figure 1

Study area showing location of tidal-creek and seagrass seine hauls in the Suwannee River estuary, located on the gulf coast of Florida.

Study design

Randomly selected sites were sampled monthly within tidal-creek and seagrass habitats from January 1997 through December 1999. Juvenile and small adult fish from each site were collected using a 21.3-m × 1.8-m nylon seine with 3.2-mm mesh and a center bag measuring 1.8-m × 1.8-m × 1.8-m. Sampling methods depended on the habitat sampled, and all seines were deployed during daylight hours.

Collections in tidal creeks consisted of six hauls per month in 1997 and increased to nine hauls per month in 1998 and 1999. Tidal creeks consisted of soft mud, deep channels, oyster bars, and steep banks. Shoreline vegetation included saltmarsh cord grass (*Spartina alterniflora*) and needle rush (*Juncus roemerianus*) near the creek mouths and changed to a variety of freshwater marsh grasses and terrestrial vegetation upstream. The seine was set from a boat in a semicircular pattern along the shoreline, retrieved onshore, and sampled an average area of 68 m^2 per haul. Shoreline areas inundated with vegetation were not sampled if the water depth was greater than 0.5 m in order to reduce the interference of vegetation during sample collections. Sampling in tidal-creeks was limited to the shoreline because the water was too deep in the channels to deploy the seine. In addition, despite the importance of oyster bar habitat, oyster bars located inside tidal creeks were not sampled because they interfered with the proper deployment of the seine.

Seagrass habitats generally surrounded the major islands near Cedar Key, including North Key and nearby islands (Fig. 1). In addition, vegetated patches extended from North Key northwestward to the mouth of the Suwannee River and were present in shallow areas approximately three kilometers west of the Suwannee River (Fig. 1). Dominant seagrass species in the Suwannee River estuary included turtle grass (*Thalassia testudi-*

[1] Leadon, C. J. 1979. Unpubl. manuscr. Environmental effects of river flows and levels in the Suwannee River subbasin below Wilcox and the Suwannee River estuary, Florida, 59 p. Suwannee River Water Management District Interim Report, 9225 County Road 49, Live Oak, FL 32060.

num), manatee grass (*Syringodium filliforme*), and shoal grass (*Halodule wrightii*). Percent coverage was estimated visually, or if water clarity was insufficient to visually inspect the bottom, bottom samples were collected at 3-m intervals during deployment of the seine. For analytical purposes, areas sampled had to contain at least ten percent seagrass to be considered seagrass habitat. Samples were classified as "vegetated" or "unvegetated" after sampling; and monthly collections varied from one to seven hauls per month depending on seagrass coverage. Seagrass habitats were sampled by pulling the seine into the current or wind, whichever was strongest. We kept the opening of the net at a constant width by maintaining tension on a 15.5-m line that was attached between each end pole of the seine while the seine was hauled for a distance of 9.1 m. The distance covered by the seine was measured by a weighted line from the starting point. The net was retrieved by bringing the end poles together and pulling the net at an angle around a vertical pole that closed the wings of the net and forced the catch into the bag. A typical seine haul over seagrass habitat covered approximately 140 m^2.

In the field, all fish were identified to the lowest possible taxon, counted, and released. Up to 40 individuals of species of special interest (important to the commercial or recreational fishery) and 10 individuals of all other species were measured to the nearest millimeter standard length (SL). For quality-control purposes, three specimens of each species collected were returned to the laboratory so that species identification could be confirmed. At each site, Secchi depth and water depth were measured, and water temperature (°C), salinity, dissolved oxygen level (mg/L), and pH were measured by using a Hydrolab Surveyor3® water-quality instrument (Hach Environmental, Loveland, CO).

Data analysis

Multivariate analyses were used to compare fish community structures along tidal-creek shorelines to those found in seagrass habitats (Field et al., 1982). Average monthly abundance estimates (number of fish divided by the number of hauls) were calculated separately for each fish species in each habitat type. Average monthly abundance estimates were then converted to percent composition to correct for bias introduced by the two different net-deployment methods and for the different levels of effort in each habitat. Fishes that were not identified to species were eliminated (<0.1% of total fish collected) except where species complexes, such as silversides (*Menidia* spp.), mojarras (*Eucinostomus* spp. <50 mm SL), menhaden (*Brevoortia* spp.), and minnows (*Notropis* spp.) were substituted. Species complexes were used when meristic characters for juveniles were insufficient to distinguish between two or more possible species (*Eucinostomus* spp. and *Notropis* spp.) or where there was possible hybridization (*Menidia* spp. and *Brevoortia* spp.).

Fish-community comparisons based on percent species composition by habitat and month were conducted by using algorithms in PRIMER (Plymouth Routines in Multivariate Ecological Research, vers. 5, Plymouth Marine Laboratory, UK) for the study of community structure (Clarke and Warwick, 1994). To identify fish assemblages, hierarchical agglomerative cluster analysis was performed with the Bray-Curtis similarity matrix calculated on fourth-root transformed percentage data. The fourth-root transformation reduced the dominance of abundant species and increased the influence of less abundant species in the community analysis. The cluster analysis was run on one matrix consisting of all transformed fish abundance estimates collected in tidal-creek and seagrass habitats combined.

To identify species that were responsible for the patterns observed in the cluster analysis, similarity and dissimilarity percentage breakdowns were conducted by using the SIMPER procedure in PRIMER (Clarke, 1993). Average similarities between assemblages were analyzed to determine the contribution of each species to the overall similarity. This procedure reduced the number of species required to explain the patterns observed in the cluster diagram and allowed for a simplified interpretation of the species assemblages. The higher the similarity value, the more alike samples were within assemblages. Alternatively, dissimilarity values were examined to identify species that were characteristic of a particular assemblage. Species that have high average dissimilarity values and low standard deviations are those that contribute consistently to samples within their group, with the result that they can be used to distinguish between groups.

The relationship between environmental variables and fish community structure was examined by using the BIO-ENV procedure. A Spearman rank correlation test was used to compare ranked values from the aforementioned biota similarity matrix to ranked values from an environmental similarity matrix, which was created from environmental variables measured in this study. Comparisons were based on normalized Euclidean distance. The environmental variables used to create the environmental similarity matrix included pH, water temperature, salinity, water depth, and Secchi depth. Dissolved oxygen was strongly correlated with water temperature and was therefore not included in the analysis because it would produce results similar to those produced by water temperature. Abiotic variables were standardized by subtracting each mean and dividing by the standard error to remove any bias associated with the different measurement scales.

The influence of recruitment of YOY fishes in defining fish assemblages was examined. By relating increases in abundance of species that were identified to be important contributors through the SIMPER procedure to decreases in their average length in both habitats, we were able to identify the timing of juvenile recruitment. Length-frequency distributions showed that the seine continued to catch larger individuals and therefore the decrease in average length was not due to a decrease

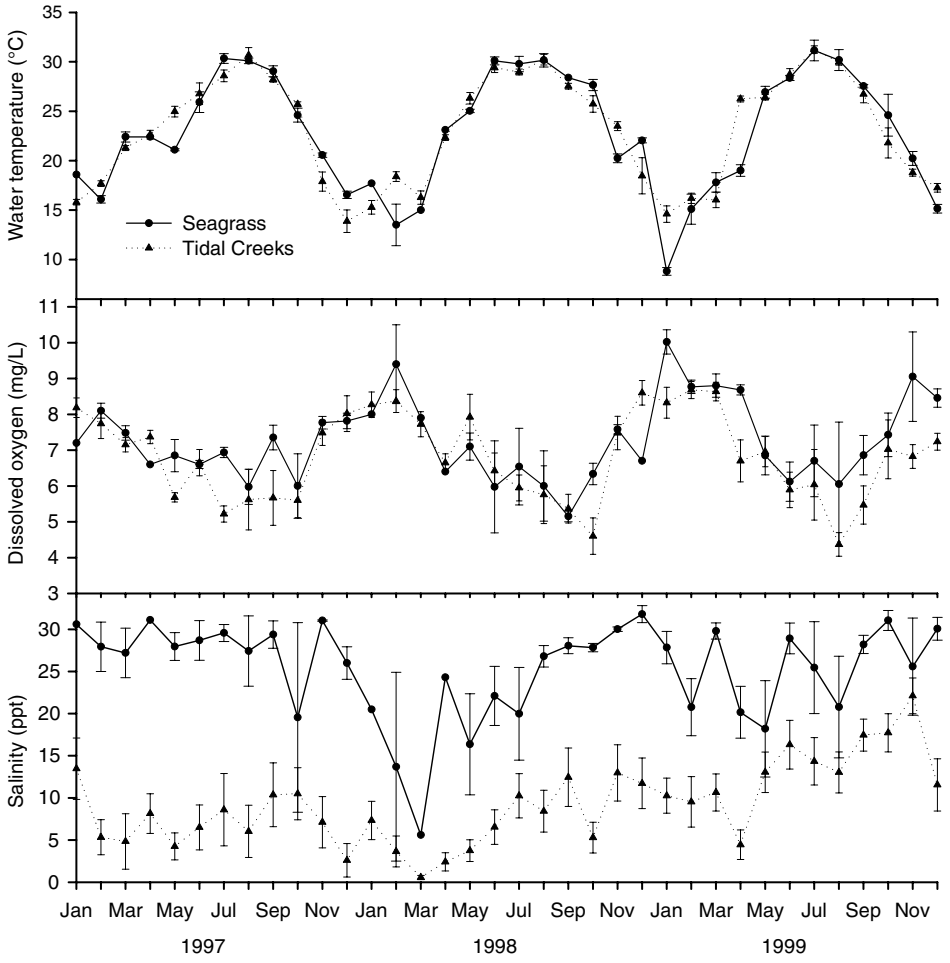

Figure 2

Monthly mean values (± standard error) for water temperature, dissolved oxygen, and salinity from January 1997 to December 1999. Circles represent values measured in seagrass habitats; triangles represent values measured in tidal-creek habitats.

in the number of larger fish. The mean length of each species in each sample was calculated by habitat, and differences in mean length were tested by using fish assemblages as the main factor in a one-way ANOVA. Multiple comparisons tests (Tukey's test) were then conducted to examine significant ANOVA results and these tests determined which assemblages contained fishes with significantly different lengths.

Results

Environmental conditions

The combination of water temperature, salinity, and water depth had the highest correlation (ρ_w=0.659) with the fish assemblages of any possible combination of measured abiotic variables. Seasonal patterns were observed for water temperature and dissolved oxygen, whereas salinity fluctuated in seagrass habitats and generally increased during 1999 in tidal-creek habitats (Fig. 2). Water temperatures ranged from 7.5° to 32.5°C (mean=23.0°C, SE=0.99) in the seagrass habitats and ranged from 10.3° to 33.3°C (mean=23.1°C, SE=0.91) in the tidal-creek habitats. Minimum values of dissolved oxygen coincided with the highest water temperatures in each habitat and ranged from 2.9 to 12.7 mg/L in the seagrass habitats and from 2.9 to 13.6 mg/L in the tidal-creek habitats. Salinity, however, was lower during all seasons in the tidal-creek habitats than in the seagrass habitats (Fig. 2). Mean salinity in the seagrass habitats was 27.1‰ (SE=0.91) and ranged from nearly fresh (1.3‰) to marine (34.8‰) depending on river discharge, whereas in the tidal creeks, mean salinity was 9.5‰ (SE=0.81) and ranged from 0.0‰ to 29.0‰. An unusually high period of rain during February and March of 1998 decreased salinity values in the tidal-creek and seagrass habitats.

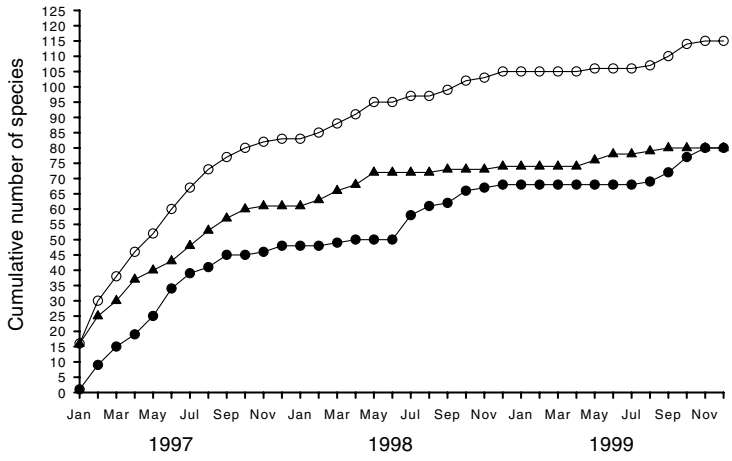

Figure 3

Cumulative number of species collected in both tidal-creek and seagrass habitats (open circles) and number of species collected in tidal-creeks (triangles) and seagrass habitats (filled circles) by year and month from January 1997 to December 1999.

Fish fauna

At the conclusion of the three-year study, 111 fish species and 4 additional species complexes had been collected. During the first year of the study, 61 species were collected in samples taken in tidal-creek habitats, and 48 species were collected in seagrass habitats (Fig. 3). Thirteen new species were added to the species list from tidal creek samples and 20 new species were added to the list from samples taken in seagrass habitats during 1998. During the final year of sampling only six additional species were collected in tidal creeks and 12 new species were collected in seagrass habitats. Overall, tidal creeks contained greater relative (uncorrected for gear efficiency) densities of fish (3.89 fish/m^2) compared with seagrass habitats (0.93 fish per m^2). In seagrass habitats, 15,395 individuals were collected in 118 samples that covered approximately 16,520 m^2 of seagrass habitat (Table 1). In tidal-creek habitats, a total of 76,176 individuals were collected from 288 samples that covered approximately 19,584 m^2 of tidal-creek shoreline habitat (Table 2). Thirty-five species were restricted to seagrass habitats, and another 35 species were collected only in tidal creeks. The remaining 45 species were collected in both habitats at least once during the study. Overall, twelve families were restricted to seagrass habitats: phycid hakes (Phycidae), toadfishes (Batrachiodidae), batfishes (Ogcocephalidae), flyingfishes (Exocoetidae), cardinalfishes (Apogonidae), barracudas (Sphyraenidae), wrasses (Labridae), combtooth blennies (Blenniidae), mackerels (Scombridae), triggerfishes (Balistidae), boxfishes (Ostraciidae), and porcupinefishes (Diodontidae; Table 1). Seven families were restricted to tidal-creek habitats: minnows (Cyprinidae), sunfishes (Centrarchidae), killifishes (Cyprinodontidae), gars (Lepisosteidae), eagle rays (Myliobatidae), pikes (Esocidae), and livebearers (Poeciliidae; Table 2).

Fish assemblages

A clear separation of fish assemblages was identified and indicated by two main branches that corresponded to fishes found in seagrass habitats and those found in tidal-creek habitats (Fig. 4). There were two months identified from seagrass samples (January 1997 and March 1998) that had a species composition that was more closely linked to samples taken from tidal creeks.

Seagrass habitats

Seasonal fish assemblages in seagrass habitats were evident during all three years of the study, which included winter–spring, summer, and fall assemblages (Fig. 4). The winter–spring assemblage consisted principally of pinfish (*Lagodon rhomboides*), pigfish (*Orthopristis chrysoptera*), dusky pipefish (*Syngnathus floridae*), southern puffer (*Sphoeroides nephelus*), and gulf pipefish (*Syngnathus scovelli*), which together accounted for more than 95% of the cumulative percent similarity. The summer assemblage had a higher average similarity value (43.67) than did the winter–spring assemblage (42.56) and consisted of more than 21 species. Eleven of these species—silver perch (*Bairdiella chrysoura*), *S. floridae*, bay anchovy (*Anchoa mitchilli*), *L. rhomboides*, *Eucinostomus* spp., spotted seatrout (*Cynoscion nebulosus*), *S. scovelli*, planehead filefish (*Monacanthus hispidus*), striped anchovy (*Anchoa hepsetus*), inshore lizardfish (*Synodus foetens*), and *O. chrysoptera*—accounted for more than 75% of the cumulative similarity of the summer assemblage. The fall assemblage had the high-

Table 1

Taxonomic list of individuals collected in seagrass habitats for each species by month and total number collected, all years combined.

Family	Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Dasyatidae	*Dasyatis sabina*	0	0	0	0	0	0	1	0	1	3	1	1	7
	Dasyatis say	0	0	0	0	0	2	0	0	0	0	0	0	2
Ophichthidae	*Myrophis punctatus*	0	0	0	1	0	0	0	0	0	0	0	0	1
Clupeidae	*Harengula jaguana*	0	0	0	0	0	0	6	230	0	162	0	0	398
	Brevoortia spp.	0	0	1	0	0	0	0	0	0	0	0	0	1
	Opisthonema oglinum	0	0	0	0	0	4	1	4	35	9	0	0	53
	Sardinella aurita	0	0	0	0	0	0	0	16	0	0	0	0	16
Engraulidae	*Anchoa hepsetus*	0	0	0	0	1	540	2	1	235	13	3	0	795
	Anchoa mitchilli	0	0	4	3	0	38	1567	3838	632	3504	53	0	9639
Ariidae	*Arius felis*	0	0	0	0	0	1	1	14	45	1	0	0	62
	Bagre marinus	0	0	0	0	0	0	0	0	1	0	0	0	1
Synodontidae	*Synodus foetens*	0	0	0	0	1	2	3	8	3	1	1	1	20
Gadidae	*Urophycis floridana*	0	0	0	0	0	0	0	0	0	0	0	6	6
Batrachiodidae	*Opsanus beta*	0	0	0	0	0	0	0	0	1	0	0	0	1
Ogcocephalidae	*Ogcocephalus radiatus*	0	0	0	1	0	0	0	0	0	0	0	0	1
Exocoetidae	*Hyporhamphus meeki*	0	0	0	0	1	7	2	0	0	0	0	0	10
Belonidae	*Strongylura marina*	0	0	0	0	0	1	3	1	0	0	0	0	5
Atherinidae	*Membras martinica*	0	10	0	0	1	10	49	21	13	15	3	0	122
	Menidia spp.	0	0	0	0	0	0	0	0	0	0	1	2	3
Syngnathidae	*Hippocampus erectus*	0	0	0	0	0	0	0	0	0	1	0	0	1
	Hippocampus zosterae	0	1	0	0	0	0	1	1	2	0	1	2	8
	Syngnathus floridae	2	7	1	9	2	34	33	53	48	26	52	38	305
	Syngnathus louisianae	0	0	0	1	0	3	4	2	1	4	3	0	18
	Syngnathus scovelli	0	3	6	4	0	11	32	4	9	10	13	13	105
Serranidae	*Mycteroperca microlepis*	0	0	0	0	0	0	0	0	0	1	0	0	1
	Centropristis striata	0	0	0	0	0	1	2	7	12	3	74	12	111
	Serraniculus pumilio	0	0	0	0	0	0	0	0	0	0	10	0	10
	Serranus subligarius	0	0	0	0	0	0	0	0	2	0	0	0	2
Apogonidae	*Astrapogon alutus*	0	0	0	0	0	0	0	0	0	1	0	0	1
Carangidae	*Caranx hippos*	0	0	0	0	0	0	0	0	0	2	0	0	2
	Chloroscombrus chrysurus	0	0	0	0	0	0	2	12	5	0	0	0	19
	Oligoplites saurus	0	0	0	0	0	7	2	2	4	2	0	0	17
	Selene vomer	0	0	0	0	0	0	0	0	0	2	0	0	2
Lutjanidae	*Lutjanus griseus*	0	0	0	0	0	0	0	1	0	1	0	0	2
	Lutjanus synagris	0	0	0	0	0	0	3	0	0	1	2	0	6
Gerreidae	*Eucinostomus gula*	0	0	0	0	0	0	0	0	6	6	4	1	17
	Eucinostomus harengulus	0	0	0	0	0	1	0	2	1	0	0	0	4
	Eucinostomus spp.	0	0	0	0	0	34	172	162	73	13	54	36	544
Haemulidae	*Haemulon plumieri*	0	0	0	0	0	0	1	6	11	4	3	7	32
	Orthopristis chrysoptera	1	0	6	26	738	30	38	0	8	4	0	1	852
Sparidae	*Diplodus holbrooki*	0	0	0	0	7	17	0	4	1	7	0	0	36
	Lagodon rhomboides	17	65	63	87	21	54	24	27	40	36	32	87	553
Sciaenidae	*Bairdiella chrysoura*	0	0	0	3	24	159	273	59	184	44	2	1	749
	Cynoscion arenarius	0	0	0	0	0	0	1	24	0	0	0	0	25
	Cynoscion nebulosus	0	0	0	0	0	4	70	37	10	6	1	0	128
	Leiostomus xanthurus	2	34	1	0	0	0	0	0	2	0	0	0	39
	Menticirrhus americanus	0	0	0	0	0	2	13	119	2	0	1	0	137

continued

Table 1 (continued)

Family	Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Sciaenidae (cont.)	*Menticirrhus saxatilis*	0	0	1	0	0	7	0	5	0	0	0	2	15
	Sciaenops ocellatus	0	0	0	0	0	0	0	0	0	0	9	0	9
Ephipipidae	*Chaetodipterus faber*	0	0	0	0	0	0	2	12	2	0	0	0	16
Mugilidae	*Mugil cephalus*	0	5	1	0	0	0	0	0	0	0	0	0	6
	Mugil curema	0	0	0	1	0	0	0	0	0	0	0	0	1
Sphyraenidae	*Sphyraena borealis*	0	0	0	0	4	0	0	0	0	0	0	0	4
Labridae	*Halichoeres bivittatus*	0	0	0	0	0	0	0	3	0	0	0	0	3
	Lachnolaimus maximus	0	0	0	0	0	0	0	0	2	1	0	0	3
Blenniidae	*Chasmodes saburrae*	0	0	0	0	0	0	9	0	5	0	2	0	16
	Parablennius marmoreus	0	0	0	0	0	0	0	1	0	0	1	0	2
	Hypsoblennius hentzi	0	0	0	0	0	0	0	0	1	0	0	2	3
	Hypleurochilus geminatus	0	0	0	0	0	0	2	0	0	0	0	0	2
Gobiidae	*Gobionellus boleosoma*	0	0	0	0	0	0	9	0	0	0	0	0	9
	Gobiosoma bosc	0	0	0	0	0	0	29	0	0	0	1	0	30
	Gobiosoma longipala	0	0	0	0	0	0	0	0	0	1	0	0	1
	Gobiosoma robustum	0	0	0	2	0	0	7	2	0	1	0	1	13
	Microgobius gulosus	0	0	0	0	0	0	3	2	0	0	2	0	7
	Microgobius thalassinus	0	0	0	0	0	0	0	77	0	0	0	0	77
Scombridae	*Scomberomorus maculatus*	0	0	0	0	0	0	0	0	1	0	0	0	1
Triglidae	*Prionotus scitulus*	0	2	0	0	0	2	5	4	2	1	0	1	17
	Prionotus tribulus	0	0	0	0	0	0	0	2	0	0	1	0	3
Bothidae	*Paralichthys albigutta*	0	0	2	2	0	0	2	0	2	0	0	0	8
	Etropus crossotus	0	3	1	0	0	0	2	1	1	0	0	1	9
	Etropus microstomus	0	0	1	0	0	0	0	0	0	0	0	0	1
Cynoglossidae	*Symphurus plagiusa*	0	0	1	0	0	1	1	9	0	0	0	1	13
Soleidae	*Achirus lineatus*	0	0	0	0	0	0	1	7	0	0	0	0	8
	Trinectes maculatus	0	0	0	0	0	0	0	0	1	0	0	0	1
Balistidae	*Aluterus schoepfi*	0	0	0	0	0	1	1	2	0	1	0	0	5
	Monacanthus ciliatus	0	0	0	0	0	0	0	2	10	8	2	19	41
	Monacanthus hispidus	0	0	0	0	2	10	1	36	3	9	7	25	93
Ostraciidae	*Lactophrys quadricornis*	0	0	2	0	0	2	0	6	6	3	3	1	23
Tetraodontidae	*Sphoeroides nephelus*	0	0	2	16	4	2	2	2	1	4	2	2	37
Diodontidae	*Chilomycterus schoepfi*	0	1	2	0	4	2	0	11	5	10	5	9	49
Column total		22	131	95	156	810	989	2382	4839	1429	3921	349	272	15,395
Number of hauls		6	10	9	4	5	15	10	11	11	11	10	16	118

est average similarity level at 48.90, and nine species—*S. floridae*, *M. hispidus*, black seabass (*Centropristis striata*), *L. rhomboides*, *Eucinostomus* spp., fringed filefish (*Monacanthus ciliatus*), *S. scovelli*, striped burrfish (*Chilomycterus schoepfi*), and *S. nephelus*—accounted for more than 91% of the cumulative similarity. *Lagodon rhomboides* and *S. floridae* were characteristic of all three assemblages, and *Eucinostomus* spp., *S. scovelli*, and *M. hispidus* were important contributors to the summer and fall assemblages. Other abundant species from seagrass assemblages included southern kingfish (*Menticirrhus americanus*), rough silverside (*Membras martinica*), and gobiids, particularly green goby (*Microgobius thalassinus*) and naked goby (*Gobiosoma bosc*).

A significant drop in salinity during March 1998 corresponded to an alteration in the fish community collected in seagrass habitats. The species present in the seagrass habitats during March 1998 were more consistent with species collected in tidal creeks and included *A. mitchilli*, *Brevoortia* spp., and spot (*Leiostomus xanthurus*), none of which were collected in March of 1997 or 1999 in seagrass habitats. Samples collected during March 1997 and 1999 contained individuals more characteristic of seagrass habitats, such as *C. schoepfi*, *L. rhomboides*, *O. chrysoptera*, and *S. nephelus* in 1997 and scrawled cowfish (*Acanthostracion quadricornis*), *O. chrysoptera*, *L. rhomboides*, *S. floridae*, and *S. scovelli* in 1999.

Table 2

Taxonomic list of individuals collected in tidal-creeks for each species by month and total number collected, all years combined.

Family	Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Dasyatidae	*Dasyatis sabina*	0	0	6	1	1	0	0	0	1	1	3	0	13
Myliobatidae	*Rhinoptera bonasus*	0	0	0	0	3	0	0	0	0	0	0	0	3
Lepisosteidae	*Lepisosteus osseus*	0	0	0	0	0	2	2	1	0	0	0	0	5
	Lepisosteus platyrhincus	0	0	1	1	0	1	1	0	2	2	0	0	8
Ophichthidae	*Myrophis punctatus*	0	0	0	0	1	0	0	0	0	0	0	0	1
Clupeidae	*Harengula jaguana*	0	0	0	0	2	1	2	9	10	2	0	0	26
	Brevoortia spp.	15	139	93	400	394	7	5	0	0	0	0	1	1054
	Sardinella aurita	0	0	0	0	0	0	22	0	0	0	0	0	22
Engraulidae	*Anchoa hepsetus*	3	0	0	1	175	482	71	33	7	0	3	0	775
	Anchoa mitchilli	86	497	825	108	612	3298	10,329	6970	5776	7436	1637	2107	39,681
Cyprinidae	*Notemigonus crysoleucas*	0	2	1	0	0	0	0	0	0	0	0	0	3
	Notropis spp.	0	0	0	0	4	9	0	0	0	0	0	0	13
Ariidae	*Arius felis*	0	0	0	0	0	0	0	2	3	0	0	0	5
Esocidae	*Esox niger*	0	0	0	1	1	0	0	0	0	0	0	0	2
Synodontidae	*Synodus foetens*	0	0	0	3	7	0	0	0	1	0	3	1	15
Belonidae	*Strongylura marina*	0	0	0	2	4	1	8	1	1	1	0	0	18
	Strongylura notata	2	0	0	0	0	0	3	2	8	0	1	0	16
	Strongylura timucu	0	0	0	0	11	1	8	3	11	0	0	0	34
Cyprinodontidae	*Adinia xenica*	7	7	0	4	1	0	12	23	0	153	14	25	246
	Cyprinodon variegatus	4	0	0	1	0	0	0	0	0	0	2	3	10
	Lucania goodei	0	0	11	0	0	0	0	0	0	0	0	0	11
	Lucania parva	0	2	2	0	0	1	2	15	4	0	0	6	32
Fundulidae	*Fundulus confluentus*	2	0	0	0	0	0	0	0	0	1	0	3	6
	Fundulus grandis	33	39	6	28	9	30	21	127	9	39	170	218	729
	Fundulus majalis	29	12	24	7	0	18	0	42	3	10	13	65	223
	Fundulus seminolis	7	2	0	1	0	14	0	14	5	6	0	1	50
Poeciliidae	*Gambusia holbrooki*	6	0	59	2	4	1	0	1	12	4	1	7	97
	Heterandria formosa	0	1	0	0	0	0	0	0	0	1	0	0	2
	Poecilia latipinna	1	0	0	0	2	2	0	17	0	4	4	12	42
Atherinidae	*Membras martinica*	0	0	4	0	9	566	2286	28	114	7	1	0	3015
	Menidia spp.	383	429	201	265	145	695	982	571	814	602	749	358	6194
Syngnathidae	*Syngnathus floridae*	0	1	0	0	0	0	0	0	1	0	0	0	2
	Syngnathus louisianae	0	0	0	0	0	0	0	0	1	0	1	0	2
	Syngnathus scovelli	2	1	2	0	1	0	1	7	5	1	2	11	33
Serranidae	*Diplectrum bivittatum*	0	0	0	0	0	0	0	0	0	0	1	0	1
Centrarchidae	*Enneacanthus gloriosus*	0	0	2	0	0	0	0	0	0	0	0	0	2
	Elassoma zonatum	0	0	0	0	4	0	0	0	0	0	0	0	4
	Lepomis gulosus	0	1	1	0	0	0	0	0	0	0	0	0	2
	Lepomis macrochirus	0	0	0	0	0	0	0	0	1	0	0	0	1
	Lepomis marginatus	0	0	0	1	0	0	0	0	0	0	0	0	1
	Lepomis microlophus	0	0	0	0	1	0	0	0	0	0	0	0	1
	Lepomis punctatus	1	0	0	1	1	1	2	2	3	2	0	0	13
	Micropterus salmoides	0	0	3	1	14	4	0	5	8	2	0	0	37
Carangidae	*Chloroscombrus chrysurus*	0	0	0	0	0	0	1	3	15	2	0	0	21
	Oligoplites saurus	0	0	0	0	0	8	53	25	47	17	6	0	156
	Trachinotus falcatus	0	0	0	0	0	0	0	0	0	3	0	0	3

continued

Table 2 (continued)

Family	Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Lutjanidae	*Lutjanus griseus*	0	0	0	0	0	2	2	9	8	6	2	1	30
Gerreidae	*Eucinostomus gula*	1	0	0	0	0	0	0	4	7	25	49	3	89
	Eucinostomus harengulus	0	25	5	2	6	3	41	150	88	100	65	45	530
	Eucinostomus spp.	17	38	6	1	1	87	1035	1082	503	862	691	358	4681
Haemulidae	*Orthopristis chrysoptera*	0	0	0	0	0	0	0	2	0	0	0	0	2
Sparidae	*Archosargus probatocephalus*	7	1	1	0	1	1	0	1	0	0	1	0	13
	Lagodon rhomboides	87	231	146	142	67	114	111	85	38	29	53	10	1113
Sciaenidae	*Bairdiella chrysoura*	0	0	7	7	200	154	58	246	117	4	3	0	796
	Cynoscion arenarius	0	0	0	5	236	102	90	91	46	76	5	0	651
	Cynoscion nebulosus	3	1	1	0	5	11	21	53	62	23	36	2	218
	Leiostomus xanthurus	9526	2044	834	771	274	42	125	24	6	5	2	31	13,684
	Menticirrhus americanus	0	0	0	0	3	12	50	36	12	10	5	0	128
	Micropogonias undulatus	4	4	0	5	2	0	0	0	1	0	6	2	24
	Pogonias cromis	0	0	0	0	2	2	0	3	0	1	0	1	9
	Sciaenops ocellatus	26	28	20	15	3	7	4	1	1	48	105	65	323
Ephipipidae	*Chaetodipterus faber*	0	0	0	0	0	1	3	1	3	0	0	0	8
Mugilidae	*Mugil cephalus*	175	159	59	25	2	39	22	7	18	1	6	6	519
	Mugil curema	1	0	0	0	0	25	2	0	0	0	0	1	29
	Mugil gyrans	0	0	0	0	0	0	0	0	2	0	0	4	6
Gobiidae	*Bathygobius soporator*	0	0	0	4	0	0	2	1	18	5	6	3	39
	Gobionellus boleosoma	0	0	3	6	9	0	1	6	15	0	4	0	44
	Gobiosoma bosc	8	3	14	7	1	40	21	17	52	20	18	67	268
	Gobiosoma robustum	0	6	3	1	0	8	7	10	6	0	4	15	60
	Microgobius gulosus	5	23	7	5	4	7	0	25	5	8	3	14	106
	Microgobius thalassinus	0	0	0	0	0	0	1	1	1	0	1	0	4
Triglidae	*Prionotus scitulus*	0	0	0	0	0	1	0	0	0	0	0	0	1
	Prionotus tribulus	0	0	0	1	0	0	0	0	1	11	4	0	17
Bothidae	*Paralichthys albigutta*	5	1	0	0	0	2	0	0	1	0	0	0	9
	Paralichthys lethostigma	0	0	1	0	0	1	0	0	0	0	0	0	2
	Etropus crossotus	0	0	0	0	0	1	0	0	0	0	0	0	1
Cynoglossidae	*Symphurus plagiusa*	6	0	0	0	0	2	2	1	13	5	1	5	35
Soleidae	*Achirus lineatus*	0	0	0	0	0	2	4	9	10	8	2	0	35
	Trinectes maculatus	1	8	10	0	5	13	1	13	2	4	2	1	60
Tetraodontidae	*Sphoeroides nephelus*	0	0	0	1	6	0	0	0	0	4	0	1	12
Column total		10,453	3705	2358	1826	2233	5821	15,414	9779	7898	9551	3685	3453	76,176
Number of hauls		24	24	24	24	24	24	24	24	24	24	24	24	288

Recruitment of YOY fishes had an influence on defining fish assemblages in seagrass habitats. The winter–spring assemblage was dominated by YOY *L. rhomboides* and *O. chrysoptera* (Table 3), which had significantly shorter standard lengths than did the other assemblages (Table 4). The summer assemblage showed an increase in the number of species and an increase in their abundance, but there were no significant differences in length for YOY for any species between assemblages.

Tidal-creek habitats

Three fish assemblages (winter–spring, summer, and fall) were identified from samples taken in tidal-creek habitats and reflected similar seasonal patterns compared with fish assemblages identified from seagrass habitats (Fig. 4). The winter–spring assemblage had an average similarity level of 51.76 and consisted of *L. xanthurus*, *Menidia* spp., *A. mitchilli*, *L. rhomboides*, *M. cephalus*, and red drum (*Sciaenops ocellatus*). These six

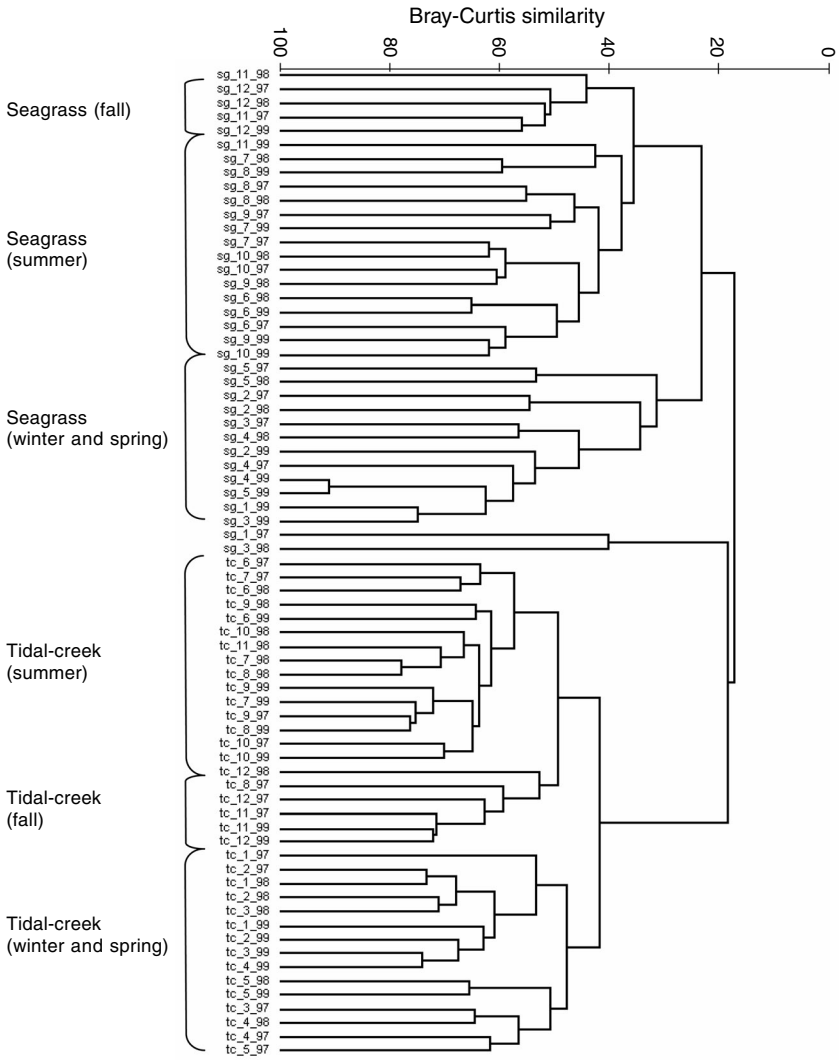

Figure 4

Results of cluster analysis for fish assemblages found in the Suwannee River estuary. SG=seagrass habitats, TC=tidal-creek habitats, 1=January, 2=February, etc., and the year is denoted by the last two digits of the year. For example, SG_1_97 corresponds to samples collected during January of 1997 in seagrass habitats. Note: Clusters are free to rotate at the point at which the lines branch.

species accounted for more than 68% of the cumulative similarity within the winter–spring assemblage. The summer assemblage had an average similarity level of 62.29 and was characterized by ten species that accounted for 70.65% of the cumulative similarity: *A. mitchilli*, *Menidia* spp., *Eucinostomus* spp., sand seatrout (*Cynoscion arenarius*), *B. chrysoura*, *C. nebulosus, L. rhomboides*, *E. harengulus, M. martinica*, and leatherjacket (*Oligoplites saurus*). The fall assemblage had an average similarity level of 60.36 and was characterized by *Eucinostomus* spp., *Menidia* spp., gulf killifish (*Fundulus grandis*), *A. mitchilli*, *E. harengulus*, diamond killifish (*Adinia xenica*), clown goby (*Microgobius gulosus*), and *M. cephalus*, which accounted for more than 67% of the cumulative similarity. Species tolerant of low salinity, such as *A. xenica*, marsh killifish (*Fundulus confluentus*), mosquitofish (*Gambusia holbrooki*), and least killifish (*Heterandria formosa*) were commonly collected in tidal creeks. There were 35 species collected, including groups such as cyprinids, cyprinodontids, poeciliids, lepisosteids, and centrarchids, which were restricted entirely to tidal creeks (Table 2).

Seasonal recruitment of juvenile fishes to tidal-creek habitats was evident and remained consistent throughout the study resulting in three clearly defined assemblages. Young-of-the-year *L. xanthurus* recruited to

Table 3

Results of SIMPER procedure showing the average percent dissimilarity (δ%) for important species between seagrass assemblages. δi is the average contribution of the ith species to the disssimilarity between groups; δi/SD(δi) is the ratio between the average contribution of the i^{th} species and the standard deviation of δi; Cum δi% is the cumulative contribution to the total dissimilarity. Species are listed in decreasing contribution to average dissimilarity.

Species	Average abundance		δi	δi/SD(δi)	δi%	Cumulative δi%
	winter–spring	summer				
Eucinostomus spp.	0.24	9.9	4.8	1.38	6.31	6.31
Lagodon rhomboides	10.75	1.83	4.5	1.69	5.91	12.22
Bairdiella chrysoura	1.01	12.76	4.38	1.25	5.75	17.97
Orthopristis chrysoptera	26.58	0.94	3.66	1.17	4.81	22.78
Monacanthus hispidus	0.09	1.89	3.25	1.22	4.27	27.05
Syngnathus floridae	1.2	3.88	3.24	1.1	4.25	31.3
Centropristis striata	0.01	1.82	2.68	0.99	3.52	34.82
Anchoa hepsetus	0.03	11.95	2.67	0.8	3.51	38.33
Syngnathus scovelli	0.8	1.13	2.48	1.36	3.25	41.58
Sphoeroides nephelus	1.24	0.19	2.27	1.2	2.99	44.57
Anchoa mitchilli	0.33	4.46	2.27	0.95	2.98	47.55
Chilomycterus schoepfi	0.18	0.46	2.12	1.07	2.78	50.33
	winter–spring	fall				
Anchoa mitchilli	0.33	478.1	10.87	2.32	13.31	13.31
Lagodon rhomboides	10.75	4.57	6.43	1.36	7.87	21.18
Orthopristis chrysoptera	26.58	1.33	4.73	1.05	5.79	26.97
Bairdiella chrysoura	1.01	8.26	3.39	1.58	4.15	31.12
Leiostomus xanthurus	0.67	0.14	3.26	0.61	3.99	35.11
Syngnathus scovelli	0.8	0.71	2.83	1.19	3.46	38.57
Syngnathus floridae	1.2	3.26	2.81	1.27	3.44	42.01
Eucinostomus spp.	0.24	5.38	2.68	1.24	3.28	45.29
Harengula jaguana	0	9.74	2.57	1.24	3.15	48.44
Sphoeroides nephelus	1.24	0.12	2.55	0.91	3.12	51.56
	summer	fall				
Anchoa mitchilli	4.46	478.1	6.13	1.98	9.30	9.30
Eucinostomus spp.	9.9	5.38	3.11	1.34	4.72	14.02
Bairdiella chrysoura	12.76	8.26	2.70	1.21	4.10	18.12
Anchoa hepsetus	11.95	0.48	2.36	0.98	3.59	21.71
Syngnathus floridae	3.88	3.26	2.35	1.05	3.56	25.27
Monacanthus hispidus	1.89	0.38	2.34	1.14	3.55	28.82
Harengula jaguana	2.79	9.74	2.15	1.25	3.27	32.09
Centropristis striata	1.82	0.64	2.06	1.01	3.13	35.22
Syngnathus scovelli	1.13	0.71	1.82	1.35	2.77	37.99
Lagodon rhomboides	1.83	4.57	1.75	1.08	2.65	40.64
Chilomycterus schoepfi	0.46	0.52	1.72	1.13	2.61	43.25
Cynoscion nebulosus	1.54	1.95	1.66	1.31	2.53	45.78
Monacanthus ciliatus	0.45	0.45	1.62	0.83	2.47	48.25
Orthopristis chrysoptera	0.94	1.33	1.62	1.04	2.46	50.71

Table 4

Results of ANOVA comparing standard length of each species between habitats and seasonal assemblages identified through PRIMER. * <0.05, **<0.01, ***<0.001.

Species	Factor	df	*F*	*P*	Tukey HSD
Bairdiella chrysoura	habitat	1	0.02	0.8750	
	season	2	0.38	0.6819	
Cynoscion nebulosus	habitat	1	2.74	0.1008	
	season	2	8.03	***	winter > summer
Lagodon rhomboides	habitat	1	6.61	*	tidal-creek > seagrass
	season	2	80.12	***	summer > fall > winter
Leiostomus xanthurus	habitat	1	6.84	*	
	season	2	29.87	***	summer > fall, winter
Mugil cephalus	habitat	1	1.23	0.2713	
	season	2	2.54	0.0862	
Orthopristis chrysoptera	habitat	1	2.96	0.0996	
	season	2	4.6	*	summer > winter
Sciaenops ocellatus	habitat	1	1.98	0.1633	
	season	2	6.28	**	summer, winter > fall

tidal creeks and dominated samples collected during January and February (Tables 2 and 5). Recruitment of YOY *L. rhomboides* and *C. arenarius* also contributed to the winter-spring species assemblage (Tables 4 and 5). The summer assemblage was influenced by recruitment of YOY *F. grandis* and *C. nebulosus*, which had significantly shorter standard lengths than they had in the winter-spring assemblage. The recruitment of *S. ocellatus* helped to characterize the fall assemblage. Emigration of larger individuals could also account for a decrease in mean length; however length-frequency plots showed that larger individuals remained vulnerable to the gear and that the reduction in mean length was due to recruitment of YOY fishes.

Discussion

Fishes collected in seagrass habitats in this study were similar to those found in other studies of seagrass habitats; resident species were present year-round and there were seasonal pulses of juveniles that used the seagrass habitats as a nursery (Reid, 1954; Livingston, 1982; Weinstein and Brooks, 1983). The assemblages we identified were the result of the staggered influx of YOY fishes of different species to seagrass habitats throughout the year. For example, YOY *L. rhomboides* and *O. chrysoptera* recruited during winter and spring, whereas other abundant species such as YOY *B. chrysoura* and *Eucinostomus* spp. entered the nursery during summer and fall. We found an increase in species abundance and species richness during summer and fall similar to that found by Reid (1954), who conducted his study near Cedar Key. The same pattern was evident in other estuarine systems (Cowan and Birdsong, 1985; Rooker et al., 1998), demonstrating that recruitment of many juvenile fish species to seagrass habitats during summer and fall allows the juveniles to use the protection provided by the growing seagrasses (Stoner, 1983) and to use the food resources found within them (Carr and Adams, 1973).

Early-life-history stages of species with commercial or recreational importance were found in each habitat, but seagrass habitats contained a greater variety of juveniles from offshore reef species than did tidal creeks. Along the southeastern United States, juveniles of many economically important species use a variety of habitats in estuaries as nurseries, including mangroves, oyster reefs, marshes, tidal creeks, and seagrass habitats (Coleman et al., 1999, Coleman, et al., 2000). In our study, YOY reef fish taxa, such as serranids, lutjanids, and haemulids, were more abundant in seagrass habitats than they were in tidal-creek habitats, except for gray snapper (*Lutjanus griseus*). Juveniles of several reef species (*C. striata*, *Mycteroperca microlepis*, *Serraniculus pumilio*, *Serranus subligaris,* and *Lachnolaimus maximus*) were found only in seagrass habitats. However, a complicating factor in our study was the elimination of oyster habitats from our sampling design. Oyster reefs are known to harbor juvenile *C. striata* and *M. microlepis* (Coleman et al., 2000) and they may have been under-estimated in our study because we did not sample these habitats. Other economically important species, such as *C. nebulosus*, also recruited to the seagrass habitats and are known to reside in them much of their life (Reid, 1954; McMichael and Peters, 1989; Mason and Zengel, 1996). These economically important species use seagrass habitats in the Suwannee River estuary as a nursery and eventually enter local fisheries. Consequently, the maintenance of healthy

Table 5

Results of SIMPER procedure showing the average percent dissimilarity ($\delta\%$) for important species between tidal-creek assemblages. δi is the average contribution of the i^{th} species to the disssimilarity between groups; $\delta i/\mathrm{SD}(\delta i)$ is the ratio between the average contribution of the i^{th} species and the standard deviation of δi; Cum $\delta i\%$ is the cumulative contribution to the total dissimilarity. Species are listed in decreasing contribution to average dissimilarity.

Species	Average abundance		δi	$\delta i/\mathrm{SD}(\delta i)$	$\delta i\%$	Cumulative $\delta i\%$
	winter–spring	summer				
Leiostomus xanthurus	177.1	8.43	4.17	2.07	7.03	7.03
Anchoa mitchilli	4.93	243.61	3.83	2.4	6.46	13.49
Brevoortia spp.	10.87	0.74	2.65	1.42	4.46	17.95
Eucinostomus spp.	0.24	22.28	2.62	1.74	4.42	22.37
Cynoscion arenarius	1.62	3.02	1.94	1.77	3.26	25.63
Mugil cephalus	4.52	0.88	1.91	1.57	3.21	28.84
Membras martinica	0.04	21.61	1.9	1.10	3.19	32.03
Lagodon rhomboides	6.46	2.92	1.83	1.46	3.08	35.11
	winter–Spring	fall				
Leiostomus xanthurus	177.1	0.96	4.33	2.32	7.85	7.85
Eucinostomus spp.	0.24	24.63	4.03	2.63	7.30	15.15
Brevoortia spp.	10.87	0.03	2.58	1.41	4.68	19.83
Eucinsotomus herengulus	0.07	2.86	2.51	2.73	4.56	24.39
Fundulus grandis	1.26	12.02	2.19	1.72	3.97	28.36
Fundulus majalis	0.77	3.47	1.66	1.40	3.02	31.38
Adinia xenica	0.23	1.82	1.62	1.55	2.94	34.32
Cynoscion nebulosus	0.07	1.16	1.60	1.68	2.90	37.22
	summer	fall				
Fundulus grandis	1.16	12.02	2.59	2.34	4.84	4.84
Anchoa mitchilli	243.61	14.92	2.52	1.69	4.70	9.54
Sciaenops ocellatus	0.53	5.36	2.09	1.39	3.91	13.45
Eucinostomus spp.	22.28	24.63	1.89	1.27	3.53	16.98
Fundulus majalis	0.26	3.47	1.88	1.45	3.51	20.49
Bairdiella chrysoura	4.06	1.53	1.81	1.71	3.38	23.87
Adinia xenica	0.97	1.82	1.76	1.9	3.28	27.15
Cynoscion arenarius	3.02	0.87	1.7	1.78	3.18	30.33

seagrasses in this area is important to the preservation of these resources.

Tidal-creek habitats in the Suwannee River estuary provided resources for many species that had restricted distributions related to salinity tolerances and included taxa that were also found in the nearby seagrass habitats. We found recreationally important freshwater taxa, such as *Micropterus salmoides* and *Lepomis punctatus*, in tidal-creek habitats. Other groups restricted to tidal-creeks were those tolerant of low salinity and included the fundulids, poeciliids, and cyprinodontids. In addition, some economically valuable species were more abundant in tidal-creeks than in seagrass habitats, including *M. cephalus*, *C. arenarius*, *S. ocellatus*, and *L. griseus*. Tidal creeks also supported a greater density of fishes than did seagrass habitats—a density that could have resulted from habitat preferences, differential mortality between habitat types, or gear avoidance. Because the seine was set along the shoreline in tidal creeks, fishes were trapped between the seine and the shoreline, perhaps making them more vulnerable to the gear, whereas in seagrass habitats, the seine was pulled along the bottom with the end open prior to retrieval and fishes could have used the opening to escape.

The results of our study showed that there was a more consistent assemblage of fishes in tidal creeks, whereas

fish assemblages found in seagrass habitats had greater variability in the species present and in the abundance of those species. The more consistent assemblage of fishes found in tidal creeks could be explained by the persistence of vegetation throughout the year in tidal creeks, which may have contributed to reduced predation and may have provided direct or indirect sources of food. Vegetation coverage in seagrass habitats was seasonal and Strawn (1961) found that above-ground seagrass biomass declined during winter and increased during summer and fall. The increased complexity resulting from blade density and seagrass species heterogeneity offered by the growing seagrasses is known to affect fish abundance and composition (Stoner, 1983). The fish community structure in our study reflected this seasonal change; fewer fish species were present during winter and spring than in summer and fall. As seagrass biomass increased, fish species composition and total numbers also increased, resulting in greater variability within seagrass fish assemblages.

We found that the combination of water temperature, salinity, and water depth, more than any other combination of abiotic variables, helped to explain the fish community structure found in the Suwannee River estuary. Although water temperatures between the two habitats were similar, tidal creeks typically had soft mud sediments instead of sand and mud, marsh-grass species instead of submerged aquatic vegetation, deeper average depths, and lower salinity values. Water temperature has been shown to correlate with timing of recruitment for YOY fishes, which is ultimately related to adult spawning patterns (Subrahmanyam and Coultas, 1980; Nelson, 1998; Paperno, 2002). Because water temperatures were similar in each habitat, differences in fish-community structures were more likely related to salinity tolerances, factors that correlate with salinity and water depth. Water depth in the Suwannee River estuary varies seasonally; lowest water levels occur during winter (Strawn, 1961). The result is a confounding effect of water temperature and water depth that probably act in concert to limit distribution of fishes. A strong indicator that salinity may be the major abiotic factor that determines fish distributions, and ultimately species assemblages, was the low-salinity event during March 1998 that changed the seagrass fish assemblage to one more closely resembling a tidal-creek assemblage. If vegetation type were the primary factor controlling species assemblages in these habitats, tidal-creek species would remain in tidal-creeks and not invade seagrass habitats when salinity values changed to more favorable conditions. Therefore, varying salinities allowed different groups of fishes to use habitats according to their salinity tolerance (Wagner, 1999).

Nordlie (2003) examined 20 studies of estuarine salt marsh fish communities in eastern North America and characterized communities based on the life history patterns exhibited by the species. General life history categories were originally established by McHugh (1967) and included permanent residents, marine nursery, marine transients, diadromous, and freshwater transients. The 45 species that had overlapping distributions among habitats in our study were consistent with the classifications for marine nursery or marine transient species. Marine transient species do not require estuarine habitats for development, but venture into estuaries during periods of low rainfall, whereas marine nursery species require estuarine conditions for development. The two exceptions in our study (*Gobionellus bolesoma* and *M. gulosus*) were considered primary residents of saltmarsh communities, but were frequently found in estuaries.

We collected 80 fish species in tidal creeks in the Suwannee River estuary—more species than have been found in most other studies of tidal creeks—and this number could be related to the long-term duration of sampling. For example, Peterson and Turner (1994) observed 29 fish species inhabiting Louisiana marshes in a one-year study, whereas we found 51 additional species in our tidal-creek habitats. Similarly, Hettler (1989) found 35 species in a one-year study of saltmarsh fishes in North Carolina, and Weinstein (1979) recorded 61 species from his one-year study of the Cape Fear River, North Carolina. Furthermore, Cain and Dean (1976) found 51 species in a one-year examination of fishes in an intertidal creek in South Carolina. The first year of our study resulted in the collection of 61 species from tidal-creek habitats. It is likely that three years of sampling in our study increased our chances of collecting rare species, which resulted in the higher level of species richness.

Another reason for the high species diversity and abundance of fishes that we found in tidal creeks could be attributed to our sampling along the tidal-creek edge, which is known for its structural complexity (Montague and Wiegert, 1990) and importance as a foraging and refuge area (Baltz et al., 1993; Kneib and Wagner, 1994; Peterson and Turner, 1994). For example, Baltz et al. (1993) collected fishes in Louisiana marsh edges to look at the importance of the marsh-edge microhabitat and found that the 15 most abundant fishes were concentrated near the marsh edge and consisted mostly of early-life-history stages. They hypothesized that the fishes aggregated near the marsh edge to take advantage of the protection provided by the vegetation and the available food resources. Our sampling targeted the tidal-creek edge, and the gear we used selected for juveniles and small-adult species, which could explain the higher diversity than that seen in other studies. Another possibility is that our randomly chosen sampling sites covered a greater variety of microhabitats along tidal-creek shorelines than did the sampling of Weinstein (1979), Hettler (1989), and Peterson and Turner (1994), which could also explain the higher species richness. Despite differences in sampling methods, the collection of 80 fish species in tidal creeks appears to be unusual.

The withdrawal of fresh water from the Suwannee River would likely change the salinity regime in the Suwannee River estuary, which may in turn reduce species diversity in the region by reducing habitat availability to groups tolerant of low salinity. Furthermore, the high abundance of juvenile fishes that use low-salinity

tidal creeks as a nursery would be altered and the responses could vary on a species-specific basis (Tsou and Matheson, 2002). A decline in the amount of freshwater inflow into the tidal-creeks could lead to an overall shift towards a more saline environment and result in the expansion of seagrass habitats. However, Strawn (1961) showed that the distribution of seagrasses at Cedar Key was affected by water depth, water clarity, and the interaction of temperature and tides during winter months, making the prospect of seagrass expansion unlikely. Although a decrease in the amount of fresh water may result in an increase in water clarity through a reduction in dissolved nutrient input and reduced primary productivity, as has been seen in Apalachicola Bay, Florida (Livingston, 2003), the extreme low tides, cold temperatures, wave action, and sediment geochemistry in the Suwannee River estuary may negate the effects of increased light penetration (Koch, 2001). Therefore, a decrease in fresh water may result in an increase in high-salinity bare substrate that has been shown to be less suitable as a fish nursery than either seagrass or tidal-creek habitats (Sogard and Able, 1991; Rozas and Minello, 1998).

Tidal-creek and seagrass habitats in the Suwannee River estuary contained diverse fish communities that reflected seasonal changes associated with recruitment of YOY fishes. Many of these species are the targets of commercial and recreational activities, which support local economies. Although much of the land surrounding the Suwannee River estuary has been preserved, measures must be taken to ensure that the supply of fresh water from the Suwannee River is also preserved to maintain the integrity of the aquatic environment and the associated estuarine fish community.

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