Environmental Biology of Fishes **58:** 183–194, 2000.

Association of large juvenile red drum, *Sciaenops ocellatus*, with an estuarine creek on the Atlantic coast of Florida

Douglas H. Adams & Derek M. Tremain
Florida Marine Research Institute, Florida Fish & Wildlife Conservation Commission, 1220 Prospect Avenue, Suite 285, Melbourne, FL 32901, U.S.A. (e-mail: doug.adams@fwc.state.fl.us)

Received 7 May 1999 Accepted 3 November 1999

Key words: Sciaenidae, seasonal abundance, habitat utilization, gill nets, age, tag, recapture

Synopsis

Seasonal abundance, size distribution, year-class presence, residence duration, and migrational patterns of red drum, *Sciaenops ocellatus*, in an estuarine marsh creek in the northern Indian River Lagoon, Florida, were investigated during a study in which gill net samples were collected monthly from August 1991 to March 1996. A total of 282 large juvenile red drum were collected, of which 161 were tagged and released and 68 were sacrificed for age determination. Although red drum were collected in the creek throughout the year, abundance levels were negatively correlated with water temperatures and reached maximum levels during the winter months. Significant correlations between fish abundance and salinity or dissolved oxygen levels were not detected. The majority (90%) of the fish collected were large juveniles (260–450 mm standard length) that were estimated to be from 10 to 26 months old. The oldest red drum we examined from the creek was estimated to be 37 months old. Tag-recapture data indicated that some fish repeatedly used or were associated with the creek for periods of up to 18 months after release. Estuarine creeks in this region provide exploitable habitat for large juvenile red drum (< age 3), which compose the majority of the species' fishery landings in Florida waters.

Introduction

The red drum, *Sciaenops ocellatus*, inhabits nearshore and estuarine waters of the U.S. Atlantic coast from Massachusetts to Florida and of the Gulf of Mexico from Florida to northern Mexico (Lux & Mahoney 1969, Mercer[1]). Many aspects of the life history and habitat requirements of the red drum have been investigated throughout its range. Much of this work has focused principally on larvae and small juveniles (Mansueti 1960, Bass & Avault 1975, Holt et al. 1983, Peters & McMichael 1987, Lyczkowski-Shultz & Steen 1991, Fuiman & Ottey 1993, Rooker & Holt 1997) or on adults (Beckman et al. 1989, Murphy & Taylor 1990, Wilson & Nieland 1994, Ross et al. 1995), but not on large juveniles.

In Florida waters, there has been no directed commercial fishery for red drum since harvest regulations were instituted in 1988; however, the species does support an important inshore recreational fishery. In 1995, recreational landings were estimated at 393 079 fish (Murphy[2]). Because of current harvest restrictions (374 mm to 580 mm standard length slot limit), the majority of fish landed in Florida are large juveniles between one and three years old (Murphy[3]). Many mature red drum move to nearshore and offshore

[1] Mercer, L.P. 1984. A biological and fisheries profile of red drum, *Sciaenops ocellatus*. North Carolina Division of Marine Fisheries, Special Scientific Report 41, Morehead City. 89 pp.

[2] Murphy, M.D. 1998. A stock assessment of red drum, *Sciaenops ocellatus*, in Florida: status of the stocks through 1997. Florida Marine Reseach Institute report to the Florida Marine Fisheries Commission, Tallahassee. 14 pp.

[3] Murphy, M.D. 1994. A stock assessment of red drum, *Sciaenops ocellatus*, in Florida. Florida Marine Reseach

areas of the Atlantic or Gulf of Mexico (Yokel 1966, Music & Pafford[4], Vaughan & Helser[5]). In the Indian River Lagoon, however, large groups of mature red drum inhabit estuarine waters on a year-round basis (FMRI unpublished data) and spawn within the estuary (Carr & Smith[6], Murphy & Taylor 1990, Johnson & Funicelli 1991).

Large juvenile red drum (defined here as approximately 200 to 600 mm standard length) depend upon estuarine habitats for food resources and refuge from predation (Vaughan & Helser[5]). Studies of red drum of these sizes show that they are widely distributed among estuarine and coastal habitat types, including seagrass beds, oyster bars, sand bottom, and mudflats (Murphy[3]), river mouths and bays (Daniel 1988); passes and continental shelf waters (Mercer[1]), and surf zone areas (Gunter 1958, Daniel 1988). In Tampa Bay, on Florida's west coast, red drum 135 to 300 mm are found not only in the bay proper, but also in rivers, canals, tidal creeks, boat basins, and passes leading to the Gulf of Mexico (Peters & McMichael 1987). Although many of these studies list habitat types where large juvenile red drum are found, they provide little quantitative information on abundance, seasonality, and residence duration within a specific habitat type.

Low-salinity marsh creeks and backwater areas are common habitat types in many estuarine systems and are important nursery areas for juvenile red drum smaller than approximately 150 mm in estuaries along both the Atlantic coast (Dahlberg 1972, Weinstein 1979, Daniel 1988) and the Gulf of Mexico coast (Peters & McMichael 1987). Red drum larger than 150 mm have not been commonly collected in these areas and may migrate to deeper estuarine waters (Pearson 1929, Simmons & Breuer 1962, Peters & McMichael 1987). Daniel (1988) speculated that the movement of larger fish out of creeks prevents competition with or predation on the following year class.

Institute report to the Florida Marine Fisheries Commission, Tallahassee. 18 pp.

[4] Music, J.F. & J.M. Pafford. 1984. Population dynamics and life history aspects of major marine sportfishes in Georgia coastal waters. Georgia. Dept. Nat. Resour. Coastal Resour. Div. Cont. Ser. 38, Atlanta. 382 pp.

[5] Vaughan, D.S. & T.E.Helser. 1990. Status of the red drum stock of the Atlantic coast: stock assessment report for 1989. NOAA Tech. Memo. NMFS-SEFS-263. 117 pp.

[6] Carr, W.E.S. & J.R. Smith. 1977. A study of the spawning movements and a tentative spawning site of the red drum, *Sciaenops ocellatus.* Final Report to Florida Sea Grant College Program, University of Florida, Gainesville. 34 pp.

However, in Florida waters, red drum up to 300 mm are collected from low salinity rivers and tidal creeks, which suggests that some portion of the population remains associated with these habitats even as large juveniles (Peters & McMichael 1987).

In August of 1991, the Florida Marine Research Institute (FMRI) initiated a gill net study within Gator Creek, an estuarine marsh creek in the northern Indian River Lagoon, Florida, to survey large juveniles and adults of large fish species, such as red drum, that might use the creek. Red drum were the most abundant sciaenid species encountered in these collections (Adams & Tremain 1995). The purpose of this paper is to describe the seasonal abundance, size distribution, year-class presence, residence duration, and migrational patterns of large juvenile and small adult red drum within this estuarine marsh creek habitat.

Methods

Study area

Gator Creek is an estuarine creek located at latitude 28° 37.75' N and longitude 80° 46.62' W in the northern Indian River Lagoon, Florida, within the boundaries of the Merritt Island National Wildlife Refuge (MINWR) (Figure 1). The water depth, substrate type, submerged vegetation, shoreline vegetation, and habitat types surrounding Gator Creek are typical of the numerous creek systems located in the northeastern area of the Indian River Lagoon. Daily water-level fluctuations in this portion of the lagoon are minor and are principally a function of prevailing wind conditions (Smith 1993). Water depths in the creek are typically shallow and range to approximately 1.5 m in the center of the creek. A sand-mud bar spans the creek mouth creating a relatively shallow creek-lagoon interface approximately 0.6 m deep. The natural drainage basins of Gator Creek and many of the other marsh creeks in this area were altered by mosquito control activities in the 1960s. Gator Creek is directly linked via culverts to three adjacent impounded marshes that are managed by the MINWR.

The portion of Gator Creek accessible with our vessels and sampling gear was characterized by three enlarged basins upstream from the mouth of the creek. These three enlarged basins (approximately 250 to 500 m wide) constituted our lower, middle, and upper gill net sampling stations (Figure 1). Sampling stations were separated by a distance of approximately

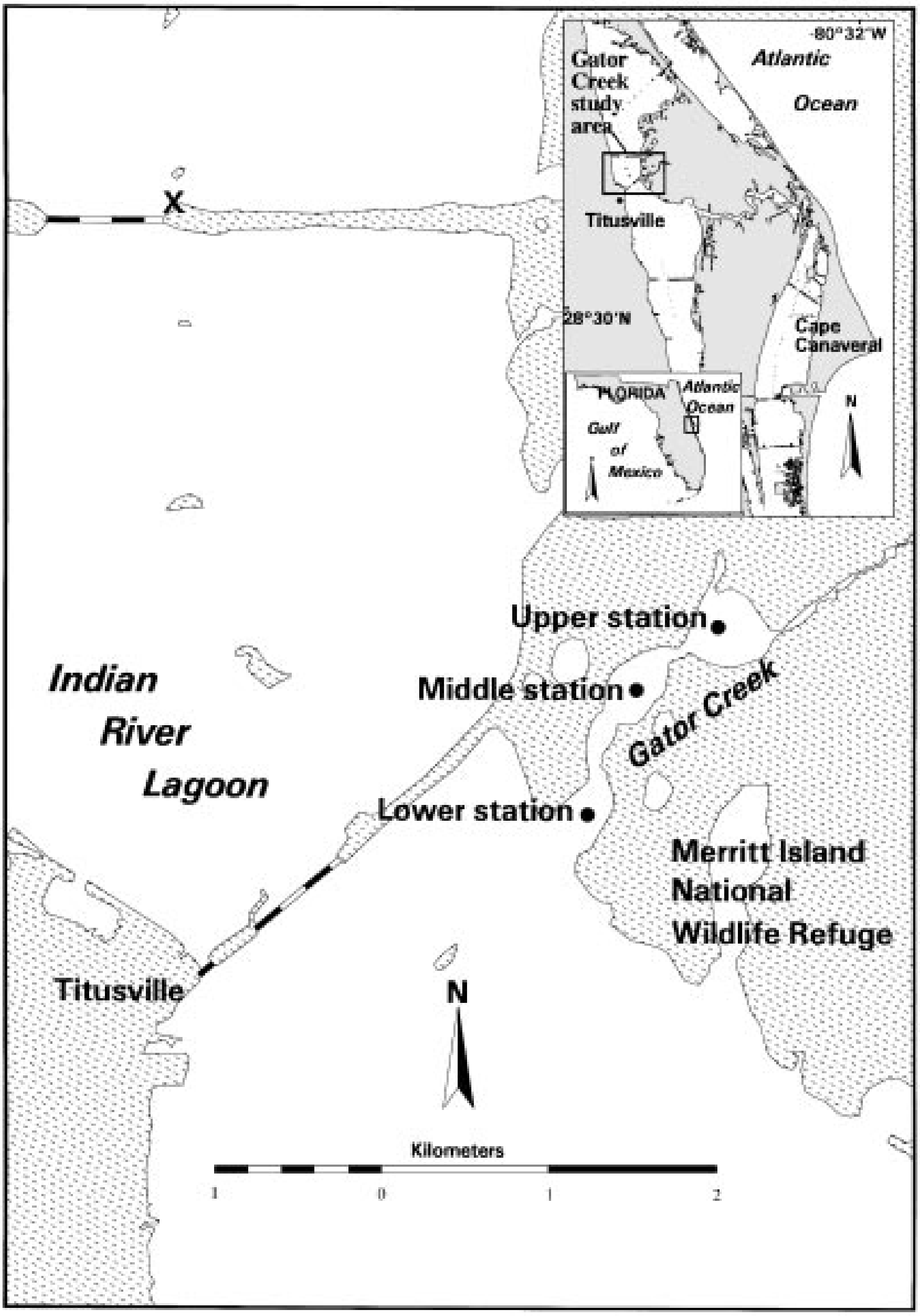

Figure 1. Map of the Gator Creek sampling area in the northern Indian River Lagoon, including the three gill net sampling stations (upper, middle, and lower) and a separate water-quality monitoring station (lagoon), indicated by '**X**', in the adjacent estuary.

800 to 1000 m, yet the physical habitat characteristics of the three stations were similar to each other. The dominant substrate types were mud in the central portion of the creek and muddy sand near the shoreline. Submerged aquatic vegetation composed principally of shoal grass, *Halodule wrightii*, with interspersed patches of manatee grass, *Syringodium filiforme*, and widgeon grass, *Ruppia maritima*, covered much of the creek bottom. The shoreline vegetation was composed principally of cordgrasses, *Spartina* spp., marshelder, *Iva frutescens*, and white mangrove, *Laguncularia racemosa*.

Sampling techniques

Fish sampling in Gator Creek was conducted monthly from August 1991 to March 1996 with 180-m-long, bottom-set gill nets. These gill nets were multiple-panel monofilament nets of incrementally increasing mesh size designed to capture fusiform fishes typically larger than 200 mm standard length (SL). Each gill net consisted of four 45.0×1.8 m panels with stretch mesh sizes of 75, 100, 125, and 150 mm and had an effective fishing depth of approximately 1.8 m. From April 1994, a 15.25×1.8 m panel with a mesh size of 50 mm was added to the nets to sample smaller fishes. On each sampling occasion, one gill net was set at each station (upper, middle, and lower), beginning with the upper station and proceeding downstream (Figure 1). Nets were anchored onshore and set perpendicular to the shoreline during the evening crepuscular period (one hour before to one hour after sunset) and fished for approximately 1 to 1.5 hours. Nets were retrieved in the same order in which they were deployed, and fishes were removed from each mesh panel and measured to the nearest 1 mm SL. Data were obtained for all species of fish, but analyses were restricted to red drum for this report.

Salinity (ppt), dissolved oxygen (ppm), and water temperature (°C) were measured each month in the creek and at a nearby site in the adjacent lagoon (lagoon station) with a Hydrolab Surveyor II water-quality measurement instrument. From August 1991 to July 1992, environmental factors in the creek were measured only at the upper station. Beginning in August 1992, measurements were also collected at the lower station. Environmental factors were measured throughout the study period at the lagoon station located approximately 5 km to the north (28° 39.75’ N, 80° 47.88’ W), for comparative purposes. No gill net data were collected at this site.

Relative fish abundances for each net were calculated as catch-per-unit-effort (CPUE) and expressed as total number of fish net^{-1} h^{-1}. Overall monthly creek CPUE values were reported as the mean CPUE of the three sets. The six red drum caught in the additional 50-mm-mesh panels deployed from April 1994 to March 1996 were included in the overall CPUE calculations. The inclusion of these six fishes did not alter the statistical interpretation of our analyses, but provided supplemental information regarding seasonality and year-class presence.

Red drum used in age determination ($n = 68$) were randomly selected to represent a wide range of sizes. Sacrificed fish were returned to the laboratory to determine age ranges within the creek and to assist in cohort assignment of unaged specimens. Saggital otoliths were removed, stored dry, and sectioned by using a Beuhler Isomet low-speed saw with diamond wafering blades. Transverse sections approximately 0.5 mm thick were cut through the core of the right sagitta and mounted on a microscope slide with mounting media. Using a dissecting microscope (35 X magnification) with reflected light, both authors independently read the sections twice. Fish ages determined from annulus counts were adjusted because annulus formation on Florida red drum otoliths begins during their second spring at approximately 18–20 months of age (Murphy & Taylor 1990). Fish ages, incremented in months, were calculated based on the biologically realistic birthdate of 1 October, which corresponds with the midpoint of the peak spawning period in Florida waters (Murphy & Taylor 1990). The resulting age-length key, combined with known collection dates, was used to determine the most likely year-class assignment of unaged fish.

Fish not used for age determination and judged to be in healthy condition following capture ($n = 161$) were tagged and released during sampling to determine patterns of habitat use and of movement. Plastic Hallprint dart tags (70 or 100 mm long) were applied below the middle of the first dorsal fin so that the barb of the tag lodged behind a pterygiophore. A plastic streamer, visible on the outside of the fish, offered a reward and instructed fishermen to contact us with the identification number, capture location, date, and size of recaptured fish.

Data analysis

Two-factor analyses of variance (ANOVA) with sampling station and sampling date as treatment effects for the model were used to determine if there were significant differences in (1) individual environmental factors (salinity, dissolved oxygen, or water temperature) between upper and lower creek stations and the lagoon station, and (2) CPUE between the three sampling stations within Gator creek (upper, middle, and lower creek stations). In cases where data were not normally distributed, either the $\log(\ln(X + 1))$ or square(X^2) transformation of the raw data was performed to meet the underlying assumptions of ANOVA (Zar 1984). When the ANOVA concluded that significant differences between sampling stations were present, we used Tukey's Studentized Range test (SAS Institute 1994) to determine where those differences occurred. We used Pearson's product moment correlation procedure to determine if monthly CPUE values (mean of all three stations for each sampling date) were correlated with corresponding monthly salinity, dissolved oxygen, or water temperature estimates (mean of upper and lower stations) in the creek. Sampling months for which environmental data were lacking because of equipment failure or other factors were not included in the ANOVA or correlation procedures.

Results

Environmental factors

Within the creek, measurements of salinity and dissolved oxygen were variable and often showed marked differences over small spatial and temporal scales (Figure 2). Salinity levels fluctuated annually and were typically highest during the first half of the year, following the dry season (December to May). In 1993, salinity levels remained relatively high throughout the year, which was likely a result of unusually low rainfall during the summer wet season. On a spatial scale, salinities within the creek showed gradient patterns typical of estuarine marsh creeks, and lowest salinities were consistently observed at the upper creek station. Salinity levels measured within Gator Creek were significantly different ($p < 0.05$) and typically lower than levels measured at the lagoon station (Table 1).

Dissolved oxygen (DO) levels were variable between sampling months and sampling stations, but generally remained greater than 4.0 ppm throughout the study period. Dissolved oxygen levels were generally highest during the winter and spring and lowest during summer. Measurements of DO recorded at the lagoon station did not differ from those recorded at the creek; however, within the creek, DO levels at the upper creek station were significantly different ($p < 0.05$) and typically lower than levels measured at the lower creek station.

Seasonal fluctuations in the water temperatures of Gator Creek and the lagoon were consistent with those in the warm-temperate regions in the northern hemisphere. Minimum temperatures occurred in December or January; maximum temperatures occurred during July or August. Monthly water temperatures at the creek stations did not differ significantly from each other ($p > 0.05$); however, there was a small but significant difference ($p < 0.05$) between water temperatures at the creek and those at the adjacent lagoon. Water temperatures were typically higher within the creek than at the adjacent lagoon station.

Patterns of estuarine creek use by red drum

Large juvenile red drum were common in Gator Creek during the study period ($n = 282$) and were collected during 53 of the 56 months sampled. Monthly CPUE values of the three creek stations were not statistically different ($p > 0.05$). Mean monthly CPUE values (mean of all 3 stations per month) ranged 0.0–3.77 fish $\text{net}^{-1}\text{hour}^{-1}$ ($\bar{x} = 1.27$; $SE = 0.12$) (Figure 3). Red drum abundances in the creek fluctuated seasonally and were highest during the winter and lowest during the summer months. Mean monthly CPUE values were negatively correlated with water temperatures (Pearson's $r = -0.35$; $p < 0.05$) but were not correlated with either salinity or dissolved oxygen levels recorded in the creek.

Lengths of red drum collected in the creek ranged from 156 to 560 mm SL ($\bar{x} = 338$; $SE = 3.8$) (Figure 4a) and most (89.7%, $n = 253$ fish) were between 260 and 450 mm SL. Large juvenile red drum became vulnerable to our sampling gear when they reached 220–250 mm SL during the late summer or early fall (Figures 4a, 5). The 1991, 1992, and 1993 year-classes were associated with the creek habitat for 22, 31, and 20 months, respectively, after they were first observed in our gear (Figure 5). The largest members of these three year-classes were typically collected during March and April but were absent from our collections during the following summer. Red drum larger than 450 mm SL were rarely collected within the creek and accounted for only 5% of the total number ($n = 14$ fish).

The majority of red drum collected from the creek were estimated to be between 10 and 26 months old

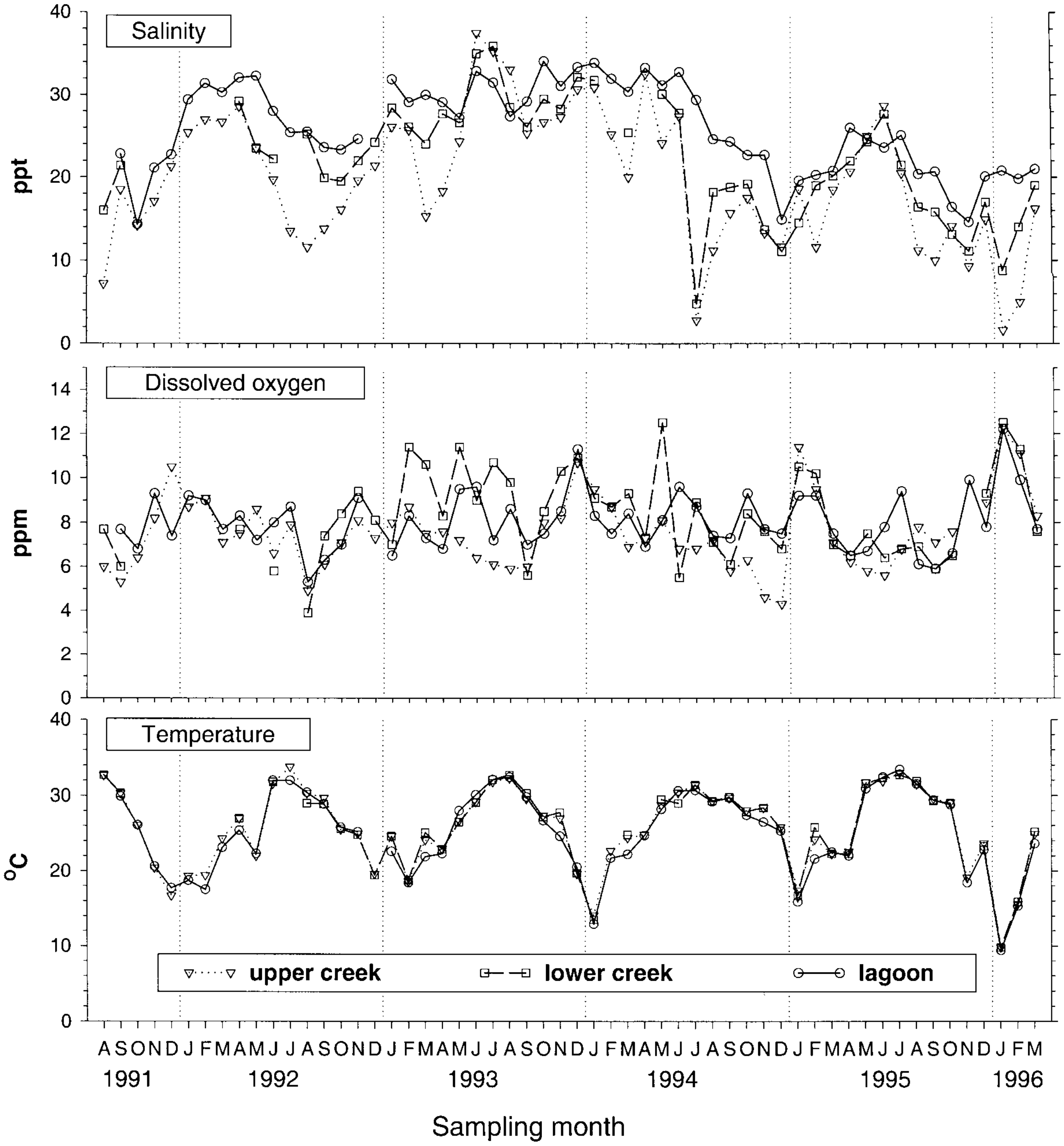

Figure 2. Monthly measurements of environmental parameters at two Gator Creek sampling stations (upper and lower) and an adjacent site in the lagoon (lagoon).

based on data derived from the 68 fish whose otoliths we examined (Figure 4b). The youngest red drum we aged was 286 mm SL and was estimated to be 10 months old; however, several smaller fish were collected, tagged, and released alive in the creek. The oldest red drum we examined was 560 mm SL and was estimated to be 37 months old.

We tagged 161 red drum during the study period. The size distribution for tagged fish (156–550 mm SL) was representative of all red drum captured in the

Table 1. Comparison of means, with standard errors (SE) and ranges, of environmental parameters measured at two Gator Creek sampling stations (upper and lower) and at a nearby site in the lagoon (lagoon). Significant differences between station means were determined by Tukey's Studentized Range test. Means with the same letter are not significantly different ($\alpha = 0.05$).

	Station	Range	Mean (SE)	Tukey grouping
Salinity	upper	1.6–37.5 ppt	19.8 (1.07)	A
	lower	4.8–35.9 ppt	21.9 (0.89)	B
	lagoon	14.3–34.1 ppt	25.9 (0.73)	C
Temperature	upper	9.8–33.8°C	25.7 (0.71)	A
	lower	9.8–33.8°C	25.9 (0.72)	A
	lagoon	9.4–33.4°C	25.0 (0.75)	B
Diss. oxygen	upper	4.3–12.3 ppm	7.5 (0.22)	A
	lower	3.9–12.5 ppm	8.3 (0.25)	B
	lagoon	5.3–12.2 ppm	8.0 (0.18)	A B

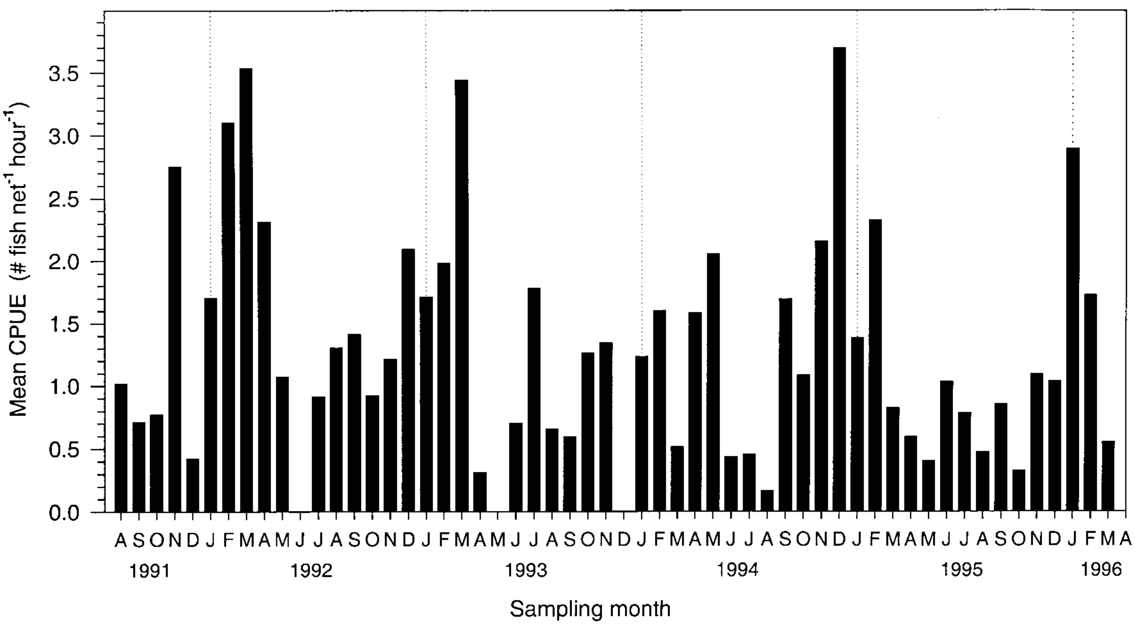

Figure 3. Mean monthly CPUE (fish per net per hour) for large juvenile red drum captured in Gator Creek (all stations pooled) between August 1991 and March 1996.

study area (Figure 4a). A total of 27 tagged fish were recaptured – angler recaptures accounted for 16 fish; FMRI gill net collections related to both this study and additional FMRI sampling in the Indian River Lagoon accounted for 11 fish (Table 2). Three of these fish were each recaptured on two different occasions, including one that was recaptured twice in the creek. Sixteen recaptures were from inside the creek and 11 recaptures were from outside the creek in the lagoon proper. The number of days at liberty ranged from 26 to 561 days ($\bar{x} = 166$ days) for fish recaptured inside the creek and from 88 to 377 days ($\bar{x} = 224$ days) for fish recaptured outside the creek.

Discussion

Estuarine creeks have been shown to be critical nursery habitats used by juveniles of many species;

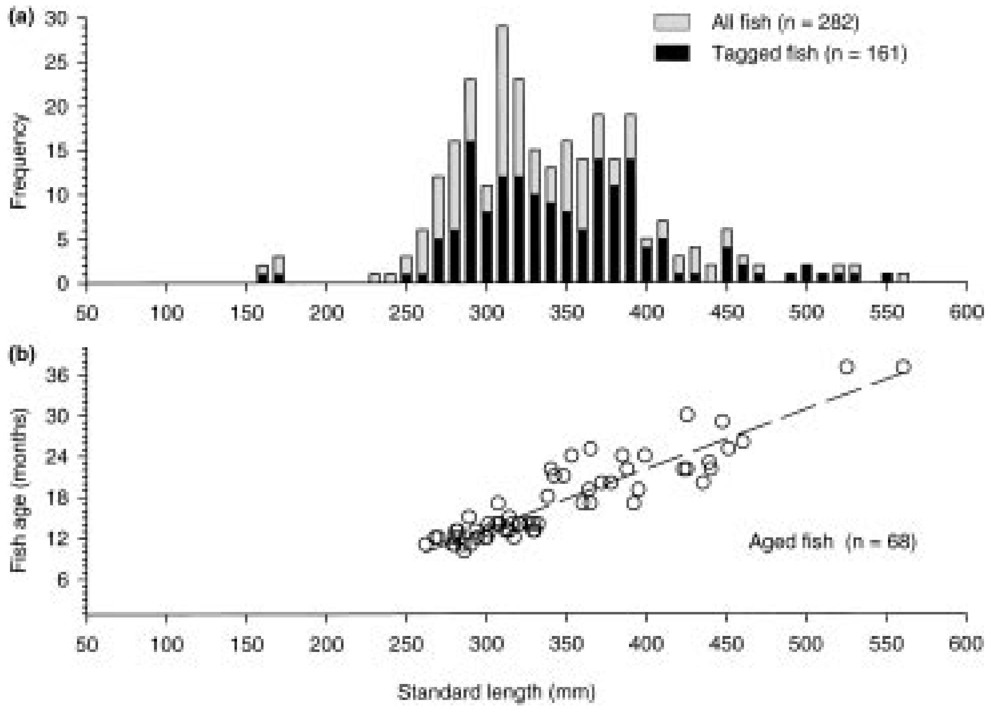

Figure 4. a – Length-frequency plots of all red drum collected from Gator Creek (light shading) and for all tagged red drum (dark shading). b – Plot of monthly incremented ages-at-length derived from examination of saggital otolith increments and based on a hypothetical birthdate of October 1. The dashed line represents a best-fit line through the age-at-length estimates.

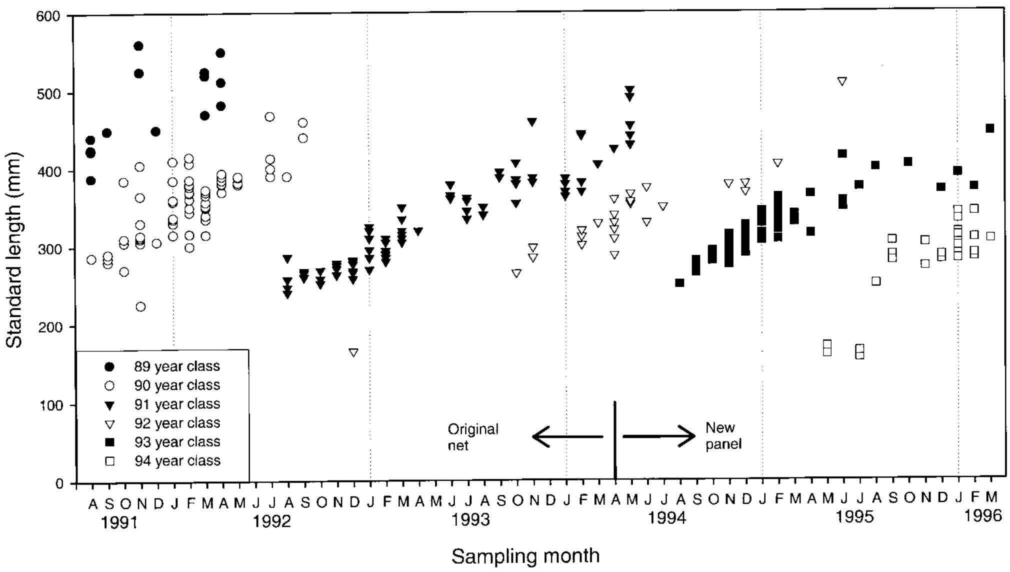

Figure 5. Plot of fish lengths (SL) by month and year-class (symbols) for red drum captured in Gator Creek between August 1991 and March 1996.

Table 2. Tag-return data for 24 of the fish originally tagged inside Gator Creek and recaptured by FMRI in gill nets or by anglers. Recapture locations are from within Gator Creek (Creek) and from lagoon waters outside the creek (Lagoon). Multiple recaptures are indicated by sequential letters in parentheses following the fish number. DAL = days-at-liberty.

Recapture location	Recapture method	Fish no.	Tag date	Recapture date	DAL
Creek	FMRI	1	8 Jan 1992	5 Mar 1992	57
		2	4 Feb 1992	10 Apr 1992	66
		3	4 Feb 1992	7 May 1992	93
		4(a)	6 Jan 1993	7 Feb 1994	398
		5(a)	8 Jul 1993	15 Nov 1993	130
		6	15 Nov 1993	7 Apr 1994	143
		7	8 Sep 1994	7 Oct 1994	30
		8	10 Nov 1994	6 Dec 1994	26
		9(a)	9 Jan 1996	7 Feb 1996	29
	Angler	10	10 Apr 1992	23 Aug 1992	135
		11	7 May 1992	10 Sep 1992	126
		4(b)	6 Jan 1993	20 Jul 1994	561
		12	17 Jun 1993	2 Oct 1994	473
		13	7 Feb 1994	2 Aug 1994	176
		14	6 May 1994	29 Oct 1994	176
		15	8 Sep 1994	25 Feb 1995	170
Lagoon	FMRI	16	9 Jan 1995	14 Nov 1995	309
		17	10 Aug 1995	14 Nov 1995	96
	Angler	18	4 Aug 1992	14 Jan 1993	163
		19	4 Feb 1992	21 Jan 1993	352
		20	10 Apr 1992	25 Oct 1992	198
		21	10 Apr 1992	9 Sep 1992	152
		5(b)	8 Jul 1993	3 Jul 1994	360
		22	7 Oct 1993	18 Oct 1994	377
		23	5 Jan 1994	17 Jun 1994	163
		24	9 Jan 1996	6 Apr 1996	88
		9(b)	9 Jan 1996	2 Aug 1996	203

however, the importance of these habitat types to larger juveniles and adult sciaenids and other fishes is not well known. In addition to the red drum discussed here, we collected large juveniles and adults of other sciaenid species in Gator Creek including spot *Leiostomus xanthurus*, black drum *Pogonias cromis*, spotted seatrout *Cynoscion nebulosus*, and silver perch *Bairdiella chrysoura*. The purpose of this study was to examine the association of large juvenile red drum with an estuarine marsh creek, a habitat type that is also important to red drum during their early life history (Peters & McMichael 1987, Daniel 1988, Baltz et al. 1993) but that has received little attention with respect to its importance to larger size-classes of the species.

The environmental data collected during this study indicated that the physical conditions in the Gator Creek study area were distinct from those in the adjacent estuary. Freshwater drainage into the creek and a lack of tidal flushing contributed to reduced salinities within the creek and a gradient of increasing salinities from the upper creek to the adjacent lagoon. The differences between the water temperatures we recorded in the creek and in the lagoon appeared to be small but may be biologically significant to species seeking thermal refugia during periods of suboptimal thermal conditions in the adjacent estuary.

The CPUE and size structure of red drum caught in gill nets varied seasonally within the creek. Catch-per-unit-effort peaked in the winter months and decreased during the summer months during all sampling years; however, specific reasons for the consistent seasonal abundance patterns we observed are unclear. Because we used multipanel gill nets capable of capturing a wide size range of red drum, it is not likely that the seasonal abundance patterns we observed were a function of gear biases but rather were a function of other environmental or biological factors that influenced the abundances of red drum or their catchability with stationary fishing gear. Seasonal movements to optimal habitats by juvenile red drum have been observed in other estuarine systems (Yokel 1966, Peters & McMichael 1987) and are likely related to changes in water temperature, salinity, or prey availability. Gillnet catches of immature red drum in Texas bays declined during the winter months, possibly because many fish moved to unsampled deep-water refugia within the bays and rivers or to the adjacent Gulf of Mexico (Matlock et al.[7], Matlock & Weaver[8]). The higher abundance of red drum in Gator Creek observed during the winter months may be due to increased habitat use of warmer creek waters when lagoon water temperatures decline. Conversely, the decrease in red drum abundance we observed during the warmer months may represent the emigration of large fish from the creek during the summer prior to the recruitment of small fish to our sampling gear in the fall. Daniel (1988) speculated that movement of red drum larger than 150 mm out of South Carolina intertidal creeks in July prevents competition with or predation on the following year-class, which recruits in August. It is known that a wide range of factors (e.g., food availability, habitat preference, juvenile – adult segregation, and hydrological characteristics) interact to determine fish distributions (Weng 1990). Consequently, a combination of mechanisms could have produced the observed patterns. Indeed, in the present study, even when correlations were significant, much of the variability in the data remained unexplained, indicating that variables other than those investigated may have influenced the catch rates we observed.

Our data on the lengths and year-class presence of fish in Gator Creek showed that red drum remained associated with the estuarine creek until they were approximately 450 mm SL or about two years old. Results by Peters & McMichael (1987) in Tampa Bay, Florida showed that post-settlement juvenile red drum used low-salinity estuarine backwater areas such as marsh creeks and canals as nursery habitats; the fish remained associated with these areas until they were approximately 150–200 mm SL and then the majority migrated back out to the open estuary. In that study, in which principally small-mesh seines and occasionally hook and line and small-mesh experimental gill nets were used, few red drum larger than 200 mm and none larger than 300 mm were collected. In our study, juvenile red drum were not fully recruited to the gill net sampling gear until they were approximately 220 mm SL, and then they continued to be collected from the creek for 20 to 31 months. Differences in the sizes of fish captured in the two studies were most likely related to differences in the primary sampling gears used (small-mesh seines vs. gill nets). Our results suggest that some portion of the stock that recruited to the creek habitat as juveniles remained associated with the habitat at much larger sizes than previously reported.

Although our observations of year-class presence indicated that large juvenile red drum used the creek for extended periods of time, it was unknown whether individual fish remained associated with the creek or whether the data reflected the presence of transient individuals from the lagoon. Tag-recapture data from our study demonstrated that approximately 60% of all recaptured fish were caught within the creek providing direct evidence that specific fish used the creek during extended periods of up to 18 months. Although the movements and whereabouts of specific fish between the time of initial tagging and recapture are unknown, one fish that we captured, tagged, and released in the creek was recaptured two additional times within the creek over the next 18 months (Table 2), which suggested a close association with this creek. These data, combined with our observations on year-class presence and published accounts of limited movements of large juvenile red drum in estuarine systems (Pafford et al.[9], Murphy & Taylor 1990), suggest repeated use of the creek during this life-history interval, and may indicate protracted residency in the creek by large juvenile red drum. In a study by Carr & Chaney (1976), a 3.2 kg red drum, which was tagged with an ultrasonic transmitter in the Intracoastal Waterway of eastern Florida and then tracked for seven hours, entered the mouth of almost every estuarine creek it encountered and moved at night to a deep area 140 m up one of these creeks. Tagging studies of red drum in

[7] Matlok, G.C., J.E.Weaver, L.W. McEachron, J.A. Daily, P.C. Hammerschmidt, H.E.Hengen, R.A. Harrington & G.M.Stokes. 1978. Trends in finfish abundance in Texas estuaries as indicated by gill nets. Coast. Fish. Branch, Texas Parks and Wildlife department, Austin. 271 pp.

[8] Matlok, G.C. & J.E. Weaver. 1979. Fish tagging in Texas bays during Nov 1975–Sept 1976. Coastal Fisheries Branch, Texas Parks and Wildlife Department, Management Data Series No. 1. 135 pp.

[9] Pafford, J.M, A.G. Woodward & N. Nicholson. 1990. Mortality, movement, and growth of red drum in Georgia. Final report to Georgia Department of Natural resources, Atlanta. 85 pp.

North Carolina (Ross & Stevens[10], Ross et al. 1995), Georgia (Pafford et al.[9]), Texas (Osburn et al. 1982), and Florida (Murphy & Taylor 1990) have shown that the majority of large juveniles do not move long distances within natal estuarine systems, and our observations may reflect the availability of suitable habitat for large juvenile red drum in close proximity to their low-salinity juvenile nursery areas.

Large juvenile red drum are widely distributed among estuarine locations and habitat types, including bays and rivers, canals, tidal creeks, boat basins, shallow vegetated or unvegetated flats, oyster bars, and passes (Mercer[1], Peters & McMichael 1987, Murphy[3]). Low-salinity backwater areas such as the estuarine marsh creek examined in this study provide one important type of nursery habitat to large juvenile red drum in both Atlantic and Gulf coast estuaries. Our results suggest repeated use and possible continual use of these creeks by red drum up to the large juvenile or young adult stages and reemphasize the value of these habitat types for some portion of the red drum population in the estuary. From a fisheries perspective, the large juvenile size classes compose the majority of all red drum fishery landings in Florida waters. A full understanding of the associations of red drum in these size classes with various habitat types will benefit fisheries managers and their efforts to protect and properly manage this important species.

Acknowledgements

We would like to thank the fisheries personnel at the FMRI Indian River Field Laboratory for collecting data and assisting in this study. In addition, A. Acosta, L. French, P. Hood, S. Kupschus, J. Leiby, R. McMichael, M. Murphy, R. Paperno, K. Peters and J. Quinn offered helpful suggestions for improving the manuscript. Thanks to L. Brant for the location map and to MINWR for allowing us access to Gator Creek. This work was supported in part under funding from the Department of Interior, U.S. Fish and Wildlife Service, Federal Aid for Sportfish Restoration, Project Number F-43, and by the State of Florida Saltwater Fishing License monies.

[10] Ross, J.L. & T.M. Stevens. 1992. Life history and population dynamics of red drum (*Sciaenops ocellatus*) in North Carolina waters. *In*: Marine Fisheries Research, North Carolina Division of Marine Fisheries, Completion Report, Project F-29, Morehead City. 130 pp.

References cited

Adams, D.H. & D.M. Tremain. 1995. Fishes of Gator Creek, Indian River Lagoon: species composition, habitat utilization and seasonal abundance patterns. Bull. Mar. Sci. 57: 278.

Baltz, D.M., C. Rakocinski & J.W. Fleeger. 1993. Microhabitat use by marsh-edge fishes in a Louisiana estuary. Env. Biol. Fish. 36: 109–126.

Bass, R.J. & J.W. Avault, Jr. 1975. Food habits, length–weight relationship, condition factor, and growth of juvenile red drum, *Sciaenops ocellata*, in Louisiana. Trans. Amer. Fish. Soc. 104: 35–45.

Beckman, D.W., C.W. Wilson & A.L. Stanley. 1989. Age and growth of red drum, *Sciaenops ocellatus*, from offshore waters of the northern Gulf of Mexico. U.S. Fish. Bull. 87: 17–28.

Carr, W.E.S. & T. Chaney. 1976. Harness for attachment of an ultrasonic transmitter to the red drum, *Sciaenops ocellata*. U.S. Fish. Bull. 74: 998–1000.

Dahlberg, M.D. 1972. An ecological study of Georgia coastal fishes. U.S. Fish. Bull. 70: 323–353.

Daniel, L.B., III. 1988. Aspects of the biology of juvenile red drum, *Sciaenops ocellatus*, and spotted seatrout, *Cynoscion nebulosus*, in South Carolina. M.S. Thesis, College of Charleston, Charleston. 58 pp.

Fuiman, L.A. & D.R. Ottey. 1993. Temperature effects on spontaneous behavior of larval and juvenile red drum, *Sciaenops ocellatus*, and implications for foraging. U.S. Fish. Bull. 91: 23–35.

Gunter, G. 1958. Population studies of the shallow water fishes of an outer beach in south Texas. Publications of the Institute of Marine Science, University of Texas 5: 186– 193.

Holt, S.A., C.L. Kitting & C. R. Arnold. 1983. Distribution of young red drums among different sea-grass meadows. Trans. Amer. Fish. Soc. 112: 267–271.

Johnson, D.R. & N.A. Funicelli. 1991. Spawning of the red drum in Mosquito Lagoon, east-central Florida. Estuaries 14: 74–79.

Lux, F.E. & J.V. Mahoney. 1969. First records of the channel bass, *Sciaenops ocellatus*, in the Gulf of Maine. Copeia 1969: 632–633.

Lyczkowski-Shultz, J. & J.P. Steen, Jr. 1991. Diel vertical distribution of red drum, *Sciaenops ocellatus*, larvae in the northcentral Gulf of Mexico. U.S. Fish. Bull. 89: 631– 641.

Mansueti, R.J. 1960. Restriction of very young red drum, *Sciaenops ocellatus*, to shallow estuarine waters of Chesapeake Bay during late autumn. Chesapeake Sci. 1: 207–210.

Murphy, M.D. & R.G. Taylor. 1990. Reproduction, growth, and mortality of red drum, *Sciaenops* ocellatus, in Florida waters. U.S. Fish. Bull. 88: 531–542.

Osburn, H.R., G.C. Matlock & A.W. Green. 1982. Red drum, *Sciaenops ocellatus*, movement in Texas bays. Contrib. Mar. Sci. 25: 85–97.

Pearson, J.C. 1929. Natural history and conservation of the redfish and other commercial sciaenids on the Texas coast. Bull. U.S. Bur. Fish. 64: 178–194.

Peters, K.M. & R.H. McMichael, Jr. 1987. Early life history of the red drum, *Sciaenops ocellatus*, in Tampa Bay, Florida. Estuaries 10: 92–107.

Rooker, J.R. & S.A. Holt. 1997. Utilization of subtropical seagrass meadows by newly settled red drum, *Sciaenops ocellatus*: patterns of distribution and growth. Mar. Ecol. Prog. Ser. 158: 139–149.

Ross, J.L., T.M. Stevens & D.S. Vaughan. 1995. Age, growth, and reproductive biology of red drums in North Carolina waters. Trans. Amer. Fish. Soc. 124: 37–54.

SAS Institute. 1994. SAS/STAT User's Guide, Version 6, Fourth Edition, Vol. 2, Cary. 846 pp.

Simmons, E.G. & J.P. Breuer. 1962. A study of redfish, *Sciaenops ocellata*, and black drum, *Pogonias cromis*. Publications of the Institute of Marine Science, University of Texas 8: 184–211.

Smith, N.P. 1993. Tidal and wind-driven transport between Indian River and Mosquito Lagoon, Florida. Fla. Sci. 56: 236–246.

Weinstein, M.P. 1979. Shallow marsh habitat as primary nurseries for fishes and shellfish, Cape Fear, N.C. U.S. Fish. Bull. 77: 339–357.

Weng, H.T. 1990. Fish in shallow areas of Moreton Bay, Queensland and factors affecting their distribution. Estuar., Coast., Shelf Sci. 30: 569–578.

Wilson, C.A. & D.L. Neiland. 1994. Reproductive biology of red drum, *Sciaenops ocellatus*, from the neritic waters of the northern Gulf of Mexico. U.S. Fish. Bull. 92: 841–850.

Yokel, B.J. 1966. A contribution to the biology and distribution of the red drum, *Sciaenops ocellata*. M.S. Thesis, University of Miami, Coral Gables. 160 pp.

Zar, J.H. 1984. Biostatistical analysis, 2nd edition. Prentice-Hall, Englewood Cliffs. 718 pp.