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Age and Growth of Sand Seatrout (*Cynoscion arenarius*) in the Estuarine Waters of the Eastern Gulf of Mexico

Douglas J. Nemeth, Jered B. Jackson, Anthony R. Knapp, and Caleb H. Purtlebaugh

Sand seatrout, *Cynoscion arenarius*, support a large recreational fishery in Florida, but information on the population characteristics of the species is lacking. Sand seatrout were collected incidentally during random sampling conducted by a fisheries-independent monitoring program in three Florida estuaries from Oct. 2001 through Sept. 2003. The collection gear included a 183-m haul seine (38-mm stretch mesh), a 183-m purse seine (51-mm stretch mesh), and a 6.1-m otter trawl (3-mm mesh liner). The sample was supplemented in one estuary with fish captured by hook and line. For aging, otoliths were extracted and sectioned from specimens greater than 90 mm standard length. This is the first comprehensive study of this species' age and growth characteristics derived from otoliths. A total of 1,080 sand seatrout were captured from the estuarine areas of Cedar Key, Tampa Bay, and Charlotte Harbor. Annulus counts had a high level of agreement between readers. Most disagreements between readers on the number of annuli present were whether zero or one annulus was present. Marginal-increment analysis indicated that annuli had been formed in most individuals by March. Otoliths had up to five annuli and estimated ages extended to nearly 6 yr. Observed mean length-at-age for fish of a given sex was similar across all estuaries. Length-at-age of females was greater than that of males in all estuaries. Von Bertalanffy growth models were significantly different for females and males ($P < 0.01$). Length: weight and length:length relationships are provided.

The sand seatrout, *Cynoscion arenarius,* is an estuarine sciaenid common in the northern Gulf of Mexico (Franks et al., 1972; Ditty et al., 1991; Rakocinski et al., 2002). It occurs from Florida Bay in southern Florida to Campeche Bay in Mexico (Guest and Gunter, 1958; Flores-Coto et al., 1998). Recreational harvest of the species is not regulated in Florida, and from 1990 to 2003 an average of 1.1 million sand seatrout per year were harvested from Florida waters (National Marine Fisheries Service, 2004). Commercial landings of sand seatrout in Florida decreased in 1995 following restrictions placed on commercial nets and have since averaged about 21,000 pounds annually (National Marine Fisheries Service, 2004).

The species was first described by Ginsburg (1930). Since that time its taxonomic status as a species distinct from weakfish, *Cynoscion regalis,* has been questioned (Ditty et al., 1991). In Florida, DNA analysis has shown that sand seatrout can hybridize with spotted seatrout (*Cynoscion nebulosus*) and weakfish (M. Tringali, pers. comm.).

Most literature regarding sand seatrout has been collected from the northern Gulf of Mexico (Gunter, 1938; Moffett et al., 1979; Shlossman and Chittenden, 1981; Sheridan et al., 1984; Flores-Coto et al., 1998), and only one study (Shlossman and Chittenden, 1981) has provided comprehensive information on the population characteristics of the species. No information has been published involving sand seatrout demographics based on otolith-derived ages, although Barger and Johnson (1980) did compare the efficacy of aging the species using scales, otoliths, and vertebrae. Aging studies based on scales or length-frequency analyses have identified specimens up to 3 yr of age, but most individuals were 0 through 2 yr old (Chittenden and McEachran, 1976; Shlossman and Chittenden, 1981).

The largest reported specimen was 590 mm total length (TL) (Vick, 1964). Other maximum lengths appearing in the literature range between 342 and 540 mm TL (Gunter, 1945; Franks et al., 1972; Chittenden and McEachran, 1976; Trent and Pristas, 1977; Shlossman and Chittenden, 1981). Females attain larger sizes than males (Franks et al., 1972; Shlossman and Chittenden, 1981).

The objective of this study was to determine the age and growth characteristics of sand seatrout populations in Florida. Here we present age and growth information from sand seatrout captured over a 24-mo period through

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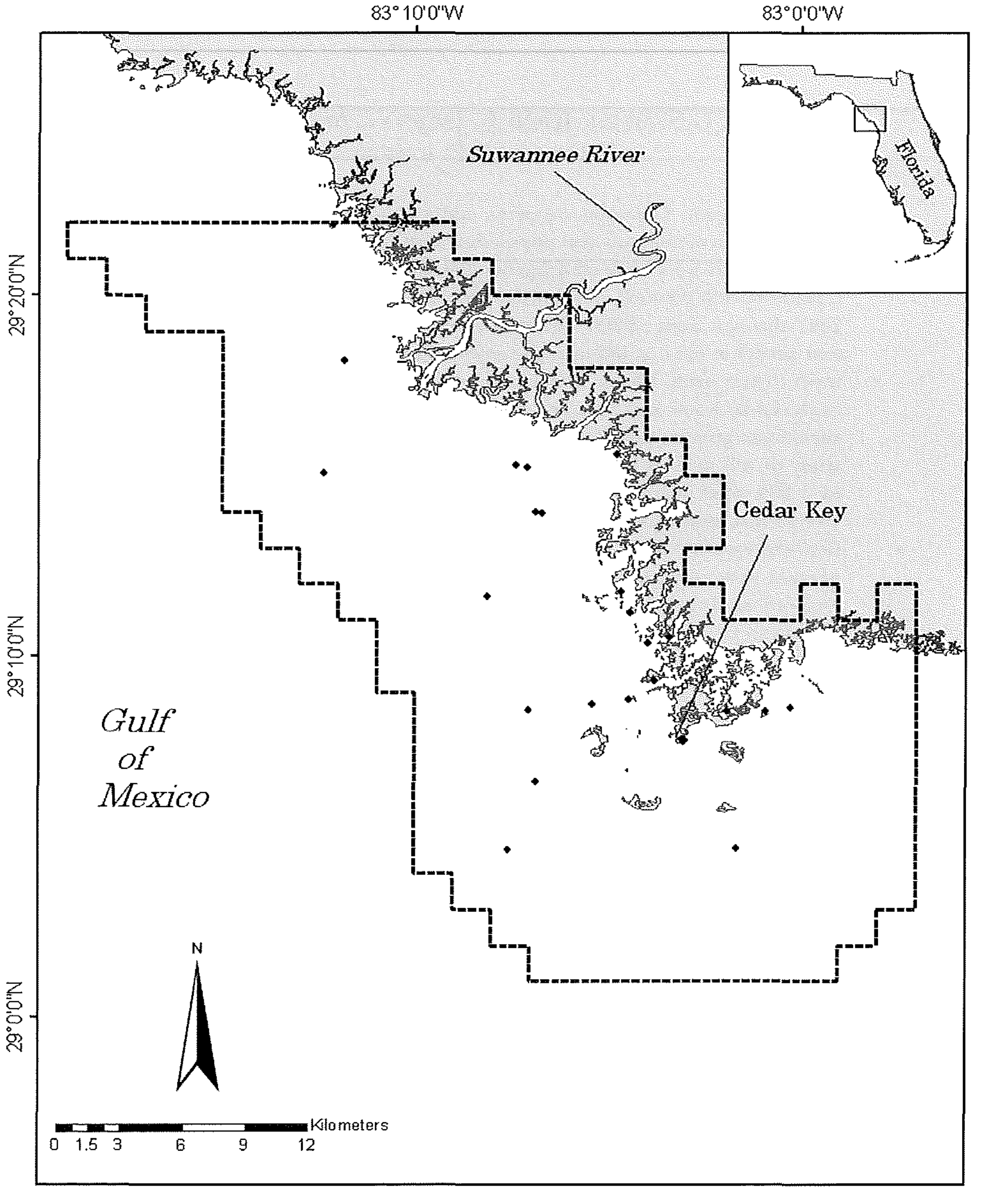

Fig. 1. Map of the Cedar Key (A), Tampa Bay (B), and Charlotte Harbor (C), sampling universes (within dashed lines) showing collection locations of sand seatrout (*Cynoscion arenarius*).

monthly sampling of three Florida estuaries in the eastern Gulf of Mexico. We used sectioned otoliths to assign ages and believe this to be the first comprehensive study of age and growth of this species based on otoliths.

Materials and Methods

Sand seatrout were collected along the west coast of Florida from the areas of Cedar Key (latitude 29.10°N), Tampa Bay (latitude 27.60°N), and Charlotte Harbor (latitude 26.70°N), FL (Fig. 1). The Cedar Key area is a shallow, open estuary influenced by the Suwannee River. The land adjacent to the estuary, and the Suwannee River watershed in general, is relatively undeveloped. The estuary is characterized by large expanses of salt marsh, tidal creeks, oyster bars, mud flats, and seagrass meadows. Tampa Bay is Florida's largest estuary, and urban development

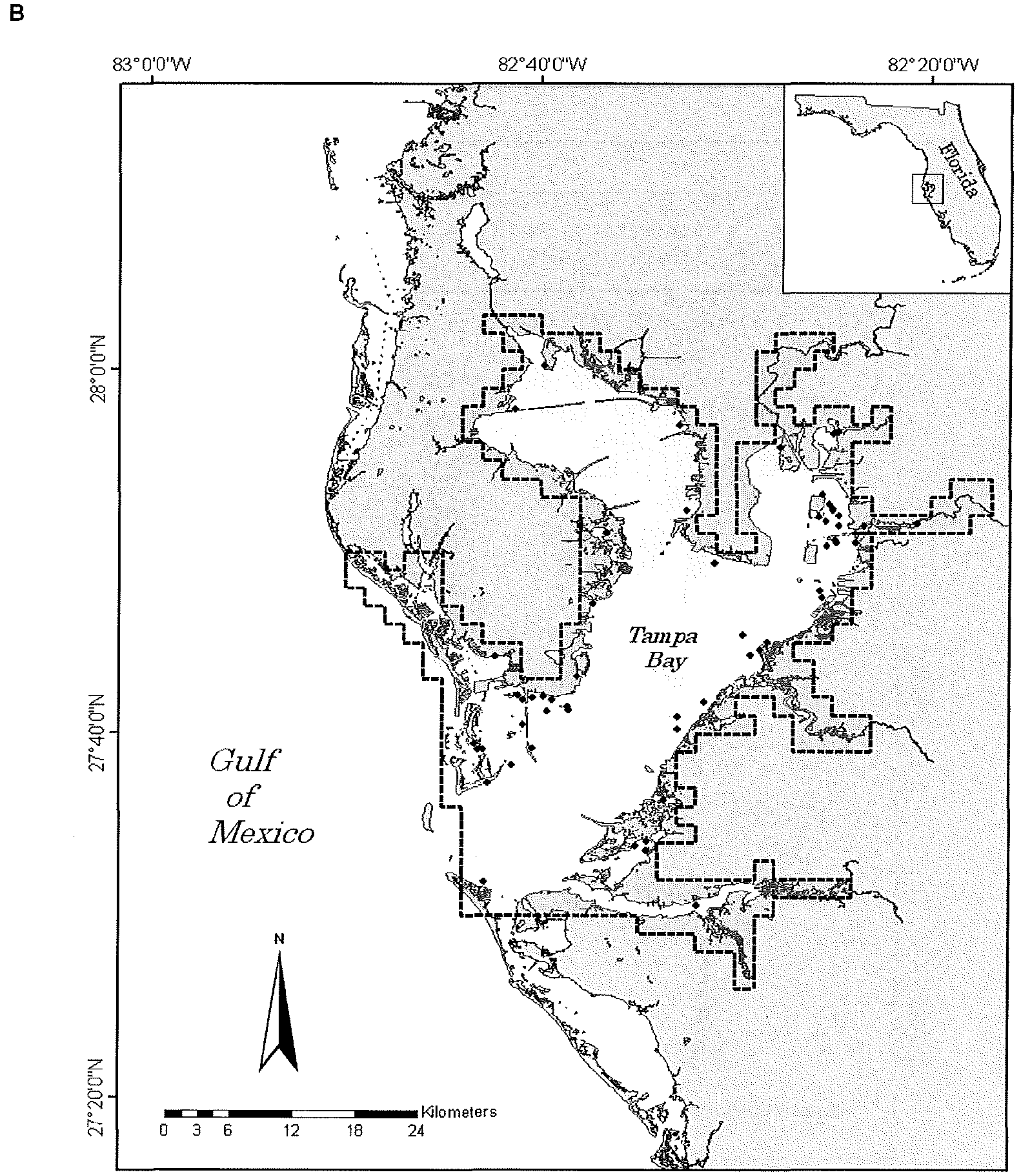

Fig. 1. Continued.

is more common around Tampa Bay than near either Cedar Key or Charlotte Harbor. Mangroves, salt marsh, mud flats, and seagrasses are common habitats in Tampa Bay. Charlotte Harbor is the second largest estuary in Florida and much of the adjacent land is relatively pristine because of its designation as an aquatic preserve. Aquatic habitats in Charlotte Harbor are similar to those found in Tampa Bay.

Sand seatrout were collected incidentally during monthly random sampling by the Florida Fish and Wildlife Conservation Commission (FWC) Fish and Wildlife Research Institute's (formerly the Florida Marine Research Institute) fisheries-independent monitoring (FIM) program from Oct. 2001 through Sept. 2003. Sampling gear used by the FIM staff at these locations were a 183-m haul seine with 38-mm stretch mesh, a 183-m purse seine with 51-mm stretch mesh, and a 6.1-m otter trawl with a 3-mm mesh liner. The purse seine was used only in the Tampa Bay and Charlotte Harbor estuaries. Haul seine deployments were shoreline-associated in water up to 2.5 m deep.

C

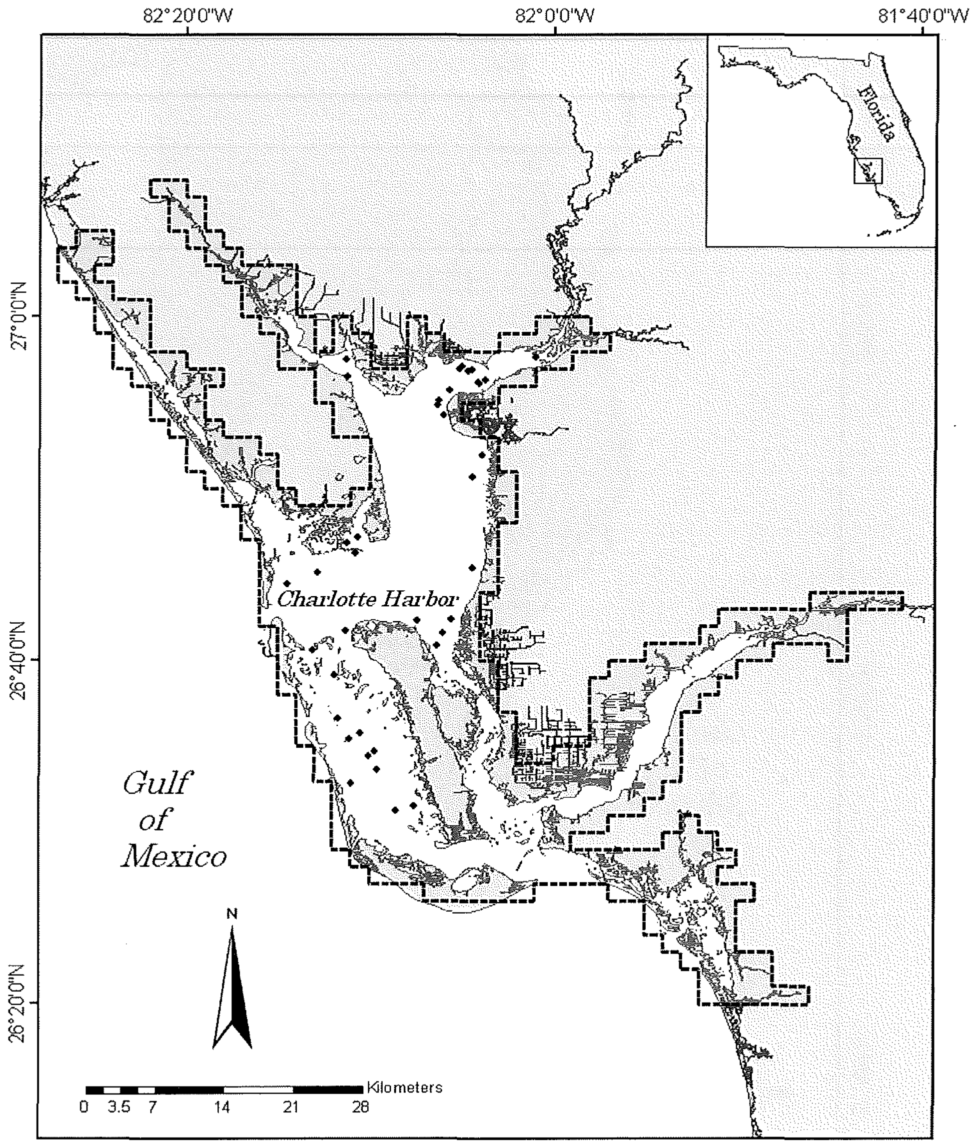

Fig. 1. Continued.

Purse seine deployments were not associated with a shoreline and occurred in water 1.0–3.3 m deep. Random sampling in the Cedar Key area did not produce sufficient sand seatrout for study. As a result, additional sampling was concentrated to the few areas where it was known the species could be captured. Also, sand seatrout collections in the Cedar Key area were supplemented through hook-and-line sampling.

Sheridan et al. (1984) reported that macroscopic determination of sand seatrout gender was first possible at standard lengths of 84 mm and 82 mm for males and females, respectively. Consequently, we chose 90 mm standard length (SL) as the minimum SL for inclusion in this study. Specimens greater than 90 mm SL were culled, placed on ice in the field, and returned to the lab for analysis. Gender, total length, and SL to the nearest millimeter, and whole wet weight to the nearest 0.1 g were recorded. Otoliths (sagittae) were removed, cleaned, and stored for sectioning.

The left sagittae were sectioned transversely with a Beuhler Isomet low-speed saw. Sections were mounted on microscope slides, and annuli, identified as opaque zones, were counted using a dissecting microscope. Three researchers independently counted annuli. If counts differed for an otolith, it was examined a second time by all three readers. If differences persisted, the otolith was excluded from age analyses. Linear distances on sectioned otoliths were measured from the otolith core to the proximal edge of each annulus and to the otolith edge using Optimas 6.2 software (Media Cybernetics, Silver Spring, MD). The percentage of marginal increment was calculated as the distance between the final annulus and the otolith margin divided by the outermost inter-annulus distance (Crabtree et al., 1996).

Age was estimated based upon annulus count, percentage of marginal increment, timing of annulus formation, capture date for each fish, and median hatch date (Lowerre-Barbieri et al., 1994; Murphy and Taylor, 1994). Use of a Jan. 1 hatch date resulted in unrealistic length-at-age estimates. Subsequently, a median hatch date (June 1) estimated from recruitment data (FWC, unpubl. data) was used. Based upon percentage of marginal increment, annuli were deposited by the end of March. Fish collected from Jan. 1 to June 1 that had recently formed an annulus were assigned an age of one less than the annulus count. All other fish were assigned an age equal to the annulus count.

Total length was fitted to age (in years) with the von Bertalanffy growth function (VBGF) for fish aged 1 yr and older. The VBGF was fitted separately for both sexes in each estuary using Proc NLIN (SAS Institute, 1989). Approximate randomization tests were used to compare VBGFs between males and females within each estuary, and to compare for between-estuary differences in VBGFs for each sex (Helser, 1996). Length-at-age was predicted using the derived growth functions.

Length:weight and TL:SL relationships were compared between sexes and estuaries using Proc GLM (SAS Institute, 1989). If the regressions for different sexes or estuaries did not have significantly different slopes and intercepts, data were combined and the new groups reanalyzed. The length:weight relationship was described using both total weight and gonad-free weight.

Results

Collections.—A total of 1,080 sand seatrout were retained for analysis from Cedar Key (n = 557), Tampa Bay (n = 232), and Charlotte Harbor (n = 291). Variation occurred in the data collected from each fish, so differences in sample size may occur depending upon which metric is discussed.

Capture of sand seatrout was not homogenous across all months, especially in Cedar Key, where captures were confined principally to March through Sept. (Fig. 2). In Tampa Bay and Charlotte Harbor, collection of sand seatrout was temporally more evenly distributed. More sand seatrout between 100 and 175 mm SL were captured in Cedar Key than in Tampa Bay or Charlotte Harbor (Fig. 3). The majority of specimens (77%) from Cedar Key were captured by a 183-m haul seine (38-mm stretch mesh) whereas the majority of specimens collected from Tampa Bay (84%) and Charlotte Harbor (100%) were captured in a 183-m purse seine (51-mm stretch mesh). The Cedar Key sample was supplemented with 74 specimens captured by hook and line and these specimens were generally larger (mean length, 250 mm SL) than those collected with the seine.

Female sand seatrout were captured more frequently than males in every estuary. Females outnumbered males in Cedar Key by 5.4:1, in Tampa Bay by 2.2:1, and in Charlotte Harbor by 2.1:1. For each estuary, sex ratios between 12-mo periods were not significantly different (χ^2 test, $P > 0.05$). The sex ratio found in sand seatrout from Cedar Key was significantly different (χ^2 test, $P < 0.001$) from the sex ratios observed in sand seatrout from Tampa Bay and Charlotte Harbor.

Age.—Of 1,042 otoliths examined, 89 (8.5%) were re-examined because of differences in annulus counts between readers. When discrepancies between readers occurred, the number of annuli counted never differed by more than one. Among the 89 disputed otoliths, 58% were re-examined to determine whether zero or one annulus was present, 16% to determine whether one or two annuli were present, 14% to determine whether two or three annuli were present, 11% to determine whether three or four annuli were present, and 1% to determine whether four or five annuli were present. Counts were reconciled for 59 of the 89 otoliths. The remaining 30 otoliths (<3% of the total) were excluded from analyses related to age and most of those (70%) involved otoliths with either zero or one annulus.

Marginal-increment analysis indirectly validated the annual periodicity of annulus formation (Fig. 4). Small sample sizes for some

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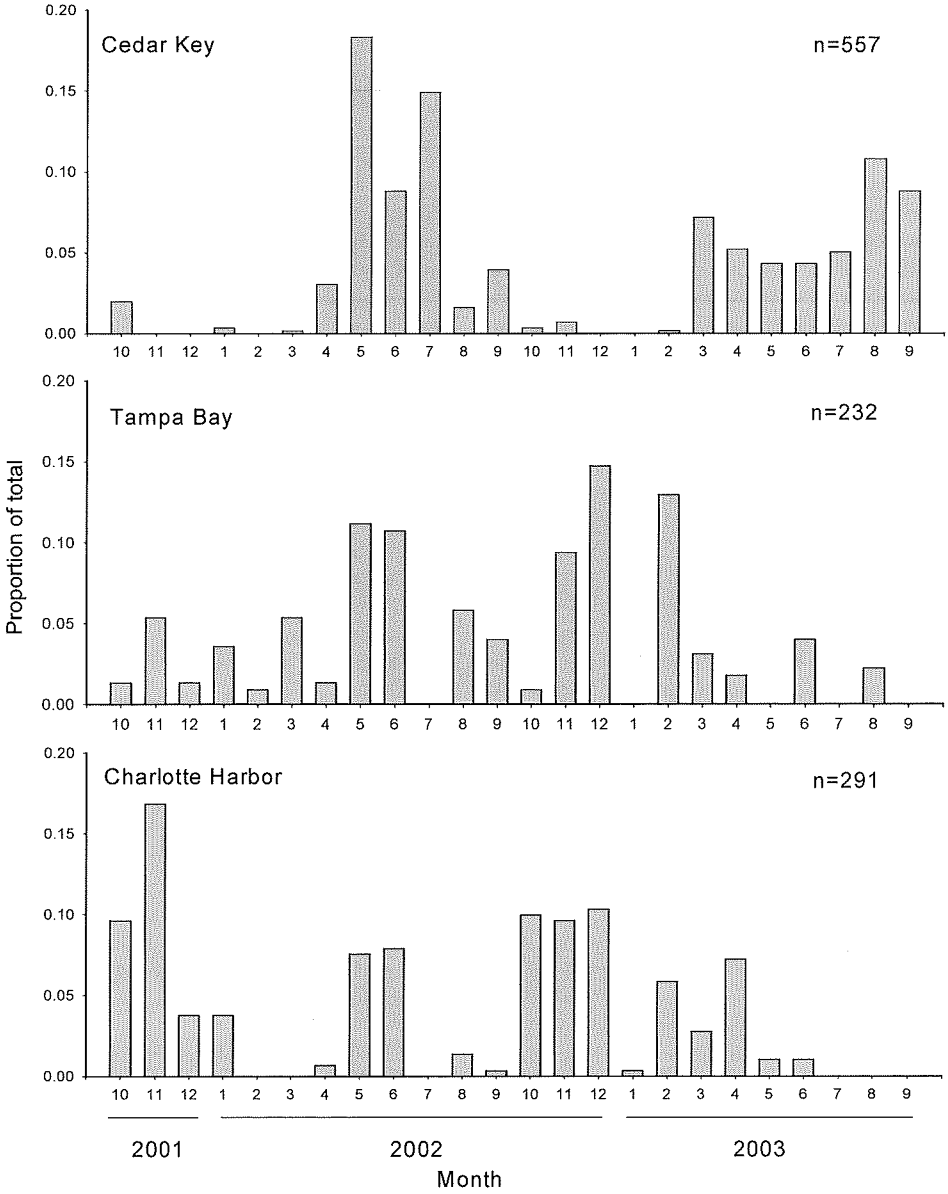

Fig. 2. Temporal distribution of sand seatrout (*Cynoscion arenarius*) sampled from the Cedar Key, Tampa Bay, and Charlotte Harbor estuaries.

age groups and a patchy temporal distribution precluded a definitive analysis of annulus deposition for each age group and estuary. However, an overall pattern was present: all individuals captured in March, regardless of estuary or annulus count, had a low marginal-increment percentage indicating that by this time an annulus had recently been formed. Annulus formation occurred as early as Jan. or Feb. in some individuals; however, there was considerable variation between individuals during these months. Percentage of marginal increments gradually increased through June and July, and increased sharply in Sept. or Oct.

Otoliths with up to five annuli were recovered from each gender and estuary (Fig. 5). Estimated ages of sand seatrout ranged from 0 to 5 yr for fish captured from Cedar Key and Charlotte Harbor and from 0 to 4 yr for fish from Tampa Bay (Table 1). Estimated age of some individuals was nearly 6 yr (Fig. 6) although no six-annulus otoliths were observed.

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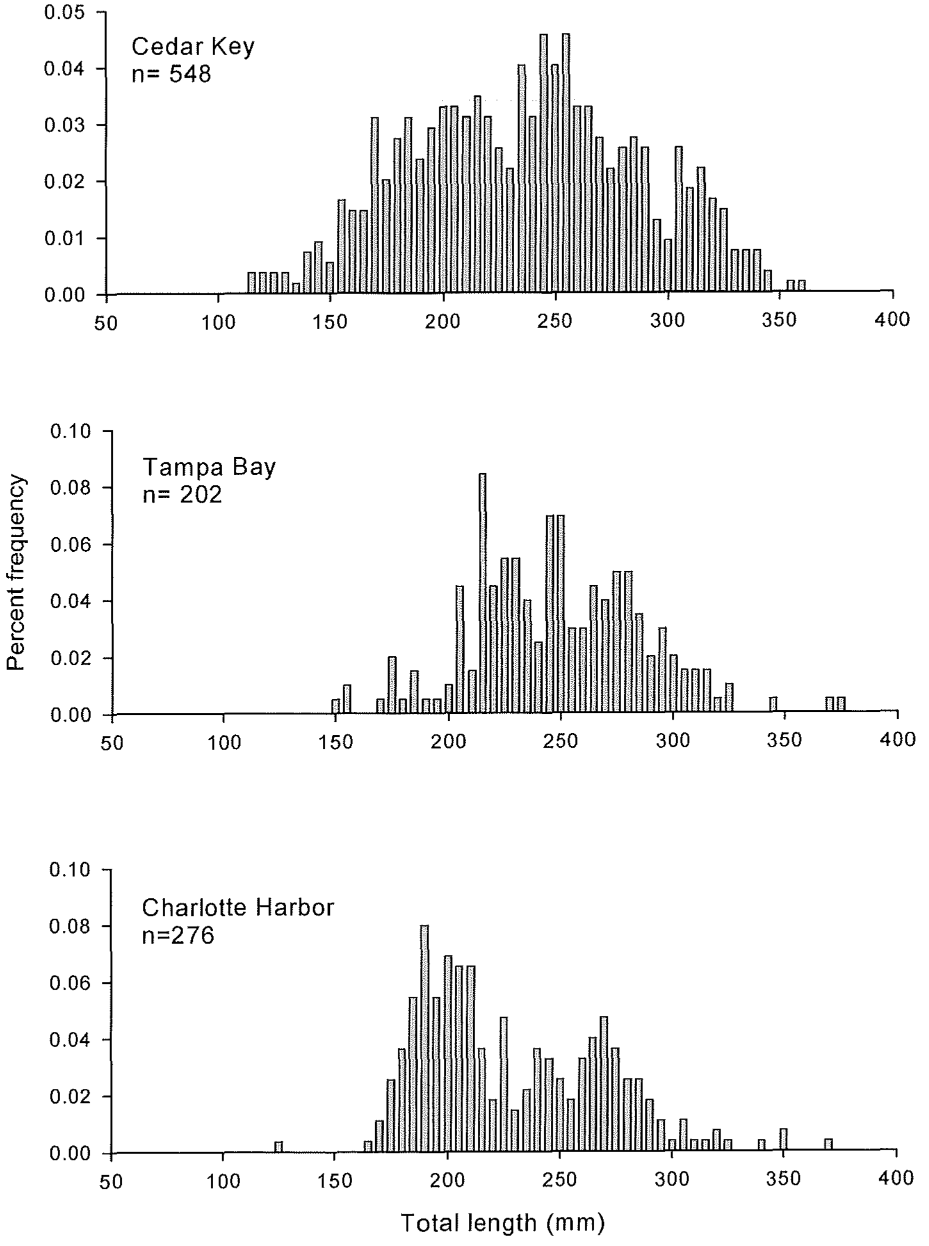

Fig. 3. Length-frequency distribution of sand seatrout (*Cynoscion arenarius*) sampled from the Cedar Key, Tampa Bay, and Charlotte Harbor estuaries.

Growth.—Von Bertalanffy growth functions fit Cedar Key and Charlotte Harbor data but a best fit could not be found with Tampa Bay data. Approximate randomization tests indicated that the VBGFs of Cedar Key and Charlotte Harbor females were not significantly different ($P > 0.05$); the VBGFs between Cedar Key and Charlotte Harbor males were also not significantly different ($P > 0.05$). Linear models applied to Tampa Bay females and males did not differ significantly in slope [analysis of covariance (ANCOVA), $F_{1,188} = 0.489$, $P = 0.491$] but had significantly different intercepts (ANCOVA, $F_{1,188} = 12.51$, $P = 0.001$) with females having the higher intercept.

We could not identify a plausible reason why Tampa Bay sand seatrout had a different growth curve than did those from Cedar Key

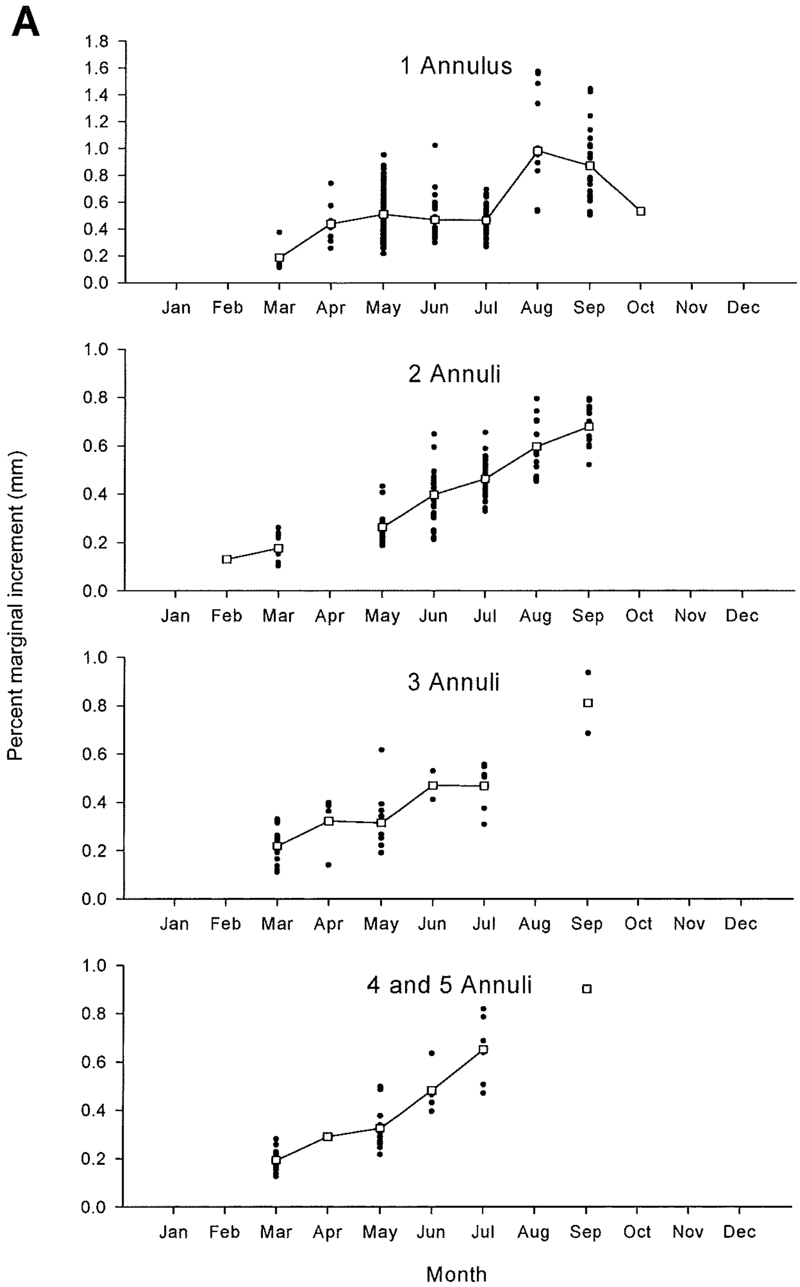

Fig. 4. Percentage of marginal increment of sectioned otoliths, by number of annuli present, for sand seatrout (*Cynoscion arenarius*) collected from Cedar Key (A), Tampa Bay (B), and Charlotte Harbor (C). Points represent observed values; the line connects mean values.

and Charlotte Harbor. Subsequent inspection of observed points along the fitted growth curves suggested that insufficient representation of the older age groups may have compromised the validity of the relationships. Additionally, gender-specific length-at-age predicted by the growth functions for Cedar Key and Charlotte Harbor compared to those predicted for Tampa Bay were small. Consequently, we pooled the data from all three estuaries by gender and recalculated the VBGFs from the combined data sets (Fig. 6). The VBGFs of females and males were significantly different (approximate randomization, $P < 0.001$):

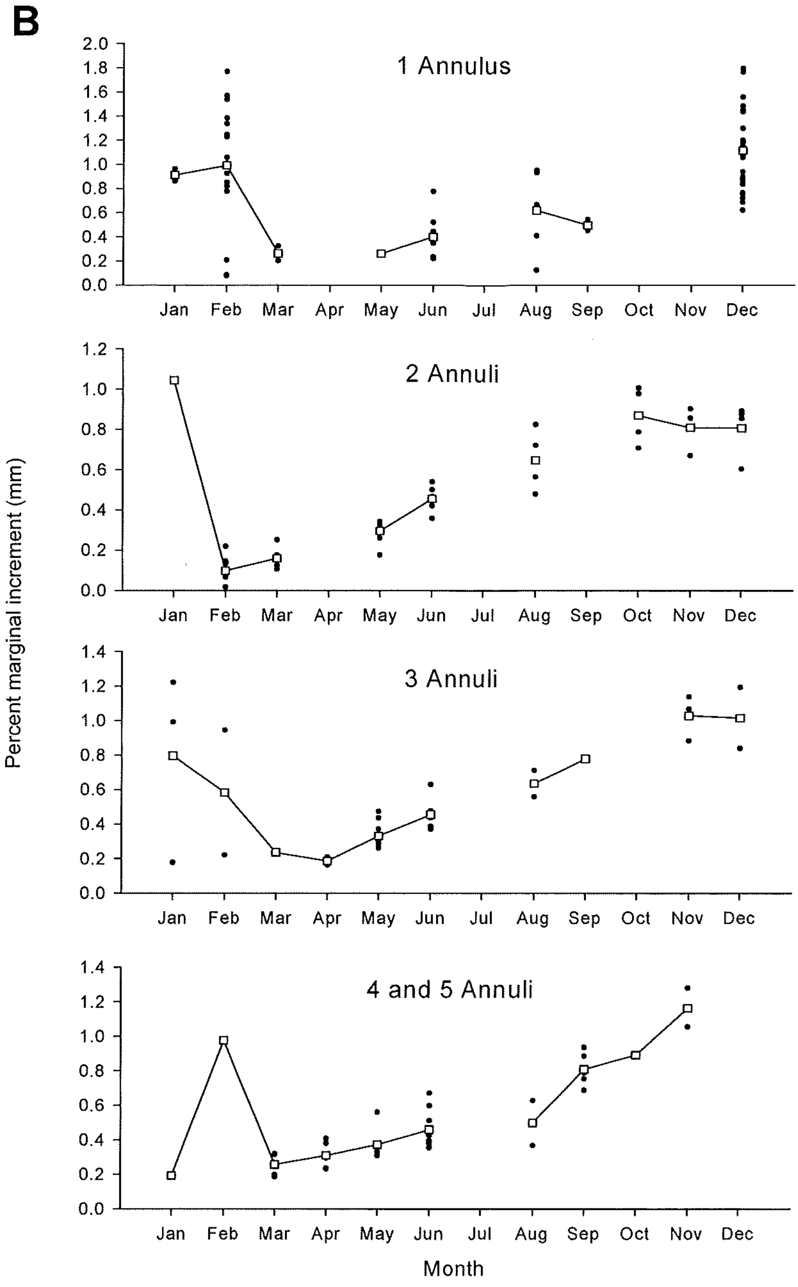

Fig. 4. Continued.

Females:

$$TL = 360.1\{1 - \exp[-0.31(Age + 1.74)]\}$$

(Proc NLIN, $F_{3,594} = 340.5$, $p < 0.001$)

Males:

$$TL = 313.6\{1 - \exp[-0.34(Age + 1.75)]\}$$

(Proc NLIN, $F_{3,196} = 107.9$, $p < 0.001$)

Observed and predicted mean lengths-at-age were always greater for females than for males in all three estuaries (Table 1). Observed mean length-at-age for fish of a given sex was similar across all estuaries. The largest difference in observed mean length between estuaries for a given age and either sex was only 36 mm. Agreement between observed and predicted sizes was high. Overall, there was no consistent pattern of observed mean length being larger or smaller than predicted mean length. Some

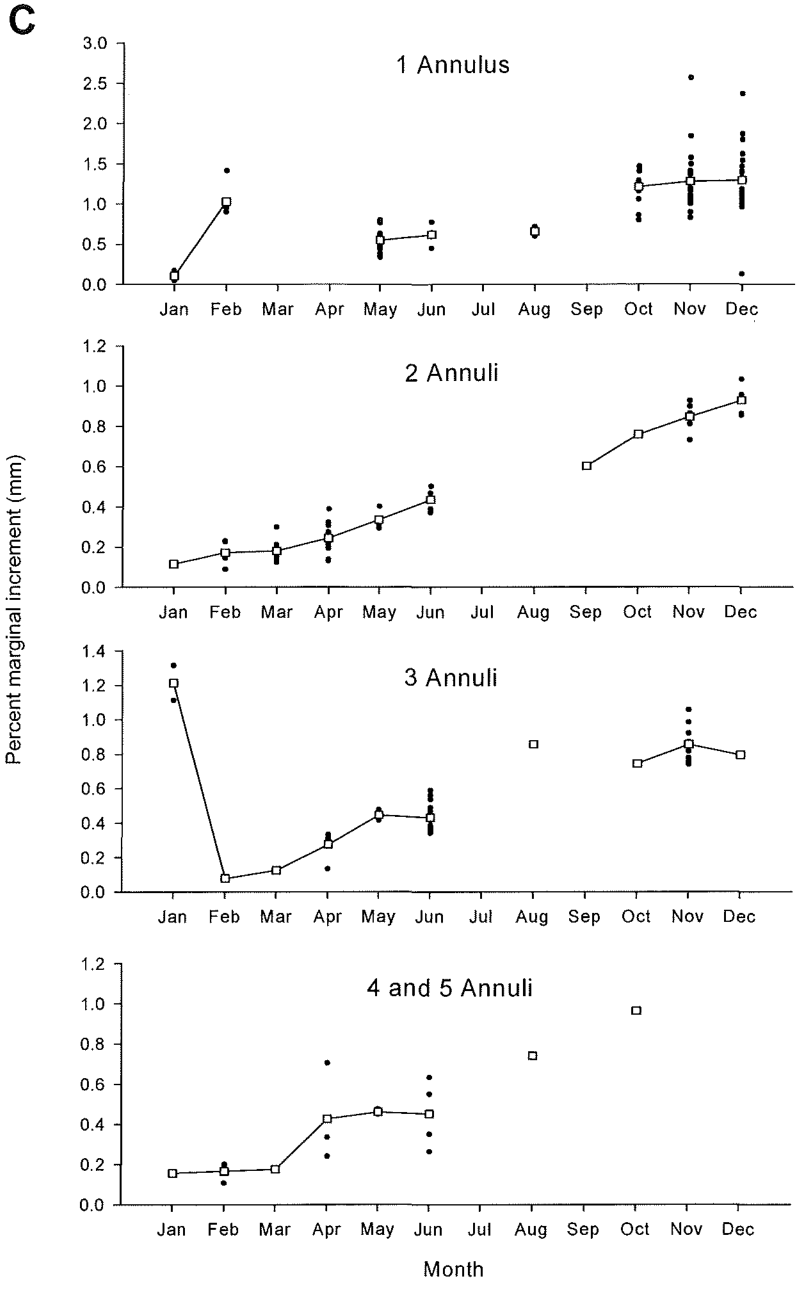

Fig. 4. Continued.

instances of negative growth between age groups occurred. All such cases involved fish aged 3 yr and older and small sample sizes.

There was no difference between sexes in the slopes or intercepts of the length: weight regressions for fish from Cedar Key (slope: ANCOVA, $F_{1,1.94}$; $P = 0.16$; intercept: ANCOVA, $F_{1,0.20}$; $P = 0.66$) or Tampa Bay (slope: ANCOVA, $F_{1,1.40}$; $P = 0.24$; intercept: ANCOVA, $F_{1,0.75}$; $P = 0.75$). Males and females from these estuaries were therefore combined for length: weight analyses. Slopes of the length:weight regressions for males and females from Charlotte Harbor, however, were significantly different (ANCOVA, $F_{1,21.67}$; $P < 0.0001$). The slope of the length:weight regression of Charlotte Harbor female sand seatrout was not significantly different from that of Tampa Bay female and

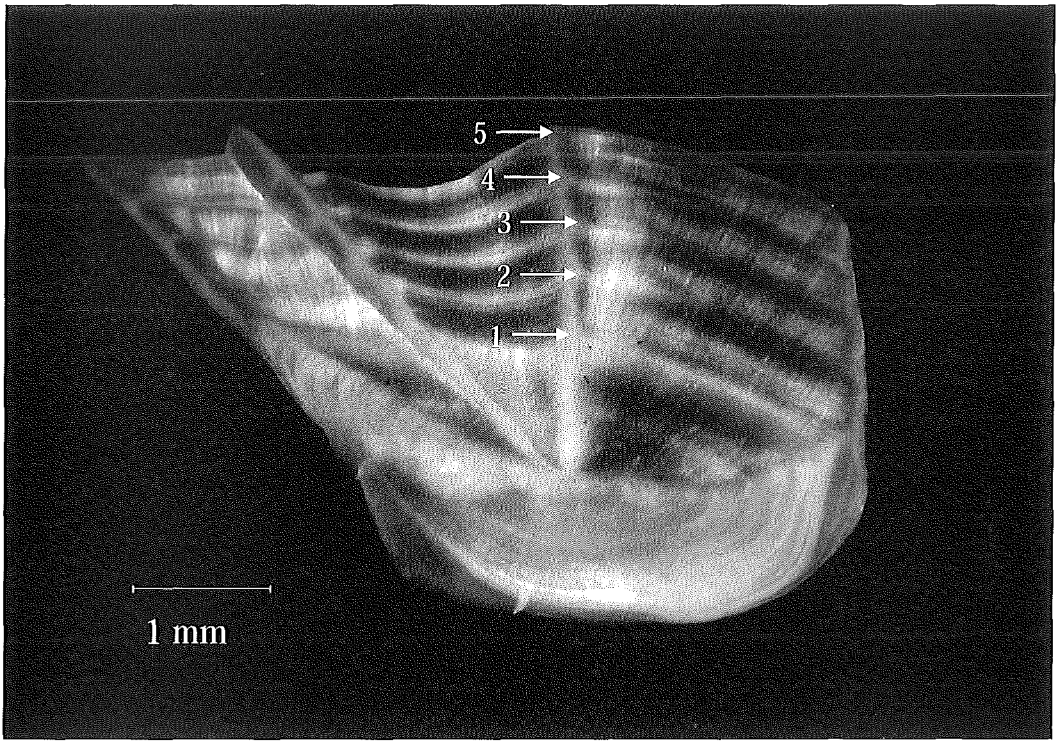

Fig. 5. Image of a sand seatrout (*Cynoscion arenarius*) otolith showing five annuli. Numbered arrows indicate positions of annuli.

male sand seatrout (ANCOVA, $F_{1,0.51}$; P = 0.48), although the intercepts were different (ANCOVA, $F_{1,98.44}$; $P < 0.0001$). Analyzing length:weight relationships based upon gonad-free wet weight revealed that only Cedar Key females had a significantly different relationship than that defined using total wet weight (ANCOVA, $F_{1,5.21}$; $P = 0.02$). Cedar Key sand seatrout increased in weight per unit length at a rate faster than the other groups; Charlotte Harbor male sand seatrout increased in weight per unit length at the slowest rate (Table 2). TL:SL regressions were not significantly different between sexes or between estuaries (Table 2).

Discussion

Collections.—Collection of sand seatrout between estuaries varied temporally. The fact that most of the Cedar Key sample was collected during the spawning season probably resulted in the skewed sex ratio of sand seatrout collected there. Sex ratios of weakfish were noted to be skewed toward females when fish were sampled during the spawning season relative to when they were migrating (Lowerre-Barbieri et al., 1996). Most of the sand seatrout sampled from Tampa Bay and Charlotte Harbor were collected by a purse seine with a larger mesh size than any net used in Cedar Key. This resulted in a smaller proportion of fish under 200 mm total length being collected in those locations than in Cedar Key. The differences in temporal distribution of the samples, coupled with differences in gear types used to make the collections, preclude comparisons of certain population parameters between the estuaries such as age structure. However, it remains significant that individuals with five annuli occurred in all three estuaries, and the morphometric comparisons included herein remain valid as they are not affected by collection biases.

Age.—The high level of agreement of annulus counts between readers and the demonstrated annual periodicity of annulus formation indirectly validated the use of sagittae to age sand seatrout. Additionally, size and growth of young-of-the-year sand seatrout through time (Perret and Caillouet, 1974) and the length-at-age data presented here indicated that first annulus formation occurs during the spring following the year of hatching.

Estimated ages of nearly 6 yr extended the known life span of this species. Previous works

TABLE 1. Sample size (n), mean observed and predicted total lengths (mm), growth increments, and observed length range by age, sex, and estuary for sand seatrout (*Cynoscion arenarius*) sampled from Cedar Key, Tampa Bay, and Charlotte Harbor estuaries. TL = Total Length, Obs. = Observed, Incr. = Increment, Pred. = Predicted, n.d. = no data.

Females

Cedar Key							Tampa Bay							Charlotte Harbor						
Age	n	Mean TL	Obs. incr.	Range	Pred. TL	Pred. incr.	Age	n	Mean TL	Obs. incr.	Range	Pred. TL	Pred. incr.	Age	n	Mean TL	Obs. incr.	Range	Pred. TL	Pred. incr.
1	193	212	56	139–321	206	41	1	52	230	30	187–279	206	41	1	44	221	47	172–283	206	41
2	109	268	39	198–330	247	30	2	36	260	11	214–323	247	30	2	38	268	25	225–310	247	30
3	38	307	−5	250–358	277	22	3	23	271	29	240–315	277	22	3	21	293	−21	212–368	277	22
4	11	302	23	269–330	299	16	4	19	300		265–375	299		4	4	272	52	244–286	299	16
5	5	325		313–339	315		5	0	n.d.	n.d.	n.d.	n.d.		5	1	324		324	315	

Males

Cedar Key							Tampa Bay							Charlotte Harbor						
Age	n	Mean TL	Obs. incr.	Range	Pred. TL	Pred. incr.	Age	n	Mean TL	Obs. incr.	Range	Pred. TL	Pred. incr.	Age	n	Mean TL	Obs. incr.	Range	Pred. TL	Pred. incr.
1	40	190	57	136–254	191	35	1	23	219	30	202–249	191	35	1	36	206	45	187–231	191	35
2	18	247	44	196–278	226	25	2	18	249	23	212–295	226	25	2	7	251	4	223–277	226	25
3	2	291	−7	276–305	251	18	3	6	272	−4	242–310	251	18	3	19	255	11	237–280	251	18
4	4	284	7	254–321	269	13	4	11	268		235–345	269		4	9	266	11	245–275	269	13
5	1	291		291–321	282		5	0	n.d.	n.d.	n.d.	n.d.		5	2	277		252–302	282	

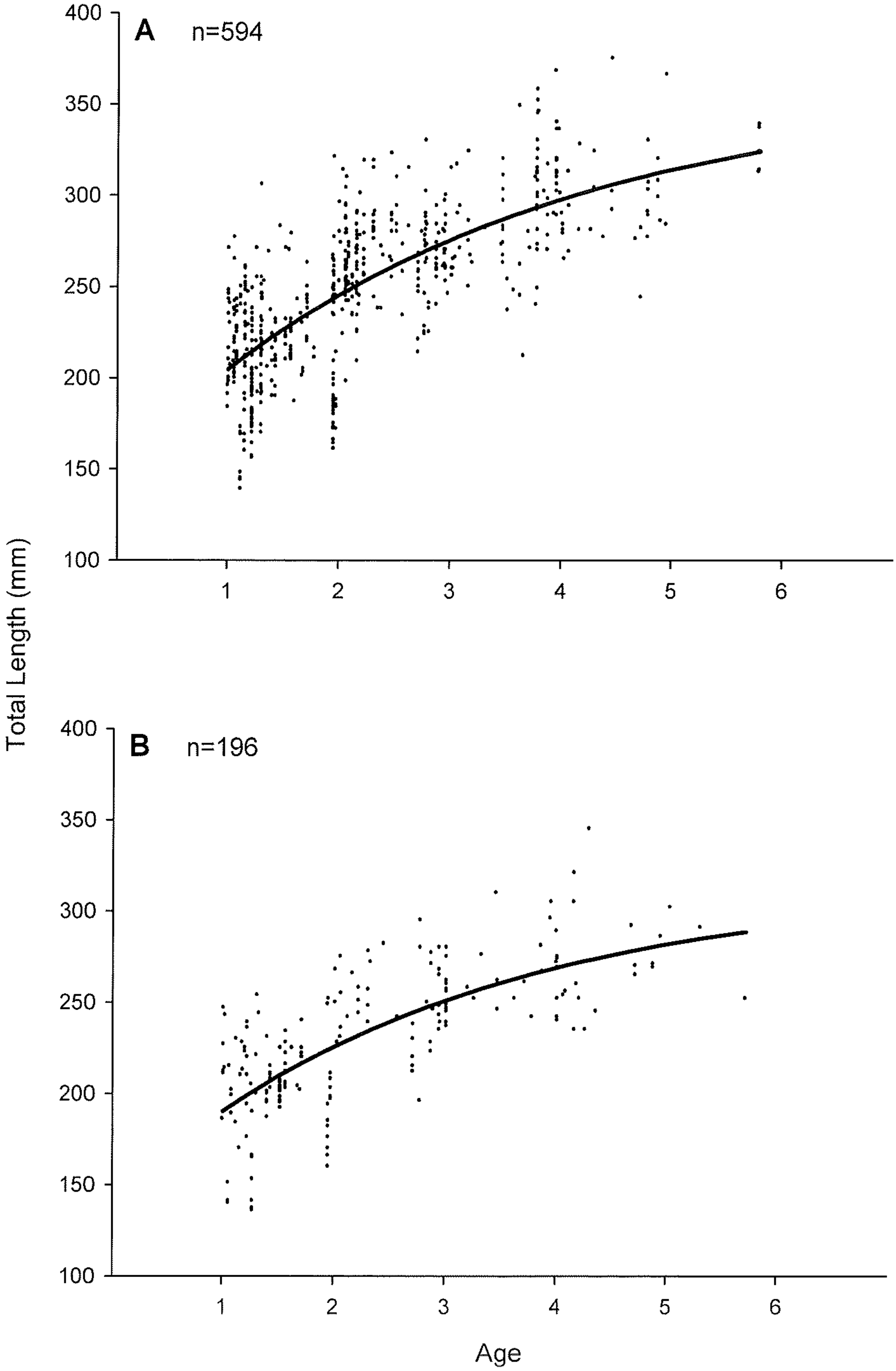

Fig. 6. Von Bertalanffy growth curves of female (A) and male (B) sand seatrout (*Cynoscion arenarius*).

reported that the species usually attains ages of less than 3 yr (Chittenden and McEachran, 1976; Barger and Johnson, 1980; Shlossman and Chittenden, 1981). Barger and Johnson (1980) estimated sand seatrout ages from sectioned otoliths but found that fish in their sample were all ages 1 or 2 yr (n = 48). Interestingly, the mean size of fish in their sample was similar to that of fish aged 4 and 5 yr in our study. Shlossman and Chittenden (1981) and Chittenden and McEachran (1976) estimated age by reading scales and through length-fre-

TABLE 2. Length : weight and length : length relationships of sand seatrout by sex and estuary (Cedar Key, Tampa Bay, and Charlotte Harbor). WT = weight (g), GFWT = gonad-free weight (g), TL = total length (mm), SL = standard length (mm).

Group	Y	X	n	Range SL	Range TL	$Y = a + bX$		r^2
						a	b	
				Length : Weight				
Cedar Key males and females	Log10(WT)	Log10(TL)	544	91–305	111–358	−5.262	3.0965	0.982
Cedar Key males and females	Log10(WT)	Log10(SL)	544	91–305	111–358	−4.576	2.9025	0.974
Cedar Key males and females	Log10(GFWT)	Log10(TL)	544	91–305	111–358	−5.135	3.0389	0.983
Cedar Key males and females	Log10(GFWT)	Log10(SL)	544	91–305	111–358	−4.461	2.8482	0.974
Tampa Bay males and females	Log10(WT)	Log10(TL)	202	119–313	147–375	−4.978	2.9749	0.962
Tampa Bay males and females	Log10(WT)	Log10(SL)	202	119–313	147–375	−4.347	2.7993	0.948
Charlotte Harbor males	Log10(WT)	Log10(TL)	86	140–263	170–302	−4.122	2.6218	0.968
Charlotte Harbor males	Log10(WT)	Log10(SL)	86	140–263	170–302	−3.836	2.5832	0.9593
Charlotte Harbor females	Log10(WT)	Log10(TL)	188	95–314	121–368	−4.85	2.9375	0.978
Charlotte Harbor females	Log10(WT)	Log10(SL)	188	95–314	121–368	−4.324	2.8054	0.977
				TL : SL				
All estuaries and sexes combined	Log10(TL)	Log10(SL)	1020	91–314	111–375	12.099	1.1313	0.989
All estuaries and sexes combined	Log10(SL)	Log10(TL)	1020	91–314	111–375	−8.502	0.8745	0.989

quency analyses. Their analyses indicated that most fish in their sample were 1 or 2 yr of age with a few 3-yr-old fish. Whether the sand seatrout populations sampled in these studies actually had different age and growth characteristics than those in our study or if results were affected by differences in sampling or aging technique is unknown and would require additional work to resolve. However, with regard to aging techniques, ages have frequently been underestimated in studies using scales or length-frequency analysis in other species of fish (Beamish and McFarlane, 1987). Benefield (1970) abandoned attempts to age sand seatrout by scales because the scales' annuli were too difficult to distinguish. In the closely related weakfish, a comparison of estimated ages based on otoliths and scales demonstrated that ages estimated using scales were less precise than those estimated using otoliths, and ages estimated using scales tended to be lower than those estimated using otoliths (Lowerre-Barbieri et al., 1994). Barger and Johnson (1980) also found that the precision of annulus counts was lower when sand seatrout scales were used than it was when otoliths were used. Because no exceptionally large sand seatrout were captured in our study [the largest sand seatrout reported in the literature (Vick, 1964) was about 220 mm larger than the largest fish captured in this study], it is possible that the species lives beyond 5 yr of age.

Growth.—Information on sand seatrout growth functions was not available in the literature for comparison purposes. Length-at-age of sand seatrout was quite variable between individuals, but within the limits previously reported for this species (Shlossman, 1980). Other closely related species, such as spotted seatrout (Murphy and Taylor, 1994) and weakfish (Lowerre-Barbieri et al., 1995), have also shown great variability at age. The protracted spawning period that these species have has been recognized as a factor contributing to wide variability in length-at-age (Lowerre-Bar-

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bieri et al., 1995). We suspect that the protracted spawning period and period of annulus formation, our application of a median hatch date, and a small number of samples for some older age groups contributed to the finding of negative growth in some instances.

The observed mean length of females at any given age was always larger than that of males, which has also been observed in other studies of sand seatrout (Franks et al., 1972; Shlossman and Chittenden, 1981). Predicted length-at-age also indicated that females were larger than males. The observed mean lengths-at-age were similar to those reported by Shlossman and Chittenden (1981) based on analysis of scales and length frequency. However, based on sectioned otoliths, Barger and Johnson (1980) reported a much larger observed size (308 mm TL) for fish with one annulus.

Spotted seatrout from Florida demonstrated much faster growth (Murphy and Taylor 1994) than we found for sand seatrout. Spotted seatrout length at age 1 yr ranged from about 100 mm to nearly 200 mm greater than sand seatrout at age 1 yr, depending upon the sex of the fish and the estuary sampled. After age 1 yr, spotted seatrout growth slowed, but the length of most 2-yr-old fish exceeded the length of the largest sand seatrout captured in this study. The length of weakfish in Chesapeake Bay at age 1 yr was similar to that of sand seatrout, but a higher growth rate was maintained at subsequent ages, and the mean length of weakfish at age 3 yr was greater than any sand seatrout captured in this study (Lowerre-Barbieri et al., 1995). Considering the differences in growth between sand seatrout and these two congeners, study of the growth characteristics of hybrids would be of interest.

Sand seatrout from Texas waters (Moffett et al., 1979; Shlossman and Chittenden, 1981) increased in weight per unit length at a rate faster than reported here, whereas fish from other areas of the northern Gulf of Mexico gained weight at rates similar to those found in this study (Dawson, 1964; Sheridan et al., 1984). Only Cedar Key females had a significantly different length:weight relationship between total wet weight and gonad-free weight. This was likely because of the fact that most of the sand seatrout sampled from Cedar Key waters were collected during the spawning season (as evidenced by enlarged and ripening gonads in the sampled fish), when gonad weight composed a higher percentage of total body weight than during the rest of the year.

Sand seatrout live beyond the age previously reported in the literature, and quite possibly beyond the age reported here. We suspect the differences in reported age between previous studies and this one were because of the methodologies used. Sagittal otolith analysis may be a more accurate method for aging sand seatrout than scales or length-frequency analysis. Growth of sand seatrout differed between sexes, but was remarkably similar between the three estuarine populations. Length-at-age for sand seatrout was less than its congeners, but the species nonetheless reached a harvestable size by 1 yr of age. Among the parameters examined, none differed sufficiently between estuaries to suggest the presence of distinct stocks of sand seatrout.

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Literature Cited

Barger, L. E., and A. G. Johnson. 1980. An evaluation of marks on hardparts for age determination of Atlantic croaker, spot, sand seatrout, and silver seatrout. NOAA Technical Memorandum NMFS-SEFC-22. U.S. Department of Commerce, NOAA, NMFS, Southeast Fisheries Center, Panama City Laboratory, Panama City, Florida.

Beamish, R. J., and G. A. McFarlane. 1987. Current trends in age determination methodology, p. 15–42. *In:* The age and growth of fish. R. C. Summerfelt and G. E. Hall (eds.). The Iowa State University Press, Ames, IA.

Benefield, R. L. 1970. A study of sand seatrout (*Cynoscion arenarius* Ginsburg) of the Galveston Bay area, p. 217–225. *In:* Texas Parks & Wildlife Dept. Coast. Fish. Proj. Rep. 4-1400-CF-3-1, Austin, Texas.

Chittenden, M. E. Jr., and J. D. McEachran. 1976. Composition, ecology, and dynamics of demersal fish communities on the northwestern Gulf of Mexico continental shelf, with a similar synopsis for the entire gulf. Texas A&M University, Dept.

of Wildlife and Fisheries Sciences, Sea Grant Publ. TAMU-SG-76-208:1–16.

Crabtree, R. E., C. W. Harnden, D. Snodgrass, and C. Stevens. 1996. Age, growth, and mortality of bonefish, *Albula vulpes,* from the waters of the Florida Keys. Fish. Bull. 94:442–451.

Dawson, C. E. 1964. Length–weight relationships of some Gulf of Mexico fishes. Trans. Am. Fish. Soc. 94:279–280.

Ditty, J. G., M. Bourgeois, R. Kasprzak, and M. Konikoff. 1991. Life history and ecology of sand seatrout *Cynoscion arenarius* Ginsburg, in the northern Gulf of Mexico: a review. Northeast Gulf Sci. 12:35–47.

Flores-Coto, C., A. Sanchez-Iturbe, F. Z. Avala-Garcia, and S. M. Warlen. 1998. Age, growth, mortality and food habits of larval *Stellifer lanceolatus, Cynoscion arenarius* and *Cynoscion nothus* (Pisces: Sciaenidae), from the southern Gulf of Mexico. Estuar. Coast. Shelf Sci. 47:593–602.

Franks, J. S., J. Y. Christmas, W. L. Siler, R. Combs, R. Waller, and C. Burns. 1972. A study of nektonic and benthic faunas of the shallow Gulf of Mexico off the State of Mississippi. Gulf Res. Rep. 4(1):90–91.

Ginsburg, I. 1930. Review of the weakfishes (Cynoscion) of the Atlantic and Gulf coasts of the United States, with a description of a new species. Bull. U.S. Bur. of Fish. 45:71–85.

Guest, W. C., and G. Gunter. 1958. The sea trout or weakfishes (Genus *Cynoscion*) of the Gulf of Mexico. Gulf States Mar. Fish. Com. Tech. Summary 1:1–40.

Gunter, G. 1938. Notes on invasion of fresh water by fishes of the Gulf of Mexico, with special reference to the Mississippi–Atchafalaya River system. Copeia 1938:69–72.

———. 1945. Studies on marine fishes of Texas. Publ. Inst. Mar. Sci., Univ. Texas 1:1–190.

Helser, T. E. 1996. Growth of silver hake within the U.S. continental shelf ecosystem of the northwest Atlantic Ocean. J. Fish Biol. 48:1059–1073.

Lowerre-Barbieri, S. K., M. E. Chittenden Jr., and L. R. Barbieri. 1995. Age and growth of weakfish, *Cynoscion regalis,* in the Chesapeake Bay region with a discussion of historical changes in maximum size. Fish. Bull. 93:643–656.

———, ———, and ———. 1996. The multiple spawning pattern of weakfish in the Chesapeake Bay and Middle Atlantic Bight. J. Fish Biol. 48: 1139–1163.

———, ———, and C. M. Jones. 1994. A comparison of a validated otolith method to age weakfish, *Cynoscion regalis,* with the traditional scale method. Fish. Bull. 92:555–568.

Moffet, A. W., L. W. McEachron, and J. G. Kay. 1979. Observations on the biology of the sand seatrout (*Cynoscion arenarius*) in Galveston and Trinity bays, Texas. Contrib. Mar. Sci. 22:163–172.

Murphy, M. D., and R. G. Taylor. 1994. Age, growth, and mortality of spotted seatrout in Florida waters. Trans. Am. Fish. Soc. 123:482–497.

National Marine Fisheries Service. 2004. Fisheries Statistics and Economics Division. Available at: www.nmfs.noaa.gov

Perret, W. S., and C. W. Caillouet Jr. 1973. Abundance and size of fishes taken by trawling in Vermillion Bay, Louisiana. Bull. of Mar. Sci. 24:52–75.

Rakicinski, C. F., B. H. Comyns, M. S. Peterson, and G. A. Zapfe. 2002. Field growth responses of juvenile white trout (*Cynoscion arenarius*) to continuous variation in physical habitat conditions. Proc. Gulf and Caribb. Fish. Inst. 53:623–635.

SAS Institute. 1989. SAS/Stat® user's guide. Version 6. 4th ed. Volumes 1–2. SAS Institute Inc., Cary, NC.

Sheridan, P. F., D. L. Trimm, and B. M. Baker. 1984. Reproduction and food habits of seven species of northern Gulf of Mexico fishes. Contrib. Mar. Sci. 27:175–204.

Shlossman, P. A. 1980. Aspects of the life history of the sand seatrout, *Cynoscion arenarius,* in the Gulf of Mexico. Masters thesis, Texas A&M Univ., College Station, TX.

———, and M. E. Chittenden. 1981. Reproduction, movements and population dynamics of the sand seatrout, *Cynoscion arenarius.* Fish. Bull., U.S. 79: 649–669.

Trent, L., and P. J. Pristas. 1977. Selectivity of gill nets on estuarine and coastal fishes from St. Andrew Bay, Florida. Fish. Bull. 75:185–189.

Vick, N. G. 1964. The marine ichthyofauna of St. Andrew Bay, Florida, and nearshore habitats of the northeastern Gulf of Mexico. Texas A&M Research Foundation, College Station Texas. A&M Project 286-D.

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