2011

Population Changes and Location-Specific Differences for Otolith-Derived Age and Growth of Recreationally Harvested Spotted Seatrout (*Cynoscion nebulosus*) From Alabama in 2007

Matthew W. Johnson
Dauphin Island Sea Lab

Stephen A. Bortone
Sanibel-Captiva Conservation Foundation

Bradley W. Klement
Sanibel-Captiva Conservation Foundation

Robert L. Shipp
University of South Alabama

Recommended Citation

Johnson, M. W., S. A. Bortone, B. W. Klement and R. L. Shipp. 2011. Population Changes and Location-Specific Differences for Otolith-Derived Age and Growth of Recreationally Harvested Spotted Seatrout (*Cynoscion nebulosus*) From Alabama in 2007. Gulf of Mexico Science 29 (1).
Retrieved from https://aquila.usm.edu/goms/vol29/iss1/2

Population Changes and Location-Specific Differences for Otolith-Derived Age and Growth of Recreationally Harvested Spotted Seatrout (*Cynoscion nebulosus*) From Alabama in 2007

MATTHEW W. JOHNSON, STEPHEN A. BORTONE, BRADLEY W. KLEMENT, AND ROBERT L. SHIPP

Spotted seatrout (*Cynoscion nebulosus*), is a nonmigratory game fish common in the Gulf of Mexico that is important in estuarine ecosystems. Population dynamics of spotted seatrout were examined using otolith-based age-and-growth models derived from observed and back-calculated length-at-age values. These data were used to identify sex-based differences and annular variation. Recent growth was quantified, using marginal increment analysis for comparisons between sexes and the two major bays in Alabama (Mobile Bay and Mississippi Sound). Sex ratios were also compared for these locations. Our results show that females were larger than males and that fish collected in Mobile Bay were larger than those from Mississippi Sound. Combined data from both bays resulted in a sex ratio that approached 1 : 1; however, examination of each bay individually showed that the Mississippi Sound had a female-biased population and that Mobile Bay had a male-biased population. Differences in observed length-at-age measurements became evident between males and females by age 2 with females typically larger than males, whereas the maximum age for males was greater. The oldest females were age 5 and the oldest males were age 8. Compared to previous estimates of trout growth in Alabama, results showed an increase in the modal length of fish and increased growth rates. Results suggest faster growth of the fish in the current population and decreased harvest of larger fish compared to historic estimates. This may be indicative of ecosystem-wide changes in spotted seatrout populations and highlights the need to closely monitor this population.

Spotted seatrout (*Cynoscion nebulosus*), is one of the most sought after species of inshore game fish along the southeastern United States (Schmidt et al., 2001; Hendon and Warren, 2003). They are a nonmigratory species found in most bay systems in the Gulf of Mexico and along the Atlantic coast (VanderKooy and Muller, 2002). Spotted seatrout have limited home ranges but are known to make intrabay migrations (Locascio and Mann, 2005; Walters, 2005; Bivins, 2011) and are an important trophic link in the estuarine food web (Hettler, 1989; Baker et al., 1993). Differences in demographics, growth characteristics, and genetics of spotted seatrout can be evident across small spatial scales (Gold et al., 1999; Bedee et al., 2002). For example, population-level differences were evident among bays in north Florida with spatial separations of tens of kilometers (Bedee et al., 2002). This combination of life history traits allows for the spotted seatrout to be managed effectively at the local level (Blanchet et al., 2001).

Growth information can be used to assess population-level responses to environmental conditions and also provide insight into population demographics and responses to harvest. Because metabolism has a significant role in otolith growth (Johnson et al., 2002; Hussy and Mosegaard, 2004), environmental variations that impact metabolic processes can also be quantified through changes in otolith morphometrics (Sinclair et al., 2002; Bortone et al., 2006). Otolith-based data of age and growth can identify changes within populations by quantifying cohort strength (Wilson et al., 2001), age related bottlenecks (Sinclair et al., 2002), and the impacts of habitat on growth (Rooker et al., 1999; Allman, 2007). Otolith-based age and growth measurements for spotted seatrout (*Cynoscion nebulosus*) have been positively correlated with seagrass abundance and salinity levels (Bortone et al., 2006). The sensitivity of otolith growth, combined with the limited variability in migration patterns, suggest that spotted seatrout age and growth has the potential to provide a predicative aspect toward the management of this species, and that the spotted seatrout may serve as an indicator species for detecting environmental variability at multiple scales (Bortone, 2003).

The spotted seatrout fishery in Alabama is the most popular inshore species targeted by recreational fishermen (ADCNR, 2007). Management of this species falls under the jurisdiction of the Alabama Department of Conservation and Natural Resources' Marine Resources Division

(ADCNR). Historically, there has been limited monitoring of the age and growth of spotted seatrout, with collections occurring in 1987, 1995–96, and 2002–06. Prior to the 2002–06 data set, fish were only collected from fishery-dependent sources (ADCNR, 2007). The mean (±SE) recreational harvest in Alabama between 2002 and 2006 was 230.4 ± 28.2 metric tons annually and the number of trips targeting spotted seatrout increased approximately 20% over that same time period. Excluding 2005, catch per unit effort (CPUE) has remained steady at approximately 0.6 fish hr^{-1}; however, harvest per unit effort has declined from 0.37 fish hr^{-1} in 2002 to 0.2 fish hr^{-1} in 2006. During 2005, CPUE increased to $\sim$ 1.1 fish hr^{-1} and harvest increased to $\sim$ 0.4 fish hr^{-1} (ADCNR, 2007). Because this is not a catch-and-release fishery, this may suggest that the population structure of spotted seatrout is shifting toward a population dominated by smaller fish. This type of shift in population structure can be harvest-related (Jennings et al., 2001).

Currently, spotted seatrout stocks are not considered to be overfished, with estimates of F being 0.72 and 0.82 for fishery dependent and fishery independent samples, respectively. However, recent increases in fishing pressure suggest that modifications may be needed for current management practices to better manage the species and prevent overfishing (ADCNR, 2007). As such, there is a need for continued monitoring of spotted seatrout population dynamics in Alabama. The objectives of this study were to model age and growth of spotted seatrout and identify area specific differences in demographics (length, age, and sex structure) between the two major bay systems within Alabama. Additionally, historic age, growth, and population structure were examined using otolith-based back-calculated techniques to assess the applicability of this technique to management of spotted seatrout.

Methods

From May to July 2007, we sampled 400 spotted seatrout from Alabama through a cooperative program with local fishing guides and clients, a fisherman-intercept program conducted during local fishing tournaments, and research-related gill net monitoring conducted by the Dauphin Island Sea Lab, Dauphin Island, AL. Alabama state waters comprise two central areas, Mobile Bay and the eastern Mississippi Sound (Fig. 1). Separation of the two bays at this location was due to the presence of a naturally occurring ''choke'' point between the deeper,

open waters of Mobile Bay proper and the shallower waters and intertidal oyster reefs of the Mississippi Sound. The area south of Dauphin Island in the Gulf of Mexico was considered part of the Mississippi Sound area because of the shallow depths and packed-sand bottom, similar to non–oyster-covered bottoms in the Mississippi Sound. Gill netting was conducted at five fixed locations (two in Mississippi Sound, three in Mobile Bay) using 30-m nets with two 15-m panels of either 5.1- and 10.1-cm mesh or 10.1- and 15.2-cm mesh. Because of the small number of fishery-independent fish collected, all the fish collected were pooled to provide for a more robust sampling of spotted seatrout. Although it is preferable to separate fishery-independent and dependent samples, low sample sizes precluded that reliable estimates would not be possible for the fishery-independent data alone. Any fish below the state size limit of 35.5 cm were collected under the appropriate scientific collection permits. For each fish, total length (TL) was measured, sex was determined macroscopically, area of capture was identified, and sagittal otoliths were removed for ageing.

Unless missing, damaged, or broken, the left otolith was used to determine age. Otoliths were sectioned transversely with a low-speed wafering saw following VanderKooy and Guindon-Tisdel (2003) and examined at ×12 with a stereomicroscope fitted to a high-resolution camera. Ages were estimated by counting the number of opaque and clear annulus pairs present in the section using methods identical to those described in Bortone et al. (2006). Because all the fish were collected over a 2-mo period near the theoretical hatch date (1 July), ring counts were considered to be actual age (Brown-Peterson et al., 1988; Brown-Peterson and Warren, 2001; Nieland et al., 2002). Otolith images were saved with PictureFrame® software and analyzed with ImagePro Express® image-analysis software. Otolith radius and annular radii were measured along the short axis parallel to the sulcus.

Back-calculated size at annulus formation was determined from fish size at capture, otolith radius, and annular radii using the Frasier–Lee method (see Morita and Matsuishi, 2001):

$$Li = a + (Lc - a) \times (Oi/Oc)$$

where Li = the TL (mm) of the fish when it became age i, a = the y-axis (TL) intercept of the relationship between otolith radius (abscissa) and TL (ordinate), Lc = TL (mm) at capture, Oi = distance (mm) from otolith core to distal edge of annulus at age i, and Oc = otolith radius
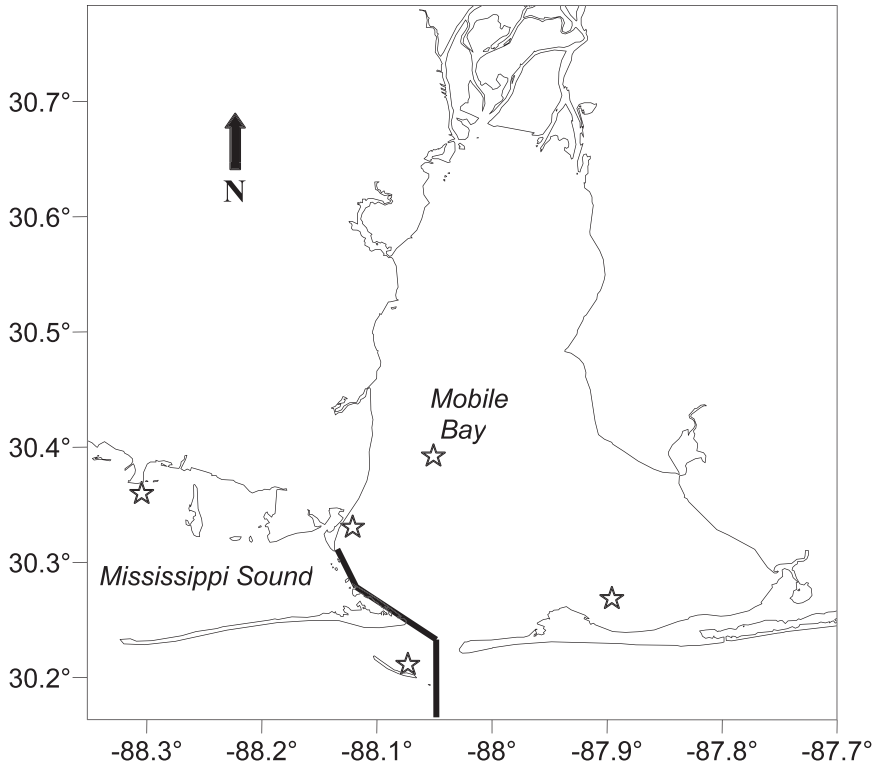
Fig. 1.   Alabama state waters designated for spotted seatrout (*Cynoscion nebulosus*) collections. The bold line represents the separation between Mobile Bay and Mississippi Sound sampling locations. Stars represent locations where research-related gill net collection occurred.

(mm). Back-calculation methods have been used for many species and rely on the assumption that there is a proportional relationship between somatic growth and otolith growth (Vigliola et al., 2000; Araya and Cubillos, 2002). Although this assumption is often violated (Araya and Cubillos, 2002), this technique has been successfully demonstrated for spotted seatrout by Bortone et al. (2006).

Growth comparisons between Mobile Bay and Mississippi Sound for fish collected were made using an estimate of recent growth along the margin of the otolith (clear otolith growth beyond the last opaque zone formed). To obtain this value, we divided the marginal increment by the month of capture to standardize growth to age (μm mo^{-1}). Because spotted seatrout make predictable intrabay migrations but minimal interbay migrations (Clark et al., 2002), and sampling was limited to a single season, specific growth responses should have been accurately attributed to specific areas (bays).

To examine differences in observed TL and observed age, a two-way analysis of variance (ANOVA) was performed for each dependent variable where sex and area were fixed, independent factors. To identify differences in recent growth from marginal increment analysis, a two-way analysis of covariance was used where area was the independent variable and age, fork length, and sex were the covariates. All values were transformed using a log transformation to meet the homogeneity of variance assumption (Sokal and Rohlf, 1981). Because previous studies indicate differences in size-at-age for spotted seatrout (Murphy and Taylor, 1990; Nieland et al., 2002), Student's t-tests were used to examine observed size-at-age between sexes to identify the age when differences in size become evident. A nonparametric binomial response test (SPSS, v. 11) was used to examine sex ratios between Mobile Bay and Mississippi Sound. The expected response for this test was a 1 : 1 ratio, male to female.

Observed and back-calculated growth rates were modeled using the Regression Wizard subroutine in SigmaPlot®. The relationship between age and TL was best described for males and females separately using a two-parameter power regression. A von Bertalanffy growth equation (VBGE) was estimated for observed female fish for comparative purposes

with previous studies (ADCNR, 2007). To compare estimated annual growth among cohorts from back-calculated growth values, we used an ANOVA. Cohorts were classified as: 2002–06 for age 1, 2003–06 for age 2, 2004–06 for age 3, and 2005–06 for age 4. Data from one hatch year was considered independent from any other hatch year. Post hoc comparisons were made with a Bonferroni test to minimize experiment-wise error rates. Due to the limited number of older spotted seatrout collected, results were restricted to fish < 5 yr old. Sexes were also analyzed separately because they grow at different rates (Murphy and Taylor, 1990; Murphy and McMichael, 2003; Nieland et al., 2002). To compare the parameters of our actual and back-calculated VBGEs with ADCNR's previously estimated parameters from 1995–96 and 2000–06, we used a likelihood ratio test using Solver function in Microsoft Excel 2007 (Kimura, 1980; Cerrato, 1990; Haddon, 2000). For all tests except the Bonferroni post hoc analysis, *P*-values were considered significant at the $\alpha < 0.05$ level.

Results

Overall, a total of 400 spotted seatrout were collected during the early summer months of 2007. Thirty-four (8.5%) were captured by hook and line by amateur fishermen from tournaments, 324 (81.0%) were captured by hook and line by fishing guides, and 42 (10.5%) from gill nets (Fig. 2). In general, guides captured fish over the entire size range whereas tournaments collected larger fish and gill nets collected smaller fish. One hundred and seventy fish were collected from Mobile Bay and 207 were collected from Mississippi Sound. Capture area for 23 fish was unknown.

Demographics of the seatrout collected varied between sexes and between areas within Alabama waters. Most females were 400–500 mm TL whereas the modal length of males was 400–450 mm TL (Fig. 3). Females were significantly longer than males (mean ± SE: 449.9 ± 4.6 mm and 405.0 ± 3.9 mm, respectively) ($F_{1,373} = 88.7$, $P < 0.001$) and fish collected in Mobile Bay were significantly longer than Mississippi Sound (441.6 ± 4.4 mm and 413.6 ± 4.4 mm, respectively) ($F_{1,373} = 53.1$, $P < 0.001$). The sex × area interaction term for TL was nonsignificant. Although females were longer than males, males were, on average, older than females (3.1 ± 0.07 yr vs 2.4 ± 0.05 yr) ($F_{1,373} = 61.9$, $P < 0.001$). Average age also differed between Mobile Bay and Mississippi Sound (3.1 ± 0.08 yr vs 2.56 ± 0.06 yr) ($F_{1,373} = 15.2$, $P < 0.001$). Females ranged in age from 1 to 5 yr with a mode of 2 yr

and males ranged from 1 to 8 yr with a mode of 3 yr (Fig. 4). There was no significant sex × area interaction with age. The sex ratio for all fish collected was 0.54 males : 0.46 females and was not significantly different from a 1 : 1 ratio ($P = 0.15$). Alternatively, sex ratios were significantly different in Mobile Bay, where they were male-biased (68% males; $P < 0.001$), and Mississippi Sound, where they were female-biased (58% females; $P = 0.26$).

Marginal increment analysis identified differential growth between the two areas sampled. Fish collected from Mississippi Sound experienced higher recent otolith, and presumably somatic, growth (0.017 ± 0.0004 μm) than those from Mobile Bay (0.014 ± 0.0004 μm) ($F_{1,371} = 16.05$, $P < 0.001$). All otoliths showed complete opaque zone formation for the winter of 2006–07 at the time of collection. Additionally, fish age, TL, and sex were not significant covariates.

Observed spotted seatrout power-regression models showed sexual dimorphism in the Alabama trout population. Size-at-age for females was greater than for males for all age classes (Fig. 5). Significant differences for size-at-age were evident for all fish age 2 and older (age 2: $t_{150} = 9.61$, $P < 0.001$; age 3: $t_{156} = 15.67$, $P < 0.001$; age 4: $t_{34} = 6.34$, $P < 0.001$; age 5: $t_{25} = 6.01$, $P < 0.001$). Estimated parameters for the female VBGE showed asymptotic maximum length (L_{inf}) values that were greater than previous estimates and a growth coefficient that was smaller than previous estimates. All parameter values were significantly different than the values estimated by ADCNR for fish collected in 1995–96 and 2000–06 (Table 1).

Back-calculated growth models resulted in adequate estimates of growth for spotted seatrout. Power regressions underestimated length-at-age values by 4.6% or less compared to observed TL for males and females (Fig. 5). Like the parameter estimates from the observed data, VBGE parameters estimated from back-calculated values resulted in maximum length values that were greater than previous estimates and a growth coefficient that was smaller than previous estimates. All parameter values were significantly different than values estimated by ADCNR for fish collected in 1995–96 and 2000–06 (Table 1).

Cohort analyses of the different-aged fish indicated significant differences for 2003 age 2 fish (males and females) compared to other years. Specifically, age 2 males in the 2003 cohort had a mean size that was greater than the age 2 fish belonging to the 2004 and 2005 cohorts (ANOVA: $F_{3,191} = 3.95$, $P = 0.01$; Bonferroni post hoc: 2003 vs 2004, mean difference = 9.6, *P*
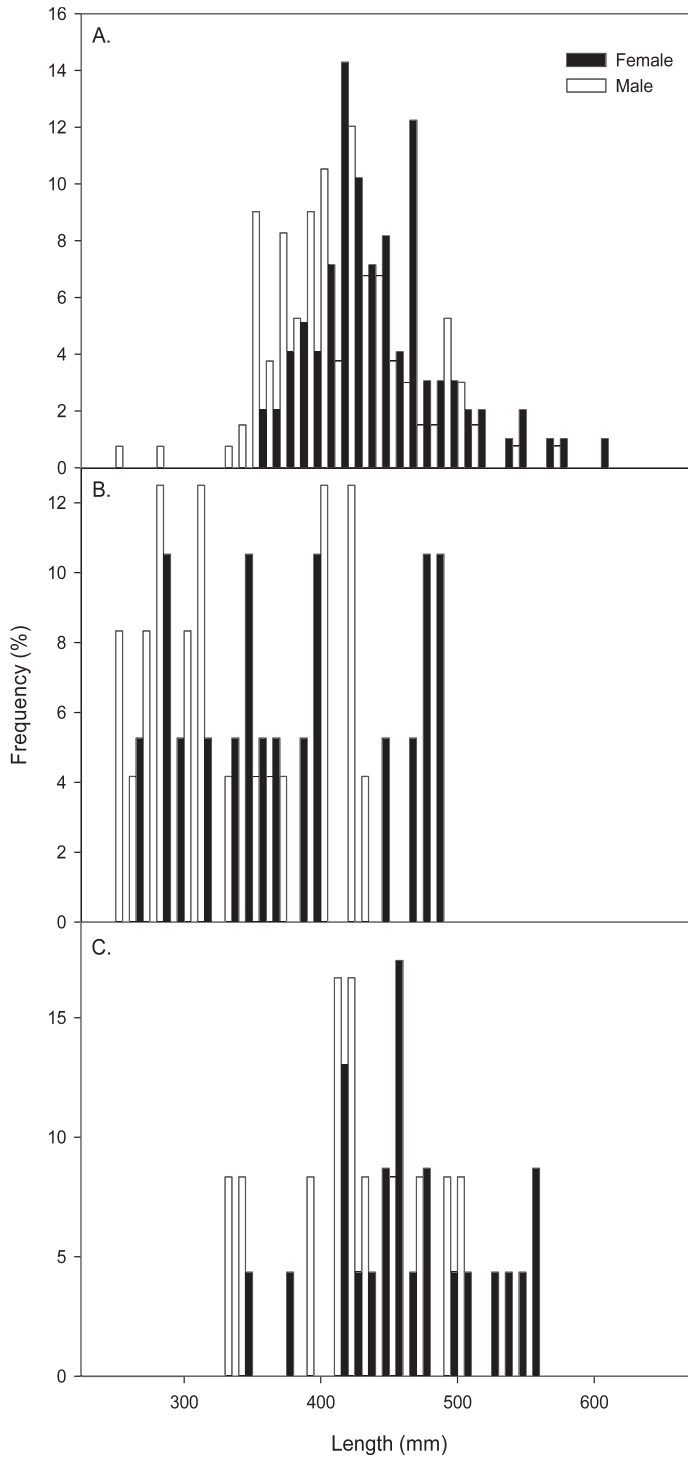
Fig. 2.   Total length–frequency histograms for female and male spotted seatrout (*Cynoscion nebulosus*) collected in Alabama during 2007 by collection method. Panel A represents fish collected from guides, panel B represents fish collected from gillnets, and panel C represents fish collected during tournaments.
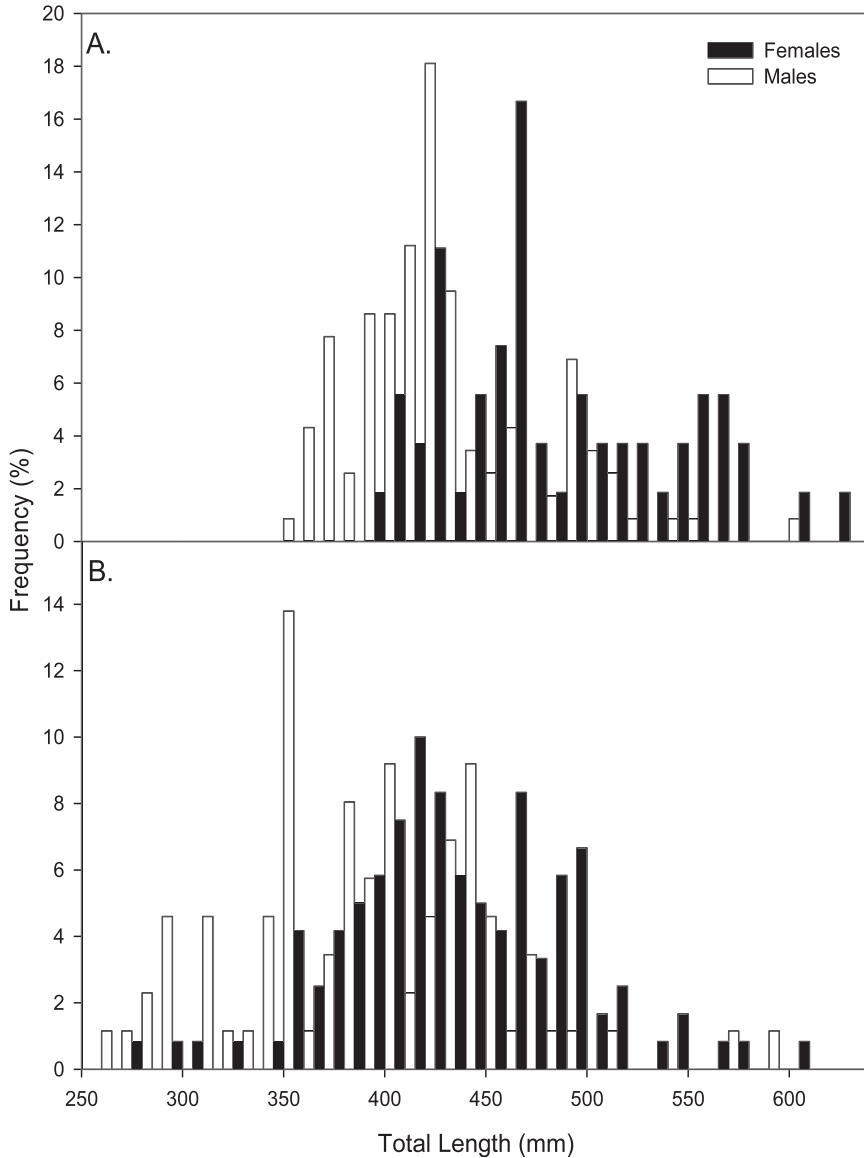
Fig. 3. Total length-frequency histograms for female and male spotted seatrout (*Cynoscion nebulosus*) collected in Alabama during 2007. Panel A represents Mobile Bay and panel B represents Mississippi Sound. Data were binned in 10-cm intervals.

= 0.03; 2003 vs 2005, mean difference = 13.4, P = 0.01). For age 2 females in the 2003 cohort, mean size was greater than the age 2 fish belonging to the 2005 cohort (ANOVA: $F_{3,191}$ = 4.04, P = 0.01; Bonferroni post hoc: 2003 vs 2005, mean difference = 7.83, P = 0.03) (Table 2).

DISCUSSION

Observed and back-calculated age and growth of seatrout in Alabama showed an increase in fish length compared to previous surveys suggesting that the average fish being harvested is larger than historical catches, but that there are fewer of these larger fish present in the population as suggested by the increase in CPUE and by the decline in yield per unit of effort (ADCNR, 2007). This could be the result of selective harvesting of older fish or an increase in the number of smaller fish within the population. This trend was evident in regression analysis, VBGEs, and length–frequency histograms. These results are not an artifact of use
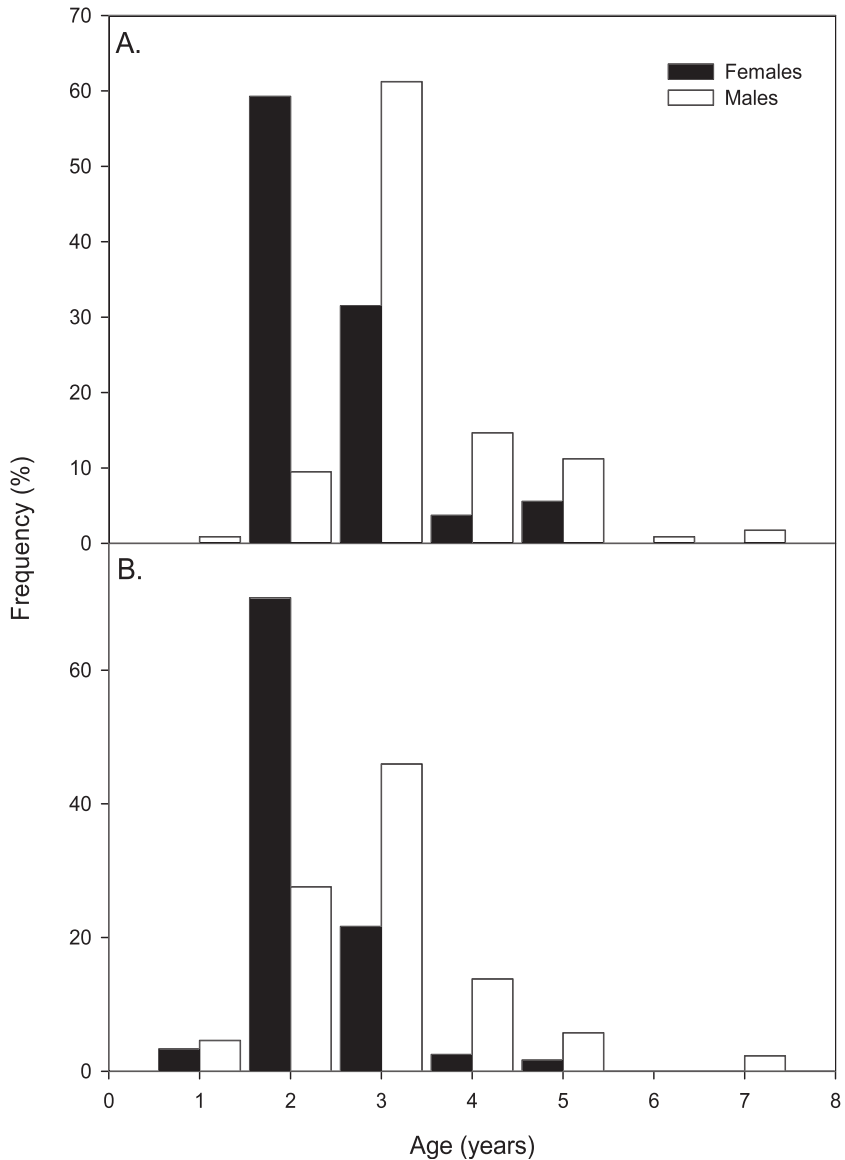
Fig. 4.   Age–frequency histograms for female and male spotted seatrout (*Cynoscion nebulosus*) collected in Alabama during 2007. Panel A represents Mobile Bay and panel B represents Mississippi Sound.

of fishery-dependent data, because prior to 2002, all age and growth analysis of fish collected by ADCNR were from creel surveys and tournament landings. Additionally, estimates from both data sets should converge in older fish, but they do not. ADCNR's assessment of spotted seatrout caught in the recreational fishery between 2002 and 2006 had a length–frequency analysis with mode of approximately 381 mm (ADCNR, 2007), approximately 10% less than the current study. However, we found that the growth rate coefficient (K) in the VBGE remained within the

range of historic values (0.35–0.53). By calculating size-at-age from ADCNR's age-and-growth estimates then applying our power regression techniques to these values (ADCNR, 2007), our model resulted in growth that was approximately 9% higher than in previous ADCNR estimates. At the macro scale, observed age and growth during 2007 was comparable to estimates of seatrout growth along the western Gulf of Mexico. Prior to 2006, age and growth estimates from Alabama were, however, more similar to locations along the northern and eastern Gulf of Mexico (see
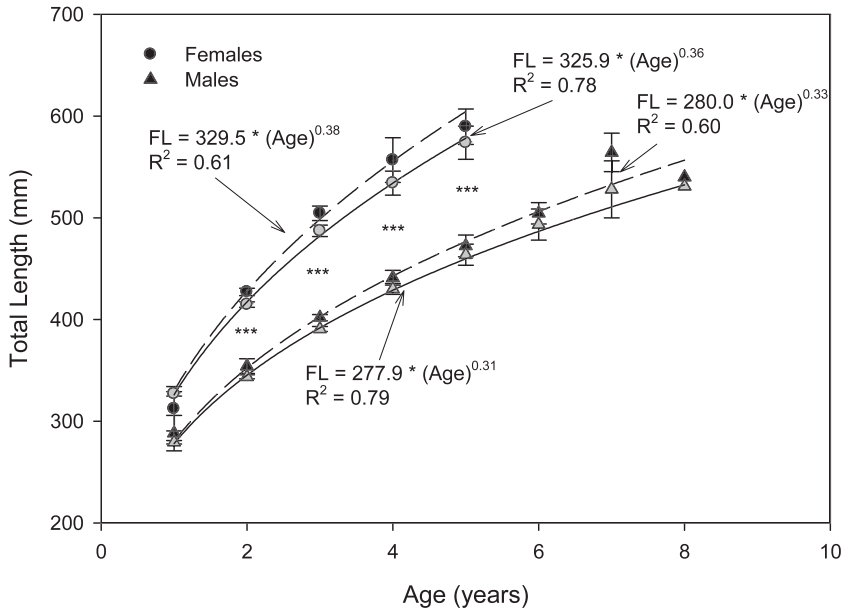
Fig. 5. Mean total lengths at age for observed (black) and back-calculated (gray) male and female spotted spotted seatrout collected in Alabama during 2007. Power regressions for captured fishes are represented by the dashed lines and regressions for back-calculated values are represented by the solid lines. Age-specific significant differences ($P < 0.05$) in length for captured fish are represented by asterisks (***).

review in GMFMC, 2001; Nieland et al., 2002; Murphy and McMichael, 2003). Changes at this scale may be indicative of changes at the ecosystem level rather than at the local level.

Shifts in fisheries production can result from environmental changes or catch-related demographic restructuring (Walters and Martell, 2004). In Alabama, there have been no changes in harvest regulations of spotted seatrout since 2000; however, there has been an increase in fishing pressure, a relatively constant CPUE, and a decline in yield per unit of effort (ADCNR, 2007). These data suggest that populations of younger fish are increasing, but that they are not entering the fishery. This shift in growth seems to be sudden, as it was not evident in the ADCNR's 2002–06 survey (ADCNR, 2007). Minimum and/or maximum size are commonly used management tools for spotted seatrout (GMFMC, 2001; VanderKooy and Muller, 2002; Hendon and Warren, 2003) and population structure of seatrout and other sciaenids can be highly influenced by fishing pressure and size limits (Murphy and Crabtree, 2001; Hendon and Warren, 2003). Removal of the fastest-growing fish could result in shifts in population structure (Zhao et al., 1997; Hsieh et al., 2010). However, if this is occurring in this population, it is expected that there would be a reduction in the variance of growth rates as slower-growing

fish became a larger part of the population. These data suggest no standardization of growth rates, indicating that catch-related restructuring of the population may not be structuring the population. Environmental changes may be the most important forcing factors. Spotted seatrout are known to have variable growth rates among estuaries, often related to environmental forcing, even when subjected to identical harvest restrictions (Bedee et al., 2002; Nieland et al., 2002; VanderKooy and Muller, 2002; Nieland and Wilson, 2005; Bortone et al., 2006).

Differences in demographics between Mississippi Sound and Mobile Bay seen in this study can be attributed to variability in habitat selection by male and female seatrout during summer spawning. This may be due to seasonal demographic segregation via intrabay migrations rather than the presence of two separate populations. Female spotted seatrout prefer to spawn in areas where there are deep channels with moving water such as in open bays, between barrier islands, or at the mouth of an embayment (Saucier et al., 1992; Saucier and Baltz, 1993). The Mississippi Sound has greater variability in depth and more islands, and is typically shallower than Mobile Bay. Mobile Bay, more specifically lower Mobile Bay, is a typical open water system with depth gradients that are sloping rather than steep drop-offs, and the primary structures are

TABLE 1. Estimated von Bertalanffy growth equation parameters (L_{inf} = asymptotic length, cm; K = von Bertalanffy growth coefficient; t_0 = theoretical age [yr] at a length of zero) from this study and those estimated by the Alabama Department of Conservation and Natural Resources (ADCNR, 2007) (section A) and results for likelihood ratio tests comparing results from this study to recent ADCNR estimates (section B). Coincident model terms from one group were set equal to terms in second group (see Haddon, 2000). Significant results are denoted by asterisks.

	Coincident	Parameters			R^2	n
		L_{inf}	K	t_0		
A.						
Observed		659.2 ± 45	0.40 ± 0.10	−0.59 ± 0.39	0.61	183
Back-calculated		707.0 ± 49	0.27 ± 0.04	−1.32 ± 0.20	0.78	449
ADCNR 1995–96		642	0.5335	−0.3449		495
ADCNR 2002–06		564	0.4689	−0.4005		549
B.						
Observed vs 1995–96						
X^2	27.70	4.63	113.13	14.59		
df	1	1	1	1		
P	< 0.001*	0.03*	< 0.001*	< 0.001*		
Observed vs 2000–06						
X^2	121.19	173.89	49.07	20.04		
df	1	1	1	1		
P	< 0.001*	< 0.001*	< 0.001*	< 0.001*		
Back-calculated vs 1995–96						
X^2	111.20	115.19	1325.17	620.75		
df	1	1	1	1		
P	< 0.001*	< 0.001*	< 0.001*	< 0.001*		
Back-calculated vs 2000–06						
X^2	432.9	41.6	995.0	44.3		
df	1	1	1	1		
P	< 0.001*	< 0.001*	< 0.001*	< 0.001*		

oil platforms and a subtidal, low-relief oyster reef (May and Bland, 1970; Chen et al., 2005). These characteristics may make Mississippi Sound more conducive for spawning activities, resulting in greater numbers of females in the Mississippi Sound compared to Mobile Bay.

Although there was little evidence of variation among cohorts, there was faster growth for the age 2 fish from the 2003 cohort, but it remains unknown why this was not evident for other age classes during the same year (i.e., age 3 from 2002 or age 1 fish from 2004). Faster growth in 2003 was interesting given the possibility of increased competition for resources resulting from the 2002 year class (age 2 fish in 2003) being 18% larger than the 2001 year class and 10% larger than the 2000 year class (ADCNR, 2007). Growth could be the result of record rainfalls during spring and early summer 2003 triggering a decade-high abundance of brown and white shrimp between 2003 and 2004 (NWS, 2003; Ware and Thomson, 2005; NMFS, 2006a, b). Shrimp is one of the primary prey items throughout the life history of spotted seatrout (Carr, 1973; Lassuy, 1983; Minello, 1984).

Alternatively, decreased salinity levels in Mobile Bay over several months (MBNEP, 2003) could have resulted in increased vulnerability for typical prey items as they were forced from their home niche in search of more saline habitats. If these two events coincided with the ontogenetic prey preferences of this cohort, this could explain the increased growth for only a single age group.

The ability to retrospectively evaluate the long-term impact of environmental disturbances in costal environments is important because resources and time are often limited for extensive monitoring programs. Since spotted seatrout move throughout the estuary in a predictable manner based on salinity and temperature (Baltz et al., 2003), changes in seatrout demographics may be a good proxy for system-wide disturbances. This may be even more important in systems without active monitoring programs. For example, Bortone et al. (2006) determined that the variations in salinity and the areal extent of seagrasses in a south Florida estuary were positively correlated with the back-calculated, otolith-derived growth for age 1 spotted seatrout.

TABLE 2. Mean back-calculated growth estimates based on total length (±SE) during multiple years for the 2002–06 year classes of spotted seatrout collected in Alabama. Significant differences are represented by uppercase letters.

| | Hatch year | | | | | |
	2002	2003	2004	2005	2006	Combined mean
Males						
Age 1	275.4 ± 4.3	272.3 ± 3.6	280.8 ± 2.1	283.4 ± 4.9	275.0 ± 15.8	279.3 ± 1.7
Age 2	66.3 ± 3.7	72.7 ± 3.0 A	63.1 ± 1.4 B	59.3 ± 3.5 B		64.2 ± 1.2
Age 3	46.7 ± 2.2	45.4 ± 1.5	47.2 ± 0.8			46.8 ± 0.7
Age 4	39.4 ± 1.6	41.0 ± 1.2				40.4 ± 1.0
Females						
Age 1	331.1 ± 8.5	315.6 ± 7.2	331.2 ± 4.2	326.6 ± 2.9	296.0 ± 22.7	326.9 ± 2.2
Age 2	79.8 ± 2.2 B	106.4 ± 7.9 A	92.0 ± 3.4	84.6 ± 1.8 B		87.1 ± 1.1
Age 3	62.4 ± 2.8	68.7 ± 5.4	66.0 ± 1.9			65.8 ± 1.6
Age 4	53.5 ± 2.8	52.5 ± 3.0				53.1 ± 2.0

Although not necessarily causative, an increase in suitable habitat and salinity levels that remain above a critical level could provide favorable conditions that enable rapid growth of juvenile spotted seatrout.

Although our analysis was limited to a single year of collection, our results concur with the opinions expressed in the latest stock assessment that spotted seatrout stock in Alabama may be experiencing population changes (ADCNR, 2007). Typically, a shift toward larger fish is indicative of success in fisheries management (e.g., implementation of size-based harvest restrictions); however, yield per unit of effort should also increase (Quinn and Deriso, 1999). This has not happened in the Alabama fishery. Identifying the underlying reason for these population trends may be critical to expanding our understanding seatrout populations in this region. Because our back-calculated regression estimates were 4% less than the regressions derived from the observed data and we limited our analysis to fish 5 yr old or younger, back-calculated lengths appearing smaller for older fish (Lee's phenomenon) was not problematic in these data (Duncan, 1979; Murphy and McMichael, 2003). Difference in models may also be indicative of the recent changes in population structure toward smaller fish. Without the recent changes, we would have expected back-calculated growth to be closer to 10% less than our observed values, matching the change in mode and observed growth rates.

In conclusion, as long as spotted seatrout remains a highly desired recreational species in Alabama, caution should be expressed related to the health of the population. The unique characteristics of this fish make it a model for small-scale, local management; moreover, population-wide effects may be quicker to manifest than in larger populations. Monitoring efforts should be increased to identify basin-wide changes in population dynamics and preemptive corrective actions that can be taken to maximize the long-term health of fishery.

LITERATURE CITED

[ADCNR] ALABAMA DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES. 2007. Spotted seatrout assessment Alabama Department of Conservation and Natural Resources–Marine Resources Division. Gulf Shores, AL.

ALLMAN, R. J. 2007. Small-scale spatial variation in the population structure of vermilion snapper (*Rhomboplites aurorubens*) from the northeast Gulf of Mexico. Fish. Res. 88:88–99.

ARAYA, M., AND L. CUBILLOS. 2002. The retrospective analysis of the growth in fish and their associated problems. Gayana 66:161–179.

BAKER, W. B., G. C. MATLOCK, L. MCEACHRON, A. W. GREEN, AND H. E. HEGEN. 1993. Movement, growth,

and survival of spotted seatrout tagged in Bastrop Bay, Texas. Contrib. Mar. Sci. 29:91–101.

BALTZ, D. M., R. G. THOMAS, AND E. J. CHESNEY. 2003. Spotted seatrout habitat affinities in Louisiana, p. 147–176. *In:* Biology of the spotted seatrout. S. A. Bortone (ed.). CRC Press, Boca Raton, FL.

BEDEE, C. D., D. A. DEVRIES, S. A. BORTONE, AND C. L. PALMER. 2002. Estuary-specific age and growth of spotted seatrout in the northern Gulf of Mexico, p. 57–77. *In:* Biology of the spotted seatrout. S. A. Bortone (ed.). CRC Press, Boca Raton, FL.

BIVINS, L. 2011. Large-scale movement patterns of spotted seatrout (*Cynoscion nebulosus*) among south Texas estuaries and the Gulf of Mexico. Thesis. Department of Life Sciences, Texas A&M Univ.– Corpus Christi, Corpus Christi, TX.

BLANCHET, H., M. VAN HOOSE, L. McEACHRON, B. MULLER, J. WARREN, J. GILL, T. WALDROP, J. WALLER, C. ADAMS, R. DITTON, D. SHIVELY, AND S. VANDERKOOY. 2001. The spotted seatrout fishery of the Gulf of Mexico, United States: a regional management plan, Gulf States Marine Fisheries Commission, Ocean Springs, MS, p. 204.

BORTONE, S. A. 2003. Spotted seatrout as a potential indicator of estuarine condition, p. 297–300. *In:* Biology of the spotted seatrout. S. A. Bortone (ed.). CRC Press, Boca Raton, FL.

———, A. J. MARTIGNETTE, AND J. P. SPINELLI. 2006. Spotted seatrout (family Sciaenidae) as an indicator of estuarine conditions in San Carlos Bay, Florida. Fla. Sci. 69:127–139.

BROWN-PETERSON, N. J., P. THOMAS, AND C. R. ARNOLD. 1988. Reproductive biology of the spotted seatrout, *Cynoscion nebulosus*, in south Texas. Fish. Bull. 86:373–388.

———, AND J. W. WARREN. 2001. The reproductive biology of spotted seatrout, *Cynoscion nebulosus*, along the Mississippi Gulf Coast. Gulf Mex. Sci. 19:61–73.

CARR, W. E. A., AND A. CLAYTON. 1973. Food habits of juvenile marine fishes occupying seagrass beds in the estuarine zone near Crystal River, Florida. Trans. Am. Fish. Soc. 102:511–540.

CERRATO, R. M. 1990. Interpretable statistical tests for growth comparisons using parameter in the von Bertalanffy equation. Can. J. Fish. Aquat. Sci. 47:1416–1426.

CHEN, Q., H. ZHAO, K. HU, AND S. L. DOUGLASS. 2005. Prediction of wind waves in a shallow estuary. J. Waterway Port Coastal Ocean Eng. 131:137–148.

CLARK, R. D., W. MORRISON, J. D. CHRISTENSEN, M. E. MONACO, AND M. S. COYNE. 2002. Modeling the distribution and abundance of spotted seatrout: integration of ecology and GIS technology to support management needs, p. 247–265. *In:* Biology of the spotted seatrout. S. A. Bortone (ed.). CRC Press, Boca Raton, FL.

DUNCAN, K. W. 1979. On the back-calculation of fish lengths; modifications and extensions to the Fraser-Lee equation. J. Fish Biol. 16:725–730.

[GSMFC] GULF STATES MARINE FISHERIES COMMISSION. 2001. The spotted seatrout fishery of the Gulf of Mexico, United States: a regional management plan. Publication 87. Ocean Springs, MS.

GOLD, J. R., L. R. RICHARDSON, AND C. FURMAN. 1999. Mitocondrial DNA diversity and population structure of spotted seatrout (*Cynoscion nebulosus*) in coastal waters of the southeastern United States. Gulf Mex. Sci. 17:40–50.

HADDON, M. 2000. Modelling and quantitative methods in fisheries Chapman & Hall/CRC, Boca Raton, FL.

HENDON, J. R., AND J. R. WARREN. 2003. Management of spotted seatrout in Mississippi: effects of changing the minimum size limit. Proc. Gulf Caribb. Fish. Inst. 54:622–634.

HETTLER, W. F., JR. 1989. Food habits of juveniles of spotted seatrout and gray snapper in western Florida Bay. Bull. Mar. Sci. 44:155–162.

HSIEH, C.-H., A. YAMAUCHI, T. NAKAZAWA, AND W.-F. WANG. 2010. Fishing effects on age and spatial structures undermine population stability of fishes. Aquat. Sci. 72:165–178.

HUSSY, K., AND H. MOSEGAARD. 2004. Atlantic cod (*Gadus morhua*) growth and otolith accretion characteristics modeled in a bioenergetics context. Can. J. Fish. Aquat. Sci. 61:1021–1031.

JENNINGS, S., M. J. KAISER, AND J. D. REYNOLDS. 2001. Marine fisheries ecology Blackwell Science, Malden, MA.

JOHNSON, M. W., J. R. ROOKER, D. M. GATLIN III, AND G. J. HOLT. 2002. Effects of variable ration levels on direct and indirect measures of growth in juvenile red drum (*Sciaenops ocellatus*). J. Exp. Mar. Biol. Ecol. 274:141–157.

KIMURA, D. K. 1980. Likelihood methods for the von Bertalanffy growth curve. Fish. Bull. 77:765–766.

LASSUY, D. R. 1983. Species profiles: life histories and environmental requirements (Gulf of Mexico) for spotted seatrout. Service, U.S. Fish and Wildlife Service. Slidell, LA.

LOCASCIO, J. V., AND D. A. MANN. 2005. Effects of Hurricane Charley on fish chorusing. Biol. Lett. 1:362–365.

MAY, E. B., AND D. G. BLAND. 1970. Survival of young oysters in areas of different salinity in Mobile Bay. Proc. Southeast. Assoc. Game Fish Comm. 23: 519–521.

[MBNEP] MOBILE BAY NATIONAL ESTUARY PROGRAM. 2003. Environmental monitoring data download, Dauphin Island, Mobile Bay Mobile Bay National Estuary Program, Mobile, AL.

MINELLO, T. J., AND R. J. ZIMMERMAN. 1984. Selection for brown shrimp, *Penaeus aztecus*, as prey by the spotted seatrout, *Cynoscion nebulosus*. Contrib. Mar. Sci. 27:159–167.

MORITA, K., AND T. MATSUISHI. 2001. A new model of growth back-calculation incorporating age effect based on otoliths. Can. J. Fish. Aquat. Sci. 58: 1805–1811.

MURPHY, M. D., AND R. E. CRABTREE. 2001. Changes in the age structure of nearshore adult red drum off west-central Florida related to recruitment and fishing mortality. N. Am. J. Fish. Manag. 21:671–678.

———, AND R. H. McMICHAEL, JR. 2003. Age determination and growth of spotted seatrout, *Cynoscion nebulosus* (Pisces: Sciaenidae), p. 41–56. *In:* Biology of the spotted seatrout. S. A. Bortone (ed.). CRC Press, Boca Raton, FL.

———, AND R. G. TAYLOR. 1990. Age, growth, and mortality of spotted seatrout in Florida waters. Trans. Am. Fish. Soc. 123:482–497.

NIELAND, D. L., R. G. THOMAS, AND C. A. WILSON. 2002. Age, growth, and reproduction of spotted seatrout in Barataria Bay, Louisiana. Trans. Am. Fish. Soc. 131:245–259.

———, AND C. A. WILSON III. 2005. Geographic variation in longevity and growth of spotted seatrout, *Cynoscion nebulosus*, in Louisiana, USA. Proc. Gulf Caribb. Fish. Inst. 56:841–843.

[NMFS] NATIONAL MARINE FISHERIES SERVICE. 2006a. Annual commercial landing statistics for brown shrimp in Alabama 1992–2006. www.st.nmfs.noaa.gov. Date accessed: March 2006.

———. 2006b. Annual commercial landing statistics for white shrimp in Alabama 1992–2006. www.st.nmfs.noaa.gov. Date accessed: March 2006.

[NWS] NATIONAL WEATHER SERVICE. 2003. May–June–July storms set rainfall records in Southeast U.S. NOAA Magazine, National Oceanic and Atmospheric Administration, www.noaanews.noaa.gov/stories/s2007.htm. Accessed: June 2007

QUINN, T. J., AND R. B. DERISO. 1999. Quantitative fish dynamics Oxford University Press, New York.

ROOKER, J. R., S. A. HOLT, G. J. HOLT, AND L. A. FUIMAN. 1999. Spatial and temporal variability in growth, mortality, and recruitment potential of postsettlement red drum, *Sciaenops ocellatus*, in a subtropical estuary. Fish. Bull. 97:581–590.

SAUCIER, M. H., AND D. M. BALTZ. 1993. Spawning site selection by spotted seatrout, *Cynoscion nebulosus*, and black drum, *Pogonias cromis*, in Louisiana. Environ. Biol. Fish. 36:257–272.

———, ———, AND W. A. ROUMILLAT. 1992. Hydrophone identification of spawning sites of spotted seatrout *Cynoscion nebulosus* (Osteichthys: Sciaenidae) near Charleston, South Carolina. Northeast Gulf Sci. 12:141–145.

SCHMIDT, T., G. DELGADO, AND M. ALVARADO. 2001. Assessment of the recreational sport fisheries of Florida Bay and adjacent waters from 1985–1998. Proc. Gulf Caribb. Fish. Inst. 52:385–401.

SINCLAIR, A. F., D. P. SWAIN, AND J. M. HANSON. 2002. Disentangling the effects of size-selective mortality, density, and temperature on length-at-age. Can. J. Fish. Aquat. Sci. 59:372–382.

SOKAL, R. R., AND F. J. ROHLF. 1981. Biometry W.H. Freeman, San Francisco.

VANDERKOOY, S., AND K. GUINDON-TISDEL. 2003. A practical handbook for determining the ages of Gulf of Mexico fishes Gulf States Marine Fisheries Commission, Oceans Springs, MS.

———, AND R. G. MULLER. 2002. Management of spotted seatrout and fishery participants in the U.S., p. 227–245. *In:* Biology of the spotted seatrout. S. A. Bortone (ed.). CRC Press, Boca Raton, FL.

VIGLIOLA, L., M. HARMELIN-VIVIEN, AND M. G. MEEKAN. 2000. Comparison of techniques of back-calculation of growth and settlement marks from the otoliths of three species of Diplodus from the Mediterranean Sea. Can. J. Fish. Aquat. Sci. 57:1291–1299.

WALTERS, C. J., AND S. J. D. MARTELL. 2004. Fisheries ecology and management. Princeton University Press, Princenton, NJ.

WALTERS, S. 2005. Mapping Tampa Bay *Cynoscion nebulosus* spawning habitat using passive acoustic surveys. M. S. Thesis. Marine Science. University of South Florida, Tampa, FL.

WARE, D. M., AND R. E. THOMSON. 2005. Bottom-up ecosystem trophic dynamics determine fish production in the northeast Pacific. Science 308:1280–1284.

WILSON, C. A., A. L. STANLEY, AND D. L. NIELAND. 2001. Age estimates from annuli in otoliths of red snapper, *Lutjanus campechanus*, from the northern Gulf of Mexico. Proc. Gulf Caribb. Fish. Inst. 52:48–62.

ZHAO, B., J. C. MCGOVERN, AND P. J. HARRIS. 1997. Age, growth, and temporal change in size at age of the vermilion snapper from the South Atlantic Bight. Trans. Am. Fish. Soc. 126:181–193.

(MWJ) DAUPHIN ISLAND SEA LAB, FISHERIES ECOLOGY LAB, 101 BIENVILLE BOULEVARD, DAUPHIN ISLAND, ALABAMA 36528; (SAB, BWK) SANIBEL-CAPTIVA CONSERVATION FOUNDATION, 900 A TARPON BAY ROAD, SANIBEL, FLORIDA 33957; AND (RLS) UNIVERSITY OF SOUTH ALABAMA, DEPARTMENT OF MARINE SCIENCE, LCSB 025, MOBILE, ALABAMA 36688. PRESENT ADDRESSES: (MWJ) HARTE RESEARCH INSTITUTE, TEXAS A&M UNIVERSITY-CORPUS CHRISTI, 6300 OCEAN DRIVE, UNIT 5869, CORPUS CHRISTI, TEXAS 78412-5869; (SAB) GULF OF MEXICO FISHERY MANAGEMENT, 2203 N. LOIS AVENUE, TAMPA, FLORIDA 33607; (BWK) 13110 BELLA CASA CIRCLE NO. 108, FORT MEYERS, FLORIDA 33966. Date accepted: February 15, 2011