Gulf of Mexico Science

Volume 19
Number 1 *Number 1*

Article 3

2001

Abundance, Spatial Distribution, and Mortality of Young-of-the-Year Spotted Seatrout (*Cynoscion nebulosus*) Along the Gulf Coast of Florida

Gary A. Nelson
Florida Fish and Wildlife Conservation Commission

Deborah Leffler
Florida Fish and Wildlife Conservation Commission

DOI: 10.18785/goms.1901.03

Gulf of Mexico Science, 2001(1), pp. 30–42

Abundance, Spatial Distribution, and Mortality of Young-of-the-Year Spotted Seatrout (*Cynoscion nebulosus*) Along the Gulf Coast of Florida

GARY A. NELSON AND DEBORAH LEFFLER

We used fixed-station and random-station sampling data from the period 1989–97 to examine spatial and temporal patterns in the abundance and size structure of young-of-the-year (YOY) spotted seatrout, *Cynoscion nebulosus*, in three Florida estuaries. YOY seatrout first appeared at shallow-water (<1.5 m) seine sites in May–June in Choctawhatchee Bay (Florida Panhandle) and in April–May in Tampa Bay and Charlotte Harbor (both along the southwest Florida peninsula). Spotted seatrout were caught at deepwater (>1.6 m) trawl stations within 1–3 mo of their initial appearance at shallow-water sites. Most spotted seatrout were caught in waters <3.7 m. Spring and summer peaks in YOY abundance, corresponding to strong influxes of newly spawned individuals, were observed only in southwest peninsula estuaries. Depending on the estuary, the occurrence of YOY spotted seatrout at shallow-water sites was associated with some combination of seagrasses, mangroves, salinity, depth, temperature, and mud. Estimates of total instantaneous mortality rates for YOY spotted seatrout in Tampa Bay were $0.027 \cdot d^{-1}$ for fixed sites and to $0.025 \cdot d^{-1}$ for randomly selected sites.

Young-of-the-year (YOY) spotted seatrout, *Cynoscion nebulosus,* play important ecological roles in estuarine and nearshore waters of Florida. They are prey for fish and birds (Carr and Adams, 1973; Johnson and Seaman, 1986) and prey upon a range of invertebrates and fish (Carr and Adams, 1973; McMichael and Peters, 1989), often to a degree that the abundance of their prey may be affected (Johnson, 1982).

Despite the ecological importance of YOY spotted seatrout, their population dynamics in western Florida estuaries have not been adequately examined. The published literature includes only information on estimates of age, growth, and spawning dates and descriptions of food habits and habitat associations (Springer and Woodburn, 1960; Carr and Adams, 1973; McMichael and Peters, 1989). Whether seasonal changes in the abundance and size structure of YOY spotted seatrout occur throughout entire estuaries or what factors influence their spatial distribution is unknown because past studies have had limited spatial coverages (sites were sampled in waters <1.5 m) and short sampling durations (<2 yr) (Springer and Woodburn, 1960; Carr and Adams, 1973; McMichael and Peters, 1989). In addition, natural mortality rates of YOY have not been estimated.

In this study, we used 4–9 yr of data to document seasonal changes in abundance and size structure in shallow- and deepwater areas, to identify factors that are associated with YOY spotted seatrout spatial occurrences, and to estimate mortality rates of YOY spotted seatrout along the gulf coast of Florida, USA.

METHODS

YOY spotted seatrout [≤100 mm standard length (SL)] were studied in Choctawhatchee Bay and Santa Rosa Sound (surface area: ca. 450 km^2), a temperate estuary located in the western Florida Panhandle, and in Tampa Bay (ca. 886 km^2) and Charlotte Harbor (ca. 575 km^2), more subtropical estuaries located on the gulf side of the Florida peninsula (Fig. 1). All three systems are characterized by average depths of <5 m, salinities of 0–36 ppt, freshwater inflow from rivers, and expanses of bottom vegetation, primarily seagrasses (*Halodule wrightii* and *Thalassia testudinum*), in shallow areas.

Spotted seatrout were sampled monthly from 1989 to 1995 at shallow-water (<1.5 m) fixed seine and deepwater (>1.6 m) fixed trawl sites. Monthly sampling began in 1993 in Choctawhatchee Bay, in 1989 in Tampa Bay, and in 1991 in Charlotte Harbor. Fixed sites were approximately evenly distributed throughout shallow- and deepwater areas. Fish were collected in a 21.3-m × 1.8-m, 3.2-mm stretched-mesh seine or a 6.1-m, 38-mm stretched-mesh otter trawl containing a 3.2-mm stretched-mesh codend liner. At beach sites, seines were set adjacent to the shoreline and hauled onshore; at offshore sites, seines were set in open-water habitats away from the shoreline and retrieved offshore. Trawls were towed

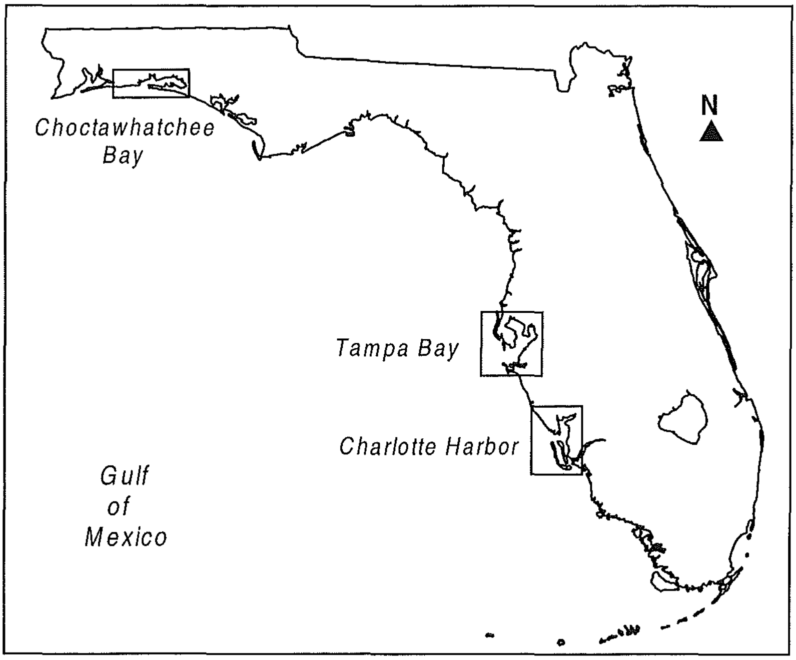

Fig. 1. Map of Florida showing the locations of Choctawhatchee Bay, Tampa Bay, and Charlotte Harbor.

at 1 knot for 10 min. Three seine hauls or trawl tows were made at each fixed site during daylight hours. Sampling occurred during the first 2 wk of each month.

Spotted seatrout were also sampled monthly at randomly selected sites so more accurate estimates of YOY relative abundance could be determined and the spatial distribution of YOY spotted seatrout in each bay could be described. To coordinate sampling logistics, each bay was subdivided into four or five arbitrarily lettered zones. All zones encompassed about equal areas. Within each zone, 1″ latitude × 1″ longitude microgrids, representing the sites to be sampled, were randomly selected within randomly selected 1′ latitude × 1′ longitude grids. At each site, one haul or tow was made with the use of the same gears and deployment techniques as those used at fixed stations. Monthly random sampling was conducted in Choctawhatchee Bay in 1996 and in Tampa Bay and Charlotte Harbor in 1996 and 1997.

For all collections, total numbers of spotted seatrout were counted, standard lengths for up to 100 randomly selected individuals per sample were measured (±1 mm), and all fish were released. Salinity (ppt), temperature (C), dissolved oxygen (ppm) levels, and depth (m) were also recorded at all sites. Dominant bottom and shoreline vegetation and sediment (mud or sand) types were recorded only at seine sites because visual assessment of bottom characteristics at trawl sites was hindered by depth.

Seasonal changes in YOY relative abundance and size structure.—To examine seasonal changes in YOY relative abundance in the shallow- and deepwater areas, comparable monthly catch rates (mean number of individuals per 100 m^2) were calculated from fixed-site and random-site sampling data by year. We separated YOY data used in all analyses from data on older individuals by using maximum size limits selected from monthly length–frequency plots. Monthly length frequencies were constructed by calculating the proportions of fish found in each length class in each year, combining yearly distributions, and standardizing the cumulative proportions to 1. Length maximum size limits used were in general agreement with those determined from analyses of the otoliths of YOY spotted seatrout from Tampa Bay (McMichael and Peters, 1989). In addition, summary statistics (mean, minimum, and maximum) of monthly length data were calculated and used to identify seasonal changes in size structure at shallow-water seine sites.

Depth distribution.—To determine whether YOY were restricted to particular depth ranges during the period surrounding peak abundance, the cumulative frequency distributions of trawl depths and depths at which YOY spotted seatrout occurred were compared by using the Kolmogorov–Smirnov two-sample test (Siegel, 1956; Perry and Smith, 1994). The cumulative frequency distributions for YOY spotted seatrout were constructed by weighting depth at each random site by the number of YOY spotted seatrout captured at that site. Trawl data from May–Sep. random sampling were combined over all years to examine overall trends rather than year-to-year variability.

Mortality.—Daily instantaneous total mortality rates were estimated for spotted seatrout by catch-curve analysis (Ricker, 1975). Natural log-transformed values of mean number of individuals per 100 m^2 per age class were plotted to select appropriate cutpoints for the descending limb of the catch curve. To estimate mortality, the following equation was fitted to the abundance at age data by least-squares regression (PROC REG; SAS Institute, 1990):

$$\ln(CPUE_i) = \ln(CPUE_0) - Z \cdot A_i,$$

where $\ln(CPUE_i)$ is the ln-transformed mean number of individuals per 100 m^2 at age i, $\ln(CPUE_0)$ is the intercept estimate, Z is the estimate of total instantaneous mortality per day (slope), and A_i is the age class in days (Ricker, 1975). The age composition of YOY spotted seatrout in seine catches was estimated from length and abundance data with the age–length predictive equation,

$$A = 12.472 + 1.836 \cdot L - 0.005 \cdot L^2, \quad r^2 = 0.88,$$

derived from YOY otolith-aged spotted seatrout in Tampa Bay (McMichael and Peters, 1989). Mortality rates were estimated only for the Tampa Bay population to avoid biases associated with potential interbay differences in growth rates of YOY spotted seatrout (Westerheim and Ricker, 1978). We used data only from months during which the effects of immigration in shallow-water areas appeared to be minimal to avoid potential biases in the rates of decline in abundance. Immigration was assumed low when no decline in minimum size and/or no substantial increases in catch rates were observed. Bias due to emigration was assumed low because there was no evidence of migration from the shallow-water areas, and the maximum size limits selected data on fishes that could not avoid the seines. Abundance data were averaged over all years prior to calculation of mean number of individuals at age to reduce the effects of interannual variability.

Factors influencing YOY spatial occurrence.—We examined variation in YOY seatrout occurrences in shallow-water areas by using multiple logistic regression (Agresti, 1996) to model the presence/absence of spotted seatrout in random seine catches as a response surface to year, deployment technique, sediment types, bottom vegetation, depth, temperature, dissolved oxygen, salinity, and shoreline vegetation. We chose to examine spatial distribution on the basis of occurrences because initial analyses with a delta-lognormal model (Lo et al., 1992; Stefansson, 1996) indicated that most of the total variation in YOY abundance that could be accounted for by predictors occurred in the presence/absence data. Therefore, the probability of the presence of spotted seatrout was modeled as a binary response function of the following form:

$$\log[P/(1 - P)] = \alpha + \sum_{i=1}^{n} \beta_i X_i + \epsilon,$$

where $P = Pr(Y = 1|X)$ is the response probability, X_i is the ith explanatory variable, n is the number of explanatory variables, α is the intercept, β_i is the slope coefficient of explanatory variable i, and ϵ is the error term (Agresti, 1996).

The selection of explanatory variables in the multiple logistic regression was accomplished by a stepwise logistic procedure (SAS Institute, 1997) with variables entered and removed on the basis of a selection criterion of $P \leq 0.05$. Only data from July–Sep. 1996 for Choctawhatchee Bay and June–Sep. of 1996 and 1997 for Tampa Bay and Charlotte Harbor were used in the analyses because the spatial extent of YOY seatrout distribution in each bay reached its maximum during these months. The presence/absence of bottom vegetation (primarily seagrasses: *H. wrightii, T. testudinum,* and *Syringodium filiforme*), mangrove (*Rhizophora mangle, Avicennia germinans,* and *Laguncularia racemosa*) stands, rocks/seawall structures, bare shoreline, overhanging shrubs/trees (e.g., *Quercus* spp.), reeds/marsh grasses (e.g., *Juncus roemerianus, Spartina alterniflora*), and mud were coded as dummy variables (i.e., 0 if absent and 1 if present). Depth, temperature, salinity, and dissolved oxygen were transformed with $\ln(x + 1)$. First-order interactions among the continuous and dummy variables were included for selection in the initial model. Interactions were considered important only if the associated main effects were also retained by the selection procedure, otherwise the interaction was dropped and the analysis was re-

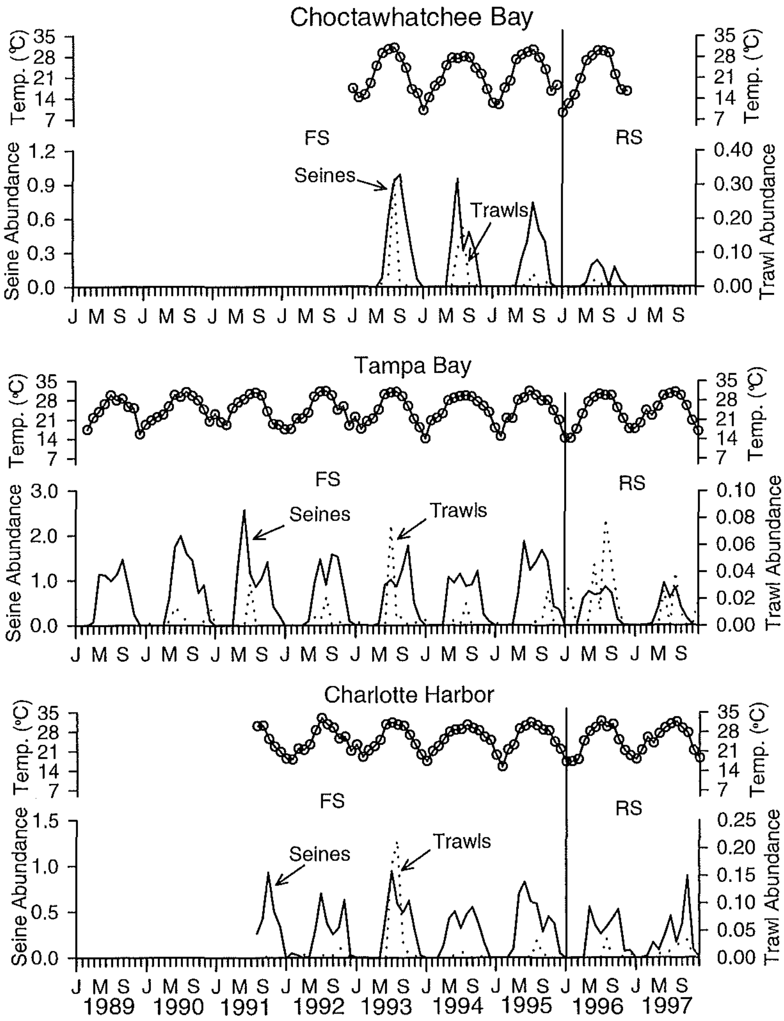

Fig. 2. Monthly relative indices of young-of-the-year abundance (no. of fish per 100 m^2) and mean monthly water temperature at fixed (FS) and random (RS) seine and trawl sites from 1989 to 1997 in Choctawhatchee Bay, Tampa Bay, and Charlotte Harbor. Separate scales are shown for seine and trawl abundances.

peated. Plots of residual deviance and Pearson chi-square statistics, which provide measures of how well the model predicts each sample observation, were examined to help identify observations poorly fit by each model. If the absolute value of deviance and Pearson residual statistics for an observation were >2.0 and >3.0, respectively, those observations were removed from the data set and the stepwise analyses were repeated (Beauchamp et al., 1992). The final model's goodness-of-fit was evaluated by the deviance, Pearson residual chi-square statistics, the Hosmer–Lemeshow goodness-of-fit test (Hosmer and Lemeshow, 1989), and concordance measures (Beauchamp et al., 1992). Standardized regression coefficents were used to determine relative importance of selected variables. Model regression coefficients were estimated by maximum likelihood (SAS Institute, 1997).

Results

Seasonal changes in YOY relative abundance and size structure.—YOY spotted seatrout appeared first as postlarvae (9–17 mm) at shallow-water seine sites during May or June in Choctawhatchee Bay when average surface temperatures were >27 C and during April or May in Tampa Bay and Charlotte Harbor when average temperatures were >23 C (Fig. 2). Spotted seatrout were first collected at trawl sites in all

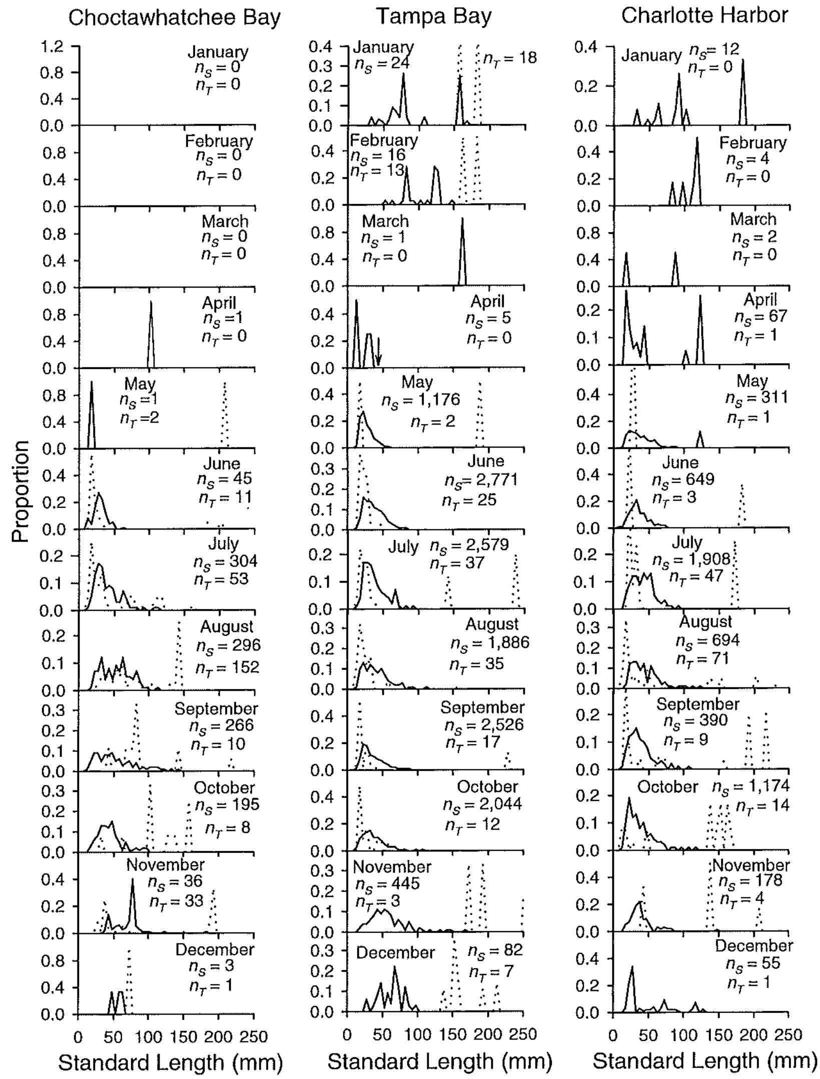

Fig. 3. Monthly length–frequency distributions of spotted seatrout captured at fixed and random seine (—) and trawl (···) sites in Choctawhatchee Bay, Tampa Bay, and Charlotte Harbor from 1989 to 1997. *n* is the number of spotted seatrout measured.

bays 1–2 mo after their initial appearance at seine sites, although their abundances in trawls were very low (Fig. 2).

Catch rates of spotted seatrout at seine sites peaked during July–Sep. in Choctawhatchee Bay and during May–July in Tampa Bay and Charlotte Harbor (Fig. 2). During midsummer (July–Aug.), catch rates of YOY spotted seatrout declined slightly in most years when water temperatures were maximum in all bays except Choctawhatchee Bay (Fig. 2). In all bays, catch rates at trawl sites generally peaked in the same month or 1–2 mo after the peak at fixed and random seine sites. A second peak in catch rates occurred in most years during Aug.–Oct. at seine sites in Tampa Bay and Charlotte Harbor (Fig. 2). Low numbers of YOY spotted seatrout were generally captured after Nov. when water temperature dropped rapidly (Fig. 2).

In all bays, the size range of YOY seatrout captured at trawl sites was generally smaller than the size range of seatrout captured at seine sites during May–Oct. (Fig. 3). Few fish <30 mm SL were captured after Oct. in any of our collections, indicating settlement of post-larvae had ended by Nov. (Fig. 3). Spotted seatrout (<75 mm SL) were caught at shallow-wa-

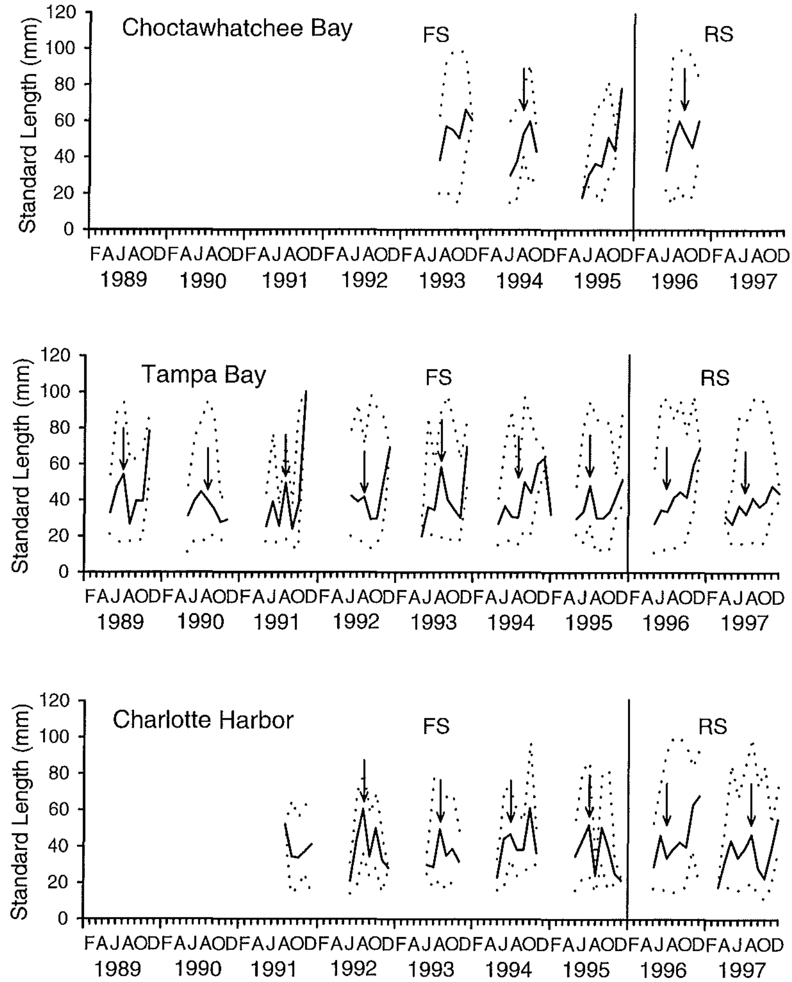

Fig. 4. Monthly mean (–), minimum and maximum (···) lengths of young-of-the-year spotted seatrout at fixed (FS) and random (RS) seine sites in Choctawhatchee Bay, Tampa Bay, and Charlotte Harbor from 1989 to 1997. Vertical arrows indicate the month of the midsummer abundance decline.

ter sites through Dec. in Choctawhatchee Bay and through Feb. in Tampa Bay and Charlotte Harbor (Fig. 3).

Plots of the monthly length statistics showed that seasonal changes in the size structure of YOY spotted seatrout occurred annually in the shallow-water areas. Mean length of YOY spotted seatrout increased after the months of first capture at fixed and random seine sites (Fig. 4). In Tampa Bay and Charlotte Harbor, mean length declined in Aug.–Sep. in most years, after the summer catch rate decline (July–Aug.). Monthly minimum and, occasionally, maximum lengths also declined during Aug.–Sep., indicating both that smaller seatrout (<25 mm SL) were recruiting to shallow-water areas on or after the summer decline in abundance and that large seatrout (>90 mm SL) had either emigrated from the shallow-water area or were avoiding the sampling gears (Fig. 4). In Choctawhatchee Bay, a similar pattern was indicated, but lengths did not decline after a summer decline in catch rates. Mean length of spotted seatrout in Tampa Bay continued to increase through fall (Oct.–Nov.) in most years, but it generally declined through late fall (Nov.–Dec.) in Charlotte Harbor (Fig. 4).

Depth distribution.—About 90% of YOY spotted seatrout caught in trawls during May–Nov. were captured in waters <3.7 m, <3.5 m, and <3.0 m in Choctawhatchee Bay, Tampa Bay, and Charlotte Harbor, respectively. Few fish (<1% of total catches) were captured in waters >4 m. The Kolmogorov–Smirnov test showed that the cumulative frequency distribution for

DOI: 10.18785/goms.1901.03

spotted seatrout depth was significantly different from that of trawl depth in Tampa Bay and Charlotte Harbor; there was no significant difference in Choctawhatchee Bay, but occurrences of spotted seatrout in trawl catches there were few (Choctawhatchee Bay: D(*KS* test statistic) = 0.31, $n_{fish\ trawls}$ = 10, n_{trawls} = 376, n.s.; Tampa Bay: D = 0.49, $n_{fish\ trawls}$ = 35, n_{trawls} = 573, $P \leq 0.001$; Charlotte Harbor: D = 0.40, $n_{fish\ trawls}$ = 17, n_{trawls} = 429, $P \leq 0.05$).

Factors associated with YOY spatial occurrence.—YOY spotted seatrout occurred at 28.7%–52.3% of the seine sites sampled during the summer periods in 1996 and 1997 (Table 1). In all bays, seatrout were captured most frequently at offshore seine sites and at sites with bottom vegetation (Table 1). In Choctawhatchee Bay, seatrout occurred most frequently at sites with seawall/rock (34.7%), reed/marsh grass (35.1%), or bare (29.0%) shorelines. In Tampa Bay and Charlotte Harbor, YOY seatrout were captured most frequently at sites with mangrove shorelines (57.4% and 59.5%, respectively) and less frequently at sites with seawall/rock (49.3% and 50.0%), reed/marsh grass (44.8% and 40.0%), or bare (35.1% and 27.8%) shorelines (Table 1). In Choctawhatchee Bay and Tampa Bay, YOY also occurred frequently at sites with mud sediments (Table 1).

The environmental parameters recorded at the capture sites were relatively similar in all three bay systems. Mean dissolved oxygen ranged 5.8–6.5 ppm, and mean temperature, 29.9–30.4 C, and mean depth was 0.7 m in all bays (Table 1). Mean salinity was the only variable that differed greatly between bays; it was lower (16.4 ppt) in Choctawhatchee Bay than in Tampa Bay (27.2 ppt) and Charlotte Harbor (26.2 ppt) (Table 1).

The probability of capturing a YOY spotted seatrout was related to some habitat attributes common to all three bays and to some that were bay specific. In all bays, the presence of bottom vegetation was the most important variable positively associated with YOY occurrences, as indicated by the standardized regression coefficents (Table 2). The probability of capturing seatrout was positively related to sampling depth and negatively related to salinity in Tampa Bay and Charlotte Harbor, and in Choctawhatchee Bay and Tampa Bay, it was positively related to dissolved oxygen levels (Table 2). The probability of capturing a YOY seatrout was also positively related to the presence of mud in Choctawhatchee Bay and to the presence of mangroves in Tampa Bay (Table 2). No first-order interactions considered in the initial selection phase remained in the logistic analyses. The nonsignificance of most goodness-of-fit statistics and the moderate to high concordance measures indicated that the final models fit the spotted seatrout data adequately after data from one random site in Choctawhatchee Bay, 11 in Tampa Bay, and 12 in Charlotte Harbor were removed from the original data sets (Table 2).

Mortality.—Estimates of daily instantaneous total mortality (*Z*) in Tampa Bay were calculated from the decline in relative abundance at age at shallow-water fixed and random seine sites; we used June data to avoid potential bias associated with the influx of the late summer cohort in July. Estimates were made for fixed-site and random-site data separately with data from age classes 42–98 days and 50–90 days, respectively (Fig. 5). Estimates of *Z* were $0.027 \cdot d^{-1}$ (fixed) and $0.025 \cdot d^{-1}$ (random) (Table 3).

Discussion

Seasonal changes in YOY abundance and size structure.—Adult spotted seatrout are believed to spawn during the night in deep channels and depressions near grass flats in high-salinity areas of estuaries when temperatures are >21 C (Tabb, 1966; Helser et al., 1993). Pelagic seatrout larvae are presumably dispersed via estuarine currents to nearshore areas, where they settle near the bottom (Peebles and Tolley, 1988). The appearance of postlarvae (9–17 mm) and small YOY spotted seatrout (<30 mm) in shallow- and deepwater sites shows that settlement occurs to both areas. The absence of spotted seatrout at deepwater sites until 1–2 mo after their first appearance at seine sites probably reflects the low levels of spawning activity during the early season (e.g., Brown-Petersen et al., 1988) and the low probability of capturing individuals when abundance is low with an inefficient sampling gear like a trawl. The occurrence of YOY seatrout mostly in waters <3.7 m is probably due to their dependence on seagrasses for cover (seagrasses are generally restricted to waters <3.0 m in Choctawhatchee Bay, Tampa Bay, and Charlotte Harbor; M. O. Ruark, Florida Marine Research nstitute, St. Petersburg, FL, pers. comm.) and to the distribution of their prey, which are also restricted to shallow-water areas (McMichael and Peters, 1989).

We believe that the differences between estuaries in the timing of the initial appearance of YOY seatrout and in the seasonal patterns of the abundance and sizes of YOY are partially

TABLE 1. (A) Total number of seine sites (n) sampled, number of sites at which spotted seatrout occurred (Trout), and percentage of seatrout occurrences (%) characterized by year, deployment technique, bottom vegetation, shoreline type, and sediment types, and (B) summary statistics for environmental parameters at sites where spotted seatrout occurred during July–Sep. in Choctawhatchee Bay and June–Sep. in Tampa Bay and Charlotte Harbor.

		Choctawhatchee Bay			Tampa Bay			Charlotte Harbor		
Variable	Category	n	Trout	%	n	Trout	%	n	Trout	%
A										
Year	1996	108	31	28.7	170	89	52.3	124	60	48.4
	1997	—	—	—	170	85	50.0	124	59	47.6
Deployment	Offshore	54	20	37.0	226	121	53.5	128	68	53.1
	Beach	54	11	20.4	114	53	46.5	120	51	42.5
Bottom vegetation	Unvegetated	72	9	12.5	134	39	29.1	52	12	23.1
	Vegetated	36	22	61.1	206	135	65.5	196	107	54.6
Shore Type	Mangrove	0	0	0.0	169	97	57.4	208	103	59.5
	Seawall	23	8	34.7	73	36	49.3	6	3	50.0
	Reeds	37	13	35.1	29	13	44.8	5	2	40.0
	Shrub/trees	13	0	0.0	5	1	20.0	3	1	33.3
	Bare shore	31	9	29.0	37	13	35.1	18	5	27.8
	Other	0	0	0.0	5	2	40.0	6	5	83.3
	Unknown	4	1	25.0	22	12	54.5	2	0	0.0
Sediment	Mud	19	11	57.9	124	71	57.2	77	37	48.0
	Sand	89	20	22.5	214	103	48.1	171	82	48.0
		Mean	SE	Range	Mean	SE	Range	Mean	SE	Range
B										
Dissolved oxygen (ppm)		6.3	0.16	3.0–8.9	5.8	0.11	0.5–11.9	6.5	0.15	1.0–11.8
Salinity (ppt)		16.4	0.65	0.0–27.7	27.2	0.28	0.3–37.0	26.2	0.49	0.8–39.0
Temperature (C)		29.9	0.14	26.7–34.5	29.9	0.08	26.3–34.6	30.4	0.10	26.1–34.6
Depth (m)		0.7	0.03	0.2–1.9	0.7	0.01	0.3–1.4	0.7	0.01	0.3–1.2

DOI: 10.18785/goms.1901.03

TABLE 2. Results of the stepwise logistic regression of the presence of young-of-the-year spotted seatrout on year, temperature, salinity, depth, dissolved oxygen, seagrasses, shore vegetation, deployment technique, and sediment type for Choctawatchee Bay, Tampa Bay, and Charlotte Harbor.

Parameter	Analysis of maximum likelihood estimates[a]		
	Parameter coefficient (SE)	Wald χ^2	Standardized coefficients
	Choctawhatchee Bay		
Intercept	−10.647 (3.9715)	7.19**	
Bottom vegetation	3.123 (0.6400)	23.81***	0.817
Mud	2.529 (0.7444)	11.53***	0.535
Dissolved oxygen	3.867 (1.9010)	4.37*	0.369
Goodness-of-fit statistics			
Chi-square	79.9 ($P > 0.90$)		
Deviance	81.2 $P > 0.90$)		
H-L test	9.8 ($P > 0.19$)		
n	107		
Concordance	0.881		
	Tampa Bay		
Intercept	6.355 (2.5226)	6.34*	
Mangrove	0.744 (0.2584)	8.29**	0.205
Bottom vegetation	1.960 (0.2791)	49.31***	0.529
Salinity	−3.468 (0.7991)	18.83***	−0.492
Depth	3.882 (0.9250)	17.61***	0.315
Dissolved oxygen	0.847 (0.3566)	5.64*	0.168
Goodness-of-fit statistics			
Chi-square	319.3 ($P > 0.60$)		
Deviance	369.9 ($P > 0.06$)		
H-L test	14.2 ($P > 0.08$)		
n	329		
Concordance	0.786		
	Charlotte Harbor		
Intercept	2.500 (1.7340)	2.08 n.s.	
Bottom vegetation	2.578 (0.4952)	27.11***	0.561
Salinity	−2.149 (0.5751)	13.97***	−0.349
Depth	4.348 (1.1826)	13.52***	0.313
Goodness-of-fit statistics			
Chi-square	235.6 ($P > 0.40$)		
Deviance	282.7 ($P < 0.02$)		
H-L test	5.3 ($P > 0.70$)		
n	236		
Concordance	0.741		

[a] n.s. = not significant, *$P \leq 0.05$, **$P \leq 0.01$, and ***$P \leq 0.001$.

related to the estuary-specific differences in the reproductive activities of adult spotted seatrout. Reproduction begins about 1 mo earlier (March–April) in southern Florida estuaries than in northern Florida Panhandle estuaries (April–May) (DeVries et al., 1997; M. D. Murphy, Florida Marine Research Institute, St. Petersburg, FL, pers. comm.), which would account for YOY appearing 1 mo earlier in Tampa Bay and Charlotte Harbor than in Choctawhatchee Bay. Spawning activity is also known to peak only once (early summer) in panhandle estuaries and twice (early spring and early summer) in the southern peninsula estuaries (Klima and Tabb, 1959; McMichael and Peters, 1989; DeVries et al., 1997). Thus, the first peak in abundance—observed during July–Sep. in Choctawhatchee Bay and May–July in Tampa Bay and Charlotte Harbor—is probably made up of those individuals spawned during spring, and the second peak in abundance—observed during Aug.–Oct. in Tampa Bay and Charlotte Harbor—is probably made up of those individuals spawned during summer. The decline in

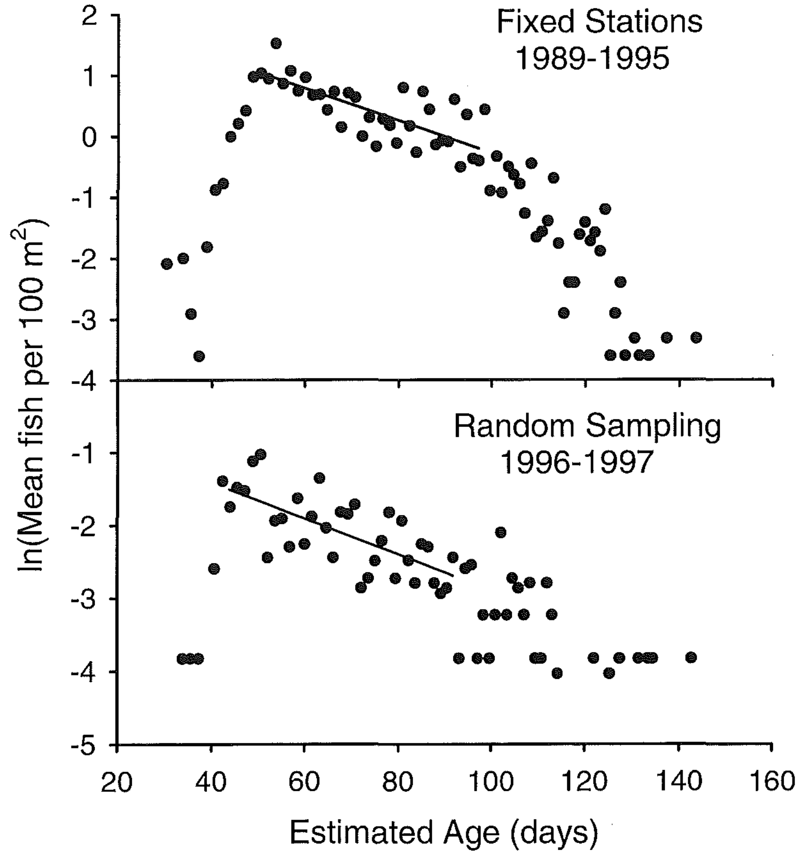

Fig. 5. Catch curves (least-square regression lines) fit to the relative abundance at age for YOY spotted seatrout at fixed stations and random sites.

mean and minimum length in late summer–early fall after the midsummer abundance decline in most years in Tampa Bay and Charlotte Harbor also confirms that the observed second peak in abundance is probably due to the settling of the second cohort of YOY in the shallow areas (Fig. 2).

Factors associated with YOY spatial occurrences.—The presence of bottom vegetation (seagrasses) was the most important habitat variable commonly associated with YOY spotted seatrout occurrences in the three Florida estuaries studied. Studies on YOY spotted seatrout by Chester and Thayer (1990), Rutherford et al. (1989), and McMichael and Peters (1989) also found that YOY seatrout distribution was associated with seagrasses. Because seagrasses provide fish with both a place to hide from predators and a place to forage for diverse prey,

TABLE 3. Summary of regression statistics from the catch curve analyses of young-of-the-year spotted seatrout in Tampa Bay at fixed sites during 1989–95 and random sites during 1996–97. Data from only age classes 42–98 days at fixed sites and 50–90 days at random sites, respectively, were used in the analyses. All intercepts and slopes were tested for significance from zero.

ln(*CPUE*$_0$)	SE[ln(*CPUE*$_0$)]	*Z*	SE(*Z*)	r^2	n
		Fixed sites 1989–95			
2.39***	0.315	−0.027***	0.0041	0.576	33
		Random sites 1996–97			
−0.41 n.s.	0.325	−0.025***	0.0046	0.483	33

***$P \leq 0.001$; n.s. = not significant.

DOI: 10.18785/goms.1901.03

seagrass habitats are believed to be very important to survival of YOY seatrout and other estuarine fishes (Stoner, 1983; Chester and Thayer, 1990; Ruiz et al., 1993; Rooker et al., 1998).

The significant associations between depth, oxygen, and mud and the spatial occurrences of YOY spotted seatrout were difficult to assess without meaningful, first-order interactions in the stepwise logistic analysis. However, because YOY abundance was strongly associated with seagrasses, the significance can be proposed in relation to the distribution of seagrasses. YOY spotted seatrout occurrences in shallow-water areas may be positively associated with water depth in Tampa Bay and Charlotte Harbor because biomass of seagrasses increases with distance from shore and depth in estuaries (Eleuterius, 1987). The positive association between dissolved oxygen and seatrout presence may reflect differences between seagrass areas (high oxygen production; Odum, 1957) and unvegetated and/or eutrophic sites (low oxygen production) of the moderately and heavily developed shorelines of Choctawhatchee Bay and Tampa Bay, respectively (Irby, 1974; Avery, 1997). Because mud is commonly associated with the patchily distributed seagrass beds in shallow-water areas of Choctawhatchee Bay (pers. obs.), higher occurrences of YOY at mud sites may be expected there.

Many fish species tend to be distributed along environmental gradients in estuaries, especially salinity gradients (Moser and Gerry, 1989; Cyrus and Blaber, 1992; Whitfield, 1999). For YOY spotted seatrout, our results strongly suggest that their spatial occurrences are negatively correlated with salinity in bays with a wide salinity range. A similar pattern in the abundance of large, post-spawning seatrout was found by Helser et al. (1993) in four Louisiana estuaries. The observed pattern may be the result of physiological preferences for salinities that minimize metabolic costs and optimize growth and survival (Wohlschlag and Wakeman, 1978) or of behavioral responses to avoid stenohaline predators (Dahlberg, 1972; Odum, 1988). It is difficult to conclude which mechanisms are operating in Tampa Bay and Charlotte Harbor because data on growth and survival over the range of environmental gradients and predator distributions are currently lacking.

Mangroves play an important role as a major source of detritus in south Florida estuaries (Lewis et al., 1985). Many fish and invertebrates eaten by YOY spotted seatrout rely on the detritus-based food web supported by mangroves. In Tampa Bay, mangrove distribution has been severely fragmented by urbanization and shoreline development (Lewis et al., 1985), but in Charlotte Harbor, where the shoreline remains relatively undeveloped, mangrove distribution is nearly continuous (Hammet, 1990; Blewett, Florida Marine Research Institute, Charlotte Harbor Field Laboratory, Port Charlotte, FL, pers. comm.). The positive relationship between mangrove presence and YOY seatrout occurrences found in Tampa Bay, but not in Charlotte Harbor, may then represent the effect of the plant's fragmented shoreline distribution and its localized influence on the detritus-based food web that supports prey of YOY seatrout.

Mortality.—Our estimates of daily mortality of YOY spotted seatrout in the shallow water of Tampa Bay were relatively low. These estimates (fixed station = 0.027; random station = 0.025) were lower than those made for YOY spotted seatrout in Florida Bay (0.035) (Rutherford et al., 1989) and were comparable to but higher than those made for YOY of estuarine-dependent species such as pinfish (*Lagodon rhomboides*) in the same Florida estuaries (0.021–0.023) (Nelson, 1998); gulf menhaden (*Brevoortia patronus*) in Fourleague Bay, LA (0.017–0.021) (Deegan, 1990); and two sciaenids; spot (*Leiostomus xanthurus*) in York River, VA (0.017) (Weinstein, 1983), and Atlantic croaker (*Micropogonias undulatus*) in Rose Bay, NC (0.023) (Currin et al., 1984).

Applying the age–length relationship for spotted seatrout developed from fish captured during the early 1980s to length data collected from seatrout captured during 1989–97 introduced a risk of biasing the age structure of the length distributions if changes in growth or survival rates had occurred between the two time periods (Westerheim and Ricker, 1978). However, this potential bias may not be great because the length data collected in this study (1989–97) and the original otolith–length data (collected in the early 1980s) used by McMichael and Peters (1989) were both combined over several years, which would have dampened interannual differences.

In summary, YOY seatrout first appeared in shallow-water areas during May–June in Choctawhatchee Bay and during April–May in Tampa Bay and Charlotte Harbor. In all bays, they were caught at deepwater sites within 1–3 mo after their shallow-water appearance. Spring and summer peaks in YOY abundance, corresponding to strong influxes of newly spawned individuals, were observed only in Tampa Bay and Charlotte Harbor. YOY spotted seatrout were generally restricted to depths <3.7 m in all bays. The occurrence of YOY spotted seatrout in shallow-water areas was associated with the presence of seagrasses and mangroves; with salinity, dissolved oxygen, and depth; and with the presence of mud sediments. Estimates of total instantaneous mortality for YOY spotted seatrout in Tampa Bay were comparable to published values for other sciaenid species.

Acknowledgments

Funding for this study was provided in part by the State of Florida Recreational Fishing License and in part by the Department of the Interior, U.S. Fish and Wildlife Service, Federal Aid for Sportfish Restoration, Project Number F-43 to the Florida Fish and Wildlife Conservation Commission. We thank the staff of the Fisheries-Independent Monitoring Program at the Florida Marine Research Institute for their dedication to sampling. H. J. Simpson provided encouragement throughout the study. Comments by Tim MacDonald, Daryl Pierce, Mike Murphy, Bob McMichael, Judy Leiby, and Jim Quinn improved the quality of the manuscript.

Literature Cited

Agresti, A. 1996. An introduction to categorical data analysis. John Wiley & Sons, Inc., New York, NY.

Avery, W. 1997. Distribution and abundance of macroalgae and seagrass in Hillsborough Bay, Florida, from 1986 to 1995, pp. 151–166. *In:* Proceedings of the Tampa Bay area scientific information symposium 3. S. F. Treat (ed.). Tampa Bay Regional Planning Council, Tampa, FL.

Beauchamp, J. J., S. W. Christensen, and E. P. Smith. 1992. Selection of factors affecting the presence of brook trout (*Salvelinus fontinalis*) in Adirondack lakes: a case study. Can. J. Fish. Aquat. Sci. 49:597–608.

Brown-Petersen, N., P. Thomas, and C. R. Arnold. 1988. Reproductive biology of the spotted seatrout, *Cynoscion nebulosus,* in South Texas. Fish. Bull. 86:373–387.

Carr, W. E. S., and C. A. Adams. 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.

Chester, A. J., and G. W. Thayer. 1990. Distribution of spotted seatrout (*Cynoscion nebulosus*) and gray snapper (*Lutjanus griseus*) juveniles in seagrass habitats of western Florida Bay. Bull. Mar. Sci. 46: 345–357.

Currin, B. M., J. P. Reed, and J. M. Miller. 1984. Growth, production, food consumption, and mortality of juvenile spot and croaker: a comparison of tidal and nontidal nursery areas. Estuaries 7(4A):451–459.

Cyrus, D. P., and S. J. M. Blaber. 1992. Turbidity and salinity in a tropical northern Australian estuary and their influence on fish distribution. Estuarine Coastal Shelf Sci. 35:545–563.

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

Deegan, L. A. 1990. Effects of estuarine environmental conditions on population dynamics of young-of-the-year gulf menhaden. Mar. Ecol. Prog. Ser. 68:195–205.

DeVries, D. A., C. D., Bedee, C. L. Palmer, and S. A. Bortone. 1997. Age, growth, maturity, and size composition of spotted seatrout, *Cynoscion nebulosus,* in the Panhandle Region of Florida. Final report for Florida Department of Environmental Protection, Marine Resources Grants MR019 and MR024.

Eleuterius, L. N. 1987. Seagrass ecology along the coasts of Alabama, Louisiana, and Mississippi. *In:* Proceedings of the symposium on sub-tropical–tropical seagrass of the southeastern United States. M. J. Durako, R. C. Phillips, and R. R. Lewis, II (eds.), Fla. Mar. Res. Publ. 42:11–25.

Hammett, K. M. 1990. Land use, water use, streamflow characteristics, and water quality characteristics of the Charlotte Harbor inflow area, Florida. U.S. Geol. Surv. Water-Supply Paper 2359-A.

Helser, T. E., R. E. Condrey, and J. P. Geaghan. 1993. Spotted seatrout distribution in four coastal Louisiana estuaries. Trans. Am. Fish. Soc. 122:99–111.

Hosmer, D. W., Jr., and S. Lemeshow. 1989. Applied logistic regression. John Wiley and Sons, Inc., New York.

Irby, E. W., Jr. 1974. A fishing survey of Choctawhatchee Bay and adjacent Gulf of Mexico waters. Fla. Mar. Res. Publ. 2.

Johnson, D. R. 1982. Effects of rainfall, recruitment, and operation of the Cedar Bayou Electric Generating Station (Baytown, Texas) on the dynamics of fish and macrocrustacean communities in the brackish water intake and discharge area. Ph.D. diss., Texas A&M Univ., College Station, TX

———, and W. Seaman, Jr. 1986. Species profiles: life history and environmental requirements of coastal fishes and invertebrates (south Florida)—spotted seatrout. U.S. Fish Wildl. Serv. Biol. Rep. 82(11.43); U.S. Army Corps of Engineers, TR EL-82-4.

Klima, E. F., and D. C. Tabb. 1959. A contribution to the biology of the spotted weakfish, *Cynoscion nebulosus* (Cuvier), from northwest Florida, with a description of the fishery. Fla. Board Conserv. Mar. Res. Lab. Tech. Ser. 30.

Lewis, R. R. III, R. G. Gilmore, Jr., D. W. Crewz, and W. E. Odum. 1985. Mangrove habitat and fishery resources of Florida, pp. 281–336. *In:* Florida aquatic habitat and fishery resources. W. Seaman, Jr. (ed.). Florida Chapter of the American Fisheries Society, Eustis, FL.

Lo, N. C., L. D. Jacobson, and J. L. Squire. 1992. Indices of relative abundance from fish spotter data based on delta-lognormal models. Can. J. Fish. Aquat. Sci. 49:2515–2526.

DOI: 10.18785/goms.1901.03

McMichael, R. H., and K. M. Peters. 1989. Early life history of spotted seatrout, *Cynoscion nebulosus* (Pisces: Sciaenidae), in Tampa Bay, Florida. Estuaries 12:98–100.

Moser, M. L., and L. R. Gerry. 1989. Differential effects of salinity changes on two estuarine fishes, *Leiostomus xanthurus* and *Micropogonias undulatus*. Estuaries 12:35–41.

Nelson, G. A. 1998. Abundance, growth, and mortality of young-of-the-year pinfish, *Lagodon rhomboides*, in three estuaries along the gulf coast of Florida. U.S. Fish. Bull. 96:315–328.

Odum, H. T. 1957. Primary production measurements in eleven Florida springs and marine turtle-grass community. Limnol. Oceanogr. 2:85–97.

Odum, W. E. 1988. Comparative ecology of tidal freshwater and salt marshes. Annu. Rev. Ecol. Syst. 19:147–156.

Peebles, E. B., and S. G. Tolley. 1988. Distribution, growth and mortality of larval spotted seatrout, *Cynoscion nebulosus*: a comparison between two adjacent estuarine areas of southwest Florida. Bull. Mar. Sci. 42:397–410.

Perry, R. I., and S. J. Smith. 1994. Identifying habitat associations of marine fishes using survey data: an application to the northwest Atlantic. Can. J. Fish. Aquat. Sci. 51:589–602.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Can. 191:1–382.

Rooker, J. R., G. J. Holt, and S. A. Holt. 1998. Vulnerability of newly settled red drum (*Sciaenops ocellatus*) to predatory fish: is early-life survival enhanced by seagrass meadows? Mar. Biol. 131:145–151.

Ruiz, G. M., A. H. Hines, and M. H. Posey. 1993. Shallow water as a refuge habitat for fish and crustaceans in non-vegetated estuaries: an example from Chesapeake Bay. Mar. Ecol. Prog. Ser. 99: 1–6.

Rutherford, E. S., T. W. Schmidt, and J. T. Tilmant. 1989. Early life history of spotted seatrout (*Cynoscion nebulosus*) and gray snapper (*Lutjanus griseus*) in Florida Bay, Everglades National Park, Florida. Bull. Mar. Sci. 44:49–64.

SAS Institute. 1990. Proc REG procedures. SAS/Stat user's vol. 2. Release 6.04 ed. 3, SAS Institute Inc., Cary, NC.

———. 1997. Proc LOGISTIC procedures. SAS/STAT Software: changes and enhancements through Release 6.12. SAS Institute Inc., Cary, NC.

Siegel, S. 1956. Nonparametric statistics for the behavioral sciences. McGraw-Hill Book Company Inc., New York.

Springer, V. G., and K. D. Woodburn. 1960. An ecological study of the fishes of the Tampa Bay area. Fla. Board Conserv. Mar. Res. Lab. Prof. Pap. Ser. 1:1–104.

Stefansson, G. 1996. Analysis of groundfish survey abundance data: combining the GLM and delta approaches. ICES J. Mar. Sci. 53:577–588.

Stoner, A. W. 1983. Distribution of fishes in seagrass meadows: role of macrophyte biomass and species composition. Fish. Bull. 81:837–846.

Tabb, D. C. 1966. The estuary as a habitat for spotted seatrout, *Cynoscion nebulosus*. Am. Fish. Soc. Spec. Publ. 3:58–67.

Weinstein, M. P. 1983. Population dynamics of an estuarine-dependent fish, the spot (*Leiostomus xanthurus*), along a tidal-creek–seagrass meadow coenocline. Can. J. Fish. Aquat. Sci. 40:1633–1638.

Westerheim, S. J., and W. E. Ricker. 1978. Bias in using an age–length key to estimate age frequency distributions. J. Fish. Res. Board Can. 35:184–189.

Whitfield, A. K. 1999. Ichthyofaunal assemblages in estuaries: a South African case study. Rev. Fish Biol. Fish. 9:151–186.

Wohlschlag, D. E., and J. M. Wakeman. 1978. Salinity stresses, metabolic responses and distribution of the coastal spotted seatrout, *Cynoscion nebulosus*. Contrib. Mar. Sci. 21:171–185.

Florida Fish and Wildlife Conservation Commission, Florida Marine Research Institute, 100 Eighth Avenue SE, St. Petersburg, Florida 33701-5095. Present address (GAN): Massachusetts Division of Marine Fisheries, Annisquam River Marine Fisheries Station, 30 Emerson Avenue, Gloucester, Massachusetts 01930. Date accepted: December 10, 2000.