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Relative Abundance and Distribution of Sand Seatrout (*Cynoscion arenarius*) in Relation to Environmental Conditions, Habitat, and River Discharge in Two Florida Estuaries

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The sand seatrout, *Cynoscion arenarius* (Ginsburg, 1930), is an abundant recreational and commercial species that resides primarily in the nearshore and estuarine waters of the Gulf of Mexico. We examined relative abundance and distribution of sand seatrout [individuals >100 mm standard length (SL)] in relation to environmental conditions and river discharge in the Tampa Bay (1997–2004) and Charlotte Harbor (1999–2004) estuaries on the west coast of Florida. Fish were collected during a long-term fisheries-independent monitoring program with a 183-m purse seine. Sand seatrout were most abundant over deep, muddy substrates devoid of seagrass. Smaller sand seatrout between 145 mm SL and 175 mm SL were found in low-salinity areas near river mouths and larger sand seatrout >175 mm SL were found in high-salinity areas in the lower portion of the estuaries. We found a negative relationship between relative abundance and mean river discharge in both estuaries and a positive relationship between relative abundance and 2-yr lagged river discharge in Tampa Bay. Annual relative abundance of sand seatrout captured via purse seine in Tampa Bay and Charlotte Harbor was significantly correlated to annual changes in recreational and commercial harvest on the west coast of Florida. Differences and changes in environmental conditions, habitat, and river discharge clearly affected the relative abundance and distribution of sand seatrout, making habitat alterations and water-allocation decisions important to sand seatrout and the fishery they support.

Sand seatrout, *Cynoscion arenarius* (Ginsburg, 1930), reside in the nearshore waters of the Gulf of Mexico from the southwestern tip of Florida westward to the Gulf of Campeche, Mexico (Moffett et al., 1979), and are one of the most common sciaenids within estuaries of the northern Gulf of Mexico (Rakocinski et al., 2002). Recent genetic research has shown that the species is also present in inshore waters on the northern Atlantic coast of Florida (Tringali et al., 2004). Sand seatrout is an unregulated species but supports substantial recreational and commercial fisheries along the gulf coast of Florida, with an average annual recreational harvest of about a million fish per year and an average annual commercial harvest of about 8.5 metric tons per year since 1997 (Fisheries Statistics Division, National Marine Fisheries Service, 2007). Recent research has shown that sand seatrout can attain an age of 5 yr (Nemeth et al., 2006) and can hybridize with the congeners weakfish (*Cynoscion regalis*) (Tringali et al., 2004) and spotted seatrout (*Cynoscion nebulosus*) (M. Tringali, Florida Fish and Wildlife Conservation Commission, pers. comm.).

Information about relative abundance, habitat, and environmental preferences of sand seatrout has mainly been limited to juveniles or has usually been ancillary to other studies, mostly conducted in the northwestern Gulf of Mexico (Texas, Louisiana, and Mississippi) (Gunter, 1945; Christmas and Waller, 1973; Gallaway and Strawn, 1974; Chittenden and McEachran, 1976; Shlossman and Chittenden, 1981). Recent research in the eastern Gulf of Mexico has demonstrated that juvenile sand seatrout (individuals <100 mm standard length [SL]) along Florida's west coast are most abundant over unvegetated mud substrates near salt marsh habitats with mesohaline salinities typically associated with either small rivers, tidal creeks, or areas adjacent to the mouths of large rivers (Purtlebaugh and Rogers, 2007). Variations in discharge from these freshwater sources alter many abiotic and biotic characteristics of estuaries, including salinity and turbidity as well as nutrient and detrital concentrations (Livingston, 1991, 1997; Winemiller and Leslie, 1992; Garcia et al., 2003; North and Houde, 2003). These changes could potentially influence the relative abundance and distribution of juvenile sand seatrout, but may also affect individuals that are entering the fishery. Our study sought to define the habitat preferences and distribution of sand seatrout >100 mm SL.

We used existing long-term fishery-independent monitoring data to analyze the influences that physical habitat, environmental conditions,

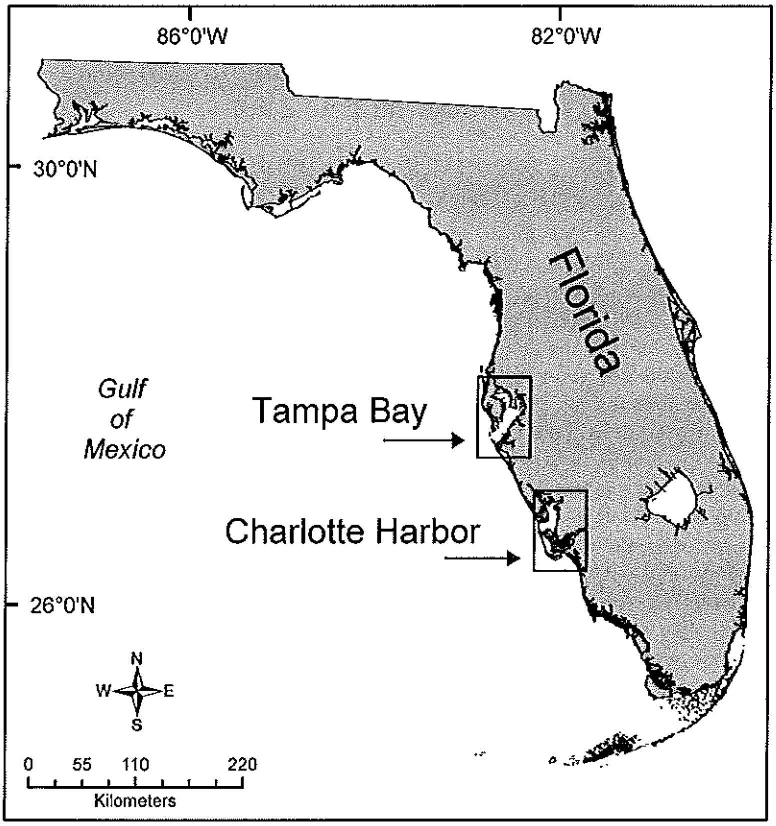

Fig. 1. Locations of the two estuaries sampled for sand seatrout in Tampa Bay and Charlotte Harbor, Florida.

and freshwater discharge rates may have on the relative abundances, and the spatial and temporal distribution of sand seatrout in Tampa Bay and Charlotte Harbor, Florida. Information obtained will establish environmental preferences, essential habitats, and ontogenetic movements of this species. Results of this study may have implications for management of habitats essential to this fishery as well as water withdrawal policies for river discharge into estuaries.

Materials and Methods

Study sites.—Sand seatrout were collected from two estuaries, Tampa Bay (sampling area approx. 886 km^2) and Charlotte Harbor (sampling area approx. 575 km^2), along the west coast of Florida (Fig. 1). Tampa Bay is the largest estuary in Florida. It receives fresh water from four major rivers (Hillsborough, Alafia, Little Manatee, and Manatee) with an average combined discharge of 1.9 to 14.6 m^3·s^{-1} annually from 1997 to 2004. Charlotte Harbor is the second-largest estuary in Florida and has two major rivers (Peace and Myakka) that had a combined average discharge of 3.4 to 34.6 m^3·s^{-1} annually from 1999 to 2004 (USGS, 2007). In both estuaries, shoreline vegetation consisted primarily of fringing mangroves and marsh grasses. Bottom substrates were typically characterized as sand, mud, oysters, or some combination thereof. Seagrass meadows were present in many areas of both bays. Both estuaries have a mean depth of 3 to 4 m, with tidal channels and dredged shipping channels up to 20 m deep (Huang, 1966; Goodwin, 1984). During our study, water temperatures ranged from 10 to 36°C in Tampa Bay and 12 to 33°C in Charlotte Harbor during sampling events. Salinities ranged from 7 to 44 practical salinity units (psu) in Tampa Bay and 0 to 41 psu in Charlotte Harbor, with higher salinities found toward the seaward portion of the estuaries and lower salinities found in the upper portions of the estuaries near river mouths.

Data collection.—Monthly stratified random sampling was conducted by the Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute's Fisheries-Independent Monitoring program from Jan. 1997 to Dec. 2004 in Tampa Bay and from Jan. 1999 to Dec. 2004 in Charlotte Harbor. Samples were collected with a 183-m × 5.2-m terminal-bag purse seine with 51-mm stretched nylon mesh. The seine was deployed by boat in a clockwise circle into the prevailing wind or current. Sampling water depths ranged from 1.0 to 3.3 m, and each net set covered an area of approximately 2,209 m^2. Sampling effort in Tampa Bay consisted of 25 net sets per month in 1997 and 20 net sets per month from 1998 to 2004. Sampling effort in Charlotte Harbor consisted of 20 net sets per month from Jan. 1999 to Oct. 2003 and 15 net sets per month from Nov. 2003 to Dec. 2004. Sampling sites were selected randomly by using a predefined grid system with 1′ latitude by 1′ longitude boundaries to ensure that sampling effort was distributed evenly within each system. All sets followed standardized protocol with regard to deployment and the area being sampled. Sampling occurred during daylight hours and at all tidal stages. Geographic position, date, salinity (psu), water temperature (°C), and water depth (m) at the bag of the net were recorded at all sampling sites. Bottom substrate (mud, sand) and bottom vegetation (seagrass, none) were assessed at each sample site. All sand seatrout collected were counted, and a minimum of 40 random individuals per sample were measured to the nearest millimeter SL. Length measurements were then extrapolated proportionally to the unmeasured portion of the sample. All catches were standardized as fish·100 m^{-2}.

Statistical analysis.—We investigated the relationship between our annual relative abundance estimates (fish·100 m^{-2}) and sand seatrout annual recreational and commercial harvest data from the west coast of Florida, using Pearson correlation (SAS Institute Inc., 1989) to determine the effectiveness of using the purse seine to sample sand seatrout entering the fishery and the possible relevance that our data may have in the future management of this species. Relative abundances from Tampa Bay (1997–2004) and Charlotte Harbor (1999–2004) were combined for this analysis to represent average catches from the west coast of Florida. Recreational harvest data represented the total recreational catch (numbers of fish) from all modes of fishing [shore, private/rental boats, party (head) boats, and charter boats] within all fishing areas (inland, state, and federal waters) along the west coast of Florida (1997–2004). Commercial harvest data represented the total commercial catch (metric tons) using hand lines along the west coast of Florida (1997–2004) (Fisheries Statistics Division, National Marine Fisheries Service, 2007).

Habitat associations of sand seatrout were determined using analysis of covariance (ANCOVA) on data pooled across all years and months in each estuary. Sand seatrout >100 mm SL were used in the ANCOVA analyses. These fish were considered to be larger age-0 through age-5 fish (Nemeth et al., 2006) and were the only size captured during this study. Relative abundance (fish·100 m^{-2}) and continuous environmental variables (water temperature, salinity, and depth) were log transformed [$\ln(x + 1)$] to homogenize variance in the parameters. A Shapiro–Wilk test was used to verify normality (Zar, 1996). Full ANCOVA models also included the classification variables month, year, bottom substrate, and bottom vegetation. Variables that were not significant ($P > 0.10$) on the basis of partial (type III) sum of squares were sequentially removed and the analysis was repeated until all nonsignificant variables were removed unless associated with a significant interaction. Significant interactions were retained in the model regardless of whether the main effects were significant to avoid masking possible significant main effects during the stepwise elimination process. Tukey's multiple-comparison tests were then used to identify differences in mean relative abundance by pairwise comparison of the means associated with classification variables found to be significant in the ANCOVA models. Linear regression was used to analyze relationships between sand seatrout relative abundance and significant continuous variables. All analyses were conducted using SAS version 9.1 (SAS Institute Inc., 1989).

The relationship between the relative abundance of sand seatrout and the annual changes in river discharge ($m^3{\cdot}s^{-1}$) was assessed using linear regression (SAS Institute Inc., 1989). To determine lagged effects of river discharge on relative abundance of age-1 and age-2 sand seatrout, linear regression models were conducted on 1- and 2-yr lagged river discharge. Only sand seatrout between 155 and 255 mm SL were included in this analysis so that the focus would be on fish that were considered to be age-1 and age-2 fish (Nemeth et al., 2006). This size range also represented the largest portion of our total number of sand seatrout collected. Annual river discharge was calculated from an aggregation of all rivers within each estuary. River discharge data were collected from U.S. Geological Survey stations approximately 24 to 47 km from river mouths in Tampa Bay and 58 km from river mouths in Charlotte Harbor (USGS, 2007).

We investigated the effects of salinity on the relative abundance of size-specific sand seatrout. In each estuary, salinity ranges for sand seatrout were established by calculating a density-weighted mean salinity ($\overline{Y_w}$) as described by McBride et al. (2001). Density-weighted mean salinity at capture was calculated for each 10-mm SL size interval in

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TABLE 1. Catch statistics for sand seatrout collected in Tampa Bay (Jan. 1997–Dec. 2004) and Charlotte Harbor (Jan. 1999–Dec. 2004), FL, with the 183-m purse seine.

Location	No. hauls	No. fish	Standard length (mm)				% Occur	Relative abundance (fish·100 m^{-2})	
			Mean	SE	Min	Max		Mean	SE
Tampa Bay	1,985	3,790	203	0.61	101	343	12.8	0.09	0.02
Charlotte Harbor	1,370	5,091	196	0.54	105	340	17.9	0.17	0.03
Total	3,355	8,881							

each estuary using the weighted formula

$$\overline{Y_w} = \left(\sum^{n} w_i Y_i\right) \Big/ \sum^{n} w_i,$$

where w_i = the number of sand seatrout per 10-mm SL interval for collection i, Y_i = the salinity measured for collection i, and n = the total number of collections with fish in that 10-mm SL interval for that estuary.

RESULTS

A total of 8,881 sand seatrout, ranging in length from 101 to 343 mm SL, were collected from Tampa Bay ($\bar{x}$ = 203 mm SL) and Charlotte Harbor ($\bar{x}$ = 196 mm SL) (Table 1, Fig. 2). Relative abundance in Charlotte Harbor (0.17 fish·100 m^{-2}) was nearly double that in Tampa Bay (0.09 fish·100 m^{-2}). Sand seatrout occurred in 12.8% of the purse seine samples from Tampa Bay and in 17.9% of those from Charlotte Harbor (Table 1). Greater than 90% of the sand seatrout collected from Tampa Bay and Charlotte Harbor were between 155 and 255 mm SL (Fig. 2). Temperatures where sand seatrout were captured ranged from 11.4 to 34.5°C in Tampa Bay and 13.5 to 32.4°C in Charlotte Harbor. Salinity ranged from 11.8 to 39.0 psu in Tampa Bay and 11.0 to 39.5 psu in Charlotte Harbor. Pearson correlation analysis indicated that annual relative abundances of sand seatrout captured in the purse seine were significantly correlated to changes in annual recreational and commercial harvests from the west coast of Florida between 1997 and 2004 ($P < 0.05$) (Fig. 3).

Sand seatrout were captured every month, with the highest monthly relative abundances occurring from Jan. to July in Tampa Bay and from Feb. to June and Nov. to Dec. in Charlotte Harbor (Fig. 4). Between Nov. and Feb., four isolated instances of large catches (n ≥ 250) occurred in both estuaries (Tampa Bay: Jan. 1999; Charlotte

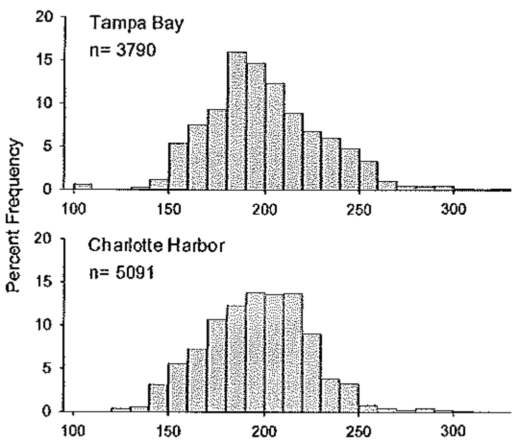

Fig. 2. Percentage length–frequency distributions for sand seatrout collected in Tampa Bay (1997–2004) and Charlotte Harbor (1999–2004), FL.

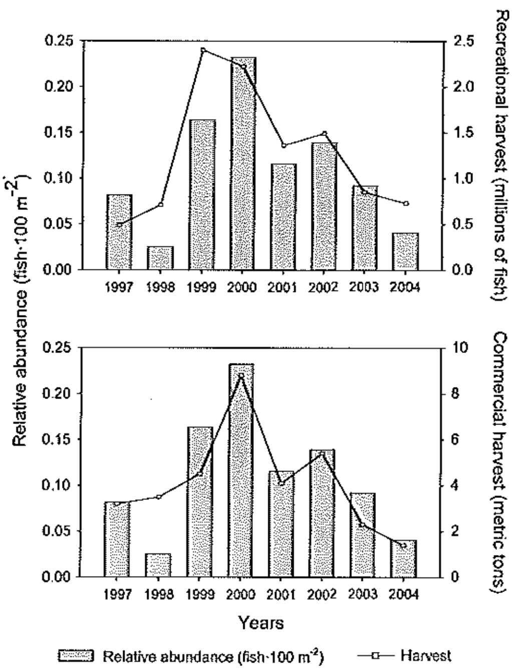

Fig. 3. Correlation between sand seatrout relative abundance (fish·100 m^{-2}) (bars) from Tampa Bay (1997–2004) and Charlotte Harbor (1999–2004), combined, and the recreational and commercial harvests of sand seatrout (line) along the west coast of Florida.

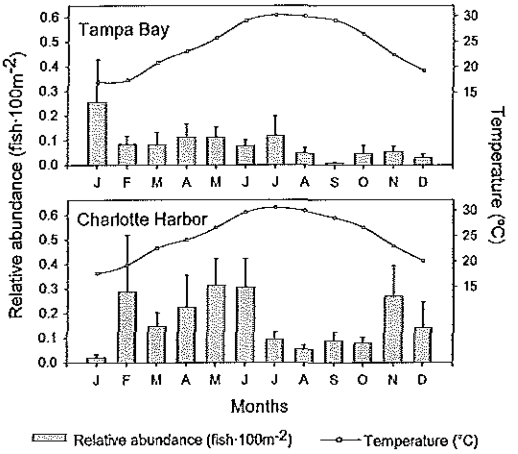

Fig. 4. Average monthly relative abundance (fish·100 m^{-2}) of sand seatrout collected in Tampa Bay and Charlotte Harbor, FL. Monthly mean water temperatures (°C) calculated from samples collected in each estuary are presented as second axis. Error bars represent +1 standard error.

Harbor: Nov. 2002, Dec. 2002, and Feb. 2003), which accounts for the large peaks in average monthly relative abundance during those cold-weather months. Fish in both estuaries demonstrated a recurring seasonal trend in which relative abundance increased in late winter and early spring (Feb./March) and decreased in late summer (July/Aug.). Between Jan. and July, when the water temperatures exceeded 19°C, Tampa Bay samples captured three times more sand seatrout and Charlotte Harbor samples captured four times more sand seatrout than when water temperatures were cooler (Fig. 4).

Final ANCOVA models accounted for 8% of the total variability in sand seatrout relative abundance in Tampa Bay and 21% of that in Charlotte Harbor ($P < 0.10$) (Table 2). Bottom substrate, depth, and month were significant variables in the final models for both estuaries. Sand seatrout relative abundance was at least 1.5 times greater over mud than over sand bottom in both estuaries ($P < 0.05$) (Fig. 5). Linear regressions indicated an increase in sand seatrout relative abundance as water depth increased ($P < 0.05$) (Fig. 6). Seventy-five percent of all sand seatrout were collected from water >2.0 m deep in both estuaries.

High variance in sand seatrout abundance due to the large number of zero catches over vegetated bottom in combination with four large catches over vegetated bottom negated vegetation as a significant variable in either estuary. However, our data strongly suggested that sand seatrout were more likely to be captured in higher abundances over unvegetated bottom (Fig. 5). In Tampa Bay, sand seatrout relative abundance was five times greater over unvegetated bottom than over vegetated bottom. In Charlotte Harbor, two abnormally high catches over seagrass (n = 891) resulted in a higher mean relative abundance over vegetated bottom. By eliminating these two high catches, sand seatrout relative abundance would have been nine times greater over unvegetated bottom than vegetated bottom (Fig. 5).

Table 2. Reduced ANCOVA models of sand seatrout relative abundances (fish·100 m^{-2}) collected in Tampa Bay and Charlotte Harbor, FL. Partial (type III) sum of squares are shown.

Estuary	Source	df	Sum of squares	F-value	$P > F$	R^2
Tampa Bay						
	Model	26	1.723	2.60	<0.001	0.08
	Depth	1	0.393	15.43	<0.001	
	Bottom	2	0.397	7.78	<0.001	
	Month	11	0.495	1.77	<0.060	
	Bottom × month	12	0.864	2.82	<0.001	
	Error	814	20.756			
	Corrected total	840	22.479			
Charlotte Harbor						
	Model	41	11.668	3.87	<0.001	0.21
	Bottom	1	2.169	29.52	<0.001	
	Month	11	2.915	3.61	<0.001	
	Depth	1	0.260	3.54	<0.060	
	Bottom veg.	1	0.186	2.53	<0.120	
	Year	5	0.708	1.93	<0.090	
	Month × bottom	11	4.210	5.21	<0.001	
	Month × bveg	11	2.624	3.25	<0.001	
	Error	591	43.432			
	Corrected total	632	55.100			

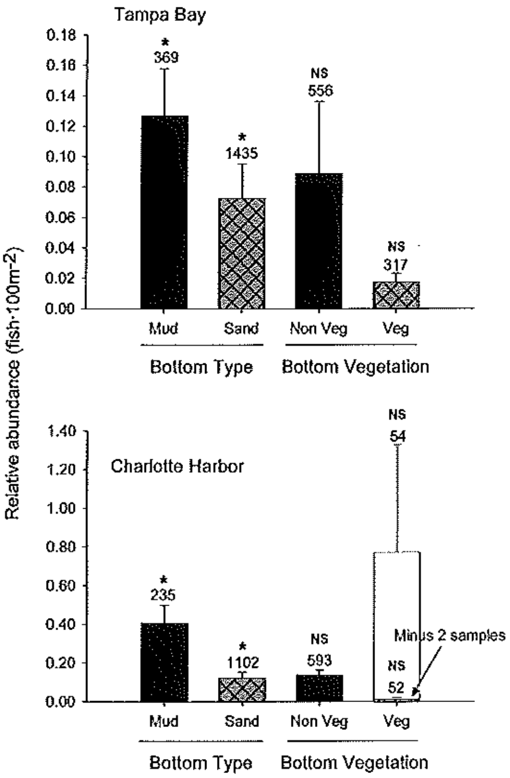

Fig. 5. Average relative abundance (fish·100 m^{-2}) of sand seatrout collected over mud vs sand bottom and vegetated vs unvegetated bottom in Tampa Bay and Charlotte Harbor, FL. Charlotte Harbor bottom vegetation includes all samples (large white bar) and samples with two abnormally high catches removed (small gray bar). Numbers over bars represent the total number of samples collected over each habitat. Significant differences ($P < 0.05$) are indicated with *. NS = not significant. Error bars represent +1 standard error.

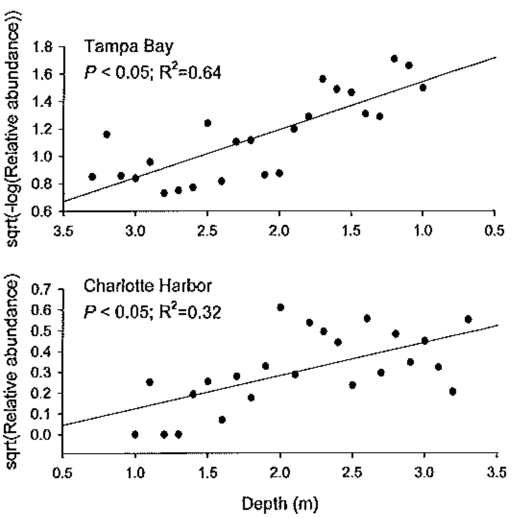

Fig. 6. Average relative abundance (fish·100 m^{-2}) at mean depth for sand seatrout in Tampa Bay and Charlotte Harbor, FL. Inverse *x*-axis for Tampa Bay is attributed to (−) log transform.

Linear regressions revealed significant relationships between sand seatrout relative abundance and average annual river discharge ($P <$ 0.05) in both Tampa Bay and Charlotte Harbor (Fig. 7). Relative abundance of sand seatrout was negatively related to increased river discharge in both estuaries. However, in Tampa Bay, a positive relationship existed between relative abundance and river discharge occurring 2 yr earlier ($P < 0.05$). Lagged river discharge in Charlotte Harbor was not significant.

High abundances of sand seatrout were captured in lower-salinity areas near river mouths as well as in higher-salinity areas near the seaward portion of the estuaries (Figs. 8, 9). Average salinities at time of capture near river mouths were 27.6 psu in Tampa Bay and 25.8 psu in Charlotte Harbor and near the seaward portion of the estuaries were 32.1 psu in Tampa Bay and 32.4 psu in Charlotte Harbor (Fig. 10). Density-weighted mean salinity at capture in Tampa Bay and Charlotte Harbor indicated that sand seatrout showed a trend toward higher-salinity waters as fish increased in length. Sand seatrout 145–175 mm SL occupied lower-salinity waters found near river mouths. As individuals >175 mm SL increased in length, they moved toward higher salinities found near the seaward portion of the estuaries (Fig. 10). Once sand seatrout moved into high-salinity areas, they appeared to remain there.

Discussion

Sand seatrout >100 mm SL were captured throughout Tampa Bay and Charlotte Harbor, typically in areas characterized by unvegetated mud substrate. The largest expanses of unvegetated mud substrate occurred in areas near river mouths and in deeper water where reduced sunlight prevented seagrass growth. Preference for this unvegetated mud habitat may have resulted from multiple factors, such as salinity, higher abundance of prey, low competition for space and food, and an affinity for conditions that optimize sand seatrout metabolic rate, growth, and survival (Wohlschlag and Wakeman, 1978; Moser and Gerry, 1989; Cyrus and Blaber, 1992; Whitfield, 1999; Nelson and Leffler, 2001).

A previous study within Tampa Bay and Charlotte Harbor estuaries reported that juvenile sand seatrout (<100 mm SL) also preferred unvegetated mud substrate (Purtlebaugh and Rogers, 2007). It is apparent from our study that

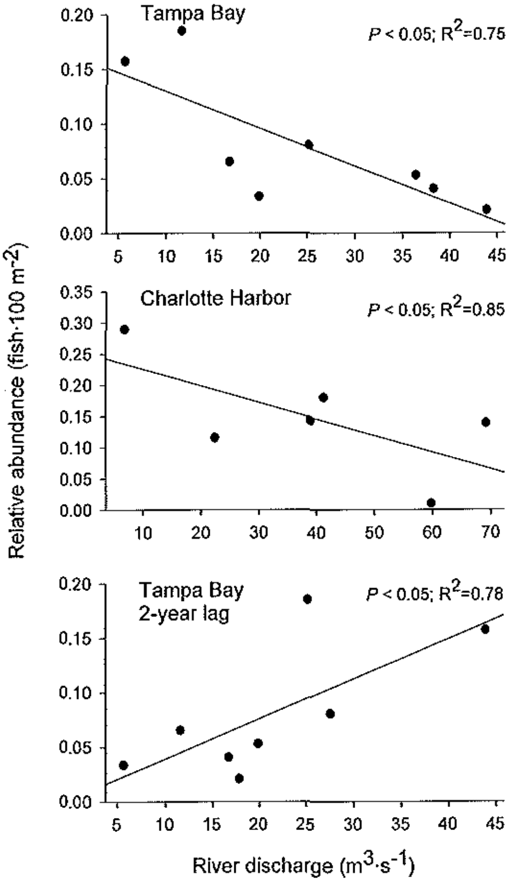

Fig. 7. Correlation between yearly relative abundance (fish 100 m^{-2}) of sand seatrout (155–255 mm SL) and annual river discharge in Tampa Bay (1997–2004) and Charlotte Harbor (1999–2004). Correlation between yearly relative abundance and annual river discharge lagged by 2 yr in Tampa Bay (1997–2004). River discharge is in cubic meters per second.

this preference continued throughout this species' life cycle. However, we also noted that the two largest catches of sand seatrout in Charlotte Harbor occurred over vegetated bottom. Further investigation of these two sampling areas revealed that although seagrass was present, there were also unvegetated mud substrates and steep depth gradients present within those areas. Our results suggest that it was this deeper, unvegetated mud bottom that the sand seatrout were occupying.

Changes in river discharge may influence the abundance and distribution of sand seatrout within an estuary. In both estuaries, the relative abundance of sand seatrout 155 to 255 mm SL declined as freshwater discharge into the estuary increased. It is unclear if this decrease in relative abundance was a result of higher mortality, migration out of the estuary, or fish seeking higher salinities in water deeper than our gear could sample. A movement of sand seatrout toward higher-salinity water as their size increased was observed in our analysis of density-weighted mean salinity. As fish grew beyond the juvenile stage, they were presumed to migrate away from river mouths and occupy higher-salinity areas throughout the seaward portion of the estuaries. Such movement has also been reported for large sand seatrout in other studies (Gunter, 1945; Christmas and Waller, 1973; Moffet et al., 1979; Warren and Sutter, 1981). This migration may have been related to changes in feeding preferences or to larger fish actively seeking deeper spawning habitats (Rooker et al., 1998). A movement toward higher-salinity areas by large sand seatrout may also be attributed to the need for reducing osmoregulatory stress, which is often associated with lower salinities (Whitfield and Harrison, 2003). We also found relative abundance of sand seatrout 155 to 255 mm SL to be positively related to a 2-yr lagged river discharge in Tampa. A large percentage of sand seatrout within this size range would have been 2 yr old (Nemeth et al., 2006), providing evidence of a positive relationship between river discharge and recruitment success. Indeed, juvenile sand seatrout in Florida have demonstrated a preference for low salinities found in proximity to rivers before moving toward higher salinities as they increased in size (Purtlebaugh and Rogers, 2007).

We observed distinct seasonal changes in sand seatrout relative abundance. Abundance increased from late winter and early spring through early summer and then dropped sharply in July and Aug. (Fig. 4). These trends were likely influenced by temperature and may also have been associated with movements of reproductively active sand seatrout. In spring, average sand seatrout relative abundance in our catches increased by nearly fourfold in both estuaries when water temperature exceeded 19°C. After a temperature peak (~32°C) in July and Aug., relative abundance markedly declined (Fig. 4). Similar relationships between sand seatrout abundance and temperature have been found in other studies (Trent et al., 1969; Copeland and Bechtel, 1974). Vetter (1982) reported that sand seatrout lack the ability to adjust their metabolic rate adequately to extreme changes in water temperature. Therefore, sand seatrout rely on migration into and out of deeper areas or the estuary to avoid temperature extremes. In our study sand seatrout may simply have been responding to changes in temperature by moving into shallow waters (and depths that our gear

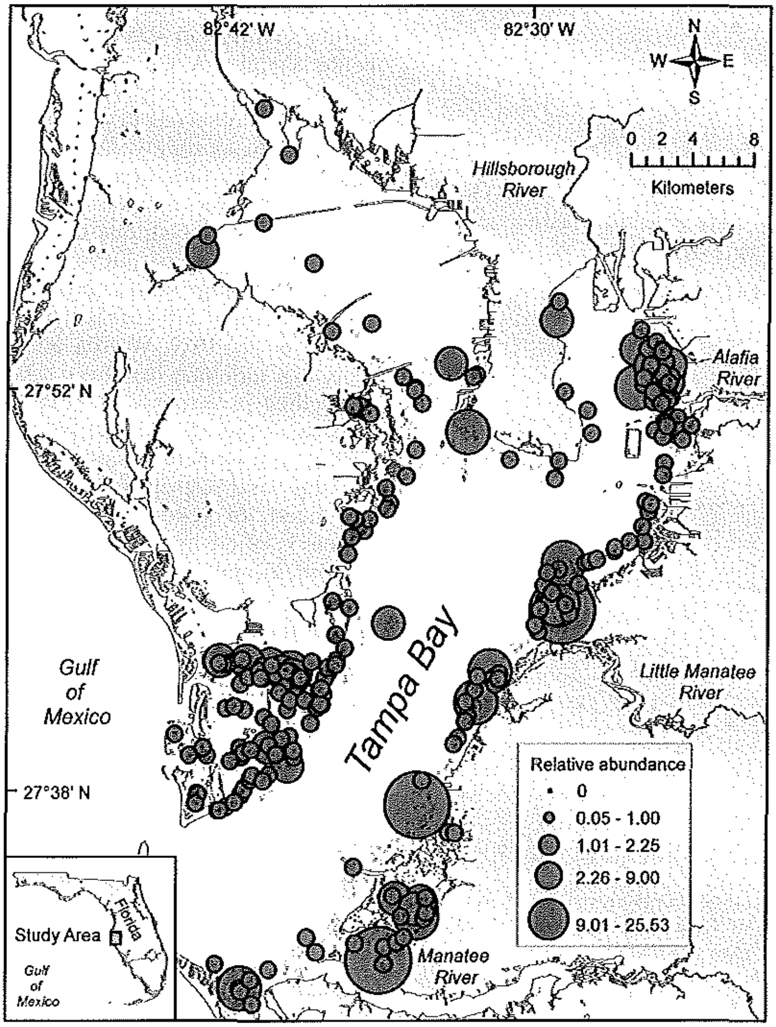

Fig. 8. Distribution and relative abundance (fish·100 m^{-2}) of sand seatrout >100 mm SL in Tampa Bay, FL.

could sample) in the spring as water temperatures increased and then back into deeper waters or out of the estuary in late summer when water temperatures peaked. Sand seatrout spawning activity may have also accounted for changes in relative abundance during summer months. Sand seatrout are reported to spawn in inshore Gulf of Mexico waters (7–22 m deep) from March to Oct., with peaks in spawning activity occurring during the cooler periods at the beginning and end of this season (Shlossman and Chittenden, 1981). Acoustic surveys in Tampa Bay confirmed that sand seatrout spawn within the estuary between April and Oct. (Walters, 2005). Almost all spawning aggregations detected by those surveys occurred in water deeper than our purse seine could sample (>3.3 m), which may partially account for the declines in relative abundance that we observed during Aug. and Sep. in Tampa Bay and June to Oct. in Charlotte Harbor. Our data did not show a decrease in abundance during the early spring and early summer months when sand seatrout would have been expected to have moved into deeper waters to spawn. This lack of detection may have been attributed to an influx of sand seatrout (spawned the previous summer) moving back into the estuary during early spring and summer months, in preparation for spawning. Shlossman and Chittenden (1981) reported that late-summer spawned fish returned to Texas estuaries during mid-spring after overwintering in deeper waters of the Gulf of Mexico. Most of these fish remained in the estuary until Aug., when they moved back into the Gulf of Mexico to spawn. Our data demonstrated similar trends in relative abundance. Abundances were higher in early spring and summer, before declining in

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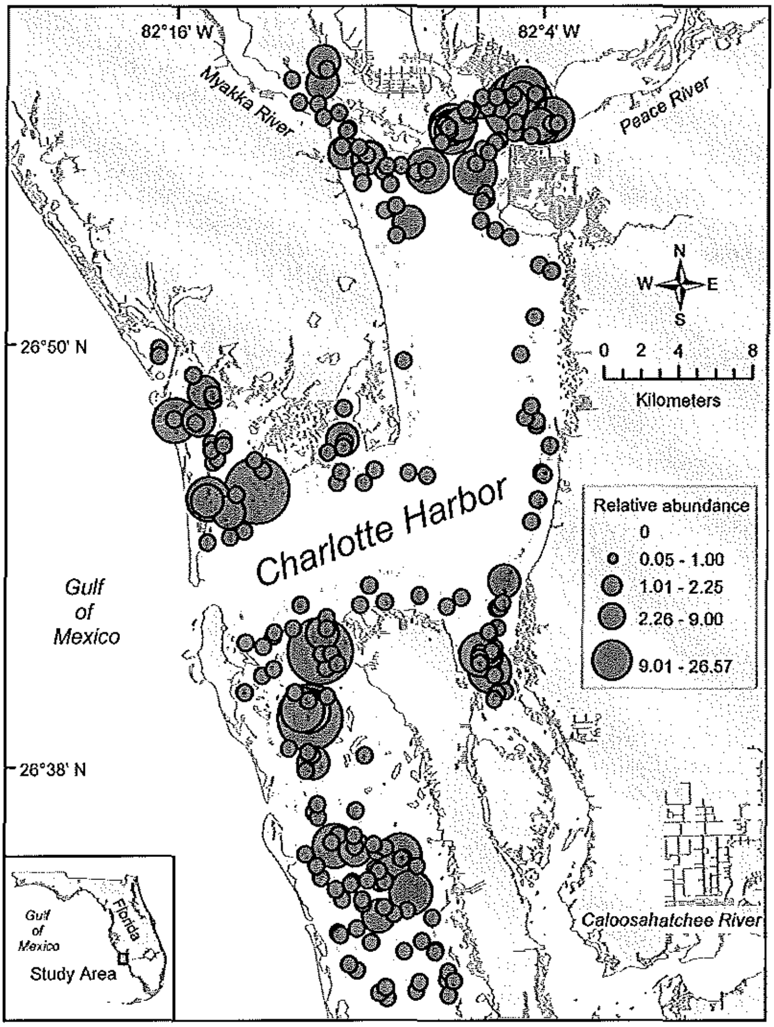

Fig. 9. Distribution and relative abundance (fish·100 m^{-2}) of sand seatrout >100 mm SL in Charlotte Harbor, FL.

primarily Aug. and Sep. in both estuaries. Because of the depth restrictions of the purse seine (≤3.3 m), we could not determine if low abundances indicated emigration from the estuaries or movement into deeper areas within the estuaries.

Our study indicated that sand seatrout may overwinter in deeper areas of subtropical Gulf of Mexico estuaries. Large isolated catches of sand seatrout occurred in the seaward portions of Tampa Bay and Charlotte Harbor during winter months, indicating that some sand seatrout may reside in the estuaries year round. Sand seatrout in northern Gulf of Mexico estuaries have been reported to migrate offshore into deeper water during winter months and then move shoreward while spawning progresses (Cowan and Shaw, 1988). In Tampa Bay and Charlotte Harbor, it is plausible that sand seatrout remained in the estuaries during cold months but simply occupied water deeper than the purse seine was able to sample.

A strong positive correlation between sand seatrout relative abundance and annual recreational and commercial harvest along the west coast of Florida supported the applicability of our data should future management of this currently unregulated species become necessary. Differences in environmental conditions, habitat, and river discharge affected the relative abundance and distribution of sand seatrout, stressing the importance of habitat alterations and water-allocation decisions that may affect sand seatrout and the fishery they support. Additional fecundity analyses, acoustic surveys, and tagging studies would enhance our understanding of sand seatrout reproduction, mortality estimates, and fish movement within these

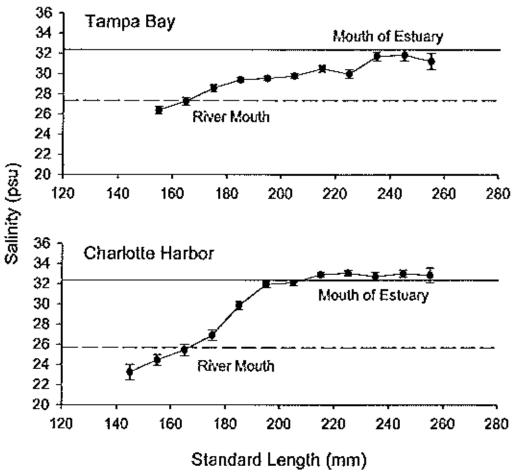

Fig. 10. Density-weighted mean salinity at capture for sand seatrout collected in Tampa Bay and Charlotte Harbor, FL. Error bars represent ±1 standard error. The solid line represents the mean salinity near the seaward portion of the estuary at time of capture, and the dashed line represents the mean river mouth salinity at time of capture.

estuaries and into the adjacent gulf, thereby providing additional information for the potential management of this species.

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LITERATURE CITED

CHITTENDEN, M. E., JR., AND J. D. MCEACHRAN. 1976. Composition, ecology, and demersal fish communities on the northwestern Gulf of Mexico continental shelf, with a similar synopsis for the entire Gulf TAMU-SG-76-208, Texas A & M Univ., College Station, TX.

CHRISTMAS, J. Y., AND R. S. WALLER. 1973. Estuarine vertebrates, Mississippi, p. 320–434. *In:* Cooperative Gulf of Mexico Estuarine Inventory and Study, Mississippi. J. Y. Christmas (ed.). Gulf Coast Res. Lab., Ocean Springs, MS.

COPELAND, B. J., AND T. J. BECHTEL. 1974. Some environmental limits of six Gulf coast estuarine organisms. Contrib. Mar. Sci. 18:169–204.

COWAN, J. H., AND R. F. SHAW. 1988. The distribution, abundance, and transport of larval sciaenids collected during winter and early spring from the continental shelf waters off west Louisiana. U.S. Fish. Bull. 86:129–141.

CYRUS, D. P., AND S. J. M. BLABER. 1992. Turbidity and salinity in a tropical northern Australian estuary and their influence on fish distribution. Estuar. Coast. Shelf Sci. 35:545–563.

GALLAWAY, B. J., AND K. STRAWN. 1974. Seasonal abundance and distribution of marine fishes at a hot-water discharge in Galveston Bay, Texas. Contrib. Mar. Sci. 18:1–137.

GARCIA, A. M., J. P. VIEIRA, AND K. O. WINEMILLER. 2003. Effects of 1997–1998 El Niño on the dynamics of the shallow-water fish assemblage of the Patos Lagoon Estuary (Brazil). Estuar. Coast. Shelf Sci. 57:489–500.

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. Bur. Fish. 45:71–85.

GOODWIN, C. R. 1984. Changes in tidal flow, circulation, and flushing caused by dredge and fill in Tampa Bay, Florida. U.S. Geological Survey, Open File Report 84-447.

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

HUANG, T. C. 1966. A sedimentologic study of Charlotte Harbor, southwestern Florida. Master's Thesis, Florida State University, Tallahassee, FL.

LIVINGSTON, R. J. 1991. Historical relationships between research and resource management in the Apalachicola River Estuary. Ecol. Appl. 1:361–382.

———. 1997. Trophic response of estuarine fishes to long-term changes of river runoff. Bull. Mar. Sci. 60:984–1004.

MCBRIDE, R. S., T. C. MACDONALD, R. E. MATHESON JR., D. A. RYDENE, AND P. B. HOOD. 2001. Nursery habitats for ladyfish, *Elops saurus*, along salinity gradients in two Florida estuaries. Fish. Bull. 99:443–458.

MOFFET, A. W., L. W. MCEACHRON, AND J. G. KAY. 1979. Observations of the biology of the sand seatrout (*Cynoscion arenarius*) in Galveston and Trinity Bays, Texas. Contrib. Mar. Sci. 22:163–172.

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.

NATIONAL MARINE FISHERIES SERVICE. 2007. Fisheries statistics division. Available at: http://www.st.nmfs.noaa.gov/st1/index.html

NELSON, G. A., AND D. LEFFLER. 2001. Abundance, spatial distribution, and mortality of young-of-the-year spotted seatrout (*Cynoscion nebulosus*) along the gulf coast of Florida. Gulf Mex. Sci. 19:30–42.

NEMETH, D. J., J. B. JACKSON, A. R. KNAPP, AND C. P. PURTLEBAUGH. 2006. Age and growth of sand seatrout (*Cynoscion arenarius*) in the estuarine waters of the eastern Gulf of Mexico. Gulf Mex. Sci. 24:45–60.

North, E. W., and E. D. Houde. 2003. Linking ETM physics, zooplankton prey and fish early-life histories to striped bass *Morone saxatilis* and white perch *M. americana* recruitment. Mar. Ecol. Prog. Ser. 260:219–236.

Purtlebaugh, C. H., and K. R. Rogers. 2007. Recruitment and essential habitat of juvenile sand seatrout (*Cynoscion arenarius*) in four estuaries along the west coast of Florida. Gulf Mex. Sci. 25:15–32.

Rakocinski, 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. Gulf Carib. Fish. Inst. 53:623–635.

Rooker, J. R., S. A. Holt, M. A. Soto, and G. J. Holt. 1998. Postsettlement patterns of habitat use by sciaenid fishes in subtropical seagrass meadows. Estuaries 21:318–327.

SAS Institute Inc. 1989. SAS/STAT user guide, Version 6. 4th ed., Vol. 2 SAS Institute Inc., Cary, NC.

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

Trent, W. L., E. J. Pullen, R. R. Mock, and D. Moore. 1969. Ecology of western gulf estuaries, p. 18–24. *In:* Rep. Bur. Comm. Fish. Biol. Lab., fiscal year 1968 U.S. Fish Wild. Serv. Circ. 325, Galveston, TX.

Tringali, M. D., S. Seyoum, E. Wallace, and M. Higham. 2004. The distribution of weakfish (*Cynoscion regalis*), sand seatrout (*C. arenarius*), and their hybrids in Florida Atlantic Waters. Florida Marine Research Institute Report Number IHR 2004-018. St. Petersburg, FL.

USGS (U.S. Geological Survey). 2007. Map of real-time streamflow compared to historical stream flow for the day of the year, Florida. Available at: http://water.usgs.gov/waterwatch/?m=real&r=fl.

Vetter, R. D. 1982. Seasonal metabolic compensation in sympatric seatrout: adaptation to the estuary. Am. Fish. Soc. 111:193–198.

Walters, S. L. 2005. Mapping Tampa Bay *Cynoscion nebulosus* spawning habitat using passive acoustic surveys. Master's Thesis, University of South Florida, Tampa, FL.

Warren, J. R., and F. C. Sutter. 1981. Industrial bottomfish-monitoring and assessment, p. II-1-1–II-1-69. *In:* Fishery monitoring and assessment, completion report. T. D. McIlwain (ed.). Gulf Coast Research Laboratory, Ocean Springs, MS.

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

———, and T. D. Harrison. 2003. River flow and fish abundance in a South Africa estuary. J. Fish Biol. 62:1467–1472.

Winemiller, K. O., and M. A. Leslie. 1992. Fish assemblage across a complex, tropical freshwater/marine ecotone. Environ. Biol. Fish. 34:29–50.

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.

Zar, J. H. 1996. Biostatistical analysis Prentice-Hall, Upper Saddle River, NJ.

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