

**Abstract**—Sand seatrout (*Cynoscion arenarius*) and silver seatrout (*C. nothus*) are both found within the immediate offshore areas of the Gulf of Mexico, especially around Texas; however information is limited on how much distributional overlap really occurs between these species. In order to investigate spatial and seasonal differences between species, we analyzed twenty years of bay and offshore trawl data collected by biologists of the Coastal Fisheries Division, Texas Parks and Wildlife Department. Sand seatrout and silver seatrout were distributed differently among offshore sampling areas, and salinity and water depth appeared to correlate with their distribution. Additionally, within the northernmost sampling area of the gulf waters, water depth correlated significantly with the presence of silver seatrout, which were found at deeper depths than sand seatrout. There was also an overall significant decrease in silver seatrout abundance during the summer season, when temperatures were at their highest, and this decrease may have indicated a migration farther offshore. Sand seatrout abundance had an inverse relationship with salinity and water depth offshore. In addition, sand seatrout abundance was highest in bays with direct passes to the gulf and correlated with corresponding abundance in offshore areas. These data highlight the seasonal and spatial differences in abundance between sand and silver seatrout and relate these differences to the hydrological and geological features found along the Texas coastline.

Manuscript submitted 24 April 2008.  
Manuscript accepted 22 August 2008.  
Fish. Bull. 107:24–35 (2009).

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## Spatial and seasonal abundance of sand seatrout (*Cynoscion arenarius*) and silver seatrout (*C. nothus*) off the coast of Texas, determined with twenty years of data (1987–2006)

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The sand seatrout (*Cynoscion arenarius*) and the silver seatrout (*C. nothus*) from the family Sciaenidae are sympatric species that co-occur within the Gulf of Mexico (GOM). In the literature, the co-occurrence and distribution of these species has been noted, particularly in offshore areas where feeding grounds overlap (Miller, 1965; Chittenden and McEachran, 1976). These studies, in concert with previous life history data from Texas (Shlossman and Chittenden, 1981; DeVries and Chittenden, 1982) have provided some insight into when and why any distributional variation occurs in the western GOM. Nevertheless, most studies of the abundance of these species have been limited on a spatial and temporal scale. Additionally, the spatial and temporal abundance of these species in relation to hydrological characteristics such as water temperature, salinity, depth, and bay access to the gulf through a channel or pass has not been thoroughly investigated.

Sand seatrout use inshore waters extensively but also move offshore seasonally to evade the temperature

extremes of the inshore bays and to spawn (Shlossman and Chittenden, 1981; Vetter, 1982). In contrast silver seatrout, although on occasion they can be collected inshore, live their entire lives offshore (Gunter, 1945; Miller, 1965). In addition to their distributional difference, differences exist in their hydrological preference, particularly in salinity and water depth, adding to the complexity of the distributional preferences of these two species (Chittenden and McEachran, 1976). However, a great deal of distributional overlap of these species occurs within the immediate offshore area, year-round (Gunter, 1938; Sheridan et al., 1984), although the spatial and temporal dynamics of this overlap are poorly understood.

Furthermore, information is limited on whether the distribution of sand seatrout offshore correlates with what is found inshore (bays) (Shlossman and Chittenden, 1981). Each of the bays along the Texas coastline is unique in their geological and hydrological characteristics, giving rise to differences in species assemblages between the bays (Blackburn, 2004).

**Table 1**

Sampling locations, location abbreviations, pass presence at locations (yes or no), and number of trawls (monthly and overall) conducted to sample sand seatrout (*Cynoscion arenarius*) and silver seatrout (*C. nothus*) in inshore and offshore waters off Texas. Geographic locations of the inshore and offshore trawling surveys are indicated in Figure 1. Offshore sampling sites (gulf stations) extended 16.7 km from the state boundary of Texas.

Location	Abbreviation for location	Pass presence	Sample size (no. of trawls /month)	Sample size (no. of trawls, overall)
<b>Inshore sites</b>				
Sabine Lake	SL	Yes	10	2760
Galveston Bay	GB	Yes	20	4800
East Matagorda Bay	EMB	No	10	2370
Matagorda Bay	MB	Yes	20	4800
San Antonio Bay	SAB	No	20	4800
Aransas Bay	AB	Yes	20	4800
Corpus Christi Bay	CCB	Yes	20	4800
Upper Laguna Madre	ULM	No	10	2400
Lower Laguna Madre	LLM	Yes	10	2400
<b>Offshore sites</b>				
Gulf station A	Gulf A	Yes	16	3840
Gulf station B	Gulf B	Yes	16	3814
Gulf station C	Gulf C	Yes	16	3822
Gulf station D	Gulf D	Yes	16	3792
Gulf station E	Gulf E	Yes	16	3829

Sand seatrout use functioning offshore passes to facilitate egg and larval transport from spawning areas (the immediate offshore) to nurseries (estuaries within bays) (Simmons and Hoese, 1959). However, the seasonal change in distribution of sand seatrout between these two locales has not been thoroughly examined. Furthermore, the differences in abundance of sand seatrout inhabiting bays with direct passes to the GOM and sand seatrout inhabiting bays with limited access to these passes have not been determined.

The purpose of this study was to expand current information regarding the distribution of sand and silver seatrout in the western GOM. To this end, two major objectives were identified 1) to compare the spatial and seasonal abundance of sand seatrout and silver seatrout within the immediate GOM, within the boundaries of Texas, and relate any distributional differences between the two species to specific hydrological variables (i.e., temperature, salinity, depth) and 2) to investigate the spatial and seasonal abundance of sand seatrout between the immediate offshore and the inshore areas (the bays) where there were direct passes to the gulf.

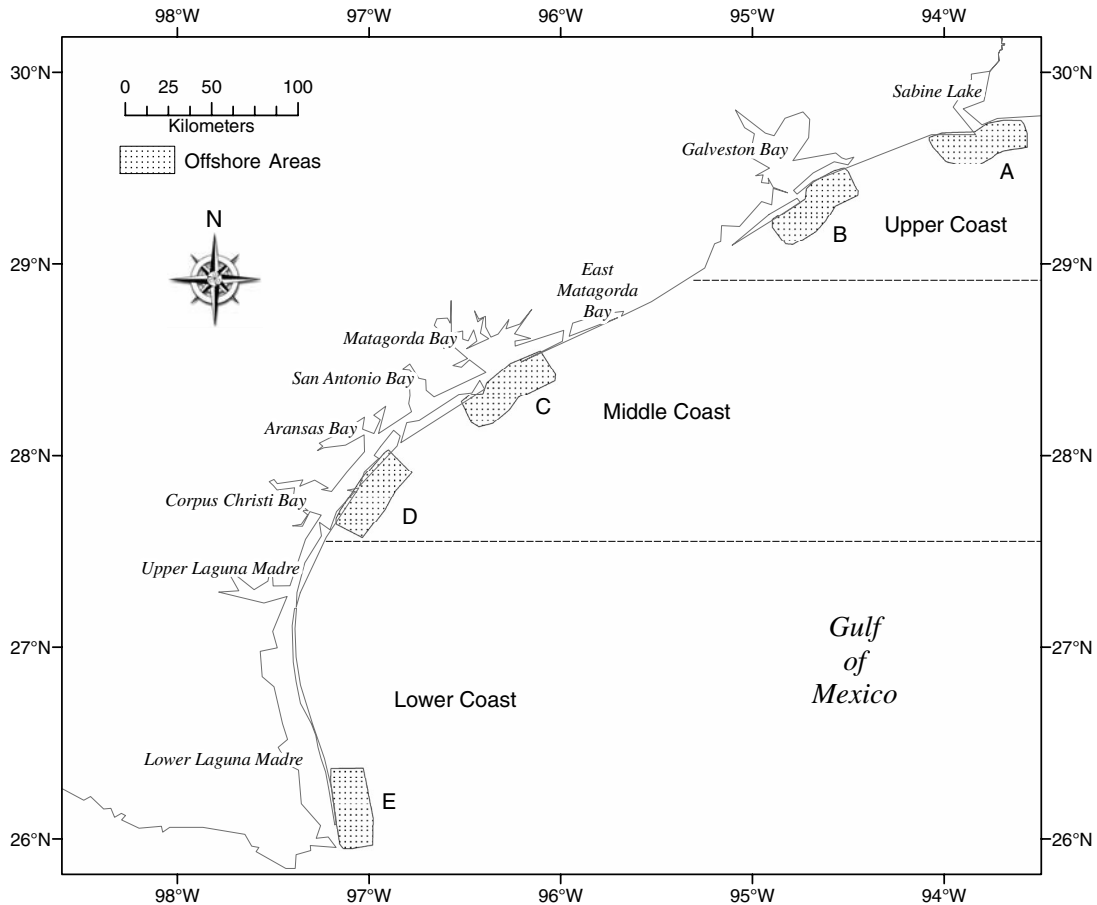
## Materials and methods

### Collections

We analyzed twenty years (1987–2006) of standardized offshore and inshore trawling data from Texas. The Coastal Fisheries Division of the Texas Parks and Wild-

life Department (CF-TPWD) conducts annual monitoring of five gulf areas, as well as nine inshore bay systems (bays) within Texas waters (Table 1, Fig. 1). All of the major bay systems in Texas are protected from the GOM by geographical features such as islands or peninsulas. As such, bays were designated as all waters contained within the area between the Texas terrestrial shoreline and the associated barrier island or peninsula. Some of these bays have access to the GOM by means of a large navigable pass or cut directly through the geographical barrier, whereas other bays have limited access because of their distance from the gulf or to the navigational barrier presented by islands (Table 1). Gulf areas were those areas immediately offshore (outside the geographical barriers) and each was situated around major passes and extended 16.7 km from shore. Sampling by trawling was divided between the first half of the month (days 1–15) and the second half of the month (days 16–end of month) throughout all years. Sampling locations for gulf areas and bays were chosen randomly from a matrix of 1.85-km square grids. Grids were not sampled more than once a month. All samples were taken during daylight hours when both species are susceptible to trawling (Shlossman and Chittenden, 1981; DeVries and Chittenden, 1982).

Trawling was conducted with a 5.7-m otter trawl with 38-mm nylon multifilament mesh, for both locations (gulf areas and major bays). Trawls were towed at the bottom parallel to the fathom curve at a speed of 4.83 km/hr for ten minutes. Abundance was determined for all trawls as individuals collected per hour (ind.



**Figure 1**

Map of the Texas coastline identifying major bay systems and offshore sampling areas routinely monitored by the Coastal Fisheries Division of the Texas Parks and Wildlife Department. Major bays are labeled by name, gulf areas discussed in the text are indicated by a shaded area and are labeled (A–E).

collected/hr) and served as a form of catch per unit of effort. Temporal variation in abundance was assessed from data by averaging the abundance of all trawls within a given season within a year and then averaging across all twenty years, and these results represented our temporal investigation. Seasons were designated as a three-month group: fall (October–December), winter (January–March), spring (April–June), and summer (July–September). In addition we recorded the mean total length (TL, mm) of each species and the following environmental variables: water temperature ( $^{\circ}\text{C}$ ) at depth of trawl (0.3 m off bottom); salinity (psu); and water depth (m) with each trawl.

#### Distribution of sand seatrout and silver seatrout

The abundance of sand seatrout and silver seatrout among offshore sampling areas was analyzed to determine 1) overall abundance of each species, within each gulf area, and 2) seasonal and species differentiation among gulf areas. First, overall differences in abundance between species were tested by using a *t*-test for species mean abundance (averaged over all years) at

each gulf area. Then, a three-factor ANOVA was used, involving the following factors: gulf areas ( $n=5$ ; all offshore sampling areas); seasons ( $n=4$ ; all seasons); and species ( $n=2$ ; both species) with all interactions. Species abundance was then correlated against each environmental variable by using Pearson correlation coefficients for each gulf area and season to determine the significance of the regressions.

Length-frequency histograms were created from the twenty-year data set by using catch-length data set, separated by month, and averaged over years for individual species collected across offshore areas. These histograms were created by partitioning individuals into 10-mm (TL) size classes and were used to describe cohort strength between species, by month.

#### Distribution of sand seatrout inshore

The abundance of sand seatrout at combined gulf areas (offshore) and at major bays (inshore) was analyzed to identify any spatial and temporal differentiation. To this end a two-factor ANOVA was employed involving the factors: location ( $n=2$ ; combined gulf areas and combined

**Table 2**

Summary of ANOVA results of abundance data for sand seatrout (*Cynoscion arenarius*) and silver seatrout (*C. nothus*) from gulf areas (three-factor ANOVAs) and abundance of sand seatrout compared between locations, pass or no pass, and bays with pass presence (two-factor ANOVAs) averaged across twenty years (1987–2006) of trawl capture monitoring by Texas Parks and Wildlife. Log-transformed abundance data were the dependent variable in all analyses. Degrees of freedom (df), mean squares (MS), *F*-values (*F*), and *P*-values (*P*) reported. ns =  $P > 0.05$ ; \* =  $P < 0.05$

Dependent variable	Factors	df	MS	<i>F</i>	<i>P</i>
Sand seatrout and silver seatrout (Log <sub>10</sub> abundance)	Gulf areas	4	18.27	60.41*	<0.0001
	Season	3	4.15	13.73*	<0.0001
	Species	1	34.66	114.58*	<0.0001
	Gulf areas × season	12	1.79	5.93*	<0.0001
	Gulf areas × species	4	10.24	33.86*	<0.0001
	Season × species	3	5.48	18.12*	<0.0001
	Gulf areas × season × species	12	0.40	1.34 <sup>ns</sup>	0.1906
Sand seatrout (Log <sub>10</sub> abundance)	Location	1	6.60	101.16*	<0.0001
	Season	2	0.35	5.31*	0.0062
	Location × season	2	0.14	2.17 <sup>ns</sup>	0.1192
Sand seatrout (Log <sub>10</sub> abundance)	Pass	1	15.47	192.74*	<0.0001
	Season	2	0.70	8.70*	0.0003
	Pass × season	2	0.17	2.11 <sup>ns</sup>	0.1255
Sand seatrout (Log <sub>10</sub> abundance)	Bays	5	3.68	22.72*	<0.0001
	Season	2	1.79	11.08*	<0.0001
	Bays × season	10	0.18	1.14 <sup>ns</sup>	0.3337

major bays) and seasons ( $n=3$ ; fall, spring and summer), and interaction (the winter season was excluded from this analysis because of the invariably low counts of sand seatrout within both locations, across all years).

To determine whether abundance differed between bays with direct GOM passes and bays either without these passes or with limited offshore access, a two-factor ANOVA was used involving the following factors: pass presence ( $n=2$ ; bays with a direct offshore pass and bays without a direct pass) and seasons ( $n=3$ ), with interaction. Analyses were then focused on bays with direct passes in order to determine whether distribution differed among individual bays with passes, seasonally. This analysis employed a two-factor ANOVA, involving the following factors: bays ( $n=6$ ; all major bays with passes) and seasons ( $n=3$ ), with interaction. Length-frequency histograms of inshore sand seatrout were then created in a similar fashion to that used for the previously created offshore length-frequency histograms in order to qualitatively evaluate differences in monthly cohort size and size classes of sand seatrout between locations (i.e., offshore and inshore).

#### Statistical analyses

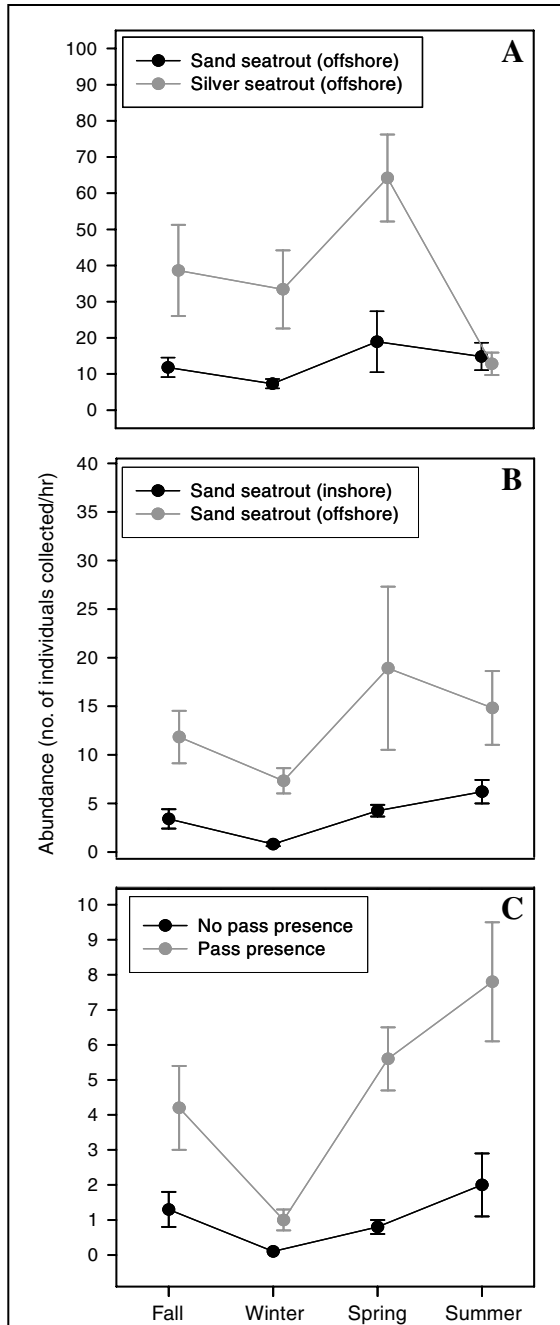
All data were first averaged across seasons for each year and then analyzed across years for all dependent variables in all parametric tests. All dependent variables in these analyses were first tested for normality by using a Shapiro-Wilk test; however, in the case of non-normality, data were log<sub>10</sub>-transformed before analysis.

All abundance data for ANOVAs involved all catch (zero catches included) so that catches were not overestimated. Statistical analyses and length-frequency histograms were carried out with SAS software (SAS vers. 8.02, SAS Inst., Inc., Cary, NC) and illustrated by using SigmaPlot (SigmaPlot vers. 10.0, Systat Software, Inc., Point Richmond, CA).

## Results

### Distribution of sand seatrout and silver seatrout

Sand seatrout abundance was significantly lower ( $13.2 \pm 6.7$ ) than that of silver seatrout ( $37.2 \pm 17.7$ ) ( $t=-8.55$ ,  $P < 0.0001$ ). In addition, significant spatial and seasonal differences existed between sand and silver seatrout abundance, including significant interactive effects, and differences between species accounted for a majority of the variance in abundance in trawls in the 3-factor model (Table 2). The first interaction, season × species, revealed a lower abundance of silver seatrout throughout the summer season (Fig. 2A). Sand seatrout abundance was high during July and decreased by August, whereas silver seatrout abundance peaked in April, declined in June, and was minimal by July (Fig. 3). The second interaction, gulf area × species, revealed a high abundance of sand seatrout and low abundance of silver seatrout in the gulf area A (Fig. 4). The gulf area × season interaction although significant, explained only a minimal amount of variance in abundance and



**Figure 2**

Differences in seasonal mean abundances (individuals collected/hr, mean  $\pm$  standard error), averaged over twenty years of trawl data (1987–2006), for (A) a comparison of sand seatrout (*Cynoscion arenarius*) collected off the coast of Texas (offshore) and silver seatrout (*C. nothus*) collected offshore, and (B) a comparison of sand seatrout collected inshore (combined major bays) and offshore (combined Gulf of Mexico sampling areas), and (C) a comparison of sand seatrout collected inshore between bays with direct passes to the gulf and sand seatrout collected in bays without direct access to the gulf.

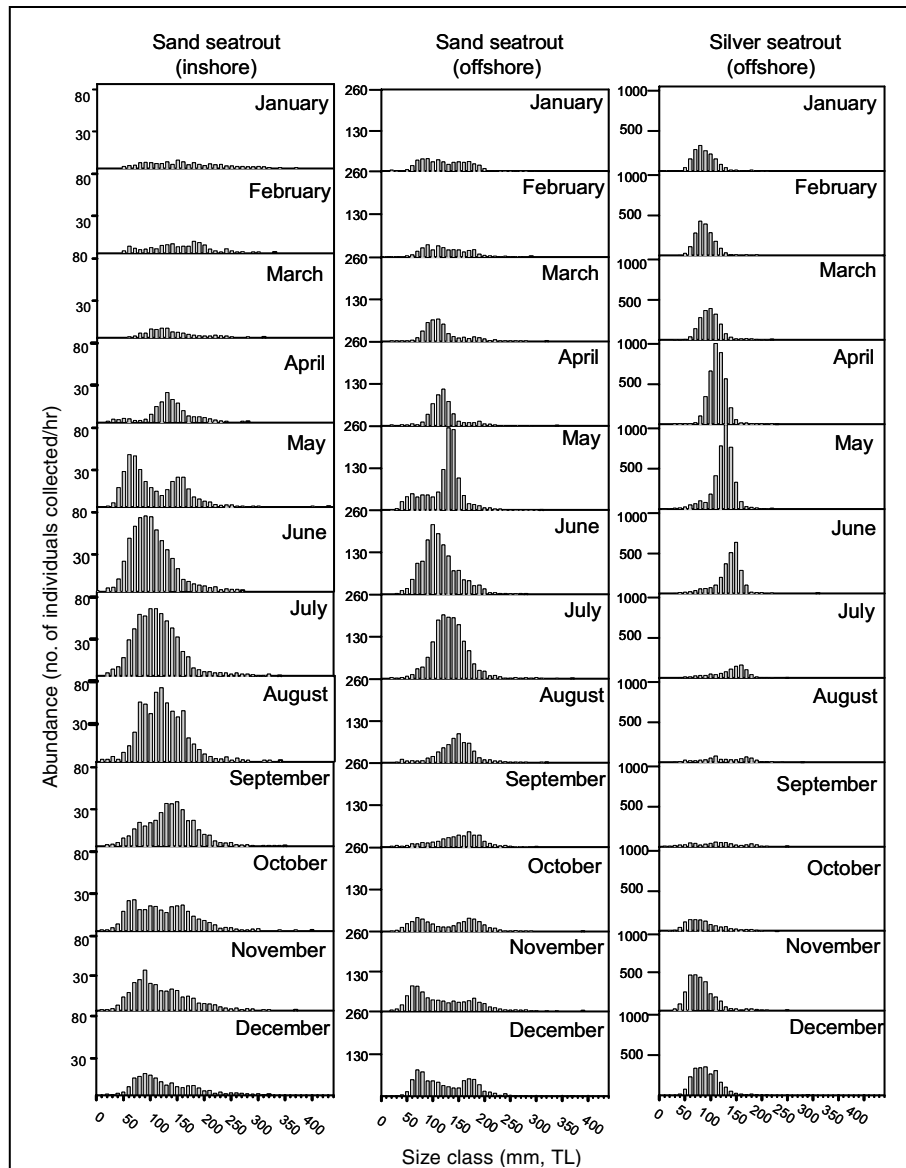
did not warrant further investigation for the primary objectives of this study. When comparing species across gulf areas, we found significant differences in species abundance across seasons. Sand seatrout appear to be in their highest abundance along the upper coast, whereas silver seatrout are found primarily in the middle coast, especially in gulf areas C and D (Figs. 1 and 5).

Water depths between our offshore sampling areas increased from north to south. Water depths (range, mean depth  $\pm$  standard deviation [SD]) among gulf areas were as follows: gulf area A (1.2–12.8, 7.6  $\pm$  2.8), gulf area B (0.9–18.0, 10.5  $\pm$  3.4), gulf area C (1.2–26.5, 14.9  $\pm$  4.8), gulf area D (0.4–23.8, 15.2  $\pm$  4.7), and gulf area E (2.4–30.0, 18.6  $\pm$  5.2). Within gulf areas, silver seatrout were more abundant at deeper water depths, and this trend was particularly strong during the fall season in gulf areas A, C, and D ( $P < 0.05$ ) and during the winter season in gulf areas of A–D ( $P < 0.01$ ). In contrast, sand seatrout abundance was inversely related to water depth within these gulf areas (Fig. 6). However, sand seatrout abundance was inversely related to water depth among gulf areas ( $r = -0.61$ ,  $P < 0.0001$ ) (Fig. 7), whereas silver seatrout abundance was not significantly correlated with depth among offshore areas ( $r = 0.06$ ,  $P = 0.49$ ). Water temperature correlation coefficients exhibited no correlation with the presence of sand seatrout, whereas the presence of silver seatrout appear to have a strong positive relationship with water temperature specifically for the winter season in gulf areas (A–D) ( $P < 0.01$ ) (Fig. 8C).

Salinity between our offshore sampling areas increased from north to south. Salinity among gulf areas were (range, mean salinity  $\pm$  SD); gulf area A (3.2–40.0, 26.4  $\pm$  4.8), gulf area B (9.0–42.0, 29.1  $\pm$  4.6), gulf area C (2.4–43.0, 31.4  $\pm$  3.5), gulf area D (2.4–44.0, 32.4  $\pm$  3.4), and gulf area E (23.0–42.6, 33.6  $\pm$  2.6). Although there were no significant differences in abundance between these species at different salinities locally (Fig. 8B), salinity did appear to play a role in the broad-scale geographic distribution of the two species, particularly that of sand seatrout. Sand seatrout displayed a strong inverse relationship with salinity among gulf areas, across years ( $r = -0.56$ ,  $P < 0.0001$ ) (Fig. 9), whereas silver seatrout displayed no relationship with salinity among gulf areas, across years ( $r = -0.02$ ,  $P = 0.8003$ ).

#### Distribution of sand seatrout inshore

Sand seatrout were much less common inshore than in offshore catches. Sand seatrout abundance inshore (mean  $\pm$  standard error of ind. collected/hr) (4.6  $\pm$  0.6) was significantly lower ( $P < 0.0001$ ) than abundance offshore (15.2  $\pm$  3.3). There was also a significantly higher abundance ( $P = 0.0062$ ) of sand seatrout collected in both summer (10.5  $\pm$  2.4) and spring (11.6  $\pm$  4.7) seasons than during the fall season (7.6  $\pm$  1.9). The interactive effects of location and season did not reveal a significant effect on sand seatrout abundance ( $P = 0.1192$ ); this result was due to trends in inshore abundance among seasons being generally predictive of trends in offshore

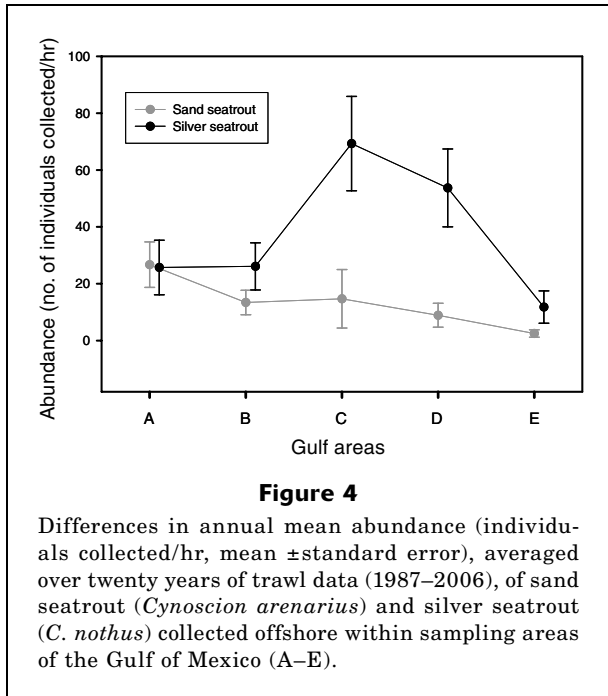


**Figure 3**

Monthly length-frequency histograms (averaged over twenty years of trawl data (1987–2006)) for combined major bays (inshore) in the Gulf of Mexico for sand seatrout (*Cynoscion arenarius*), combined gulf sampling areas (offshore) for sand seatrout, and for combined offshore sampling areas for silver seatrout (*C. nothus*), by 10-mm total length (TL) size classes.

abundance, although overall abundance remained higher offshore (Fig. 2A). The length-frequency histograms further illustrated differences in abundance among locations (Fig. 3). Sand seatrout collected inshore appeared to decrease in abundance after August, whereas offshore sand seatrout began to decrease in abundance after spring, specifically after July. Additionally, clear bimodal peaks in abundance were evident for May in both inshore and offshore areas, reflecting the bimodal spring and late-summer+fall spawning times of sand seatrout (Shlossman and Chittenden, 1981).

Sand seatrout were significantly higher ( $P < 0.0001$ ) in abundance in major bays with passes (mean  $\pm$  SE) ( $5.9 \pm 0.8$ ) than in bays without direct passes ( $1.4 \pm 0.4$ ) (Table 2). There was also significant seasonal difference ( $P = 0.0003$ ) inshore; abundance was higher in the summer ( $4.9 \pm 1.3$ ) than in spring ( $3.2 \pm 0.9$ ) and fall ( $2.8 \pm 0.8$ ). The interactive effects of pass presence and season were not significant ( $P = 0.1255$ ) (Fig. 2B). However, sand seatrout differed significantly in abundance among bays with passes ( $P < 0.0001$ ) (Table 2), and all bays were significantly greater in abundance than the

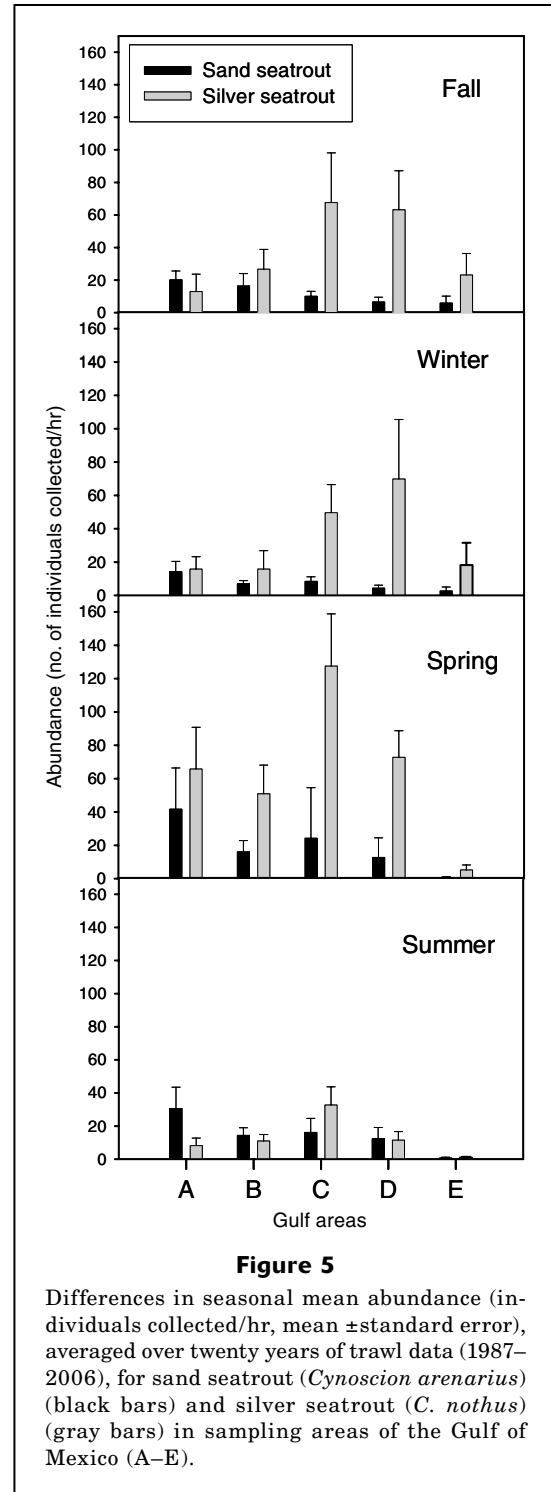


Lower Laguna Madre (Fig. 10). There was a significant seasonal difference ( $P < 0.0001$ ) among bays with passes; abundance was greater in summer ( $7.6 \pm 1.5$ ) than in spring ( $5.3 \pm 1.0$ ) and fall ( $4.1 \pm 0.8$ ). No significant interactive effects were reported for bays with direct passes and seasons ( $P = 0.3337$ ), and this result was due to parallel seasonal patterns among the bays. Abundance of sand seatrout was highest for inshore areas from Corpus Christi Bay north, for all seasons (Fig. 11).

## Discussion

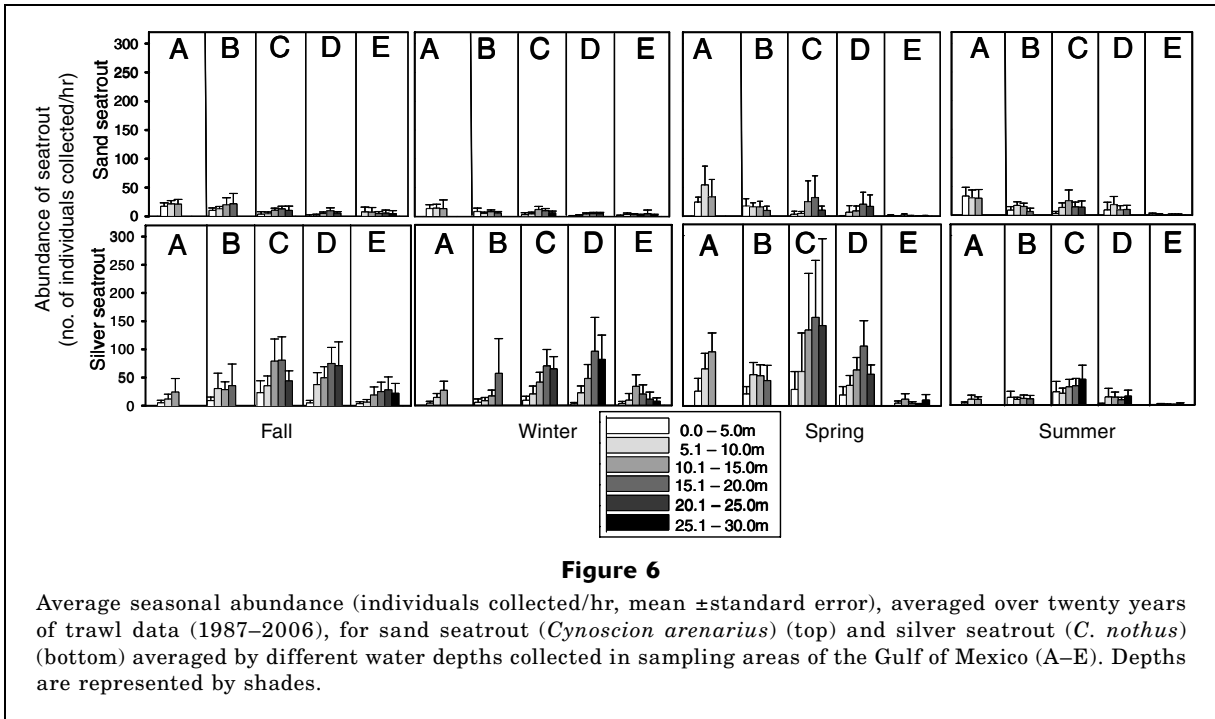
### Distribution between species offshore

Evidence from this study established a significantly lower concentration of sand seatrout than that of silver seatrout within 16.7 km of the immediate GOM, within the boundaries of Texas. Miller (1965) and Chittenden and McEachran (1976) also recorded a lower abundance of sand seatrout than silver seatrout, but they did not investigate the cause. The lower abundance of sand seatrout than silver seatrout is most likely due to differences in their life histories and environmental preferences. Sand seatrout use both the offshore and inshore bays in contrast to silver seatrout which use the offshore throughout their lives (Shlossman and Chittenden, 1981; DeVries and Chittenden, 1982). Sand seatrout primarily use these estuaries during early life stages, most probably because of the relatively sensitive tolerances of juveniles to salinity. In contrast, silver seatrout have a much higher salinity tolerance and are more likely to be abundant off the coast of Texas where salinities are



higher than off the coasts of Louisiana or Mississippi, where salinities are reduced by the productive Mississippi and Atchafalaya rivers (Dinnel and Wiseman, 1986).

The offshore abundance of sand seatrout was lower than that of silver seatrout for every season other than summer. In the summer season, offshore silver seatrout

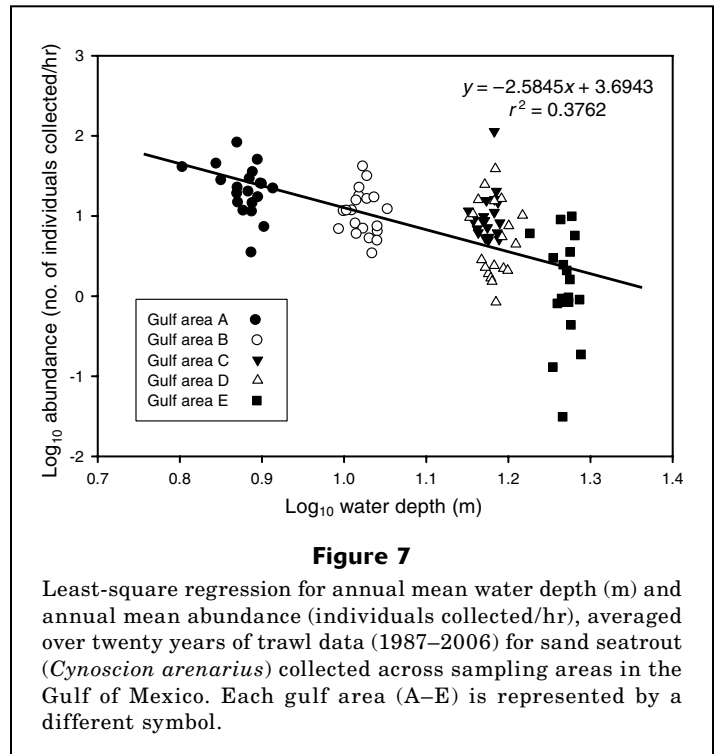


abundance tended to drop dramatically. This finding is similar to the results of DeVries and Chittenden (1982) who also described a reduction in silver seatrout abundance offshore in summer and may also be due to offshore migrations, die offs, or sampling errors.

Low silver seatrout abundance during the summer season may be due to their migrations farther offshore. Although summer migration outside of CF-TPWD sampling areas (>16.7 km from shoreline) has not been reported for silver seatrout, they do migrate during winter (DeVries and Chittenden, 1982) and summer migrations occur in similar species (Vetter, 1982). A spatial analysis of offshore sampling areas indicated that samples of both species were commonly collected in the outermost (most offshore) grids sampled (data not shown). Thus, it is possible that the true center of distribution of silver seatrout was not sampled in our study and that offshore migration during summer months is reflective of seasonal movements into deeper water.

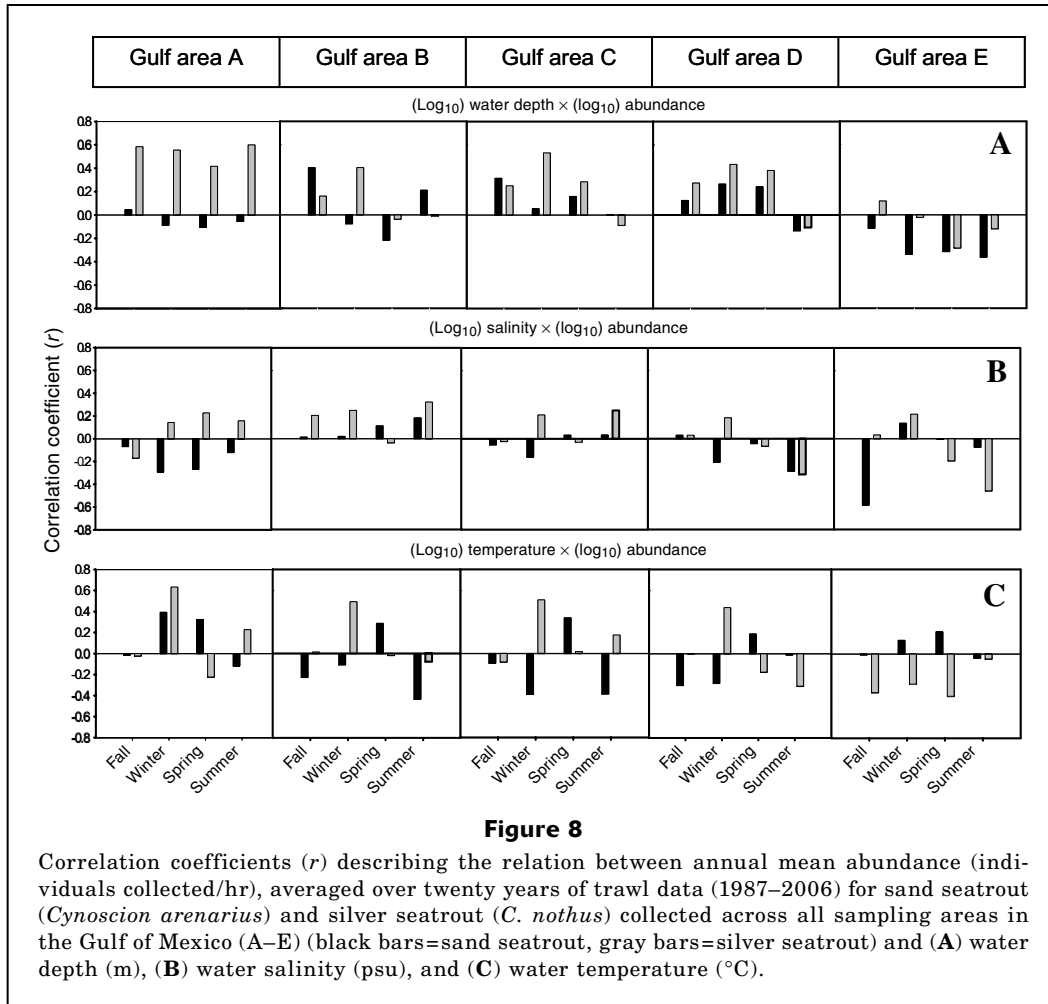
Low silver seatrout abundance during the summer season may also be due to adult die offs of a species with a short life span. DeVries and Chittenden (1982) estimated a maximum life span for silver seatrout of one to one-and-a-half years of age. Not only are they short-lived, but they are also summer spawners. Thus, the reduction in abundance in summer may reflect cyclic spawning, followed by the die-off of spawners.

Finally, low silver seatrout abundance during the summer season may be due to sampling bias in that



the capture of the larger-size silver seatrout may have been limited. Sheridan et al. (1984) captured numerous silver seatrout >200 mm TL; our samples were rarely >200 mm TL. However, Sheridan et al. (1984) did not describe their trawl methods, specifically their

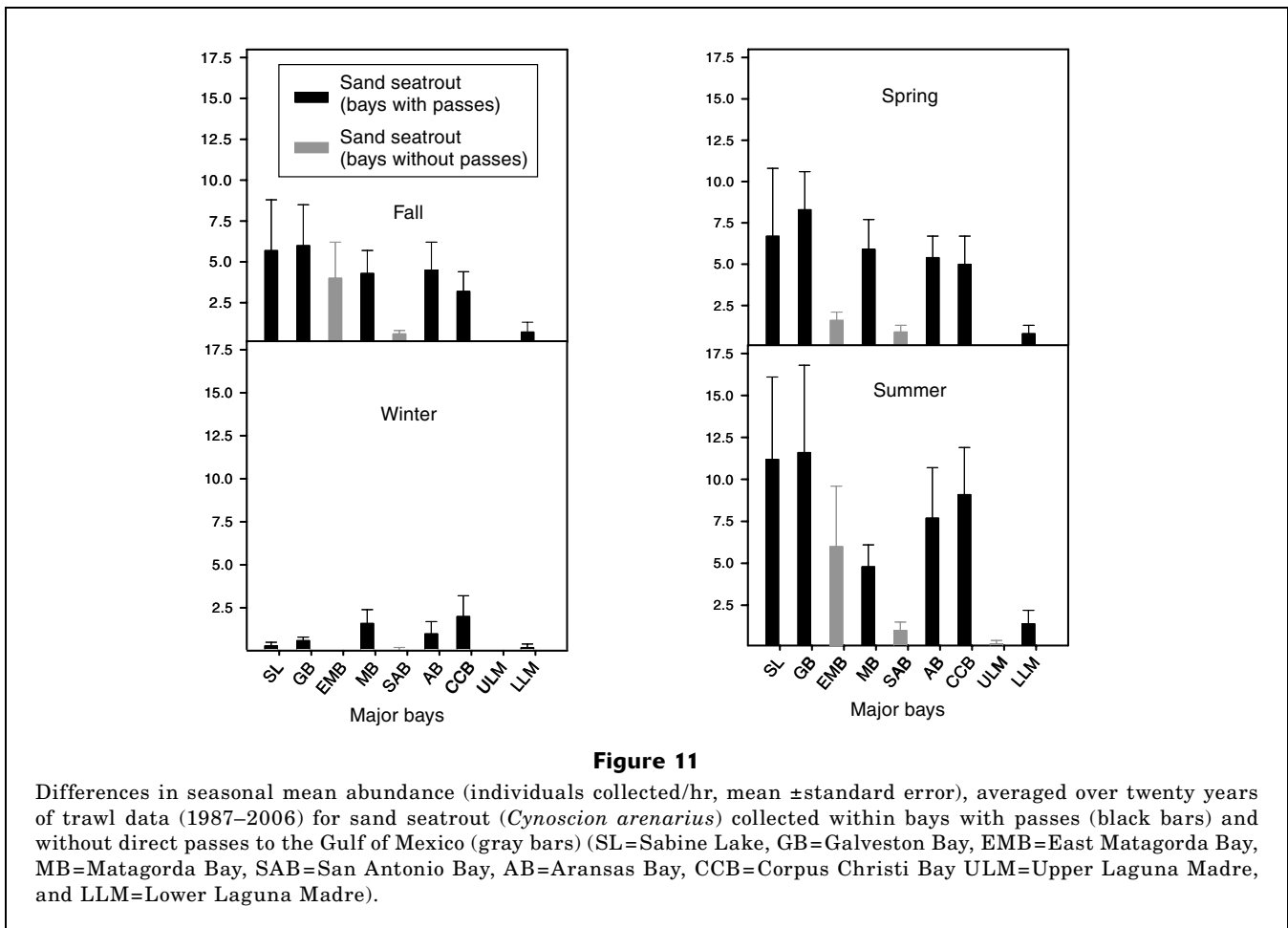
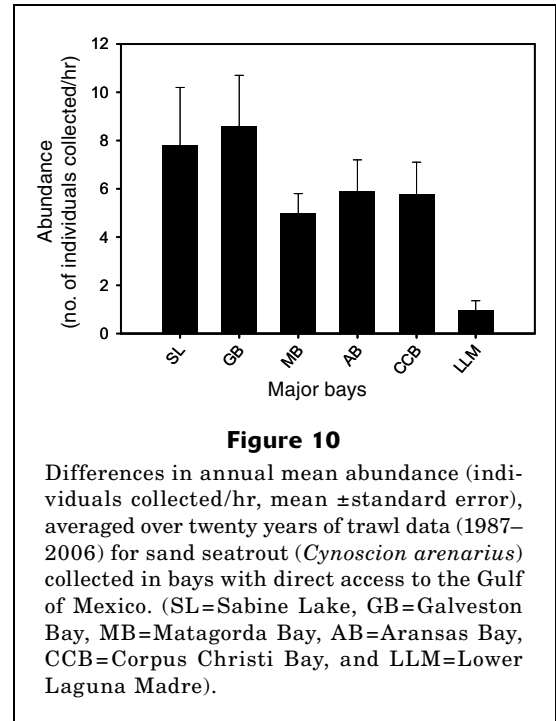
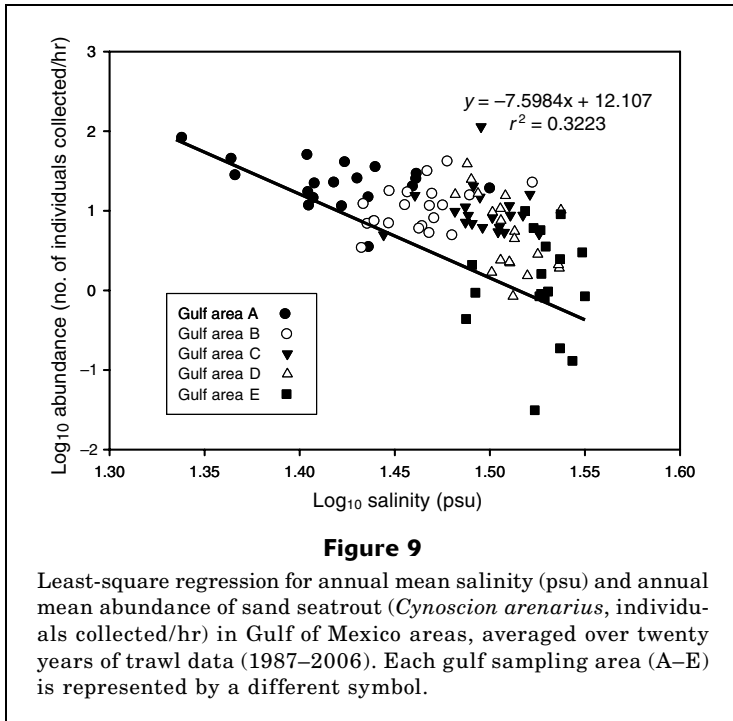




mesh sizes, and therefore a direct comparison of data cannot be made. Depending on their ability and size, fishes attempt to avoid contact with trawl gear by either maintaining position at the net opening (Wardle, 1983) or by falling back along the taper of the body panel of the trawl net towards the codend opening (Wardle, 1983), as discussed by Broadhurst et al. (2000). Thus trawl configuration can play a role in limiting the size and condition of fishes that are captured. In contrast to silver seatrout, sand seatrout are found offshore within gulf areas in highest abundance during the spring and summer seasons. Increased spring abundance may be due to both the mature-size individuals emigrating from bays to the offshore in order to spawn as well as to the presence of recently spawned young of the year during May–July (Fig. 3). In any case, the relative abundance of sand seatrout off the coast of Texas is dramatically lower than that of silver seatrout, in all seasons other than summer.

There is a difference in the distribution of both sand and silver seatrout in offshore gulf areas. Whereas silver seatrout are found predominately along the middle coast, sand seatrout, although lower in overall abun-

dance, appear to decrease in abundance from north to south. Moore et al. (1970) described somewhat similar results, namely a higher abundance of sand seatrout within Louisiana waters and more silver seatrout in Texas waters. The distributional distinctions between species in our study correlated well with both salinity and water depth. Sand seatrout were shown to have a preference for lower salinities, whereas silver seatrout prefer higher salinities (ranging from 7.5 to 38.6 psu) (Swingle, 1971). In addition, Ginsburg (1931) and Miller (1965) have reported the water depth preferences for sand seatrout (shallower depths) and silver seatrout (deeper depths). Gulf area A, because it is shallower and less saline than the other gulf areas, appears to be ideal habitat for sand seatrout, whereas silver seatrout prefer the deeper and more saline gulf areas C and D. Correlation between depth and abundance also occurred locally, within selected sampling areas. For instance, within gulf area A, silver seatrout were found specifically within the deepest grids, for all seasons. Also, silver seatrout were found in deeper waters during fall and winter, across most sampling areas, indicating the occurrence of an offshore winter migration during



cooler months, as reported by DeVries and Chittenden (1982). Sand seatrout also may migrate to the deeper waters of the GOM in response to either photoperiod or temperature extremes of winter and summer (Vetter, 1982), although they tend to be found at shallower depths than those occupied by silver seatrout in the gulf areas. The environmental variables for Gulf area E formed an exception in our data; there were no correlations found with the presence of either species. This result may have been caused by environmental factors that were outside the optimum for both species, which resulted in neither species being found in high abundance in this area.

Water temperature displayed some correlation with the preference of silver seatrout for warmer waters, during the winter season across relevant gulf areas (A–D). This correlation, in conjunction with the propensity of silver seatrout to be found deep in the water column, may indicate that they have less temperature tolerance than sand seatrout.

#### Distribution of sand seatrout inshore

Sand seatrout are unique among their GOM congeners in their extensive use of both inshore and offshore areas, compared to spotted seatrout (a primarily inshore species) and silver seatrout (a primarily offshore species). Therefore the intent of the second objective of our study was to relate the abundance of sand seatrout between these two locations and further to characterize factors that correlated with their inshore distribution. To this end, the overall abundance at the offshore and inshore locations was compared. Second, the effectiveness of direct passes between the inshore and offshore areas in predicting sand seatrout abundance was examined. Finally, the correlation between abundance inshore and offshore was examined in order to demonstrate whether increased inshore abundance was predictive of increased offshore abundance in the same area.

Despite using both offshore and inshore areas, sand seatrout were significantly less abundant inshore than offshore, in all seasons. Additionally, trends in inshore abundance appeared to mirror trends in offshore abundance, with abundance increasing in spring and summer and decreasing in fall and winter. These trends correspond with spawning cycles followed by spawning inactivity, and are comparable to trends suggested by Shlossman and Chittenden (1981). For instance, sand seatrout migrate offshore from inshore areas during temperature extremes (Vetter, 1982) and for spawning (Gunter, 1945). Additionally, older fish may become more tolerant of higher salinity levels with age, in general resulting in older fish using offshore areas more frequently. The offshore abundance of sand seatrout may also result from nutritional preferences of mature fish. Sand seatrout found offshore are generalists, preying on both fish and crustaceans that are found at offshore depths of 3.5–22 m (known white shrimp grounds) during June–September and that are most common in the depths of 22–91 m (known brown shrimp grounds)

during January–March (Chittenden and McEachran, 1976; Byers, 1981). Finally, sand seatrout are found in highest abundance inshore during the summer, a finding that is similar to what has been indicated by Byers (1981). Shlossman and Chittenden (1981) suggested that this abundance is due to the introduction of the recently spring-spawned offspring to the inshore population (Shlossman and Chittenden, 1981), which thus consists primarily of age-1 individuals that have not yet moved offshore.

Inshore sand seatrout abundance was different among locations, and correlated closely with the presence or absence of direct access to GOM spawning grounds. It has previously been noted that sand seatrout have a higher affinity for bays with direct passes to the offshore than to bays with no direct passes. For instance, Simmons and Hoese (1959) suggested that pass presence is imperative for seasonal sand seatrout migration, although they did not directly quantify the effect of pass presence on abundance. The data in the present study demonstrated a disparity in abundance between bays with direct access to offshore water and bays with some limitations to offshore water, whether it is distance or a barrier by islands. In fact, pass presence is the most influential global factor in affecting abundance among the various inshore bays. Pass presence clearly affects movements of fishes offshore and inshore; therefore, for a migratory species that moves between the two areas annually, pass presence is critical to inshore abundance. Shlossman and Chittenden (1981) suggested that although sand seatrout nurseries may be found both in estuarine and offshore habitats, estuarine areas may be the most important habitat for late summer age-1 fish. Finally, Shlossman and Chittenden (1981) noted that the spawning of sand seatrout coincides with onshore winds and surface currents that facilitate passive transport of eggs and larvae to inshore nurseries; thus pass presence would have a significant effect on abundance within bays, particularly during early life stages.

A second factor that significantly indicated inshore abundance of sand seatrout was abundance in the contiguous offshore area. Sand seatrout abundance within bays with direct passes is significantly higher in bays from Corpus Christi Bay, north, and this high abundance correlates with the overall abundance of sand seatrout offshore, year round. For major bays with low sand seatrout abundance, such as the Lower Laguna Madre, there is a corresponding lower overall abundance offshore (i.e., in gulf area E). One exception to this finding is the unique assemblage of species found in the hypersaline Lower Laguna Madre—species that are not seen elsewhere along the Texas coast. In this instance, it is likely that both hypersaline conditions and low offshore abundance have limited the abundance of sand seatrout inshore of Lower Laguna Madre.

Sand seatrout inshore abundance is thus related to a host of different factors. Access to offshore waters is the most significant factor, but it is important to note that inshore transport of eggs and larvae and offshore mi-

gration of adults are limited by pass size, configuration, and distance. However, there are also global factors such as the population abundance within offshore areas that affect inshore abundance, which decreases from north to south along the Texas coast. In turn, offshore abundance is likely related to hydrological factors such as depth and salinity, such that inshore populations of sand seatrout are not independent of offshore abiotic conditions. However, offshore abundance may be equally affected by the presence and availability of estuarine nursery areas, because estuaries are highly productive and offer an alternative location for the growth of age-1 individuals. This supposition was not explicitly tested in our study because all offshore gulf areas in this study were located near estuarine passes. However, it is clear that offshore and inshore abundance are closely linked, and the presence of a pass between the two likely affects abundance of local populations as a whole.

### Acknowledgments

We thank biologists of the Texas Parks and Wildlife Department-Coastal Fisheries Division (TPWD-CF), specifically the countless dedicated technicians and biologists who collected the data as part of their routine monitoring activities that are funded in part by Federal Aid in Sportfish Restoration Grant (FRM-34). We thank B. Balboa for his expertise and time. Improvements to the first draft were provided by M. Fisher (TPWD), B. Karel (TPWD), C. Williams (TSU), and wife Christa (of Dusty McDonald), and three anonymous reviewers. This research project was funded in part by dedicated funds from a Federal Aid in Sportfish Restoration Grant (F-158-R).

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