Abstract–Life-history dynamics of pinfish (*Lagodon rhomboides*) were examined from data derived from random-station surveys conducted in Tampa Bay and adjacent Gulf of Mexico waters during 1993–97. In addition, patterns in spatial distribution and abundance in Gulf of Mexico waters were investigated. Ages determined from whole otoliths ranged from 0 to 7 years, and von Bertalanffy growth models for males and females were not significantly different. Von Bertalanffy growth model parameters were L_∞=219.9 mm SL, k =0.33/yr, and t_0 =–1.10 years for all fish combined. High gonadosomatic indices during October–December indicated that some spawning may occur in Tampa Bay. Estimated lengths at 50% maturity were 132 mm SL for males and 131 mm SL for females. Total instantaneous mortality rates derived from the Chapman-Robson estimator ranged from 0.88 to 1.08/yr, and natural mortality was estimated to be 0.78/yr. In Gulf of Mexico waters, pinfish catch rates declined with increasing depth, and most pinfish were caught in <17 m of water. Length distributions showed that pinfish segregate by size with increasing depth.

Age, growth, mortality, and distribution of pinfish (*Lagodon rhomboides*) in Tampa Bay and adjacent Gulf of Mexico waters

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The pinfish (*Lagodon rhomboides*) is an ecologically important sparid that inhabits estuarine and offshore waters of the United States from Massachusetts to Texas (Darcy, 1985). Young-of-the-year pinfish are predators on a range of invertebrates in estuaries, often to the degree that entire assemblages of macrobenthic fauna are affected (Young et al., 1976; Young and Young, 1977; Nelson, 1978). They also consume seagrasses during their estuarine phase, which makes them an important link between primary and secondary production (Stoner, 1982; Weinstein et al., 1982; Montgomery and Targett, 1992). Both young-of-the-year and adult pinfish are prey for other fishes (Gunter, 1945; Darnell, 1958; Carr and Adams, 1973; Seaman and Collins, 1983) and are used as bait for many recreationally and commercially important species.

Despite their ecological and economical importance, the population biology and dynamics of pinfish in Florida have not been adequately examined. Most knowledge about growth (Reid, 1954; Caldwell, 1957; Hellier, 1962; Nelson, 1998), distribution and migration (Caldwell, 1957; Hansen, 1970; Nelson, 1998), and mortality (Nelson, 1998) comes from studies of young-of-the year pinfish in estuaries. The only information available on older individuals comes from estuarine studies that describe size and age at spawning (Caldwell, 1957; Hansen, 1970), gross fecundity (Caldwell, 1957), and longevity and size at age (Hansen, 1970).

However, that information may contain biases because sampling did not extend into offshore waters where larger, and presumably older, pinfish are thought to occur, particularly during cooler months (Darcy, 1985).

In this study, age, growth, mortality, and maturation of pinfish were evaluated by studying data from multigear fisheries-independent surveys conducted in Tampa Bay, Florida, and in offshore waters off west-central Florida. In addition, patterns in abundance and spatial distribution of pinfish in the Gulf of Mexico were examined.

Methods

Biology

Pinfish for aging, maturity, and mortality analyses (*n*=711) were collected opportunistically from fall 1993 to spring 1997 during multiple fisheries surveys conducted in Tampa Bay and offshore Gulf waters by the Florida Marine Research Institute (Fig. 1). Pinfish from Tampa Bay were collected primarily during multigear seasonal (spring and fall) and monthly fisheries-independent surveys designed to estimate relative abundance of small estuarine fishes and evaluate life-histories parameters of large estuarine fishes (Table 1). During the surveys, sites were chosen by randomly selecting 1″ latitude × 1″ longitude microgrids, representing the site to be sampled, within randomly selected 1′ latitude ×
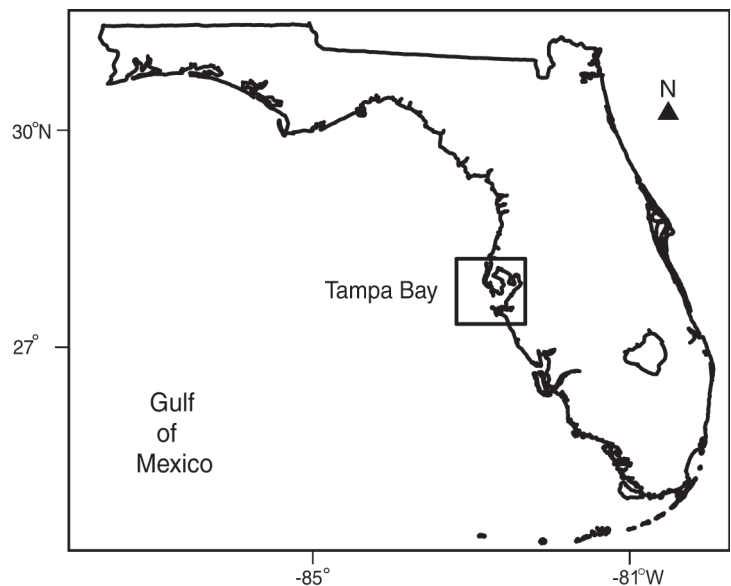
Table 1

Length summary statistics (by area, year, and gear) for pinfish collected during biological sampling. Exp. gill net = experimental gill net.

Year	Gear	Stretched mesh (mm)	Pinfish SL (mm)			
			Minimum	Maximum	Mean	*n*
Tampa Bay						
1993	trammel net	76, 305	179	255	211.8	31
1995	exp. gill net	50–152	170	185	180.0	3
	183-m seine	38	73	202	121.1	50
	trammel net	76, 305	173	216	191.4	8
	21-m seine	3.2	73	150	112.1	24
	61-m seine	25.4	72	165	132.6	19
1996	183-m seine	38	66	207	126.9	313
	purse seine	50	100	181	125.9	34
	trammel net	76, 305	203	203	203.0	1
	21-m seine	3.2	34	174	89.0	28
	hook and line	—	198	205	202.0	3
1997	183-m seine	38	83	155	111.3	62
	purse seine	50	91	156	108.9	16
	21-m seine	3.2	25	104	71.7	18
Gulf of Mexico						
1996	hook and line	—	116	149	135.2	17
1997	bottom trawl	254	95	175	128.8	84

1′ longitude grids. At each site, gears were deployed with standardized procedures (see Nelson [1998] and Tremain and Adams [1995] for detailed description of the survey design and deployment techniques). Selected individuals were immediately placed on ice for transport and frozen whole at the laboratory.

Pinfish from the Gulf of Mexico were collected primarily during a bottom-trawl survey conducted in spring in the Gulf of Mexico to document baitfish abundance and distribution. The Gulf trawl survey was conducted during April from 1994 to 1997 at stations randomly selected along line transects randomly placed perpendicular to the west coast of the Florida peninsula adjacent to Tampa Bay. At each station, a 19.8-m, 254-mm stretched-mesh modified ballon trawl with 25.4-mm codend liner and 2.2-m² China V-doors was towed at approximately 3 knots for 30 min during daylight hours in depths ranging between 6 and 31 m. At each station, trawl catches were sorted by species, counted, weighed collectively, and 50 individuals per haul were measured to the nearest 1 mm fork length (see Pierce and Mahmoudi [2001]) for a detailed description of the survey design). Depth (m) at the start and end of the trawl tow and surface salinity and temperature were recorded at all stations. To match data collected from the Tampa Bay samples, all length data were converted to standard length by using conversion equations derived from this study. Individual fish were immediately frozen whole and returned to the

Figure 1

Maps of Florida showing study area.

laboratory. Occasionally, supplemental samples were collected by hook-and-line fishing in Tampa Bay and the offshore waters (Table 1).

In the laboratory, standard length (SL ±1 mm), fork length (FL ±1 mm), total length (TL ±1 mm) and total

weight (TW ±0.01 g; measured after each individual was blotted dry) were recorded for all thawed, undamaged individuals. Gonads were excised from a subsample of individuals (~80%) of each collection, identified macroscopically (and microscopically if needed) as ovaries or testes, blotted dry on a paper towel, and weighed (±0.01 g). Seasonal conversion equations for length measurements were generated by least-squares regression (SAS, 1990a).

Age and growth

Sagittal otoliths for aging studies were excised, cleaned of extraneous tissue, and stored dry in vials. Otolith length was measured under a binocular dissecting microscope at 10× with a calibrated ocular micrometer, and an otolith length (mm) versus fish standard-length relationship was derived by using least squares regression. For age determination, one whole otolith (either left or right) was placed on black velvet to enhance the visibility of opaque zones, submerged in a 60% glycerin solution, and viewed at 32× with reflected light. Otolith edges were classified as either opaque or hyaline to determine time of opaque ring formation. The number of opaque rings was considered to equal the age in years of the pinfish. Age determinations were repeated three times on all whole otoliths. If two of the three age readings were in agreement, the value was accepted. If age varied between all readings, the structure was not included in the analysis. The accuracy with which whole otoliths can be used to age pinfish was confirmed by comparing whole otolith ages from a subsample of the largest pinfish to age readings made on thin sections of the same otoliths. Methods of Hood and Johnson (1999) were used to section otoliths. To verify the consistency of the opaque ring counts, a random subsample (13%) of all whole otoliths was aged once by an experienced second reader and the results were compared to the final age determination. Pinfish larvae are present off the west coast of Florida between November and February (Darcy, 1985); therefore a 1 January birthdate was assumed for all pinfish. Age in years was designated with a decimal extension that represented the date of capture in days from the 1 January birthdate.

Growth was modeled by fitting length-at-age for all years combined to the von Bertalanffy equation:

$$L_{i,t} = L_\infty * \left(1 - \exp^{(-k*(age-t_0))}\right) + \varepsilon_{ij},$$

where $L_{i,t}$ = the standard length of the i th individual at age t;
L_∞ = the asymptotic maximum length;
k = a growth constant;
t_0 = the hypothetical age at which length is zero; and
$\varepsilon_{ij}s$ = independent, identically distributed, normal random errors.

Parameters L, k, and t_0 were estimated by using SAS nonlinear regression (Proc NLIN) with the Marquardt method (SAS Institute, 1990b). Lack of fit was assessed by using residuals plots (Bates and Watts, 1988).

Growth-rate differences between sexes were investigated by using an approximate randomization test to compare growth curves (Helser, 1996). Essentially, differences were investigated by comparing an observed test statistic to an empirical probability density function of a test statistic under the null hypothesis of no difference. The observed test statistic for pinfish was developed by fitting the von Bertalanffy growth functions to length-at-age data for sexes combined and to length-at-age for each sex separately. The sums of the residual sum of squares from the two sex-specific models were then used to calculate the observed test statistic

$$t(x_0) = \sum_{i,t} (l_{i,t} - \hat{l}_t)^2 - \sum_{l,t,p} (l_{i,t,p} - \hat{l}_{t,p})^2,$$

where $t(x_0)$ = the test statistic;
l_t = the predicted length-at-age for all sexes combined; and
$l_{t,p}$ = the predicted length-at-age for each sex (p=1,2) (Helser, 1996).

To generate the empirical probability density function (pdf), length-at-age data for both sexes were pooled and then assigned randomly without replacement to two groups with sample sizes equal to the original number of observations per sex. Growth curves were then fitted separately to the length-at-age data of the randomized groups, and the test statistic under the null hypothesis of no difference was calculated as

$$t(x) = \sum_{i,t} (l_{i,t} - \hat{l}_t)^2 - \sum_{i,t,p} (l_{i,t,p}^* - \hat{l}_{t,p}^*)^2,$$

where $t(x)$ = the difference in residual sum of squares between the von Bertalanffy fits to the entire pooled data set and von Bertalanffy fits to the randomized groups (denoted by *).

The randomization procedure was repeated 1000 times to obtain the pdf of $t(x)$. The null hypothesis of no difference was rejected if $t(x_0) > t(x)$ at α=0.05.

Reproduction, sex ratios, and maturity

Gonads excised from selected individuals were classified macroscopically as either immature or mature by using the maturation criteria of Nikolsky (1963) and Cody and Bortone (1992). Seasonality of reproduction was determined by noting when changes in the gonad condition took place. A gonadosomatic index (GSI) was calculated to show changes in gonad weight in relation to gonad-free total body weight. The index was computed as

$$GSI = gonad\ weight/(total\ body\ weight - gonad\ weight) \times 100.$$

Length at 50% maturity was estimated for pinfish captured during the season of gonadal maturation. The prob-

ability of pinfish being mature was modeled as a logistic function of the following form:

$$P_i = \frac{\exp^{(\alpha+\beta*x_i)}}{1+\exp^{(\alpha+\beta*x_i)}} + \varepsilon_i,$$

where P = the response probability;
x = the standard length (mm) of the i th fish;
α = the intercept;
β = the slope coefficient of standard length; and
ε_i = the error term.

Model regression coefficients were estimated using maximum likelihood (SAS, 1997). Goodness-of-fit was assessed with the chi-square test.

Chi-square analyses were used to test for deviations from a theoretical 50:50 sex ratio.

Length-weight relationships

Because of the seasonality of reproduction, data on body length and weight were separated into two groups representing two time periods to construct length-weight relationships that reflected seasonal changes in gonad weight. Data collected during March–August composed the data group representing the spring–summer period, and data collected during September–February composed the data group representing the fall–winter period. Seasonal regression equations for $\log_{10}$-transformed standard length and body weight (total and gonad-free weight) were generated by the least-squares regression. One-way analysis of covariance (Sokal and Rohlf, 1981), conducted by using SAS PROC MIXED (Littell et al., 1996), was used to test for differences between regression slopes and adjusted means of the length-weight relationships by sex and season.

Mortality

Total instantaneous mortality (Z) was estimated in Tampa Bay and the Gulf of Mexico from pinfish numbers-at-age data by using the Chapman-Robson equation for survival (S) estimation:

$$-Z = \ln(S) = \ln\left(\frac{\sum_{i=1}^{n} x_i}{n + \sum_{i=1}^{n} x_i - 1}\right),$$

where $\ln$ = the natural log;
x_I = the number of years the i th fish is older than the age-at full-recruitment;
S = annual survival; and
n = the total number of fully recruited fish (Chapman and Robson, 1960).

The variance of Z was estimated from the variance of S by

$$V(Z) = \frac{S(1-S)^2}{n*S^2}$$

(Jensen, 1985). The Chapman-Robson estimator was used because it is more robust to sample size variation in numbers-at-age (Jensen, 1996; Murphy, 1997).

In addition to Z, natural mortality (M) of pinfish was estimated by using a multiple regression equation relating M to L_{∞} (TL in cm) and k (per yr) of the von Bertalanffy equation, and to mean annual water temperature (°C)(Pauly, 1980). To estimate the growth parameters used in the equation, the von Bertalanffy function was refitted to total length and age data. Mean annual water temperature was estimated from temperature data of the Tampa Bay survey.

Distribution

To determine if pinfish catch rates in the Gulf of Mexico were associated with depth, a generalized linear model (McCullagh and Nelder, 1989) was used to model the random trawl catches during the April survey from 1994 to 1997. Catch data were transformed by using $\ln(x+1)$ to stabilize the variance and reduce the influence of sampling variability between tows. Year, average depth of the trawl tow, and their first-order interaction were included in the model. Only depth was analyzed because surface readings of temperature and salinity were thought to not reflect bottom conditions where the trawl tows were made. Size structure of pinfish caught during the Gulf of Mexico survey was also examined by calculating summary statistics (mean and percentiles) of length data to identify patterns related to depth.
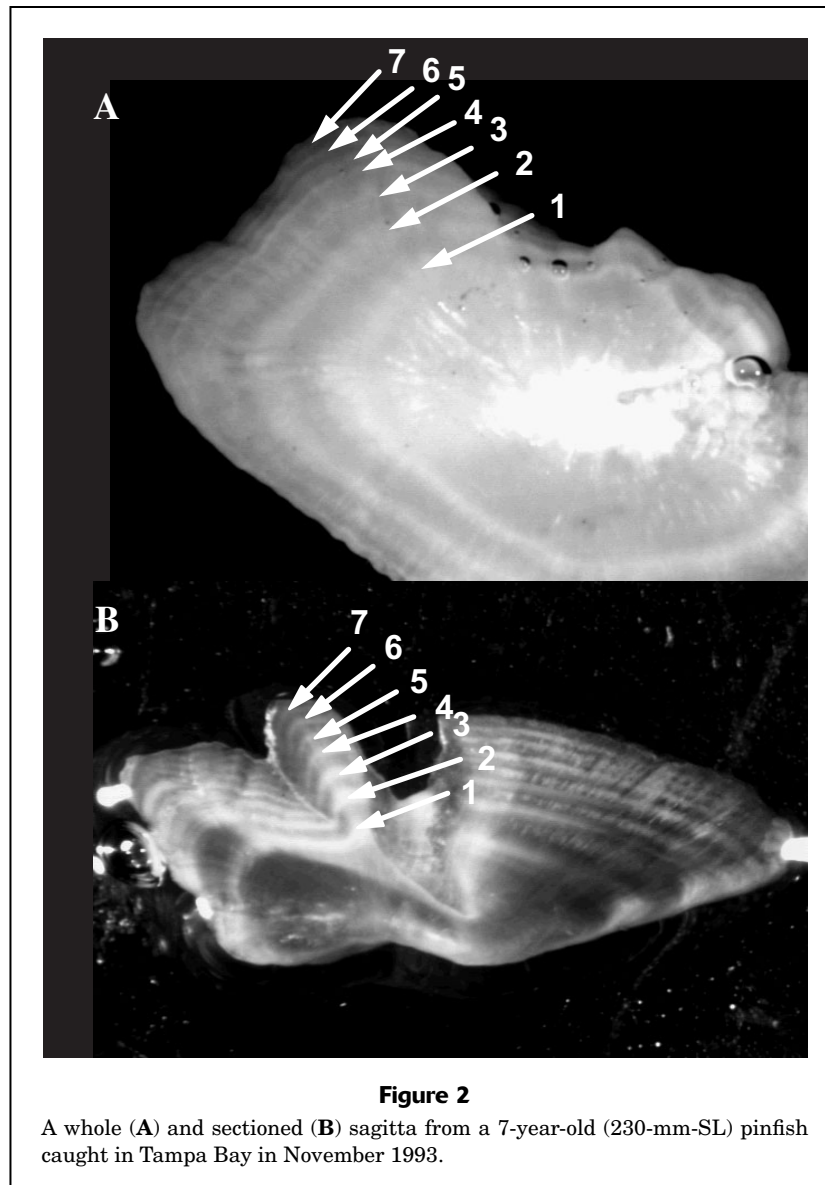
Results

Biology

Length-conversion equations are listed in Table 2. All slopes and intercepts were significantly different from zero.

Age and growth

Age determination was based on sagittae from 658 pinfish (66–255 mm SL). Alternating opaque and hyaline zones, which composed an annual growth increment, were evident on whole pinfish otoliths (Fig. 2A). Only 13 otoliths were considered unreadable. Agreement between the number of opaque bands counted on whole otoliths and the number counted on sections of the same otoliths (Fig. 2B) was 96.3% (26/27), indicating that whole otoliths can be used to reliably age pinfish. The high percentage of agreement (89.6%) between the author's final annulus counts and those made by a second reader, and no apparent bias towards a particular aging error, indicated that ages were consistently interpreted.

Plots of the monthly proportions of otolith with opaque edges for pinfish ages 1 to 3 indicated that an opaque ring

Figure 2

A whole (**A**) and sectioned (**B**) sagitta from a 7-year-old (230-mm-SL) pinfish caught in Tampa Bay in November 1993.

is formed only once a year, during late winter to late spring. Deposition of opaque material began as early as January; it peaked during March, April, or May depending on age; and it was completed, or nearly so, by June (Fig. 3).

A single regression equation characterized the relationship between otolith length (OT in mm) and standard length for a random sample of pinfish 71–230 mm SL (standard errors are in parentheses) used in age analysis:

$$OT = 8.03(1.07) + 0.39(0.008) \times SL; \quad [r^2 = 0.95, n = 132].$$

The intercept and slope coefficients were significantly different from zero ($P<0.001$).

Ages of pinfish ranged from 0 to 7 years (66–255 mm SL) in Tampa Bay and from 1 to 6 years (95–175 mm SL) in the Gulf of Mexico (Fig. 4A). The majority (88.1%) of

aged pinfish were ≤2 years. Residual plots from the growth models showed near-random patterns, indicating that the von Bertalanffy model adequately described the growth of male and female pinfish. Results of the randomization test did not indicate a significant difference between male and female growth models ($t(x_0)$=2,691; $p(t(x)>t(x_0))$=0.27); therefore, a von Bertalanffy model was fitted to all pinfish data combined (Fig. 4B, Table 3). Growth rate of pinfish was rapid for the first 1–3 years of life but gradually decreased thereafter (Fig. 4B).
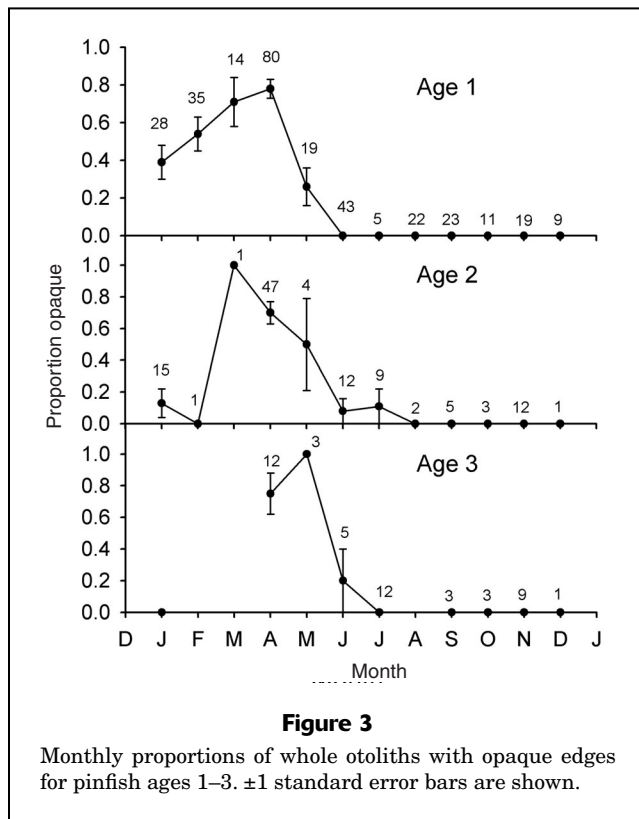
Reproduction, maturity, and sex ratios

Seasonality of reproduction was indicated by monthly changes in the GSIs of all pinfish over time. In Tampa Bay and the Gulf of Mexico, GSIs for males and females were ≤0.5% during the spring and summer months (Fig. 5).
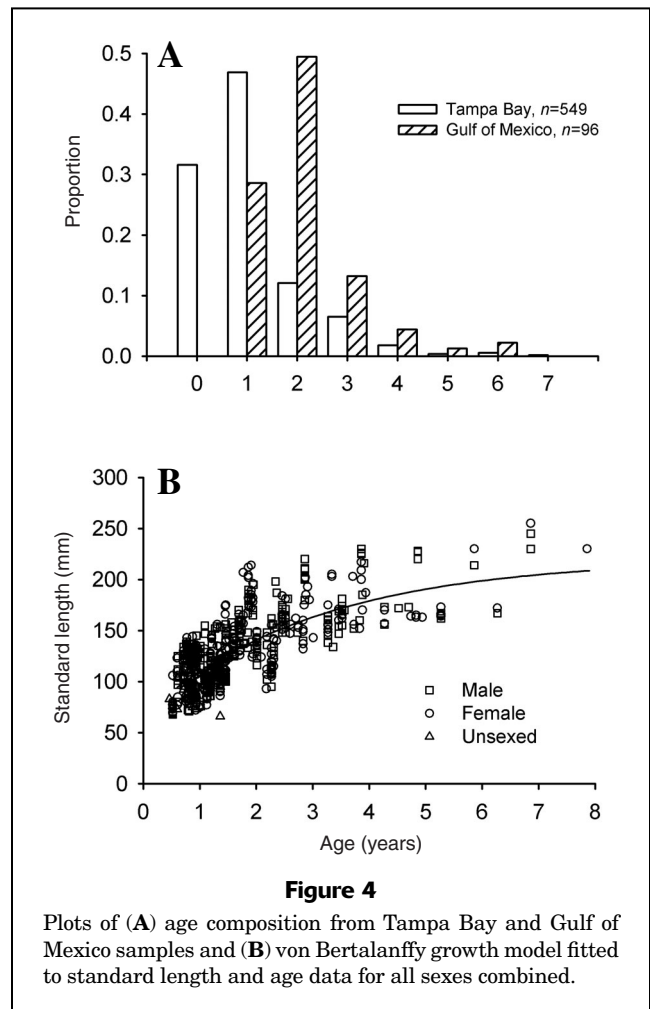
Table 2

Linear regression statistics showing the length conversion and length-weight relationships for pinfish. For the length conversions, the model is $y = \alpha + \beta \times x$. For the weight-length relationships, the model is $\log_{10}(y) = \alpha + \beta \times \log_{10}x$. α is the regression intercept, β is the slope coefficient, r^2 is the coefficient of determination, n is the sample size, MSE is the mean square error, FL is fork length (mm), SL is standard length (mm), TL is total length (mm), GFW is gonad-free body weight, and TW is total body weight (g). SP–SU is spring–summer and FA–WI is fall–winter. All slopes and intercepts were significantly different ($P \leq 0.05$) from zero. Slopes between TW-SL relationships were significantly different ($P \leq 0.01$).

y	x	Season	α	SE(α)	β	SE(β)	r^2	n	MSE
FL	SL	All	2.65	0.368	1.14	0.003	0.996	603	4.736
TL	SL	All	−2.20	0.542	1.33	0.004	0.994	625	13.745
TL	FL	All	−3.73	0.412	1.15	0.003	0.997	591	5.695
GFW	SL	SP–SU	−4.56	0.061	3.04	0.029	0.977	257	0.0020
TW	SL	SP–SU	−4.53	0.045	3.03	0.021	0.983	343	0.0020
GFW	SL	FA–WI	−4.57	0.064	3.07	0.030	0.977	244	0.0024
TW	SL	FA–WI	−4.68	0.043	3.11	0.021	0.987	302	0.0023

Figure 3

Monthly proportions of whole otoliths with opaque edges for pinfish ages 1–3. ±1 standard error bars are shown.

Figure 4

Plots of (**A**) age composition from Tampa Bay and Gulf of Mexico samples and (**B**) von Bertalanffy growth model fitted to standard length and age data for all sexes combined.

GSIs began to increase in October (females) and November (males) in Tampa Bay. The highest GSIs for males and females in Tampa Bay were 5% and 8%, respectively, observed in December. High and moderate GSIs for females and males during January in the Gulf of Mexico indicated continued spawning, but low values in April suggested that spawning ended prior to that month (Fig. 5).

Maturity of male and female pinfish was related significantly to length (male: Wald χ^2=18.8, $P \leq 0.001$; female:

Wald χ^2=32.1, $P \leq 0.001$) by logistic equations, and there was no evidence of lack of model fit (male: χ^2=81.1, df=94, P=0.82, max-rescaled r^2=0.38; female: χ^2=109.2, df=121,

Table 3

Estimates of the von Bertalanffy growth parameters for pinfish by sex and for all sexed and unsexed fish combined. MSE is the mean square error, r^2 is the coefficient of determination, and n is the sample size. Asymptotic standard errors are shown in parentheses.

Sex	L_∞	k	t_0	MSE	r^2	n
Male	228.5 (19.733)	0.31 (0.079)	−1.21 (0.331)	517.926	0.57	285
Female	212.0 (16.504)	0.33 (0.082)	−1.16 (0.309)	551.020	0.51	330
All fish	219.9 (12.204)	0.33 (0.055)	−1.10 (0.203)	537.490	0.55	645

Figure 5

Plots of monthly gonadosomatic indices (GSI) for male and female pinfish from Tampa Bay and the Gulf of Mexico. The solid line connects median values.

P=0.77, max-rescaled r^2=0.60). Parameter estimates (standard error) were $\alpha = -7.78$ (1.745) and $\beta = 0.06$ (0.014) for males, and $\alpha = -9.83$ (1.721) and $\beta = 0.08$ (0.013) for females. The estimates of length at 50% maturity ±95% C.I. were similar for both sexes: 132 ±8 mm SL for males and 131 ±8 mm SL for females. The smallest mature male was 112 mm SL and the smallest mature female was 92 mm SL. The largest immature male pinfish was 245 mm SL and female pinfish was 173 mm SL.

Chi-square tests indicated that sex ratios did not deviate significantly (P>0.05) from unity in any season.

Length-weight relationships

No significant differences (P≥0.10) in slopes or intercepts of standard-length on body-weight relationships were observed between sexes in any period; therefore all data were pooled for the subsequent analyses. Seasonal length-weight regressions for both sexes combined are listed in Table 2 for total and gonad-free body weight. Regression slopes were significantly different between periods only for the standard-length on total-body-weight relationship (P≤0.01). The regression slope was highest in fall–winter, which indicates that pinfish gain more weight per unit increase in length during this period than in spring–summer. Adjusted means for the standard-length on gonad-free body-weight relationship were not significantly different between periods (P>0.05).
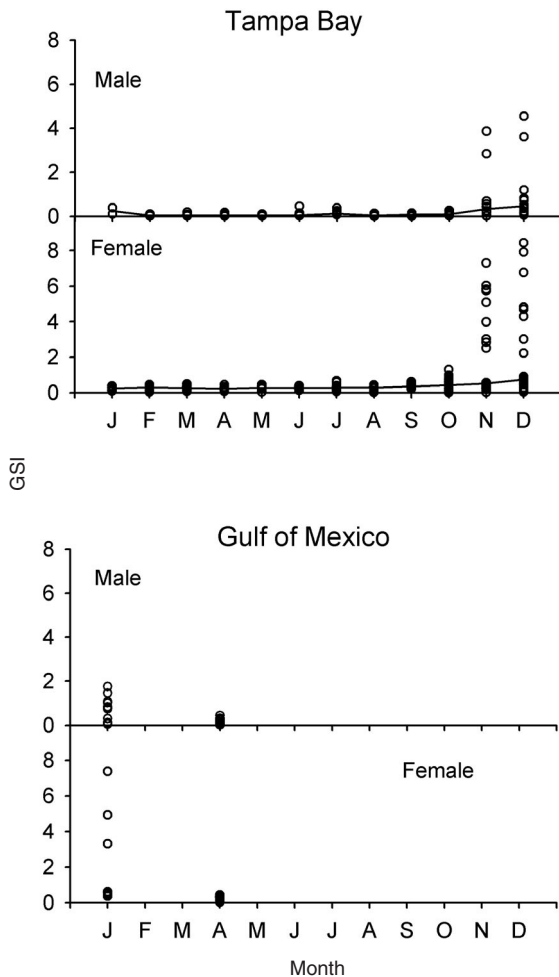
Mortality

Based on frequency plots by age, age-at-full-recruitment was age 1 for pinfish in Tampa Bay and age 2 for those in the Gulf of Mexico. Estimates of Z were 1.08/yr for Tampa Bay pinfish and 0.88/yr for the Gulf of Mexico pinfish (Table 4). Estimates of Z for all areas combined, assuming full recruitment at age 2, were intermediate to the Z estimates made for each area separately (Table 4).

The estimate of M was 0.78/yr from Pauly's (1980) multiple regression equation by using $L_\infty = 30.1$ cm, k=0.31/yr, and mean annual temperature of 24°C.

Distribution

In the Gulf of Mexico, pinfish were captured at 90% (55/61) of sites where trawls were pulled in depths of 6 to 30 m during the baitfish survey (Fig. 6). Catch rates of pinfish in the Gulf of Mexico varied significantly between years and were associated with depth, but the significant interaction term indicated that the relationship between depth and catches varied between years (Table 5). Plots of cumulative proportions of total catches by year showed that most trawl catches (95%) occurred in waters <15 m during the 1994, 1995, and 1997 surveys, but in 1996, 95% occurred in waters <17 m (Fig. 7A).
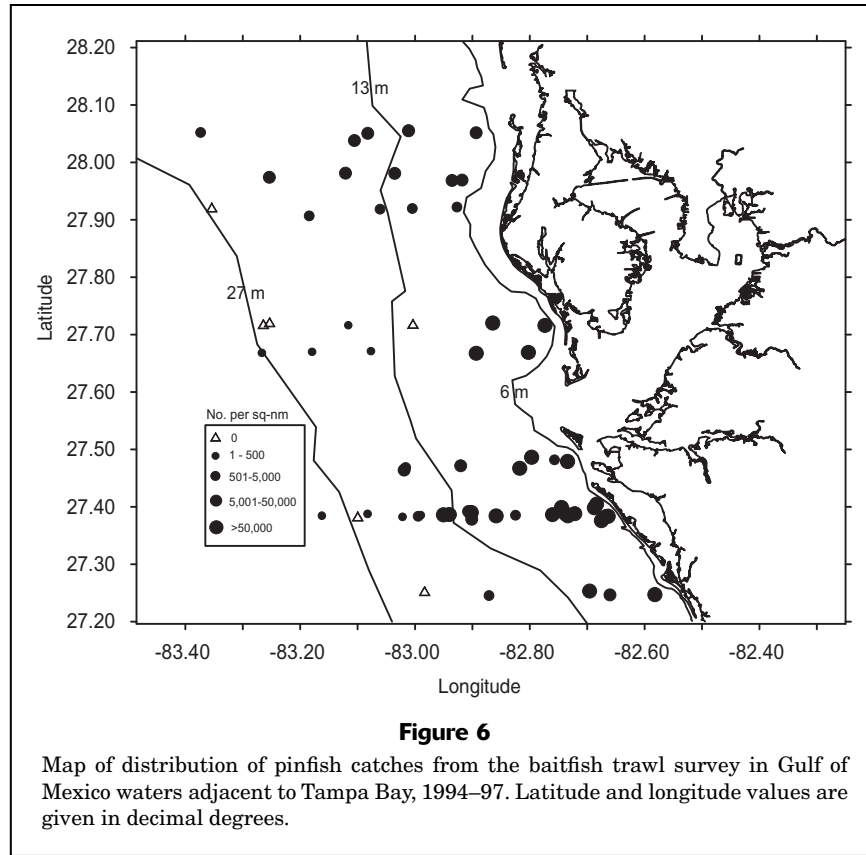
Length summary plots for pinfish caught during the baitfish survey showed that pinfish became segregated by size as depth increased. Median length increased from 109 mm SL in the 6–10-m depth range to 152 mm SL in the 26–30 m depth range (Fig. 7B). The smallest (80-mm-SL)

Figure 6

Map of distribution of pinfish catches from the baitfish trawl survey in Gulf of Mexico waters adjacent to Tampa Bay, 1994–97. Latitude and longitude values are given in decimal degrees.

Table 4

Estimates of annual survival (S) and total instantaneous mortality (Z) of pinfish determined by using the Chapman-Robson (1960) estimator for Tampa Bay, the Gulf of Mexico, and both areas combined. n_r is the sample size at each age of full recruitment and n_a is the number of age classes included.

	Age (yr) at full recruitment	n_r	n_a	Estimate		Variance	
				S	Z	S	Z
Tampa Bay (n=549)	1	379	7	0.34	1.08	0.0004	0.0033
Gulf of Mexico (n=96)	2	70	5	0.41	0.88	0.0020	0.0120
Combined (n=645)	2	189	6	0.40	0.90	0.0008	0.0043

and the largest (203-mm-SL) pinfishes were captured in the 6–10 m and 11–15 m depth ranges, respectively.

Discussion

Age and growth

This study is the first to report otolith-derived age estimates for pinfish. Hansen (1970) reported scale-derived age estimates for pinfish from a Florida Panhandle estuary. In the current study, annuli were identified and counted on whole otoliths and were then identified and counted on thin sections. The high initial agreement (89.6%) between the age determinations of the author and a second reader suggests a high degree of precision can be attained without sectioning the otolith. Given the high degree of error generally associated with estimating ages of fish from their scales (Jearld, 1983; Beamish and McFarlane, 1987), I believe that age estimations made from pinfish otoliths are far more likely to be accurate.

Deposition of opaque material in the sagittal otoliths of pinfish occurs over a protracted late-winter to early-spring period and indirectly validates the formation of annuli in

Table 5

Results of the generalized linear model analysis of ln (x+1) pinfish catches (in number per nmi^2) from the baitfish cruises in the Gulf of Mexico, 1994–97. ***=P≤0.001.

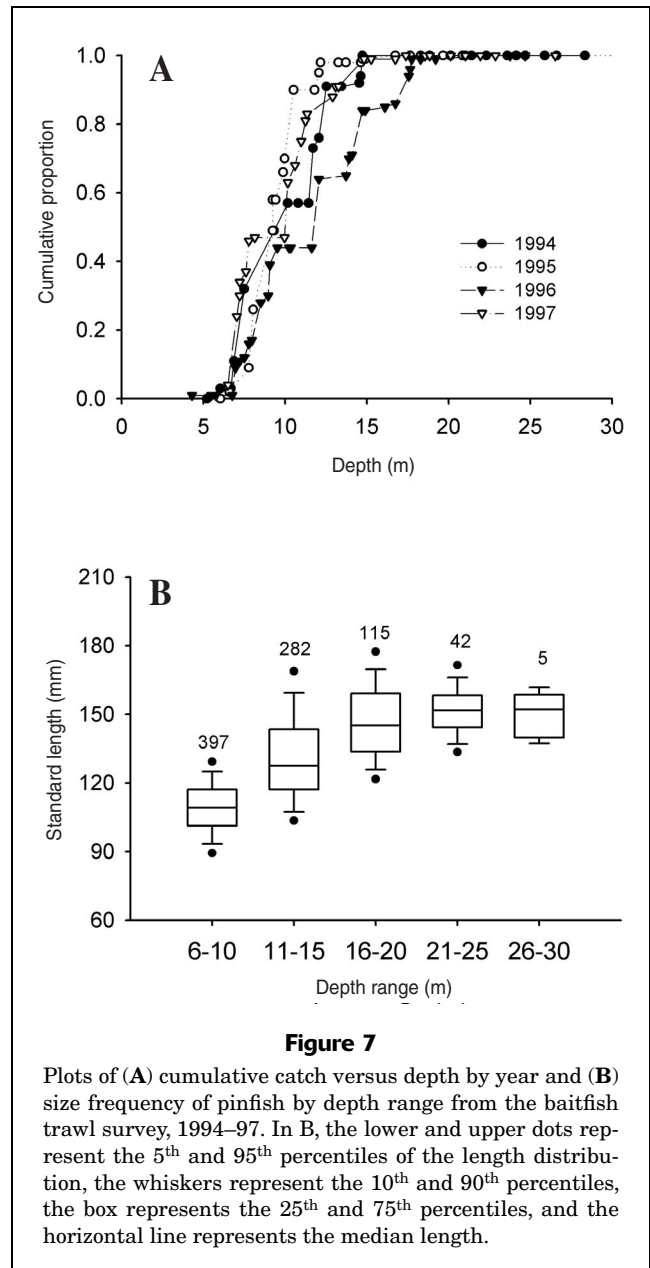| Source	df	MS	F	r^2
Model	7	79.9	16.1***	0.680
Year	3	25.5	5.1***	
Depth	1	389.3	78.4***	
Year × depth	3	31.3	6.3***	
Error	53	5.0		
Corrected total	60	13.7		

pinfish. Similarly, Hansen (1970) found that annuli on scales are generally formed once a year, in April.

The maximum age of pinfish determined in this study was 7 years, which exceeded the maximum age of 2 years reported by Hansen (1970). The difference in maximum age is probably due to Hansen's inadequate sampling of the entire size range of pinfish in Pensacola Bay—he collected pinfish at only two stations using a single, selective trawl. In addition, Hansen's use of scales as the primary aging structure may have contributed to the underestimate of the maximum age of pinfish (Beamish and McFarlane, 1987). In contrast, pinfish collected in this study were sampled from numerous locations in Tampa Bay and adjacent Gulf waters with multiple types of gears that had various mesh sizes, and otoliths, which are more reliable aging structures than scales (Beamish and McFarlane, 1987), were used for age determination. Coincidentally, Caldwell (1957) projected from the growth rates of age-1 pinfish that a 328-mm-SL pinfish may have been as old as 7 years; my results provide direct evidence that supports his estimate.

Reproduction, sex ratios, and maturity

The monthly changes in GSIs show that pinfish are late-autumn to early-spring spawners in Tampa Bay and adjacent Gulf of Mexico waters; this conclusion was also reported by Darcy (1985) and Cody and Bortone (1992). Pinfish spawning is suspected to occur in offshore oceanic waters (Hansen, 1970; Darcy, 1985); however, the high GSIs of pinfish collected in Tampa Bay and the occurrences of several of these pinfish with late-developing gonads in waters about 3–6 km into the bay during October–December suggest that some spawning activity may occur in this estuary. This is not surprising because most studies that have examined gonadal activity in pinfish have used samples only from offshore waters (Franks et al., 1972; Stott et al., 1980, 1981), did not use gear with various mesh sizes to adequately sample the entire size range of pinfish found in estuaries (Caldwell, 1957; Hansen, 1970), or did not compare data on an estuary-offshore basis (Cody and Bortone, 1992).

Figure 7

Plots of (**A**) cumulative catch versus depth by year and (**B**) size frequency of pinfish by depth range from the baitfish trawl survey, 1994–97. In B, the lower and upper dots represent the 5th and 95th percentiles of the length distribution, the whiskers represent the 10th and 90th percentiles, the box represents the 25th and 75th percentiles, and the horizontal line represents the median length.

Length-weight relationships

The length-weight relationships were affected by gonadal maturation. During the September–February period, gonad weight of both sexes increased, which resulted in a standard-length to total-body-weight relationship that was higher than it was in March–August period. Differences in predicted total weight at length were 2–8% between the September–February and March–August periods and illustrate the effect of maturation on these relationships. The slopes of the length-weight relationships from both periods (3.03–3.11) were higher than the slopes of length on weight relationships (2.91 and 2.90, respectively) developed by Caldwell (1957) and Cameron (1969).

Mortality

This study is the first to report total instantaneous mortality (*Z*) rates (0.88–1.08) for pinfish older than young-of-the-year. It is difficult to conclude whether the mortality rate in Tampa Bay is really higher than that in the Gulf. The small mesh characteristics of the sampling gear, the restricted spatial coverage of sampling from Tampa Bay to the shallows of the estuary where young pinfish dominate (most gears were employed in waters <3 m), or the migration of pinfish from estuaries to offshore waters to spawn may have contributed to the older (>age 1) fish being underrepresented in the sampling of bay waters (Hansen, 1970; Darcy, 1985; Nelson, 1998). By assuming that pinfish are fully recruited at age 2 (Table 4), I estimated that *Z* from data for both areas combined is probably more realistic because the numerical proportions of pinfish ages 2 and older in Tampa Bay were nearly identical to the numerical proportions of pinfish age 2 and older from the Gulf of Mexico. The estimate of *Z* from data for both areas combined (0.90/yr) was close to the natural mortality estimate of 0.78/yr, suggesting that the portion of annual mortality attributed to fisher activity, calculated by (*Z–M*)/*Z*, is low [13%].

Distribution

Darovec (1995), Franks et al. (1972), and Darcy and Gutherz (1984) reported that pinfish from the Gulf of Mexico occurred in trawls to depths between 73 m and 93 m. However, most pinfish captured in Gulf waters off west-central Florida were captured from depths <19 m (Darovec, 1995). The results from the baitfish survey were very similar in that most pinfish (95%) were caught in waters <17 m, but the abundance-depth relationship varied between years, and larger pinfish were generally associated with greater depths. The propensity of pinfish to limit their depth distribution and alter their size distribution with depth is probably due to the distribution of their epibenthic prey (Stoner, 1980; Nelson and Bortone, 1996), the distribution of their predators, and (because pinfish are visual feeders) reduced light intensity with depth (Kjelson and Johnson, 1976; Luczkovich, 1988).

In summary, ages determined from whole otoliths ranged from 0 to 7 years, and von Bertalanffy growth model parameters for all aged fish were L_∞=219.9 mm SL, *k* =0.33/yr, and t_0 =–1.10 years. High gonadosomatic indices during October–December indicated that some spawning may occur in Tampa Bay. Estimated lengths at 50% maturity were 132 mm SL for males and 131 mm SL for females. Total instantaneous mortality rates from the Chapman-Robson estimator ranged from 0.88 to 1.08/yr, and natural mortality based on Pauly's (1980) equation was 0.78/yr. Catch rates of pinfish were related to depth in the Gulf of Mexico.

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