

AGE AND GROWTH OF RED DRUM, *SCIAENOPS OCELLATUS*, FROM OFFSHORE WATERS OF THE NORTHERN GULF OF MEXICO¹

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ABSTRACT

Otolith (sagitta) sections are used to accurately age red drum, *Sciaenops ocellatus*, from the offshore northern Gulf of Mexico. Marginal increment analysis indicated that annuli were formed during winter and spring months.

Ages of offshore schooling red drum ranged from 1 to 37 years. Age distributions indicated variability in relative abundances of year classes, with the majority of fish sampled being over 10 years of age. Male and female age distributions did not differ significantly.

Growth differed significantly between males and females. The von Bertalanffy growth equation for males was $L_t = 909(1 - e^{-0.137(t+7.74)})$, and for females was $L_t = 1,013(1 - e^{-0.088(t+11.29)})$, where t is age (years) and L_t is fork length (mm).

The red drum, *Sciaenops ocellatus*, is a large sciaenid that inhabits temperate and subtropical near-shore and estuarine waters from Massachusetts to northern Mexico. Juveniles are most abundant in estuarine waters and move from estuarine to near-shore waters as they near maturity (Pearson 1929). The primary spawning stock in the Gulf of Mexico is thought to spawn in nearshore open waters (Overstreet 1983).

The red drum is one of the most popular recreational and commercial fish species in the northern Gulf of Mexico. Recent increase in demand for red drum has escalated the controversy concerning its management; however, little has been reported concerning its growth and population structure.

Age and growth-rate estimates of red drum have only used immature fish from inshore estuarine waters. Pearson (1929) and Wakeman and Ramsey (1985) identified modes in length-frequency distributions and performed scale analysis to determine age estimates. However, Wakeman and Ramsey (1985) reported that scale annuli were unsatisfactory for accurately estimating the age of red drum. Theiling and Loyacano (1976) reported age estimates of red drum from a South Carolina salt marsh impoundment based on otolith examination. Growth rates of juveniles were reported by Roessler (1970), Bass and Avault (1975), and Simmons and Breuer (1962).

No age or growth rate estimates have been published for adult red drum from offshore waters. Accurate information on the age and growth of adult red drum is necessary for determining population dynamics and monitoring the population's response to fishing pressure. Due to the reduction in growth rate in larger individuals, which leads to size overlap between age classes, age estimation by cohort analysis is not feasible. Otolith sections have provided valid age estimates for many large, long-lived fish species (Beamish and McFarlane 1987).

The purposes of this study were to determine if otoliths (sagittae) could be used to obtain valid age estimates for red drum and to estimate growth rates and determine the age structure of the oceanic schooling population of red drum.

MATERIALS AND METHODS

Red drum (1,726 fish) were collected in Texas, Louisiana, Mississippi, and Alabama offshore coastal waters of the northern Gulf of Mexico from September 1985 through October 1987 by purse seine ($N = 1,428$ from 67 sets) (Fig. 1), gill net ($N = 134$ from 9 sets), and hook and line ($N = 164$ from 12 dates). Samples captured by unknown gear from February 1985 through June 1987 ($N = 96$) were included for marginal increment analysis only.

After fish were randomly sampled from landings, they were measured (fork length) and weighed, and their sex was determined. Sex identifications were

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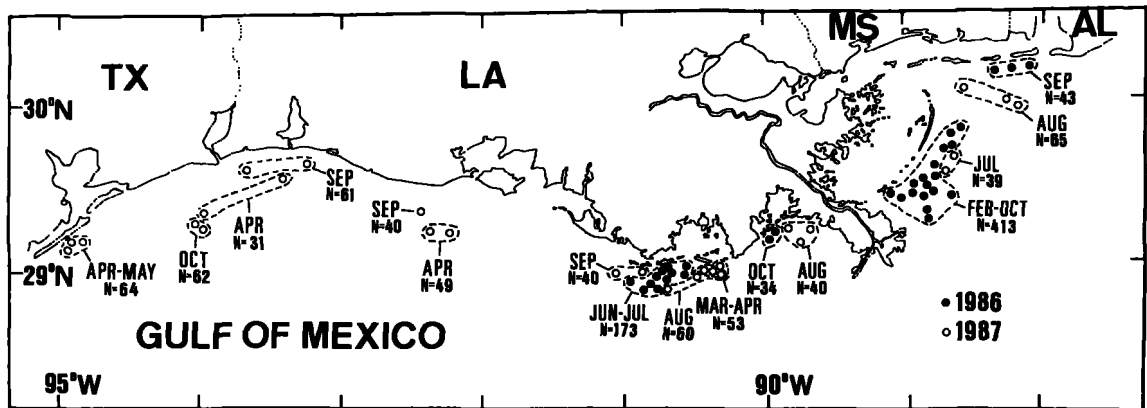


FIGURE 1.—Purse seine sampling locations in the northern Gulf of Mexico. Points represent individual purse seine sets. N's refer to the total numbers of red drum sampled from sets indicated. Precise locations were not available for 6 sets ($N = 161$).

unavailable for 182 individuals. Sagittae were removed, cleaned, and stored dry for later processing.

Length-weight regressions were fit to the data using the model: $\text{weight} = a \text{FL}^b$, where weight = body weight (g) and FL = fork length (mm). Regressions for male and female red drum were compared using analysis of covariance (Ott 1977). A Komolgorov-Smirnov two-sample test (Tate and Clelland 1957) was used to detect possible sampling bias by comparison of length-frequency distributions of fish caught by different sampling gears.

Otoliths were processed for age analysis by embedding them in an epoxy resin (Spurr 1969) and sectioning transversely (0.7 mm thick) through the core of the left sagitta (or the right when the left sagitta was not available), using a Buehler Isomet³ low-speed saw. Sections were mounted on glass slides with thermoplastic cement (Crystalbond 509 adhesive), sanded on 600 grit wet sandpaper to remove saw marks, polished with alumina micro-polish (0.3 μm), and then examined with a compound microscope (transmitted light at 40 \times magnification). Opaque zones (annuli) were counted in sections from the core to the margin in the medial direction. Appearance of the margin was recorded as either opaque or translucent. If the left sagitta was unreadable, the right sagitta, if available, was prepared and examined. Validation of age estimates was accomplished and the timing of annulus formation determined by plotting percent occurrence of otoliths with opaque margins by month.

Each otolith was aged by two readers, and the resulting age estimates were compared. The coefficient of variation was calculated for age estimates independent of magnitude (Sokal and Rohlf 1981; Chang 1982). If readers' initial age estimates for an otolith did not agree, the section was reread. If the resulting age estimates did not agree, the fish's other sagitta was prepared and read. If the readers did not reach agreement on an age or sections from both otoliths were unreadable, the data for that fish were not used in analyses. All ageing was done without knowledge of the sample source or any previous age estimates.

Year-of-birth was back-calculated from age estimates by subtracting estimated age from the year of capture and assuming that the first annulus formed in winter of year 2 (Beckman et al. in press). Age-frequency distributions were compared using a Komolgorov-Smirnov two-sample test (Tate and Clelland 1957).

Von Bertalanffy (1938, 1957) growth curves were fit separately for males and females by nonlinear regression. The growth equation for length was $L_t = L_\infty [1 - e^{-K(t-t_0)}]$ and for weight was $W_t = W_\infty [1 - e^{-K(t-t_0)}]^3$, where L_t and W_t are the estimated length and weight, L_∞ and W_∞ are the asymptotic length and weight, K is the growth coefficient, t is the age (years), and t_0 is the hypothetical age when length or weight would be zero. A full model, in which separate parameters were fit for males and females, was compared with a reduced model in which sex was not considered. An F -test (Ott 1977) was used to test for differences in the models.

³Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

RESULTS

Length-weight regressions for males and females were not significantly different ($P = 0.842$ for intercepts, $P = 0.605$ for slopes). The combined length-weight regression was

$$\text{Weight} = 2.9 \times 10^{-6} \text{ FL}^{3.22} \quad r^2 = 0.91$$

$$N = 1,626.$$

The length-frequency distributions of red drum collected by purse seine (Fig. 2) were significantly different from those obtained by gill net ($P < 0.01$) and hook and line ($P < 0.01$). Therefore, to avoid gear selectivity bias, only purse seine samples were assumed to represent the age-frequency distribution of the offshore spawning population.

Because the sagittae were extremely thick and opaque, they needed to be sectioned before they could be aged. Distinct opaque and translucent growth zones were observed in transverse sections. Annuli were most distinct and the most consistent growth patterns were observed in the region from

the core to the proximal surface of the sagitta along the ventral margin of the sulcus acousticus. All counts were made in this region (Fig. 3).

The percentage of sagittae with opaque margins was plotted by month to determine the timing of annulus formation. Opaque zones were deposited in the sagittae during winter and spring months in three successive years of sampling (Fig. 4A). As a consistent pattern of annulus formation was exhibited each year, data were combined for all years in order to compare annulus formation between size groups (Fig. 4B). Data were grouped according to maturity (Overstreet 1983) and growth patterns. Groupings were chosen to include an adequate sample size within each group for analyses as follows: 0–4 annuli – immature and early maturity, rapid growth; 5–9 annuli – mature, rapid growth; 10–19 annuli – mature, reduced growth; and 20–36 annuli – maximum ages, reduced growth. A single peak per year in all plots indicates that one annulus was formed each year in all groups. Age in years for red drum was equal to the number of annuli observed in sections of sagittae. Age estimates were obtained

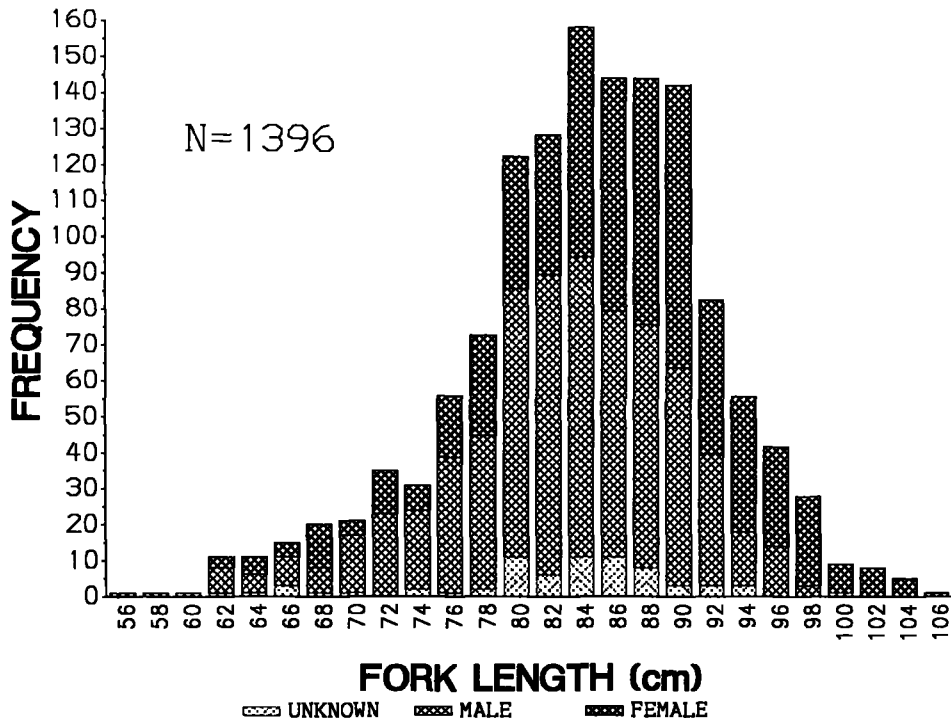


FIGURE 2.—Length-frequency distribution for red drum captured by purse seine from offshore northern Gulf of Mexico waters. “Unknowns” are individuals for which sex identifications were not available.



FIGURE 3.—Photomicrograph of a transverse section of red drum otolith (sagitta) sampled in May 1986. Ventral is to the left and proximal is to the top in this figure. "C" indicates the core of the otolith. Numbers indicate annuli in the region where counts were made. There are 18 annuli and an opaque edge. Bar equals 1 mm.

by assuming a birth date of early October (Simons and Breuer 1962; Ditty 1986) and annulus formation beginning the winter of the second year.

Of the 1,726 fish processed, only 94 (5.4%) otoliths were judged unreadable by at least one reader. Of the 58 companion otoliths available from the unreadable fish, only one was judged unreadable. No data were obtained from 36 fish with the first otolith unreadable because their second otoliths were not available. Age estimates, agreed exactly between readers in 95.9% of the samples, were within one year for 99.8% and within two years for 100%. The coefficient of variation for age estimates (V) was 0.0058. Exact agreement was improved to 99.5% by recounting sections for which agreement was not initially reached. Readers differed by one year for the remaining 0.5% of samples, and these differences were resolved for all but one sample (not included in analyses) by counting a section of the other sagitta.

The oldest female red drum was 36 years (995 mm FL, 11.96 kg) and the oldest male was 37 years (940

mm FL, 10.49 kg), both captured by hook and line. Ages of offshore schooling red drum captured by purse seine ranged from 1 to 34 years for females and from 2 to 34 years for males.

There were no significant differences between male and female age distributions in samples taken by purse seine ($P > 0.20$). Age distributions were grouped by year of capture (October through September for 1985–86 and 1986–87) and compared (Fig. 5). Sufficient samples were not available for 1984–85 for comparisons. The 11–14 year age classes dominated the 1985–86 samples and 12–15 year old fish dominated in 1986–87. There was an apparent coherence between the age-frequency distributions for the two sample years. Anomalies in the age distribution for 1985–86 lagged one year behind corresponding anomalies for 1986–87. Age distributions differed significantly between the two sample years ($P < 0.01$); however, there were no significant differences between year of birth distributions between sample years ($P > 0.20$). Therefore, samples were combined for all years to obtain year-

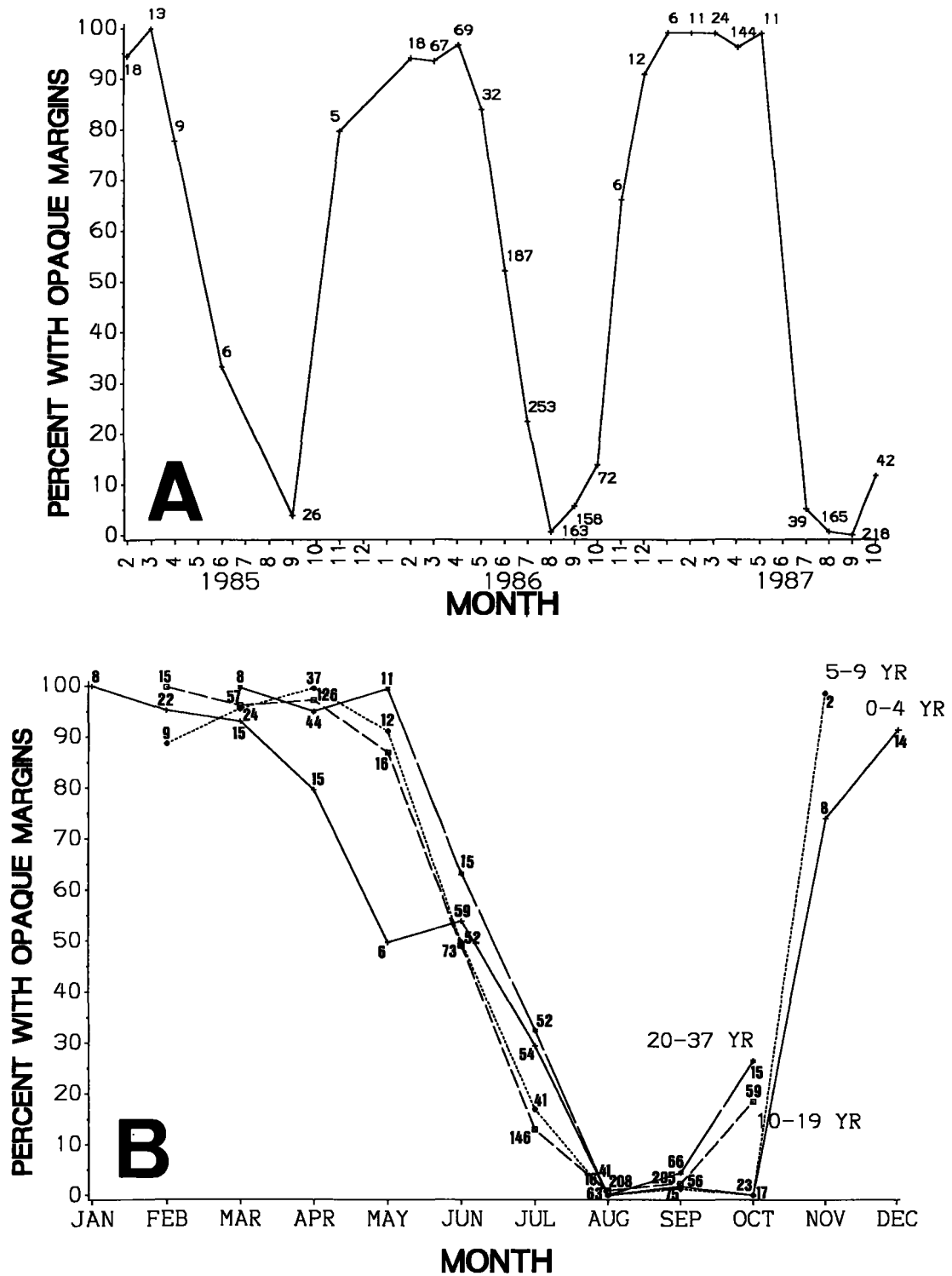


FIGURE 4.—Plot of percent occurrence of otoliths (sagittae) with opaque margins vs. month of capture for red drum A) by sample month and year and B) grouped by annulus counts, sample years combined. Sample size is indicated next to points.

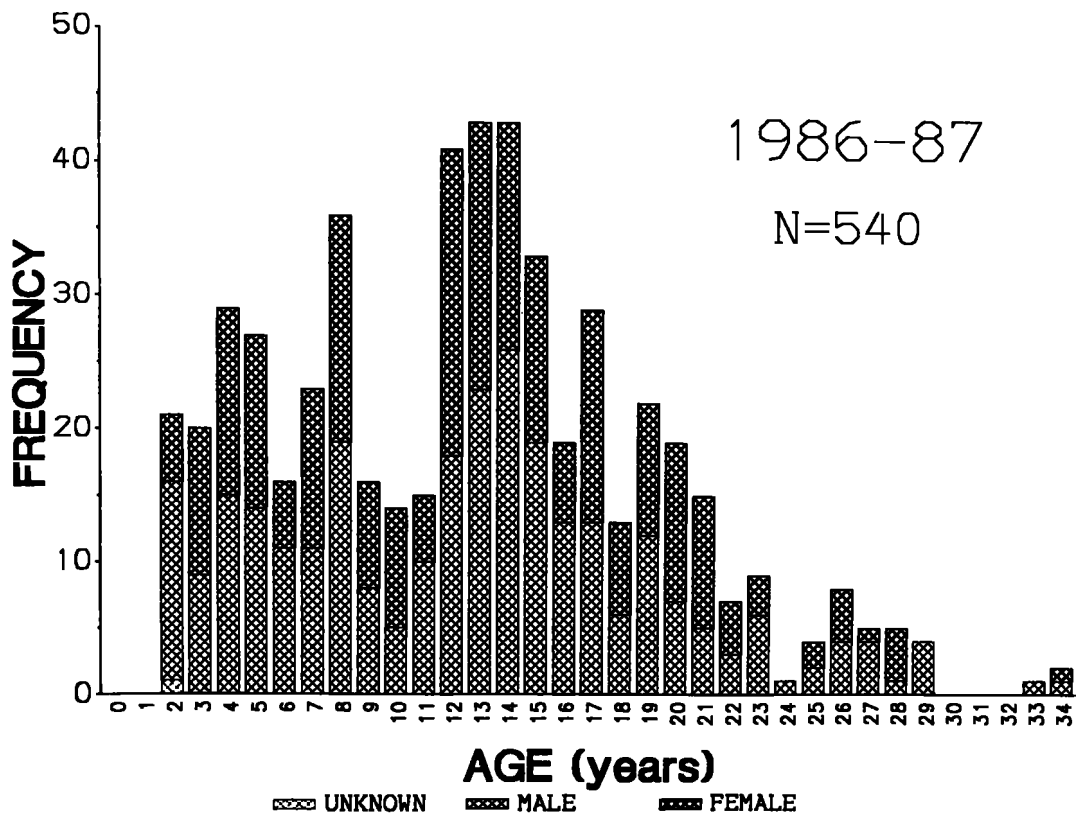
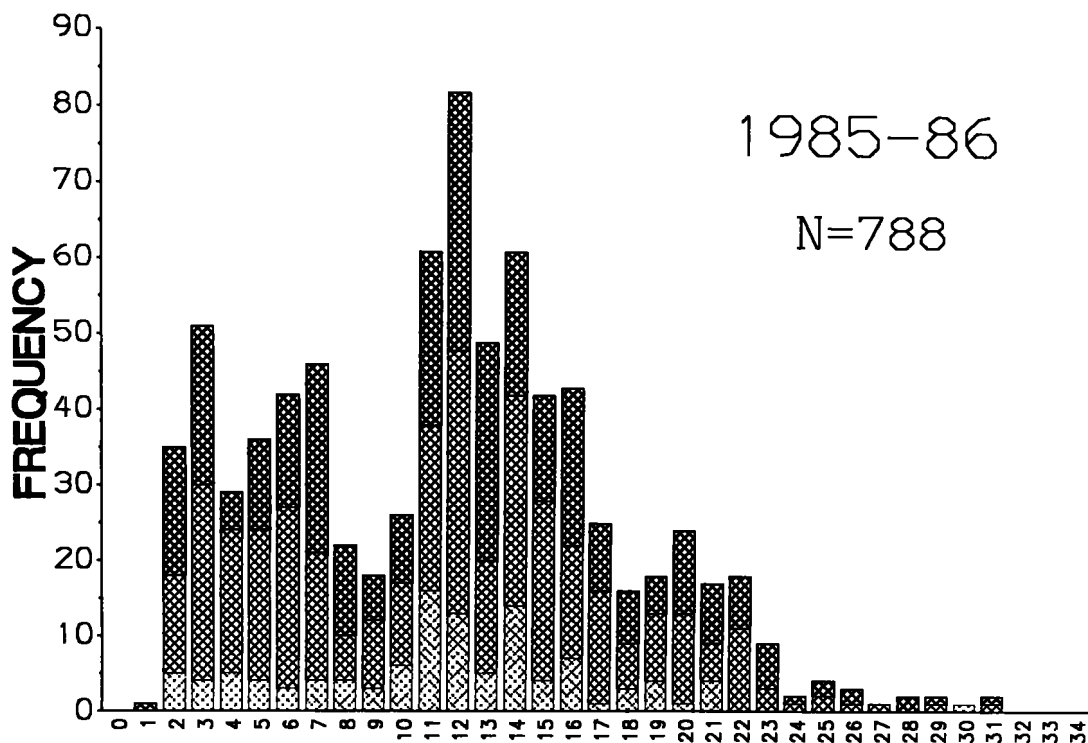


FIGURE 5.—Age-frequency distributions for red drum captured October 1985–September 1986 and October 1986–September 1987 by purse seine from offshore northern Gulf of Mexico waters.

of-birth distributions (Fig. 6). Variability in year-class success is suggested by differences in relative numbers of individuals between year classes.

The separation of sexes in growth models resulted in a significantly better fit by weight ($P < 0.001$) and length ($P < 0.001$) when compared with models in which sexes were combined. Separate von Bertalanffy growth curves best described changes in length (Fig. 7A) and weight (Fig. 7B) of red drum. Equations by length were

males: $L_t = 909(1 - e^{-0.137(t+7.74)})$

females: $L_t = 1,013(1 - e^{-0.088(t+11.29)})$

and by weight:

males: $W_t = 10,548(1 - e^{-0.117(t+8.69)})^3$

females: $W_t = 15,207(1 - e^{-0.079(t+11.57)})^3$

DISCUSSION

Sampling

Comparison of length-frequency distribution between gear types demonstrated that gill net and hook and line were different from purse seine collections. Therefore, to provide a basis for documenting and comparing age structure in the offshore schooling population only purse seine collections were used. We assumed that purse seine samples would result in the smallest size selection bias (Nielson and Johnson 1983). We assumed that temporal and spatial bias was minimized because sets were made throughout the year and

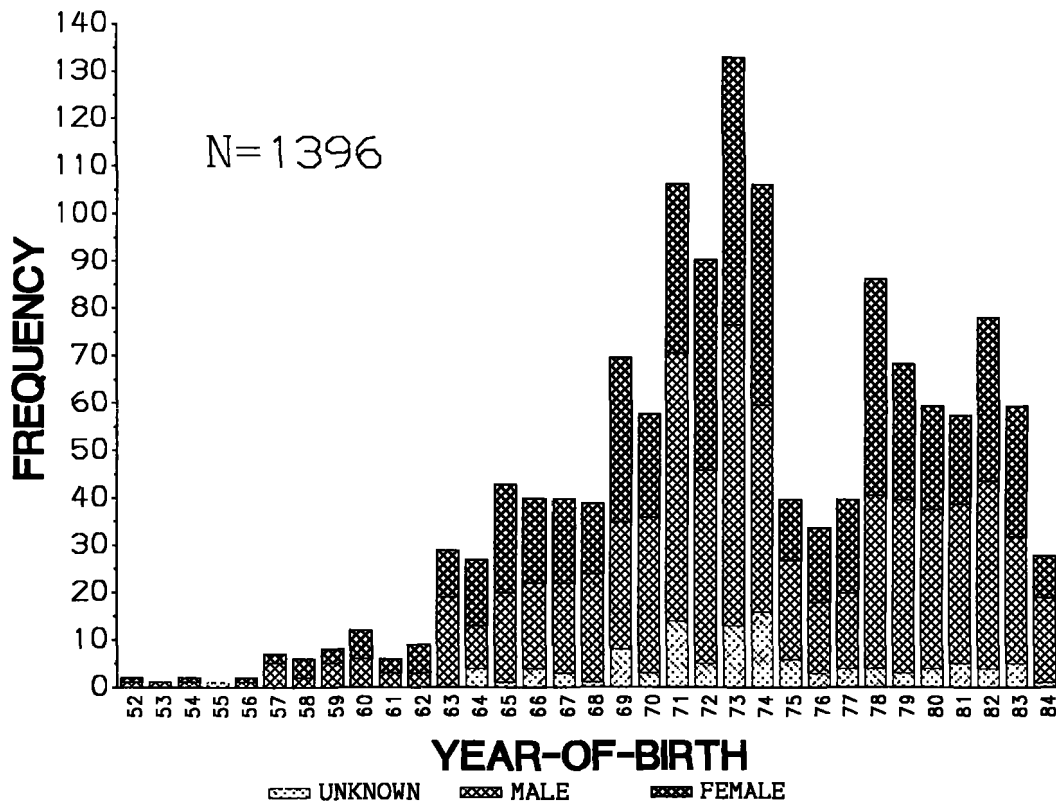
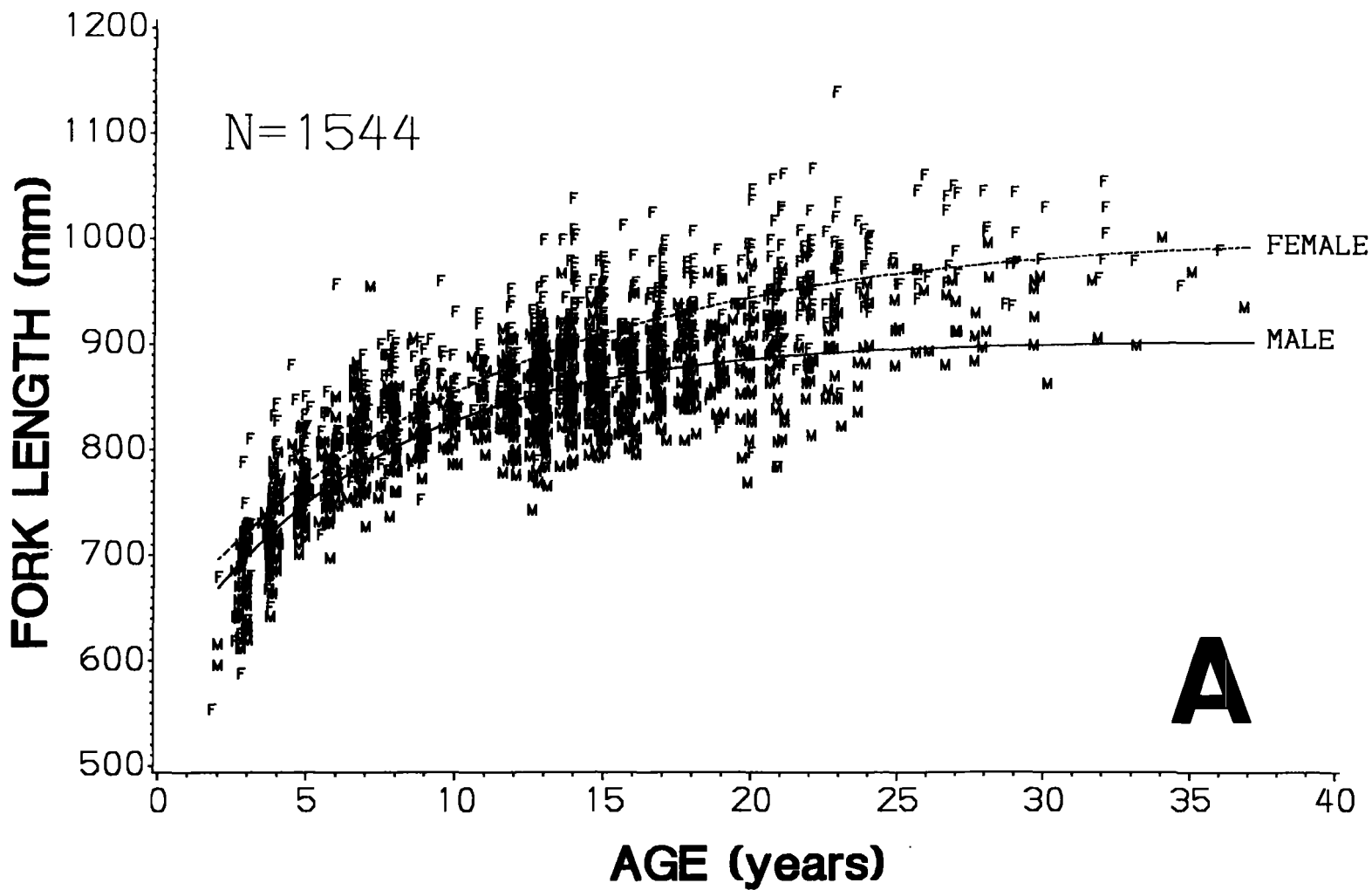


FIGURE 6.—Year-of-birth frequency distributions for red drum captured by purse seine from offshore northern Gulf of Mexico waters, September 1985–October 1987.



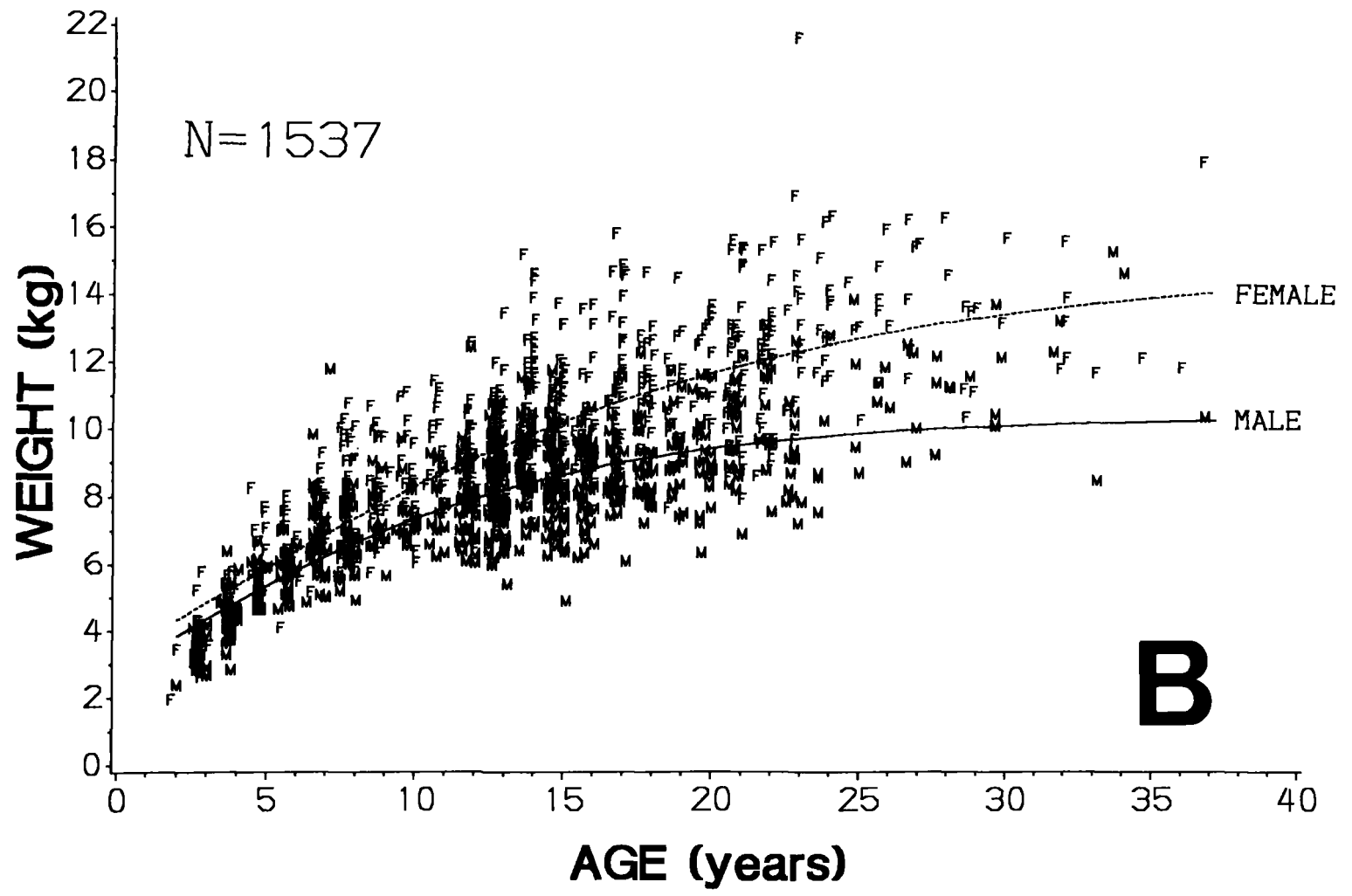


FIGURE 7.—Growth models for male (M) and female (F) red drum captured in offshore northern Gulf of Mexico waters by A) length and B) weight.

across the coastline of the north-central Gulf of Mexico.

Validation

Periodicity of formation of ageing structures must be confirmed over all year classes to validate the use of that hardpart for ageing (Beamish and McFarlane 1983). Beckman et al. (in press) validated that the first two annuli were formed yearly in sagittae of immature red drum from estuarine waters. The use of marginal increment analysis in this study validated that annuli continued to be deposited in red drum sagittae once per year in fish up to 37 years old. There was no significant variability in timing of annulus formation with stage of maturity or with change in growth rates with age.

Precise, reproducible age estimates were obtained for red drum using transverse sections of sagittae. Almost 100% agreement between two readers was achieved by recounting otoliths or counting the fish's other sagitta when age estimates disagreed. Initial disagreements were usually resolved by recounting the otolith, suggesting initial miscounts or errors were due to recording and transcription. Unreadable otoliths were primarily those with inadequate sample preparation. Discarding difficult-to-age otoliths, which are often from older fish, could bias age distributions as well as von Bertalanffy growth parameters (Hirschhorn 1974). Recounting otoliths for which age estimates did not initially agree and utilizing both sagittae to obtain a readable sample allowed us to minimize the number of unused sections.

The same seasonal pattern of annulus formation reported in this study was observed in sagittae of red drum in inshore estuaries (Beckman et al. in press). This pattern is also similar to that observed in another sciaenid, the Atlantic croaker (Barger 1985). The formation of an opaque zone in red drum sagittae in winter and spring months may correspond to reduced growth rate during this period (Doerzbacher et al. 1988). In West African sciaenids an opaque zone was formed apparently in response to cold temperatures (Poinsard and Troadec 1966).

Growth

The von Bertalanffy growth coefficients for other sciaenids (e.g., Barger 1985; Wakeman and Ramsey 1985, cited by Pauly 1980) were generally greater than those obtained for red drum in this study. Growth parameters reported herein differ from those obtained by Wakeman and Ramsey (1985) for

red drum; however, their model was based only on young fish from inshore waters that have higher growth rates (Beckman et al. in press). The growth models reported in this study were derived primarily from mature slower growing fish. The negative values of t_0 predicted suggests that our models do not adequately describe growth of young fish unrepresented in our data. Separate models may be necessary to describe growth of immature red drum from inshore waters (Richard Condrey pers. commun.⁴). The large variation in size at age beyond year 5 makes it impossible to precisely predict age of red drum using length or weight.

Our estimates of maximum red drum age are greater than those previously suggested. Pearson (1929), Simmons and Breuer (1962), and Wakeman and Ramsey (1985) used the scale method and reported a maximum age of 5, 3, and 4 years, respectively. The use of validated ageing techniques for red drum from otoliths more accurately estimates their ages and provides much improved management data bases.

Female red drum attained significantly larger sizes than did males, with growth curves diverging with increasing age and maturity. Larger size in females has been postulated as a life history strategy in fish for increasing reproductive potential through increased egg production capability (Roff 1983). The similarities in age-class compositions between sexes indicated that the increased female size was attained through somewhat higher growth rates and not greater longevity.

Age Structure

Examination of the age composition of the offshore population revealed that red drum begin to appear in the offshore population as early as year 2. Their appearance offshore coincides with their absence inshore by four or five years of age (Pearson 1929; Simmons and Breuer 1962; Wakeman and Ramsey 1985). The 1973 year class was the most abundant, and earlier year classes demonstrated a decay pattern indicative of natural mortality. The year classes since 1973 were variable and could be interpreted variously to indicate several poor year classes, high mortality, or incomplete recruitment to offshore schooling populations, assuming no bias in the sampling procedures. Inadequate data are available to determine which are primary factors affecting age distributions.

⁴Richard Condry, Coastal Fisheries Institute, Louisiana State University, Baton Rouge, LA 70803, pers. commun. January 1988.

Comparison of age distributions between years provided two estimates of the population age-class structure, varying in time and areas sampled. The similarities in year-of-birth distributions in 1985-86 and 1986-87 suggest that the same population was sampled in both years and that distributions may reflect the true offshore schooling population of red drum, assuming no sampling selectivity. Recruitment into the population from one year to the next was evident only in the youngest age classes, possibly due to migration from inshore nursery areas. The relatively low numbers of individuals in age classes of less than 10 or 11 years suggests a possible delay or reduction in recruitment into the schooling population sampled. Other possible factors affecting abundance of younger age classes offshore are fishing pressure on inshore red drum, size specific fishing offshore, or other factors affecting survival.

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