Abstract—Growth, recruitment, and abundance of young-of-the-year (YOY) striped mullet (*Mugil cephalus L.*) in estuarine habitats in South Carolina from 1998 to 2000 were examined and compared to historical data (1986–91) of growth, recruitment, and abundance. Daily growth increments from the sagittal otoliths of juvenile striped mullet were validated by using fish immersed in oxytetracycline hydrochloride (OTC) for five hours from the Charleston Harbor Estuary system. The distribution of back-calculated birthdates indicated that striped mullet spawn from October to late April and estuarine recruitment occurs from January through May. Juveniles were more abundant in mesohaline and polyhaline salinity regimes but were found throughout the estuary. Juvenile growth after recruitment into the estuary can be described by the relationship *Total length* (mm) = 0.341 $(Age)^{1.04}$ (r^2=0.741, P=0.001). Growth of juveniles according to the analysis of size-frequency data from historical surveys (1986 to 1991) in the same estuaries gave the relationship *Total length* (mm) = 8.77 $(month)^{1.12}$ (r^2=0.950, P=0.001). The similarity in the growth curves for both groups of fish suggests that juvenile striped mullet in South Carolina have consistent annual growth during the first year of life.

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Growth, recruitment, and abundance of juvenile striped mullet (*Mugil cephalus*) in South Carolina estuaries*

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The striped mullet (*Mugil cephalus*) is distributed circumglobally in tropical and semitropical waters between latitudes 42°N and 42°S (Thomson, 1963; Rossi et al., 1998). The species can be found year round throughout the full range of estuarine salinities (including freshwater) in the southeastern United States (Jacot, 1920; Anderson, 1958). Striped mullet are harvested commercially throughout the world and used in aquaculture. Along the southeastern coast of the United States there are significant commercial fisheries in North Carolina and Florida. South Carolina and Georgia have smaller landings (Statistics and Economic Division[1]). The species is also harvested in the Gulf Coast states.

Fishing for striped mullet (for "roe fish") is most intense during the fall spawning migration. Throughout the rest of the year striped mullet are fished commercially for bait, if they are fished at all (Anderson, 1958). Landings of this species in the areas where it is heavily fished were significant and yielded an economic value of 38.2 million dollars from 1994 to 1998 (Statistics and Economic Division[1]). Striped mullet are also one of the most important forage fishes in the estuaries of the southeast and represent a significant food source for upper-level piscivores (Wenner et al.[2]).

Striped mullet spawn from October through February along the southeast coast of the United States (Jacot,1920; Broadhead, 1956; Anderson, 1958; Arnold and Thompson, 1958; Stenger, 1959; Dindo and MacGregor, 1981; Greeley et al., 1987; Render et al., 1995; and Hettler et al., 1997) and are considered isochronal spawning fishes (Greeley et al., 1987; Render et al., 1995) (i.e. they have synchronous gamete development and spawn all their reproductive material at once or in batches over a very short period of time). There have been few observations of spawning activity (Arnold and Thompson, 1958) and eggs and yolk-sac larvae have rarely been collected offshore (Anderson, 1958; Finucane et al., 1978; Collins and Stender, 1989).

Juvenile striped mullet recruit to the estuarine nursery habitat in South Carolina as early as December (Cain and Dean, 1976); this movement continues into June, peaking in February and March (Jacot, 1920; McGovern and Wenner, 1990). Juveniles are 18–30 mm total length (TL) at recruitment and have the silvery sheen of the pelagic stage. They are more laterally compressed than older juveniles and adults and hence are more streamline in shape. This shape is lost after they reach inshore waters at 32 mm TL (Eggold and Motta, 1992).

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[1] Statistics and Economics Division. 2000. Personal commun. Statistics and Economic Division, National Marine Fisheries Service, 1315 East-West Hwy., Silver Spring, MD 20910. http://www.st.nmfs.gov/st1/index.html.

[2] Wenner, C. A., W. A. Roumillat, J. E. Moran, M. B. Maddox, L. B. Daniel, and J. W. Smith. 1990. Investigations on the life history and population dynamics of marine recreational fishes in South Carolina, part 1, p. 6–35. South Carolina Marine Resources Research Institute, Completion reports, Project F-37, Charleston and Project F-31, Brunswick. Marine Resources Research Institute, P.O. Box 12559, Charleston, SC 29422-2559.

The size range of striped mullet at the time of estuarine recruitment is well documented; however, the ages of these juveniles are not well known (Chang, et al., 2000). These data are most easily obtained by examining the sagittal otoliths for daily growth increments. The importance of daily growth increments to estimate age in juvenile and larval fish for life history characteristics such as growth, recruitment, and determining spawning season is well documented (Brothers et al., 1976; Ralston and Miyamoto, 1983; Jones, 1986; Ralston and Williams, 1988; Campana and Moksness, 1991; Campana et al., 1994; Sponaugle and Cowen, 1997; Gillanders and Kingsford, 1996).

Several authors (Jones, 1986; Campana and Moksness, 1991; Campana et al., 1994) have concluded that daily growth increments should be validated for each species individually because of the variability in the time of deposition of the first daily increment, consistency of their formation, and their legibility with time. Radtke (1984) validated daily growth increments in cultured larval striped mullet in Hawaii and showed that daily growth increments were deposited well into the juvenile stage. Daily growth increments in juvenile striped mullet caught in the wild from Taiwan have also been validated (Chang et al., 2000).

The periodicity of increment deposition can be determined by either of two methods. Rings on otoliths from fish of known age (hatched in the laboratory) can be counted back to the core at specified times to check the increments. This method is accurate because factors affecting the fish (environmental, behavioral, and biological) can be more tightly controlled or manipulated in the laboratory (Jones, 1986). However, cultured conditions, at best, can only closely approximate conditions in the wild. In the second method, the otoliths of wild fishes are chemically marked. Fishes are sampled at various times and the increments deposited after this reference point are counted to estimate daily age (Jones, 1986).

The purposes of our study were 1) to demonstrate that juvenile striped mullet in South Carolina deposit daily growth increments on the sagittae; 2) to validate these marks as daily; 3) to use these validated ages and length data to model growth during the first year. Accurate age determinations through daily aging would provide important life history information, such as age at recruitment and the length of the spawning season through back-calculation of the spawning date. In addition, comparisons of the growth, spawning season, and occurrence of juvenile striped mullet from our study were made with historical data of abundance and length frequencies in South Carolina (1986 to 1991).

Materials and methods

Data collection and processing

The juvenile aging study was conducted from April of 1998 to December of 2000. A minimum of 20 juvenile striped mullet were collected monthly with a 7-m seine with 6-mm stretch mesh from the mudflats located in Grice Cove near Fort Johnson, South Carolina (Fig. 1). Additional samples came from the South Carolina Department of Health and Environmental Control (DHEC) and were caught from an electroshock boat in the freshwater portions of the Santee River, Cooper River, Ashley River, and Combahee River. Also, the Tidal Creek Project workgroup of the South Carolina Department of Natural Resources (SCDNR) used cast nets (1.87-m diameter with 6-mm mesh) in the tidal creeks of the lower Ashley River to catch juvenile striped mullet. A total of 2800 juvenile striped mullet were collected during the study; the number of these fish that were aged was 335.

Hydrographic data (water temperature and salinity) were recorded after sampling. Each specimen was measured in millimeters (mm) for total length (TL), fork length (FL), and standard length (SL). Sagittal otoliths were removed from the fish, and the right otolith was mounted on a microscope slide with Cytoseal mounting medium. Otoliths were polished with a felt polishing wheel loaded with tin oxide polishing compound (10 micron grit) by using a Crystalite lapidary polisher along the sagittal axis until the core was clearly discernible with increments visible to the outer edge. Age was determined at 1000× magnification under visible light as the mean of two independent readings of the counts of increments from the core to the outer edge. A third reading was made if the counts of the two previous readers differed by more than 10%.

Age validation

For the age validation experiment, 275 juvenile striped mullet were collected on 29 February 2000 from Fort Johnson Creek, a tributary of Parrot Point Creek in the Charleston Harbor estuary (Fig. 1), by seining. Specimens were transported to the laboratory and placed in a 1.3-m diameter tank, and acclimated overnight in well water at 15 parts per thousand (ppt) and 20°C. After transferral to a 38.7-L aquarium (15 ppt; 20°C) for marking, fish were immersed in oxytetracycline hydrochloride (OTC) at a concentration of 10 parts per million for five hours (Hettler, 1984). There were no mortalities during the treatment process. Marked specimens were placed in an outdoor 1.8-m diameter tank filled with (15 ppt, 20°C) well water. Water in the tank was replaced over a twenty-four hour period with ambient water from Charleston Harbor. These juveniles remained in the outside tank for the duration of the experiment to approximate as closely as possible the natural conditions of the local creek habitats. The fish were fed a daily ration of Tetramin floating commercial flakes (Tetramin, Blacksburg, VA) and were observed feeding one day after the OTC treatment. Salinity and water temperature, as well as dissolved oxygen concentration, were monitored daily.

Ten specimens were collected weekly for the next three weeks. Sagittal otoliths were removed and subjected to the same process as that given the otoliths used in the juvenile aging study. Each otolith was checked for the OTC mark under ultraviolet (UV) light at 1000× magnification by using a Nikon labophot compound microscope. The OTC mark appeared as a fluorescent mark when exposed to UV light (Fig. 2). Once the OTC mark was identified and its position marked, counts of increments after the OTC mark were made under visible light and recorded. This count was compared to the known number of days that had passed since marking with OTC.

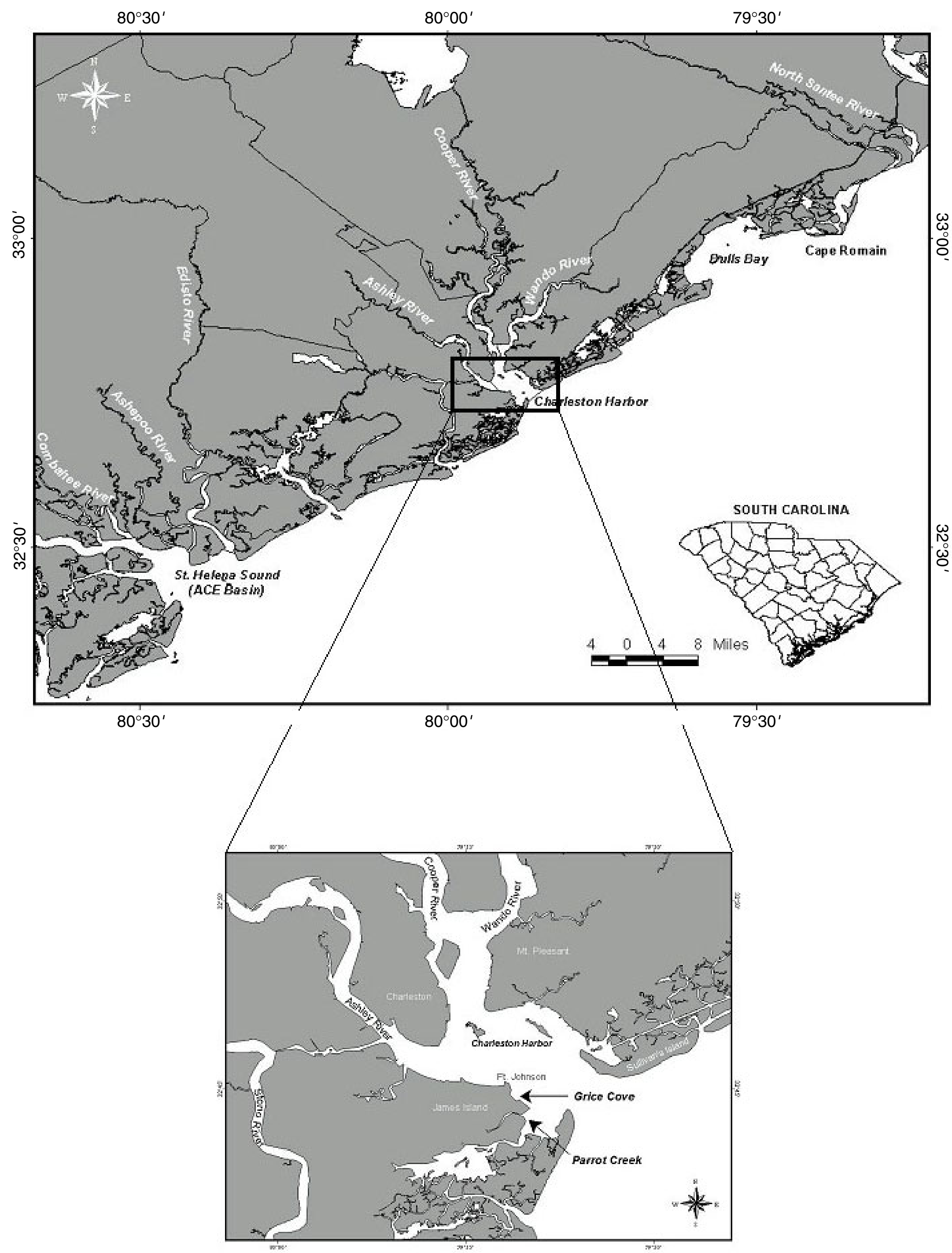

Figure 1

The major estuaries sampled during the juvenile aging study. Locations of collection sites for aging (Grice Cove) and increment validation (Parrot Creek) in the Charleston Harbor estuary are indicated in the inset.

Data analysis

The null hypothesis for the validation study was that the number of increments counted after the OTC mark equaled the number of days since marking. If these two numbers did not differ significantly, we could accept the hypothesis that the increments were deposited daily. The null hypothesis was tested by using a linear regression and a parametric paired t-test.

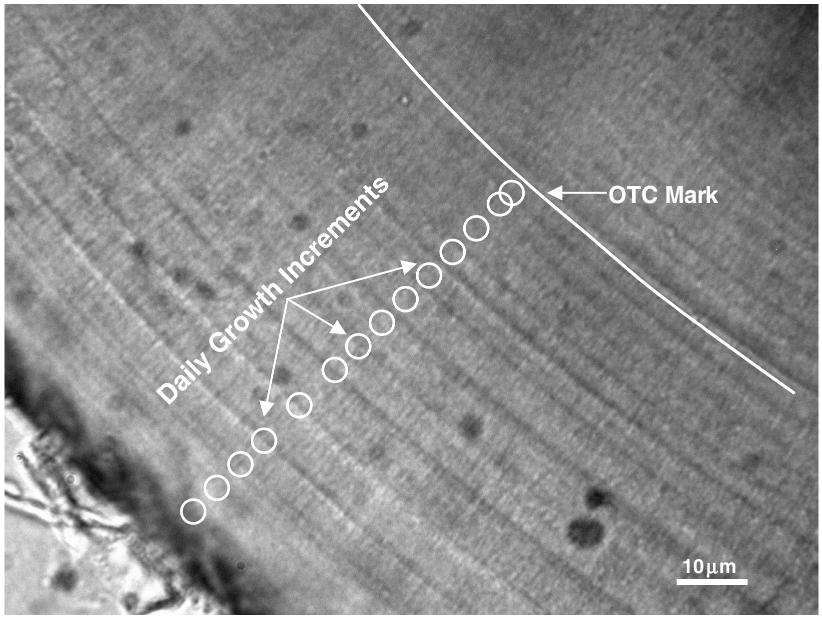

Figure 2

Photomicrograph of daily growth increments from the otolith of a striped mullet at 1000× magnification 14 days after OTC marking. The OTC mark is indicated and each subsequent daily growth increment is marked.

We also estimated the accuracy of the assigned ages of the fish. At the end of the study, 69 previously aged specimens were chosen at random and re-aged without knowledge of the prior assigned age. The percent agreement between the two sets of age readings was examined, and an age-bias plot was constructed for comparisons of the coefficients of variation between the two sets of ages for the same specimens (Campana et al., 1995).

The growth of juvenile striped mullet and the relationship of size at age once they recruit into the estuarine nursery habitats were described by using a least squares regression:

$$Y = aX^b \pm \varepsilon,$$

where Y = total length;
X = age;
a = the y-intercept;
b = the regression coefficient (slope); and
ε = the error term.

This would give a basic growth model from the juvenile aging study.

The distribution of the birthdates for the juveniles aged was backcalculated by subtracting the daily age of the fish from the date of capture. For the historical-survey fish (captured with rotenone), age was predicted from the application of the growth equation (least squares regression of size at age) to the observed lengths. We assumed in using the predicted age to estimate birthdates for the historical-survey fish that both groups (i.e. historical and current survey) had equal variances and similar growth patterns.

The historic data analyzed in our study were obtained from rotenone and plankton-net surveys in South Carolina from 1986 to 1991. The sampling technique for these surveys has been described (see Wenner et al.[2]). These data included length and hydrographic data similar to the data collected during our juvenile aging study and represented an additional 5498 fishes. The historical data were collected from three different salinity zones (oligohaline, mesohaline, and polyhaline) primarily within the Charleston Harbor estuary. The growth of juvenile striped mullet for the historical data was calculated from changes in mean total length per month by using a least squares regression. For fishes collected with rotenone, month of capture was substituted for age in the model. Mean size per month for each year of the rotenone survey (1986 to 1991) was determined separately. The growth from the juvenile aging study and from the historical data were then compared by using an analysis of covariance (ANCOVA) to compare the differences in the slopes and intercepts.

The different salinity regimes within the estuaries were defined by using the Venice scale of estuarine salinities (Anonymous, 1959). This scale provides five distinct salinity regimes within an estuary: freshwater (0 ppt), oligohaline (0.1 to 5 ppt), mesohaline (5.1 to 18 ppt), polyhaline (18.1 to 30 ppt), and euhaline (>30.1 ppt). Growth was compared between the different salinity regimes and significance was tested by comparing the changes in mean size per month within each salinity regime against the others by using an ANCOVA.

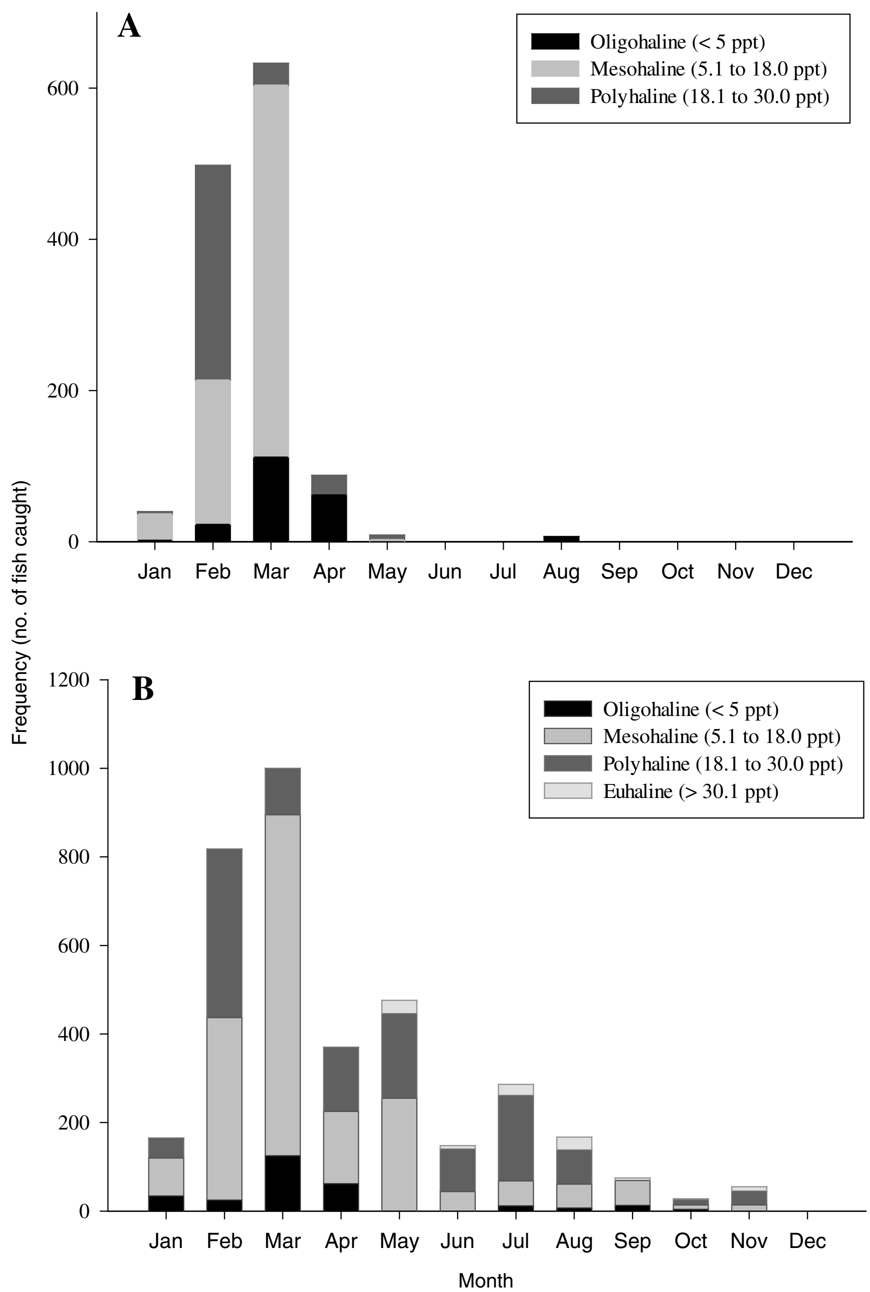

Figure 3

Total catch frequency for juvenile striped mullet stratified by salinity regime from plankton net tows (**A**) (n=1252) and rotenone surveys (**B**) (n=4246).

Results

Abundance and recruitment

Plankton tows from 1986 and 1987 showed that the highest abundance of striped mullet in the Charleston Harbor Estuary occurred in February and March (Fig. 3A). The majority of these young-of-the-year were captured in mesohaline (65% of the total) and polyhaline salinities (28% of the total).

The historical rotenone surveys indicated that numerical abundance of juvenile striped mullet was highest in February and March (Fig. 3B). The earliest captures of young-of-the-year striped mullet in the rotenone survey were 19 specimens in November of 1986 and a single specimen in December of 1986. Abundances for the different salinity

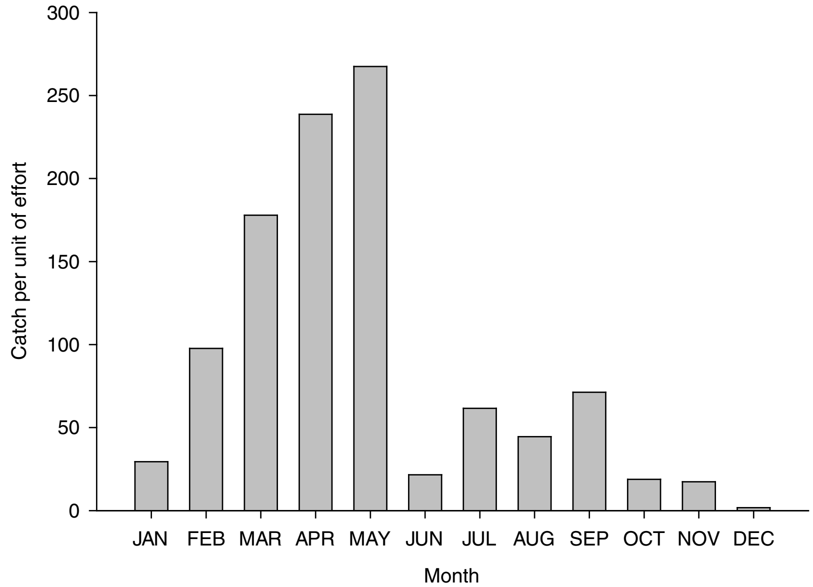

Figure 4

Catch per unit of effort for juvenile striped mullet in South Carolina estuaries from rotenone surveys, 1986 to 1991. n = 4246.

regimes showed that most of these fish were recruiting into mesohaline and polyhaline salinities. One difference in the rotenone data was that few juveniles were caught at oligohaline sites during the recruitment time period. Young-of-the-year striped mullet were caught at euhaline sites starting in May when the mean size was greater than 40 mm. Specimens captured by plankton net in freshwater and oligohaline salinities had very low abundances. The plankton net did not catch any juveniles in euhaline salinities. Catch per unit of effort (CPUE) for the rotenone surveys also demonstrated increasing abundance from February to May (Fig. 4).

Size frequencies in the different salinity regimes for the juvenile aging study (Fig. 5) showed young-of-the-year striped mullet (fish less than 200 mm) were found mostly at mesohaline and polyhaline salinities. The earliest occurrence of a young-of-the-year specimen in the juvenile aging study was a 25-mm specimen captured in December of 2000.

Age validation

The variability in the physical parameters during the age validation experiment approximated the diurnal variations in tidal creek habitats. Temperature and salinity ranged from 14.2° to 19.0°C and 21.3 ppt to 29.0 ppt . Dissolved oxygen ranged from 6.2 mg/L to 8.1 mg/L during the experiment.

There was no detectable growth during the experiment—probably a result of the short duration of the experiment. Age ranged from 57 to 121 days and mean age was 83 ±17.4 days. The mean age did increase over the course of the experiment with each collection (65.3 ±1.45 days, 82.2 ±2.47 days, and 102.5 ±3.59 days, respectively).

The OTC mark was visible under UV fluorescence on all the specimens examined. A paired t-test between the number of days after OTC marking and the number of increments counted after the OTC mark showed that the two variables were not significantly different (P=0.000, t=0.000, df=29, F=1648.0). Regression analysis (Fig. 6) indicated that the slope of the line running through these points did not differ significantly from 1.0 (r^2=0.998). These analyses allow the acceptance of the null hypothesis that the increments counted were deposited daily.

There was an 84.5% agreement between the original age and the second age read for the subsample of 69 specimens that were re-aged. An age bias plot (Fig. 7) showed the difference between the two ages for each specimen and the original age assigned to that specimen showed no detectable age bias. In addition, the coefficients of variance for each set of ages were similar (originally assigned age CV=0.434 and the second blind read age CV=0.429). An ANOVA comparing the mean ages for each group (original age=170.7 ±8.93 and blind read second age mean=170.6 ±8.80) also showed no significant differences (P=0.00, df=68, F=6878.8).

Growth

Growth of striped mullet from the juvenile aging study was described by the equation

$$\textit{Total length} = 0.342\ (\textit{Age})^{1.039}\ \pm 19.4 \quad (r^2=0.741 \text{ at } P=0.001).$$

Size at age was more variable in fish larger than 90 mm TL (Fig. 8); however, there was still clearly a strong relationship.

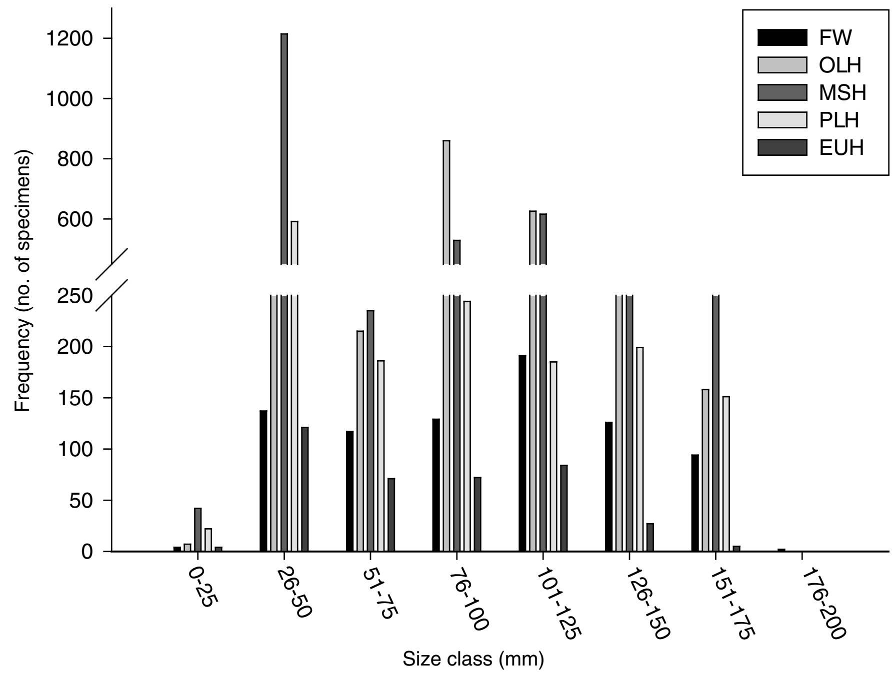

Figure 5

Striped mullet abundance stratified by size class and salinity regime for young-of-the-year (< 200 mm) for all years and gear types combined. Salinity zones: FW = freshwater, OLH = oligohaline, MSH = mesohaline, PLH = polyhaline, and EUH = euhaline. n = 8714.

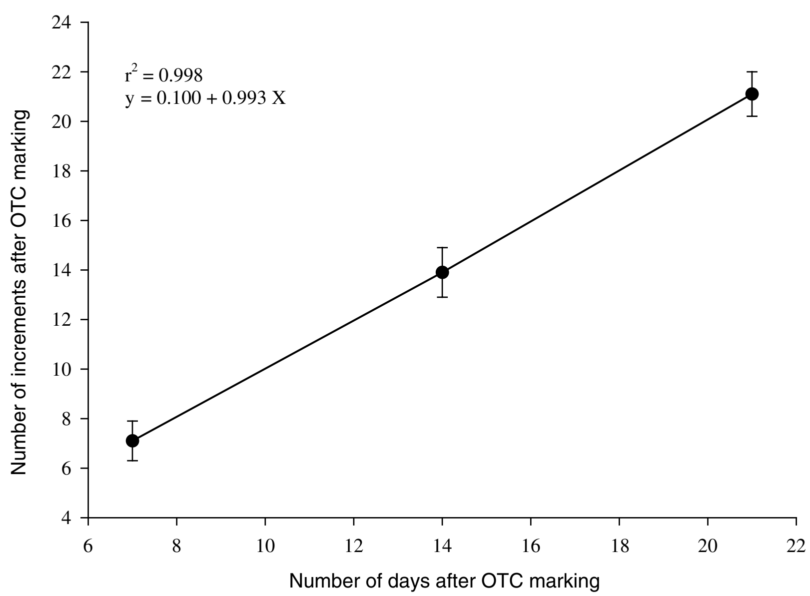

Figure 6

Regression analysis of striped mullet daily growth increments and number of days after oxytetracycline (OTC) marking. Each data point represents the mean number of daily growth increments for ten specimens taken each week of the experiment and error bars represent standard errors of the mean.

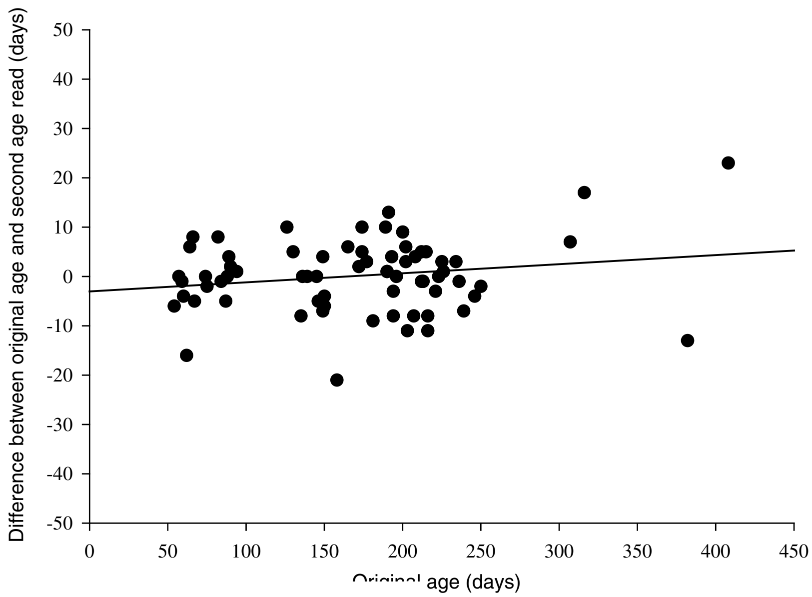

Figure 7

Age bias plot for juvenile striped mullet showing differences between blind read ages and the originally assigned ages. n = 69.

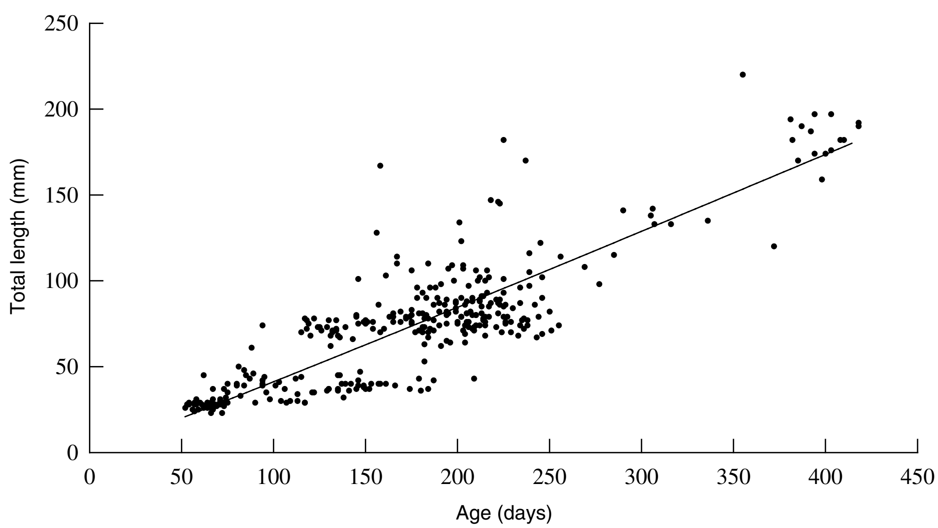

Figure 8

Size at age regression for young-of-the-year striped mullet. r^2 = 0.992 at P = 0.001, n = 335.

Mean size and age per month for these juveniles (Fig. 9, A and B) indicated steady growth throughout the year. One particular problem occurred in the month of April for fish in the juvenile aging study. For the first year when juveniles were collected, the size range was 130 to 180 mm and for the second year of the study, an April collection was not made because of equipment problems. The mean size and age for the fish collected in April indicated that these fish were one-year-old juveniles, not young of the year. Therefore, these fish were removed from the data set in subsequent analyses.

Specimens were not present for every month of every year for the rotenone survey, except for 1990 and 1991, because of differing sampling strategies employed. Therefore, all the rotenone data were pooled and collections for every month were represented in one data set. The resulting

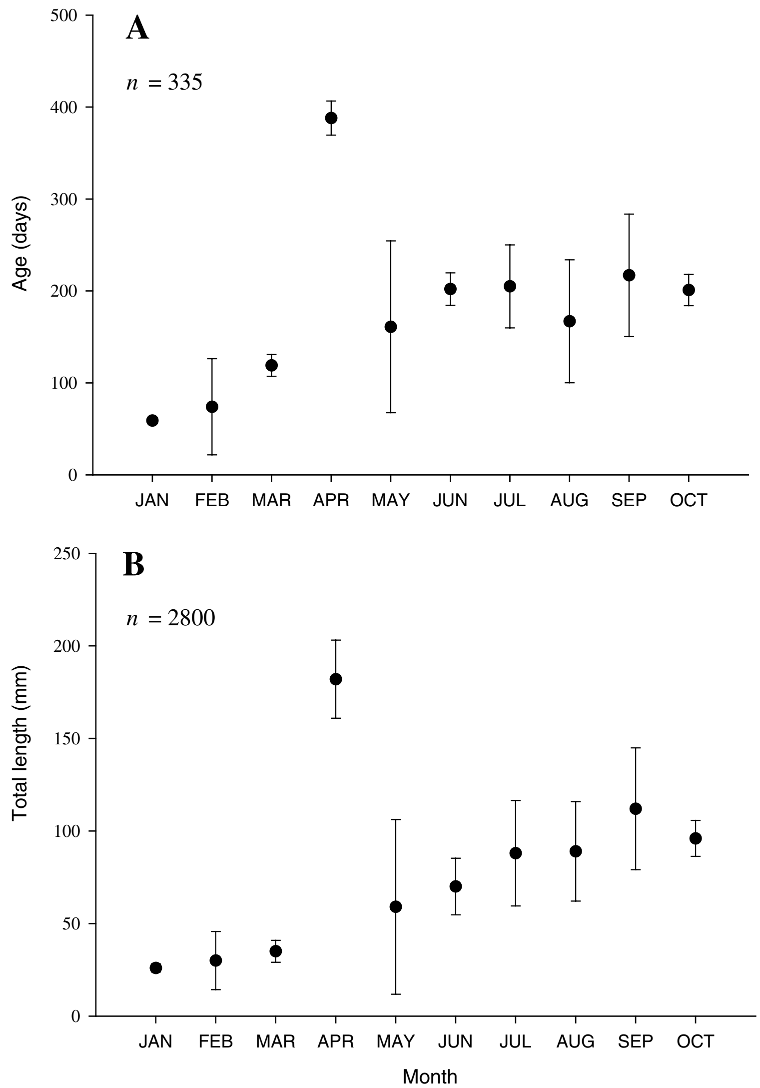

Figure 9

Mean age (**A**) and total length (**B**) at capture by month for young-of-the-year striped mullet from the juvenile aging study, 1998 to 2000.

growth curve (Fig. 10) for the rotenone study was described by the equation

$$\textit{Total length} = 8.77\ (\textit{month of capture})^{1.13} \pm 9.20$$
$$(r^2{=}0.950 \text{ and } {=}235.0 \text{ at } P{=}0.001).$$

Month of capture was a good approximation of age because January represented the approximate middle of the spawning season (October to April) and it provided a measurable time frame in which to make both statistical comparisons and calculate growth rates.

The ANCOVA indicated that there was no significant difference between the slopes of our juvenile aging study and the rotenone studies (P=0.001); the coefficients of variation were not significantly different, and the residuals were normally distributed. However, there was a difference in the y-intercepts (0.346 for the juvenile aging study and 8.77 for the rotenone study). This difference was due to the age factor used in the separate regressions. Days were the units and in our juvenile aging study, whereas month of capture was used for age in the rotenone study. The higher r^2 for size at age in the rotenone survey reflected the use of changes in mean size per month for a larger sample (n=2576) than the actual size at age used for the juvenile aging study data (n=335).

The distribution of back-calculated birth dates for striped mullet from the juvenile aging study shows that the main spawning period ranges from October through April (Fig. 11A). The birthdate distribution for the rotenone fish defines the main spawning period from October to Febru-

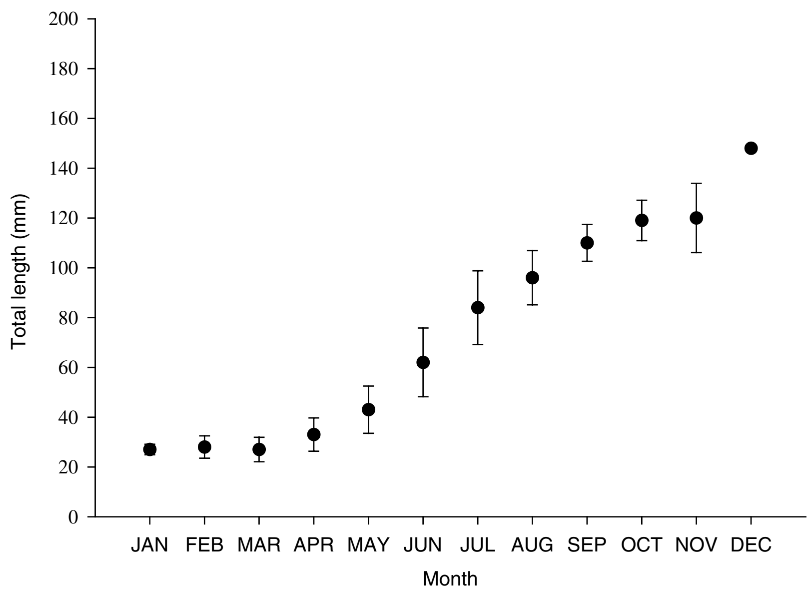

Figure 10

Mean total length per month for young-of-the-year striped mullet from historical rotenone and plankton net collections, 1986 to 1991. n = 5498.

ary with much less spawning activity in March and April (Fig. 11B). Both groups of striped mullet had peak spawning in December. The distribution of birthdates from fish in the juvenile aging study indicated a more protracted spawning season. A few individuals had birthdates outside the October–April time period, but the percentage of these fish was extremely low and within the margin of error for the back-calculated birthdates.

There was no significant difference in the mean size per month of juveniles captured at different salinity regimes (P=0.05) (Fig. 12). The initial growth rates for fish in all salinity regimes were very similar and fairly flat from January through April, and the mean size was still less than 40 mm. Growth increased noticeably in May and continued at a higher rate through the end of the year.

Discussion

Recruitment

The backcalculated birthdates from the juvenile aging study indicated that the spawning season extended from October to April. The earliest recruitment for fish in the rotenone surveys occurred in November and in December for the juvenile aging study. However, these were not standard samples and the early recruits represented a very small percentage of the young-of-the-year. Given that the youngest fish in the juvenile aging study were the most recent recruits, this was direct evidence that fish spawned in October were recruiting to South Carolina estuaries as early as November. Other studies have also found early recruits occurring prior to January in other estuaries from South Carolina (Cain and Dean, 1976), North Carolina (Hettler et al., 1997), Georgia (Anderson, 1958; Rogers et al., 1984), and Florida (Kilby, 1949). One of the earliest reported occurrences of young-of-the-year striped mullet was 19 November (Anderson, 1958) in Georgia. Offshore studies of ichthyoplankton in the South Atlantic Bight have indicated that the major spawning period occurs from December to February (Anderson, 1958; Collins and Stender, 1989). The smallest identifiable larvae caught in these studies were in the 3–5 mm range, and according to our growth model would have been approximately two to six days old. No studies to date have documented actual striped mullet spawning areas in the South Atlantic Bight. However, there is some evidence that striped mullet spawn near the edge of the continental shelf (Collins and Stender, 1989).

The peak abundances in our study for young-of-the-year striped mullet in South Carolina (February to May) agreed with available published data (Jacot, 1920; Anderson, 1958; McGovern and Wenner, 1990). In North Carolina, larval abundance has been shown to be highest from January through March and peaks in February (Hettler et al., 1997). The lack of substantial change in length and weight of striped mullet over the recruitment season suggested continued recruitment of new individuals from offshore (Hettler et al., 1997). Juveniles already recruited had dispersed throughout the estuary and were not abundant in catches afterwards. The recruitment of these juvenile striped mullet into North Carolina estuaries in pulses approximately three to four weeks apart was possibly related to the lunar cycle (Hettler et al., 1997). This type of pulse of new recruits into South Carolina was not seen in our study. In Georgia,

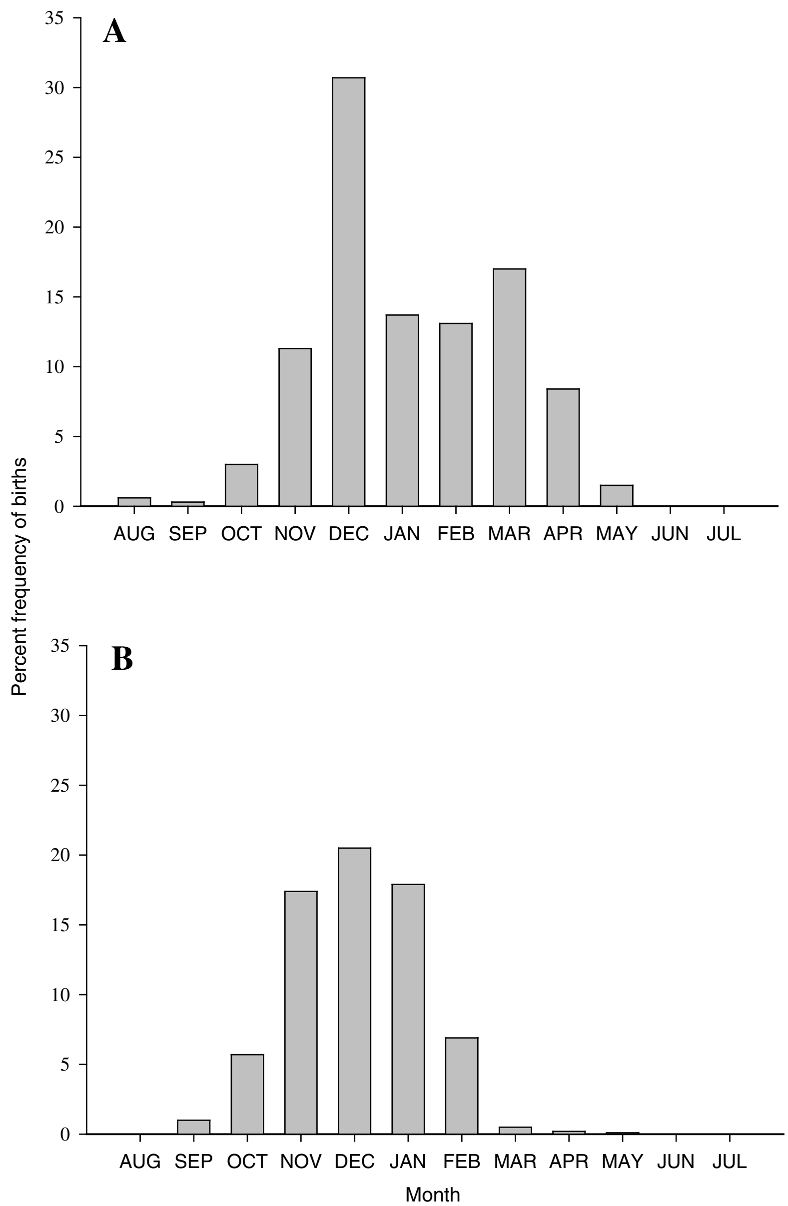

Figure 11

Percent frequency of births per month for striped mullet from the juvenile aging study (**A**) (n= 335) and the historical surveys (**B**) (n=5498).

mean lengths of young-of-the-year striped mullet also remained relatively constant from December to June, indicating an even more protracted period of juvenile recruitment than in either North or South Carolina (Rogers et al., 1984). Recruitment in Florida also appeared to occur over a much broader time scale than that for the Carolinas; newly recruited juveniles occurred from December to June (Kilby, 1949; Anderson, 1958). The longer recruitment season seen in the southern portion of the South Atlantic Bight may be due to faster onshore transport of striped mullet larvae and juveniles, proximity to the spawning grounds, i.e. the continental shelf, or a longer spawning season resulting from warmer temperatures.

Age validation

Otoliths form a permanent record of growth in juvenile fishes and can be an important "barometer" of growth and the conditions under which it occurred. Radtke (1984) validated daily growth increments in striped mullet juveniles from Hawaii using hatchery-reared fish. The primary difference in our study was the use of wild-caught juveniles

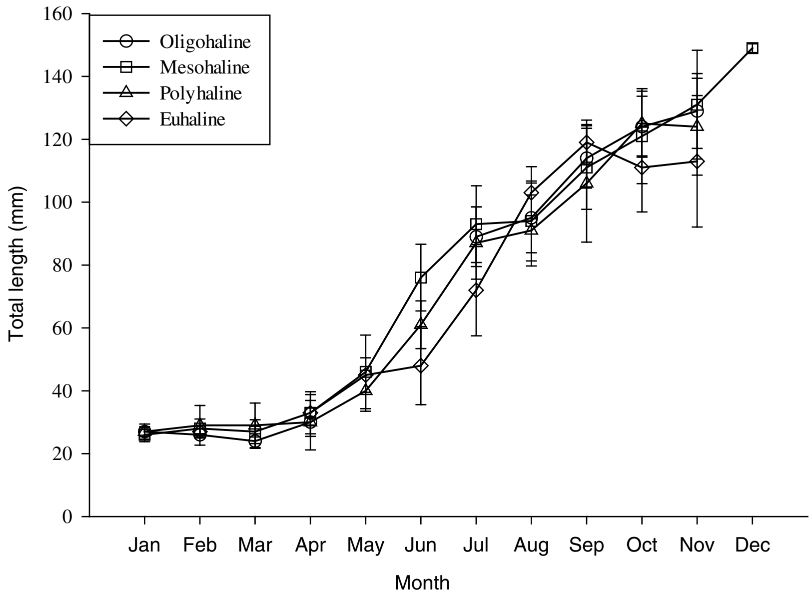

Figure 12

Mean size per month for young-of-the-year striped mullet stratified by salinity regime for pooled data from 1986 to 2000. n = 8714.

to validate daily growth increments. Another more recent study by Chang et al. (2000), using wild-caught striped mullet marked with OTC, also validated daily growth increments in Taiwanese estuaries.

The variation in physical parameters of temperature, salinity, and dissolved oxygen throughout the validation experiment approximated the existing conditions found in the harbor during this time period. Food sources may have differed between the tank and the tidal creeks; however, the fish were observed feeding on the growth on the sides of the tank in addition to ingesting the floating commercial food during most of the experiment. Because the mullet were observed actively feeding during this experiment, starvation stress probably did not affect increment deposition. In addition, concurrent collections of wild striped mullet for the juvenile aging study revealed size and age distributions similar to those for specimens used in the age validation part of our experiment.

Validation of daily growth increments is an important step in providing estimates of growth and age for larval and juvenile fishes. Accurate age and growth information enables better examinations of recruitment, population dynamics, and other important aspects of the life histories of juvenile fishes. Validation of daily growth increments in striped mullet allows for more accurate estimates of age in adults and juveniles, in particular, and thus this process helps to determine the first growth increment. Validation also helps determine different aspects of size at age in juvenile striped mullet, sexual differentiation, and development, and a more precise determination of spawning time periods in adult striped mullet through back calculation of birthdates.

Growth

Growth of newly recruited fish during the January–April time period was relatively low when compared to the rest of the year. This time period also coincided with the time of heaviest recruitment of these juvenile mullet. However, when we look at mean size per month for all of the juveniles pooled together, we find a similar growth curve in both the historical and current data. It was not until May, when the juvenile striped mullet reach a mean size of greater than 40 mm, that growth increased markedly. The results of the growth curves from our study appeared to support this. The greatest increase in growth came after a mean size of 40 mm was reached and during the months when mean monthly temperatures were higher. However, the differences in growth between different salinity regimes examined in our study were not found to be significant.

Growth for juvenile striped mullet was similar in both the rotenone study (1986 to 1991) and the juvenile aging study (1998 to 2000). This was evident from the nonsignificant differences in the slopes of the two curvilinear regressions. The coefficient of variation was also similar between the two groups. Because the growth rate for the rotenone study specimens was calculated from pooled data over a six-year period, it provided a fairly good estimate of growth over a range of environmental and biological conditions. As with the fish from the juvenile aging study, growth in the rotenone mullet study was fairly flat from January until May when mean size reached 40 mm or larger. After May the growth rate increased dramatically until it slowed again in the fall. The increase in growth rate from May to

October also coincided with seasonal increases in photoperiod and temperature.

The mean size at one year of age has been found to vary from 140 mm to 222 mm (TL, FL, SL) in striped mullet (Broadhead, 1956; Anderson, 1958; Thomson, 1966; Chubb et al., 1981). This wide range is most likely due to differences in methods of measurement. Previous studies have used length frequencies or ages determined from scales to calculate size at one year of age. These techniques are not as accurate in determining age as methods where otoliths are used (Campana et al., 1995). Our estimates of size at one year of age were 157 ±9.20 mm total length for the rotenone-caught fish and 157 ±19.4 mm for the fish in the juvenile aging study. Again, these sizes (in this case, mean size at one year of age) are consistent between the two studies, despite the different time scales used to calculate the growth curves. The ability to estimate size at age is important in the determination of the first annulus; however, the first annular growth increment for striped mullet in South Carolina was deposited in July at 15 to 23 months of age (McDonough, unpubl. data). Therefore, at 12 months of age the first annular increment would not have been deposited yet. The time lag between 12 months in age and the actual time of annual increment deposition probably also contributed to the wide range in sizes at one year of age in the literature.

The wide range of size at age of both juveniles and adult striped mullet is probably due to a range of environmental and biological factors that affect their growth. Kuo et al. (1973) found the greatest mortality in striped mullet during the first ten days of life. The end of this period coincided with the onset of intensive feeding behavior, which was approximately five days after complete yolksac depletion. The differences in the size range of these striped mullet during the 42-day larval period indicated differential growth. In Kuo et al.'s (1973) experiment, food was not a limiting factor and all the fish were hatched at the same time. A similar wide range in size at age was observed in the fish from the juvenile aging study. If food was not a growth-limiting factor for these fish, the only biological processes that could account for the differences would be either differing specific metabolic rates or intraspecific competition among larvae. These fish could have come from a wide range of geographic areas (where spawning occurred) at different times of the spawning season and food resources offshore could have been better for some groups of larvae than for others. Environmental factors that may have affected growth could include temperature and photoperiod, which could vary for larvae spawned at different times of the spawning season. Fish spawned in the mid-part of the spawning season (December to February) may have some advantage over fish spawned either earlier or later in the season. Rooker and Holt (1997) found cohort-specific growth rates to be higher in larval red drum (*Sciaenops ocellatus*) that were spawned during mid-season versus fish spawned at the beginning and end of the season. Fish that arrived earlier would spend more time in cold water and have slower growth. In addition, resources at spawning locations probably vary and these differences may show up as differential growth in comparably aged fish. We have found that variability in size at age is even more apparent in adult fish (McDonough, unpubl. data). The wide range of size at age found in the adults may be due to the same factor that causes differential growth in larval and juvenile striped mullet. This would not be uncommon because processes that occur during the larval phases of oceanic spawning fishes have been found to affect many characteristics of the adult population, namely recruitment, abundance, and growth (Houde, 1987, 1997; Bradford, 1992; Mertz and Myers, 1995; Comyns, 1998; Levin, 1998).

In summary, striped mullet in South Carolina deposit daily growth increments on the sagittal otoliths. The spawning season for these fish, as determined through birthdate back-calculation, was from October though April and subsequent recruitment occurred from January through May. However, there was evidence that young-of-the-year striped mullet can recruit as early as November. After recruitment, juvenile striped mullet were found most frequently at mesohaline and polyhaline salinities within the estuaries of South Carolina. Growth during the first year appears to be relatively consistent over time for juvenile striped mullet as indicated by the similarities in growth between fish collected in our study (1998 to 2000) and those collected in the rotenone study (1986 to 1991).

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