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Age, Growth, and Reproduction in Florida Stocks of Spanish Mackerel, *Scomberomorus maculatus*

DION POWELL

Florida Department of Natural Resources
Marine Research Laboratory

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Age, Growth, and Reproduction in Florida Stocks of Spanish Mackerel, *Scomberomorus maculatus*

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1975

Florida Department of Natural Resources
Marine Research Laboratory

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ABSTRACT

Powell, D. 1975. Age, Growth, and Reproduction in Florida Stocks of Spanish Mackerel, Scomberomorus maculatus. Fla. Mar. Res. Publ. No. 5.22 p. During the period January 1968 through December 1969, Spanish mackerel were sampled from commercial and sport landings throughout Florida. Age and growth were determined by examination and mathematical analysis of otoliths. Reproduction was evaluated upon the basis of microscopic examination of ovarian sections.

Age groups 0-VIII were represented in a total usable sample of 2060 otolith pairs. However, growth analysis was limited to ages I-V due to insufficient numbers of older fish. Females grow faster and attain greater size than males. Von Bertalanffy growth equations are as follows:

for males

\[ L_t = 515 \left[1 - e^{-0.48(t + 1.12)}\right], \]

for females

\[ L_t = 645 \left[1 - e^{-0.45(t + 0.78)}\right]. \]

These data do not directly compare with those of other investigators due to differences in otolith interpretation. Length-weight relationships are as follows:

for males

\[ W = 1.1519 \times 10^{-5}SL^{2.9822}, \]

for females

\[ W = 4.7491 \times 10^{-6}SL^{3.1373}. \]

Evaluation of reproductive development, although hampered by insufficient samples of older age groups, indicates that mature Spanish mackerel spawn repeatedly during a prolonged, spring-summer, spawning season. Conclusive determination of age of initial maturity was hindered by inadequate collection of ovarian tissue from older specimens due to their scarcity in summer landings. Although some evidence indicates that full maturity is probably not attained until age III, other evidence shows that some younger females contain fully developed eggs, suggesting that they may be capable of spawning.

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INTRODUCTION

The Spanish mackerel, *Scomberomorus maculatus* (Mitchill), is a migratory pelagic fish with a geographic range from the Gulf of Maine to Brazil, including the Gulf of Mexico (Briggs, 1958) but excluding the Caribbean (Erdman, 1949). *S. maculatus* is usually considered to be an inhabitant of neritic waters, preferring the open waters of the Atlantic Ocean and the Gulf of Mexico, but will enter estuaries during its spawning migrations.

Spanish mackerel provide an important fishery in Florida with significant commercial activity dating to about 1920 (Lyles, 1969). In the five year period, 1968-1972, dockside values of commercial landings have exceeded $1,000,000 annually (Johnson, 1969-1973). The sport fishery is also of major importance. Censusing of sport landings in 1965 provided an estimate of over 21 million pounds of "Spanish mackerel" (includes both *S. maculatus* and the cero mackerel, *S. regalis*) landed by sportsmen from Cape Hatteras to the Mississippi River (Deuel and Clark, 1968).

Earll (1882) and Ryder (1882) were the first to study the biology and fishery of *S. maculatus*. At that time commercial activity was centered in Virginia and attempts were made to augment the fishery with hatchery reared fish. Ryder (1882), Earll (1882), Hildebrand and Cable (1938), and Wollam (1970) describe larvae and young juveniles with comments on spawning, larval development, and occurrence in the North Atlantic and the Gulf of Mexico. Dwinell and Futch (1973) report on occurrence and abundance of larvae and young juveniles in the northeastern Gulf of Mexico. Klima (1959) investigated the biology of *S. maculatus* and its fishery in South Florida. Nomura (1967) described age and growth of *S. maculatus* in Brazilian waters.

METHODS AND MATERIALS

From January 1968 through December 1969, Spanish mackerel were sampled from commercial and sport landings. Gill nets are the most commonly used commercial fishing gear. However, beach seines and, by special permit, a purse seine were also used. Stretched mesh sizes of gill nets ranged from 3 to 3-5/8 inches (7.6-9.2 cm) with 3-3/8 inch (8.5 cm) being the most prevalent. Stretched mesh sizes of beach seines were 1-1/4 and 2-3/4 inches (3.2 and 4.4 cm). Purse seine mesh size was 3/4 inch (1.9 cm). Sport catches were made by hook and line.

During periods of peak commercial activity, primarily during winter in South Florida, *S. maculatus* was sampled in proportion to its occurrence, by length, in large commercial landings. Length frequencies, by 5 cm fork length intervals, were determined from several hundred mackerel selected randomly from the catch. These fish were then subsampled in proportion to their numbers as they occurred in each segment of the length frequency tally. Other samples, collected throughout the year and along both coasts, were taken directly from small commercial and occasional sport landings.

Individual fish from the subsamples were measured to the nearest 0.5 cm standard length (SL) and fork length (FL), and weighed to the nearest ounce. Otoliths (lagittae) were removed, cleaned, and stored in glycerin. Sex and gonadal development were determined macroscopically from all fish sampled and sections of gonadal tissue were periodically removed and fixed in Bouin's fluid for later microscopic examination. These tissues were processed to produce six micron sections stained with Papanicolau hematoxylin (Harris)/eosin Y.

For examination, otoliths were immersed in glycerin in a black-bottomed watch glass and viewed through a dissecting microscope using reflected light. Two independent determinations of age were made. A third reading was conducted for the purpose of measurement. Measurements, using an ocular micrometer, were made from the growth center of the otolith, posteriorly, to each age mark and to the outside edge (Figure 2).

Only individuals for which age determinations were consistently the same were used in growth analysis. Because of exceedingly large numbers of one and two year old fish, these groups were subsampled with the aid of a random number table. Specific sample sizes are given in Table 1. Regression analyses follow the recommendations of Ricker (1973) wherein the regression coefficient is \[ \sqrt{\frac{\sum y^2}{\sum x^2}}. \]

AGE AND GROWTH

RESULTS

Otoliths were obtained from 2,222 fish. Of these, 162 were too obscure for age determina-
tion. Approximately 93% of the remaining otoliths were from fish three years old or younger. Age group I was most numerous (42.7%). The oldest Spanish mackerel sampled was eight years old, represented by one female. Mackerel older than age group V total only nineteen fish. Consequently, growth analysis was limited to age groups I through V.

Annular marks on bony structures are typically represented by contrasting, alternating bands created by seasonal metabolic changes. Spanish mackerel otoliths, when viewed against a dark background with reflected light, show bands appearing as decreasingly broad, opaque, white areas divided by narrower, dark, translucent areas. Opaque bands represent spring-summer periods and translucent bands correspond to fall-winter periods. Klima (1959:31), in describing Spanish mackerel otoliths noted that winter marks, after the first winter mark, appear as “heavy opaque areas”. No similar marks were consistently found on otoliths that I examined. Only dark, translucent bands were interpreted as winter marks. Figures 1 through 6 show typical Spanish mackerel otoliths from fish in age groups 0 through V.

Justification for use of otoliths in determining age and growth in this study is based on proportional growth between otolith radius, fish length, and a consistent time of differentiation of annuli. Correlation of otolith radius with standard length was calculated for 351 mackerel of both sexes. The correlation coefficient, $r = 0.84$, is sufficiently high to show proportional growth between otolith radius and standard length. Figure 7 is a plot of marginal increment (interpreted here as the width of the last summer band when it occurs as the last band on the otolith) against time. The marginal increment is minimum in late spring-early summer and maximum in late fall-early winter; thus indicating that annuli are differentiated at approximately the same time each year.

Comparison of mean standard length at each age between the sexes indicated that female Spanish mackerel grow faster than males (Figure 8). Therefore, subsequent growth analysis was applied separately to each sex. Estimates of
Figure 2. Otolith from age I, 350 mm SL male taken near Ft. Pierce Inlet, Florida, in March 1968. Measurement of otoliths were as illustrated in this figure. Measurements were made in line with the sulcus acousticus for consistency.

Figure 3. Otolith from age II, 430 mm SL male taken near St. Lucie Inlet, Florida, in November 1968.
Figure 4. Otolith from age III, 585 mm SL female taken near St. Lucie Inlet, Florida, in November 1968.

Figure 5. Otolith from age IV, 620 mm SL female taken near Ft. Pierce Inlet, Florida, in October 1968.
Figure 6. Otolith from age V, 545 mm SL male taken near St. Joe Point, Florida, in August 1968.

Figure 7. Mean marginal increment of Spanish mackerel otoliths in ocular micrometer units.
standard length at annulus formation (Table 1) were calculated from the Van Oosten direct proportion backcalculation formula: \( L' = \frac{S'}{S} L \) (Lagler, 1956: 121); where \( L' \) = calculated length, \( S' \) = radius of annulus, \( S \) = radius of otolith, and \( L \) = length at capture. Mean backcalculated standard lengths were used to establish Walford lines (Figures 9 and 10) where length at age \( t + 1 \) is plotted against length at age \( t \) (Walford, 1946). The asymptotic length \( (L_{\infty}) \), where the Walford line intersects a diagonal line, was refined by plotting \( \log_e(L_{\infty} - L_t) \) against \( t \) for several estimates of \( L_{\infty} \). The straightness of this line is sensitive to changes in \( L_{\infty} \) and trials are made until best fit is obtained (Ricker, 1958:195).

Data from Walford plots were applied to the growth model: \( L_t = L_{\infty}[1 - e^{-K(t-t_0)}] \) developed by von Bertalanffy (1938); where \( L_t \) = length at some specified age, \( L_{\infty} \) = theoretical maximum attainable length, \( e \) = base of the natural logarithm, \( K \) = rate of change of growth, \( t \) = the specified age and \( t_0 \) = theoretical length at beginning of growth.

The growth equation for males is

\[
L_t = 515\left[1 - e^{-0.48(t+1.12)}\right]
\]

and for females

\[
L_t = 645\left[1 - e^{-0.45(t+0.78)}\right].
\]

Values of \( L_t \) are plotted along with mean empirical and backcalculated lengths in Figure 11.

The poor fit between empirical and calculated data at age I in Figure 11 is probably due to net selection (Figure 12).

Length-weight regressions were calculated for 135 males and 217 females. Justification for
TABLE 1. MEAN STANDARD LENGTHS AT CAPTURE AND MEAN BACKCALCULATED LENGTHS AND THEIR MEANS FOR MALE AND FEMALE SPANISH MACKEREL. LENGTHS IN MILLIMETERS.

<table>
<thead>
<tr>
<th>AGE</th>
<th>( \bar{X} ) SL AT CAPTURE</th>
<th>N</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>AGE</th>
<th>( \bar{X} ) SL AT CAPTURE</th>
<th>N</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>362</td>
<td>30</td>
<td>306</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>I</td>
<td>404</td>
<td>54</td>
<td>333</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>405</td>
<td>30</td>
<td>292</td>
<td>372</td>
<td></td>
<td></td>
<td></td>
<td>II</td>
<td>459</td>
<td>44</td>
<td>344</td>
<td>423</td>
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<td></td>
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<tr>
<td>III</td>
<td>445</td>
<td>38</td>
<td>316</td>
<td>388</td>
<td>418</td>
<td></td>
<td></td>
<td>III</td>
<td>528</td>
<td>30</td>
<td>346</td>
<td>450</td>
<td>500</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>476</td>
<td>20</td>
<td>315</td>
<td>402</td>
<td>431</td>
<td>456</td>
<td></td>
<td>IV</td>
<td>554</td>
<td>24</td>
<td>337</td>
<td>443</td>
<td>493</td>
<td>526</td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>497</td>
<td>10</td>
<td>330</td>
<td>397</td>
<td>428</td>
<td>452</td>
<td>474</td>
<td>V</td>
<td>598</td>
<td>11</td>
<td>364</td>
<td>466</td>
<td>516</td>
<td>550</td>
<td>577</td>
</tr>
</tbody>
</table>

TOTAL N | 128 |   |   |   |   |   |   | TOTAL N | 183 |   |   |   |   |   |
MEAN LENGTHS | 312 | 390 | 426 | 454 | 474 |   |   | MEAN LENGTHS | 345 | 446 | 503 | 538 | 577 |   |

Separation of the sexes was further established by analysis of covariance which gave significant differences (\( P = .05 \)) for both slope

\( F = 5.0189; \) df = 1,348

and elevation

\( F = 5.0890; \) df = 1,349.

For males the relationship is

\[ W = 1.1519 \times 10^{-5}SL^{2.9822} \]

and for females

\[ W = 4.7491 \times 10^{-6}SL^{3.1373} \] (Figure 13).

For circumstances where sex distinctions are impractical the equation for combined sexes is

\[ W = 9.9632 \times 10^{-6}SL^{3.0076} \]

The relationships between fork length and standard length were determined for each sex. However, a “t” test detected no significant difference between sexes

\[ t = 1.3240; t_{0.05[\infty]} = 1.96. \]

Therefore, the relationships

\[ FL = 1.0728SL + 2.4267 \]

and

\[ SL = 0.9321FL - 2.2619 \]

stand for both sexes.

DISCUSSION

Klima (1959) described growth of *S. maculatus* in terms of backcalculated estimates of length at annulus formation. Nomura (1967) expressed growth of Spanish mackerel from Brazil in terms of von Bertalanffy growth equations. He also, by some unspecified method, adapted Klima’s data to the von Bertalanffy model (Nomura, 1967:33). Theoretical fork lengths at ages I through V as determined by Nomura for his and Klima’s data, are compared with mine in Table 2. There is reasonably close agreement between Nomura’s and Klima’s results, but my results differ. This is especially true at age I, but decreasingly so at older ages. A possible explanation for this difference lies with interpretation of otoliths.

Klima (1959:30) provided a photograph of a Spanish mackerel otolith he claimed to be in age group III. Anuli were emphasized by short pen marks but no measurement scale was provided, nor was the length of the fish specified, thus precluding direct comparison with my examples. However, I find it difficult to detect an annulus at the position Klima marked as the first annulus. Also, the relative distances between the annuli are peculiar. Usually these distances decrease with age but the contrary is indicated by Klima’s marks. Furthermore, neither I nor Nomura (1967:31) found the opaque winter marks noted by Klima (1959:31).

Nomura (1967:30) provided a drawing of an otolith, with a measurement scale, from a 189 mm FL Spanish mackerel which was indicated to be at least one year old. From this drawing I judge that the radius of the annulus is 1.3 mm and the otolith radius is 1.9 mm. The annulus radius is somewhat less than the range
Figure 9. Walford plot of mean backcalculated standard lengths of male Spanish mackerel.
Figure 10. Walford plot of mean backcalculated standard lengths of female Spanish mackerel.
Figure 11. Plots of mean empirical, backcalculated and theoretical standard length for male and female Spanish mackerel. Theoretical lengths usually fall within two standard errors of the empirical mean. The exceptions, at age I, are attributed to selective net mortality.
of first annulus radii (1.6 to 3.3 mm) of otoliths from fish of both sexes in my growth analysis samples. Furthermore, the backcalculated estimate of length of Nomura’s example at annulus formation, by my reckoning, is approximately 139 mm. This is not only smaller than my age 1 fish, but also those in age group 0 (Figure 14).

The evidence presented above leads me to conclude that Klima (1959) and Nomura (1967) misinterpreted otoliths and that their age determinations are off by about one year. When the data from Table 2 are plotted, and those of Klima and Nomura shifted one age younger, a better fit with my results is achieved (Figure 15).

REPRODUCTION

RESULTS

This analysis is based on microscopic examination of prepared ovarian tissues. Comparison of microscopic determinations of reproductive development with gross observations made in the field indicate that macroscopic determinations missed important details and were sometimes misleading. Seven classes of oocytes were recognized in this study. Photomicrographs with descriptions are provided in Figures 16 through 22.

Unfortunately, histologically based data poorly represented older age groups, especially during the spawning season. This appears to have little serious effect on analysis of spawning periodicity but precluded a conclusive analysis of age of maturity. Nevertheless, certain trends were apparent and warrant presentation here, if only as a guide for further consideration. Collections of testes were particularly sparse and observations difficult to quantify. Consequently, male reproduction will be ignored here except for the perhaps obvious assurance that they doubtless contribute as needed.

SPAWNING PERIODICITY

Size frequencies of oocytes in each of three developmental categories: Inactive (classes 1 and 2), Active (class 3) and Ripening (class 4) were determined for semi-monthly periods from samples collected in 1968. Mean oocyte diameter in each category for each period is plotted in Figure 23.

Inactive oocytes were present throughout the year. The onset of reproductive development occurred in March with the appearance of Active oocytes. This was followed in about a month by development of Ripening oocytes. Active and Ripening oocytes were present throughout spring and summer until mid-September. Neither Inactive nor Active oocytes fluctuated more than 35 μ in mean diameter. Ripening oocytes, however, varied 156 μ in mean diameter or about 4.5 times as much as their predecessors. This suggests that ripening oocytes do not develop synchronously but do so intermittently throughout the spawning season.

AGE OF MATURITY

Histologically based data for females collected in both sampling years were partitioned by age group and month of capture and evalu-
Figure 13. Logarithmic and exponential length-weight relationships of male and female Spanish mackerel.

### TABLE 2. COMPARISON OF THEORETICAL FORK LENGTHS OF SPANISH MACKEREL AS DETERMINED BY THE AUTHOR AND NOMURA (1967). LENGTHS IN MILLIMETERS.

<table>
<thead>
<tr>
<th>AGE</th>
<th>MALES</th>
<th>FEMALES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>POWELL</td>
<td>NOMURA</td>
</tr>
<tr>
<td>I</td>
<td>355</td>
<td>203</td>
</tr>
<tr>
<td>II</td>
<td>431</td>
<td>316</td>
</tr>
<tr>
<td>III</td>
<td>479</td>
<td>410</td>
</tr>
<tr>
<td>IV</td>
<td>508</td>
<td>486</td>
</tr>
<tr>
<td>V</td>
<td>526</td>
<td>548</td>
</tr>
</tbody>
</table>
Figure 14. Mean standard lengths and length ranges of age 0 Spanish mackerel at month of capture. This plot suggests a more rapid early growth than indicated by earlier investigators. The fairly consistent distribution of mean lengths throughout the indicated period also suggests a prolonged spawning season.
Figure 15. Comparison of theoretical growth curves of male and female Spanish mackerel as determined by the author and Nomura (1967), (P) Powell, (N) Nomura (1967), (K) Klima (1959). As shown here, greater similarity between the curves is achieved when those of Nomura and Klima are shifted one age younger.
Figure 16. Class 1. Early oocytes (arrows), usually round, 2-50 μm diam; cytoplasm weakly basophilic. Nucleus not strongly defined, about 1/2 oocyte diam. From age III, 550 mm SL specimen taken in January 1968.

Figure 17. Class 2. Resting oocytes, shape variable, often elongate due to crowding, to 140 μm diam; cytoplasm strongly and evenly basophilic. Nucleus well defined, about 1/3 oocyte diam. From age III, 610 mm SL specimen taken in January 1968.

Figure 18. Class 3. Active oocytes, usually round, 90-220 μm diam; cytoplasm less basophilic, with a band of acidophilic yolk globules in mid portion. Nucleus, about 1/2 oocyte diam, contains lambrush chromosomes and several peripheral nucleoli. Zona radiata evident as a thin, acidophilic membrane surrounding the cytoplasm. From age VI, 640 mm SL specimen taken in March 1969.

Figure 19. Class 4. Ripening oocytes, usually round, 160-540 μm diam; cytoplasm with acidophilic yolk in increasing abundance, initially globular, then coalescing into a uniform mass as development proceeds. Nucleus prominent initially, later vague and displaced toward periphery of oocyte. Zona radiata strongly acidophilic, noticeably thicker and marked with finely divided radial striae. From age III, 480 mm SL specimen taken in April 1968.
Figure 20. Class 5. Maturing oocytes, not well preserved in my samples, usually amoeboid precluding direct measurement; however, sometimes loosely associated with a follicle which measured to about 800 µm diam; cytoplasm with yolk finely granular and evenly distributed, contained small vacuoles which were probably sites of oil droplets. Nucleus not apparent. Zona radiata relatively thin, without striae. From age II, 425 mm SL specimen taken in April 1968. Three other individuals; an age I, 410 mm SL, an age IV, 505 mm SL, both taken in April 1968 and an age I, 390 mm SL taken in September 1968 had similar appearing oocytes.

Figure 21. Class 6. Rejuvenated oocytes, probably derived from Class 3 oocytes and become similar to Class 2 oocytes; cytoplasm bizonal with a relatively narrow, lightly staining, outer zone distinctly separated from a broader, darkly staining zone surrounding the nucleus. Shown (arrows 1-4) are various stages of rejuvenation. 1) Normal or near normal Class 3 oocyte. 2-3) Stages of partial resorption of cytoplasm. 4) Rejuvenated oocyte. From age II, 330 mm SL specimen taken in May 1968.

Figure 22. Class 7. Regressing oocytes, probably derived from Class 4 oocytes that failed to mature. Characterized by lysed zona radiata, degenerating internal structure and eventually, complete absorption. From age II, 480 mm SL specimen taken in July 1968.

ated on the basis of reproductive development. Results are presented as percentages of sample in Figure 24.

All four females classified as Ripe in Figure 24 were captured with gill nets in the Atlantic off Florida’s east coast in 1968. Three fish were taken in April on two consecutive days, 2 and 4 miles north of Ft. Pierce Inlet. The fourth fish was caught in September on Cape Canaveral Shoals. Sections of ovaries from these fish were similar to that shown in Figure 20. Comments annotated in the field indicated that ovaries were ripe and that at least half the eggs were clear. Spawning in at least one age II fish was considered imminent. Other ovaries, not collected, were similar. (D. S. Beaumariage, personal communication). It appears then that some female Spanish mackerel as young as age I may spawn.

However, 44% of 96 specimens of age I and II fish collected during the period April through August had ovaries that were regressing. Ripening oocytes (class 4) were degenerating (Figure 22) and Active oocytes (class 3) were either not apparent or were rejuvenating (Figure 21). It seemed unlikely that these fish had spawned or would spawn during that season. This process was evident in half or more of fish in all age groups in September, the end of the spawning season. By October only Inactive oocytes were
Figure 23. Semi-monthly distribution of mean oocyte diameters from collections made in 1968. Data developed from 107 specimens.
Figure 24. Monthly reproductive activity of female Spanish mackerel, by age group, plotted as percent of sample. Collections from 1968 and 1969.
present. Unfortunately, small or non-existent samples from older age groups during most of the spawning season make comparison with younger fish difficult.

DISCUSSION

Hildebrand and Cable (1938: 510) cite Earll (1882) as stating that Spanish mackerel spawn from the Carolinas in April to Long Island in late August and that individuals spawn repeatedly for up to ten weeks. The authors took exception with this, putting the earliest spawning in the Carolinas as probably later since they had not found Spanish mackerel larvae in the vicinity of Beaufort, North Carolina before late June. Larval collections in the eastern Gulf of Mexico (Wollam, 1970; Dwinnell and Futch, 1973) show that Spanish mackerel larvae < 10 mm SL occurred at various stations from June to September. Collections earlier than June were not made because this sampling was initiated upon the basis of macroscopic evaluation of reproductive seasonality. However, my results indicate that spawning may take place as early as April.

There appears to be little doubt that Spanish mackerel spawn repeatedly during a prolonged spawning season. This is indicated by several factors, including: 1) asynchronous development of ripening oocytes throughout the spring and summer (Figure 23); 2) occurrence of small larvae throughout the summer; and 3) pronounced overlap of length ranges between age groups (Figure 11) as well as relatively small variation in mean SL in age group 0 fish over a ten month period (Figure 14).

The appearance of maturing oocytes in age I and II fish (Figure 24) indicates a potential for spawning at those ages. However, several observations lead me to suspect that Spanish mackerel under age III do not contribute substantially to the annual spawn. These are: 1) the paucity of ripe females in my samples, the majority of which were in age groups I and II; 2) the scarcity of fish older than age III during the spawning season; and 3) the regular occurrence of regressing ovaries in age I and II females throughout the spring and summer (Figure 24). The degeneration and absorption of vitellogenic oocytes is indicative of the end of the spawning season (Yamamoto and Yamazaki, 1961: 107; Moe, 1969: 22) and can be noted in the majority of my samples in September. The lack of sufficient comparative material from older groups notwithstanding, the prevalent occurrence of regressing ovaries in younger fish during the spawning season, I think, signifies the end of spawning for them in that season. How many of these fish actually spawned, even once, remains an open question.

Gesteira (1972) put the age of maturity of Brazilian stocks of Spanish mackerel at between age III and IV. She also found few ripe fish in her samples; attributing this to the occurrence of spawning areas beyond that of the fishery from which her samples came. Intraspecific segregation of fish by age is not unusual and is sometimes indicative of sexual maturity (Moe, 1969: 71; Clemens, 1961: 97, 100; Sette, 1950: 298). Little is specifically known about the migratory pattern of Florida stocks of Spanish mackerel other than it is ambiocoastal, corresponds to water temperature (Munro, 1943) and, depending on water temperature, may be quite extensive (Arnold, 1951; Bigelow and Schroeder, 1953).

SUMMARY

1. Commercial and sport landings of Spanish mackerel in Florida were sampled regularly from January 1968 through December 1969. Length, weight, and capture data were recorded. Otoliths and, periodically, gonads were removed for analysis of age, growth, and reproduction.

2. Two independent determinations of age were made by counting annular bands on otoliths. Validity of this technique was further established here by correlation of otolith radius with standard length and time of annuli differentiation.

3. The total sample of 2060 usable otolith pairs contained age groups 0 - VIII but was heavily biased toward younger ages. The largest group, age I, represented 42.7% of the sample. Age groups 0 through III represented 93.6% of the sample. Consequently growth analysis was limited to age groups I-V.

4. Von Bertalanffy growth equations, (mm SL) arrived at through backcalculated length at annulus formation and Walford Plots, are:

   for males
   \[ L_t = 515 [1 - e^{-0.48(t + 1.12)}] \]

   for females
   \[ L_t = 645 [1 - e^{-0.45(t + 0.78)}] \]
These results do not directly compare with those of other investigators. Comparisons of otolith descriptions and measurements indicate differences in otolith interpretation. Comparison of theoretical growth curves indicate over estimation of age, by others, of one age group.

5. Length-weight relationships differ significantly between the sexes.

The equation for males is

\[ W = 1.1519 \times 10^{-5}SL^{2.9822} \]

for females

\[ W = 4.7491 \times 10^{-6}SL^{3.1373} \]

The relationships of fork length to standard length hold for both sexes.

They are:  \[ FL = 1.0728SL + 2.4267 \]

and  \[ SL = 0.9321FL - 2.2619 \].

6. Evaluation of reproductive development was based on microscopic examination of prepared ovarian tissues. Seven classes of oocytes were recognized. Photomicrographs and descriptions of oocytes are provided.

7. Analysis of occurrence and mean diameter of oocytes indicates that ripening oocytes develop asynchronously from about April until September. This and other supportive evidence indicates that mature Spanish mackerel spawn repeatedly throughout a prolonged, spring-summer spawning season.

8. Mature oocytes were noted in three specimens in age groups I and II, indicating a potential for spawning at those ages. However, other evidence indicates that Spanish mackerel may not be fully mature until at least age III and spawning of younger fish is probably of minor significance. Older fish were scarce during spring migration in Florida waters and throughout the summer. These fish evidently travel long distances and may not move through areas occupied by the fishery.

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