Age, Growth, and Reproduction of King Mackerel, *Scomberomorus cavalla*, in Florida

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Florida Department of Natural Resources
Marine Research Laboratory

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ABSTRACT

Beaumariage, D. S. 1973. Age, Growth, and Reproduction of King Mackerel, *Scomberomorus cavalla*, in Florida. Fla. Mar. Res. Publ. No. 1. 45 p. King mackerel were sampled during 1968 and 1969 from commercial and sports dockside landings. Most (79%) were age III or younger. Although the oldest was age XIII, only those comprising the first seven age groups (365 specimens) were represented by at least 10 individuals of each sex in each age class, and were thus used to prepare Walford graphs to determine von Bertalanffy theoretical growth curves.

Growth rates of east and west coast fish were similar but differed between sexes after age II, that for males being

$$ l_t = 840 \left( 1 - e^{-1.35 \left( t + 2.5 \right)} \right) $$

for females

$$ l_t = 1150 \left( 1 - e^{-0.21 \left( t + 2.4 \right)} \right) $$

These theoretical curves adequately fit mean empirical lengths observed at each age through age VII and conform to the shape of a curve joining backcalculated lengths at each age. Females weigh more than males of comparable lengths according to length-weight relationships for 237 males

$$ (W_t = 1.330 \times 10^{-5} \text{ SL}^{2.94}) $$

and 293 females

$$ (W_t = 3.907 \times 10^{-6} \text{ SL}^{3.13}) $$

Food items, other than bait, most often encountered in 41.6% of 306 stomachs examined were clupeid fishes and penaeid shrimps.

Evaluation of spermatogenesis in 163 slides of testicular tissue and of oogenesis in 185 slides of ovarian tissue indicated males age III or older and females age IV or older probably spawn from May through August. With full recruitment at ages II or III, Florida’s king mackerel fishery seemingly relies upon immature fish. Annual survival rate during 1968 was 0.52 for the southwest coast gill net fishery and 0.46 for the southeast coast trolling fishery. The survival estimate for Florida’s trolling fishery approximates that developed for a similar coastal fishery in Brazil. Fish captured with gill nets in 1968 were larger than those captured by the traditional method of trolling.

Pelagic fish populations are usually considered highly fractioned so differential availability of stock segments could account for older age groups being poorly represented within the current fishery. Future research should be oriented toward determining population dispersal, especially with regard to spawning locations.

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INTRODUCTION

King mackerel, *Scomberomorus cavalla* (Cuvier), the largest species of the genus (Rivas, 1951), is the fish most often sought by Florida anglers and the most prominent species taken by the charter fishing fleet (Moe, 1963). Florida has also been acknowledged as the center of commercial production of king mackerel (Carson, 1944). The magnitude of Florida’s landings (Figure 1) from 1950 through 1969 is a good index of the importance of the species as a commercial resource. As a recreational resource, total angler catch for the southeastern United States including the eastern Gulf of Mexico has been estimated by Deuel and Clark (1968:12) to be 83 million pounds in 1965. If Florida contributed 75% of that amount (62 million pounds), then the Florida sports catch would be an astounding 14 times the 1965 commercial catch (4.4 million pounds). Values of Florida commercial landings of king mackerel have steadily increased from $600,000 in 1965 to over $1,000,000 in 1970 (Lyles, 1969:19; Johnson, 1969, 1970, 1971).

Virtually all known biological information on king mackerel has been thus far accumulated by Brazilian scientists. A recent exception is a study by Beardsley and Richards (1970) on length-weight relationships of specimens destined for trophy mounting.

Costa and Paiva (1963, 1964, 1965, 1966, 1967, 1968, 1969) reported monthly length frequencies from catches off Fortaleza, Ceará, along the northeastern coast of Brazil. According to Fonteles (1968), these fish are caught by trolling within 6 to 16 nautical miles of the beach mainly during the first and last quarters of the year. Nomura and Costa (1966, 1968) described length-weight relationships of "cavala" and Rodrigues and Bezerra (1968) estimated instantaneous and annual mortalities for the fishery. Diet of king mackerel collected from March 1965 to April 1968 was reported by Menezes (1969a).

Nomura and Rodrigues (1967) used otoliths to establish age structure of the fishery, and Alves and Tomé (1966, 1967a) described general morphology and tissue composition of various visceral organs. Menezes (1969b) found certain osteological and meristic differences between king mackerel from northeastern Brazil and those from the Atlantic coast of the United States.

A good review of some basic pelagic fish management concepts was presented in a summary of 20 years of research by the Inter-American Tropical Tuna Commission (Joseph, 1970). Three principal objectives were:

1) Establishment of relationship between amount of fishing and catch, and effect catch has on stock.

2) Development of separate estimates of recruitment, mortality, reproduction and growth that determine rate of natural increase of stock.

3) Derivation of effects of all important environmental factors (physical, chemical, and biological) to integrate such information with that obtained from first two phases.

The first objective is extremely difficult to attain for pelagic fishes, due to their highly variable temporal and spatial distribution (Ricker, 1958:36). In Florida these drawbacks persist since the current method of cataloging landings only according to the receiving port yields inadequate information on fishing effort or success by applicable location and date. The third objective is unfortunately beyond the present level of usage of advanced technological capabilities. Research on Florida king mackerel has thus been directed toward satisfying the second objective.

In an unexploited fish stock, growth and recruitment are precisely balanced by natural mortality. Upon exploitation a new balance will be established by increased recruitment, by increased growth rate of those fish escaping capture, or by decreased natural mortality (Ricker, 1958:37-38). Intrinsic rate of population increase is affected by such life history aspects as:

1) Age of initial reproduction
2) Growth rate
3) Maximum longevity and adult survival
4) Spawning frequency and fecundity
5) Larval and juvenile survival

Investigations of the first three aspects constitute the basis of this paper.
SYNONYMY AND DISTRIBUTION

SYNONYMY

Rivas (1951) reviewed the taxonomy of western North Atlantic mackerels and tunas giving a key to the genera and species and complete synonymies for each species, including *S. cavalla*, as follows:

*Scomberomorus cavalla* (Cuvier)
Kingfish; King mackerel; Cavalla; Serrucho;
Sierra; Carite

*Cybium cavalla* Cuvier, 1829:200 (original description after Guarapuca of Maregrave; Brazil). Cuvier and Valenciennes, 1831:187 (description; Brazil).

*Cyprinomus immaculatum* Cuvier and Valenciennes, 1831:191 (description; no locality).


In a comparative osteological study of *Scomberomorus*, Mago (1959:334-335) found *S. cavalla* the most divergent member of the genus. Most prominent among several distinctions were the differences in vertebral counts—a notably conservative character in mackerels. *S. cavalla* has only 42-43 vertebrae while *S. regalis* has 47-49 and *S. maculatus* 52-53. De Sylva (1954) reported a possible instance of hybridization, but this may well have been an unusually large, but still immature, *S. cavalla*.

SEASONAL DISTRIBUTION

Early king mackerel literature dealt principally with distribution or prominence within seasonal fisheries. Jordan and Evermann (1896) broadly described the range as “the open seas of the tropical Atlantic from Cape Cod [about 40° N Latitude] to Africa and Brazil [about 10° S Latitude].” They implied that its large size (up to 5 feet and 100 pounds) led to the derivation of the specific name, *cavalla*, from the Spanish, caballus [sic], meaning horse.

King mackerel range as far north as Long Island, Chesapeake Bay, Buzzards Bay, and Cape Cod during August through October (Latham, 1919; Bigelow and Schroeder, 1953; Mather, 1954; Mather and Gibbs, 1957; Massmann, 1960; Butz and Mansueti, 1962). They are common during the spring and fall along the North Carolina coast, especially the Beaufort/Cape Lookout section (Taylor, 1951:270). Longley and Hildebrand (1941:72) list king mackerel as abundant in Key West only during winter, while Baughman (1950) found them abundant off Texas during spring (April through June).

Briggs (1958) lists *S. cavalla* as occurring from the Gulf of Maine to Rio de Janeiro and throughout the Gulf of Mexico. Erdman (1949) caught king mackerel while trolling during May through September throughout the Greater Antilles (except Jamaica) and throughout the Lesser Antilles as far south as the Grenadines. Fowler (1953) frequently observed “carite” (*S. cavalla*) in a Cartagena, Colombia fish market from August through September. Cervigon (1966) lists them as abundant in February and March off the Venezuelan islands of Margarita and Cubagua, where they are traditional island fare. Griffiths (1971) considered the mackerels, especially *S. cavalla* and *S. maculatus*, to have greater commercial potential in Venezuela than do the tunas.

FISHERY

Moe (1963) described the status of Florida’s offshore fisheries; king mackerel was the species most desired by private boat anglers and the staple of the charter fleet. A small southeast coast trolling fishery existed during 1961-1962, contributing most of the mere 0.7% “surface effort” expended by commercial fishermen. The following more recent characterization of the fishery is based upon personal observations. Other sources of information such as Florida boat registration records were not sufficiently accurate for this purpose.

Commercial vessels, 24 to 44 feet long and capable of holding 1,000 to 5,000 pounds of fish, typically troll 200 feet of No. 9 wire with
spoons or handmade jigs throughout the year along Florida's southeast coast. Electronic depth recorders facilitate school location and use of electric reels enables each boat to land approximately 2,000 pounds of fish on a good day.

From December through March, most fishing is concentrated between Jupiter Inlet [26° 55'N] and Palm Beach Inlet [26° 45'N]. Fishing activity shifts slightly northward during the remainder of the year, moving to Ft. Pierce and Sebastian Inlets [27° 30'N and 27° 50'N], with some commercial catches also landed at Port Canaveral [28° 30'N].

Sports fishing supplements east coast commercial activity during winter when private vessels and chartered “drift boats” join the fleet. Many fish taken by sportsmen are subsequently sold, thus entering commercial landings. Some king mackerel are taken by summer anglers in conjunction with commercial production north to Cape Canaveral, but northward sports fishing predominates.

Northeast Florida landings were small compared to the rest of the state, and minimal sampling effort was expended in that area (one trip in July 1968). King mackerel caught during summer as far north as the Carolinas are probably from the same population wintering in south Florida, but verification must await tagging studies.

The winter commercial fishery in the Florida Keys is comprised solely of trolling boats similar to those described. Much of the Key West production comes from an area approximately 40 miles west known as “No-Man’s-Land” [24° 40' to 25° 00'N, 81° 55' to 82° 41'W]. Trolling boats also fish off Naples [26° 05'N] and Ft. Myers Beach [26° 40'N] in the Gulf of Mexico, particularly preceding northward migration of the stocks in April. Returns from a limited tagging study substantiate this “spring migration” (Moe, 1966: Table 9; Beaumariage, unpublished data).

Number 18 nylon gill nets, 600-650 yards long and 200 meshes deep (4¾-inch stretch), capable of fishing in deep water (70 feet) have also been used in southwestern Florida since net retrieval with power blocks was implemented in 1963. Twelve boats, 38 to 80 feet long, capable of holding 18,000 to 50,000 pounds of fish, were operating during 1968 and 1969. Aerial fish spotting for deployment of large net vessels has substantially increased west coast king mackerel production.

One purse seine vessel, 70 feet long and capable of holding 70,000 pounds of fish, was also operating during the study. It was the only vessel using brine refrigeration for fish storage (all others carried crushed ice). The seine was 600 yards long with the wings (2½-inch stretch) and bunt (1-5/16-inch stretch) made of No. 24 nylon, and the 10 mesh skirt (5-inch stretch) made of No. 72 nylon. During the study a legal quota was established, limiting total purse seine production of king mackerel to 9% of the average statewide catch during the previous five years. Several permits were issued, but only one company fished the gear successfully.

Sports activity also supplements the winter commercial fishery in the Florida Keys and along the southwest coast. However, when schools begin to move northward during the spring run (April), sports effort accelerates tremendously along Florida’s Gulf coast while commercial production halts. King mackerel are taken all along the Florida west coast north of Tampa Bay from about May through October, but greatest sports effort is by Panama City and Destin charter boats in the northern Gulf west of Cape San Blas [30° 20'N between 85° 25' and 86° 50'W]. In Destin alone, 60 charter boats fish continuously during the season for king mackerel (Edwin Irby, personal communication).

Since fewer than a dozen major ports support commercial king mackerel production, our two-man team could obtain samples representative of the some six million pounds landed annually throughout Florida. Unfortunately, sports landings were more diverse, and although the active summer sports fishery in northwestern Florida was systematically sampled each month, it was not possible to determine the percent of the total catch examined.

METHODS AND MATERIALS

Seasonal distribution and abundance of king mackerel are shown as average monthly landings
from 1967 through 1969 for each sampling area (Figure 2). Cube roots of landings were used to facilitate graphic presentation. The clear areas of three histograms represent landings from which an aliquot was examined during 1968. This sampling was accomplished by maintaining close contact with those seafood companies handling large volumes of king mackerel. Only fresh material was examined and a record kept of the amount, location, and date of all catches sampled. Poor representation (seasonal or size gaps) in the 1968 data was partially filled by spot collections during 1969.

Fish taken commercially are usually gutted prior to landing, but since gonads are not removed and discarded with the viscera, each fish could be sexed during measurement. During winter, 8,447 fish were measured (to 0.5 cm FL) by examining several hundred from each large commercial catch sampled. Number of individuals selected for otolith and gonad removal was proportional to the number in each 5-cm segment of the frequency curve on the tally sheet. Thus, collections were essentially proportional to the number in size classes most susceptible to major commercial effort. Collections from small commercial catches or sports landings were all random.

Fish from which otoliths and gonads were collected were weighed to the nearest ounce on a dial spring scale of 60-lb (27 kg) capacity and measured to the nearest 0.5 cm (SL and FL) in the manner prescribed by Hubbs and Lagler (1967). For convenience, measurements were converted to mm in all calculations. Otolith pairs were removed from each fish by separating the posterior gill arch attachment and excising a ventral portion of the otic capsule, a procedure not impairing fish marketability. Each sagitta (largest of the otoliths) was cleansed of its saccus, and each pair temporarily held in water before being transferred to glycerin for permanent storage.

Otoliths were examined in glycerin in a black-bottomed watch glass under direct light with a compound dissecting microscope (16X). Radial and annular measurements were made with an ocular micrometer (1 um - 67 μ).

Reproductive stages of each fish were cursorily evaluated in the field and some small gonadal cross-sections (ca 12 mm) were fixed in Bouin’s Fluid and transferred within 30 days to a dehydrant (Technicon S-29). This tissue was sectioned (6 μ) and stained with Papanicolaou hematoxylin (Harris)—eosin Y for later examination. Although every effort was made to collect gonadal tissue from fresh specimens, some fish were dead several hours before being iced at dockside (when tissue could be excised and preserved). During summer this undoubtedly accelerated tissue degeneration.

Since the numerous fish landed during the winter were primarily of ages I, II, and III, five females of each age were selected from each monthly gonadal collection to facilitate gonadal analysis. During summer, sports catches were a primary source of material and were randomly sampled, as were small summer commercial landings on Florida’s east coast. All summer gonad slides were used.

Oogenesis was quantified by counting cells of each stage appearing along perpendicular transects made at 100X across each ovarian cross-section. Ten percent of each oocyte type were then measured at random. This allowed a synoptic evaluation of the extent of oogenesis throughout the year. In attempting to evaluate oogenetic progression during the summer spawning season, at least 30 oocytes of each developmental stage were measured in 100 slides from tissue collected from 6 May through 11 August. Most of these collections (88%) were made during 1968 and represented an average of 14.3 specimens per each two week interval.

Oogenetic development criteria followed cellular stages described by Moe (1969:14-22). Spermatogenesis proceeds more rapidly than oogenesis, so its seasonal progress could not be defined by examining relative abundance of different spermatocytes each month. Therefore, all testicular slides were categorized as one of four phases (inactive, active, ripe or spent) according to proliferation of various spermatocyte stages and continuity of crypts with sinuses and lumen.

RESULTS AND DISCUSSION

AGE AND GROWTH

Three independent age assessments were made on each of 1,888 otolith pairs (858 from
Figure 2. Average seasonal distribution of king mackerel from 1967-1969 landings throughout Florida. Clear area indicates landings sampled during 1968.
east coast and 1,030 from west coast collections) without reference to fish size or sex. Seventy-six percent (1,431 otoliths) were legible; of these, 79% were from fish age III or younger.

A maximum of five fish of age III or younger having legible otoliths were randomly selected from each monthly collection (years combined) from each Florida coast. Consequently, a more manageable number (338 fish) represented these younger ages. All age IV or older fish having legible otoliths were used in the age analysis. Stratified subsampling (Ketchen, 1949) would have better defined age structure at a considerably reduced effort.

To determine growth rate by backcalculation from annular marks in durable structures (scale, otolith, vertebra, spine, or opercular bone), growth of the specific structure must be proportional to that of the fish. The equation \( Y = 11.370X - 88.448 \) describes the linear regression of standard length (mm) on otolith radius (omu) for 605 fish (380 - 1590 mm SL) from which legible otoliths were collected. A t-test reveals this line does not lie within confidence limits which include the origin \( (t_{0.05} = 5.677^*) \).

Neither measurement was considered sufficiently free of variation to be readily recognized as the independent variable, thus otolith radius was chosen since I wished to determine proportional growth of the fish from otolith growth. Sokal and Rohlf (1969:483) prescribe Bartlett’s Three-Group Method for solving a bivariate or “Model II” regression where the error term is not known in either variable. In applying their technique, I arranged all measurements by order of magnitude of the independent variable (otolith radius) and divided them into three groups, the initial and final groups having the same number (201). Ten percent were then randomly chosen (males and females equally represented in each group) for computations of the equation \( Y = 11.1164X - 68.5077 \) (95% CI about \( b = \pm 1.444 \)). This line (Figure 3) was found to intersect within confidence limits that included the origin \( (t_{0.05} = 0.7406, \text{NS at } 58 \text{ df}) \). A zero intercept is theoretically logical since otoliths comprise part of the sensory system in fish and develop quite early ontogenetically. Otoliths have been discerned with polarized light in a 23 mm SL cleared and stained juvenile king mackerel.

Check marks must be formed annually if they are to be correlated with fish lengths at previous ages and used to determine growth rates through backcalculation. Most otolith margins become opaque (form annuli) during April, May, and June (Figure 4).

The direct proportion backcalculation method presented in 1929 by van Oosten (Lagler, 1952:121) assumes that fish length and aging structure size are linearly related with an intercept at the origin. Since my data satisfy that assumption, the formula used to derive backcalculated lengths was:

\[
SL' = \frac{OR'}{OR} (SL)
\]

where \( OR = \) otolith radius at capture, \( SL = \) standard length at capture, \( OR' = \) otolith radius at annulus formation, and \( SL' = \) standard length at annulus formation. Annuli were counted only when a hyaline interface distinguished resumption of more rapid deposition of calcium carbonate crystals (Figures 5-10). Relative distances between annuli decrease with age.

Relative (percental) growth, as used by Weymouth and McMillin (1931) to compare growth of the Pacific razor clam from various coastal locations, is a percentage increase per time interval dependent upon the size attained at the beginning of each period. Relative annual growth may be expressed as a plot of the logarithms of length on age.

Females grow more rapidly than do males after age II (Figure 11). Growth rates do not differ for either sex between coasts (Figures 12 and 13); therefore, growth rates of male and female king mackerel should be determined independently but are applicable to fish taken from either coast.

An standard lengths from all accurately aged fish are presented with backcalculated lengths for ages I through VII (Tables 1 and 2). King mackerel live as long as 13 years, but age groups older than seven were not sufficiently represented for a reliable analysis of growth. At least 20 accurately aged individuals were available in the first seven age groups, so Walford Lines for each sex were derived from their average standard lengths (Figures 14 and 15).
Figure 3. Regression of standard length on otolith radius.
Walford Lines were not directly fitted by least squares, but by a trial and error method recommended by Ricker (1958:195). Average maximum or "asymptotic length" was adjusted until the straightest possible line was obtained from a plot of $\log_e (l_\infty - l)$ against time. Slope of the Walford Line (k) was determined from the average differences of all points with $l_\infty$, and slope of the natural logarithm line (K) from the relationship, $K = \log_e k$.

Theoretical time zero (when king mackerel began growing at rates for which the common average estimate $K$ is being sought) was derived from the relationship between the Y-axis intercept of the plot of $\log_e (l_\infty - l)$ vs. time, and from the natural logarithm of the asymptotic length (Ricker, 1958:197).

Theoretical growth derived through applica-
Figure 5. Otolith from a young-of-the-year (age Class 0) male king mackerel (385 mm SL) collected during March. No opaque annulus has been formed.

Figure 6. Otolith from an age I female king mackerel (640 mm SL) collected during January. A wide hyaline band and clear margin indicate aragonite deposition since formation of the first annulus—characteristic of the accelerated growth of young fishes.
Figure 7. Otolith from an age II female king mackerel (710 mm SL) collected during June. A clear margin indicates the beginning of the third year’s deposition of hyaline aragonite. All measurements were made from the kernel (base) along an axis closely approximating an extension of the sulcus acousticus.

Figure 8. Otolith from an age IV female king mackerel (780 mm SL) collected during November. A marginal increment (clear area) is easily discernible beyond the fourth annulus.
Figure 9. Otolith from an age V female king mackerel (945 mm SL) collected during April. The margin is opaque where the sixth annulus is forming.

Figure 10. Otolith from an age VIII female king mackerel (1075 mm SL) collected during April. Increasing thickness with age tended to obscure annuli making age assessment difficult and measuring tedious. The margin is becoming opaque as the eighth annulus forms (notice slender tip).
Figure 11. Relative annual growth of each sex throughout Florida.
Figure 12. Relative annual growth of males from each Florida coast.
Figure 13. Relative annual growth of females from each Florida coast.
TABLE 1. BACKCALCULATED STANDARD LENGTHS (mm) FOR MALE KING MACKEREL, AGES I-VII.

<table>
<thead>
<tr>
<th>Age Group</th>
<th>X SL at Capture</th>
<th>N</th>
<th>Average Backcalculated Standard Length at Age:</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>594</td>
<td>37</td>
<td>456</td>
</tr>
<tr>
<td>II</td>
<td>679</td>
<td>31</td>
<td>448 630</td>
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<tr>
<td>III</td>
<td>718</td>
<td>24</td>
<td>444 597 666</td>
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<tr>
<td>IV</td>
<td>760</td>
<td>19</td>
<td>424 588 654 703</td>
</tr>
<tr>
<td>V</td>
<td>777</td>
<td>11</td>
<td>389 605 665 711 753</td>
</tr>
<tr>
<td>VI</td>
<td>789</td>
<td>8</td>
<td>452 606 672 715 750 782</td>
</tr>
<tr>
<td>VII</td>
<td>811</td>
<td>10</td>
<td>417 583 640 681 719 751 781</td>
</tr>
</tbody>
</table>

Number of fish examined: 140
Number of backcalculations: 140 103 72 49 39 18 10
Grand X calculated standard length: 433 602 659 702 741 766 781
Average annual increment in SL (mm): 169 57 43 39 25 15

TABLE 2. BACKCALCULATED STANDARD LENGTHS (mm) FOR FEMALE KING MACKEREL, AGES I-VII.

<table>
<thead>
<tr>
<th>Age Group</th>
<th>X SL at Capture</th>
<th>N</th>
<th>Average Backcalculated Standard Length at Age:</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>614</td>
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<td>II</td>
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<td>53</td>
<td>439 633</td>
</tr>
<tr>
<td>III</td>
<td>777</td>
<td>44</td>
<td>475 647 728</td>
</tr>
<tr>
<td>IV</td>
<td>819</td>
<td>26</td>
<td>463 637 711 764</td>
</tr>
<tr>
<td>V</td>
<td>882</td>
<td>23</td>
<td>443 662 738 797 851</td>
</tr>
<tr>
<td>VI</td>
<td>956</td>
<td>12</td>
<td>487 684 760 817 868 916</td>
</tr>
<tr>
<td>VII</td>
<td>999</td>
<td>10</td>
<td>474 677 756 816 866 914 958</td>
</tr>
</tbody>
</table>

Number of fish examined: 225
Number of backcalculations: 225 168 115 71 45 22 10
Grand X calculated standard length: 464 657 739 798 862 915 958
Average annual increment in SL (mm): 193 82 59 64 53 43

Theoretical growth curve for females is quite similar to that presented for bluefin tuna, Thunnus thynnus (Linnaé) by Mather and Schuck (1960: Figure 17). Their curve was prepared from length frequencies of the first four age groups and from vertebral annuli of older fish (sexes combined). Both scombrids apparently grow quite rapidly during the first four years of their life span, and both live to at least 13 or 14 years.

In age assessment from annuli, Nomura and Rodrigues (1967: Figure 1) counted only clear
Figure 14. Walford Line of observed standard length in male king mackerel.
Figure 15. Walford Line of observed standard length in female king mackerel.
Figure 16. Theoretical male growth fitted to standard lengths observed at each age. Range, standard error, and mean standard lengths are plotted for each age group. Broken line joins average backcalculated lengths.
Figure 17. Theoretical female growth fitted to standard lengths observed at each age. Range, standard error, and mean standard lengths are plotted for each age group. Broken line joins average backcalculated lengths.
zones and included the segment prior to the first year's opaque annulus, thus adding an extra portion of a year to their estimates of age groups. This undoubtedly contributed to their inability to identify early age classes, reported as poorly represented in their collections. Consequently, backcalculation to obtain fish sizes at ages I-III probably influenced improper alignment of their Walford Lines, resulting in selection of larger asymptotic lengths for each sex. Caution should be used in extrapolating for fish size at older ages with my theoretical growth curve since it was derived from Walford Line graphs utilizing mostly the smaller sizes attained during the fish's life span and thus will yield conservative estimates. Plots of the average lengths observed for fish older than age VII in Figures 16 and 17 verify this artifact.

Figure 19 illustrates the length-weight relationship of 237 males and 293 females. A similar relationship has been reported for *Scomberomorus commerson* Lacépède from Madagascar waters by Prado (1970: Figure 1). Analysis of Variance for each regression is presented in Table 3. Comparison of regression coefficients \( t_{0.05} = 3.235^* \) indicates females weigh more than males of a similar standard length. Sexual distinction may not always be possible when monitoring landings, so Figure 20 presents the relationship for combined sexes.

Three estimates of length-weight relationships of king mackerel are compared in Table 4. Nomura and Rodrigues (1967) found a b-value falling within my 95% confidence limits for males but not for females. The b-value found by Beardsley and Richards (1970) for king mackerel destined for trophy mounts falls above my confidence limits.

Relationship of fork length to standard length for 100 randomly selected fish (550-1045 mm SL) is linear (Figure 21). Expressed by the equation, \( FL = 1.096 \times SL - 17.143 \), the line lies within confidence limits that include the origin \( t_{0.05} = 1.738 \).

### Table 3. ANOVAs for Regression of \( \log_{10} \) Weight (g) on \( \log_{10} \) Standard Length (mm) for King Mackerel.

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MALES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard Length</td>
<td>1</td>
<td>7.8131</td>
<td>7.8131</td>
<td>4.88319*</td>
</tr>
<tr>
<td>Weight</td>
<td>235</td>
<td>0.3803</td>
<td>0.0016</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>236</td>
<td>8.1934</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>FEMALES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard Length</td>
<td>1</td>
<td>22.3568</td>
<td>22.3568</td>
<td>8.59877*</td>
</tr>
<tr>
<td>Weight</td>
<td>291</td>
<td>0.7683</td>
<td>0.0026</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>292</td>
<td>23.1251</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 18. Theoretical growth curves of king mackerel from Brazil compared with those from Florida waters. Nomura & Rodrigues' equation measurements (FL cm) were converted after deriving the size at each age to SL mm (SL = FL + 17.143) to facilitate comparison with my theoretical growth rates (uppermost curves).
Figure 19. Length-weight relationships for male and female king mackerel.
Figure 20. Length-weight relationship for king mackerel—sexes combined.
### TABLE 4. COMPARISON OF KING MACKEREL LENGTH-WEIGHT RELATIONSHIPS.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Sex</th>
<th>Number Examined</th>
<th>SL mm</th>
<th>Size Range</th>
<th>FL cm</th>
<th>Weight</th>
<th>W = aL^b</th>
<th>95% CI for b</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>a</td>
<td>b</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Upper</td>
<td>Lower</td>
</tr>
<tr>
<td>This study</td>
<td>M</td>
<td>237</td>
<td>465-1,030</td>
<td>879-9,752 g</td>
<td>1.330X10^-5</td>
<td>2.9372</td>
<td>3.0201</td>
<td>2.8543</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>293</td>
<td>390-1,590</td>
<td>454-37,195 g</td>
<td>3.907X10^-6</td>
<td>3.1256</td>
<td>3.1922</td>
<td>3.0590</td>
</tr>
<tr>
<td></td>
<td>Combined</td>
<td>530</td>
<td>390-1,590</td>
<td>454-37,195 g</td>
<td>4.981X10^-6</td>
<td>3.0881</td>
<td>3.1377</td>
<td>3.0385</td>
</tr>
<tr>
<td>Nomura &amp; Rodrigues (1967)</td>
<td>M</td>
<td>338</td>
<td>46.5-105.5</td>
<td>770-7,800 g</td>
<td>9.078X10^-3</td>
<td>2.962</td>
<td>None given</td>
<td></td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>355</td>
<td>42.5-123.5</td>
<td>570-14,010 g</td>
<td>1.026X10^-2</td>
<td>2.933</td>
<td>None given</td>
<td></td>
</tr>
<tr>
<td>Beardsley &amp; Richards (1970)</td>
<td>Combined</td>
<td>197</td>
<td></td>
<td>58.5-150.0</td>
<td>14.7-32.09kg</td>
<td>2.701X10^-6</td>
<td>3.2300</td>
<td>None given</td>
</tr>
</tbody>
</table>
REPRODUCTION

Reproductive stages were provisionally determined in the field and verified in detail by microscopic examination of histological preparations. This allowed estimates of age of initial spawning and of spawning seasonality. Ovarian tissue collected from females age III or younger accounted for 80.2% of all material. Therefore, five slides were randomly selected from each monthly collection of tissue from each of these young year classes to facilitate oocyte enumeration. In quantifying oogenesis these were combined with all slides from fish age IV or older. Catches sampled during 1968 and 1969 were represented by 257 ovarian tissue sections, but these were inadequate for determination of progressive oogenic development throughout the year because collections were too infrequent. For instance, data analysis revealed that fewer than 10 ovarian samples were obtained.
within two week intervals during half the study period. Fortunately, seven consecutive biweekly intervals (6 May through 11 August) yielded an average 14.3 specimens, although most (87%) were from females age III or younger.

Protracted spawning of multiple frequency is indicated by successive increases in vitellogenic oocyte size during summer (Figure 22). Each year’s collection (although limited) was presented independently in Figure 22 to determine seasonal consistency. Relative oocyte size at each stage generally agrees with measurements from Brazilian king mackerel (Alves and Tomé, 1967b; Table I). Average diameters of their “ovocitos II and III” fall within the 95% confidence intervals of my stages III and IV (Table 5).

Further evidence of protracted spawning is presented by Dwinell and Futch (1973). They found small larval S. cavalla (<3.1 mm SL) in northwestern Florida coastal waters during June, August and September. Most of their specimens (78) were collected in September and the largest (28.8 mm SL), in August.
TABLE 5. COMPARISON OF KING MACKEREL OOCYTE SIZES.

<table>
<thead>
<tr>
<th>Source</th>
<th>Oocyte Stage</th>
<th>Number Measured</th>
<th>Diameter Range μ</th>
<th>Mean Diameter</th>
<th>95% CI = ± 2 Sx</th>
</tr>
</thead>
<tbody>
<tr>
<td>This Study</td>
<td>Oogonia</td>
<td>none</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Stage I</td>
<td>None</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Stage II</td>
<td>3,205</td>
<td>20-140</td>
<td>69.8</td>
<td>67.21-72.31</td>
</tr>
<tr>
<td></td>
<td>Stage III</td>
<td>2,634</td>
<td>90-290</td>
<td>160.5</td>
<td>154.04-166.94</td>
</tr>
<tr>
<td></td>
<td>Stage IV</td>
<td>1,341</td>
<td>190-620</td>
<td>332.4</td>
<td>314.41-350.45</td>
</tr>
<tr>
<td></td>
<td>Stage V</td>
<td>few observed</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

| Alves and Tomé (1967b) | Oogonias | 100 | 8.3-41.6 | 25.0 |
| Ovocitos I | 100 | 62.4-99.8 | 82.2 |
| Ovocitos II | 100 | 124.8-191.4 | 156.9 | Not Given |
| Ovocitos III | 100 | 233.0-416.0 | 325.3 |
| Table I | Ovulos | 100 | 465.3-761.4 | 595.7 |

Their small king mackerel were estimated to be only 4 to 6 days old and larger ones only a month.

Stage I and II oocytes (Figures 23 and 24) present throughout the year (Figure 25), form the initial source and residual fund of those oocytes which become filled with yolk and develop into eggs during the spawning season. Not every vitellogenic oocyte progresses through late stage IV to develop into stage V (egg). Some oocytes regress (Figure 26), returning to a resting stage II, as observed in

Figure 23. Ovarian tissue from an age II king mackerel collected off Destin in May. Cells of four oogenetic stages are compactly associated. Stages I and II (lower and upper arrows) seasonally yield transitional stage III and yolk forming stage IV oocytes during spring.

Figure 24. Ovarian tissue from an age III king mackerel collected off Destin in August.

Liopsetta obscura (Herzenstein) by Yamamoto (1956:368). Bowers and Holliday (1961:13) contend that yearly fecundity in Clupea harengus harengus Linné depends upon the number of "resting phases" (stage II oocytes) of the previous year.

Vitellogenic oocytes (stages III and IV) were found from May through October, and they appeared relatively more numerous in older fish. However, some yolk formation occurred even in the youngest females (Figure 25; Figures 26, 27 and 28). Initial spawning may result when sufficient numbers of resting or rejuvenilized oocytes accumulate so that annual
vitellogenesis can produce enough developing oocytes to culminate in the release of fully-yolked (stage V) eggs. Yamamoto (1956:367) found that young flounder reflected the spawning rhythm of mature fish by developing primary yolk stage oocytes (similar to early stage IV). However, these were abortive, rejuvenilizing to become the reserve fund for following seasons.

Female king mackerel, age III or younger, are thus considered immature (probably never have spawned) because most vitellogenic oocytes
(stage IV) were small ($\bar{x} = 332 \mu$ diameter) and appeared to be securely retained within very compact lamellae (Figures 24 and 26) compared with the unrestrained stage IV oocytes profusely scattered throughout older ovaries (Figures 29 and 30). Age IV is probably the first major spawning class. In the Pacific, *Scomber japonicus* Houptyn does not spawn until its third or fourth year (Fitch, 1951:16; 1952:383). Watanabe (1970:6) reported that larger females have a more protracted season than do smaller ones, and that spawning time may vary from year to year depending upon characteristics of the parent stock (size, relative location with regard to temperature regimes, etc.). Some four-year-old albacore, *Thunnus alalunga* (Bonnaterre), may spawn, but the majority of the spawning population is composed of fish age V or older (Clemens, 1961:97).
Most summer gonadal collections were from king mackerel caught near 30°N Latitude. In Figure 32, photoperiod at that latitude is superimposed upon: 1) vitellogenic oocyte size and 2) otolith translucent marginal increment. This shows a coincidence of minimal otolith marginal increment with initial yolk formation as the spring photoperiod exceeds 13 hours. Somatic growth is apparently retarded as energy is annually required for yolk formation regardless of fish maturity. Oocyte differentiation was observed during June, even in a specimen too young to be sexed macroscopically (Figure 31).

Although increase in photoperiod is an obvious environmental parameter, it may not be solely responsible for reproductive seasonality. Menaker (1972) illustrated that visual reception of changing light patterns was not involved in sparrow testis growth. Circannual clocks are even known to operate when environmental signals are absent, as illustrated by reproductive development in *Orconectes pellucidus* (Telmkampf), a blind cave-dwelling crayfish (Pengelley and Asmundson, 1971). However, the authors stress that some significance must be attributed to the natural environment, for without cues from light variation or temperature, an animal's rhythm could become increasingly out of phase with natural seasons.

Female goldfish, *Carassius auratus* (Linné), have been hypophysectomized and seasonal gonadal development monitored to determine that pituitary gonadotrophin is not directly concerned with growth of reserve oocytes (stages I and II) but rather with accumulation of yolk (Yamazaki, 1965:16, 34). The pituitary, quite responsive to various environmental factors, possibly secretes a follicle-stimulating hormone that directly initiates yolk accumulation. Bowers and Holliday (1961:9,10) found an individual blood supply for each oocyte in herring and believed complete oocyte development depended upon properties of surrounding granulosa cells.

Seasonal differences in spermatogenesis were not as readily distinguishable. Figure 33 shows only that most older males are "ripe" during the same four months in which females exhibit the largest average diameter of yolk-laden oocytes. Alves and Tomé (1968: Table I) show an average sperm count of some 850 cells per mm$^3$ in 20 male king mackerel, 501-1,000 cm FL. They observed no difference in sperm density throughout the size range.

"Spent" males first appear among age II or older fish during September in Florida. One-year-old males designated as "spent" (August and October) should be considered "post-
Figure 32. Comparison of seasonal change in vitellogenic oocyte size and otolith marginal increment with 30° north latitude photoperiod.
active" since spermatozoan-filled sinuses never reached the expansion seen in older specimens. As in females, some annual reproductive activity occurs in immature males. Degree of spermatogenesis in age III fish strongly suggests that males spawn initially one year earlier than do females.

In a review of gonadal abnormalities in scombroid fishes hermaphroditism has been reported in Scomber scombrus Linné, in Rastrelliger kanagurta (Cuvier), and Katsuwonus pelamis (Linné), but not among the "seerfishes" (genus Scomberomorus), nor among billfishes (Thomas and Raju, 1964).
ADULT SURVIVAL

In Florida, the east coast winter trolling fishery is the oldest commercial fishery for king mackerel, with gill nets being employed on the west coast only during the last decade. Length frequencies from large winter hook and line catches during early 1968 were compared by sex (Figures 34 and 35) with length frequencies of fish captured with gill nets further offshore along the west coast. Gill nets took larger fish: 43% of males and 30% of females exceeded 800 mm FL (approximately 3.7 kg), while corresponding values of fish captured by trolling were only 20 and 16 percent.

Expression of these length frequencies as catch curves (sexes combined) allows a comparison of gear efficiency (Figure 36). Size of full recruitment and survival estimates were derived from data in Table 6 according to methods prescribed by Robson and Chapman (1961). Size of complete recruitment was found to be 750-799 mm FL (age II females and age III males) for king mackerel caught by trolling nearshore off southeast Florida during January through March 1968. Larger fish, 800-849 mm FL (age III females and age IV or V males) appeared fully recruited into the southwest coast offshore gill net fishery during that same period. Respective estimates of annual survival were 0.46 and 0.52.

It appears that fewer king mackerel were caught with gill nets than were captured by trolling during this period. Both large and small fish are vulnerable to capture with hook and line but commercial trollers do seek smaller “school kings” during winter since more can be boated per man-day than can larger fish. Schools of larger king mackerel are less frequently encountered during winter but are avidly sought by sports fishermen. The better survival estimate obtained from analysis of the gill net catch curve could therefore simply be an artifact of relative availability of schools composed of older fish off southwest Florida during 1968. A better comparison of gear efficiency could be obtained if both fisheries existed within the same area.

Continual examination is required for verification, but I suspect that king mackerel older than age III may not be as accessible to major fishing pressure as are younger fish. Analogously, Clemens (1961:100) described how Pacific albacore, Thunnus germin [ = T. alalunga], drop out of California’s coastal fishery after age III and become the mainstay of the Japanese longline fishery at age IV. Similarly, Sette (1950:298) noticed that schools of young Atlantic mackerel, Scomber scombrus, were captured close to shore during summer, whereas schools of larger, adult mackerel were captured farther from shore.

Rodrigues and Bezerra (1968) give an annual mortality estimate of 0.48 and show catch curves displaying modes between ages IV and V (Figure 1) for fish captured by trolling off Brazil. However, the average size of 22,517 king mackerel measured during their five-year study was 72.3 cm FL (Table I). This corresponds to the length of a 2.7 kg, age II fish within the modal size group of the catch curve for Florida’s trolling fishery (Figure 36). Exploitation of the two stocks thus seems quite similar and the graphic discrepancy is probably due to the previously mentioned inaccurate age estimates of Brazilian king mackerel.

DIET

Adequate evaluation of king mackerel diet in Florida waters was hindered by handling procedures. Fish caught commercially were usually eviscerated prior to being landed; exceptions were usually dead several hours—long enough for enzymatic action to liquefy stomach contents. Even examination of stomachs from specimens freshly caught by sportmen yielded negative results because the fish either regurgitated after being hooked, or rapid digestion left little identifiable material. Morovic (1961) believed rapid and intense digestion accounted for consistently empty stomachs observed in 250 Adriatic bluefin tuna (4 to 5 kg) captured at the surface with ring nets.

I examined 306 stomachs, principally during spring and summer, and found 58.4% empty. Only 39% of those with food contained identifiable items other than bait. Food identified in the field consisted of clupeid fishes (59%) including Opisthonomia oglinum (Lesueur) and Harengula pensacolae Goode and Bean; other fishes (8%) of the families Carangidae, Lutjanidae. Pomadasyidae, Sparidae, or Trigidae; and invertebrates (33%) including penaeid shrimp, squid, and a single
Figure 34. Size comparison of male king mackerel captured by trolling and with gill nets.
Figure 35. Size comparison of female king mackerel captured by trolling and with gill nets.
Figure 36. Comparison of catch curves for king mackerel (sexes combined) taken commercially by trolling (A) and with gill nets (B). s represents annual survival estimate.
TABLE 6. KING MACKEREL CATCH CURVE COMPARATIVE DATA.

<table>
<thead>
<tr>
<th>Fish Size (FL mm)</th>
<th>SW Coast Jan.-Mar. '68</th>
<th>East Coast Jan.-Mar. '68</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Comm. Gill Nets</td>
<td>Comm. Trolling</td>
</tr>
<tr>
<td>Sexes Combined</td>
<td>N</td>
<td>%</td>
</tr>
<tr>
<td>400-449</td>
<td></td>
<td></td>
</tr>
<tr>
<td>450-499</td>
<td></td>
<td></td>
</tr>
<tr>
<td>500-549</td>
<td></td>
<td></td>
</tr>
<tr>
<td>550-599</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>600-649</td>
<td>48</td>
<td>1.4</td>
</tr>
<tr>
<td>650-699</td>
<td>408</td>
<td>11.7</td>
</tr>
<tr>
<td>700-749</td>
<td>870</td>
<td>25.0</td>
</tr>
<tr>
<td>750-799</td>
<td>881</td>
<td>25.3</td>
</tr>
<tr>
<td>800-849</td>
<td>616</td>
<td>17.7</td>
</tr>
<tr>
<td>850-899</td>
<td>311</td>
<td>8.9</td>
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<tr>
<td>900-949</td>
<td>159</td>
<td>4.6</td>
</tr>
<tr>
<td>950-999</td>
<td>73</td>
<td>2.1</td>
</tr>
<tr>
<td>1000-1049</td>
<td>50</td>
<td>1.4</td>
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<tr>
<td>1050-1099</td>
<td>34</td>
<td>1.0</td>
</tr>
<tr>
<td>1100-1149</td>
<td>17</td>
<td>0.5</td>
</tr>
<tr>
<td>1150-1199</td>
<td>10</td>
<td>0.3</td>
</tr>
<tr>
<td>1200-1249</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1250-1299</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

3,482  2,008

These results are comparable to those of other studies. In Texas, Knapp (1950) found fish and shrimp predominant among stomach contents of 327 king mackerel. Menezes (1969a) examined stomachs from 798 king mackerel captured by trolling off northeastern Brazil during March 1965 through April 1968. Fish also comprised their basic diet, with clupeids prominent among 19 families; Opisthonomema oglinum, commonly used as bait, was the dominant inclusion. Crustaceans (mostly penaeids) and squid were also present.

Menezes reported a greater percentage of empty stomachs during the first quarter of the year, and attributed this to spawning initiation since Fonteles (1968:137) proposed that king mackerel assembled near the Brazilian coast during the first and fourth annual quarters to spawn. Menezes also reported an increase in appetite after spawning. A predominance of empty stomachs when fish are most abundant during the fourth and first annual quarters is reported by fishermen for Florida stocks as well.

PROBABLE ECOLOGICAL HETEROGENEITY OF STOCK DISTRIBUTION AND RELATED MANAGERIAL CONSIDERATIONS

Results from several studies emphasize the need for an adequate understanding of correlations between unique oceanographic conditions and the various ecological requirements of pelagic fishes, requirements which can change seasonally and can vary according to the age of the species being studied. Substantial evidence exists that scombrid fishes are distinctly distributed by age. California research (Clemens, 1961; Clemens and Craig, 1965:127) has established this in Pacific albacore, Thunnus alalunga, as have Nakagome et al. (1965) for yellowfin tuna in the tropical Atlantic. Recent studies (Shingu, 1970; Suda, 1970) stress how stock distributions change with age in southern
bluefin tuna, *Thunnus maccoyii* (Castelnau), and how such changes might affect fishing in Pacific bigeye tuna, *T. obesus* (Lowe), and albacore, *T. alalunga*.

Beardsley (1969) investigated relationships between cold water domes of upwelling water (enriched areas) in the eastern tropical Atlantic and the attraction of yellowfin tuna. He found larger deep-swimming fish were influenced by different oceanographic features than were smaller surface-schooling fish. Allain and Aloncle (1969) reported certain effects of temperature variations on albacore migrations between Portugal and southwest Ireland. Clemens (1965:106) found Pacific albacore smaller than 20 pounds (9 kg) in water temperatures of 15.6-18.3°C off California, while larger fish were more abundant in water temperatures of 18.9-21.1°C.

Size/age-specific schooling of certain scombrid fishes is further reflected in stomach content analyses, as reported by Raju (1964), Dragovich (1969) and Bane (1970).

Spawning is a critical life history aspect often influencing population distribution. Considerable difficulty was initially experienced in establishing definite reproductive patterns of Pacific tunas off Central America or the Northern Marshall Islands (Schaefer and Marr, 1948; Marr, 1948); in Philippine tunas (Wade, 1950); in western equatorial Pacific tunas (Shimada, 1951); in Hawaiian albacore (Otsu and Uchida, 1959); and in albacore taken in the central south Pacific (Otsu and Hansen, 1962). Schaefer (1948:199) did notice selective size schooling in tunas, probably our first indication of complications involved in adequately sampling the large adult spawning portion of scombrid populations.

Scombrid reproductive patterns are now more precisely defined. Mori (1970) contended from ovarian condition and larval collections that yellowfin tuna probably spawn off the Japanese coast south of 35°N Latitude in June and July. Watanabe (1970) recognized selective temperature and depth zones frequented by adult *Scomber japonicus* during the spawning season and emphasized how spawning duration and larval metamorphosis depend upon optimal environmental conditions. The population structure of *S. japonicus* can apparently be predicted by correlating hatching and larval distribution with prevailing oceanographic conditions affecting juvenile survival.

Adult king mackerel in spawning condition have yet to be adequately sampled, but collections of larval mackerels suggest areas where future sampling may be oriented during summer. Mackerel larvae have been found scattered throughout the eastern Gulf of Mexico and in the Atlantic off northeastern Florida (Wollam, 1970; Dwinell and Futch, 1973). Klawe (1961) found four 20-30 mm specimens among 50 scombrids collected from the stomachs of two bonita, *Euthynnus alletteratus* (Rafinesque), caught off the mid-Atlantic coast in September, but was only able to identify them to genus due to partial digestion. Potthoff and Richards (1970), leaving no term unstoned, found juvenile scombrids among regurgitations of terns feeding in the vicinity of Dry Tortugas, but no juvenile *Scomberomorus* were among them. King mackerel spawning locations should be defined by exploratory plankton sampling during summer in the northern Gulf of Mexico and in the Atlantic near Cape Hatteras.

The younger, immature portion of the king mackerel population is exploited by commercial and sports fishing in Florida. Although no evidence of stock depletion is currently apparent, the king mackerel fishery should be continually monitored to ascertain trends in annual abundance. Huntsman (1948) emphasized that “depletion” may often be only a decrease in part of a fish population, especially when fishing is selective for size or for fish in only one part of their range.

In a review of world tuna production and associated problems, Chapman (1967) stressed how older yellowfin tuna stocks occupying deeper water are avidly sought by Japanese longliners. He suggested that separate consideration be given each fraction in evaluating biological reaction to the fishery. Therefore, it would also be beneficial for mark and recapture studies to be conducted on Florida king mackerel for a number of years while landings are closely studied to provide estimates of population abundance and stock distribution.
SUMMARY

1. King mackerel have long been commercially important, and are considered the most prominent recreational marine fish in Florida, the center of its range within coastal waters of North America.

2. Previous biological information has developed from a series of studies conducted on king mackerel stocks which support an annual trolling fishery off the coast of Ceará, Brazil.

3. During 1968 and 1969 length frequencies of 8,447 king mackerel were obtained from south Florida commercial landings and otolith pairs were removed from 1,884 individually weighed (gutted) and measured fish from these and other commercial and sports catches landed year-round in Florida. Gonadal tissue, excised from over 400 fish, was preserved in Bouin's Fluid and sectioned and stained for later microscopic examination. Information obtained from analysis of these collections constitutes basic biological knowledge of Florida's king mackerel resources.

4. King mackerel live as long as 13 years with females growing much faster than males after age II. Theoretical growth rates (SL mm) for each sex expressed by von Bertalanffy's equation are: $L_t = 840 \left(1 - e^{-0.35 (t + 2.5)}\right)$ for males and $L_t = 1150 \left(1 - e^{-0.21 (t + 2.4)}\right)$ for females. These equations are developed from Walford graphs of the first seven years of life.

5. Length-weight relationships are: $W_t = 1.330 \times 10^{-5}$ SL$^{2.94}$ for 237 males, $W_t = 3.907 \times 10^{-6}$ SL$^{3.13}$ for 293 females, and $W_t = 4.981 \times 10^{-6}$ SL$^{3.09}$ for the combined sexes.

6. Female king mackerel probably do not spawn until their fourth summer, but males may spawn during their third. Correlation of gonadal development (evaluated from sectioned and stained tissue) with seasonal change in photoperiod indicates spawning most likely extends throughout summer. The population seems to segregate by age (size), so it is believed that the mature fraction has not been adequately sampled during the summer spawning season.

7. Otolith annuli form when gonadal activity peaks just prior to the proposed spawning time. Annual gonadal development is observed in immature fish. Pituitary activity (stimulated by lengthening daylight) may be influential in both instances.

8. King mackerel are recruited at ages II or III into southeast Florida's winter trolling fishery, the oldest commercial production method. Survival rate of this fishery in 1968 closely approximates that of Brazil's trolling fishery.

9. Gill nets, used exclusively in southwest Florida during winter, produced king mackerel mostly older than age III—perhaps due more to relative availability of schools composed of larger fish than to gear selectivity.

10. King mackerel generally feed on clupeid fishes, with other fish species, penaeid shrimps, and squid following in order of importance. Rapid digestion complicates adequate determination of diet preferences, but if behavior is similar to other scombrids, considerable variation may occur seasonally as well as with age.

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