SPAWNING AND FECUNDITY OF ATLANTIC MACKEREL, *SCOMBER SCOMBRUS*, IN THE MIDDLE ATLANTIC BIGHT

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ABSTRACT

Collections of Atlantic mackerel, *Scomber scombrus*, were made during spring 1977 from Maryland to Rhode Island. Length-weight relationships were determined for total and fork lengths and total and gutted weights. Spawning time was determined from gonad somatic indices and peak spawning occurred between 21 April and 4 May. Egg diameter frequencies from running ripe ovaries indicated five to seven egg batches are spawned by each female during the spawning season. Fecundity was estimated and ranged from 285,000 to 1,980,000 for fish between 307 and 438 mm fork length. Fecundity was related to fork length, gutted weight, and age.

The Atlantic mackerel, *Scomber scombrus* Linnaeus, is a schooling, pelagic species ranging from the Gulf of St. Lawrence to North Carolina in the northwest Atlantic and from Norway to Spain in the northeast Atlantic. The northwest Atlantic population has been separated into northern and southern contingents on the basis of size composition, spawning times, summer distributions, and tagging studies (Sette 1950; Moores et al. 1975; MacKay[2]).The northern contingent spawns in the southern Gulf of St. Lawrence from about the end of May to mid-August (Ware 1977). The southern contingent spawns from mid-April to June from North Carolina to Massachusetts (Berrien 1978).

Fecundity estimates of northwest Atlantic mackerel are limited to a few observations ranging from about 500,000 to 1,000,000 eggs (Brice 1898: 208-213; Sette 1943). Fecundity of northeast Atlantic mackerel ranged from approximately 130,000 to 1,100,000 eggs for fish 28.5-46.0 cm total length (Macer[3]; Lockwood[4]). This paper presents the results of a fecundity and spawning time investigation of the southern contingent.

METHODS

Atlantic mackerel were collected between 9 April and 21 May 1977 from recreational and commercial catches from Maryland to Rhode Island (Table 1). Length frequencies of males and females are shown in Figure 1. All fish were measured to the nearest millimeter fork length (FL) and total length (TL), and weighed to the nearest gram total weight (TW) and gutted or somatic weight (GW). Otoliths were extracted for age determination. Ovaries of all mature females were exsected, weighed to the nearest 0.01 g, and preserved in 10% Formalin.[5]

Preliminary observations of eggs from ovaries in the spawning condition revealed that three egg types were present: 1) small, translucent eggs; 2)

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[2]MacKay, K. T. 1973. Aspects of the biology of Atlantic mackerel in ICNAF Subarea 4. Int. Comm. Northwest Atl. Fish., Res. Doc. 73/70, 11 p.

[3]Macer, C. T. 1976. Observations on the maturity and fecundity of mackerel (*Scomber scombrus* L.) Int. Counc. Explor. Sea, CM 1976/H:6, 7 p.

[4]Lockwood, S. J. 1978. The fecundity of mackerel, *Scomber scombrus* L. Int. Counc. Explor. Sea, CM 1978/H:9, 5 p.

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

TABLE 1.—Catch data of Atlantic mackerel sampled in 1977.

Date	Port	Numbers of fish examined: Female	Male	Capture method
9 April	Ocean City, Md.	16	8	Otter trawl
16	Cape May, N.J.	15	10	Hook and line
20	Ocean City	26	26	Otter Trawl
25	Barnegat, N.J.	20	25	Hook and line
27	Greenport, N.Y.	64	36	Pound net
28	Belford, N.J.	10	15	Otter trawl
28	Sheepshead Bay, N.Y.	6	16	Hook and line
30	Sheepshead Bay	9	12	Hook and line
1 May	Sheepshead Bay	6	17	Hook and line
4	Barnegat	16	36	Hook and line
5	Barnegat	39	66	Hook and line
7	Sheepshead Bay	11	19	Hook and line
8	Point Pleasant, N.J.	17	8	Hook and line
9	Point Judith, R.I.	42	43	Otter trawl
11	Belmar, N.J.	5	20	Hook and line
14	Sheepshead Bay	12	38	Hook and line
15	Sheepshead Bay	4	33	Hook and line
17	Sandy Hook, N.J.	22	20	Hook and line
18	Point Judith	32	48	Otter trawl
22	Sheepshead Bay	77	21	Hook and line
Totals		449	517	

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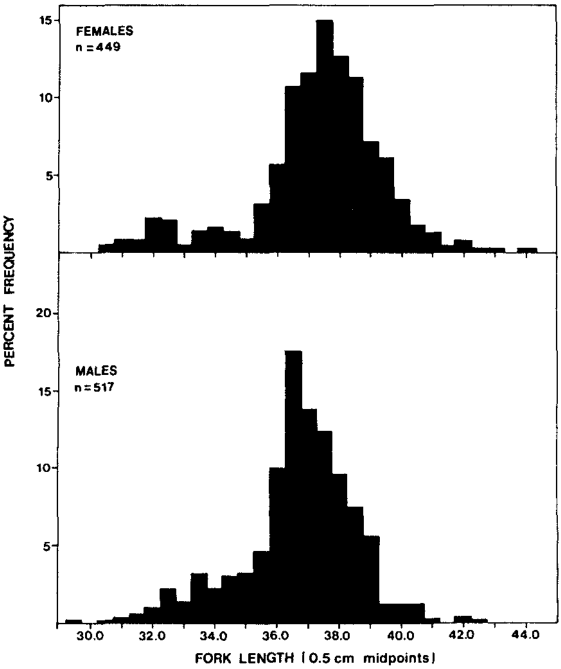

FIGURE 1.—Length frequencies of male and female Atlantic mackerel used in this study.

TABLE 2.—Maturity stages of Atlantic mackerel ovaries.

Stage	Description
1. Developing	Ovary enlarged, usually orange colored with a granular appearance. No translucent eggs, maximum egg diameters 0.8-0.9 mm.
2. Ripe	Ovary fills most of gut cavity, yellow colored, in advanced stage some translucent eggs are visible through wall. Maximum egg diameter 1.0-1.2 mm.
3. Running ripe	Similar in appearance to stage 2, eggs are extruded with pressure on abdomen of fish. Maximum egg diameters 1.2-1.4 mm.
4. Partially spent	Ovary is flaccid, often hemorrhaging is evident at anterior portion of ovary, some residual mature eggs (1.1-1.4 mm) present.

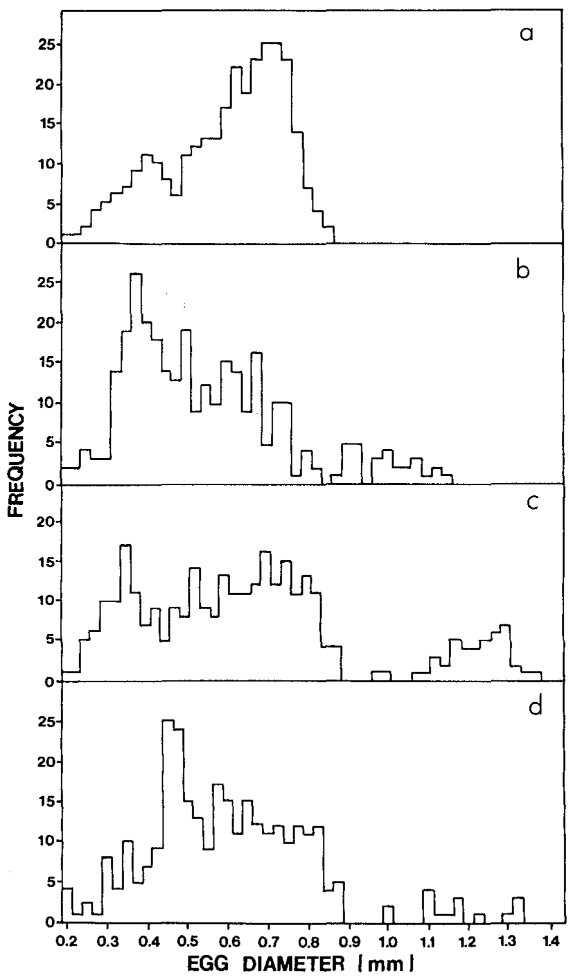

FIGURE 2.—Egg diameter frequencies of Atlantic mackerel ovaries in stages: developing (a), ripe (b), running ripe (c), and partially spent (d). Each graph based on 300 egg measurements.

larger opaque, yolked eggs; and 3) large translucent eggs. There appeared to be no clear size separation between egg types, which is indicative of serial spawners (Hickling and Rutenberg 1936). Therefore, the method described by Hislop and Hall (1974) for whiting, *Merlangus merlangus*, was used to determine which eggs would be shed during the current spawning season. Since yolk deposition indicates eggs are ripening for spawning, random samples of 300 eggs were measured from ovaries at successive maturity stages to determine the average minimum size of yolked eggs. Eggs 0.20 mm and larger contained yolk and were included for fecundity estimation. Ovaries were classified into four maturity stages based upon macroscopic examination and the occurrence of mature eggs (Table 2). Egg diameter frequencies of yolked eggs from ovaries in the developing, ripe, running ripe, and partially spent condition are shown in Figure 2.

Ovaries in the ripe condition (Figure 2b) were used for fecundity estimations. If large translucent eggs (1.00-1.35 mm) were present in the lumen of the ovary, which is indicative of the running ripe condition (Figure 2c), the ovary was not utilized for fecundity because some eggs may have been shed and fecundity would be underestimated. Suitable ovaries were removed from the Formalin solution, placed in glacial acetic acid for 5 min, and washed, and the eggs were separated with a gentle stream of water and agitated in a 0.20 mm mesh sieve. Following removal of the ovarian tissue, the eggs were air dried on blotter paper for 2-3 min and weighed (±0.01 g), and two subsamples were removed and weighed (±0.01 mg). All eggs in each subsample were counted and the mean used to calculate total egg numbers based on the weight of all eggs in the ovary. If the two subsample counts differed by 10% or more, additional samples were taken until two counts differed by <10%.

Ages were determined from otoliths as described by Steven (1952).

RESULTS

The allometric relationships of length-weight were expressed by the power function:

$$Y = aX^b \qquad (1)$$

where X is length, Y is weight, and a and b are constants. Equation (1) was converted to the linear form by a logarithmic (base 10) transformation to:

$$\log Y = \log a + b \log X . \qquad (2)$$

The interrelationships between length measurements and between weight measurements were expressed by the linear function:

$$Y = a + bX \qquad (3)$$

where Y and X are both length or both weight. All data were fitted using least-squares regression techniques.

Predictive regression equations were calculated using all observations for males and females and an analysis of covariance applied to determine possible sex related differences. No significant differences ($P = 0.05$) were indicated between sexes and sexes were therefore pooled. The pooled regression equations and associated statistics are presented in Table 3.

To determine the peak spawning time the mean gonad somatic index (GSI = percent ovary weight of the gutted weight) was calculated for each week of the sampling period (Figure 3). It appears that individual fish attain their maximum GSI just prior to spawning the first egg batch and a decline in GSI occurs as successive batches are spawned. This was shown by comparing the mean GSI of each maturity stage (Table 4) which showed an increase from stage 1 to 3 and a rapid decrease at stage 4. Similar results were reported by Kaiser (1973) for horse mackerel, *Trachurus murphyi*. He found that gonad somatic indices reflected maturation changes of the ovaries and a sharp decline in the mean GSI coincided with the appearance of the earliest spawning females. In this study the weekly mean GSI increased during the first 3 wk of sampling, peaked between 21 April and 4 May, and then declined steadily through the end of the sampling (22 May). All females examined from the last sampling week were partially spent and indicated spawning was nearly completed within the study area.

TABLE 3.—Length and weight relationships of Atlantic mackerel collected in the Middle Atlantic Bight, 1977. TW = total weight (grams); GW = gutted weight (grams); TL = total length (millimeters); and FL = fork length (millimeters). Symbols refer to the equation $Y = a + bX$; n = sample size; r = correlation coefficient; $S_{y.x}$ = standard deviation about the line.

Y	a	b	X	n	r	$S_{y.x}$
Curvilinear relationships between transformed variates						
log TW	-5.767	3.275	log TL	966	0.905	0.036
log GW	-5.420	3.106	log TL	966	0.924	0.030
log TW	-5.780	3.334	log FL	966	0.905	0.036
log GW	-5.374	3.140	log FL	966	0.924	0.030
Linear relationships between untransformed variates						
TL	1.793	1.098	FL	966	0.986	3.594
TW	-20.410	1.282	GW	966	0.979	22.397

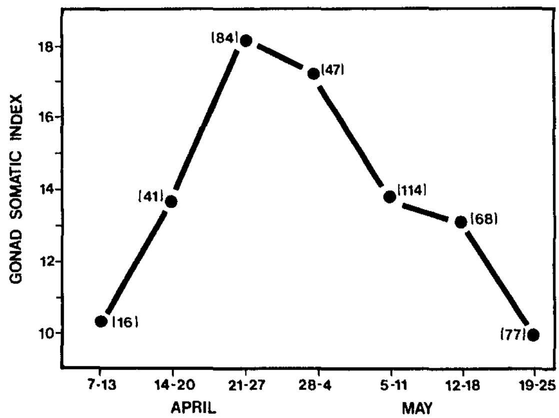

FIGURE 3.—Mean gonad somatic index (ovary weight as a percent of gutted weight) plotted by week for Atlantic mackerel sampled in 1977. Numbers in parentheses are sample sizes.

TABLE 4.—Mean gonad somatic index (GSI) and standard deviation for each maturity stage of Atlantic mackerel.

Stage	Mean GSI	SD	*n*
1. Developing	10.4	2.9	68
2. Ripe	15.0	4.2	247
3. Running ripe	24.9	4.7	41
4. Partially spent	8.6	2.2	93

The egg diameter frequencies shown in Figure 2 indicate Atlantic mackerel are serial spawners, i.e., several batches of eggs are shed by individuals throughout the spawning season. The presence of multiple modes in the egg diameter frequencies (Figure 2a-c) and ripening eggs in partially spent ovaries (Figure 2d) are indicators of serial spawning (Clark 1935; MacGregor 1957). A cytological study by Bara (1960) has shown that eggs are not shed continuously as stated by Cunningham (1889) but are shed in several batches during the 2-mo spawning period.

The potential number of batches spawned was estimated by determining the ratio of ripe eggs to all yolked eggs in six running ripe ovaries. Atlantic mackerel eggs, from plankton samples, ranged from 1.01 to 1.29 mm diameter (Berrien 1975; Ware 1977); therefore, in this study, eggs 1.05 mm and larger were assumed to constitute the next egg batch to be spawned. The ratios ranged from 13.7 to 21.7% and averaged 17.0%. Thus the potential number of batches spawned per individual was five to seven and averaged six batches.

Fecundity estimates ranged from 285,000 to 1,980,000 eggs for fish between 307 and 438 mm FL. Preliminary plots indicated a curvilinear relationship existed for fecundity-length and a linear relationship for fecundity-weight and fecundity-age. However, correlation coefficients (r) were higher for the logarithmic relationships of fecundity-weight and fecundity-age, therefore, all variables were transformed and linear regression equations of the form $\log Y = a + b(\log X)$ were calculated. Data plots and the equations relating fecundity to fork length, gutted weight, and age are shown in Figures 4-6.

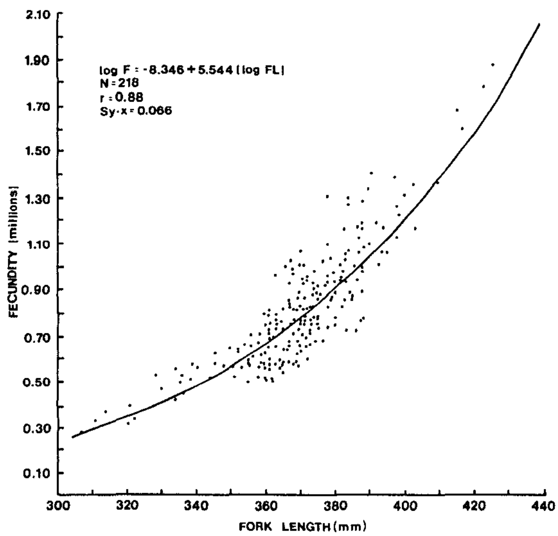

FIGURE 4.—Relationship of fecundity and length and the predictive logarithmic (base 10) regression for Atlantic mackerel in 1977.

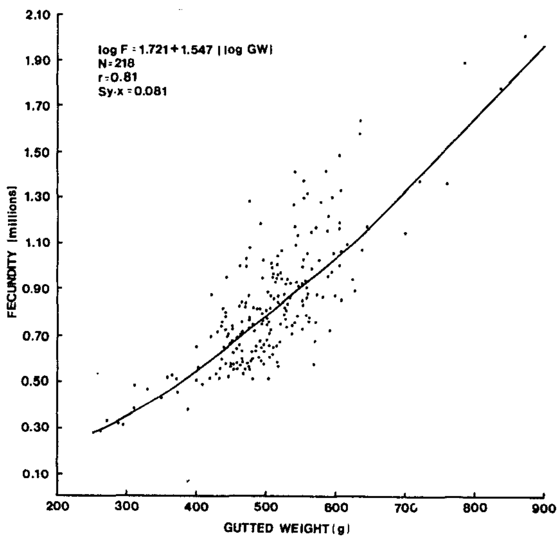

FIGURE 5.—Relationship of fecundity and weight and the predictive logarithmic (base 10) regression for Atlantic mackerel in 1977.

DISCUSSION

Spawning by the southern contingent of Atlantic mackerel apparently peaked during the 2-wk period between 21 April and 4 May 1977. This 2-wk period represents the mean peak spawning time within the study area (Maryland to Rhode Island) since there is a north and eastward progression of spawning during the spring migration (Bigelow and Schroeder 1953; Berrien 1978). Berrien et al.[6] observed the north and east progression in plankton mackerel egg densities. They found spawning intensity in the Middle Atlantic Bight was low during mid-April and increased rapidly by late April, and maximum egg densities occurred about 25 April. Spawning continued at a reduced rate throughout May and then decreased steadily during June. Very similar results are indicated from my analysis of gonad somatic indices during the 1977 spawning season.

[6]Berrien, P. L., A. Naplin, and M. R. Pennington. 1979. Atlantic mackerel, *Scomber scombrus*, egg production and spawning population estimates for 1977 in the Gulf of Maine, Georges Bank, and Middle Atlantic Bight. Int. Counc. Explor. Sea ICES/ELH Symp./DS:9, 17 p.

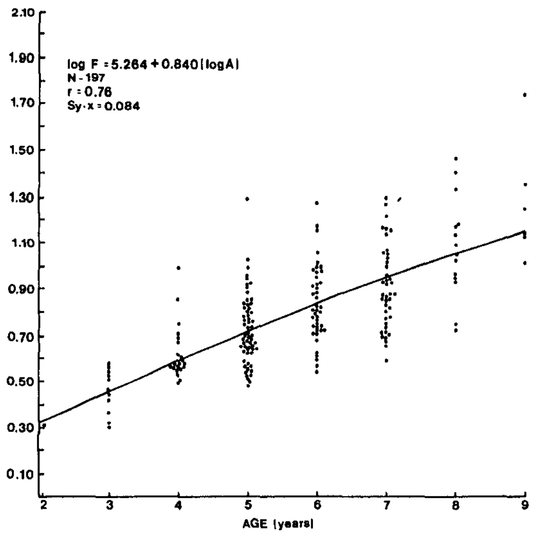

FIGURE 6.—Relationship of fecundity and age and the predictive logarithmic (base 10) regression for Atlantic mackerel in 1977.

Observations of spawning times of various temperate-water fish have indicated peak spawning dates may be relatively fixed. Cushing (1969) postulated an indirect link between the fixity of spawning season and the primary production cycle. Ware (1977) investigated the relationship of spawning time of Atlantic mackerel at St. Georges Bay, Nova Scotia, to the size and abundance of 80 μm plankton. He found the mean peak egg production date was 1 July ± 1 wk and coincided with the maximum abundance of summer plankton. It would appear, at least for the southern contingent, that the time of peak spawning is more variable than that indicated for St. Georges Bay. Sette (1943) determined maximum spawning occurred during mid-May (1928-32) off Middle Atlantic and southern New England States. Ichthyoplankton surveys during the mackerel spawning season in 1966 and 1975-77 (Berrien 1978; Berrien et al. see footnote 6; Berrien and Anderson[7]) within the Middle Atlantic Bight indicated spawning peaked during May in 1966 and 1975 and during April in 1976 and 1977. In fact, eggs were collected as early as 13 April in 1977. Berrien and Anderson (see footnote 7) attribute the April 1976 spawning peak to increased water temperatures within the study area.

The factors controlling the spawning time of Atlantic mackerel are unclear. The regularity shown by Ware (1977) would indicate internal control or a constant external stimulus such as photoperiod. Sette (1943) presented evidence indicating water temperature is a limiting factor controlling migration and in turn the timing of spawning in a fixed location. Cushing (1967, 1969) suggested that some fish spawn at a relatively fixed date that is linked to planktonic productivity and that changes in plankton production would cause dramatic changes in year-class success. It appears that a variable spawning date, as shown by the southern contingent—linked to the factors affecting plankton productivity, e.g., temperature, photoperiod, nutrient content—would increase the chances for larval survival.

The fecundity estimates presented here must be considered as maximum potential egg production because, as reported by Macer (see footnote 3), resorption may significantly reduce the number of eggs spawned. Preliminary observations by Macer indicated an average of 11.4% of yolked eggs were being resorbed. Bara (1960) observed degeneration in a "few" mature eggs though no quantitative data were presented. Studies are needed to define the extent and possible annual changes of resorption rates and their relationship to fecundity.

[7]Berrien, P. L., and E. D. Anderson. 1976. *Scomber scombrus* spawning stock estimates in ICNAF Subarea 5 and Statistical Area 6, based on egg catches during 1966, 1975, and 1976. Int. Comm. Northwest Atl. Fish., Res. Doc. 76/XII/140, 10 p.

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LITERATURE CITED

BARA, G.
1960. Histological and cytological changes in the ovaries of the mackerel, *Scomber scombrus* L., during the annual cycle. Rev. Fac. Sci. Univ. Istanbul, Ser. B, 25:49-86.

BERRIEN, P. L.
1975. A description of Atlantic mackerel, *Scomber scombrus*, eggs and early larvae. Fish. Bull., U.S. 73:186-192.
1978. Eggs and larvae of *Scomber scombrus* and *Scomber japonicus* in continental shelf waters between Massachusetts and Florida. Fish. Bull., U.S. 76:95-115.

BIGELOW, H. B., AND W. C. SCHROEDER.
1953. Fishes of the Gulf of Maine. U.S. Fish Wildl. Serv., Fish. Bull. 53, 577 p.

BRICE, J. J.
1898. A manual of fish-culture, based on the methods of the United States Commission of Fish and Fisheries. Rep. U.S. Comm. Fish Fish. 23:1-261.

CLARK, F. N.
1935. Maturity of the California sardine (*Sardina caerulea*), determined by ova diameter measurements. Calif. Dep. Fish Game, Fish Bull. 42:5-49.

CUNNINGHAM, J. T.
1889. Studies of the reproduction and development of teleostean fishes occurring in the neighborhood of Plymouth. J. Mar. Biol. Assoc. U.K. 1:10-54.

CUSHING, D. H.
1967. The grouping of herring populations. J. Mar. Biol. Assoc. U.K. 47:193-208.
1969. The regularity of the spawning season of some fishes. J. Cons. 33:81-92.

HICKLING, C. F., AND E. RUTENBERG.
1936. The ovary as an indicator of the spawning period in fishes. J. Mar. Biol. Assoc. U.K. 21:311-316.

HISLOP, J. R. G., AND W. B. HALL.
1974. The fecundity of whiting, *Merlangus merlangus* (L.), in the North Sea, the Minch and at Iceland. J. Cons. 36:42-49.

KAISER, C. E.
1973. Gonadal maturation and fecundity of horse mackerel *Trachurus murphyi* (Nichols) off the coast of Chile. Trans. Am. Fish. Soc. 102:101-108.

MACGREGOR, J. S.
1957. Fecundity of the Pacific sardine (*Sardinops caerulea*). U.S. Fish Wildl. Serv., Fish. Bull. 57:427-449.

MOORES, J. A., G. H. WINTERS, AND L. S. PARSONS.
1975. Migrations and biological characteristics of Atlantic mackerel (*Scomber scombrus*) occurring in Newfoundland waters. J. Fish. Res. Board Can. 32:1347-1357.

SETTE, O. E.
1943. Biology of the Atlantic mackerel (*Scomber scombrus*) of North America. Part I: Early life history, including growth, drift, and mortality of the egg and larval populations. U.S. Fish Wildl. Serv., Fish. Bull. 50:149-237.
1950. Biology of the Atlantic mackerel (*Scomber scombrus*) of North America. Part II: Migrations and habits. U.S. Fish Wildl. Serv., Fish. Bull. 51:251-358.

STEVEN, G. A.
1952. Contributions to the biology of the mackerel, *Scomber scombrus* L. III. Age and growth. J. Mar. Biol. Assoc. U.K. 30:549-568.

WARE, D. M.
1977. Spawning time and egg size of Atlantic mackerel, *Scomber scombrus*, in relation to the plankton. J. Fish. Res. Board Can. 34:2308-2315.