ISSN: 0001-5113
AADRAY

ACTA ADRIAT.,
42 (2): 85-92, 2001

UDC: 597.5 :591.1 (262.3)
Original scientific paper

Population structure, reproduction, age and growth of Atlantic mackerel, *Scomber scombrus* L. in the Adriatic Sea

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Atlantic mackerel, Scomber scombrus *L. biological data were collected monthly between 1991 and 1993 from Croatian fishing grounds in the eastern part of the Adriatic Sea. The catch variation of this pelagic species from the period 1950-1992 was presented as well.*

Mean length at age data, derived using otolith readings of 1048 specimens were used to estimate the growth parameters of the von BERTALANFFY equation : $L_\infty = 42.0$ *cm,* $K = 0.37$ *year*$^{-1}$ *and* $t_0 = -0.5$. *Growth-performance index* $\Phi = 2.8146$. *Growth rings were read to 9 years: from 0 to 8+ years. Weight-length relationship was* $W = 0.0014\ L_S\ 3.6036$. *The mean cubic condition factor* (K') *was calculated to be* K' = *0.8434, and empiric* (C) *condition factor as* C = *0.1193.*

Key words: Atlantic mackerel, Adriatic, population structure, reproduction, age, growth

INTRODUCTION

Atlantic mackerel, *Scomber scombrus* L. are rather widely distributed in the Adriatic Sea and play an important role in the Croatian commercial fisheries although the values of their catches are rather low.

The object to the present study was to examine the population structure, reproduction and characteristic growth pattern of Atlantic mackerel as biological data of this species adult stage was only preliminary one (SINOVČIĆ, 1995).

MATERIAL AND METHODS

A total of 1048 analyzed specimens of *Scomber scombrus* L. from commercial purse seine catches were taken from the Croatian fishing grounds in the eastern Adriatic between 1991 and 1993. The fish were transported to the laboratory and immediately analyzed as to length, weight, sex, maturity stage and age. Data on Atlantic mackerel length referring to their total (L_T), standard (L_S) and fork (L_F) lengths are read to the nearest 0.5 cm for length frequency and aging analyses, but to the nearest millimetre for the length-weight analysis. Weights of the fish were expressed with the accuracy of 0.1 g and the gonad weight with the accuracy of 0.01 g. The present study used otoliths to determine age.

Reading was done in a dark room under reflected light. Dorsoventral part of the concave sagittal otolith side was read. Otoliths were examined (n = 1048) in water on a darkened slide. The age of Atlantic mackerel was deter-

mined by hyaline (winter) and opaque (summer) rings on the sagittal otoliths where the periodical growth is evident. The central opaque nucleus is followed by alternating hyaline and opaque zones which, under reflected light against a darkened background, appear as dark and white bands respectively. Rings are concentric to the outer margin, being more clearly defined from the posterior edge to the opaque nucleus region. Older fish show the outer rings as narrow, closely spaced bands.

A number of splits and growth checks occured each year after the first year. Each otolith was read twice, on two separate occasions, and the readings for a given otolith were accepted only if both readings were identical. When there was a discrepancy between the two readings, a third reading was affected. Agreement between readings was high: 97%.

The vertebrae were counted by lens, from occipital condyle (not counted) to urostyle included.

Sex was determined considering shape, look and gonad structure. Determining sex was not a problem with the exception of the smallest specimens in an inactive period of sexual cycle, in which case it was not possible to determine sex in the course of routine analysis. In such specimens sex was determined microscopically.

Gonad state of Atlantic mackerel was recorded macroscopically considering size, colour and look of gonads. We used the empiric scale described by SINOVČIĆ (2000).

Atlantic mackerel sexual cycle in detail, the monthly gonad weight amounts and gonosomatic index (GSI) were determined.

The length and weight growth of Atlantic mackerel was plotted by the von BERTALANFFY equation (1938), which was modified to this (BEVERTON and HOLT, 1956):

$$l_t = L_\infty [\, 1 - e^{-K(t-t_0)} \,]$$

where L_∞ is asymptotic length , K = species growth coefficient, t_0= theoretical age of the fish at the length l_o, that is the age when the formation of otoliths, which are used to estimate age, starts.

Value t_0 was plotted by the expression:

$$t_0 = t + 1/K \ln (L_\infty - l_t)/L_\infty$$

Growth-performance index, Φ was determined according the equation:

$$\Phi = \log K + 2 \log L_\infty$$

Allometric relationship between length (L) and weight (W) of Atlantic mackerel was estimated by GM functional regression (RICKER, 1975):

$$\log W = \log a + b \log L$$

where W is specimen weight and L is length.

Cubic condition factor (K') was calculated as:

$$K' = W / L^3$$

and empiric condition factor (C) as:

$$C = W / L^b$$

RESULTS AND DISCUSSION

Catch

Atlantic mackerel, *Scomber scombrus* L. plays an important role in the Croatian commercial fisheries although the values of its catches are rather low (Figs. 1 and 2); they varied between 8 t and 3,323 t in the 1950-1993 period. Unfortunately, there are no official Atlantic mackerel catch data available since 1993 onward.

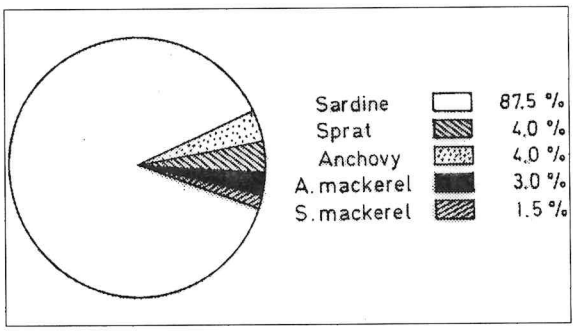

Fig. 1. Contribution of individual species of small pelagic fish in total Croatian catches during the 1983-1993 period

The data on Atlantic mackerel catches show considerable fluctuations; they could be distinguished in two separate phases. In the first

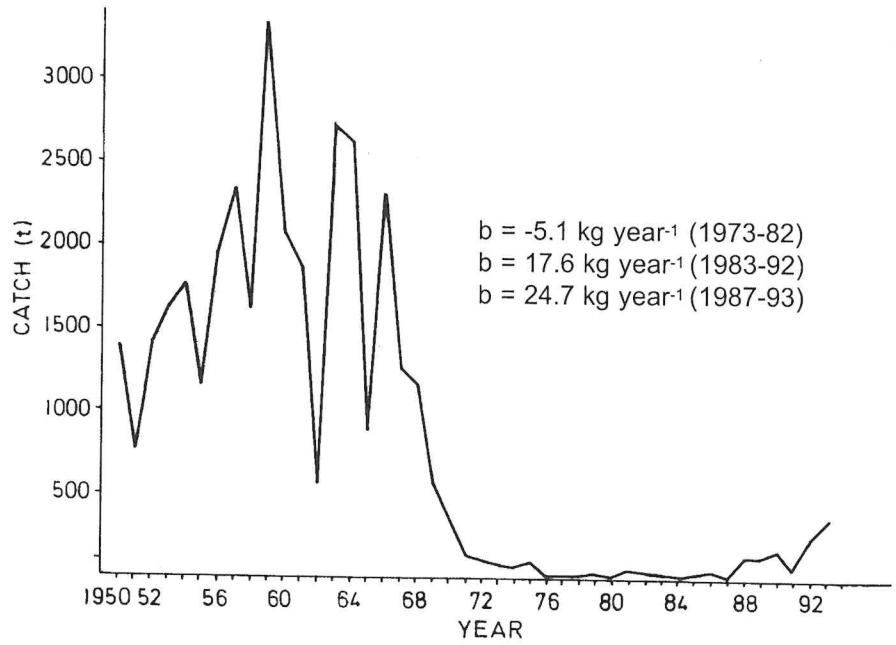

Fig. 2. Fluctuations of Croatian Atlantic mackerel Scomber scombrus *catches during the 1950-1993 period*

phase, from 1950 to 1969, relatively high amounts of catches are evident and they show considerable variations. The highest amount of catch: 3, 330 tons in 1959, was realized in this period. Last relatively high catch amount of 1,233 tons was realized in 1966. Upon 1966 the amounts of catches suddenly dropped to stagnate particularly in the 1971-1987 period, when they fluctuated from the lowest values of not more than 9 tons in 1987 to the most of 44 tons in 1986. The most recent data are indicative of an increase in mackerel catches.

The last investigated decade is characterized by a trend of slight increase in mackerel catches (b = 17.6 kg year^{-1}) which has been slightly better pronounced for the last six years of this period (b=24.7 kg year^{-1}) with statistically significant positive correlation. Trend quotient was 2,588 kg year^{-1} for the above mentioned decade and even higher, 2,386 kg year^{-1} for last six years of the decade with statistically significant correlation (r=0.83). On the contrary, the decade, which preceeded this period, was characterized by a decrease of mackerel catches (b= -5.1kg year^{-1}) with statistically significant negative correlation (r= -0.69).

Population structure

Total of 1017 Atlantic mackerel individuals were examined.

A modal vertebral number in all specimens was 30 vertebrae. Vertebrae number of 29 vertebrae was represented very rarely (3%).

The average values of mackerel specimens total length at age varied from 12.2 to 40.1 cm (Table 1). Weights of the analyzed individuals ranged between 4.44 and 779.08 g. Their life span was 9 years: from 0 to 8+ years. Mean length and weight of all the individuals analysed was 29 cm and weight 181.73 g.

Table 1. Average length per age of Atlantic mackerel Scomber scombrus *in the eastern Adriatic during 1991-1993*

Age	0	1+	2+	3+	4+	5+	6+	7+	8+
$\bar{x}$ L_T(cm)	12.2	21.5	29.7	34.0	36.2	37.6	38.7	39.6	40.1

The age composition of the Atlantic mackerel is presented in Fig 3. The most conspicuous feature of the distribution is the dominance of age group 3+ (25%), then 4+ (20%) and 2+ (18%). All mackerel specimens have undergone the first sexual maturation; gonad maturation state in analyzed, most abundant 2+ and 3+ aged specimens, denoted as maturity stages in range between III and VII. Consequently, the greatest presence of fully mature specimens of mackerel is naturally favourable for the state of its population.

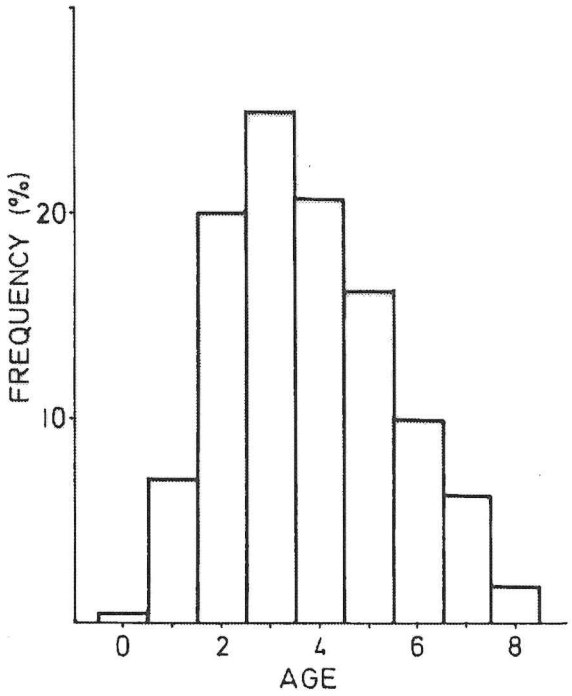

Fig. 3. Age composition of Atlantic mackerel Scomber scombrus *samples from the eastern Adriatic during the 1991-1993 period*

Conversion of lengths

As Atlantic mackerel standard (L_S) and fork body length (L_F) are often used instead of its total length (L_T), we plotted the total length conversion coefficient into standard length and *vice versa*, to make the comparisons possible. In that case the following equations were obtained:

$L_T = 1.0560\ L_S - 1.0693$;
$L_S = 0.9430\ L_T - 0.7437$;
$r = 0.998$ ($P < 0.001$)

$L_T = 1.0510\ L_F + 0.8022$;
$L_F = 0.9507\ L_T - 0.7437$;
$r = 0.999$ ($P < 0.001$)

Reproduction and sexual cycle

Monthly variations of gonad weight and gonosomatic index of Atlantic mackerel were presented in Fig. 4. The specimens of same length classes (between 8.0 and 40.0 cm) were used for this parameter consideration to eliminate the errors that might appear because of fish length influence on this parameter.

Data adequately describes the reproductive activity of Atlantic mackerel; reproductive activity started in October and lasted till March with peak in January. According the considerable presence of Atlantic mackerel eggs from December to February in the eastern Adriatic, GAMULIN (1954), HURE (1960, 1961), GAMULIN and HURE (1983), concluded that spawning season of this species takes place during the colder part of the year, which is in accordance with our data.

Age and growth

Atlantic mackerel life span is from 0 to 8+ years and following growth parameters were derived:

$L_\infty = 42.0$ cm ; $K = 0.37$ year $^{-1}$; $t_0 = -0.5$

According to our results, von BERTALANFFY's exponential growth equation for Atlantic mackerel from the eastern Adriatic has this form.

$$l_t = 42\ [\ 1\text{-}e^{-0.37\ (t+0.5)}]$$

Entered into the von BERTALANFFY equation, this gives the means of estimated lengths at age of mackerel from the eastern Adriatic. The lengths for each age group calculated from this equation are graphically presented in Fig. 5. It is

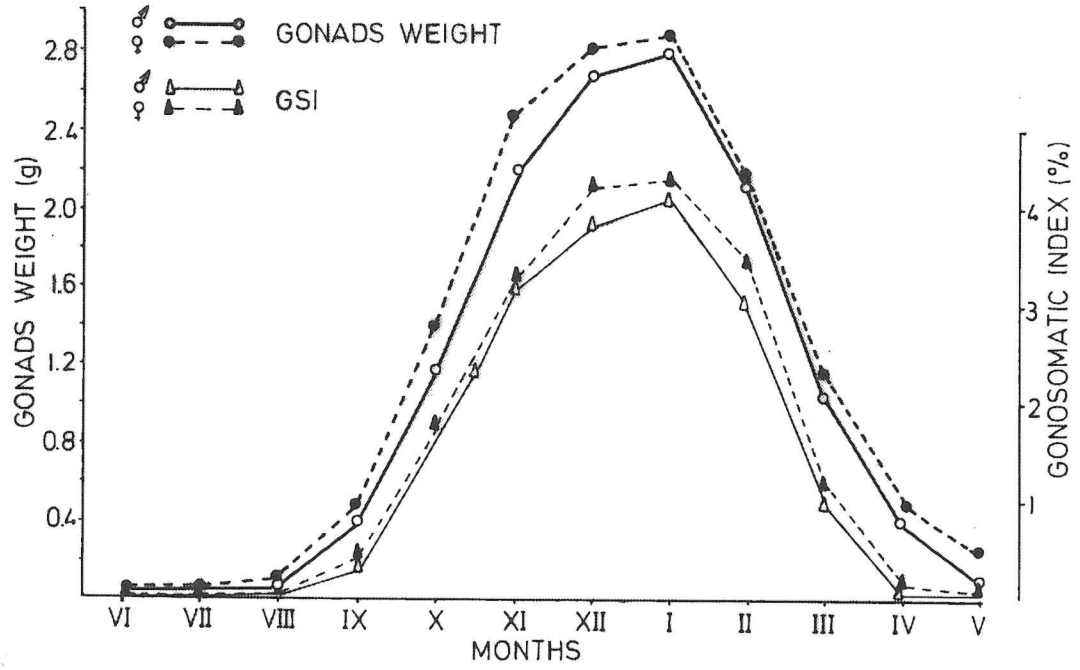

Fig. 4. Monthly fluctuations of gonad weight and gonosomatic index (GSI) of male and female Atlantic mackerel Scomber scombrus *samples from the eastern Adriatic from June 1991 to May 1992*

obvious that the most rapid growth in mackerel length takes time during the initial three years of its life and gradually decreased with the greater age and practically ceased at the 6+. A significant reduction in mackerel growth after third year of its life is probably the result of energy conversion to gonad maturation.

Largest analyzed specimen observed during the sampled period was 41.9 cm.

The estimates of L_∞= 42.0 cm for *Scomber scombrus* corresponds very closely to the maximum observed lengths (L_{max}) of 41.9 cm. Also K = 0.37 year $^{-1}$ denotes the moderate growth increment as well as the mean value of t_0 = -0.5 corresponds closely to the hatching period of the eggs which indicates that this parameter has been correctly estimated. As t_0 is the theoretical age at which the length of the fish is zero and as age is referred to the time of hatching, this correspondence would be expected.

An inverse proportion between an assumed maximum possible length in the life span of Atlantic mackerel and growth coefficient is in accordance with the general trend for the species with high values of L_∞ to have lower

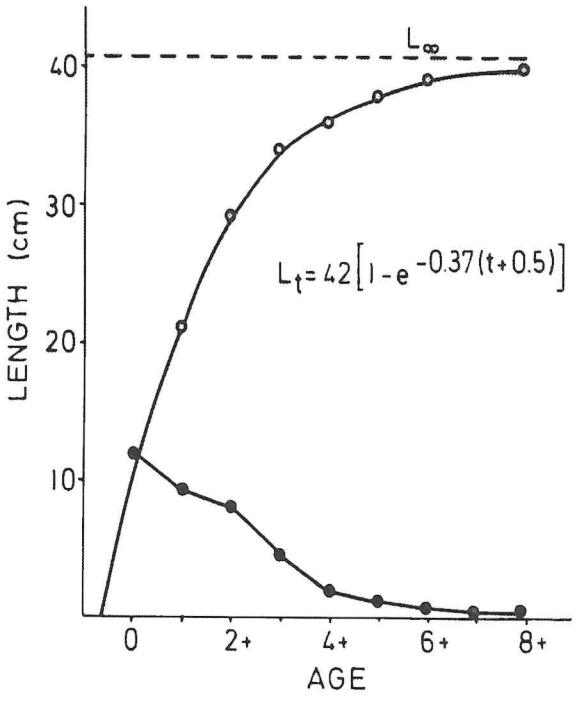

Fig. 5. Growth curve and ageing increment of Atlantic mackerel Scomber scombrus *samples from the eastern Adriatic during the 1991-1993 period*

values of K and *vice versa*. It is mathematically logical, since growth coefficient is represented by the curve slope, therefore, the curve slope degree is greater with the greater value of K, so the curve reaches asymptotic length sooner. In other words, with a greater growth rate, the fish reach asymptotic length faster, and final length is smaller. Growth coefficient is considered a genetic feature of a species, whilst L_∞ is phenotypic and can be limited by various environmental factors. Temperature is stated by some authors (GUNTER, 1950) to be the most important limiting factor. They explain that higher temperature stimulates a premature onset of sexual maturity. Growth becomes slower or interrupted and final result is a smaller maximum length.

If we compare the greatest mackerel length of 41.9 cm recorded during our investigation with the estimated theoretically greatest length value that mackerel could research in the life span (42.0 cm), the obtained value points to the fact that 99.8% of maximum Atlantic mackerel length was reached. It is an advantage for the species with such a high value of maximum length reached, because the species most probably realized its reproductive potential several times.

It is evident that the maximum increment of 12.2 cm is present during the first year of Atlantic mackerel life (0+), then 9.3 cm in 1+, 8.2 cm in 2+, 4.3 cm in 3+, 2.2 cm in 4+ and after that period the length of mackerel increases a little to 8+ years of life, practically only approximately one cm per year.

Weight - length relationship

The calculated weight (W) - length (L) equation was:

$$W = 0.0014\ L_S^{3.6036}$$

or in logarithmic form:

$$\log W = 3.6036\ L_S - 2.840\ ;\ (r^2 = 0.995)$$

In weight (W) - length (L) relationship a positive allometry (b=3.604) was established; Atlantic mackerel weight increased allometrically with size (Fig. 6).

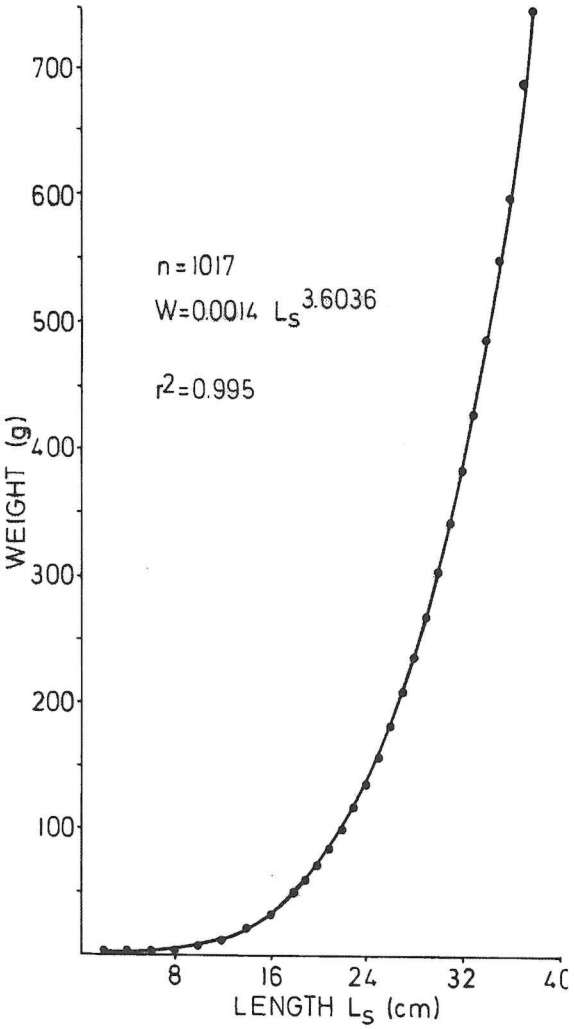

Fig. 6. Weight-length relationship of Atlantic mackerel Scomber scombrus *samples from the eastern Adriatic during the 1991-1993 period*

The mean cubic condition factor (K) was calculated to be K = 0.8434, and empiric (C) condition factor as C = 0.1193.

Comparison with other results is not possible because they do not exist. These are the first results for Atlantic mackerel and generally in the Mediterranean.

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Accepted: 5 July 2001

Struktura populacije, reprodukcija, starost i rast skuše, *Scomber scombrus* L. u Jadranskom moru

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SAŽETAK

U ovom se radu iznose rezultati izučavanja strukture populacije, razmnožavanja, starosti i rasta skuše, *Scomber scombrus* L. iz mjesečnih uzoraka lovina s ribolovnog područja istočnog dijela Jadranskog mora tijekom razdoblja 1991-1993.

Obrađeno je kupno 1048 primjeraka. Prikazano je i kolebanje lovina ove pelagičke vrste za razdoblje 1950 - 1992.

Izračunate su srednje dužine određene starosti skuše u svrhu utvrđivanja parametara rasta von BERTALANFFY-jeve jednadžbe: L_∞= 42.0 cm, K = 0.37 god^{-1} i t_0 = - 0.5. Indeks snage rasta ϕ je iznosio 2.8146. Ustvrđeno je 9 prstenova rasta ove vrste: od 0 do 8+, koji su odredili devet godina starosti skuše. Ustvrđen je i dužinsko-maseni odnos ove vrste: W = 0.0014 L_S 3.6036, prosječni kubični faktor kondicije (K') koji je iznosio K' = 0.8434, te naposlijetku i srednji empirijski faktor kondicije C = 0.1193.