



Length-weight relationship and maturity of the Atlantic mackerel *Scomber scombrus* from the Adriatic Sea (Eastern Mediterranean)

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Abstract: The Atlantic mackerel, *Scomber scombrus*, is widely distributed throughout the Mediterranean Sea. Most studies on *S. scombrus* have been realized from the Atlantic Sea and updated information about this species in the Mediterranean Sea is still poor. Data on *S. scombrus* sampled in the South Adriatic Sea have been analysed to elucidate seasonal and annual pattern of weight-length relationship and maturity of gonads. A total of 828 specimens were analysed from November 2000 to October 2001. The Atlantic mackerel is confirmed as a winterspawner species. A negative allometry was established during the spawning period for total and gutted fish weight analysis, which recorded the same trend during the year. Otherwise the annual allometry coefficient "b" values showed, for both sexes, an isometric and an allometric (negative) growth for total and gutted fish weight respectively. No differences among sexes were observed.

Résumé : Relations taille-poids et maturité chez le maquereau atlantique *Scomber scombrus* de la Mer Adriatique (Méditerranée Orientale). La plupart des études sur *S. scombrus* ont été réalisées sur des spécimens de l'Atlantique et les informations récentes sur cette espèce en Méditerranée sont rares. Les données acquises sur des spécimens récoltés dans le sud de la Mer Adriatique ont été analysées pour élucider les variations saisonnières et annuelles des relations taille-poids et de la maturité des gonades. Un total de 828 spécimens a été analysé de novembre 2000 à octobre 2001. L'étude confirme que le maquereau Atlantique est une espèce qui se reproduit l'hiver. Une allométrie négative a été établie pendant la saison de reproduction d'après une analyse du poids total et du poids éviscéré, montrant la même tendance toute l'année. Les valeurs annuelles du coefficient d'allométrie « b » ont montré pour les deux sexes une croissance isométrique et allométrique (négative) pour le poids total et le poids éviscéré respectivement. Aucune différence entre les sexes n'a été observée.

Keywords: Length-weight relationship, Maturity, Teleostei, *Scomber scombrus*, Adriatic Sea.

Introduction

The length-weight relationship is an important parameter that gives useful information on stock conditions such as

biomass estimate from length data, condition estimate and for comparisons of life histories of the species between regions (Banegal & Tesh, 1978; Goncalves et al., 1996; Froese & Pauly, 1998).

This study deals with the seasonal and annual patterns of the length-weight relationships and its relation with the gonadosomatic index values of the Atlantic mackerel, *Scomber scombrus*, Linnaeus, 1758 in the Adriatic Sea.

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The Atlantic mackerel is much exploited in the fishing industry. According to FAO reports, it is the species most actively fished by Spanish, Italian, Greek and Turkish fleets (Collette & Nauen, 1983). The mackerel holds a central role in the trophic chain of the Mediterranean ecosystem, being an essential food of larger pelagic fish and sea mammals. It eats large quantities of Clupeids and pelagic crustaceans. Most studies on *Scomber scombrus* are from the Atlantic Sea (Mackay, 1979; Hamre, 1980; Simard et al. 1992; Studholme et al., 1999). Otherwise update informations about this species in the Mediterranean Sea are still very poor (Campillo, 1992; Petrakis & Stergiou, 1995; Sinocvic, 1995, 2001).

Materials and methods

Specimens were collected from commercial landings of professional catches by purse seine in the port of Bari, during the programme: "Fisheries and population structure of *Scomber spp.* in the Mediterranean and South Iberian Atlantic waters" funded by EU (Tsangridis et al., 2002).

A total of 828 specimens (461 females and 367 males) were examined randomly from November 2000 to October 2001. Fork length measured from the snout to the fork of caudal fin (FL; 0.5 cm), total weight (TW; 0.1 g), gutted weight (GW; 0.1 g), weight of gonads (GW; 0.01 g) and sex, were used for analysis. Maturity stages were defined according to the appearance of the gonads observed in situ, using the maturity six stages scale described by Nikolsky (1963) and consequently modified. The data were assembled in four maturity stages: immature, maturing, mature and post-spawning (stages I, II, III and IV).

The data were pooled over three seasonal periods according to the similarity of the weight-length relationship parameters: December-March, May-July and August-

November. Most specimens were mature in the December-March period.

The length-weight relationships were elaborated by sex, both on annual and seasonal scale, according to the equation: $W = a \cdot FL^b$. Weight and FL data were log-transformed, and linearized relationships fitted by least square regression were used to calculate coefficients "a" (intercept) and "b" (allometry) (Sparre & Venema, 1996).

Student's t-test was used to evaluate the isometric growth and to compare the slope among sexes and periods.

The gonadosomatic index (Table 1) was calculated by sex according to the equation: $GSI = [(weight\ of\ gonads\ (g)) / 100 / gutted\ weight\ (g)]$.

Sex ratio (M/F) was also calculated.

Results

Atlantic mackerel lengths ranged for males from 19.5 to 38.0 cm FL (mean 27.45 ± 3.09) and for females from 19.5 cm to 37.5 cm FL (mean 27.6 ± 2.91) (Table 1). The mean value obtained showed that females were not significantly larger than males ($P < 0.01$). The weight values were included between 50.7 and 501.5 g, and between 54.4 and 595.3 g, for gutted and total weight respectively.

The annual allometry coefficient "b" for the length-total weight was 2.93 for females and 2.94 for males (Table 1). These values were not significantly different from value 3. Comparing the "b" values, no significant difference amongst the two sexes was observed. Moreover, the annual regression coefficient of the length-total weight for the total of specimens sampled (Fig. 1a) was also calculated ($b = 2.953$) showing an isometric growth (Fig. 1a, Table 1).

Regarding the seasonal regression coefficient values, significant differences ($P < 0.001$) for both sexes during December-March and May-July and during December-

Table 1. Length-weight relationship parameters for total and gutted weights of *Scomber scombrus* during 3 season periods. (n) number of specimens; (FL range) fork length range in cm; (a) intercept; (b) allometry coefficient; (SE) standard error of b; (s) significance level of b vs 3; (s') among sex for the same season (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$).

Tableau 1. Paramètres de la relation taille-poids chez *Scomber scombrus* pendant 3 périodes saisonnières. (n) nombre de spécimens ; (FL) gamme de taille en cm ; (a) ordonnée à l'origine ; (b) coefficient d'allométrie ; (SE) erreur standard de b ; (s) niveau de signification de b par rapport à 3 ; (s') entre les sexes pour une même saison (* $p < 0,05$, ** $p < 0,01$, *** $p < 0,001$).

Season	Sex	n	FL range	TOTAL WEIGHT (g)						GUTTED WEIGHT (g)					
				a	b	SE (b)	r	s	s'	a	b	SE (b)	r	s	s'
Dec - Mar	F	178	20-37.5	0.206	2.711	0.053	0.969	***	ns	0.214	2.644	0.051	0.968	***	ns
	M	148	20.5-38	0.189	2.765	0.051	0.976	***	ns	0.179	2.770	0.049	0.977	***	ns
May - July	F	164	25-31.5	0.060	3.589	0.192	0.827	**	ns	0.064	3.516	0.176	0.843	**	ns
	M	117	24.5-31	0.076	3.429	0.179	0.873	*	ns	0.069	3.464	0.148	0.909	**	ns
Aug - Nov	F	119	19.5-31.5	0.072	3.412	0.077	0.972	***	ns	0.076	3.355	0.082	0.967	***	ns
	M	102	19.5-31.5	0.085	3.296	0.073	0.976	***	ns	0.082	3.305	0.076	0.974	***	ns
Annual	F	461	19.5-37.5	0.150	2.929	0.053	0.933	ns	ns	0.173	2.799	0.051	0.933	***	ns
	M	367	19.5-38	0.139	2.981	0.052	0.949	ns	ns	0.159	2.852	0.046	0.956	**	ns

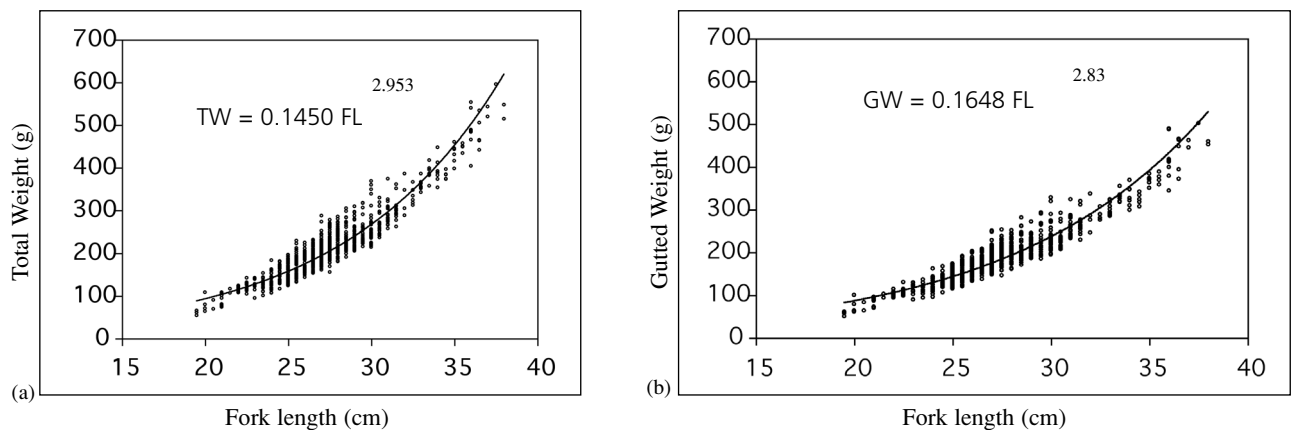


Figure 1. Annual relationship between weight (a: total weight; b: gutted weight) and fork length of the Atlantic mackerel *Scomber scombrus* for both males and females.

Figure 1. Relation annuelle entre le poids (a : poids total ; b : poids éviscéré) et la longueur totale du maquereau atlantique *Scomber scombrus*, mâles et femelles confondus.

March and August-November were observed. The allometry coefficient was significantly different from 3 in both sexes in each period. In particular, a negative allometry was detected in the first period: otherwise a positive allometry was observed from late spring to autumn.

However, the annual coefficient for the length-gutted fish weight relationship was significantly less than value 3 for

both sexes (Table 1) and differs from the regression coefficient of the length-total weight relationship ($P < 0.1$). The annual regression coefficient for combined sex was $b = 2.830$ (Fig. 1b, Table 1).

The trend of the gonadosomatic index during the year, for males and females, was synchronous (Table 2). The spawning period was observed from December to March

Table 2. Number of specimens (n), mean fork length (FL) and gonadosomatic index (GSI) of *Scomber scombrus* by sex and month for each maturity stage.

Tableau 2. Nombre d'individus (n); longueur moyenne (FL) et indice gonadosomatique (GSI) de *Scomber scombrus* en fonction du sexe, pour chaque mois et pour chaque stade de maturité.

month	sex	n	%	Stage I		%	Stage II		%	Stage III		%	Stage IV	
				range FL	GSI		range FL	GSI		range FL	GSI		range FL	GSI
Nov-00	F	19	26.4	22.4	0.517	36.8	23.8	0.965	—	—	—	36.8	24	0.929
	M	17	94.2	24	0.409	5.8	20.5	0.799	—	—	—	—	—	—
Dec-00	F	12	—	—	—	—	—	—	100	28.5	7.225	—	—	—
	M	16	—	—	—	—	—	—	100	26.4	9.009	—	—	—
Jan-01	F	58	—	—	—	—	—	—	100	24.3	11.27	—	—	—
	M	42	—	—	—	—	—	—	100	23.5	7.71	—	—	—
Feb-01	F	54	—	—	—	—	—	—	100	29.1	10.15	—	—	—
	M	46	—	—	—	—	—	—	100	28.9	9.752	—	—	—
Mar-01	F	54	—	—	—	7.4	29.5	1.4888.9	33.3	7.58	3.7	30.7	0.707	—
	M	45	—	—	—	4.4	29.7	0.7695.6	33.3	10.19	—	—	—	—
Apr-01	—	—	—	—	—	—	—	—	—	—	—	—	—	—
May-01	F	35	5.7	29.2	0.35	—	—	—	—	—	—	94.3	27.6	0.59
	M	65	33.8	26.8	0.206	—	—	—	—	—	—	66.2	26.7	0.592
Juin-01	F	76	40.8	26.4	0.152	48.7	26.4	0.618	10.5	27.2	0.66	—	—	—
	M	22	86.3	26.3	0.56	9.2	26.2	0.726	4.5	25.5	0.878	—	—	—
Juil-01	F	53	24.5	27.7	0.57	75.5	27.5	0.667	—	—	—	—	—	—
	M	30	30	27.4	0.145	70	27.5	0.665	—	—	—	—	—	—
Aug-01	F	23	21.7	25.6	0.196	78.3	25.6	0.712	—	—	—	—	—	—
	M	22	95.4	25.5	0.166	4.6	26.5	0.468	—	—	—	—	—	—
Sep-01	F	18	22.2	26	0.19455.6	25.3	0.744	22.2	26.3	0.71	—	—	—	—
	M	22	90.9	25.2	0.164	9.1	26.2	0.545	—	—	—	—	—	—
Oct-01	F	59	20.4	28.4	0.239	—	—	—	—	—	—	79.6	28.4	1.042
	M	41	70.7	28.1	0.638	9.8	27.8	0.738	—	—	—	19.5	27.8	0.467

when almost all specimens were at the maturity stage III and the highest GSI was recorded (Table 1). Otherwise a period of sexual rest from May to November was observed. The smallest mature female was 20.0 cm of FL and the smallest males was 20.5. In the three periods the sex ratios were always in favour of females.

Discussion

Many ecological (quantity and size of food, temperature, salinity etc.) and biological (i.e. maturity) factors may affect the weight-length relationship parameters of many species during different period of the year (Pauly, 1984; Weatherley & Gill, 1987; Dulcic & Kraljevic, 1996; Andrade & Campos, 2002). In this respect the use of the monthly and seasonally parameters instead of the annual ones is suggested (Dulcic & Kraljevic, 1996; Andrade & Campos, 2002).

The data here discussed support this opinion; in fact the oscillations of allometry coefficient during the year are large. The lowest coefficient values (negative allometry) were obtained during the spawning period (winter) both for total and gutted weight analysis, which recorded the same trend during the year. Otherwise the annual "b" values showed, for both sexes, an isometric and allometric (negative) growth for total and gutted fish weight respectively.

It is worth noting that, comparing annual and seasonal regression values, the relationship made on gutted fish weights showed always an allometric growth, otherwise the values obtained from total weight showed two different types of growth. These variations are obviously linked to food availability and mainly to the reproduction process. In fact, during gonadic maturation, the growth of gonads would increase and the somatic growth would decrease.

Moreover the data regarding the spawning period confirm that *Scomber scombrus* is a winterspawner species as previously assessed for the Adriatic Sea by other authors (Gamulin, 1954; Hure, 1960, 1961; Gamulin & Hure, 1983; Sinovcic, 2001).

Comparing seasonal and annual length-weight relationships in the two sexes, an homogeneity of relative growth, which evolves in the same way in relation to time, was observed in the sexes.

Observing the values of the allometry coefficient coming from different areas, such as Newfoundland (Moore, 1975), the Bay of Biscay and the Celtic Sea (Dorel, 1985), the North-east Atlantic (Coull et al., 1989), the Gulf of Lion (Campillo, 1992), the Aegean Sea (Petrakis & Stergiou, 1995) and the Eastern Adriatic (Sinovcic, 1995), these are always greater than those we found here.

So, besides the monthly variations, the allometry coefficient seems to show a high variability between

different stocks coming from different Atlantic and Mediterranean sites.

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