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Biometry markers of chub mackerel, *Scomber japonicus* Houttuyn, 1782, in the Adriatic Sea

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The aim of the study was to present biometric analyses of chub mackerel, Scomber japonicus *Houttuyn, 1782, from catch samples caught in the eastern Adriatic Sea between January 1998 and December 2008. Nine morphometric and eight meristic characters were analysed. The fork length (FL) of all observed specimens (N=4,157) ranged from 10.1 to 39.1 cm (mean ± SD: 23.8 ± 4.68 cm). All analysed length-length relationships were linear with high values of the coefficients of determination (r2>0.750). Males had significantly larger body depth than females as well as significantly larger number of soft rays in the pectoral fin; therefore, the possibility of sexual dimorphism was noted.*

Key words: morphometrics, meristics, *Scomber japonicus,* Adriatic Sea

INTRODUCTION

Chub mackerel (*Scomber japonicus* Houttuyn, 1782), is a coastal pelagic fish species that usually lives between the surface and depths of 250 or 300 m (BAUCHOT, 1987). It is a geographically widespread species that inhabits the moderate and warm waters of the Atlantic, Pacific and Indian Oceans (COLLETE & NAUEN, 1983). It is also rather frequent in the Mediterranean and its adjacent seas (Black Sea, Adriatic Sea) (WHITEHEAD *et al.,* 1986). Together with other small and middle pelagic fish species, chub mackerel is an essential element of the marine ecosystem due to its biomass at intermediate levels of the food web, playing a relevant role in associating the lower and upper tropic levels (RICE, 1995; BAKUN, 1996; CURY *et al.,* 2000). Besides its importance in the food web, chub mackerel is also a commercially important fish that is traditionally exploited in the Adriatic by purse seiners (National fishery statistics). During the year, it migrates towards the coastline and channel areas for spawning that lasts from April until September (ČIKEŠ KEČ & ZORICA, in press). After spawning, adults and their offspring migrate to deeper and colder offshore areas (NIKOLSKY, 1954). Chub mackerel is also well adapted to vertical daily migrations which are driven by feeding activities (MAIGRET & LY, 1986).

Biometric data of this species in the Adriatic Sea, as well as in general, are rather scarce. The main aim of this study was to report on biometric markers of the chub mackerel population inhabiting the Adriatic Sea, in order to contribute to morphometric studies of this species generally used for discrimination of fish populations (SABORIDO-REY & NEDREAAS, 2000; PALMA & ANDRADE, 2002).

MATERIAL AND METHODS

Monthly samples of *S. japonicus* were collected between January 1998 and December 2008 during the night with artificial light using purse seine nets with a stretched mesh size of 8-10 mm. The purse seine is the preferred fishing gear for capturing fish species which school or aggregate, close to the surface, including sardines, mackerels, anchovies, herrings and some species of tuna.

A total of 4,157 chub mackerels were sampled and analysed in the laboratory immediately after the landing, among which 1,085 were males and 1,620 were females.

Morphometric measurements of chub mackerel body dimensions were performed on fresh fish. All lengths were measured to the nearest 0.1 cm. Nine morphometric characters were measured: total length (*TL*), fork length (*FL*), anal length (*AL*), head length (HL), eye diameter (*ED*), body depth (*BD*), length of the first (*LDF1*) and the second (*LDF2*) dorsal fin basis, as well as the length of pectoral fin (*LPF*) (Fig. 1). Specimens were dissected for macroscopic sex determination, so all biometry results were separated regarding sex and overall sample. All the specimens were also weighed to the nearest 0.01 g.

All morphometric characters were expressed as a percentage of fork length (*FL*), except the fork length itself and eye diameter (*ED*), which was expressed as a percentage of total length (*TL*) and the head length (*HL*), respectively. All length-length relationships as well as relative relationships of each body dimension ratio in relation to fork length were established using linear, power and exponential regression analyses.

Eight meristic characters were taken: number of spines and rays in first (*DF1*) and second dorsal (*DF2*), in pectoral (*PF*) and in anal fin (*AF*), number of pinnulae on the ventral (*PV*) and dorsal (*PD*) body part, number of branchiospines in the first right branchial arch (Brsp) and number

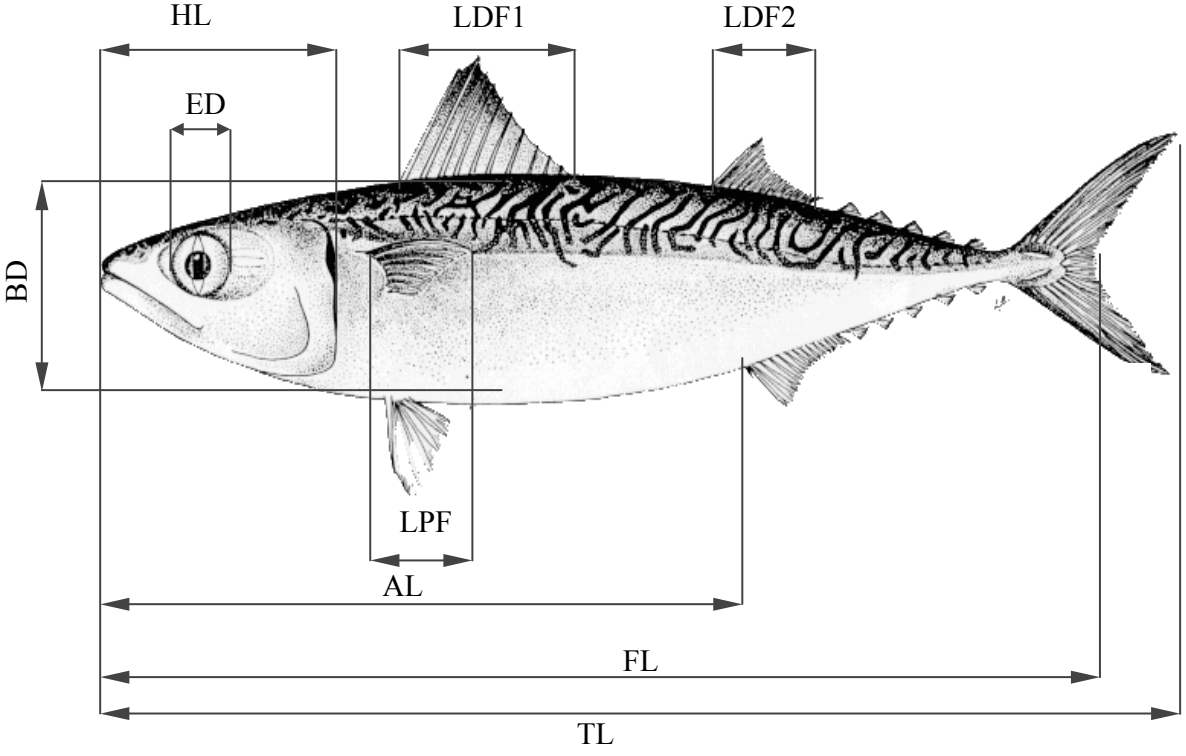

Fig. 1. Schematic drawing of chub mackerel body with measured dimensions: TL - total length, FL - fork length, AL - anal length, HL - head length, ED - eye diameter, BD - body depth, LDF1 - length of the first dorsal fin basis, LDF2 - length of the second dorsal fin basis, LPF - length of the pectoral fin

of vertebrae (Vert). After morphometric measurements, the number of vertebrae was determined, from radiographs taken by X-ray (121 cm, 40 kV, 2.5 mAs), from the occipital condyle (not counted) to the urostyle (included).

Mean value ($\bar{x}$), standard deviation (*s*) and coefficient of variation (*CV*) were used to process the numerical data. Parameters (a) and (b) of the relationship, as well as the coefficient of determination (r^2) were estimated through the Student t-test. Statistical analyses were performed with SPSS 5.5 software package and a level of significance of α=0.05 was accepted.

RESUTLS

Biometric characteristics

Fork length and weight for overall analysed specimens (*N* = 4,157) ranged from 10.1 to 39.1 cm (mean ± *SD*: 23.8 ± 4.68 cm) and from 8.90 to 804.50 g (mean ± *SD*: 164.49 ± 102.70 g), respectively. The fork length of males (*N*=1,085) varied from 17.9 to 38.8 cm (mean ± *SD*: 26.0 ± 3.83 cm, modal at 25.5 cm) and for females (*N*=1,620) from 14.9 to 39.0 cm (mean ± *SD:* 25.3 ± 3.45 cm, modal at 23.5 cm).

Table 1. Relative relationship of measured body dimension ratios of male (♂), female (♀) and overall specimens (tot, non determined sex included) of chub mackerel from the eastern Adriatic Sea catch samples (N, is the sample size, $\bar{x}$ -mean value, SD -standard deviation, V(%) –coefficient of variation, r2- determination coefficient, t- value of Student t-test for linear regression parameter)

Body proportion	Sex	*N*	Range (%)	$\bar{x} \pm SD$	*V (%)*	Regression parameters: Equation	r^2	t
FL/TL	♂	1027	85.3-97.6	91.9 ± 0.012	1.42	*FL* = 0.910 *TL*- 0.237	0.996	0
	♀	1483	81.1-98.4	91.9 ± 0.013	1.34	*FL* = 0.927 *TL*- 0.216	0.994	
	tot	4007	80.6-98.4	91.8 ± 0.013	1.38	*FL* = 0.922 *TL* -0.109	0.997	
AL/FL	♂	566	48.2-77.4	61.7 ± 0.030	4.87	*AL* = 0.651 *FL*- 0.902	0.936	0.72
	♀	895	43.4-83.3	61.6 ± 0.031	5.03	*AL* = 0.635 *FL*- 0.499	0.929	
	tot	2070	43.4-96.0	61.7 ± 0.028	4.53	*AL* = 0.623 *FL* -0.140	0.974	
HL/FL	♂	566	14.8-26.8	23.6 ± 0.012	6.00	*HL* = 0.227 *FL*+ 0.215	0.923	0.79
	♀	895	16.9-37.6	23.5 ± 0.013	5.27	*HL* = 0.215 *FL* +0.523	0.909	
	tot	2070	14.8-37.6	23.9 ± 0.014	5.55	*HL* = 0.214 *FL* +0.572	0.965	
BD/FL	♂	558	13.7-24.1	18.3 ± 0.015	8.40	*BD* = 0.205 *FL*-0.620	0.896	4.50 *
	♀	901	12.3-24.6	17.9 ± 0.015	8.23	*BD* = 0.184 *FL*-0.139	0.877	
	tot	2059	12.3-24.6	18.0 ± 0.015	8.04	*BD* = 0.187 *FL*-0.193	0.949	
LDF1/FL	♂	582	6.0-22.4	14.3 ± 0.018	12.86	*LDF1* = 0.127 *FL*+0.463	0.796	0.17
	♀	914	6.0-18.3	14.3 ± 0.017	11.97	*LDF1* = 0.118 *FL*+0.659	0.785	
	tot	2138	6.0-22.4	14.5 ± 0.017	11.87	*LDF1* = 0.127 *FL*+0.426	0.907	
LDF2/FL	♂	582	7.7-19.5	10.9 ± 0.015	12.50	*LDF2* = 0.108 *FL*-0.055	0.884	1.90
	♀	914	7.1-19.7	10.7 ± 0.014	13.79	*LDF2* = 0.108 *FL*-0.079	0.876	
	tot	2138	7.1-19.7	10.8 ± 0.014	12.77	*LDF2* = 0.098 *FL*+0.225	0.855	
LPF/FL	♂	582	8.7-16.6	12.2 ± 0.009	7.48	*LPF* = 0.108 *FL*+0.338	0.888	1.01
	♀	914	9.2-16.7	12.2 ± 0.010	7.91	*LPF* = 0.113 *FL*+0.211	0.874	
	tot	2138	8.7-16.7	12.3 ± 0.009	7.63	*LPF* = 0.115 *FL*+0.179	0.950	
ED/HL	♂	566	19.2-40.6	25.5 ± 0.022	8.76	*ED* = 0.159 *HL*+0.591	0.782	1.77
	♀	881	15.4-33.9	25.2 ± 0.022	8.58	*ED* = 0.168 *HL*+0.516	0.750	
	tot	2055	15.4-40.6	25.1 ± 0.023	9.07	*ED* = 0.228 *HL*+0.132	0.813	

**Results show a statistically significant difference between sexes, p<0.05*

Total weight of males ranged between 22.95 and 710.60 g (mean ± *SD*: 213.50 ± 114.69 g), whereas for females it varied from 16.51 to 701.66 g (mean ± *SD*: 186.16 ± 92.22 g). The fork lengths of males, females and overall were distributed according to the normal distribution (Kolmogorov-Smirnov test: d= 0.0505 males, d= 0.0375 females and d= 0.0450 total; P<0.05).

Results of the morphometric characteristic ratios, length-length equations and relevant parameters are given in Table 1. The maximum ratio range of chub mackerel morphometric relationships was noted for AL/FL (ΔAL/FL = 52.6% in total sample). On the other hand LPF/FL had the minimal range (ΔLPF/FL = 7.5% for females). With the exception of these two morphometric relationships, other obtained ratios ranged from 10.4% to 21.4% for males, and from 12.6% to 18.5% for chub mackerel females.

Mean values of morphometric relationships varied slightly between sexes from 0% (FL/TL, LDF1/FL, LPF/FL*)* to 0.004% (BD/FL). In all relationships where differences occurred, males had larger mean values than females. A statistically significant difference was established only in the relationship BD/FL (t=4.48). Namely, males had a significantly larger body depth than females.

Table 2. Relative relationship of meristic characteristics of male (♂), female (♀) and overall spe cimens (tot, non determined sex included) of chub mackerel from the eastern Adriatic Sea catch samples (N is the sample size, $\bar{x}$ - mean value, SD - standard deviation, V(%) – coefficient of variation)

Meristic characters	Sex	*N*	Range	$\bar{x}$ ± *SD*	*Mod*	*V(%)*
DF1	♂	233	IX - XI	9.34 ± 0.61	IX	6.58
	♀	529	IX - XI	9.36 ± 0.41	IX	4.35
	tot	1000	VIII - XI	9.39 ± 0.30	IX	3.19
DF2	♂	233	XII	12.00 ± 0	XII	0
	♀	529	XII	12.00 ± 0	XII	0
	tot	1000	X - XIII	11.94 ± 0.38	XII	3.18
PF *	♂	233	15 - 22	18.92 ± 1.29	19	6.84
	♀	529	15 - 22	18.61 ± 0.80	19	4.28
	tot	1000	15 - 22	18.45 ± 0.58	18	3.15
AF	♂	233	I + 11-12	11.98 ± 0.79	I +12	6.55
	♀	529	I + 11-13	12.00 ± 0.52	I +12	4.35
	tot	1000	I + 11-13	11.98 ± 0.38	I +12	3.17
PD	♂	233	5	5.0 ± 0	5	0
	♀	529	5	5.0 ± 0	5	
	tot	1000	5	5.0 ± 0	5	
PV	♂	233	5	5.0 ± 0	5	0
	♀	529	5	5.0 ± 0	5	
	tot	1000	5	5.0 ± 0	5	
Brsp	♂	233	36 - 47	42.31 ± 3.37	43	7.96
	♀	529	36 - 47	42.15 ± 1.81	43	4.23
	tot	1000	36 - 47	42.00 ± 1.33	43	3.17
Vert	♂	233	31	31.0 ± 0	31	0
	♀	529	31	31.0 ± 0	31	0
	tot	1000	30 - 31	31.0 ± 0.98	31	3.16

**Results show a statistically significant difference between sexes, p<0.05*

Coefficients of variation (*CV*) of body proportions were more evident in males than females. Thus, males had higher coefficients of variation than females for FL/TL, ED/HL, BD/FL, LDF1/FL and LDF2/FL. On the other hand, females had higher values of this coefficient for AL/FL, LH/FL and LPF/FL.

Linear regressions showed the best accuracy for all length-length relationships. Among obtained length-length relationships, the best fit was recorded between total length (TL) and fork length (FL) (r^2= 0.997), while the lowest value of coefficient of determination was established between eye diameter (ED) and head length (HL) (r^2= 0.750).

Obtained relative morphometric relationships were also analysed as a function of fork length and the best fit was recorded with linear regressions. The coefficients of linear regression point to the fact that bigger specimens of *S. japonicus* have a longer total length (TL/FL; *a*= 0.027; r^2= 0.010), anal length (AL/FL; *a*= 0.027; r^2= 0.010) and body depth (BD/FL; *a*= 0.026; r^2= 0.004). At the same time, they have a smaller head length (HL/FL; *a*= -0.057; r^2= 0.029), length of first (LDF1/FL; *a*= -0.042; r^2= 0.007) and second dorsal fin (LDF2/FL; *a*= -0.075; r^2= 0.035) and also smaller length of pectoral fin (LPF/FL; *a*= -0.078; r^2= 0.035) and eye diameter (ED/HL; *a*= -0.134; r^2= 0.004) than the smaller specimens.

Meristic characters of *S. japonicus*, their range, mean values and coefficients of variation are presented in Table 2. All analysed specimens had the same number of spines in the second dorsal fin (DF2*),* number of pinnulae on the ventral (PV) and dorsal (PD) body part and number of vertebrae *(*Vert*)*. The greatest aberrance was noticed in number of branchiospines *(*Brsp*)*.

Even though slight differences in numbers between males and females for some meristic characters were noted (DF1 t= 0.42; AF t= 0.37; Brsp t= 0.56), only one was statistically significant. Namely, males had a statistically significant larger number of soft rays in the pectoral fin (t= 3.24) than the females.

Coefficients of variation of chub mackerel meristic characters were more evident in males than in females *(*DF1, PF, AF, Brsp*)*, although overall values of this coefficient were very low (<7.96%).

DISCUSSION

As genetic and morphological data have revealed the clear existence of two chub mackerel groups, i.e. the Mediterranean and the South Atlantic (SCOLES *et al*., 1998; ROLDAN *et al.,* 2002), the analogies of data presented in this study with the data given by other authors are made only for those specimens caught in the Mediterranean and adjacent seas.

The presented fork length distribution of the chub mackerel adults caught in the eastern Adriatic Sea ranged between 10.1 and 39.0 cm. The observed length frequency distribution was more or less in agreement with the results reported for this species in the Mediterranean and its adjacent seas (SEVER *et al*., 2006; TUGGAC, 1957; KIPARISSIS *et al*., 2000) caught with the same fishing gear. It seems that this length structure pattern might be common for chub mackerel adults collected with purse seiners. As this species is also caught with pelagic trawlers, possible differences in the length distribution between these two fishing gears are to be investigated.

All analysed length-length relationships were linear and very well fitted (r^2>0.750); increments among the lengths were proportional. In the Adriatic Sea, the fork length of chub mackerel goes from 1.0 to 1.8 times in the total body length of this species. Anal length ranges from 1.0 to 2.3, head length from 2.7 to 6.7, body depth from 4.1 to 8.1, length of the first dorsal fin from 4.5 to 16.8, length of second dorsal fin from 5.1 to 14.1, length of pectoral fin goes from 6.0 to 11.5 times in the fork length of S. japonicus, while eye diameter goes from 2.5 to 6.5 times in the head length of this species.

The relationship between fork and total length of chub mackerel in the Adriatic Sea has been determined as 92.7%. The same relationship given by MOUTOPOULOS & STERGIOU (2002) for the population inhabiting Greek waters was much lower (73.6%). The observed aberration can be a result of the different length structure

Table 3. Meristic characteristics of Scomber japonicus in the literature for the Mediterranean and Adriatic Seas

Reference	*DF1*	*DF2*	*PF*	*AF*	Study area
Present study	VIII-XI	X - XII	15-22	I 11-13	Adriatic Sea
Tuggac (1957)	IX-X	I + 10-11	19-21(17-18)	I + I 10-12	Marmara Sea
Jardas (1996)	VIII-X	-	-	-	Adriatic Sea

of the analysed specimens (22.9-33.0 cm in Greek waters, 10.1-39.0 cm in the Adriatic Sea) which affected this relationship, or there possibly exists an actual difference among these two parameters in these two geographical areas.

The results of chub mackerel meristic characters presented in this paper and the results previously given by other authors presented in Table 3 are rather similar, apart from second dorsal fin counts. According to the past literature data (TUGGAC, 1957), in the second dorsal fin, only the first ray was spine. This was not the case in this study - all rays were spines. Furthermore, observing the worldwide habitats of this species, some authors also reported only spines in the second dorsal fin (COLLETE & NAUEN, 1983).

Vertebrae number and number of pinnule presented in the present study (31 vertebrae and 5+5 pinnule) were in agreement with the only other reported results, though not from the Mediterranean, obtained by COLLETE & NAUEN (1983) who found 31 vertebrae and 5+5 pinnulae and ROEDEL (1952) who also established that out of 2,352 analysed specimens from the California Bay, 99.6% had 31 vertebrae, 0.1% had 30 vertebrae and 0.3% had 32 vertebrae, drawing attention to the homogeneity of this species population as regards the noted aspects.

In this study, for the first time the possibility of sexual dimorphism was noted. It was evident that the males had a significantly larger body depth than females as well as the significantly larger number of soft rays in the pectoral fin. Nevertheless, the differentiation between males and females regarding the number of rays or body depth needs further investigation and analysis.

Morphometric studies have proved to provide an insight into discrimination of marine stocks (KINSEY *et al.,* 1994). However, as the variability of morphometric as well as meristic characters of the species inhabiting different geographical regions have both environmental (BARLOW, 1961) and genetic components (ROLDAN *et al.,* 2002) further and more detailed investigations, especially concerning genetic structure, should be carried out. Nevertheless, this biometric type of analysis could be sufficient for fisheries management purposes.

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Biometrijske značajke lokarde *Scomber japonicus* Houttuyn, 1782 u Jadranskom moru

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SAŽETAK

U ovom su radu prikazani rezultati istraživanja biometrijskih značajki populacije lokarde, *Scomber japonicus* iz istočnog dijela Jadrana. Korištene su komercijalne lovine iz razdoblja siječanj 1998. - prosinac 2008. godine. Analizirano je devet morfometrijskih i osam merističkih značajki. Vilične dužine svih analiziranih jedinki (N=4157) kolebale su između 10,1 i 39,1 cm (23,8 ± 4,68 cm). Svi dužinsko-dužinski odnosi su pokazali linearnu ovisnost s visokim koeficijentima determinacije (r^2>0,750). Uočena je mogućnost spolnog dimorfizma; mužjaci su imali statistički značajnije deblje tijelo kao i veći broj nečlankovitih šipčica u prsnoj peraji nego ženke.

Ključne riječi: morfometrija, meristika, *Scomber japonicus*, Jadransko more