

## Biometry, length-length and length-weight relationships of juveniles and adults of Atlantic bonito, *Sarda sarda*, in the eastern Middle Adriatic Sea

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*This paper presents some biological features of juvenile and adult specimens of Atlantic bonito, *Sarda sarda* (Bloch, 1793), in the eastern middle Adriatic Sea. A total of 194 specimens were analysed, of which 93 were juveniles and 101 were adults. Juvenile individuals ranged from 5.7 to 8.4 cm while adults ranged from 39.3 to 56.7 cm.*

*In order to analyse biometry, nine morphometric characters were analysed. Length-length equations for overall converted body lengths of fish were linear. Comparison of length-length relationships between juvenile and adult specimens showed statistically significant differences in almost all morphometric characteristics, except for the fork length-second dorsal fin base. Females insignificantly prevailed in adults. Overall gonads were in post-spawning state. Juveniles were unsexed. Length-weight relationships of juveniles and adults were  $W = 0.0033LF^{3.424}$  and  $W = 0.0149LF^{2.984}$ , respectively.*

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**Key words:** *Sarda sarda*, Adriatic Sea, juveniles, biometry, length-weight relationship

### INTRODUCTION

The Atlantic bonito, *Sarda sarda* (Bloch, 1793), besides *Auxis rochei* (Risso, 1810) is one of the most abundant small tuna-like species which exists with a wide ranging distribution spanning tropical and temperate areas of the Atlantic ocean, including the Mediterranean and Black Sea (YOSHIDA, 1980; SABATÉS & RECASENS, 2001). In the Adriatic Sea this species is distributed in bays and open sea waters, especially in the middle and southern parts (JARDAS, 1983). Considering the abundance and commercial importance of this species in the Mediterranean and in the eastern Atlantic, as well as

in the Adriatic Sea, the objective of the present study was to examine the pattern and extent of differences in morphological properties between Atlantic bonito juvenile and adult specimens which has very important consequences on common assumptions made in stock assessments.

### MATERIAL AND METHODS

*Sarda sarda* juvenile specimens were noted for the first time in the Adriatic Sea. Namely, Atlantic bonito juveniles (n=93) were collected by beach seine (mesh size of 8 mm) in August 2005 in the Zrmanja River estuary-Novigrad Sea (44° 15'N; 15° 30'E). For the purpose of

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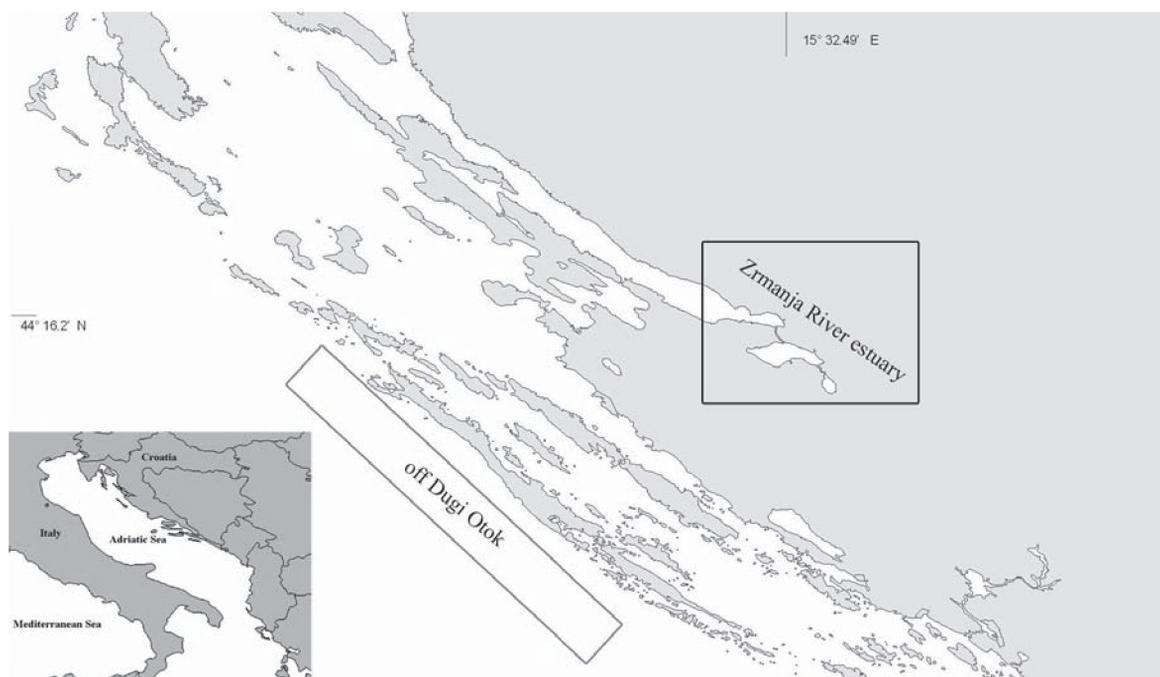


Fig.1. Sampling areas of the Atlantic bonito, *Sarda sarda*, in the eastern Adriatic Sea

comparison of their morphology to adult specimens, adults ( $n=101$ ) were collected in October 2007 from commercial catches that had used purse seines in the open sea waters of the eastern middle Adriatic Sea (Fig.1).

Atlantic bonito specimens were analysed immediately after landing. Morphometric measurements were taken to the nearest 0.1 cm. The weight of each fish was recorded by digital scale with accuracy of  $\pm 0.01$  g. Sex was determined according to the shape and appearance of the gonads; assessment of gonad maturity stages was determined by macroscopical scale (SINOVIĆ, 1978). Nine morphometric measurements ( $LT$  – total length,  $LF$  – fork length,  $LA$  – distance of anal fin,  $LH$  – head length,  $LD1$  – first dorsal fin base,  $LD2$  – second dorsal fin base,  $LP$  – pelvic fin,  $ED$  – eye diameter,  $BD$  – max. body depth) were examined (Fig. 2). They were expressed as % of fork length ( $LF$ ). Fork length was expressed as % of total length ( $LT$ ) (Fig. 2).

Statistical differences between juveniles and adults, as well as the hypothesis of isometric growth test, were determined by Student's  $t$ -test (ZAR, 1966). Fish specimen distribution was

tested with the Kolmogorov-Smirnov (K-S) test (SIEGEL & CASTELLAN, 1988).

Length-length relationships were determined by the least squares method to fit a simple linear regression model. Length conversion equations were derived for fork length ( $LF$ ).

To establish the length-weight relationship, the commonly used relationship  $W = aL^b$  was applied (RICKER, 1975), where  $W$  is the weight (g),  $L$  is the fork length (cm),  $a$  is the intercept (condition factor) and  $b$  is the slope (growth coefficient, i.e. fish relative growth rate). The parameters  $a$  and  $b$  were estimated by the least squares linear regression on log-log transformed data:  $\log W = \log a + b \log L$ . The coefficient of determination ( $r^2$ ) was used as an indicator of the quality of the linear regression.

## RESULTS

The fork length of analysed *S. sarda* juveniles varied from 5.7 to 8.4 cm and body weight from 1.09 to 5.24 g. The mean values and standard errors ( $S.E.$ ) of weight and fork length, which were used for all relationship analyses, were between  $3.23 \pm 0.66$  g and  $7.4 \pm 0.44$  cm,

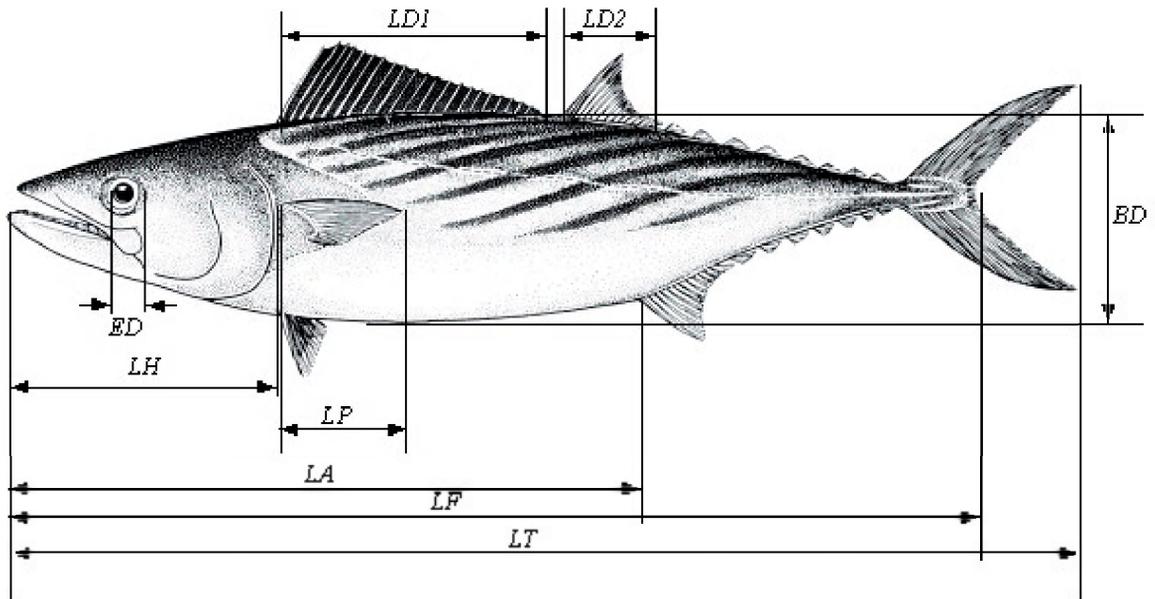


Fig. 2. Morphometric characteristics of the Atlantic bonito, *Sarda sarda*

respectively. Fork length of all 101 analysed adult *S. sarda* specimens ranged from 39.3 to 56.7 cm and the mean value was  $49.78 \pm 0.31$  cm. Their body weight ranged from 905.5 to 2908.8 g with a mean value of  $1747.18 \pm 30.95$  g. The length frequency distributions of juvenile and adult specimens of Atlantic bonito are shown in Fig. 3.

Overall data of relative morphometric relationships of measured body proportions for Atlantic bonito juveniles and adults are presented in Table 1. The ranges of all observed morphometric relationships were within narrow limits – their variability coefficients ( $V$ ) were relatively low (Table 1). The Kolmogorov-Smirnov test ( $d = 0.299, P < 0.01$ ) obtained for separate data sets

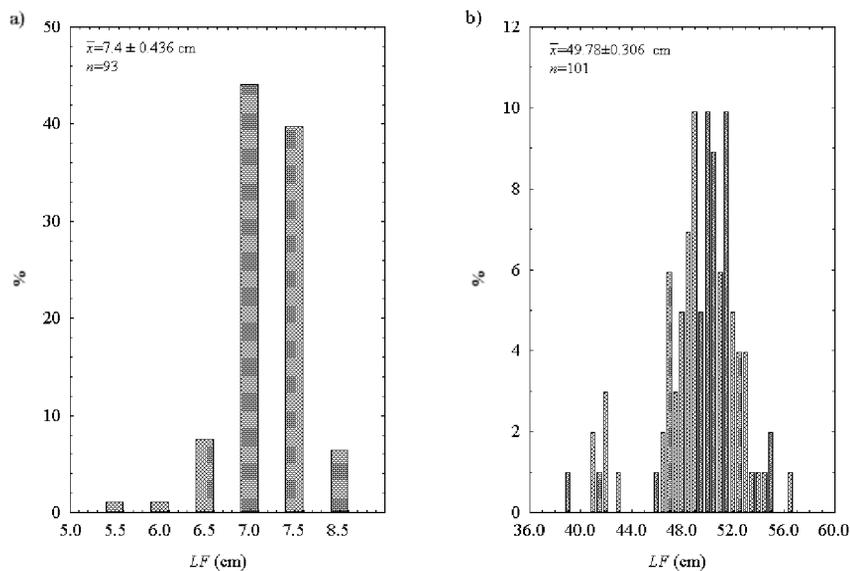


Fig. 3. Length frequency distributions of juveniles (a) and adults (b) of the Atlantic bonito, *Sarda sarda*, from catch samples collected in the eastern Middle Adriatic Sea

Table 1. Morphometric characters of Atlantic bonito *Sarda sarda* juvenile ( $n = 93$ ) and adult ( $n=101$ ) specimens from the eastern Middle Adriatic Sea

Relation	Stage	Range (%)	$\bar{x} \pm S.E.$ (%)	$t$	$V$ (%)
$LF/LT$	juvenile	90.80 – 97.06	$94.574 \pm 0.129$	19.307*	1.541
	adult	74.39 – 93.07	$90.236 \pm 0.180$		3.275
$LA/LF$	juvenile	57.89 – 66.67	$62.287 \pm 0.218$	5.202*	4.431
	adult	58.78 – 75.12	$63.666 \pm 0.156$		2.455
$LC/LF$	juvenile	22.08 – 27.85	$24.093 \pm 0.098$	7.740*	0.895
	adult	20.11 – 27.04	$22.910 \pm 0.116$		1.348
$O/LF$	juvenile	4.05 – 6.94	$5.536 \pm 0.064$	46.479*	0.378
	adult	2.14 – 3.02	$2.599 \pm 0.015$		0.023
$H/LF$	juvenile	12.28 – 20.25	$15.162 \pm 0.106$	53.426*	1.037
	adult	20.71 – 26.05	$22.557 \pm 0.091$		0.828
$LD1/LF$	juvenile	11.91 – 16.89	$14.118 \pm 0.118$	98.522*	1.297
	adult	27.51 – 35.81	$30.312 \pm 0.114$		1.318
$LD2/LF$	juvenile	7.14 – 13.70	$10.165 \pm 0.174$	0.205	2.808
	adult	8.70 – 12.20	$10.202 \pm 0.072$		0.520
$LP/LF$	juvenile	5.95 – 10.53	$9.006 \pm 0.080$	38.682*	0.602
	adult	11.43 – 14.88	$12.494 \pm 0.045$		0.202

\*  $P < 0.05$ 

of juveniles and adults confirmed a normal distribution for both data sets. Statistically significant differences between juvenile and adult specimens were established for almost all morphometric characteristics, except for the second dorsal fin base length ( $LD2$ ).

The estimated parameters of the length-length relationships as well as the coefficients of determination ( $r^2$ ) are presented in Table 2. All observed length-length relationships of juvenile and adult specimens are linear. The best fit for juvenile length-length relationships was recorded between total length ( $LT$ ) and fork

length ( $LF$ ) ( $r^2 = 0.978$ ). The lowest value of determination coefficient was found between the fork length ( $LF$ ) and the length of the second dorsal fin base of juveniles ( $LD2$ ) ( $r^2 = 0.277$ ) as well as of adults ( $r^2 = 0.553$ ). The highest length-length relationship coefficient for adult Atlantic bonito specimens was for the  $LF-LA$  relationship ( $r^2 = 0.964$ ) (Table 2).

Of 101 analysed adult specimens, 46 were males and 55 were females. Sex could not be determined for juveniles. An insignificant preponderance of females over males was observed ( $\delta/\text{♀} = 0.84$ ), which insignificantly deviat-

Table 2. Length-length relationships of *S.sarda* juveniles ( $n=93$ ) and adults ( $n=101$ ) from the eastern Middle Adriatic Sea

Juveniles		Adult	
Equation	$r^2$	Equation	$r^2$
$LT = 1.109LF - 0.384$	0.978	$LT = 1.094LF + 0.298$	0.751
$LA = 0.627LF - 0.027$	0.870	$LA = 0.635LF - 0.010$	0.964
$LC = 0.237LF + 0.031$	0.826	$LC = 0.223LF + 0.296$	0.780
$O = 0.071LF - 0.117$	0.566	$O = 0.021LF + 0.223$	0.675
$H = 0.197LF - 0.339$	0.758	$H = 0.215LF + 0.483$	0.840
$LD1 = 0.080LF + 0.450$	0.400	$LD1 = 0.283LF + 0.948$	0.866
$LD2 = 0.082LF + 0.143$	0.277	$LD2 = 0.072LF + 1.459$	0.553
$LP = 0.073LF + 0.130$	0.480	$LP = 0.129LF - 0.205$	0.902

ed from the hypothetical distribution of 1:1 ( $\chi^2 = 0.63$ ; d.f. = 1;  $P < 0.05$ ). All analysed specimens showed the post-spawning stage of gonads (stage VII, according to SINOVIĆ, 1978) indicating the end of spawning.

The length-weight relationships for juvenile and adult specimens of *S. sarda* are shown in Fig. 4. The equation for juvenile specimens is:  $W = 0.0033LF^{3.424}$ ;  $r^2 = 0.9399$  and for adult individuals:  $W = 0.0149LF^{2.984}$ ;  $r^2 = 0.9585$ . The functional regression value ( $b$ ) derived from the length-weight relationships indicated a positive allometry for juvenile specimens ( $b = 3.424$ ;  $t = 10.78$ ,  $P > 0.05$ ), while for adult specimens isometric growth was established ( $b = 2.984$ ;  $t = 0.007$ ,  $P > 0.05$ ). The allometry coefficient difference between the juvenile and adult coefficients of allometry is statistically significant ( $t = 107.22$ ,  $P < 0.05$ ).

## DISCUSSION

The analysed morphological variation among *S. sarda* juveniles and adults collected in the eastern part of the Adriatic Sea showed that the differences between juvenile and adult specimens were statistically significant. They

are probably associated with growth rate oscillations during their life span.

Conversion among fish length variations, in other words, relationships between fork length ( $LF$ ) and all other examined body measures ( $LT$ ,  $LA$ ,  $LC$ ,  $O$ ,  $H$ ,  $LD1$ ,  $LD2$ ,  $LP$ ) indicated that overall body lengths were linearly increasing with fork length (Table 2) and are in accordance with earlier investigations of *S. sarda* adults from catch samples from the same part of the Adriatic Sea (FRANIČEVIĆ *et al.*, 2005).

Although females slightly prevailed in the samples collected in 2007, the sex ratio was not significantly different from 1:1. Macroscopic investigation of all *S. sarda* gonads, which were spent (maturity stage VII, according to SINOVIĆ, 1978), suggested that all analysed individuals were adults in a post-spawning period. The current findings support the data obtained by FRANIČEVIĆ (2001) who reported the monthly variation of maturity stages and  $GSI$  values in both sexes of *S. sarda*. Namely, Franičević (*ibid.*) established that the spawning period of *S. sarda* in the Adriatic Sea occurs between May and November, while maximum gonad development occurs simultaneously for both sexes in the July-August period. The finding of juveniles in the Adriatic Sea is very important, as prior to

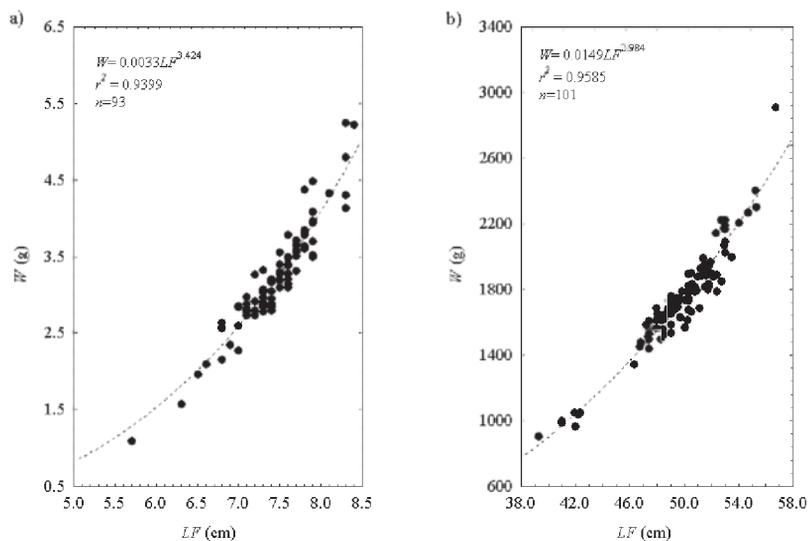


Fig. 4. Length-weight relationships for (a) juveniles and (b) adults of the Atlantic bonito, *Sarda sarda*, from catch samples collected in the eastern Middle Adriatic Sea

our study no reported data of this species recruitment existed. The analysed juvenile specimens originated from early spawning parent stock and their eggs and larvae probably passively immigrated from offshore waters where they spawn (FRANIČEVIĆ, 2001) into the Novigrad Sea where they found the best environmental conditions, just like other small pelagic fish species (SINOVIĆ, 1998).

The length-weight relationship of juvenile Atlantic bonito specimens showed a positive allometry in relation to the fork length ( $b = 3.424$ ), whereas the adults grew isometrically ( $b = 2.984$ ). Thus, it seems that during the juvenile phase Atlantic bonito specimens showed a proportionally higher weight increase than length increase. When they reached the adult phase, their growth became isometrical. Significant variations in fish growth in terms of length and weight can be explained as an adaptive response to different ecological conditions (season, feeding, state of gonads, habitat) (NIKOLSKY, 1963; BAGENAL & TESCH, 1978; WOOTTON, 1992). Thus, positive allometry was observed in *S. sarda* from the eastern Atlantic and western Mediterranean ( $b=3.164$ ;  $LF = 19.0-71.5$  cm; REY *et al.*, 1984) and in the eastern Adriatic Sea ( $b = 3.123$ ;  $LF = 33.0-67.0$  cm; FRANIČEVIĆ *et al.*, 2005). The negative allometry

for the same species was reported from the N.E. Atlantic ( $b = 2.877$ ;  $LF = 22.0-83.5$  cm; MORATO *et al.*, 2001), S.W. Atlantic ( $b = 2.952$ ;  $LF = 33.0-77.0$ ; HANSEN, 1987), W. Mediterranean ( $b = 2.9719$ ;  $LF = 36.0-67.5$  cm; RODRIGUEZ-RODA, 1966) and the E. Mediterranean and Black Sea ( $b = 2.870$ ;  $LF = 14.0-90.0$  cm; KARA, 1979).

The current findings present biometrical features and differences between juvenile and adult *S. sarda* from the Adriatic Sea that are essential for the stock assessment of this species. Further biological studies on the reproductive biology, length at maturity, age and growth would be very useful to supplement information on this species for its complete biology.

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## **Biometrija, dužinsko-dužinski i dužinsko-maseni odnosi juvenilne i adultne palamide, *Sarda sarda* (Bloch, 1793), u istočnom srednjem Jadranu**

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### **SAŽETAK**

U radu su analizirani juvenilni i adultni primjerci palamide, *Sarda sarda* (Bloch, 1793), prikupljeni na području istočnog dijela srednjeg Jadranskog mora. Ukupno je obrađeno 194 primjerka, od čega je 93 juvenilnih i 101 adultni. Analizom biometrijskih svojstava zabilježene su promjene morfometrijskih odnosa s porastom vilične dužine ( $LF$ ), te je utvrđeno da postoji statistički značajna razlika između morfometrijskih odnosa juvenilnih i adultnih primjeraka palamide, osim kod odnosa  $LF-LD2$ . Spol je bilo moguće odrediti samo kod adultnih primjeraka, gdje su brojčano neznatno dominirale ženke. Analizom stanja gonada utvrđeno je da su se svi adultni primjerci izmrijestili. Kod juvenilnih primjeraka dužinsko-masenim odnosom je utvrđena pozitivna alometrija ( $b = 3.424$ ), dok je kod adultnih primjeraka utvrđena izometrija ( $b = 2.984$ ).

**Ključne riječi:** *Sarda sarda*, Jadransko more, juvenilni primjerci, biometrija, dužinsko - maseni odnos

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