ISSN: 0001-5113
AADRAY

ACTA ADRIAT.,
46 (2): 213 - 222, 2005

UDC: 597.5:591.134(262.3)
Original scientific paper

# Biometry analysis of the Atlantic bonito, *Sarda sarda* (Bloch, 1793), in the Adriatic Sea

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*This paper presents the biometry analysis of the Atlantic bonito,* Sarda sarda *(Bloch, 1793), population in the eastern mid Adriatic Sea for 1997-2000. A total of 665 specimens were analyzed. Fork length ranged 33.0-67.0 cm. Nine morphometric and seven meristic characters were assessed. Sexual dimorphism was noticed in two meristic and three morphometric characters. The relation between total length and fork length is presented. Relative growth was studied by comparing changes in morphological characters with growth in fork length. Length-weight relationship is presented as well.*

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

## INTRODUCTION

Knowledge of biometric variations is necessary in descriptions of species. As a rule, specimens originating from different areas differ from one another in morphology. The Atlantic bonito, *Sarda sarda* (BLOCH, 1793), is a widely distributed epipelagic, neritic, schooling species that can adapt to gradual changes in the environment, but is susceptible to sudden ones (COLLETTE & NAUEN, 1983). Biogeographically, it belongs to the Atlantic-Mediterranean region (JARDAS, 1983) and is distributed along tropical and temperate coasts of the Atlantic Ocean (including the Gulf of Mexico), the Mediterranean, and the Black Sea (COLLETTE & CHAO, 1975; YOSHIDA, 1980). Biometric variation in *S. sarda* from different areas was described by COLLETTE & CHAO (1975) using a morphometric approach. PUJOLAR *et al.* (2001) and VIÑAS *et al.* (2004) studied the patterns of differentiation in two sub-populations of Atlantic bonito inhabiting the Mediterranean. In the Adriatic, the species is distributed in bays and open waters, especially in the mid and southern parts. The present study aimed to determine the variation of meristic and morphometric characters of Atlantic bonito caught in the eastern mid Adriatic.

## MATERIAL AND METHODS

Twenty-one samples containing 665 specimens of *S. sarda* were collected from purse seine commercial catches in Croatian fishing grounds in the eastern mid Adriatic Sea from June 1997 to September 2000 (Fig. 1).

Body lengths were measured to the nearest millimeter and total weight to the nearest 0.01 g. Sex was determined macroscopically. Nine

morphometric characteristics were examined (Fig. 2): total length (LT), fork length (LF), length from head to anal fin (LA), head length (LH), pelvic fin length (LP), eye diameter (ED), length of first dorsal fin base (LD1), length of second dorsal fin base (LD2), and maximum body depth (BD). Seven meristic characteristics were examined: number of spines in the first dorsal fin (D1), number of pectoral rays (P), number of dorsal finlets (NPD), number of anal finlets (NPV), number of gillrakers (Brsp), number of vertebrae (Vert), and number of teeth (Dent). The vertebrae were counted from the occipital condyle to the urostyle, inclusive. Meristic characteristics were considered absolute values while morphometric characteristics were relative to the fork or head length. The significance of differences between males and females was tested by *t* test.

Length-length relationships were determined by the method of least squares to examine morphometric changes occurring with increases of fork length. The relationship between the length and weight of the fish was estimated using the equation $W = aLF^b$ (RICKER, 1975), where W is the weight of the fish, LF is the fork length, and *a* and *b* are constants. STUDENT's *t* test was applied to determine the significance of differences (95% level) between the isometric growth ($b = 3$) and the estimated *b* value of the equation.

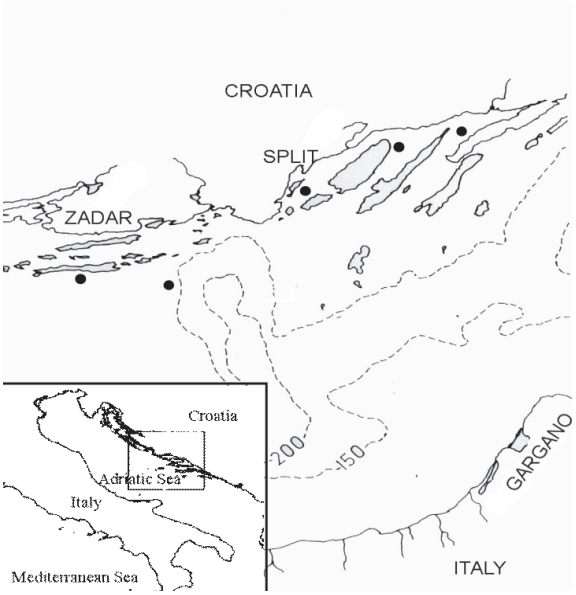


*Fig. 1. Sampling area of the Atlantic bonito,* Sarda sarda*, in the eastern mid Adriatic Sea*

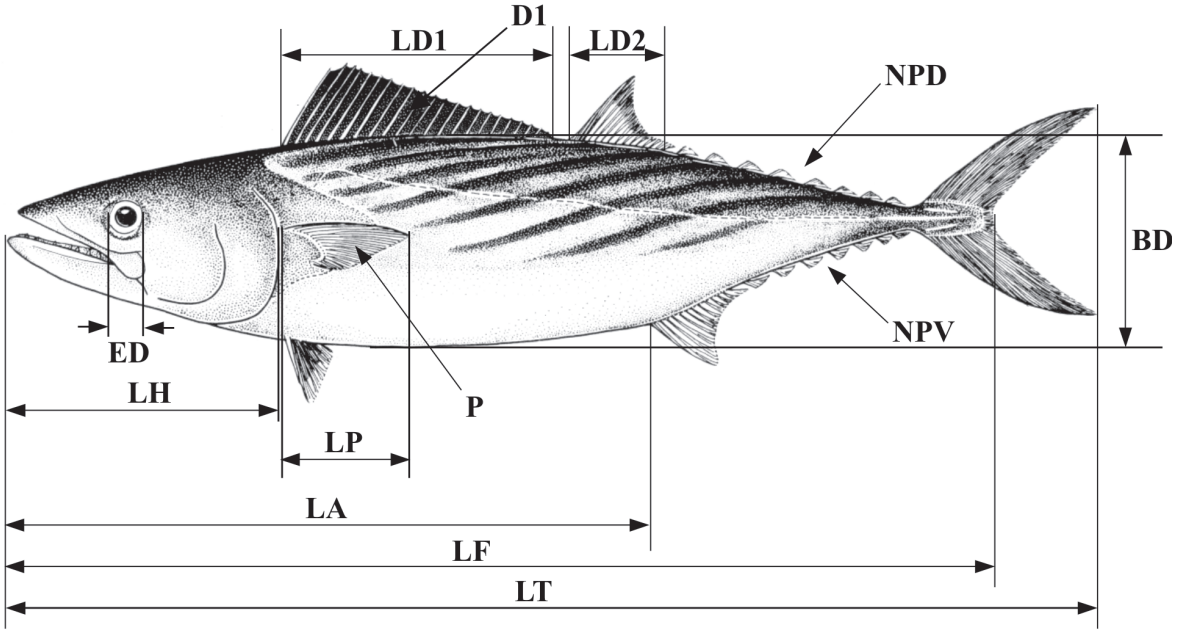


*Fig. 2. Meristic and morphometric characteristics of the Atlantic bonito,* Sarda sarda

## RESULTS

### Length frequency distribution

Of the 665 specimens, 353 were females (53.08%), 285 were males (42.86%), and 27 (4.06%) were of undetermined sex. Fork lengths ranged 33.0-67.0 cm with a mean of 42.2±6.077 cm and mode of 38.0 cm (7.07%; Fig. 3). Fork length in males ranged 35.0-67.0 cm with a mean of 43.2±6.269 cm and mode of 40.0 cm. Fork length in females ranged 33.0-64.5 cm with a mean of 41.8±5.889 cm and mode of 38.0 cm (8.22%). There were no significant differences between sexes in overall mean fork length ($t$ = 1.054; $t_{crit}$ = 1.96).

The ranges and mean fork lengths and $t$ test results comparing males with females are presented for each year of the investigation (Table 1). The mean fork lengths did not significantly differ between sexes in 1997 but they did in 1998. The two dominant length groups were 38.5 cm (11.69%) and 39.0 cm (13.33%). Males were more abundant in the 38.5 cm length group and females in the 39.0 cm length group. During 1999, the mean fork length of males was significantly higher than that of females. Males had a mode of 40.0 cm (12.61%), females of 38.0 cm (9.35%), and the total sample 38.5 cm (8.12%). In 2000, male and female fork lengths did not significantly differ.

*Table 1. Fork lengths* (LF) *and means* (±SD) *of Atlantic bonito males, females, and totals, by year*

| Year | Sex | n | LF (cm) | $\bar{x}$ ± SD (%) | $t$ |
|---|---|---|---|---|---|
| 1997 | ♂ | 42 | 35.0-50.0 | 42.54±5.705 | 0.512 |
| | ♀ | 42 | 35.5-50.5 | 43.12±5.625 | |
| | total | 84 | 35.0-50.5 | 42.83±5.639 | |
| 1998 | ♂ | 77 | 35.0-56.0 | 42.08±6.661 | 2.771* |
| | ♀ | 120 | 33.0-57.0 | 39.60±5.195 | |
| | total | 210 | 33.0-57.0 | 40.28±5.846 | |
| 1999 | ♂ | 119 | 36.0-67.0 | 41.98±4.614 | 5.093* |
| | ♀ | 139 | 34.5-54.0 | 40.67±3.300 | |
| | total | 271 | 34.5-67.0 | 40.86±3.349 | |
| 2000 | ♂ | 47 | 38.5-63.5 | 48.79±6.892 | 0.896 |
| | ♀ | 52 | 37.5-64.0 | 47.51±7.328 | |
| | total | 100 | 37.5-64.0 | 48.04±7.118 | |

*statistically significant ( $t$ = 1.96; $p$ = 0.05)

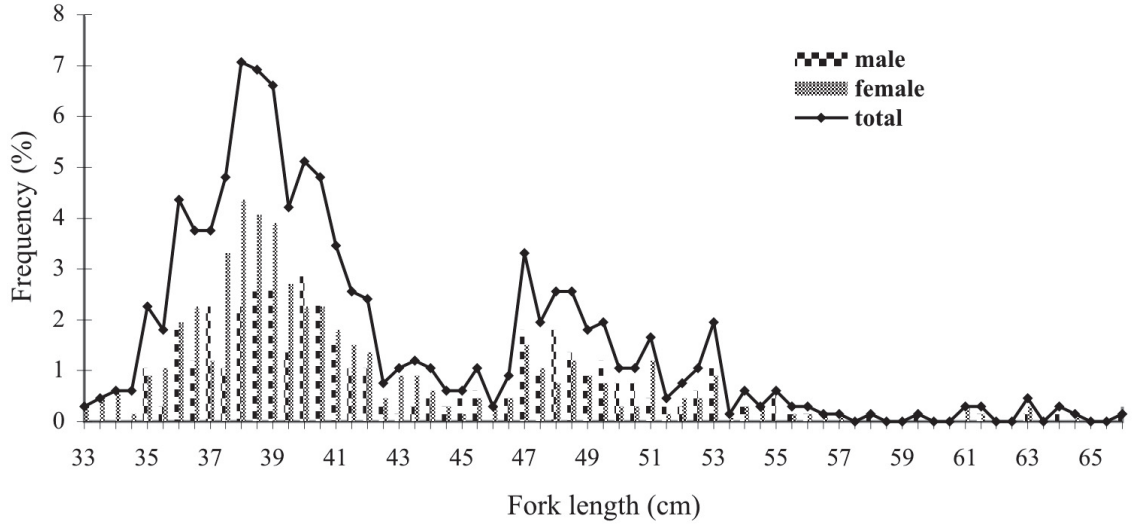


*Fig. 3. Total lengths of Atlantic bonito,* Sarda sarda*, from the eastern mid Adriatic Sea*

### Morphometric characteristics

Differences between the sexes were statistically significant in three morphometric relationships (Table 2): length of first dorsal fin base (LD1) and distance from head to anal fin (LA) in relation to fork length (LF) and eye diameter (ED) in relation to head length (LH). Length-length relationship coefficients were high ($r^2$>0.876) and significant ($p$<0.001; Table 3). All analyzed morphometric characteristics were entirely proportionate to fork lengths.

### Meristic characteristics

Data on meristic characteristics are presented in Table 4. Statistically significant differences between the sexes were found in the number of spines in the first dorsal fin (D1) and number

*Table 2. Morphometric characters of Atlantic bonito* Sarda sarda *from the eastern mid Adriatic Sea: a) by sex, b) as total*

a)

| Relationship | Sex | n | Range (%) | $\bar{x}$ ± S.D. (%) | $t$ | V (%) |
|---|---|---|---|---|---|---|
| LD1/LF | ♂ | 226 | 25.12 – 32.44 | 29.623 ± 1.0064 | 2.9362* | 3.3905 |
| | ♀ | 300 | 26.49 – 33.05 | 29.889 ± 1.0597 | | 3.5453 |
| LD2/LF | ♂ | 226 | 8.49 – 12.50 | 10.344 ± 0.7409 | 0.3522 | 7.1624 |
| | ♀ | 300 | 8.70 – 14.03 | 10.367 ± 0.7444 | | 7.1808 |
| LP/LF | ♂ | 226 | 11.50 – 14.22 | 12.653 ± 0.6218 | 0.1683 | 4.9139 |
| | ♀ | 300 | 11.11 – 14.25 | 12.622 ± 0.5871 | | 4.6917 |
| LA/LF | ♂ | 274 | 60.40 – 73.02 | 64.215 ± 1.6504 | 2.1332* | 2.5701 |
| | ♀ | 337 | 61.33 – 77.73 | 64.500 ± 1.6325 | | 2.5311 |
| LH/LF | ♂ | 274 | 21.79 – 27.94 | 24.568 ± 0.8942 | 1.8341 | 3.6396 |
| | ♀ | 337 | 20.00 – 27.36 | 24.431 ± 0.9471 | | 3.8766 |
| BD/LF | ♂ | 226 | 18.54 – 24.69 | 21.273 ± 1.2937 | 0.3006 | 6.0814 |
| | ♀ | 300 | 18.29 – 25.83 | 21.306 ± 1.1809 | | 5.5424 |
| ED/LH | ♂ | 226 | 9.68 – 18.84 | 11.609 ± 1.2166 | 2.7218* | 10.8830 |
| | ♀ | 300 | 9.68 – 17.89 | 11.910 ± 1.2961 | | 10.4795 |
| LF/LT | ♂ | 285 | 85.08 – 94.19 | 90.266 ± 1.9552 | 0.3539 | 2.1660 |
| | ♀ | 353 | 84.76 – 94.64 | 90.213 ± 1.7839 | | 1.9774 |

*statistically significant ( $t$=1.96; P=0.05)

b)

| Relationship | n | Range (%) | $\bar{x}$ ± S.D. (%) | $t$ |
|---|---|---|---|---|
| LD1/LF | 533 | 25.12 – 33.42 | 29.803 ± 1.0687 | 3.5860 |
| LD2/LF | 533 | 8.49 – 14.03 | 10.356 ± 0.7410 | 7.1549 |
| LP/LF | 533 | 11.11 – 14.25 | 12.608 ± 0.6087 | 4.8279 |
| LA/LF | 638 | 60.40 – 77.73 | 64.380 ± 1.6419 | 2.5503 |
| LH/LF | 638 | 20.00 – 27.94 | 24.471 ± 0.9462 | 3.8665 |
| BD/LF | 553 | 18.48 – 25.83 | 21.281 ± 1.2144 | 5.7064 |
| ED/LH | 553 | 9.68 – 17.89 | 11.814 ± 1.2767 | 10.8064 |
| LF/LT | 665 | 84.76 – 94.65 | 90.295 ± 1.8633 | 2.0636 |

*Table 3. Estimated parameters of Atlantic bonito* Sarda sarda *for converting morphometric characteristics to fork length (LF)*

| Sex | Equation* | n | Constant a | Slope b | $r^2$ |
|---|---|---|---|---|---|
| Males | LF = a+bLT | 285 | 0.9127 | -0.4938 | 0.9867 |
| Females | | 535 | 0.9086 | -0.3015 | 0.9884 |
| Both | | 665 | 0.9081 | -0.2625 | 0.9878 |
| Males | LD1 = a+bLF | 226 | 0.2835 | 0.5251 | 0.9684 |
| Females | | 300 | 0.2880 | 0.4414 | 0.9644 |
| Both | | 553 | 0.2839 | 0.5668 | 0.9636 |
| Males | LD2 = a+bLF | 226 | 0.1038 | -0.0255 | 0.8762 |
| Females | | 300 | 0.1055 | -0.0773 | 0.8841 |
| Both | | 553 | 0.1044 | -0.0394 | 0.8816 |
| Males | LP = a+bLF | 226 | 0.1528 | -1.1008 | 0.9702 |
| Females | | 300 | 0.1507 | -0.9918 | 0.9682 |
| Both | | 553 | 0.1522 | -1.0671 | 0.9697 |
| Males | LA = a+bLF | 274 | 0.6262 | 0.6728 | 0.9848 |
| Females | | 337 | 0.6418 | 0.1289 | 0.9820 |
| Both | | 638 | 0.6324 | 0.4690 | 0.9834 |
| Males | LH = a+bLF | 274 | 0.2221 | 0.9931 | 0.9697 |
| Females | | 337 | 0.2261 | 0.7434 | 0.9624 |
| Both | | 638 | 0.2269 | 0.7357 | 0.9649 |
| Males | BD = a+bLF | 226 | 0.2493 | -1.4673 | 0.9077 |
| Females | | 300 | 0.2090 | 0.1647 | 0.9208 |
| Both | | 553 | 0.2215 | -0.3449 | 0.9127 |

* Abbreviations as in Table 2

of finlets on the dorsal side (NPD), suggesting the existence of sexual dimorphism. Overall, the number of spines in the first dorsal fin of females was significantly higher than in males ($t$ = 2.29, $p$<0.05), while males had a greater number of finlets on the dorsal side than females ($t$ = 3.43). Comparisons of data from this study with previously published data show that there were significant differences in the number of teeth on the upper and lower jaws (Table 5).

*Table 4. Meristic characteristics of Atlantic bonito* Sarda sarda *from the eastern mid Adriatic Sea*

| Character | n | Range | $\bar{x}$±SD (%) | V (%) |
|---|---|---|---|---|
| D1 | 522 | 19-23 | 21.318±0.6026 | 2.8269 |
| P | 485 | 23-26 | 24.038±0.7361 | 3.0622 |
| NPD | 550 | 7-9 | 8.056±0.5214 | 6.4720 |
| NPV | 550 | 6-8 | 6.8652±0.452 | 6.5859 |
| Brsp | 469 | 17-23 | 20.7079±0.9795 | 4.7299 |
| Vert | 53 | 53 | 53 | - |
| Dent (upper/lower) | 37 | 38-48/30-38 | 41.53±2.984/33.79±2.451 | 7.186/7.254 |

*Table 4. cont'd*

| Character | Sex | n | Range | $\bar{x}$±SD (%) | *t* | V (%) |
|---|---|---|---|---|---|---|
| D1 | ♂ | 215 | 19-23 | 21.251±0.6501 | 2.2866 | 3.0590 |
| | ♀ | 282 | 20-23 | 21.383±0.5679 | | 2.6560 |
| P | ♂ | 195 | 23-26 | 23.979±0.7389 | 1.1219 | 3.0814 |
| | ♀ | 264 | 23-26 | 24.064±0.7189 | | 2.9872 |
| NPD | ♂ | 225 | 7-9 | 8.151±0.5381 | 3.4302 | 6.6017 |
| | ♀ | 298 | 7-9 | 7.990±0.4888 | | 6.1181 |
| NPV | ♂ | 225 | 6-8 | 6.907±0.4484 | 1.6207 | 6.4924 |
| | ♀ | 297 | 6-8 | 6.835±0.4536 | | 6.6371 |

D1 = number of spines in first dorsal fin, P = number of pectoral rays, NPD = number of dorsal finlets, NPV = number of anal finlets, Brsp = number of gillrakers, Vert = number of vertebrae, Dent = number of teeth

*Table 5. Meristic characteristics of Atlantic bonito* Sarda sarda *from various geographic regions*

| Area | D1 | P | NPD | NPV | Vert | Brsp | Dent (upper/lower) |
|---|---|---|---|---|---|---|---|
| N. America* | XX-XXIII | 23-26 | 7-9 | 6-8 | 50-53 | 16-22 | 17-22/12-19 |
| S. America* | XX-XXI | 23-26 | 7-9 | 6-7 | 50-53 | 17-21 | 16-23/14-18 |
| N.E. Atlantic* | XX-XXII | 24-26 | 7-9 | 6-8 | 51 | 18-21 | 18-25/15-24 |
| Gulf of Guinea (S. Africa)* | XXI-XXII | 23-25 | 7-9 | 6-7 | 52-55 | 18-23 | 17-24/13-19 |
| Mediterranean/Black Sea* | XXI-XXIII | 23-25 | 7-9 | 6-8 | 53-54 | 18-23 | 16-24/13-20 |
| Turkish waters** | XVII-XXIII | 22-26 | | | 52-55 | | 14-26/12-22 |
| Adriatic Sea*** | XIX-XXIII | 23-26 | 7-9 | 6-8 | 53 | 17-23 | 38-48/30-38 |

* COLLETTE & CHAO, 1975; ** DEMIR, 1964; *** this paper
Abbreviations as in Table 4

### Length-weight relationship

The analyzed specimens weighed 498.68-4500.00 g. The length-weight relationship was calculated separately for each sex and all specimens (Table 6). Correlation coefficients ($r$>0.9) showed the high correlation between estimated and empiric data for male, female, and all specimens taken together. The growth in weight relative to fork length showed positive allometry: for males b = 3.34, for females b = 3.24, and for all specimens b = 3.12. The b values significantly differed from 3.0 for males, females, and all specimens ($t$-test): for males $t$ = 6.8808, $p$>0.05, for females $t$ = 5.5609, $p$>0.05, and for all $t$ = 4.1245, $p$>0.05, and between sexes ($t$ = 10.283; $p$<0.001), with greater differences among larger specimens. Our results somewhat differ from those of other authors in different regions.

*Table 6. Comparison of relationships between fork length (LF) and weight (W) of Atlantic bonito from various regions of the Atlantic and Mediterranean where $W = aLF^b$*

| Author | Region | n | Fork length (cm) | a | b | Sex |
|---|---|---|---|---|---|---|
| HANSEN, 1987 | S.W. Atlantic | | 33.0-77.0 | 0.0135 | 2.952 | Both |
| GIACCHETTA et al., 1995 | Gulf of Taranto | 845 | | $0.0252 \times 10^{-3}$ | 2.83 | Both |
| | | 158 | | $0.0234 \times 10^{-3}$ | 2.85 | Both |
| CORT *et al*., 1995 | Gulf of Taranto | 663 | 34.0-78.0 | 0.0351 | 2.755 | M |
| | | 130 | 54.0-69.0 | 0.0311 | 2.789 | F |
| | | 105 | 52.0-65.0 | 0.0574 | 2.633 | Both |
| | | 158 | 38.0-81.0 | 0.0190 | 2.909 | Both |
| | | 833 | 36.5-80.5 | 0.0071 | 3.151 | Both |
| | E. Aegean Sea | 287 | 32.8-70.6 | 0.01640 | 2.943 | M |
| | | 111 | | 0.01708 | 2.934 | F |
| | | 134 | | 0.01672 | 2.937 | Both |
| REY *et al*., 1984 | E. Atlantic | 242 | 33.0-65.2 | 0.00653 | 3.1865 | M |
| | W. Mediterranean | 229 | 33.2-70.5 | 0.00844 | 3.1218 | F |
| | | 878 | 19.0-71.5 | 0.00724 | 3.1644 | Both |
| FARUK KARA, 1979 | Black Sea<br>Aegean Sea<br>Sea of Marmara | 1608 | 14.0-90.0 | 0.02361 | 2.8703 | Both |
| RODRIGUEZ-RODA, 1966 | W. Mediterranean | 263 | 36.0-67.5 | $1.4861 \times 10^{-5}$ | 2.9719 | Both |
| MORATO, 2001 | N.E. Atlantic | 31 | 22.0-83.5 | 0.0176 | 2.877 | Both |
| Our results | E. Adriatic | 285 | 35.0-67.0 | 0.0038 | 3.3414 | M |
| | | 353 | 33.0-64.5 | 0.0056 | 3.2364 | F |
| | | 665 | 33.0-67.0 | 0.0085 | 3.1230 | Both |

## DISCUSSION

Data presented in this paper indicate that Atlantic bonito have diverged in morphology. Differences in length frequency distribution by sex and sampling year could be related to the procedures for sampling from commercial catches, sample size, and studied length range. All former fishery surveys of this species focused on fork lengths of commercial specimens, except HANSEN (1988) who studied morphometric characteristics in relation to total length. The juvenile phase is mainly missing from the samples.

This study demonstrates the existence of meristic and morphometric variations between

sexes in Atlantic bonito. The number of spines in the first dorsal fin of females was significantly higher than in males, while males had a greater number of finlets on the dorsal side. The length of the first dorsal fin base and distance of the anal fin from the head in relation to fork length were significantly higher in females than in males ($t$ = 2.94 and $t$ = 2.13, respectively). Females had a significantly higher eye diameter in relation to head length than males ($t$ = 2.72). Examination of relationships of morphometric lengths and correlation coefficients showed that all morphometric relationships increased pro-rata with fork length.

Variation of morphometric and meristic characters in specimens from different geographical populations could be caused by differences in genetic structure or environmental conditions. The number of vertebrae is genetically fixed within narrow limits and minor aberrations are due to influences of environmental factors, especially temperature (GABRIEL, 1944; LINDSAY, 1954; BLAXTER, 1957; SINOVČIĆ, 1982). According to LARRAÑETA (1958), statistically significant differences in number of vertebrae represent independent populations. Few authors have described the meristic characters of Atlantic bonito (DEMIR 1964; COLLETTE & CHAO, 1975). The number of teeth is the only meristic character that significantly differed between this and other studies.

The growth in weight showed positive allometry in relation to fork length. There is general agreement that differences in the length-weight parameter $b$ could be a reflection of influences of the genotype or environmental or habitat factors, including the water thermal regime, salinity, food, sex, stage of maturity, disease, and season or time of capture (BAGENAL & TESCH, 1978; SHEPHERD & GRIMES, 1983; SAFRAN, 1992; JOBLING, 1997). The $b$ values changed from year to year within the same region (CORT *et al*., 1995). According to BROWN (1957) and RICKER (1958), $b$ values may range 1.4-4.0 or 2.5-4.0 (HILE, 1936; MARTIN, 1949). Comparing $b$ values of length-weight relationships from different regions showed that this value varies from negative to positive allometry. Positive allometry was observed in *S. sarda* from the east Atlantic, west Mediterranean, and east Adriatic.

The biometric results in this paper are preliminary and provide an insight into distinguishing among Atlantic bonito stocks that might be useful in fisheries management (LOWE *et al.*, 1998). These results should be verified in future genetic studies.

## ACKNOWLEDGEMENTS

This study was supported by the MINISTRY OF SCIENCE AND TECHNOLOGY OF THE REPUBLIC OF CROATIA and was part of the scientific project, Sustainable Exploitation Researches of the Adriatic Sea Resources.

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Received: 02 June 2003
Accepted: 26 June 2005

# Analiza biometrijskih svojstava palamide, *Sarda sarda* (Bloch, 1793), u Jadranskom moru

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**SAŽETAK**

U radu su analizirane biometrijske karakteristike palamide, *Sarda sarda* (Bloch, 1793), koja je prikupljena na području istočnog dijela srednjeg Jadranskog mora u razdoblju od 1997. do 2000. godine. Ukupno je obrađeno 665 primjerka ove ribe. Vilična dužina se kretala u rasponu između 33,0 i 67,0 cm. Analizirano je 9 morfometrijskih i 7 merističkih obilježja ove vrste. Utvrđeno je da je kod 3 morfometrijska i 2 meristička obilježja postojala značajna razlika između mužjaka i ženki. Zabilježene su promjene morfometrijskih odnosa s porastom vilične dužine (LF). Analizom dužinsko-masenog odnosa palamide je utvrđena pozitivna alometrija.

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