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Phenotypic characteristics of garfish *Belone belone* (Linnaeus, 1761) in the Adriatic Sea

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The results of biometrical analysis, i.e. twelve morphometric and five meristic characters of garfish, Belone belone *(L.1761.), are presented in this paper. All representative samples were collected from commercial catches in the eastern Adriatic Sea during the period from 2003 to 2008. The total length (TL) of all observed specimens (N=3393) ranged from 20.8 to 75.4 cm (38.3±7.94 cm). The sex ratio of all specimens was 1:1.*

Key words: morphometry, meristics, garfish, Adriatic, Mediterranean

INTRODUCTION

Garfish, *Belone belone* (Linnaeus, 1761), is an epipelagic migratory species that is widely distributed in the north-eastern Atlantic, Mediterranean as well as the Black Sea and is generally considered of minor commercial importance (national fishery statistics). Three subspecies have been recognised (COLETTE & PARIN, 1986): *B. belone belone* (Linnaeus, 1761) - restricted to the north-eastern Atlantic, *B. belone gracilis* Lowe, 1839 - distributed from the south of France in the Mediterranean Sea to the Canary Islands in the Atlantic, and *B. belone euxini* Günther, 1866 - which is found in the Black Sea and the Sea of Azov. Garfish are mainly found in offshore areas except for the spawning period when they migrate into coastal regions where they are also susceptible to commercial exploitation (ZORICA *et al*., 2011).

Biometric analysis is known as a powerful tool which can complement other approaches to stock identification such as genetics, mark-recapture techniques, chemical analyses of tissue and hard parts (KUMPF *et al*., 1987). The main goal of this paper was to identify the garfish stock in the Adriatic Sea according to its morphometric and meristic characteristics as these have not been systematically studied to date.

MATERIAL AND METHODS

Garfish specimens were collected monthly in the eastern part of the middle Adriatic Sea from January 2003 to December 2008 (Fig. 1). Monthly samples of *B. belone* were collected during the night using a seine net with a stretched mesh size of 10 mm (the main net) to 34 mm (the net cod end). All biometric measurements were obtained on the fresh specimens immediately after landing. Twelve morphometric variables were measured: total length (*TL*), standard length (*SL*), fork length (*FL*), preanal (*PA*) distance, head length (*LH*), eye diameter (*O*), maximum (*H*) and minimum (h) body height, length of dorsal fin (*LD*) and anal fin basis (*LA*), length of pectoral fin (*LP*), length of ventral fin (*LV*), as well as five meristic characters: number of rays in dorsal fin (*D*), in pectoral fin (*P*), in ventral fin (*V*), in anal fin

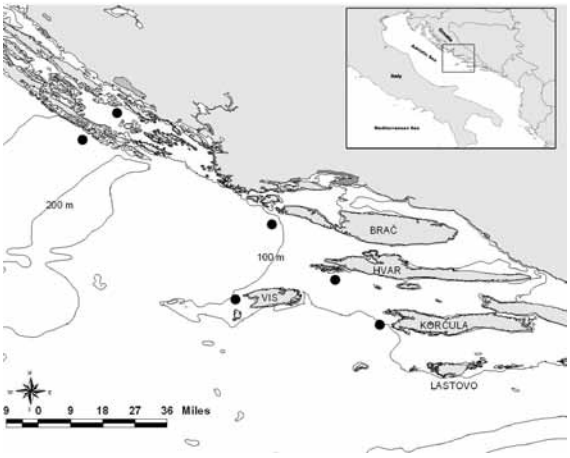

Fig. 1. Study area of the eastern Adriatic Sea with marked sampling sites

(A) and number of vertebrae (Vert), according to JARDAS (1996) (Fig. 2). The vertebrae were counted on radiographs taken by X-ray (110 cm, 40 KV, 2.5 mAs), from occipital condyle to urostyle included.

All body lengths were measured to the nearest 0.1 cm and sex was determined macroscopically. Therefore, all the biometric analyses were conducted for separate sexes and overall. Morphometric characters were expressed as % of TL, with the exception of the eye diameter (*O*) which was expressed as % of *LH*, and also minimum body height (h) which was expressed as % of maximum body height (*H*).

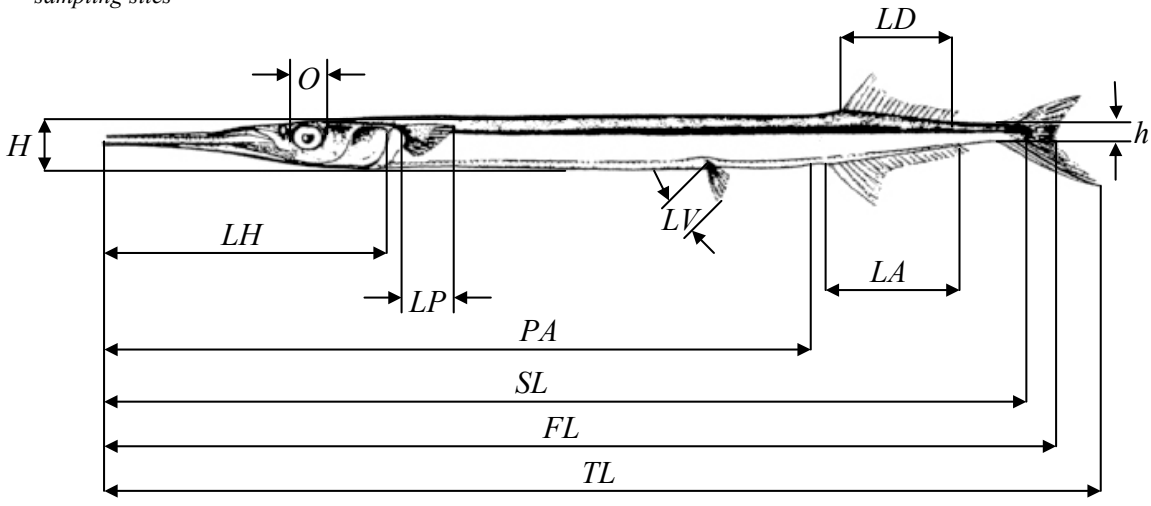

Fig. 2. Stylised drawing of body proportions measured on garfish: TL- total length, FL- fork length, SL- standard length, PA- preanal distance, LC- head length, O-eye diameter, H- maximum body height, h- minimum body height, LD- length of the dorsal fin basis base?, LA- length of anal fin basis, LP- length of pectoral fin, LV- length of pelvic fin

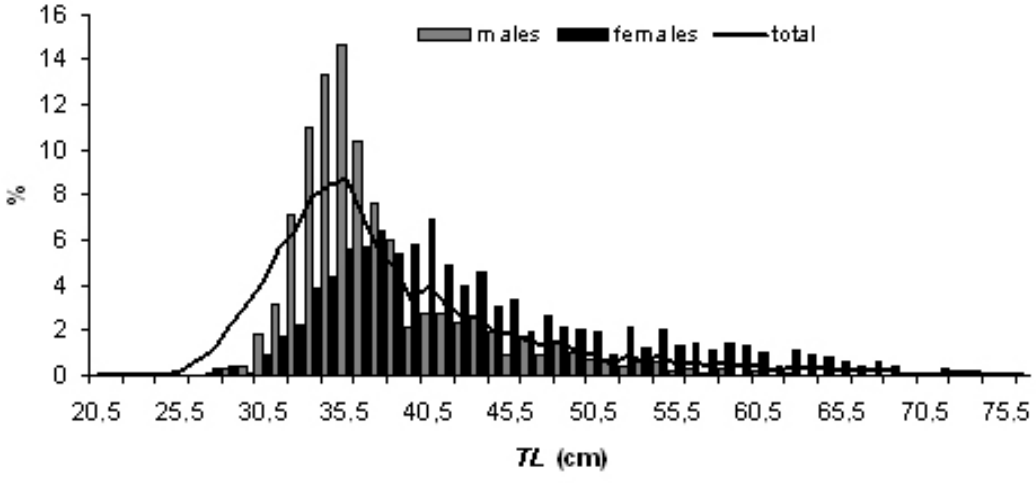

Fig. 3. Length frequency distributions of male, female and overall garfish specimens collected in the eastern Adriatic Sea, 2003 – 2008

Table 1. Relative relationships of measured body proportions of garfish Belone belone *caught in the eastern part of the middle Adriatic Sea from January 2003 to December 2008 ($\bar{x}$ - mean value; SD – standard deviation; SE - standard error of mean value; CV – coefficient of variation)*

Relation	Sex	*N*	Range (%)	$\bar{x} \pm SD$ (%)	$\bar{x} \pm SE$ (%)	*CV* (%)
FL/TL	♂	920	90.1 – 99.2	96.0 ± 0.81	96.0 ± 0.03	0.84
	♀	1013	89.3 – 99.7	96.2 ± 0.71	96.2 ± 0.02	0.74
	Total	2613	89.3 – 99.7	96.2 ± 0.74	96.2 ± 0.01	0.77
SL/TL	♂	824	87.2 – 99.2	93.6 ± 0.90	93.6 ± 0.03	0.96
	♀	1069	88.0 – 97.1	93.8 ± 0.74	93.8 ± 0.02	0.79
	Total	2583	87.2 – 99.2	93.8 ± 0.81	93.8 ± 0.02	0.86
PA/TL	♂	612	52.1 – 78.7	70.8 ± 1.32	70.8 ± 0.05	1.86
	♀	877	57.3 – 79.5	71.3 ± 1.25	71.3 ± 0.04	1.75
	Total	2081	52.1 – 79.5	71.1 ± 1.25	71.1 ± 0.03	1.76
LH/TL	♂	612	22.8 – 33.8	29.4 ± 1.59	29.4 ± 0.06	5.41
	♀	878	23.3 – 34.1	28.6 ± 1.81	28.6 ± 0.06	6.33
	Total	2082	22.6 – 36.1	29.4 ± 1.59	29.4 ± 0.04	5.61
O/LH	♂	538	6.9 – 11.8	9.0 ± 0.70	9.0 ± 0.03	7.78
	♀	790	6.1 – 13.4	8.8 ± 0.79	8.8 ± 0.03	8.98
	Total	1874	5.3 – 13.4	8.7 ± 0.89	8.7 ± 0.02	10.23
H/TL	♂	539	4.2 – 7.4	5.5 ± 0.53	5.5 ± 0.02	9.64
	♀	774	3.9 – 7.7	5.6 ± 0.61	5.6 ± 0.02	10.90
	Total	1870	3.6 – 8.1	5.5 ± 0.61	5.5 ± 0.01	11.10
h/H	♂	100	23.1 – 45.8	29.5 ± 3.52	29.5 ± 0.35	11.93
	♀	93	20.0 – 36.8	27.3 ± 4.16	27.3 ± 0.43	15.24
	Total	205	20.0 – 45.8	28.7 ± 4.15	28.7 ± 0.29	14.50
LD/TL	♂	150	8.4 – 12.8	10.9 ± 0.62	10.9 ± 0.05	5.69
	♀	305	9.3 – 12.5	10.9 ± 0.61	10.9 ± 0.03	5.60
	Total	520	8.4 – 12.8	10.9 ± 0.60	10.9 ± 0.03	5.50
LP/TL	♂	150	4.2 – 6.5	5.4 ± 0.43	5.4 ± 0.04	7.96
	♀	305	3.8 – 6.7	5.2 ± 0.43	5.2 ± 0.02	8.27
	Total	520	3.8 – 6.7	5.3 ± 0.43	5.3 ± 0.02	8.11
LA/TL	♂	150	10.9 – 15.2	13.1 ± 0.82	13.1 ± 0.07	6.26
	♀	305	8.1 – 15.1	12.9 ± 0.81	12.9 ± 0.05	6.28
	Total	520	8.1 – 15.2	13.0 ± 0.83	13.0 ± 0.04	6.38
LV/TL	♂	143	2.6 – 5.1	4.0 ± 0.42	4.0 ± 0.04	10.5
	♀	282	2.1 – 5.2	4.0 ± 0.42	4.0 ± 0.03	10.5
	Total	520	2.1 – 5.2	4.0 ± 0.41	4.0 ± 0.02	10.3

Length-length relationships were determined by the method of least squares to fit a simple linear regression model. Length conversion equations were derived for total length (TL), head length (LH) and the maximum body height (H).

Statistical analyses were performed with the SPSS 5.5 software package and a level of significance of α=0.05 was accepted.

RESULTS

All analysed specimens (*N*=3,393) varied in total length from 20.8 to 75.4 cm (mean ± *SD*: 38.3 ± 7.94 cm). The total length of males varied between 27.7 and 62.6 cm (mean ± *SD*: 37.4 ± 5.37 cm), whereas for females varied from 27.2 to 75.4 cm (mean ± *SD*: 43.6 ± 9.12 cm)

(Fig. 3). No statistically significant difference between length distribution of male and female garfish specimens collected during the entire investigated period was detected (Kolmogorov-Smirnov Test, $P<0.05$), although all specimens with TL > 62.5 cm were exclusively female. Of all garfish specimens sampled during the study 1166 were males, 1195 females and 1032 were undetermined specimens (20.8<TL<52.5 cm; mean ± SD: 33.2 ± 4.42 cm). The overall sex ratio was 0.98, which insignificantly deviated from the hypothetical distribution of 1:1 ($\chi 2$= 0.332, *d.f*=1, $P<0.05$). The results of relative morphometric relationships of measured body proportions expressed in percentages for males, females and overall are given in Table 1.

The coefficient of variation (CV) values were relatively low (CV < 16 %) for all relative morphometric relationships (Table 1). The lowest value (0.74%) was recorded for the relative relationship of fork and total body lengths (FL/TL) in females, while the highest (15.24%) was registered for the morphometric relationship of minimum and maximum body height (h/H) in females. Statistically significant differences between sexes were established in six morphometric relationships: *SL/TL* (Z=-4.23), *PA/TL* (t=-2.56), *LH/TL* (t=1.13), *O/LH* (t=3.76), h/H (t=4.45) and *LP/TL* (t=2.39). The modal values of observed relationships are presented in Figure 4. Almost all graphs were unimodal, with the exception of minimal body height (h). The relative morphometric relationships obtained were also analysed as a function of total body length (TL), head length (LH) and maximum body height (H). Namely, it was established that with the increment of garfish total body length (TL) some morphometric relationships slightly decrease such as : *FL/TL*, *LH/TL*, *LD/TL*, *LA/TL*, *LP/TL* and *LV/TL*, while three morphometric relationships: *SL/TL*, *PA/TL* and *H/TL,* minimally increase with increase of total body length. The relative morphometric relationship between eye diameter (*O*) and head length (*LH*) increases with increment of head length (*LH*). The relationship between minimum and maximum body height (*h/H*) also showed a slight increase with maximum body height (*H*) attained.

All calculated length-length relationships were fitted well by linear regression with very high values of the coefficient of correlation (r > 0.880). The estimated parameters of the length-length relationship as well as the coefficient of determination (r^2) are presented in Table 2.

Table 2. Length-length regression parameters (a,b) and coefficient of determination (r^2) of Belone belone *(N=2613) caught in the eastern part of the middle Adriatic Sea from January 2003 to December 2008*

Equation	*a*	*b*	r^2
FL=a+bTL	0.145	0.958	0.999
SL=a+bTL	-0.066	0.940	0.999
PA=a+bTL	-0.313	0.719	0.999
LH=a+bTL	2.200	0.235	0.964
O=a+bLH	-0.089	0.095	0.901
H=a+bTL	-0.529	0.069	0.930
h=a+bH	-0.006	0.290	0.775
LD=a+bTL	-0.018	0.110	0.972
LP=a+bTL	0.075	0.051	0.939
LA=a+bTL	0.527	0.117	0.961
LV=a+bTL	-0.002	0.040	0.915

Meristic counts of analysed garfish specimens are given in Table 3 for each sex separately, with the exception of vertebrae number, and overall. For all meristic characteristics coefficients of variation (CV) generally remained at low levels, with a maximum value of 6.83 % obtained for pectoral fin rays (P) and a minimum value of 1.14 % gained for anal fin rays (A). No statistically significant difference was noted between sexes for all meristic characters (*D* : t=-0.99; *P*: t=-0.14; *A*: Z=1.56; *V*: Z=-0.81).

DISSCUSION

In the present study, all 3393 garfish specimens from the eastern part of the Adriatic Sea were analysed between January 2003 and December 2008 in order to determine their morphoplogic and meristic characteristics. The obtained length frequency distribution of investigated garfish specimens inhabiting the Adriatic

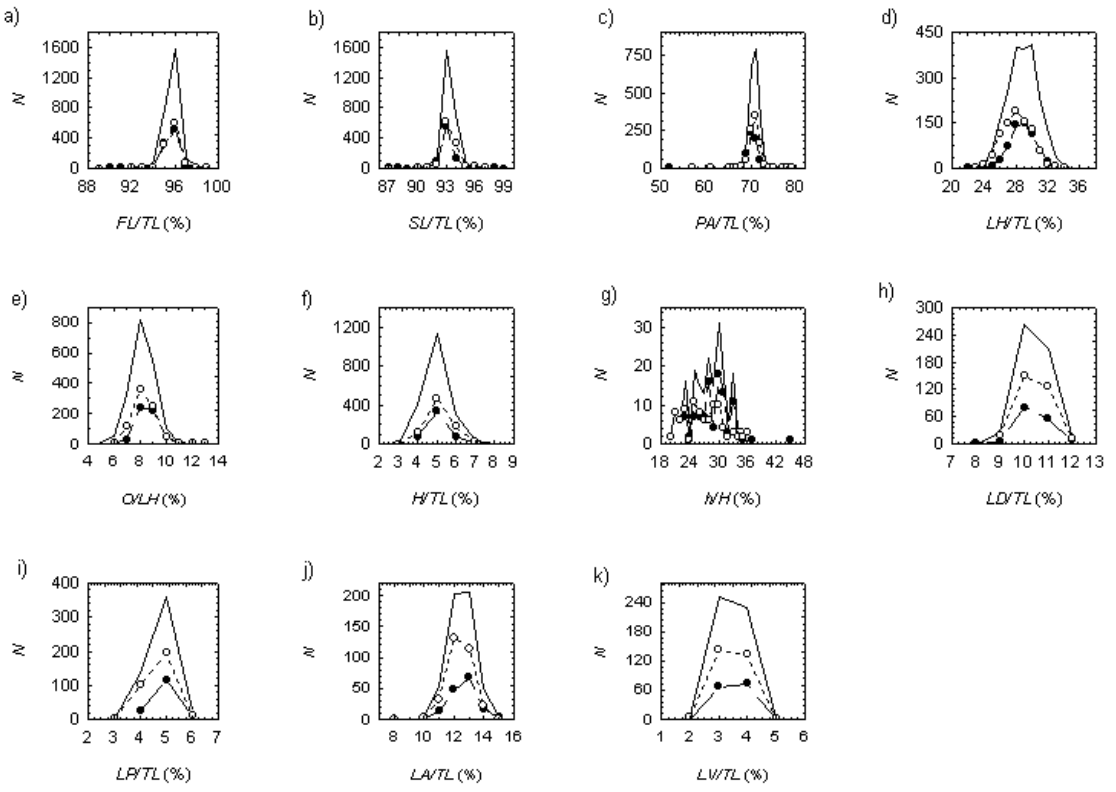

Fig. 4. Frequency distribution of relative morphometric relationships (in percentages): a) FL/TL, b) SL/TL, c) PA/TL, d) LH/TL, e) O/LH, f) H/TL, g) h/H, h) LD/TL, i) LP/TL, j) LA/TL and k) LV/TL for males (--●--), females (○) and overall (-) garfish specimens caught in the eastern Adriatic Sea, 2003 – 2008

Sea was the widest reported in comparison to the length range of the same species from the Mediterranean and Black Seas (YÜCE, 1970; BEDOUI *et al*., 2002; FEHRI-BEDOUI & GHARBI, 2004; SINOVČIĆ *et al.*, 2004; UÇKUN *et al*., 2004; SAMSUN *et al*., 2006). The noted differences in length frequency distribution could be attributed to fishing gear and its vulnerability and selectivity. The overall sex ratio showed an insignificant preponderance of females over males as was earlier reported and discussed for the same population by ZORICA *et al.* (2011) in a paper dealing with its reproduction pattern.

Morphometric values as well as their relative relationships presented in this paper were compared with data found in the literature, which were generally scarce. Values of the relative relationship between standard and total body length (*SL/TL*=93.8%) were in agreement with the data reported by SINOVČIĆ *et al.* (2004) for the Adriatic garfish population. For the garfish population inhabiting the eastern part of the Mediterranean FEHRI-BEDOUI & GHARBI (2004), lower values for morphometric relationships of fork and total length (*FL/TL*= 70.0%) and standard and total length (*SL/TL*= 78.0%) were obtained than those calculated in this study (*FL/TL*=96.2%, *SL/TL*=93.8%). TORTONESE (1970) and JARDAS (1996) reported that maximum body height comprises from 0.06% to 0.07 % of total body length which is slightly lower than that given in this paper (3.6%<*H/TL*<8.1%). Those authors also noted that the range of the relative morphometric relationship between head length and total body length (*LH/TL*) varies within the range 28.6%<*LC/TL*<33.3%. That result was similar to the one obtained in this study (22.6%<*LC/TL*<36.1%). Observed differences are probably associated with the different number of analysed specimens and its length frequency distribution. Moreover, it is known that environmental factors such as temperature and salinity, food availability or swimming patterns might be significant in determining

Table 3. Meristic characteristics of garfish caught in the eastern part of the middle Adriatic Sea from January 2003 to December 2008 ($\bar{x}$ - mean value; SD – standard deviation; SE - standard error of mean value; CV – coefficient of variation)

Meristic characteristic	Sex	*N*	Range (%)	$\bar{x} \pm SD$ (%)	$\bar{x} \pm SE$ (%)	*CV* (%)
Dorsal fin rays (*D*)	♂	331	15 – 20	17.3 ± 0.71	17.3 ± 0.04	4.10
	♀	491	16 – 19	17.3 ± 0.61	17.3 ± 0.03	3.52
	Total	938	15 – 20	17.3 ± 0.65	17.3 ± 0.02	3.76
Pectoral fin rays (*P*)	♂	332	10 – 14	12.0 ± 0.82	12.0 ± 0.05	6.83
	♀	492	10 – 14	12.1 ± 0.78	12.1 ± 0.04	6.45
	Total	940	10 – 14	12.1 ± 0.79	12.1 ± 0.03	6.53
Anal fin rays (*A*)	♂	326	19 – 23	21.0 ± 0.26	21.0 ± 0.01	1.24
	♀	487	18 – 23	21.0 ± 0.24	21.0 ± 0.01	1.14
	Total	921	18 – 23	21.0 ± 0.24	21.0 ± 0.01	1.14
Ventral fin rays (*V*)	♂	326	5 – 7	6.0 ± 0.11	6.0 ± 0.01	1.83
	♀	487	5 – 7	6.0 ± 0.11	6.0 ± 0.01	1.83
	Total	921	5 – 7	6.0 ± 0.11	6.0 ± 0.01	1.83
Vert.	Total	192	75 - 80	77.41 ± 1.18	77.41 ± 0.01	1.53

the phenotypic differentiation among the same species inhabiting different geographical areas (ALLENDORF, 1988; WIMBERGER, 1992; MURTA, 2000; TZENG, 2004; KUMAR *et al*., 2010). Regardless of sexual dimorphism in six morphological relationships, a statistically significant difference was confirmed for the first time according to the available literature. Namely, female garfish specimens had significantly longer standard length, preanal distance, head length, eye diameter and length of pectoral fin than males, while males had significantly higher values of minimal body height than females.

The meristic characters obtained for garfish collected in the Adriatic Sea for this study showed very low variability with respect to data previously reported for this species from different geographical areas (Table 4). Only BĂNĂRESCU (1964) and SVETOVIDOV (1964) noted the presence of spines in anal and dorsal fins, respectively. Other authors reported exclusively soft rays in all fins as in this study.

According to the literature for this species three subspecies have been recognised depending on it area of distribution (COLETTE & PARIN, 1986). It seems that stock identification based on morphological and meristic characters, which are scarce or overlapping in this case, should in the future be confirmed by genetic evidence to verify that the phenotypic differences reflect some degree of reproductive isolation rather than simply environmental differences. Nevertheless, stock discrimination by morphologic markers might be appropriate for fisheries management even if this phenotypic divergence is not reflected by genetic differentiation (ERGUDEN *et al*., 2009). In conclusion, the present morphometric and meristic analyses revealed very similar patterns of biometric characteristics of the garfish population from the Adriatic Sea to the subspecies *B. belone gracilis* Lowe, 1839 that is distributed throughout the Mediterranean (excluding the Black Sea) and as far as the Canary Islands in the Atlantic.

Table 4. Meristic characteristics of Belone belone from different geographical areas: D- dorsal fin rays, A – anal fin rays, P – pectoral fin rays, V – ventral fin rays and Vert. – number of vertebrae

Author	*D*	*A*	*P*	*V*	*Vert.*	Geographical area
This study	15 - 20	18 - 23	10 - 14	5 - 7	75 - 80	Adriatic Sea
JARDAS (1996)	16 - 19	19 - 23	11 - 14	6		Adriatic Sea
DIEUZEIDE (1954)	16 - 19	20 -22	12 - 15	6		Mediterranean
BĂNĂRESCU (1964)	14 - 16	II/18 - 20			77 - 81	Black Sea
SVETOVIDOV (1964)	II/14 - 16	II/18 - 20	9 - 11			Black Sea
COLETTE & PARIN (1986)	16 - 20	19 - 23	11 - 14		75 - 84	Mediterranean, NW Atlantic and Black Sea
TORTONESE (1970)	16 - 19	19 - 22	12 - 15		77 - 81	Coastal area of Italy
DORMAN (1991)	18.22	21.26	12.88		82.06	Baltic Sea

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Fenotipske značajke iglice *Belone belone* (Linnaeus, 1761) u Jadranskom moru

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SAŽETAK

U ovom radu su izneseni rezultati biometrijske analize iglice, *Belone belone* (Linnaeus, 1761), u čiju svrhu je analizirano dvanaest morfometrijskih i pet merističkih značajki. Sve analizirane jedinke iglice su uzorkovane iz komercijalnih lovina ostvarenih u istočnom dijelu Jadranskog mora u razdoblju od 2003. do 2008. godine. Ukupna dužina tijela (TL) svih jedinki je kolebala od 20,8 cm do 75,4 cm (38.3 ± 7.94 cm). Omjer spolova je iznosio 1:1.

Ključne riječi: morfometrija, meristika, iglica, Jadran, Mediteran