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Biometric properties of Horse mackerel, *Trachurus trachurus* (Osteichthyes: Carangidae), from the middle Adriatic Sea

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Twelve morphometric measurements and eight meristic characteristics were examined in 257 specimens of horse mackerel (115 females, 103 males and 39 immature ones) caught in the middle Adriatic. Morphological differences between males and females were not marked. Modal values of the morphometric measurements and the meristic properties indicate that the horse mackerel population in the middle Adriatic is homogeneous. No differences indicate the existence of subpopulations. Some morphometric changes occurred as the total body length increased. Comparison with other studies indicated that there are no marked morphological differences between mid-Adriatic horse mackerel populations and those inhabiting different parts of the Mediterranean, northeastern Atlantic and Black Seas.

Key words: *Trachurus trachurus*, morphometric and meristic characteristics, Adriatic Sea

INTRODUCTION

The horse mackerel *Trachurus trachurus* (Linnaeus, 1758) is distributed in the eastern Atlantic, Mediterranean and Black Seas (BINI, 1968; TORTONESE, 1975; WHITEHEAD *et al.*, 1986; FISCHER *et al.*, 1987). It is also distributed throughout the Adriatic Sea, living in schools mainly between 80 and 200 m depth. There are no reliable statistical data on *Trachurus trachurus* landings in the eastern Adriatic but a tentative estimate of the annual catch is around 400 tons (FAO, 2000). In the Mediterranean, this species is of major importance in the pelagic and demersal fisheries and annual landings fluctuated from 5155 to 21,998 tons from 1989 to 1998 (FAO, 2000). Presently, this species is still abundant in the Adriatic Sea, compared to other economically important species that are considered over-fished (VRGOČ, 2000). The biology of this species has been well documented for the Adriatic (ALEGRÍA-HERNÁNDEZ, 1984, 1984a, 1990, 1994; ARNERI, 1984), Mediterranean (KARLOU-RIGA & ECONOMIDIS, 1996; KARLOU-RIGA & SINIS, 1997) and eastern Atlantic (FARINA-PEREZ, 1983; KERSTAN, 1985; ABAUNZA

et al., 1995). However, their morphometric and meristic characteristics have not yet been systematically studied. Some data on individual meristic characters are available (DIEUZEIDE *et al.*, 1955; POLJAKOV *et al.*, 1958; BANARESCU, 1964; SVETOVIDOV, 1964; TORTONESE, 1975; FISCHER *et al.*, 1987; KRPO, 1987; JARDAS, 1996), but data on their morphometry are very scarce. The goal of this paper is to investigate morphological properties of the Adriatic horse mackerel population by analyzing morphometric and meristic characters.

MATERIAL AND METHODS

Fish

Fish were collected in 1996 from five trawling grounds in the middle Adriatic: the areas of Svetac and Vis islands, Maslinica, Split Channel, around Jabuka Islet and Blitvenica (Fig. 1). The investigated areas are situated on the circalittoral shelf at a depth of 60 m (Split Channel) to 175 m (around Jabuka islet).

A total of 257 horse mackerel specimens sampled from commercial trawl catches were subjected to a biometric analysis. The sample consisted of 115 females, 103 males and 39 immature individuals. The total length (Lt) of the samples ranged from 10.1 to 36.8 cm. The total length of the females ranged 13.7-36.4 cm and of the males 13.9-36.8 cm. The sample was categorized into centimeter length classes.

Morphometric and meristic characters

Biometric measurements were performed on fresh fish. Specimens were boiled to facilitate the separation of the muscular tissue from the spine and vertebrae were counted. Twelve mor-

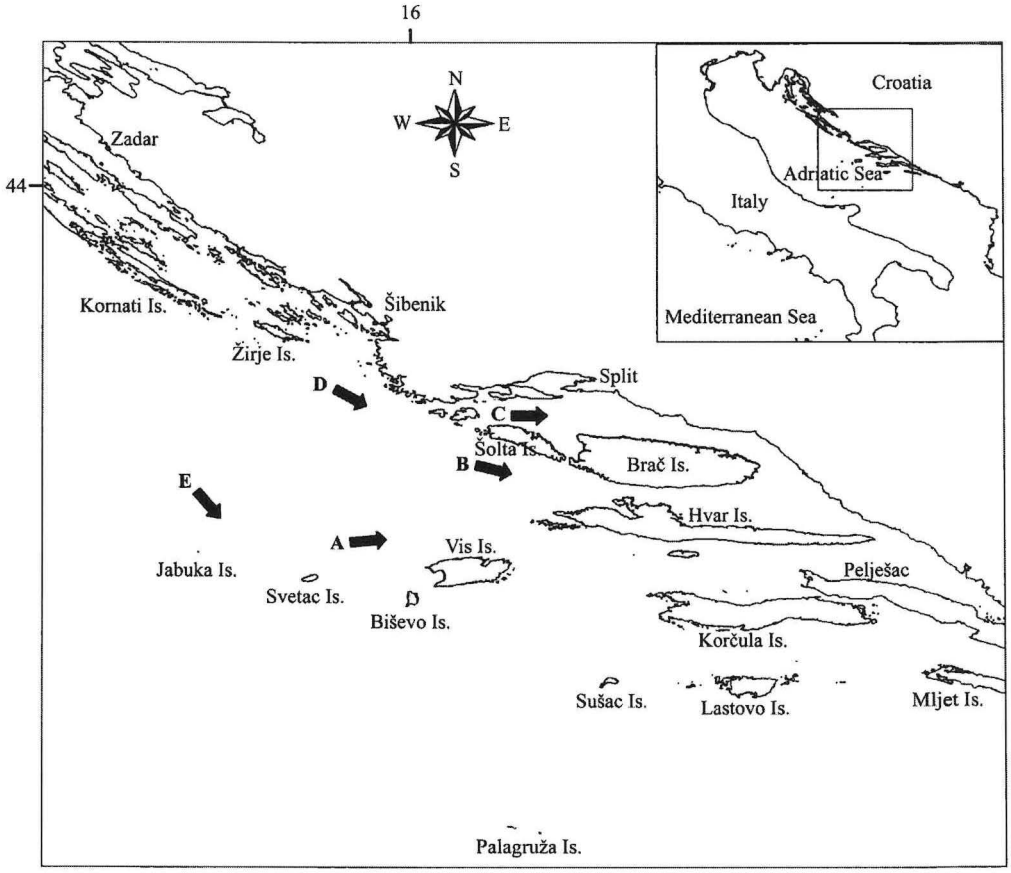

Fig. 1. Study area and sampling localities of Trachurus trachurus *from the middle Adriatic: A - areas of Vis and Svetac islands, B - area of Maslinica, C - Split Channel, D -Blitvenica fishing area, E - area of Jabuka Island*

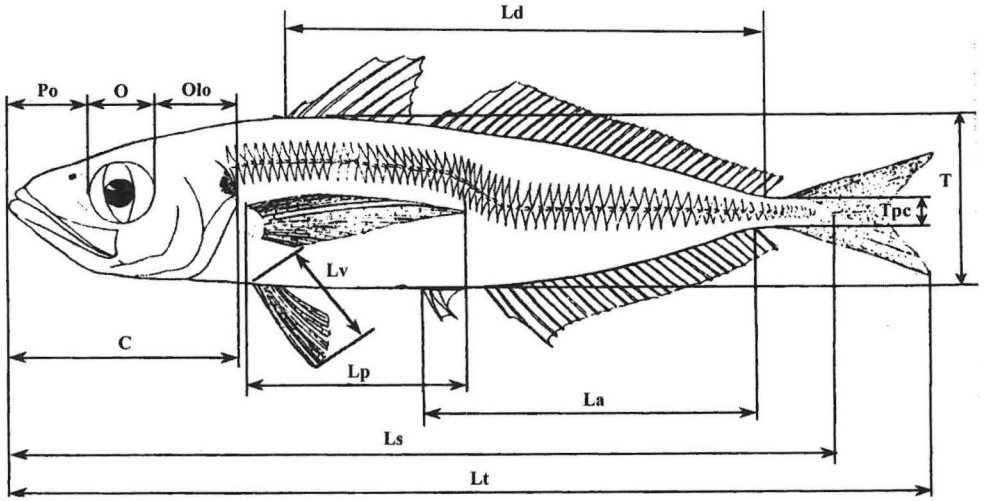

Fig. 2. Stylized drawing of body proportions measured on horse mackerel: Lt - total length, Ls - standard length, C - head length, Ld - dorsal fin length, La - anal fin length, Lp - pectoral fin length, Lv - ventral fin length, T - maximum body height, Tpc - minimum body height, O - eye diameter, Po - preocular distance, Olo - postocular distance

phometric and eight meristic body characters were examined (LAEVASTU, 1965).

The morphometric characters that were analyzed were (Fig. 2): total length (*Lt*), standard length (*Ls*), anal fin length (*La*), pectoral fin length (*Lp*), ventral fin length (*Lv*), dorsal fin length (*Ld*), head length (*C*), preocular distance (*Po*), eye diameter (*O*), postocular distance (*Olo*), maximum body height (*T*) and minimum body height (*Tpc*).

The analyzed meristic characters were: number of spined and branched rays in dorsal (*D*), ventral (*V*) and anal (*A*) fins, number of pectoral rays (*P*), number of vertebrae (*Vert.*), number of gill rakers (*Brsp.*), number of scales on linea lateralis (*L.lat.*) and number of pyloric appendices (*A.p*).

The total and standard lengths were measured to the nearest 0.1 cm. The rest of the morphometric measurements were measured to the nearest 0.01 mm. Measurements of the head were expressed as percentages of the head length whereas other body measurements were expressed as percentages of the standard length. The standard length was expressed as a percentage of the total length (*Ls/Lt*) and the minimum height was expressed as a percentage of the maximum body height (*Tpc/T*).

Statistical analysis

Arithmetic means, standard deviations and variability coefficients were used to process the numerical data. The significance of differences in the studied characters between males and females were tested with *t* test (SOKAL & ROHLF, 1981). Polynomial and linear regression were used to examine the morphometric changes occurring with the increasing total length.

RESULTS

The differences between the mean values of the measured morphometric characteristics in the males and females were not statistically significant in any case (Table 1).

The closest statistical significances of differences in relationship were between the length of the anal fin and standard length (*La/Ls*) and between the minimum and maximum height (*Tpc/T*). The variability coefficients of morphometric relationships for males, females and the total sample were relatively low (Tables 2,3).

Table 1. Relative relationships of measured body proportions for females (N=115) and males (N=103) of horse mackerel

Body Proportions	Sex	Range	$\bar{x}$ ± SD	$\Delta\bar{x}$	t	V(%)	ΔV
Ls / Lt	♀♀	83.54 – 87.36	85.12 ± 0.7943	0.03	0.28	0.88	0.09
	♂♂	82.45 - 86.90	85.09 ± 0.8276			0.97	
C /Ls	♀♀	25.56 – 31.27	28.00 ± 1.1300	0.25	1.72	4.75	1.15
	♂♂	25.82 - 30.63	28.25 ± 1.0189			3.60	
Ld / Ls	♀♀	51.67 – 59.84	54.41 ± 1.6761	0.11	0.15	3.08	0.12
	♂♂	51.00 - 59.84	54.52 ± 1.6160			2.96	
La / Ls	♀♀	31.90 – 39.93	36.62 ± 1.8635	0.45	1.95	5.08	0.86
	♂♂	31.66 - 39.92	37.07 ± 1.5645			4.22	
Lp / Ls	♀♀	25.00 – 30.76	27.88 ± 1.1091	0.34	0.72	3.97	0.03
	♂♂	25.24 - 29.95	27.54 ± 1.1029			4.00	
Lv / Ls	♀♀	12.87 – 17.94	15.48 ± 0.9049	0.02	0.05	5.84	0.62
	♂♂	12.26 - 16.98	15.50 ± 0.8094			5.22	
T / Ls	♀♀	20.00 – 26.66	22.07 ± 1.2685	0.18	1.04	5.74	0.36
	♂♂	19 75 24 66	22 25 ± 1 3578			6 10	
Tpc / Ls	♀♀	2.41 - 3.85	2.96 ± 0.2348	0.06	1.81	7.93	0.67
	♂♂	2.46 - 3.94	3.02 ± 0.2598			8.60	
O / C	♀♀	23.85 – 29.27	27.26 ± 1.2386	0.11	0.71	4.54	1.31
	♂♂	24.11 - 29.59	27.15 ± 1.0458			5.85	
Po / C	♀♀	28.66 – 34.63	31.63 ± 1.3416	0.33	1.83	4.24	0.15
	♂♂	29.29 - 35.46	31.96 ± 1.3096			4.09	
Olo / C	♀♀	37.12 – 44.42	41.18 ± 2.0851	0.29	1.18	5.06	1.39
	♂♂	37.30 - 45.04	40.89 ± 1.5043			3.67	
Tpc / T	♀♀	11.57 – 16.06	13.40 ± 0.9324	0.28	1.95	6.95	1.54
	♂♂	11.67 - 17.66	13.68 ± 1.1616			8.49	

♀♀ = females
♂♂ = males
$\bar{x}$ = mean values
SD = standard deviation
$\Delta\bar{x}$ = differences of mean values between males and females
t = values of t-test
V= variability coefficient
ΔV = differences of variability coefficient between males and females

Table 2. Relative relationships of measured body proportions for total sample (females, males and immature specimens) of horse mackerel (N=257) and polynomial regression coefficients. Explanations for coefficients: a, b, c = regression coefficients of the polynomial regression ($y = a + bx + cx^2$), R^2=determination coefficient

Body proportion	Range	$\bar{x}$ ± SD	V (%)	a	b	c	R^2	Form of curve
Ls/Lt	82.45 - 87.36	85.05 ± 0.7811	0.91	83.354	0.0879	-0.0004	0.9684	parabola
C/Ls	25.56 - 31.27	28.40 ± 1.2121	4.26	32.770	-0.2212	0.0012	0.9843	hyperbola
Ld/Ls	51.00 - 59.84	54.30 ± 1.7253	3.17	45.445	0.5913	-0.0079	0.9521	parabola
La/Ls	31.66 - 39.93	37.01 ± 1.7371	4.69	39.807	-0.1558	0.0012	0.9544	hyperbola
Lp/Ls	25.00 - 30.76	27.56 ± 1.1458	4.15	23.463	0.2731	-0.0026	0.9820	parabola
Lv/Ls	12.26 - 17.94	15.63 ± 0.9162	5.86	17.205	0.0992	0.0002	0.9772	hyperbola
T/Ls	19.75 - 25.66	22.14 ± 1.2521	5.65	23.712	-0.1276	0.0010	0.9766	hyperbola
Tpc/Ls	2.41 - 3.94	3.03 ± 0.2595	8.56	3.8483	-0.0756	0.0012	0.8963	hyperbola
O/C	23.86 - 29.59	27.30 ± 1.1651	4.26	27.527	0.0052	-0.0019	0.9453	parabola
Po/C	28.66 - 35.46	31.82 ± 1.3133	4.12	29.421	0.1726	-0.0010	0.9502	parabola
Olo/C	37.12 - 45.04	40.90 ± 1.8746	4.58	38.294	0.1020	0.0009	0.9392	hyperbola
Tpc/T	11.57 - 17.66	13.71 ± 1.1005	8.02	15.396	0.1058	0.0006	0.9678	hyperbola

Modes were identical in males and females for most analyzed morphometric relations (Figs. 3,4). A difference of 1.0% or lower was found only for eye diameter (*O/C*) and preorbital distance (*Po/C*). There also were no differences in meristic characters between sexes (Tables 4,5).

Table 3. Regression (a, b) and determination coefficients (R^2) of linear regression and polynomial , regression of total sample (N = 257)

Body proportion/coefficient	Linear regression a	b	R^2	Polynomial regression R^2	Average differs of R^2
Ls/Lt	83.559	0.0678	0.9664	0.9684	0.0020
C/Ls	32.225	-0.1669	0.9819	0.9843	
Ld/Ls	49.138	0.2303	0.9010	0.9521	
La/Ls	39.229	-0.0991	0.9473	0.9544	
Lp/Ls	24.682	0.1535	0.9865	0.9820	0.0127
Lv/Ls	17.109	-0.0897	0.9769	0.9772	
T/Ls	23.235	-0.0807	0.9692	0.9766	
Tpc/Ls	3.2953	-0.0212	0.8799	0.8963	
O/C	28.422	-0.0827	0.9215	0.9453	
Po/C	29.730	0.1246	0.9470	0.9502	0.0096
Olo/C	37.871	0.1435	0.9374	0.9392	
Tpc/T	15.126	-0.0792	0.9653	0.9678	0.0025

Table 4. Meristic characters for females (N = 115) and males (N = 103) of horse mackerel. Explanations: D = number of rays in dorsal fin; A = number of rays in anal fin; P = number of rays in pectoral fin; V = number of rays in ventral fin; Brsp. = total number of branchiospines; L.lat. = number of scales in linea lateralis; Vert. = number of vertebrae; A.p. = number of pyloric appendices

Peculiarity	Sex	Range	$\bar{x}$ ± SD	$\Delta\bar{x}$	t	V (%)	ΔV
D	♀♀	39 - 43	40.41 ± 1.0172	0.01	0.08	2.51	0.29
	♂♂	39 - 43	40.42 ± 0.8922			2.20	
A	♀♀	29 - 32	30.93 ± 0.6846	0.08	0.83	2.21	0.20
	♂♂	29 - 32	30.85 ± 0.7463			2.41	
P	♀♀	20 - 22	20.87 ± 0.5322	0.02	0.33	2.55	0.19
	♂♂	20 - 22	20.85 ± 0.4932			2.36	
V	♀♀	6	6.00 ± 0	0	0	0	0
	♂♂	6	6.00 ± 0			0	
Brsp. (total)	♀♀	57 - 63	59.91 ± 1.4543	0.13	0.65	2.42	0.30
	♂♂	57 - 63	60.04 ± 1.6352			2.72	
L. lat.	♀♀	69 - 81	73.93 ± 2.8706	0.01	0.02	3.88	0.53
	♂♂	69 - 80	73.94 ± 2.4806			3.35	
Vert.	♀♀	24	24.00 ± 0	0	0	0	0
	♂♂	24	24.00 ± 0			0	
A. p.	♀♀	15	15.00 ± 0	0	0	0	0
	♂♂	15	15.00 ± 0			0	

♀♀ = females
♂♂ = males
$\bar{x}$ = mean values
SD = standard deviation
$\Delta\bar{x}$ = differences of mean values between males and females
t = values of t-test
V= variability coefficient
ΔV = differences of variability coefficient between males and females

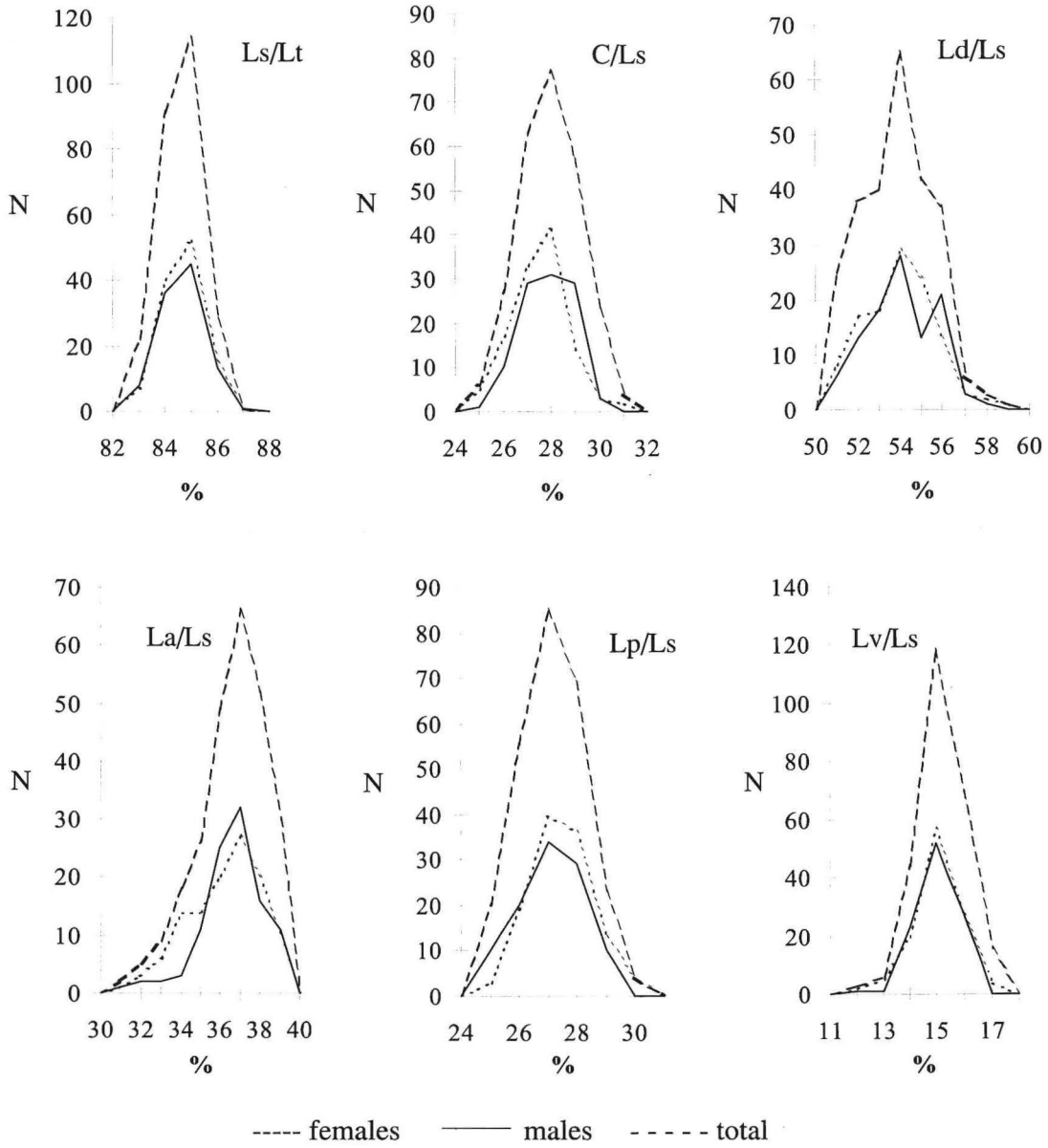

Fig. 3. Relative relationships (in percentage) of measured body proportions (Ls/Lt, C/Ls, Ld/Ls, La/Ls, Lp/Ls, Lv/Ls), expressed in range and modal values, for females, males and total samples of horse mackerel

Table 5. Meristic characters for total sample (females, males and immature specimens) of horse mackerel (N=257)

Peculiarity	Range	$\bar{x}$ ± SD	V (%)
D	39 - 43	40.38 ± 0.9372	2.32
A	29 - 32	30.87 ± 0.7071	2.29
P	20 - 22	20.87 ± 0.5154	2.46
V	6	6.00 ± 0	0
Brsp.	57 - 63	59.98 ± 1.5038	2.50
L. lat.	69 - 81	73.96 ± 2.6352	3.56
Vert.	24	24.00 ± 0	0
A. p.	15	15.00 ± 0	0

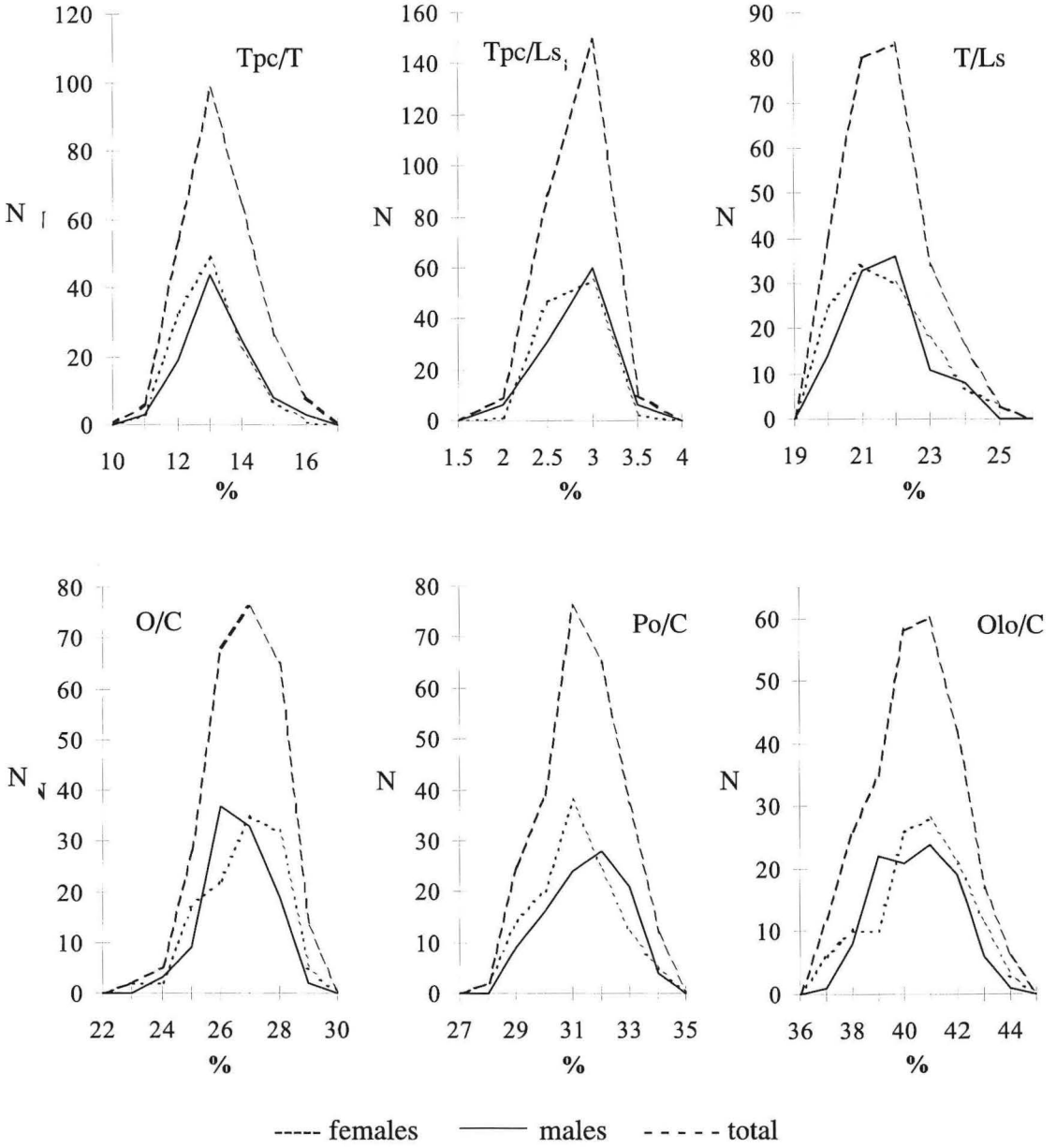

Fig. 4. Relative relationships (in percentage) of measured body proportions (Tpc/T, Tpc/Ls, T/Ls, O/C, Po/C, Olo/C), expressed in range and modal values, for females, males and total samples of horse mackerel

DISCUSSION

Our results indicate that a homogeneous horse mackerel population inhabits the middle Adriatic. On the basis of branchiospines, vertebra and dorsal fin rays analysis, KRPO (1987) also reported that the horse mackerel population in the middle Adriatic is homogeneous. The coefficients of polynomial and linear regression point to the fact that smaller specimens have a longer head (*C/Ls*) and longer anal (*La/Ls*) and ventral fins (*Lv/Ls*) as well as a greater maximum (*T/Ls*) and minimum (*Tpc/Ls*) body height. At the same time they have shorter dorsal (*Ld/Ls*) and pectoral (*Lp/Ls*) fins than adult specimens. As to other morphometric relationships, small specimens have smaller preorbital (*Po/C*) and postorbital (*Olo/C*) distances and a

Table 6. Meristic characters of horse mackerel from the Adriatic sea, Mediterranean, Black sea and NE Atlantic

Area and data of authors	D	A	P	V	L.lat.	Brsp.	Vert.
Our results	VIII+I / 30-33 (34)	II+I / (26) 27-28	20-22	I / 5	69-81	57-63	10+14
Middle Adriatic							
KRPO (1987)	VIII+I / 29-35 (36)	-	-		-	53-70	10+14
Eastern Adriatic							
JARDAS (1996)	VIII+I/29-33	II+I/24-29	20-21	I/5	66-75	-	10+14
POLJAKOV *et al.* (1958)	VIII(IX)+I/27-34	II+I/23-30	-	-	80-90	-	10+14
Italian coast							
TORTONESE (1975)	VIII+I/28-33	II+I/25-33	20-21	I/5	69-79	-	-
Moroccoan coast COLLIGNON & ALONCLE (1973)	VIII+I/28-36	II+I/25-34	-	-	69-80	-	-
Tunisian coast DIEUZEIDE *et al.* (1955)	VIII+I/32-34	II+I/25-34	20-21	I/5	-	-	-
Mediterranean FISHER *et al.* (1987)	VIII+I/29-33	II+I/24-29	-	-	66-75	59-64	10+14
Mediterranean and NE Atlantic BAUCHOT & HUREAU (1986)	VIII+I/29-33	II+I/24-29	-	-	66-75	60-64	-
Black Sea							
SVETOVIDOV (1964)	VIII+I/28-34	II+I/25-29	-	-	68-76	-	10+14
BANARESCU (1964)	VIII(IX)+I/28-35	II+I/26-30	-	-	69-79	-	10+14

bigger eye diameter (*O/C*) than larger specimens. The preorbital and postorbital distances increase as the size of the horse mackerel increases. Negative correlations for the maximum (*T/Ls*) and minimum (*Tpc/Ls*) body depth indicate that the horse mackerel body progressively elongates. Our data agree with those of MATTA (1959) who also reported that, in horse mackerel from Italian waters, head length and eye diameter decrease as body length increases. Coefficients of determination (R^2) are similar for both regressions.

Data from the literature on morphometric relations are comparable since they refer to total body length. POLJAKOV *et al.* (1958) reported that head length makes up 22.2-25.0% of the total body length in horse mackerel from Albanian waters. MATTA (1958) and COLLIGNON & ALONCLE (1973) and BANARESCU (1964) reported that the head constitutes 25% of the total body length in horse mackerel from the Mediterranean and Black Seas, respectively. We established that the head makes up 28.4% of the standard body length. Data relating to head length are also comparable. According to POLJAKOV *et al.* (1958), eye diameter (*O/C*) constitutes 22.0-28.8% of the head length, which is in agreement with the range we found in the present study. MATTA (1958), COLLIGNON & ALONCLE (1973) and BANARESCU (1964) obtained eye diameters (*O/C*) of 25.0% of total head length, very close to the mean value in our study (27.3%).

Meristic characters of horse mackerel from the middle Adriatic are compared with data from the literature in Table 6.

The same numbers of vertebrae (*Vert.*), ventral fin rays (*V*) and pectoral fin rays (*P*) were recorded for horse mackerel from different localities. Variation in the ranges of branched

rays in dorsal (*D*) and anal (*A*) fins was very small. It has been experimentally established that the number of vertebrae is genetically fixed within narrow limits, and that aberrations of a small extent are probably effected by temperature during the so-called sensitive period (BLAXTER, 1957). Apart from the authors mentioned in Table 6, LETACONNOUX (1951) and KOMPOWSKI (1981) also found 24 vertebrae in horse mackerel. The number of spined rays in the dorsal fin (*D*) was constant in fish from different areas. KRPO (1987) found a mode of 32 soft rays in the dorsal fin of horse mackerel from the middle Adriatic (Blitvenica, Dugi otok, Rogoznica and Palagruža), which agrees with our records. The number of branchiospines may indicate adaptations to changes in the environment inhabited by the species (ANDREU, 1969). Apart from the number of vertebrae, the number of rays in the dorsal fin and the number of branchiospines also define the level of homogeneity of a population (ALEGRÍA-HERNÁNDEZ, 1985). No difference in number of branchiospines was recorded for the middle Adriatic (KRPO, 1987), supporting our assumption that the middle Adriatic is inhabited by a homogeneous horse mackerel population. The mean number of branchiospines (60.82) recorded by KRPO (1987) is very close to the number we recorded in the present study (59.98).

The mean number of branchiospines in horse mackerel from the Tunisian coast (60.88), Malta (58.20), Aegean Sea (59.85), Gulf of Lyon (60.19), Gascogne Bay (61.65) and Atlantic coast of Morocco (61.69) are very similar (BEN SALEM *et al.*, 1981). The mean number of branchiospines reported by the same author for the Aegean Sea fish is almost the same as ours. The significance of the differences in number of scales of the lateral line is difficult to establish, since only ranges are reported in the literature. LETACONNOUX (1951) found that the number of scales in the lateral line in horse mackerel from the Bay of Biscay ranged 67-81 with a mode of 74. These data are in agreement with our results (range 67-81; mean 73.96).

In general, everything reported shows that there are no significant morphological differences between the horse mackerel population in the Adriatic and those in other Mediterranean areas (including the Black Sea) and the north-eastern Atlantic.

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Biometrijska svojstva šnjura, *Trachurus trachurus* (Osteichthyes: Carangidae), srednjeg Jadrana

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SAŽETAK

Na 257 primjeraka šnjura (115 ženki, 103 mužjaka i 39 spolno nezrelih) ulovljenih u srednjem Jadranu analizirano je 12 morfometrijskih i 8 merističkih karaktera. Morfološke razlike između mužjaka i ženki nisu izražene. Modalne vrijednosti morfometrijskih odnosa kao i dobivene merističke osobine ukazuju da u srednjem Jadranu obitava homogena populacija ove vrste; nisu izražene razlike koje bi ukazivale na postojanje podpopulacija. Uočene su promjene morfometrijskih odnosa u vezi s porastom tjelesne dužine (*Lt*). Pretpostavka je da izmedu primjeraka čnjura duž pojedinih dijelova Sredozemlja, sjeveroistočnog Atlantika i Crnog mora nisu izražene morfološke razlike.