

BIOMETRIC PROPERTIES OF THE EUROPEAN HAKE, *MERLUCCIUS MERLUCCIUS* (OSTEICHTHYES: MERLUCCIIDAE), FROM THE CENTRAL ADRIATIC SEA

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Abstract – The relationship between morphometric measurements (16) and meristic characters (6) was examined in 460 specimens of the European hake (225 females, 210 males and 25 immature ones) caught in the central Adriatic Sea. Morphological difference between males and females was not marked. Biometric analyses of the morphometric and meristic characteristics indicated a homogenous morphology stock of *M. merluccius* in the central Adriatic Sea. Changes in some morphometric characteristics obtained in conjunction with an increase in body length showed that smaller specimens have a longer head, anal and ventral fin than adult specimens. The negative correlation recorded for the maximum and minimum body depth indicated that the body becomes progressively elongated. The meristic characteristics of the European hake from different Mediterranean and NE Atlantic areas are mostly in agreement with the data in our study.

Key words: *Merluccius merluccius*, morphometric and meristic characteristics, Adriatic Sea

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INTRODUCTION

The European hake, *Merluccius merluccius* (Linnaeus, 1758), is distributed throughout the Mediterranean and the north-eastern Atlantic (Fisher et al., 1987). It is common in the Adriatic Sea on muddy seabeds, mostly between depths of 100-200 m (Jardas, 1996). In the Adriatic Sea, seabed trawlers actively exploit the European hake (Grubišić, 1988). There are no reliable statistics on *M. merluccius* landing in the eastern Adriatic, but rough estimates of the total annual catch is around 800 tons (FAO, 2009). In the Mediterranean, this species is of major importance to the demersal fisheries where annual landings have fluctuated between 27,707 and 32,448 tons from 2005 to 2008 (FAO, 2009). The European hake is still abundant in the Adriatic Sea compared to other economically important species that are considered to be overfished (Vrgoč, 2000). The biology of this species is considered to be well documented for the Adriatic Sea (Županović, 1968;

Jukić, 1972; Jukić and Piccinetti, 1981; Županović and Jardas, 1986; Vrgoč, 2000). However, their morphometric and meristic characteristics have not been thoroughly studied. The goal of this paper is to analyze these characteristics of the European hake in the central Adriatic Sea, and thereby to investigate: a) whether there are morphological differences between males and females; b) the existence of possible homogenous or heterogeneous stock morphology; and c) changes of morphometric characteristics with increase in body length.

MATERIALS AND METHODS

During 2008, a total of 460 European hake specimens were sampled to study their biometric characteristics. The sample consisted of 225 females, 210 males and 25 immature individuals. The fish were collected by commercial seabed trawls (using a 22 mm stretched mesh size cod-end) from five different trawling grounds in the eastern central Adriatic Sea:

the areas of Svetac and Vis islands, the area of Maslenica, Split Channel, around Jabuka Islet and Blitvenica (Fig. 1). The duration of each haul was 2 to 3 h and the trawling speed fluctuated from 2 to 3 knots. The investigated areas are situated on the circalittoral shelf mostly at depths from 90 to 125 m.

Biometric measurements were performed on fresh fish. Specimens were boiled to facilitate the separation of the muscular tissue from the verte-

bral column. After that the number of vertebrae was counted.

Sixteen morphometric and six meristic characteristics were measured. The analyzed morphometric characteristics analyzed are: total length (Lt), standard length (Ls), head length (C), lengths of dorsal (Ld) and anal fins (La), lengths of pectoral (Lp) and ventral fins (Lv), predorsal (Lpd), preanal (Lpa), pre-ventral (Lpv) and prepectoral (Lpp) distances, maxi-

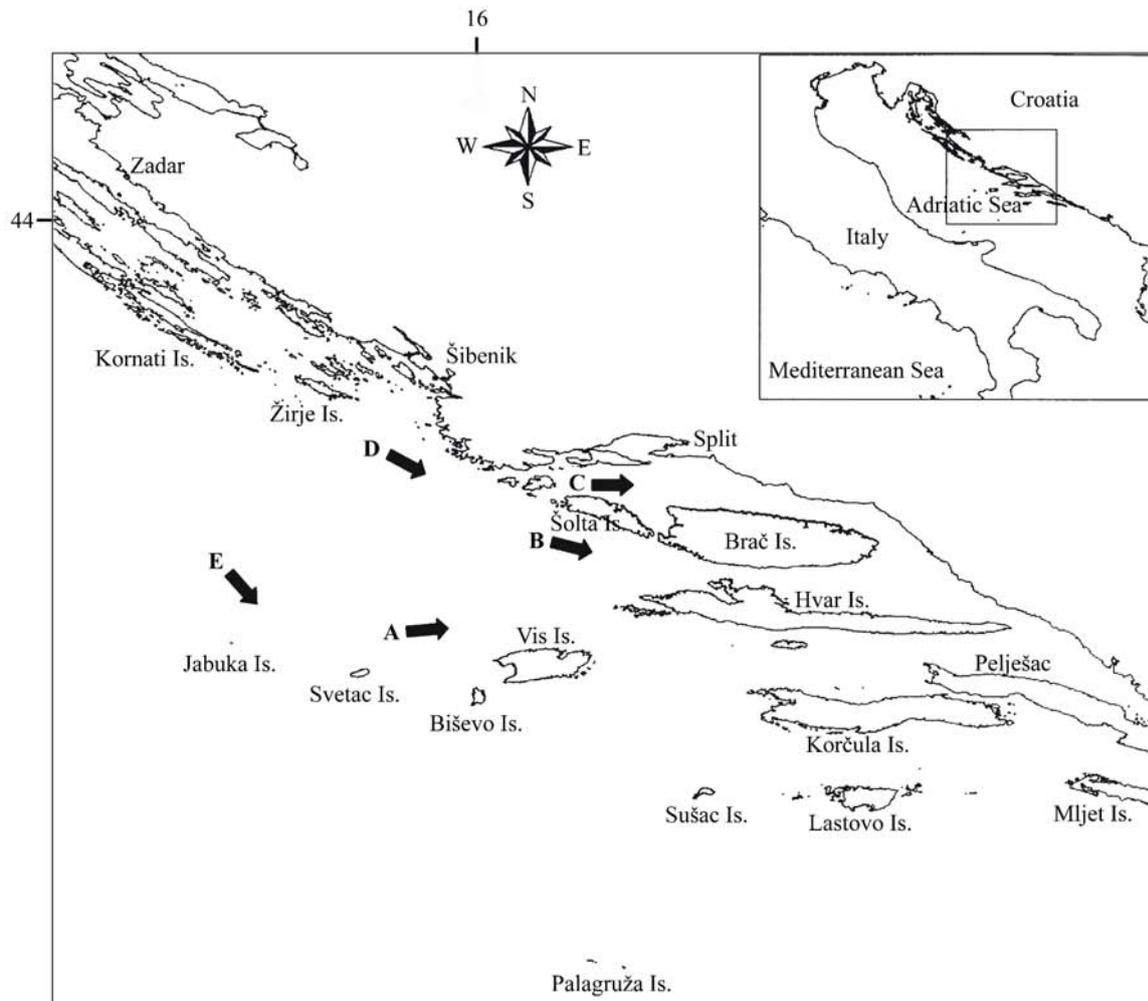


Fig. 1. Study area and sampling localities of the European hake from the central Adriatic Sea: A – areas of Vis and Svetac islands, B – area of Maslenica, C – Split Channel, D – Blitvenica fishing area, E – area of Jabuka island. Arrows represent the fishing direction.

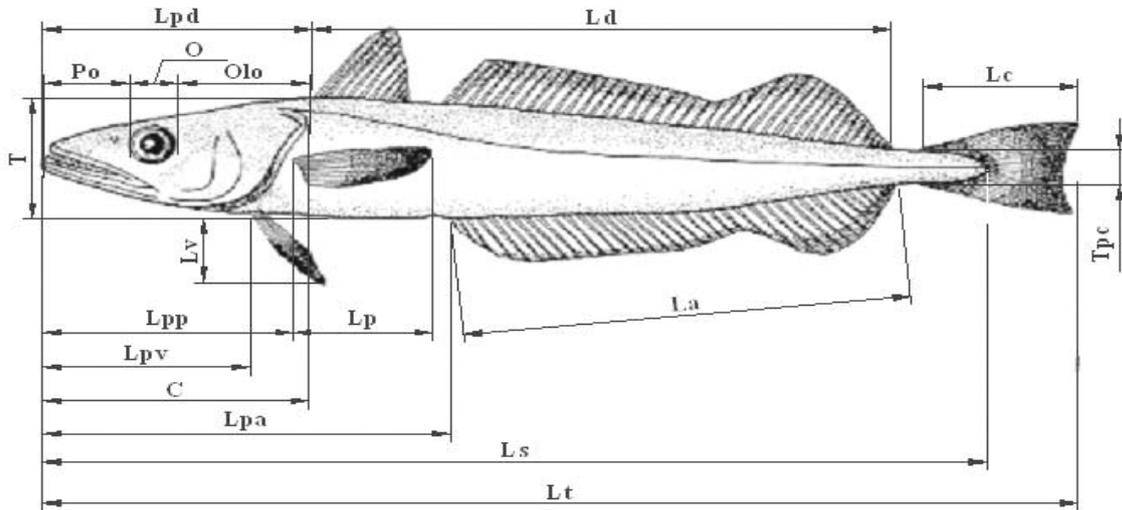


Fig. 2. Morphometric measurements of the European hake: Lt – total length, Ls – standard length, C – head length, Ld - dorsal fin length, La – anal fin length, Lp – pectoral fin length, Lv – ventral fin length, Lpd – predorsal distances, Lpa – preanal distances, Lpv – preventral distances, Lpp – prepectoral distances, T – maximum body height, Tpc – minimum body height, O – eye diameter, Po – preocular distance, Olo – postocular distance.

imum (T) and minimum body heights (Tpc), eye diameter (O), preocular (Po) and postocular distance (Olo) (Fig. 2).

The analyzed meristic characteristics are: number of rays in dorsal (D), ventral (V), anal (A) and pectoral (P) fins, number of vertebrae (Vert.) and number of scales on the linea lateralis (L. lat).

The total and standard lengths were measured with a fish meter to the nearest 0.1 cm. The rest were measured with a caliper to the nearest 0.01 mm. The entire sample was categorized into centimeter length classes. Measurements of the head were expressed as percentages of head length whereas the other body measurements were expressed as percentages of the standard length (Ls). The standard length was expressed as a percentage of the total length (Ls/Lt) and minimum height was expressed as a percentage of the maximum body height (Tpc/T). Sex was determined macroscopically according to the shape and appearance of the gonads.

The arithmetic mean, standard deviation and variability coefficient were used in processing the bi-

ometry data. Significance of differences in the studied characteristics between males and females were tested with the *t*-test (Sokal and Rohlf, 1981). Linear regression was applied to the examined morphometric relations in comparison with an increase in total length.

RESULTS

Overall, 460 specimens of *M. merluccius* were examined for morphometric and meristic characteristics. The total length (Lt) of all samples ranged from 14.6 to 45.0 cm. The total length of females ranged from 19.9 to 45.0 cm and males from 18.8 to 35.1 cm.

Differences in the mean values of the measured morphometric relations between males and females were not statistically significant in any individual case (Table 1). In addition, the morphometric relations for males, females and the total sample showed relatively low values of the variability coefficient except in the relation between the minimum and maximum height (Tpc/T). The coefficients of linear regressions for morphometric characteristics are shown in Table 2.

Meristic data from the present study are shown in Table 3. Significant differences in meristic characteristics between males and females were not recorded (t-test). In all specimens, the ventral fin ray was composed of seven rays. The anal fin was composed of ten to twelve rays and the number of dorsal fin rays ranged between 45 and 49.

DISCUSSION

Morphological differences between males and females of the European hake in the central Adriatic were not observed. The relatively low values of variability coefficient suggest that there is no morphological difference between the collected specimens. The high values of the variability coefficients (> 10%) were found only for the morphometric characteristics in the relation between minimum and maximum heights. Values of this coefficient within populations are usually far greater than 10% in fish (Carvalho, 1993). The results in our study point to the possibility of a homogenous morphology stock of *M. merluccius* in the central Adriatic Sea. The low values of variability coefficient indicate a minimal or very low intrapopulation variation of *Mullus barbatus* and *Leipotherapon plumbeus* (Mamuris et al., 1998; Quilang et al., 2007). On the basis of some morphometric and meristic properties, Županović (1968) also reported that a homogenous morphology stock of European hake exists in the eastern Adriatic Sea. Similar to our study, the analysis of *M. merluccius* morphology indicated a homogenous morphology stock in the northern and western parts of the Adriatic Sea (Matta, 1954; Ghirardelli, 1959).

The available data on the morphometric characteristics of the European hake are very rare. Only Županović (1968), Jardas (1996) and Cohen et al. (1990) published some comparable morphometric data on *M. merluccius* from the Adriatic Sea and eastern Atlantic and Mediterranean. In the Adriatic Sea, Županović (1968) reported that the eye diameter constitutes 18.0 – 25.0% of the head length. According to Jardas (1996), the maximum body height constitutes 13.0% of the standard body length. Head length makes up to 27.0 – 32.0% of the standard

length (Jardas, 1996). In the eastern Atlantic and Mediterranean, the head length constitutes 25.1 – 30.5% of the standard length (Cohen et al., 1990). Generally, these data are very close to the data presented in our study.

Meristic characteristics of the European hake from the central Adriatic Sea were compared with the available literature data (Table 4). The number of rays in the ventral fin (7) is the same for all compared locations (Adriatic, Italian waters, Atlantic and Mediterranean). The number of rays in the second dorsal fin was constant in fish for all areas but the number of rays in the first dorsal fin varied from 7-11. The number of rays in the anal fin mostly varied between 36-40 rays. A similar range was observed in our study. Variation in the number of scales on the linea lateralis was very small for this species in the Adriatic, Mediterranean Sea and eastern Atlantic. Piccinetti and Piccinetti-Manfrin (1971) also recorded 52 vertebrae in the European hake from the northern and central Adriatic. They found that all the analyzed specimens belonged to the same population, supporting our assumption that the central Adriatic is inhabited by a homogenous morphology stock of *M. merluccius*. However, comparing the vertebral count in *M. merluccius* from the Adriatic and Mediterranean Sea, Piccinetti and Piccinetti-Manfrin (1971) suggested that there did not exist two different populations in these areas. The Adriatic hake represents an intermediate species between the eastern and western Mediterranean (Županović and Jardas, 1986). The similarity in the vertebrae counts is particularly marked in the European hake from the western Mediterranean and that from the northern Adriatic (Piccinetti and Piccinetti-Manfrin, 1971). This similarity may be associated with the divergence zones and respective hydrographical factors in the central Adriatic Sea (Jabuka Pit) which is known as the European hake spawning ground in the Adriatic (Županović, 1968; Piccinetti and Piccinetti-Manfrin, 1971).

The meristic characteristics of the European hake in our study mostly agree when compared with data from different areas. The coefficients of linear

Table 1. Relative relations of morphometric characters for females (n = 225), males (n = 210) and total sample (n = 460) of European hake from eastern central Adriatic Sea.

Relation	Sex	Range (%)	Mean \pm SD	t	V (%)
Ls /Lt	F	86.50 – 91.91	89.84 \pm 0.97	0.15	1.07
	M	83.41 – 91.75	89.95 \pm 1.44		1.60
	total	82.66 – 91.91	89.75 \pm 1.67		1.86
C/Ls	F	26.50 – 31.67	29.66 \pm 1.13	0.17	3.80
	M	26.45 – 31.92	29.70 \pm 1.09		3.67
	total	26.40 – 31.92	29.65 \pm 1.13		3.81
Lpd/Ls	F	28.37 – 34.48	32.45 \pm 1.17	0.78	3.60
	M	27.61 – 33.73	31.26 \pm 1.14		3.64
	total	27.61 – 34.48	31.31 \pm 1.11		3.54
Lpa/Ls	F	42.39 – 49.00	45.92 \pm 1.38	0.53	3.00
	M	42.88 – 49.58	45.77 \pm 1.28		2.79
	total	42.39 – 49.58	45.86 \pm 1.46		3.18
Lpp/Ls	F	26.06 – 30.49	29.22 \pm 0.77	0.12	2.63
	M	26.14 – 30.59	29.20 \pm 0.84		2.87
	total	26.06 – 31.03	29.31 \pm 0.84		2.86
Lpv/Ls	F	22.92 – 28.36	25.19 \pm 0.88	0.83	3.49
	M	22.20 – 29.24	25.36 \pm 1.04		4.10
	total	22.20 – 29.24	25.32 \pm 1.00		3.94
Ld/Ls	F	54.66 – 61.37	59.16 \pm 1.16	0.71	1.96
	M	55.37 – 61.39	58.95 \pm 1.47		2.49
	total	53.24 – 61.39	58.76 \pm 1.66		2.82
La/Ls	F	40.51 – 47.78	44.97 \pm 1.36	0.11	3.02
	M	40.66 – 48.67	44.95 \pm 1.93		4.29
	total	40.49 – 48.76	44.73 \pm 1.60		3.57
Lp/Ls	F	14.26 – 17.45	15.98 \pm 0.75	1.09	4.69
	M	12.57 – 17.67	15.80 \pm 0.91		5.75
	total	12.57 – 17.67	15.70 \pm 0.97		6.17

Table 1. continued

Relation	Sex	Range (%)	Mean \pm SD	t	V (%)
Lv/Ls	F	14.19 – 18.62	16.11 \pm 1.00	1.33	6.20
	M	14.01 – 18.71	16.39 \pm 1.00		6.10
	total	14.01 – 18.77	16.42 \pm 1.03		6.27
T /Ls	F	8.49 – 14.03	11.90 \pm 0.95	0.30	7.98
	M	8.92 – 14.74	11.82 \pm 1.01		8.54
	total	7.50 – 14.74	11.40 \pm 1.08		9.47
Tpc/Ls	F	2.35 – 5.75	3.48 \pm 0.30	1.35	8.62
	M	2.66 – 4.34	3.43 \pm 0.33		9.62
	total	2.09 – 5.75	3.36 \pm 0.32		9.52
Po/C	F	35.10 – 40.71	39.10 \pm 1.10	1.45	2.80
	M	35.62 – 40.47	39.90 \pm 1.39		3.48
	total	35.09 – 40.78	39.65 \pm 1.44		3.63
O/C	F	14.46 – 21.40	18.40 \pm 1.66	1.30	9.02
	M	14.89 – 21.97	18.56 \pm 1.66		8.94
	total	14.46 – 21.40	18.51 \pm 1.60		8.64
Olo/C	F	44.07 – 50.99	48.15 \pm 1.52	1.37	3.15
	M	43.96 – 50.05	48.95 \pm 1.50		3.06
	total	43.33 – 50.99	47.69 \pm 1.54		3.22
Tpc/T	F	24.07 – 33.69	28.60 \pm 3.10	1.46	10.93
	M	24.41 – 33.70	29.32 \pm 3.31		11.28
	total	24.07 – 33.78	28.82 \pm 3.43		11.90

F = females

M = males

SD = standard deviation

t = values of t-test

V = variability coefficient

regressions indicate that fish with a smaller body length have a longer head (C/Ls), anal (La/Ls) and ventral fins (Lp/Ls) as well as a greater maximum (T/Ls) and minimum body height (Tpc/Ls). At the same time they have shorter dorsal (Ld/Ls) and pectoral

fins (Lp/Ls) than adult fish. Also smaller individuals have shorter predorsal (Lpd/Ls), preanal (Lpa/Ls), preventral (Lpv/Ls) and prepectoral (Lpp/Ls) distances. As to the other morphometric relations, the small specimens have smaller preorbital (Po/C)

Table 2. Regression (a, b) and determination coefficients (R^2) of linear regression for total sample (n = 460).

Relation	a	b	R^2
Ls /Lt	80.766	0.076	0.960
C/Ls	28.544	- 0.155	0.894
Lpd/Ls	29.129	0.068	0.961
Lpa/Ls	38.976	0.080	0.973
Lpp/Ls	28.988	0.079	0.896
Lpv/Ls	25.530	0.788	0.927
Ld/Ls	49.675	0.343	0.863
La/Ls	42.096	- 0.098	0.944
Lp/Ls	15.781	0.284	0.966
Lv/Ls	17.087	- 0.081	0.976
T/Ls	12.536	- 0.089	0.954
Tpc/Ls	4.091	- 0.024	0.863
Po/C	37.863	0.128	0.941
O/C	17.419	- 0.088	0.942
Olo/C	43.213	0.151	0.913
Tpc/T	26.122	0.086	0.961

Table 3. Meristic characters for females (n = 225), males (n = 210) and total sample (n = 460) of European hake from eastern central Adriatic Sea. 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, L. lat. = number of scales in linea lateralis, Vert. = number of vertebrae

Meristic character	Sex	Range	Mean \pm SD	t	V (%)
D	F	45 - 49	47.77 \pm 1.11	0.88	2.32
	M	45 - 49	47.53 \pm 1.69		3.55
	total	45 - 49	47.64 \pm 1.11		2.33
A	F	36 - 39	37.00 \pm 0.95	0.79	2.56
	M	36 - 39	37.15 \pm 0.86		2.31
	total	36 - 39	37.14 \pm 0.88		2.36
P	F	10 - 12	12.02 \pm 0.15	1.41	1.24
	M	10 - 12	11.96 \pm 0.29		2.42
	total	10 - 12	12.00 \pm 0.22		1.83

Table 3. continued

Meristic character	Sex	Range	Mean \pm SD	t	V (%)
V	F	7	7.00 \pm 0	0	0
	M	7	7.00 \pm 0		0
	total	7	7.00 \pm 0		0
L. lat	F	130 - 152	141.14 \pm 3.22	1.30	2.28
	M	132 - 148	140.05 \pm 2.89		2.06
	total	130 - 152	140.90 \pm 3.01		2.13
Vert.	F	52	52 \pm 0	0	0
	M	52	52 \pm 0		0
	total	52	52 \pm 0		0

F = females

M = males

SD = standard deviation

t = values of t-test

V = variability coefficient

Table 4. Meristic characters of European hake from the Adriatic Sea, Mediterranean and NE Atlantic.

Area and data of authors	D	A	P	V	L. lat	Vert.
Eastern central Adriatic, our result	9 - 10 / 35 - 40	36 - 40	10 - 12	7	130 - 156	52
Eastern Adriatic Županović (1968)	9 - 10 / 35 - 40	35 - 40	10 - 12	7	-	-
Jardas (1996)	8 - 10 / 35 - 40	36 - 40	12 - 14	7	127 - 156	-
Italian coast Bini (1968)	9 - 11 / 36 - 40	36 - 40	12 - 14	7	-	-
Tortonese (1975)	9 - 11 / 35 - 40	35 - 40	12 - 14	7	130 - 150	-
Mediterranean and NE Atlantic, Fisher et al (1987)	8 - 11 / 35 - 40	-	-	-	127 - 156	-
Cohen et al. (1990)	7 - 10 / 35 - 40	36 - 40	-	-	127 - 156	-

and postorbital distances (Olo/C) and a bigger eye diameter (O/C) than the larger *M. merluccius* specimens. Preorbital and postorbital distances increase relatively to the European hake's body length. The negative correlation recorded for the maximum (T/Ls) and minimum body depth (Tpc/Ls) points to the fact that the body is progressively elongated.

In conclusion, the results in this study show that there are no morphological differences between males and females. Biometric analysis indicated changes in some morphometric characteristics during fish growth as well as the possibility of the existence of a homogenous morphology stock of the European hake in the central Adriatic.

REFERENCES

- Bini G. (1968). Gadidae. In: *Atlante dei pesci delle coste italiane*, 4. Osteitti. 93-94. Mondo Somerso, Milano.
- Carvalho, I. (1993). Evolutionary aspects of fish distribution: genetic variability and adaptation. *J. Fish Biol.* **43**, 57-73.
- Cohen, D.M., Iwamoto T. and N. Scialabba (1990). Gadiform fishes of the world. In: *FAO species catalogue*. 4.
- FAO Fish. Stat (2009). *Capture production*.
- Fisher, W., Bauchot, M-L. and M. Schneider (1987). *Fishes FAO d'identification des espèces pour les besoins de la pêche. Méditerranée et Mer Noire*. **2**, 1173-1174. FAO. Rome.
- Ghirardelli, E. (1959). Contribution à la connaissance de la biologie du merlu (*Merluccius merluccius*) eu moyenne Adriatique. *Proc. Gen. Fish. Count.Medit.* **5**, 498-494.
- Grubišić, F. (1988). *Ribe, rakovi i školjke Jadrana*. ITRO Naprijed, Zagreb-GRO Liburnija, Rijeka. 239 pp.
- Jardas, I. (1996). *Jadranska ihtiofauna*. Školska knjiga d d, Zagreb, 533 pp.
- Jukić, S. (1972). Ishrana oslića (*Merluccius merluccius*), bukve (*Boops boops*), trlje (*Mullus barbatus*) i arbuna (*Pagellus erythrinus*) u Kaštelanskim zaljevu. *Acta Adriat.* **14**, 1-40.
- Jukić S. and C. Piccinetti (1981). Quantitative and qualitative characteristics of demersal resources in the Adriatic Sea with some population dynamics estimates. *FAO Fish Rep.* **253**, 73-91.
- Mamuris, Z., Apostolidis A.P, Panagiotaki P., Therodorou A.J. and C. Triantaphyllidis (1998). Morphological variation between red mullet populations in Greece. *J. Fish Biol.* **52**, 107-117.
- Matta, F. (1954). Il merluzzo di Mediterraneo, 2. *Boll. Pesca. Piscicult Idrobiol.* **9**, 5-29.
- Piccinetti, C. and G. Piccinetti-Manfrin (1971). Osservazioni sull'alimentazione dell merluzzo (*Merluccius merluccius*) in alto e medio Adriatico. *Note Lab. Biol. Mar. Pesca, Fano.* **4**, 41-64.
- Quilang, J.P., Basiao Z.U., Pagulayan R.C., Roderos R.R. and E.B. Barrios (2007). Meristic and morphometric variation in te silver perch, *Lepiotherapon plumbeus* (Kner, 1864), from three lakes in the Philippines. *J. App. Ichthyol.* **23**, 561-567.
- Sokal, R.R. and F.J. Rohlf (1981). *Biometry*. W.H. Freeman and Company, San Francisco.
- Tortonese, E. (1975). Osteichthyes (Pesci ossei). *Fauna d' Italia*. Calderini, **11**, Bologna. 636 pp.
- Vrgoč, N. (2000). Struktura i dinamika pridenenih zajednica riba Jadranskog mora. *Ph.D. Thesis*. PMF, University of Zagreb. 197 pp.
- Županović, Š. (1968). Study of hake (*Merluccius merluccius* L.) biology and population dynamics in the central Adriatic. *FAO Stud. Rev.* **32**, 1-24.
- Županović, Š. and I. Jardas (1986). A contribution to the study of biology and population dynamics of the Adriatic hake. *Acta Adriat.* **27**, 97-146.

