short communication

Morphometric and meristic characteristics of poor cod, *Trisopterus minutus* (L. 1758), from the eastern central Adriatic Sea

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Abstract

Background and Purpose: *Poor cod*, Trisopterus minutus *(Linnaeus, 1758) is a gadoid fish, which inhabits the Mediterranean and eastern Atlantic. The aim of present work was to investigate the morphological properties of poor cod in the eastern central Adriatic Sea by analyzing classical morphometric and meristic characteristics, and thereby investigating: a) whether there are morphological differences between males and females; b) the existence of possible homogenous or heterogeneous stock morphology; and c) the changes in morphometric characteristics with increase in body length.*

Material and methods: *Samples of 410 poor cod specimens (209 females, 201 males) were collected by bottom-trawl between 2014 and 2016 from five localities in the eastern central Adriatic Sea. In order to analyze biometry of the species; fifteen morphometric and eight meristic characteristics were measured.*

Results and Conclusions: *Total length of all specimens ranged from 8.8 to 25.5 cm. Morphological differences between males and females was not marked. Biometric analysis of the morphometric and meristic characteristics indicated a homogenous morphology stock of* Trisopterus minutus *in the Adriatic Sea. Changes in some morphometric characteristics obtained in conjunction with an increase in body length showed that smaller specimens have a longer head, eye diameter, ventral fins and second anal fins than adult specimens. The negative correlation recorded for the maximum and minimum body depth indicated that the body elongated with poor cod growth. Comparison of the meristic characteristics that were published earlier show some differences between the poor cod populations inhabiting the Adriatic, Black Sea and eastern Atlantic.*

INTRODUCTION

Poor cod, *Trisopterus minutus* (Linnaeus, 1758) is a gadoid fish, which inhabits the Mediterranean and eastern Atlantic coast from Norway to the coast of Morocco *(1)*. It is common in the Adriatic Sea on the sandy-muddy bottoms between depths of 40 and 250 m *(2)*. This species is serial spawner with prolonged spawning period. It spawns in the winter-spring seasons *(2)*. They reach first sexual maturity before the end of the first year of life *(3)*. The poor cod is an opportunistic predator whose diet consist various bottom-living prey groups, with wide range of sizes and morphologies *(4)*. Poor cod is one of the most abundant demersal species and in the Mediterranean Sea, annual landings by

commercial trawl fisheries fluctuated from 1191 to 3534 tonnes (*5*). *T. minutus* is one of the most abundant demersal species, and in the Mediterranean Sea, annual landings by commercial trawl fisheries have fluctuated from 1191 to 3534 tonnes (*5*). The biology of this species is considered to be well documented for the Adriatic Sea (*6, 7, 8, 9*). However, their morphometric and meristic characteristics of this abundant species have not been systematically analyzed. Some data on individual meristic characteristics of poor cod are available (*10, 11, 12, 13, 1, 2*), however, morphometric data are scant and incomplete. Some classical morphometric relations have been reported for poor cod in the Adriatic Sea (*12, 2*).

Morphological differences based on general body type have been used to distinguish and compare among species and groups. Morphometric and meristic studies have provided useful results for identifying marine fish stocks and describing their spatial distributions. However, in description of species, knowledge of its morphometric and meristic traits is necessary especially because specimens from different areas differ from one another in morphology (*2*).

The aim of present work was to investigate the morphological properties of poor cod in the eastern central Adriatic Sea by analyzing classical morphometric and meristic characteristics, and thereby investigating: a) whether there are morphological differences between males and females; b) the existence of possible homogenous or heterogeneous stock morphology; and c) the changes in morphometric characteristics with increase in body length.

We expect these results will provide the first complete biometric description of *T. minutus* in the Adriatic Sea. The presented data are a step forward in improving the knowledge of the biology of these species.

MATERIALS AND METHODS

Fish sampling

Poor cod were collected from five localities in the eastern central Adriatic Sea (Figure 1). The investigated areas are situated on the continental shelf mostly at depths of
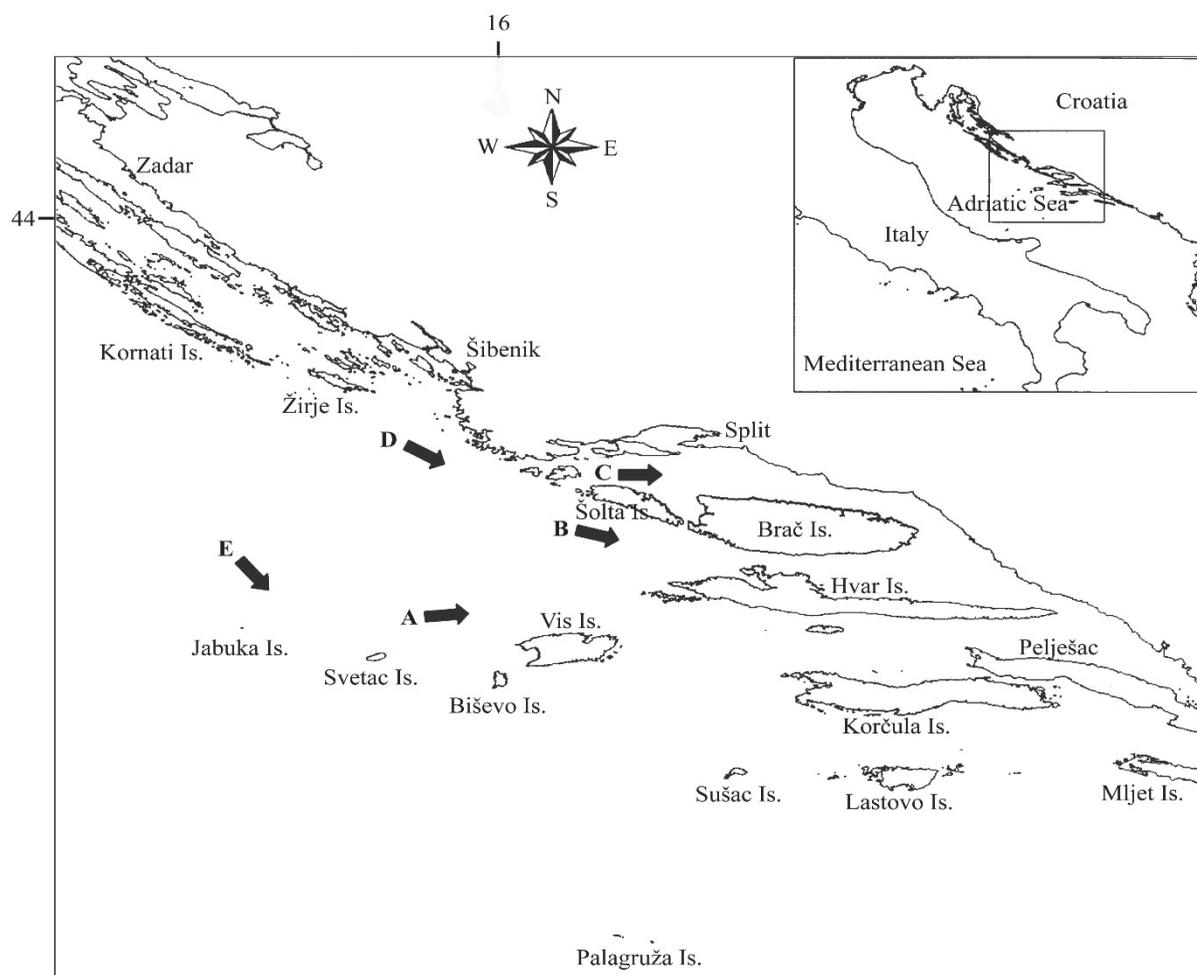

Figure 1. *Study area and sampling localities of* T. minutus *in the eastern central Adriatic: A – near islands of Vis and Svetac, B – south of Maslenica, C – Split Channel, D – Blitvenica fishing area, D – Islands of Jabuka.*
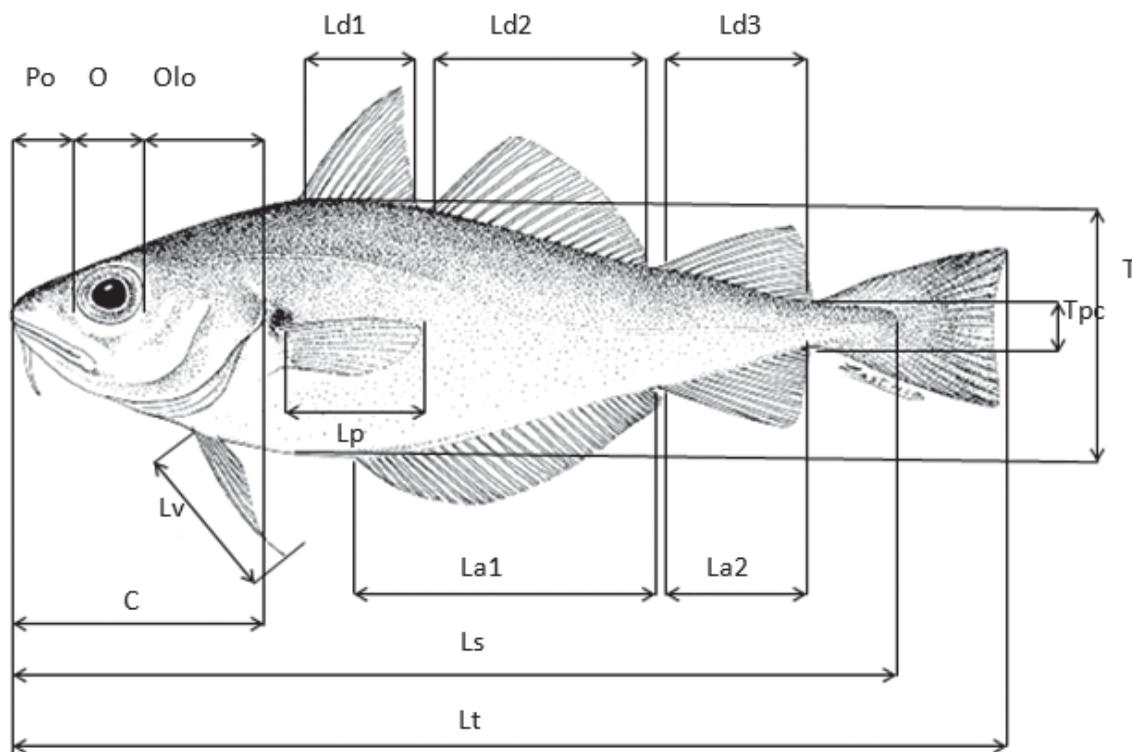
Figure 2. *Morphometric measurements of* T. minutus: *Lt – total length, Ls – standard length, Ld1 – length of first dorsal fin, Ld2 – length of second dorsal fin, Ld3 – length of third dorsal fin, La2 – length of first anal fin, La2 – length of second anal fin, Lp – length of pectoral fin Lv – length of ventral fin, T – maximum body height, Tpc – minimum body height, C – head length, O – eye diameter, Po – preocular distance, Olo – postocular distance.*

90 to 120 m. Poor cod specimens were sampled with a commercial vessel with bottom trawls using a 22-mm stretched mesh size cod-end. Duration of each haul was 2 – 3 h; trawling speed fluctuated from 5 to 7 km/h. Samples were collected from 2014 to 2016, with a total of 410 specimens (201 males and 209 females).

Biometric measurements

Biometric measurements were performed on fresh fish. In the laboratory, the specimens were boiled to facilitate the separation of the muscular tissue from the vertebral column. After this step, the number of vertebrae was counted. Fifteen morphometric and nine meristic characteristics were measured.

The analyzed classical morphometric characteristics are: total length (Lt), standard length (Ls), lengths of three dorsal (Ld1, Ld2, Ld3) and two anal (La1, La2) fin bases, lengths of pectoral (Lp) and ventral fins (Lv). Also, maximum (T) and minimum (Tpc) body heights, head length (C), eye diameter (O), preocular (Po) and postocular (Olo) distances were measured (Figure 2).

The analyzed meristic characteristics are: number of rays in dorsal (D1, D2, D3), anal (A1, A2), pectoral (P) and ventral fins (V), number of gill rakers on the first gill arch (G.r.) and number of vertebrae (Vert.).

The total and standard lengths were measured with a fish meter to the nearest 0.1 cm. The other morphometric characteristics were measured with a caliper to the nearest 0.01 mm. The entire sample was categorized into cm-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 percentage of the total length (Ls/Lt) and minimum height was expressed as percentage of maximum body height (h/H). Sex was determined macroscopically according to the shape and appearance of gonads.

Statistical analysis

The arithmetic mean, standard deviation and variability coefficient were used in processing biometry data. Significance of differences in studied characteristics between males and females were tested with *t*-test (*14*). Linear regression was applied to the examined morphometric relations in comparison with an increase in total length.

RESULT

Overall, 410 specimens of *T. minutus* were examined for morphometric and meristic characteristics. The sample was composed of 209 females and 201 males. Total
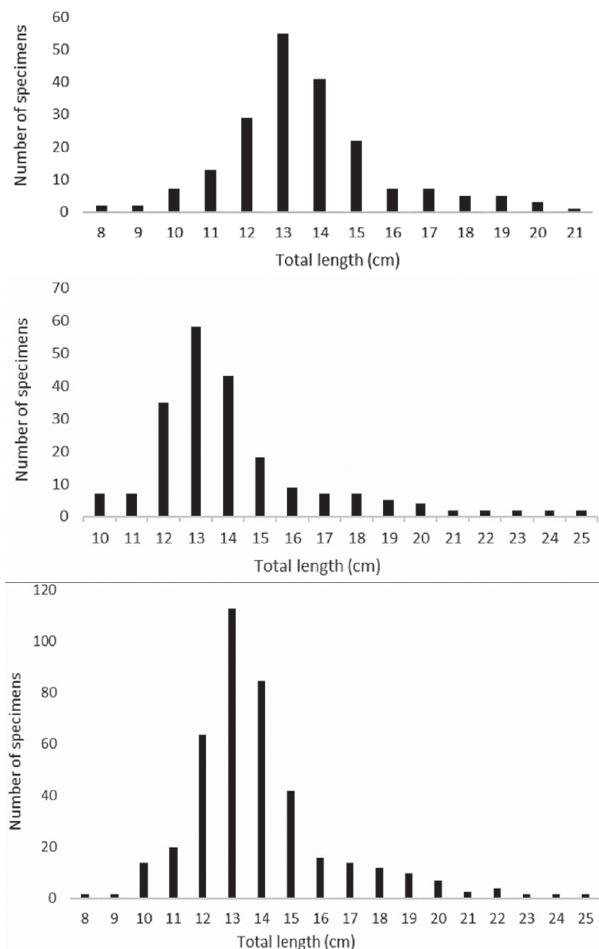
Figure 3. *Length frequency distributions of* T. minutus *for a) males (n = 201), b) females (n = 209) and c) total samples (n = 410) caught in the eastern central Adriatic*

TABLE 1 *Relative relations of morphometric characters for females (n = 209), males (n = 201), and total sample (n = 410) of poor cod from eastern central Adriatic Sea.*

Relation	Sex	Range (%)	Mean ± SD	t	V (%)
Ls/Lt	F	85.71 – 95.80	90.01 ± 2.38		2.65
	M	84.03 – 92.72	89.07 ± 1.60	0.21	1.80
	total	84.03 – 95.80	89.57 ± 2.08		2.32
C/Ls	F	20.49 – 28.83	24.70 ± 1.64		6.63
	M	21.43 – 29.17	25.31 ± 1.57	0.16	6.19
	total	20.49 – 29.17	24.99 ± 1.62		6.49
Ld1/Ls	F	10.03 – 14.87	12.66 ± 0.65		5.13
	M	10.41 – 15.00	12.99 ± 0.85	0.43	6.54
	total	10.03 – 15.00	12.78 ± 0.77		6.02
Ld2/Ls	F	16. 98 – 23.59	20.49 ± 1.49	0.76	7.27
	M	16.51 – 23.40	20.38 ± 1.23		5.88
	total	16.98 – 23.59	20.42 ± 1.32		6.46
Ld3/Ls	F	12.90 – 17.55	15.95 ± 1.01	0.97	6.33
	M	12.99 – 17.79	15. 11 ± 0.90		5,95
	total	12.90 – 17.79	15.64 ± 0.98		6.26
Lp/Ls	F	13.97 – 20.19	16.39 ± 1.43		8.72
	M	14.07 – 20.56	16.95 ± 1.41	0.14	8.31
	total	13.97 – 20.56	16.65 ± 1.40		8.40
La1/Ls	F	20.86 – 29.03	25.99 ± 1.89		7.27
	M	20.98 – 28.90	25.59 ± 1.11	0.89	4.33
	total	20.86 – 29.03	25.80 ± 1.54		5.96
La2/Ls	F	12.56 – 19.78	15.98 ± 0.88	0.77	5.55
	M	12.21 – 19.66	16.91 ± 0.99		5.85
	total	12.21 – 19.78	16.50 ± 0.96		5.81
Lv/Ls	M	9.01 – 18.45	14.29 ± 1.19		8.32
	F	9.11 – 18.79	13.88 ± 1.22	0.26	8.78
	total	9.01 – 18.79	13.94 ± 1.20		8.60
T/Ls	F	20.69 – 32.99	26.54 ± 2.47		9.31
	M	23.68 – 34.86	28.06 ± 2.66	0.26	9.47
	total	20.69 – 34.86	27.26 ± 2.66		9.77
Tpc/Ls	F	3.82 – 8.33	6.00 ± 0.56		9.33
	M	4.55 – 7.69	6.18 ± 0.51	0.08	8.25
	total	3.82 – 8.33	6.08 ± 0.55		9,04
Tpc/T	F	15.15 – 34.38	22.59 ± 2.48		10.97
	M	16.67 – 27.78	22.01 ± 2.66	0.34	12.08
	total	15.15 – 34.38	22.31 ± 2.59		11.60
Relation	Sex	Range (%)	Mean ± SD	t	V (%)
O/C	F	28.13 – 38.71	33.49 ± 3.04	0.33	9.07
	M	26.67 – 42.31	33.79 ± 3.37		9.97
	total	26.67 – 42.31	33.63 ± 3.35		9.96
Po/C	F	21.05 – 36.00	28.20 ± 2.54		9.00
	M	21.88 – 35.48	27.96 ± 2.50	0.35	8.94
	total	21.05 – 36.00	28.08 ± 2.51		8.93
Olo/C	F	51.35 – 67.86	58.60 ± 5.60		9.56
	M	51.43 – 67.88	59.29 ± 4.39	0.50	7.40
	total	51.35 – 67. 89	58.93 ± 5.03		8.53

F = females; M = males; SD = standard deviation; t = values of t-test; V = variability coefficient

length (Lt) of all samples ranged from 8.8 to 21.5 cm (14.58 ± 1.89). Total length of females ranged from 10.3 to 25.5 cm (14.86 ± 1.84) and males from 8.8 to 21.5 cm (13.99 ± 1.98). The length frequency distribution exhibited a mode at 13 cm (Figure 3).

Morphometric mesaurements for males, females and total poor cod sample are presented in Table 1. Morphological differences between poor cod females and males were not marked. Namely, the differences in the mean values of the measured morphometric relations between females and males were not statistically significant in any individual case. The morphometric relations for males, females and the total sample showed relatively low values of variability coefficients (< 10%) except in relation to the minimum and maximum body height (T/Tpc).

The coefficients of linear regressions for morphometric characteristics are shown in Table 2. Morphometric relations Ls/Lt, Ld1/Ls, Ld2/Ls, Ld3/Ls, La1/Ls, Lp/Ls, Po/C and Olo/C, show positive correlation. Other measured morphometric relations (C/Ls, La2/Ls, Lv/Ls, T/Ls, Tpc/Ls, Tpc/T, O/C) indicate negative correlation.

TABLE 2 *Regression (a, b) and determination coefficients (R²) of linear regression for total sample (n = 410).*

Relation	a	b	R²
Ls /Lt	92.022	0.078	0.979
C/Ls	35.221	−0.099	0.898
Ld1/Ls	39.098	0.257	0.873
Ld2/Ls	42.341	0.342	0.758
Ld3/Ls	34.125	0.654	0.671
La1/Ls	33.654	0.091	0.799
La2/Ls	32.760	−0.086	0.843
Lp/Ls	20.765	0.104	0.943
Lv /Ls	12.986	−0.791	0.976
Tpc/Ls	5.010	−0.081	0.888
T/Ls	24.713	−0.076	0.911
Tpc/T	17.731	−0.071	0.815
Po/C	29.221	0.022	0.943
O/C	27.121	−0.047	0.923
Olo/C	35.558	0.180	0.909

Meristic data are shown in Table 3. Significant differences in meristic characteristics between males and females were not recorded (t-test). Poor cod has only soft rays in all the fins and their number varies, except in ventral fin, which compsed of six rays in all the specimens. The first dorsal fin was composed of 9–14 rays, second dorsal of 15–21 rays and the number third dorsal fin rays ranged between 14–19. The pectoral fin rays ranged between 14 and 20. The number of gill rakers on the first gill arch ranged between 15–20, and the number of vertebrae varied from 40–45.

DISCUSSION

Morphological differences between poor cod females and males in eastern central Adriatic were not observed. The relatively low values of the variability coefficient (< 10%) suggest that there was no morphological difference between the collected specimens. Values of this coefficient within populations are usually far greater than 10% in fish (*15*). The results in our study point to the possibility of a homogenous morphology stock of *T. minutus* in the eastern central Adriatic Sea.

The available data on the classical morphometric characteristics of poor cod are very rare. Some comparable morphometric relationships for *T. minutus* are presented from the Adriatic Sea (*12*, *2*). Head length constitutes 27.1% of the standard length while eye diameter makes 31.3% of the head length (*12*). Maximum body height constitutes 25.0 – 29.4% of the standard length (*2*). Generally, these data are very close to the data presented in our study.

TABLE 3. *Meristic characters for females (n = 209), males (n = 201) and total sample (n = 410) of poor cod from the eastern central Adriatic Sea.*

Meristic character	Sex	Range	Mean ± SD	t	V (%)
D1	F	9 – 14	11.23 ± 1.06	0.10	0.09
	M	10 – 13	11.24 ± 0.94		0.08
	Total	9– 14	11.24 ± 1.00		0.09
D2	F	15 – 21	18.02 ± 1.45	0.15	0.08
	M	15 – 21	18.38 ± 1.52		0.08
	total	15 – 21	18.20 ± 1.40		0.08
D3	F	14 – 19	15.85 ± 1.14	0.11	0.07
	M	13 – 18	15.68 ± 0.98		0.06
	total	13 – 19	15.76 ± 1.06		0.07
A1	F	22 – 29	25.69 ± 1.44	0.12	0.06
	M	24 – 28	25.16 ± 0.77		0.03
	total	22 – 29	25.43 ± 1.18		0.05
A2	F	12 – 22	16.83 ± 2.37	0.21	0.14
	M	14 – 20	16.34 ± 1.78		0.11
	total	12 – 22	16.59 ± 2.10		0.13
V	F	6	6.00 ± 0	0	0
	M	6	6.00 ± 0		0
	total	6	6.00 ± 0		0
P	F	14 – 18	15.81 ± 1.16	0.13	0.07
	M	15 – 20	16.40 ± 1.39		0.08
	total	14 – 20	16.10 ± 1.30		0.08
G.r.	F	15 – 20	16.94 ± 1.16	0.12	0.07
	M	16 – 20	17.92 ± 1.01		0.06
	total	15 – 20	17.42 ± 1.19		0.07
Vert.	F	40 – 45	41.56 ± 1.39	0.13	0.03
	M	40 – 44	41.94 ± 1.19		0.03
	total	40 – 45	41.75 ± 1.30		0.03

D1 = number of rays in first dorsal fin, D2 = number of rays in second dorsal fin, D3 = number of rays in third dorsal fin, A1 = number of rays in first anal fin, A2 = number of rays in second anal fin, P = number of rays in pectoral fin, V = number of rays in ventral fin, G. r. = number of gill rakes on the first gill arch, Vert. = number of vertebrae (M = males; F = females; SD = standard deviation; t = values of t-test; V = variability coefficient)

The coefficients of linear regressions for morphometric characteristics are shown in Table 2. These coefficients indicate that fish with a smaller body have a longer head (C/Ls), eye diameter (O/C), ventral fins (Lv/Ls), second anal fins (La2/Ls) as well as greater minimum (T/Ls) and maximum body height (Tpc/Ls). At the same time, they have shorter standard length (Ls/lt), dorsal fins (Ld1/Ls, Ld2/Ls, Ld3/Ls), pectoral (Lp/Ls) and first anal fins

TABLE 4. *Meristic characters of poor cod from the Adriatic Sea, Mediterranean, Black Sea and NE Atlantic.*

Area and data of authors	D1	D2	D3	A1	A2	P	V	Vert.	G. r.
Eastern central Adriatic Our results	9 – 14	15 – 21	13 – 19	22 – 29	12 – 22	14 – 20	6	40 – 45	15 – 20
Algerian waters Dieuzeide et al. (1955)	11 – 13	16 – 21	17 – 20	26 – 30	16 – 20	19	6	39	–
Italian waters Bini (1970)	11 – 13	18 – 22	17 – 19	27 – 30	18 – 20	19	6	39	17 – 20
Tortonese (1970)	11 – 13	16 – 22	17 – 20	26 – 30	16 – 20	–	–	45 – 48	–
North eastern Atlantic and Mediterranean Svetovidov (1986)	12 – 13	23 – 27	20 – 25	27 – 30	20 – 25	–	–	47 – 51	25 – 32
Black Sea Svetovidov (1964)	10 – 12	17 – 20	15 – 17	25 – 29	15 – 20	–	–	–	17 – 20
Adriatic Sea Jardas (1996)	8 – 12	10 – 14	11 – 16	15 – 18	12 – 16	14 – 19	6	40 – 45	15 – 20

(Ld1/Ls). The negative correlation recorded for the maximum and minimum body depths points to the fact that body is progressively elongated. As to other morphometric relations, small specimens have smaller preocular (Po/C) and postocular distances (Olo/C) and a larger eye diameter (O/C) than the larger *T. minutus* specimens. Preocular and postocular distances increase relatively to the poor cod body length.

The meristic characters of poor cod from the eastern central Adriatic Sea were compared with the available literature data (Table 4). Cited literature is based only on books that describe fauna of certain areas. Therefore, there are no sample sizes or exact research areas defined.

The number of rays in the pectoral fin is defined by three authors (*10, 11, 2*) and it varies from 14 to 20. The number of rays in the ventral fin (six rays) is the almost the same in Adriatic Sea, Italian and Algerian waters. The number of gill rakers is mostly found to be from 15-20. In other hand, in the Atlantic population this number is from 25–32 (*1*), contrasting with the present study where this range was lower. In poor cod there are between 45-48 vertebrae. However, in Atlantic population this number can be bigger (47–51) (*1*). Also, Atlantic population of poor cod, show increased number of rays in second and third dorsal and second anal fins compared to those from other areas (Adriatic, Black Sea, Italian and Algerian waters). The significance of differences among reported data could not be established since only ranges of meristic data are given in literature. The meristic data from this study suggest that population of poor cod from the Adriatic Sea is slightly different in morphology compared to the Black Sea population. This differences in some meristic characteristics of poor cod from various geographical areas could be result of spatial segregation and different environmental conditions. It had been assumed earlier that variation in meristic and morphometric characteristics are entirely genetic (*16*), but recently it has been found that they have

environmental and genetic components as well (*17*). The number of rays in the dorsal and anal fins from this study show greater range compared with results of Bini (*11*) and Jardas (*2*). These differences were probably related to the larger analyzed sample and wider size-interval of poor cod specimens in our study.

In conclusion, results in this study show that there are no morphological differences between males and females. Biometric analysis has revealed changes in some morphometric characteristics during fish growth and points to the possibility of the existence of a homogenous morphology stock of the poor cod in the eastern central Adriatic. Differences in some meristic characteristics between the poor cod populations in the Atlantic, Adriatic and Black Sea exist and could be the result of different environmental conditions. So, further studies should investigate the possible connection between observed variability and environmental factors.

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