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Length-weight relationships of ten fish species from the Bulgarian Black Sea waters

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Abstract: Length-weight relationships (LWRs) of 16,842 specimens of fish caught in the Bulgarian Black Sea waters, covering 9 families, 10 genera, and 10 species, were studied. Spiny dogfish (*Squalus acanthias* L.), thornback ray (*Raja clavata* L.), sprat (*Sprattus sprattus* L.), pontic shad (*Alosa immaculata* Eichwald), anchovy (*Engraulis encrasicolus* L.), whiting (*Merlangius merlangus euxinus* Pallas), horse mackerel (*Trachurus mediterraneus* Aleev), bonito (*Sarda sarda* Bloch), round goby (*Neogobius melanostomus* Pallas), and turbot (*Psetta maxima* L.) were collected from May 2006 to December 2008. The fishes were caught by different fishing techniques, such as gill net, trawl net, and trap nets. The slope or allometric coefficient (b) of the functional regression between length and weight values varied from between 2.302 and 3.839 with the mean b = 3.152. The LWRs for *S. acanthias* and *R. clavata* have been reported for the first time for the Bulgarian Black Sea waters.

Key words: Length-weight relationships, fish species, Black Sea waters, Bulgaria

Introduction

The Bulgarian Black Sea waters are a significant spawning and growing area for several fish species (Stoyanov et al., 1963). The most important species for industrial fishing are turbot, sprat, and horse mackerel. Depending on the stock states in different periods, this group may also involve pontic shad, bonito, round goby, anchovy, and some others.

The knowledge of the biology of commercially important fish in economic terms (size values, i.e. minimum, maximum, and mean; and size relationships, i.e. length-weight) helps for the sustainable exploitation of the Black Sea's natural resources. Length and weight measurements in conjunction with age data can give information on the stock composition, age at maturity, life span, mortality, growth, and production (Bolger and Connolly, 1989; Diaz et al., 2000). Length-weight relationships (LWRs) allow fishery scientists to convert growth in length equations to growth in weight in stock assessment models (Morato et al.,

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2001; Stergiou and Moutopoulos, 2001), estimate biomass from length frequency distribution (Petrakis and Stergiou, 1995; Dulčić and Kraljević, 1996), and calculate fish condition (Petrakis and Stergiou, 1995). However, the information about the length-weight relationships of fish species in the western part of the Black Sea is very scarce and incomplete. Data about previous investigations of LWRs for fish species from the Mediterranean, Black, and Azov seas are presented in Table 1.

In this study, we report the LWR parameters of 10 species that are of economic and ecological relevance in the commercial fisheries off the Bulgarian Black Sea coast.

Materials and methods

The investigated area includes the Bulgarian Black Sea waters in front of Cape Kaliakra, Varna, Cape Emine, Bourgas, and Sozopol (Figure), and the study was conducted from May 2006 to December 2008. A total of 16,842 specimens from 10 fish species were collected by different fishing techniques (gill net with mesh size 2a = 400 mm; trawl net with an "effective" part of the mouth of 16 m, vertical opening of 4 m, mesh size of the cod end of 6.5 mm; and trap nets). The samples were transported to the research laboratory in polythene bags containing ice blocks to prevent spoilage and were then stored in a deep freezer (-30 °C) to avert deterioration. The total length

Table 1. Some of the results of LWR parameters estimated in different localities for the similar fish species targeted in the present study.

	L_{min}-L_{max}	a	b	Area	Sources
M. m. euxinus	9-24	0.004	3.24	Mid-Black Sea	Samsun and Erkoyuncu, 1998
	5-40	0.005	3.14	Eastern Black Sea	Genç et al., 1999
	5-32.5	0.004	3.24	Black Sea	İşmen, 2002
		0.005	3.11	Bulgaria	Maximov et al., 2009
S. sarda		0.015	2.984	Adriatic Sea	Zorica and Sinovčić, 2008
A. immaculata	9-36	0.063	2.55	Bulgaria	Kolarov, 1991
	11.6-31.6	0.002	3.39	Mid-Black Sea	Samsun, 1995
E. encrasicolus	6-15	0.007	2.92	Mid-Black Sea	Samsun et al., 2004
S. sprattus	9-17.4	0.004	3.16	Adriatic	Sinovčić et al., 2004
	8.6-11.9	0.022	2.51	Adriatic Sea	Sinovčić et al., 2004
	7.2-13.2	0.002	3.46	Eastern Black Sea	Şahin, 1999
T. mediterraneus	10.5-17	0.035	3.30	Bulgaria	Yankova et al., 2010
		0.0051	3.17	Eastern Black Sea	Genç et al., 1999
S. acanthias	27.00-70.50	0.0031	3.10	Aegean Sea	Filiz and Mater, 2002
		0.0040	2.95	Southeastern Black Sea	Avsar, 1996
R. clavata	20.50-99.00	0.0016	3.29	Aegean Sea	Filiz and Mater, 2002
P. maxima		0.0074	3.22	Black Sea	Samsun et al., 2007
N. melanostomus	0.0972	2.431	Sea of Azov	Froese and Pauly, 2009	

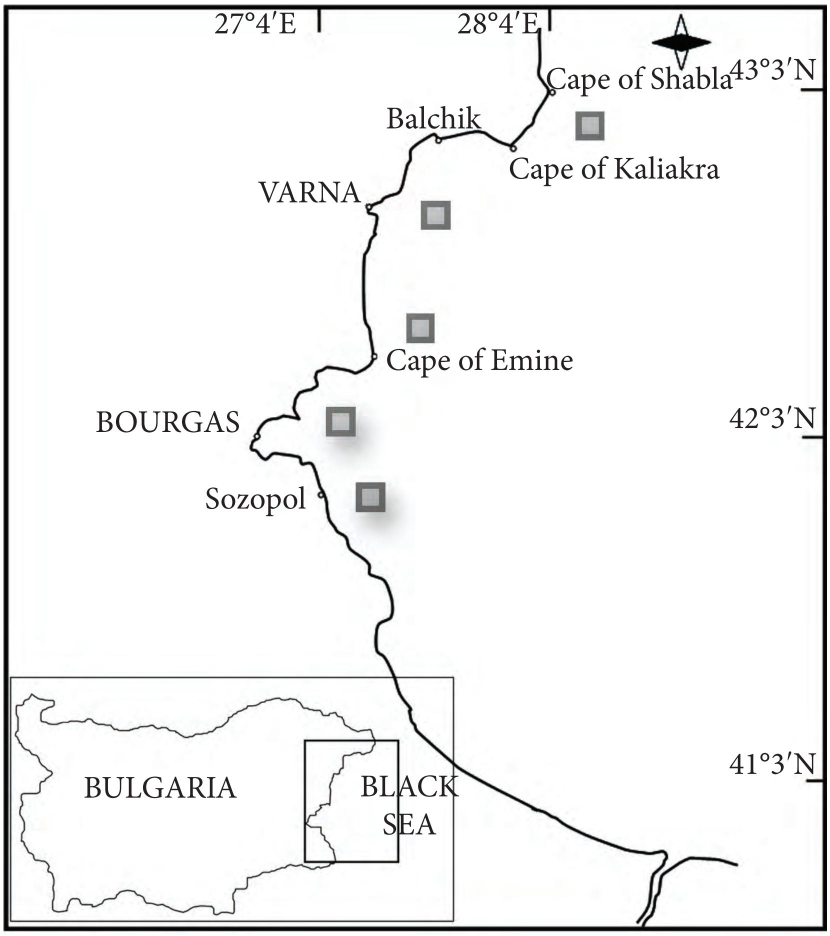

Figure. Scheme of area investigated.

of each fish (measured to the nearest 0.1 cm) was taken from the tip of the snout to the extended tip of the caudal fin using a measuring board. Body weight was measured to the nearest gram using a balance. Five species, *Squalus acanthias*, *Psetta maxima*, *Raja clavata*, *Sprattus sprattus*, and *Merlangius merlangus euxinus*, were collected by the research vessels *Elis* and *RK-3* (boat lengths 13.7 and 17 m, engine horsepower 1.7 and 1.8 hp, respectively). After hauling, the catch was removed, and analyses were carried out on the deck of the research vessel and later in the laboratory. The mathematical function suggested by Le Cren (1951) was used in estimating LWRs:

$$W = aL^b$$

where W is the total body weight (g), L the total length (cm), and a and b are the coefficients of the functional regression between W and L. An allometric coefficient b value larger or smaller than 3.0 shows an allometric growth, or isometric growth when it is equal to 3.0 (Bagenal and Tesch, 1978). In order to confirm whether the b values obtained in the linear regressions were significantly different from the isometric value (b = 3), t-tests for independent samples were used. Data concerning the t-tests are presented in Table 2. The values of constants a and b were estimated from the log transformed values of length and weight, i.e.:

$$\log W = \log a + b \log L$$

via least square linear regression. The degree of association between the variables was computed by the determination coefficient, r^2.

Table 2. Mean total length, weight, parameters of the LWR, and statistical results from the t-test for 10 species caught from the Bulgarian Black Sea coast.

	Length characteristics				Weight characteristics			Parameters of relationship					
Family, Species	**N**	**MTL**	**±SE**	**TL_{min}-TL_{max}**	**MW**	**±SE**	**W_{min}-W_{max}**	**a**	**b**	**r^2**	**SE(b)**	**t-test**	**P**
Squalidae													
S. acanthias	22	125	0.02	112-144	10.35	0.68	6.2-14.2	0.001	3.153	0.81	0.18	0.16	0.89
Rajidae													
R. clavata	24	68.81	1.38	56-79	2.89	0.24	1.2-5.5	0.001	2.302	0.86	0.16	1.71	0.11
Clupeidae													
S. sprattus	3060	9.59	0.03	6-11.5	5.25	0.04	1.32-7.99	0.010	2.733	0.95	0.01	20.32	0.001
A. immaculata	191	29.11	0.14	24.2-37.7	318.66	4.34	175-515	0.071	2.488	0.78	0.24	2.70	0.03
Engraulidae													
E. encrasicolus	4027	12.13	0.02	10.3-15.7	12.89	0.06	8.26-24.5	0.024	2.507	0.99	0.05	9.36	0.001
Gadidae													
M. m. euxinus	3715	15.23	0.05	5.5-22.5	29.02	0.29	1.05-80.9	0.004	3.151	0.99	0.15	0.88	0.43
Carangidae													
T. mediterraneus	1432	13.38	0.04	7-18.4	20.19	0.21	4.5-55	0.005	3.168	0.92	0.35	0.97	0.38
Cybiidae													
S. sarda	411	33.35	0.08	29-37.6	540.3	5.26	300-880	0.001	3.839	0.89	0.22	2.34	0.08
Gobiidae													
N. melanostomus	3910	15.45	0.01	13.6-19.2	58.11	0.16	37.5-113	0.006	3.346	0.98	0.21	0.28	0.80
Bothidae													
P. maxima	50	53.05	0.67	44.7-71.7	2.72	0.12	1.39-5.96	0.001	3.278	0.84	0.25	0.90	0.42

Results and discussion

The sample size; the minimum, maximum, and mean lengths and weights; the values of *a* and *b*; and the coefficient of determination r^2 of 10 fish species belonging to 9 families are shown in Table 2. The sample size ranged from 22 individuals for *Squalus acanthias* to 4027 for *Engraulis encrasicolus*. The coefficient of determination ranged from 0.78 for *Alosa immaculata* to 0.99 for *Engraulis encrasicolus* and *Merlangius merlangus euxinus*, and all regressions were highly significant (Table 2, $P < 0.001$). The *b* value ranged from 2.302 for *Raja clavata* to 3.839 for *Sarda sarda*. The growth was negatively allometric for *R. clavata*, *Sprattus sprattus*, *A. immaculata*, and *E. encrasicolus*.

S. acanthias, *M. merlangus euxinus*, *Trachurus mediterraneus*, *S. sarda*, *Neogobius melanostomus*, and *Psetta maxima* exhibited positive allometric growth. The findings reported in this study represent the first data on the LWRs of *S. acanthias* and *R. clavata* in the western Black Sea. The growth was negatively allometric (Table 2) for *R. clavata*. In the Aegean Sea, the *b* value for the same species denoted positive allometric growth (Filiz and Mater, 2002). According to Moutopoulos and Stergiou (2002), such differences in the *b* values could be ascribed to differences in the number of specimens examined, as well as to the area and seasonal effects. The latter implies distinctions in the observed length ranges of the specimens caught, to which the duration of the sample collection can be added, as well. Studies for *S. sprattus* in the Adriatic (Sinovčić et al., 2004) and in the eastern Black Sea (Şahin, 1999) revealed positive allometric growth. Negative allometric growth was established in the western Black Sea (Table, $P < 0.05$), as the differences of the *b* parameter might be related to specific environmental settings and the trophic base.

Anchovy exhibited negative allometric growth (Table 2). Samsun et al. (2004) also found that the anchovy functional regression was less than 3 in the mid-Black Sea.

Horse mackerel showed positive allometric growth (Table 2), and this result is similar to the data reported by Yankova et al. (2010) for Bulgarian waters, but different from the data of Genç et al. (1999) for the eastern Black Sea. This discrepancy may be due to the specific habitat conditions and morphological differences. According to Aleev (1959), the species is represented by 4 local subpopulations, each one with its own biological characteristics.

The first LWR of *A. immaculata* in Bulgarian waters (Kolarov, 1991) displayed negative allometry, similar to that established in the present study (Table 2), but different from the population data for the central Black Sea, which exhibited positive allometry (Samsun, 1995). The differences of allometric growth (between the values of *b*) might have arisen from several ecological factors variations, such as temperature, specific spawning and feeding conditions, and biotope characteristics (Ricker, 1975).

M. merlangus and *S. sarda* exhibited positive allometric growth (Table 2). The previous data about LWRs in the Black Sea are presented in Table 1. During the present study, the *b* values were generally in agreement with the former results. The allometric coefficient of bonito given by Zorica and Sinovčić (2008) for the Adriatic Sea is smaller than that obtained in the present study. This might be due to differences in the sampling periods and to variations in the food availability or water temperatures between the basins.

The growth was positively allometric for *P. maxima*, *S. acanthias*, and *N. melanostomus*. Samsun et al. (2007) also reported positive allometric growth for *P. maxima* in the Black Sea. The LWR constants of spur dog fish from the Aegean Sea are similar to the data given in this study, but different from the *b* values given by Avsar (1996) for the southeastern Black Sea. This difference might be due to interpopulation variations and to differences in sampling time.

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