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- RESEARCH ARTICLE -

Length-Weight Relationships and Condition Factors of 15 Fish Species from Kizilirmak-Yesilirmak Shelf Area, the Southeastern Black Sea

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Abstract

Length-weight relationships of 15 fish species from Kizilirmak-Yesilirmak Shelf Area, Southeastern Black Sea were described. A total of 21.246 fish specimens were caught between 2009-2014 using bottom and pelagic trawl nets. Parameters of b estimated for these species varied between 2.82 and 3.49, and r^2 varied from 0.82 to 0.99. The lowest and the highest condition factors were estimated for *Aphia minuta* as 0.50±0.005 and *Scophthalmus maximus* as *1.68±0.014*, respectively.

Keywords:

Length-weight relationships, demersal fish, pelagic fish, Black Sea.

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Introduction

The length and weight relationship in fisheries biology is a useful and common tool. This relationship is commonly used to generate the biological data. Primarily, the relationship allows to estimate the mean weight from the given length group by establishing a mathematical relationship between two variables (Beyer, 1991; Froese, 2006). LWR can be used for inter-specific and inter-populational morphometric comparison of fish species. It allows estimation of the condition factor. The condition factor informs about the physiological state of the fish in relation to the general welfare and is associated with biological factors such as age, sex, gonadal development, suitability of the environment and fatness (LeCren, 1951). The estimation of population size of a fish stock requires LWRs knowledge of individuals in the population (Dulčić & Kraljević, 1996). The length

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and weight relationships can also be used to set yield equations in order to estimate the number of fish landed and to make spatial and temporal comparisons (Beverton & Holt, 1957).

The LWR equation is used to explain the isometric or allometric growth pattern of organisms and a number of studies have been carried out on length-weight relationships in Black Sea (Kalayci et al., 2007; Ak et al., 2009; Kasapoglu & Duzgunes, 2013; Yankova et al., 2011; Yesilcicek et al.2015; Yildiz et al., 2018).

The present study reports the length-weight relationships of nine demersal and six pelagic species from the south-eastern Black Sea sampled in commercial and experimental bottom and pelagic trawl operations.

Materials and Methods

The samples were monthly collected from Kizilirmak-Yesilirmak Shelf area (KYSA) in the south-eastern Black Sea coast within fishing periods of 2009-2014. The captured fish species were as follows with number of specimens in parantheses: *Merlangius merlangus* (4727), *Mullus barbatus* (3470), *Scophthalmus maximus* (512), *Gobius niger* (1740), *Parablennius tentacularis* (423), *Trachinus draco* (164), *Gaidropsarus mediterraneus* (164), *Aphia minuta* (308), *Pomatoschistus marmoratus* (553), *Arnoglossus kessleri* (251), *Sprattus sprattus* (4975), *Engraulis encrasicolus* (830), *Trachurus mediterraneus* (1595), *Alosa immaculata* (825) and *Pomatomus saltatrix* (709). These species were caught via bottom and pelagic nets along the depth ranges from 0 to100 m. Fish specimens were moved to the laboratory and total length (to the nearest 0.1 cm) and total weight (to 0.01 g the nearest) were measured and the sex is recorded.

Length-weight relationships for female, male and pooled specimens of 15 species were estimated using the logarithmic form of Equation (1); where, *W* is the fish body weight in g, *TL* is the fish total length in cm, *a* is the intercept and *b* is the slope of regression (Froese, 2006).

$$W = a \times TL^{b} \quad (1)$$

Type of LWR was described using Student's-t test. The sex ratio was calculated except *Aphia minuta*, *Pomatoschistus marmoratus* and *Arnoglossus kessleri*. A χ^2 test was performed to check any significant difference in sex ratio. The ANCOVA test was used to see whether LWRs between sexes is significantly different or not. Fulton's condition factor was estimated with the Equation (2) (Froese, 2006); where, *W* is the fish body weight in g, *TL* is the fish total length in cm. A *t* test was used to determine whether there is a significant difference between the mean conditions of sexes. All analyses were performed using SPSS v17.0.

$$K = \left(\frac{W}{L^3}\right) \times 100 \quad (2)$$

Results

In the present study, a total of 21.246 specimens belonging to 15 different fish species and 12 families were analyzed to estimate the LWR parameters. Gobiidae was represented by three species and Clupeidae was represented by two. The sample size (*N*), sex ratio, total length, total weight, parameters of LWRs *a* and *b*, 95% confidence interval for *b*, coefficient of determination (r^2) and growth type for each species and condition factor (*K*) were presented at Table 1.

Table 1. Descriptive statistics for the 15 fish species from KYSA, south-eastern Black Sea. (TL: total length; TW: total weight; N: sample size; M: male; F: female; Σ: all individuals; min: minimum; max: maximum; a and b: parameters of LWRs; CI: confidence intervals; r^2: coefficient of determination; GT: growth type; A^+: positive allometric: A^-:negative allometric: I: isometric. [a] new maximum total length according to Fishbase data. [b] b value different from Bayesian LWR estimates in FishBase, K: Fulton's condition factor)

				TL (cm)		TW(g)		Regression parameters for LWR					
Species		**F:M**	**N**	**min**	**max**	**min**	**max**	**a**	**b**	**95 %CI of b**	**r^2**	**GT**	**K±SE**
***Merlangius merlangus* (Linnaeus, 1758)**	Σ	1.31:1	4727	5.1	23.2	0.20	105.44	0.00512	3.1400	3.126-3.153	0.98	A^+	0.72±0.001
	M		1323	7.2	18.0	2.17	42.92	0.00577	3.0937	3.060-3.127	0.96	A^+	0.73±0.002
	F		1727	6.7	23.2	2.39	105.44	0.00571	3.1016	3.076-3.127	0.97	A^+	0.75±0.002
***Mullus barbatus* Linnaeus, 1758**	Σ	1.80:1	3470	5.2	19.6	1.08	75.00	0.00740	3.1267	3.112-3.140	0.98	A^+	1.00±0.001
	M		639	6.9	15.6	3.00	37.61	0.00845	3.0688	3.010-3.127	0.94	A^+	0.99±0.003
	F		1154	7.5	19.6	3.76	75.00	0.00819	3.0855	3.058-3.112	0.98	A^+	1.02±0.002
***Scophthalmus maximus* (Linnaeus, 1758)**	Σ	1:1	512	7.5	81.3	6.53	102000.00	0.01260	3.0796	3.056-3.103	0.99	A^+	1.68±0.014
	M		133	10.8	57.5	19.90	3200.00	0.01217	3.0873	3.021-3.153	0.98	A^+	1.65±0.020
	F		134	8.4	81.3	9.46	102000.00	0.01531	3.0329	2.958-3.107	0.98	I	1.75±0.050
***Gobius niger* Linnaeus, 1758**	Σ	1.08:1	1740	3.6	12.6	0.35	25.19	0.00572	3.2970	3.269-3.324	0.97	A^+	1.08±0.003
	M		674	4.5	12.5	0.89	22.92	0.00803	3.1376	3.085-3.191	0.95	A^+	1.12±0.005
	F		732	4.7	12.6	0.90	25.19	0.00530	3.3496	3.299-3.400	0.90	A^+	1.10±0.005
***Parablennius tentacularis* (Brünnich, 1768)**	Σ	2.59:1	423	4.8	10.8	0.84	12.85	0.00737	3.1477	3.064-3.229[b]	0.93	A^+	0.99±0.005
	M		103	5.8	10.8	1.85	12.85	0.01050	2.9766	2.825-3.127	0.93	I	1.00±0.009
	F		267	4.8	9.7	0.84	10.91	0.00648	3.2123	3.086-3.337	0.91	A^+	0.99±0.006
***Trachinus draco* Linnaeus, 1758**	Σ	1.06:1	164	4.4	25.5	0.66	115.75	0.00735	3.0055	2.953-3.058	0.98	I	0.75±0.06
	M		45	9.3	18.2	5.41	44.15	0.00526	3.1259	2.953-3.298	0.97	I	0.74±0.009
	F		48	10.1	14.4	7.06	106.09	0.00642	3.0599	2.850-3.269	0.95	I	0.77±0.014
***Gaidropsarus mediterraneus* (Linnaeus, 1758)**	Σ	1.23:1	164	4.5	23.6	0.25	95.30	0.00293	3.2851	3.232-3.337[b]	0.98	A^+	0.61±0.007
	M		26	11.2	23.6	8.81	95.30	0.00520	3.0693	2.826-3.312	0.96	I	0.63±0.014
	F		32	10.8	21.9	6.73	87.72	0.00154	3.4238	3.357-3.690	0.98	A^+	0.66±0.017
***Aphia minuta* (Risso, 1810)**	Σ		308	2.9	5.8	0.07	1.10	0.00255	3.4906	3.305-3.674	0.82	A^+	0.50±0.005
***Pomatoschistus marmoratus* (Risso, 1810)**	Σ		553	2.5	6.5	0.11	1.81	0.00566	3.0931	3.018-3.167	0.93	A^+	0.65±0.004
***Arnoglossus kessleri* Schmidt, 1915**	Σ		251	2.9	12.8[a]	0.03	16.70	0.00948	2.9561	2.814-3.092	0.87	I	0.92±0.010
***Sprattus sprattus* (Linnaeus,1758)**	Σ	3.14:1	4975	4.5	12.8	0.49	12.98	0.00463	3.0984	3.077-3.119	0.95	A^+	0.54±0.001

	M		1114	4.5	12.0	0.49	11.54	0.00472	3.0943	3.055-3.133	0.96	A^+	0.57±0.002
	F		1753	4.6	12.1	0.59	12.98	0.00426	3.1534	3.125-3.180	0.94	A^+	0.59±0.002
***Engraulis encrasicolus* (Linnaeus, 1758)**	Σ	1.28:1	830	5.3	14.2	0.62	18.08	0.00467	3.1026	3.063-3.142	0.97	A+	0.60±0.002
	M		178	6.7	13.4	2.06	13.95	0.00774	2.9072	2.772-3.042	0.91	I	0.63±0.004
	F		229	7.0	14.0	2.10	18.08	0.00787	2.8975	2.791-3.003	0.93	I	0.61±0.003
***Trachurus mediterraneus* (Steindachner, 1868)**	Σ	1:1.24	1595	5.3	18.8	1.34	49.77	0.00758	3.0311	3.005-3.056[b]	0.97	A^+	0.82±0.002
	M		382	7.1	18.8	2.85	46.44	0.00922	2.9524	2.899-3.005	0.97	I	0.82±0.004
	F		308	6.9	18.4	3.11	49.77	0.01034	2.9085	2.851-2.965	0.97	A^-	0.82±0.003
***Alosa immaculata* Bennett, 1835**	Σ	1.39:1	825	10.1	29.9	6.40	208.45	0.00384	3.1901	3.150-3.229[b]	0.97	A^+	0.66±0.002
	M		188	12.7	27.0	11.81	129.45	0.00396	3.1883	3.088-3.288	0.95	A^+	0.68±0.006
	F		262	11.1	29.9	8.89	208.45	0.00336	3.2353	3.166-3.303	0.97	A^+	0.66±0.004
***Pomatomus saltatrix* (Linnaeus, 1766)**	Σ	1.45:1	709	9.1	34.6	6.13	227.91	0.00838	3.0415	3.008-3.074[b]	0.98	A^+	0.94±0.004
	M		179	10.4	25.4	10.2	162.89	0.00812	3.0513	2.975-3.127	0.97	I	0.94±0.007
	F		261	10.7	29.3	10.41	227.91	0.00884	3.0199	2.971-3.068	0.98	I	0.94±0.005

All regressions scores were highly significant (P<0.001). The sample sizes (*N*) varied between 26 for *Gaidropsarus mediterraneus* (female) and 4727 for *Merlangius merlangus* (all individuals). The exponent *b* values ranged from 2.82 (in male *Gaidropsarus mediterraneus*) to 3.49 (in *Aphia minuta*). Only one species, female *Trachurus mediterraneus*, showed negative allometric (*b*<3), 12 cases showed isometric (*b*=3) and remaining cases showed positive allometric patterns (*b*>3). Coefficient of determination r^2 varied between 0.82 and 0.99.

The lowest value of r^2 was calculated for *Aphia minuta*. No significant differences were found between the sex rates of Sco*phthalmus maximus*, *Gobius niger*, *Trachinus draco* and *Gaidropsarus mediterraneus* (P>0.05). There was no statistically significant differences between the sexes with respect to LWRs for *Gobius niger, Gaidropsarus mediterraneus, Trachurus mediterraneus* and *Alosa immaculata* (P>0.05).

The lowest value of *K* was recorded for *Aphia minuta.* The mean *K* was found to be significantly different within sexes of *Merlangius merlangus, Mullus barbatus, Gobius niger, Sprattus sprattus* and *Alosa immaculata.*

Discussion

The present study provided the first reference on LWRs of *Aphia minuta* in the Black Sea coast of Turkish waters and for *Pomatoschistus marmoratus* and *Arnoglossus kessleri* in mid-southern Black Sea coasts.

The *b* value for all species were between 2.5-3.5 ranges reported by Froese (2006). Parameters *a* and *b* of LWRs may indicate variation due to sex, season, year, locality, length range and effected by gonad development and factors such as nutritional condition, temperature and salinity (Froese, 2006). For example, the present study reported that different growth patterns between the male and female for eight species. Females of *Scophthalmus maximus* showed isometric while males of this species showed positive allometric growth patterns. The condition factor varies according to stomach content, size, season, gonad development and sex (LeCren, 1951; Costa & Araújo, 2003; Froese, 2006). This study showed that sexes have different condition patterns. Table 2 is displayed to discuss the results of present study with the LWRs studies' from different localities.

In our study, we defined a positive allometric LWR in all cases of whiting (*M. merlangus*). In another study conducted along the south-western Black Sea coasts of Turkey, it is determined as isometric for sexes separately and the positive allometric relationship pattern for overall (Yildiz et al., 2018). However, Yesilcicek et al. (2015) reported a positive allometric relationship type for both sexes in the southern Black Sea. Yildiz et al. (2018) described an isometric relationship for the turbot (*S. maximus*) female and male individuals but in this study the isometry was only described in females.

There is no LWR data identified for sexes for tentacled blenny (*P. tentacularis*) in FishBase. The positive allometry pattern for the species has been described in the coasts of eastern Aegean Sea (N= 15) and of south-western Black Sea (N=27) (Kara et al., 2016; Yildiz et al., 2018). However, in this study the number of individuals were higher and the relationship is defined as isometric in females and positive allometric in males. While the relationship shows a negative allometry in the Aegean Sea (Filiz & Togulga, 2009), it is estimated as isometric and positive allometric in the Black Sea (Ak et., 2009; Yildiz et al., 2018). It seems that the LWR of the black goby (*G. niger*) is highly variable. Ak et al. (2009) reported a positive allometric LWR for the greater weever (*T. draco*) in the eastern Black Sea. In the present study an isometric pattern is recorded. The *b* value in shore rockling (*G. mediterraneus*) is different from Bayesian LWR estimates in FishBase. The *b* value estimated by Kasapoglu & Duzgunes (2013) for the species is outside the range reported by Froese (2006) (b> 3.5). An isometric length-weight relationship was recorded for the shore rockling in the Sea of Marmara (Bök et al., 2011).

In the south-western Black Sea, LWR of the species is generally positive allometric (Yildiz et al., 2018). In this study, a positive allometric LWR was defined for marbled goby (*P. marmoratus*) from 553 individuals. Yildiz et al. (2018) reported an isometric relationship from 13 individuals. Although, the studies have been conducted in a similar sampling region, LWRs defined for sprat (*S. sprattus*) have varied. The relationships were reported as positive allometric in this study while as negative allometric by Kalayci et al. (2007). The case is similar for anchovy (*E. encrasicolus*). While Kalayci et al. (2007) described a negative allometric LWR pattern for the species, in this study it is defined as positive allometric for the sexes, and isometric for the pooled data.

Different types of relationship were determined for sexes and for the pooled data of horse mackerel (*T. mediterraneus*) in this study. In Bulgarian Black Sea waters, the relationship was isometric. Bayesian LWR estimates in FishBase is b = 2.96 (2.93 - 2.99) for the species. The record from the south-western Black Sea is in accordance with the findings of this study for the bluefish (*P.saltatrix*) (Yildiz et al., 2018). On the other hand, Kalayci et al. (2007) reported a negative allometry for sexes and isometry for the pooled data in the south-middle Black Sea waters.

Table 2. Data derived from different studies revealing LWR parameters for 15 fish species in Black Sea.

Species	N	Length range	a	b	Location	References
M.merlangus	2705	7.6-24.2	0.0046	3.195	Southern Black Sea	Yesilcicek et al., 2015
M. barbatus	2693	5.3-19.0	0.0074	3.123	Eastern-central Black Sea	Kasapoglu & Duzgunes, 2013
S.maximus	224	6.5-51.7	0.0139	3.054	Western Black Sea	Yildiz et al., 2018
G. niger	112	6.80-15.8	0.0180	2.860	South-Eastern Black Sea	Kasapoglu, 2016
P.tentacularis	27	5.5-11.0	0.0061	3.263	Western Black Sea	Yildiz et al., 2018
T.draco	338	5.0-35.0	0.0040	3.433	Eastern Black Sea	Ak et al., 2009
G.mediterraneus	21	10.8-27.1	0.0012	3.616	Eastern and Central Black Sea	Kasapoglu & Duzgunes, 2013
P.marmoratus	13	4.9-7.1	0.0050	3.328	Western Black Sea	Yildiz et al., 2018
A.kessleri	60	4.3-9.8	0.0210	2.984	Eastern Black Sea	Ak et al., 2009
S. sprattus	5087	5.6-12.6	0.0079	2.867	Middle Black Sea	Kalayci, et al., 2007
E. encrasicolus	575	8.0-14.7	0.0174	2.601	Middle Black Sea	Kalayci, et al., 2007
T. mediterraneus	1312	9.2-19.0	0.0089	2.900	Eastern Black Sea	Sahin, et al., 2009
A. immaculata	36	9.9-28.4	0.0049	3.142	Western Black Sea	Yildiz et al., 2018
P. saltatrix	25	12.5-20.2	0.0092	3.005	Eastern and Central Black Sea	Kasapoglu & Duzgunes, 2013

† There is no information about LWR for *A.minuta* in the Black Sea

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