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Weight–length relationships of 28 fish species in the Sea of Marmara

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Abstract: Weight–length relationships (WLRs) for 28 fish species were investigated in an enclosed basin in the Sea of Marmara. Due to low sample sizes (<15), 11 species were not taken into account, but length results were represented. WLR information for 8 species was taken for the first time in the Sea of Marmara, and these 8 species were examined according to sex. Parameters b were found to be insignificant between the sexes (P > 0.05). In this study, WLRs for *Pomatoschistus marmoratus* are presented for the first time in Turkish waters. Additionally, this study represents the first results for the entire Sea of Marmara and carries significant importance for the WLR database in light of previous studies, which only provided information for limited parts of this sea.

Key words: Weight–length relationship, fish, Sea of Marmara, allometry

Introduction

An organism's assimilation of materials from the environment results in a measurable increase in its mass, which is called growth. This phenomenon is extremely heterogeneous and complex in both descriptive and causal analytic aspects (von Bertalanffy, 1938). The usual starting point in fisheries' work is determination of growth quality, the basis of which is the weight–length relationship (WLR) of the target species. Estimation of weight regarding a given length is expressed as the WLR, and comparisons of condition, fatness, or well-being in fishes are evaluated using condition factors (Tesch, 1968). This is based on the simple hypothesis that heavier fish of a given length are in better condition (Froese, 2006).

It is well known that the parameters of WLRs are different not only between species but also among different stocks of the same species in relation to region, sex, season, and age group (Tıraşın, 1993; Froese, 2006; Gerritsen and McGrath, 2007). Many biological parameters are known to vary over small geographical ranges, and for stock assessment purposes, length–weight relationships are often assumed to be uniform for an entire stock (Gerritsen and McGrath, 2007).

WLRs of 28 fishes, including commercially important species collected from the Sea of Marmara, are presented in this study. The Sea of Marmara is an enclosed basin where Atlanto-Mediterranean–originated commercial pelagic fishes spawn while migrating from the Mediterranean and Aegean seas to the Black Sea (Kocatas et al., 1993). The Sea of Marmara is formed by 2 distinct and permanent water masses throughout the entire year. While the thin upper layer originates from the brackish waters

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of the Black Sea (salinity: approximately 18‰), the bottom layer is constituted of saline Mediterranean waters (salinity: approximately 38.5‰). Between these 2 layers there is a sharp density interface (Besiktepe et al., 1994).

There is a lack of information on growth and biological characteristics of fish species in the Sea of Marmara. Previous studies on WLRs for fish species in the Sea of Marmara include that of Keskin and Gaygusuz (2010), which was limited to the southwestern part of the basin. In addition, Atasoy et al. (2006) and Eryılmaz and Meriç (2005) concentrated on only one species, and JICA (1993) evaluated WLRs of species that were a combination of all individuals collected from Turkish waters. The results of the present study constitute the first WLR information for 8 of the 28 species taken from Sea of Marmara populations. Moreover, for one species, our WLR results are the first for populations in Turkish waters.

Materials and methods

Data on the weight and length of fish species were collected during 3 cruises between December 2009 and February 2011 in the Sea of Marmara. Sampling was performed by 40 bottom trawl hauls at 17 stations at depths between 30 and 90 m (Figure). Fish species were identified based on the methods of Fischer et al. (1987) and Whitehead et al. (1986). The FishBase electronic database was used to check the scientific names of each species (Froese and Pauly, 2011). Total length (TL) of each specimen was measured to the nearest centimeter and weight (W) was measured in grams. For ray species, total length is defined as the disk width (cm) from one wing tip to the other.

The equation $W = aL^b$ expresses the relationship between total length (L) and total weight (W) for almost all fish species. Values are calculated by their logarithmic (base 10) equivalent, such as $\log W = \log a + b \log L$. A straight line is plotted with a slope of b and the Y-axis intercept, $\log a$, which is formed by log W against log L forms (King, 1995). Invariably, b is expected to be close to 3 for all species (Schneider et al., 2000), which indicates isometric growth, and generally varies between 2.5 and 3.5 (Zar, 1996). Growth type was identified using Student's t-test to see if parameter b with its confidence interval ($\alpha = 0.05$) covers 3 or is significantly different from 3. WLRs of 8 species were evaluated by male–female differentiation. In order to test for possible significant differences between the sexes, Student's t-test was used for the comparison of the 2 slopes (Zar, 1996). Species recovered in a small sample size ($n < 15$) were not taken into account; they are represented with descriptive results.

Results and discussion

In this study, 5116 individuals from 39 species belonging to 27 families were sampled and examined. Species with a minimum sample size of 15 individuals were considered for WLR analysis. As a result, the WLRs of 28 species belonging to 20 families were

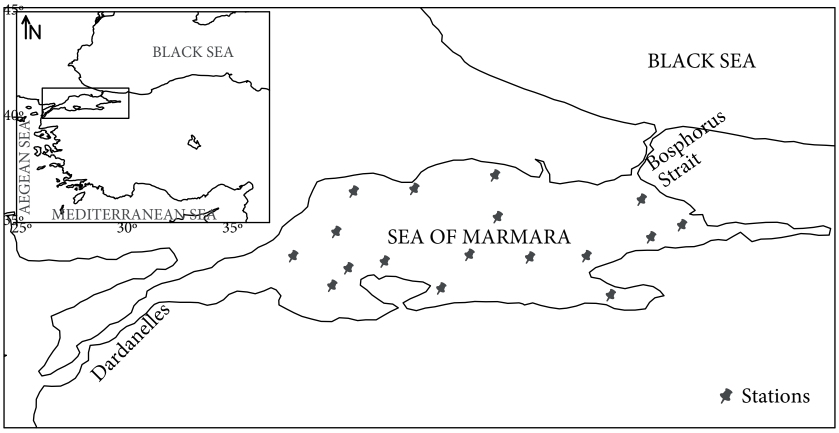

Figure. Study area and trawling stations.

calculated. In this study, the first WLR data for the Sea of Marmara is provided for 8 of the 28 species examined: *Scyliorhinus canicula*, *Chalaroderma ocellata*, *Trachurus mediterraneus*, *Spicara maena*, *Pomatoschistus marmoratus*, *Citharus linguatula*, *Trigloporus lastoviza*, and *Lepidotrigla cavillone*. *C. linguatula* was also investigated according to sex differentiation.

In Table 1, sample size; minimum, maximum, and mean length ± standard deviation (SD); parameters *a* and *b*; standard error of the slope; coefficient of determination; r^2; and growth type are listed for each species.

The sample size ranged from 15 individuals for *Lophius piscatorius* to 715 for *Merluccius merluccius*. All regressions were highly significant ($P < 0.01$). No r^2 values less than 0.70 were found. The parameter *b* varied from 1.193 for *C. macrophthalma* to 3.432 for *Diplodus annularis*. The mean value of *b* was 2.860 ± 0.005. The median value of *b* was 2.852, and in addition, 50% of the values varied between 2.623 and 3.055. The lowest *b* value was under the lower limit, $b = 2.5$ (Froese, 2006), for only 1 species, *C. macropthalma*. Stergiou et al. (1992) reported that *C. macrophthalma* lives in vertical burrows from which it hunts small crustaceans and chaetognaths (Stergiou et al., 1992). For this reason, Froese (2006) pointed out that this particular lifestyle is reflected in the exponent *b* and favored with an overproportional increase in length relative to growth in weight. In this study, WLRs for *P. marmoratus* were presented for the first time in Turkish waters.

According to t-test results, growth type was isometric ($b = 3$) for 15 species while it was allometric for the other 13. Positive allometry ($b > 3$) was observed in 2 species, whereas negative allometry ($b < 3$) was found in 11 species. No significant differences ($P > 0.05$) were found in WLRs between the sexes for 8 species: *S. canicula*, *Raja clavata*, *M. merluccius*, *C. lyra*, *C. linguatula*, *Arnoglossus laterna*, *Solea solea*, and *Buglossidium luteum* (Table 1). According to Le Cren (1951), different life stages, sexes, stages of gonad development, and seasons affect WLRs. *M. merluccius* spawns throughout the year in the Mediterranean Basin (Murua, 2010). *C. linguatula* also spawns throughout the year (Tsikliras et al., 2010), but the lowest spawning period is recorded in winter (Teixeira et al., 2010). The rest of the species studied spawn between spring and autumn (King et al., 1994; Rodriguez-Cabello et al., 1998; Özütok and Avşar, 2004; Demirel et al., 2007; Saglam and Ak, 2011). Samplings in the present study were performed in winter, which is out of spawning period or characterized with low reproductive activity for the following species: *S. canicula*, *R. clavata*, *M. merluccius*, *C. lyra*, *C. linguatula*, and *A. laterna*. We conclude that the lack of significant differences between the sexes in WLRs may imply considerable effects from spawning activity and gonad development.

Available literature data were not sufficient for the comparison of *b* values for all species appearing in this study (Table 2). Estimated parameter *b* and growth type were different for *M. merlangius* in our study ($b = 2.836$ and standard error [SE] = 0.05 with negative allometry) compared to a previous study ($b = 3.140$ with positive allometry) (Atasoy et al., 2006). This is because Atasoy et al. (2006) took their samples from a fish market. These fish come mostly from the northeastern part of the sea, and their results may reflect a regional bias. No significant difference was found in *C. lucerna* parameter *b* values from the previous study (Eryılmaz and Meriç, 2005). Results for 5 species, *M. surmuletus*, *S. hepatus*, *D. annularis*, *A. laterna*, and *C. lucerna*, were compared with a previous study (Keskin and Gaygusuz, 2010) performed in the shallow waters of the southwestern part of the Sea of Marmara. With the exception of *C. lucerna*, all parameter *b* values and growth types of the remaining 4 species were different from our study results. These differences may be the result of sampling methods, selectivity of fishing gear (Rosa et al., 2006), or sample size, which was limited to 15 individuals for each species in our study. Froese (2006) recommended that samples collected for WLR calculation include equal numbers of randomly selected small, medium-sized, and large specimens. In Table 3 we show length characteristics of the species with fewer than 15 sampled individuals. Several studies also indicated that spatial variation in fish growth is caused by water quality, food availability, observed length ranges, and changes in

Table 1. WLRs for 28 fish species from the Sea of Marmara.

Species	Sex	n	Length (cm)				Parameters of relationship				P	G
			Mean	Min.	Max.	SD	*a*	*b*	SE	R^2		
Scyliorhinus canicula	C	189	35.2	20.0	50.0	5.0	0.004	2.869	0.081	0.868		I
	F	30	35.2	25.3	50.0	5.2	0.021	2.471	0.221	0.817	0.000	A-
	M	31	35.6	25.0	41.7	4.4	0.002	3.041	0.259	0.825		I
*Raja clavata**	C	170	26.0	9.6	65.0	12.4	0.113	2.420	0.100	0.774		A-
	F	35	28.6	10.5	65.0	14.1	0.028	2.900	0.069	0.981	0.025	I
	M	23	22.1	9.6	45.0	7.8	0.028	2.887	0.063	0.990		I
Merlangius merlangus	C	234	17.1	10.6	24.5	2.8	0.012	2.836	0.050	0.932		A-
Merluccius merluccius	C	715	23.5	9.3	52.0	5.9	0.010	2.886	0.027	0.938		A-
	F	337	23.9	9.3	52.0	7.5	0.009	2.932	0.029	0.966	0.000	A-
	M	378	23.1	9.8	35.0	4.0	0.015	2.755	0.056	0.864		A-
Lophius piscatorius	C	15	14.4	9.3	18.2	2.1	0.022	2.846	0.381	0.810		I
Chalaroderma ocellata	C	21	11.8	9.8	14.7	1.3	0.018	2.859	0.254	0.899		I
Callionymus lyra	C	99	15.8	6.5	22.5	2.9	0.021	2.554	0.077	0.918	0.014	A-
	F	42	15.1	9.0	18.2	1.9	0.016	2.668	0.209	0.801		A-
	M	23	17.6	8.5	22.5	3.0	0.018	2.613	0.092	0.974		A-
Trachurus mediterraneus	C	496	13.4	7.5	18.5	1.9	0.018	2.727	0.053	0.842		A-
Trachurus trachurus	C	156	13.9	11.2	21.0	1.1	0.027	2.951	0.163	0.769		I
Spicara maena	C	175	14.3	10.4	18.0	1.4	0.010	3.025	0.096	0.850		I
Cepola macrophthalma	C	20	29.1	18.5	43.1	6.8	0.339	1.193	0.118	0.848		A-
Gobius niger	C	83	11.9	8.0	14.3	1.4	0.008	3.129	0.096	0.929		I
Pomatoschistus marmoratus	C	71	7.8	3.7	9.0	0.9	0.004	2.522	0.328	0.721		A-
Mullus surmuletus	C	354	14.4	8.5	23.0	2.5	0.006	3.179	0.045	0.932		A+
Mullus barbatus	C	94	15.1	9.6	22.7	2.1	0.015	3.004	0.214	0.860		I
Pomatomus saltatrix	C	17	16.3	14.5	18.5	1.2	0.387	2.770	0.310	0.853		I
Serranus hepatus	C	379	10.2	6.5	13.7	1.1	0.036	2.623	0.078	0.748		A-
Diplodus annularis	C	81	13.4	10.0	16.7	1.5	0.004	3.432	0.229	0.739		A+
Uranoscopus scaber	C	49	15.5	8.0	25.1	4.1	0.015	3.061	0.116	0.936		I
Arnoglossus laterna	C	328	12.5	6.0	19.5	2.5	0.013	2.785	0.058	0.874	0.026	A-
	F	98	13.0	7.4	19.5	3.1	0.018	2.674	0.089	0.906		A-
	M	224	11.6	6.5	17.4	2.0	0.011	2.825	0.083	0.838		A-
Citharus linguatula	C	108	13.1	7.3	22.5	3.4	0.029	2.828	0.054	0.915	0.002	I
	F	44	14.3	7.3	22.5	4.0	0.004	3.035	0.184	0.873		I
	M	64	12.4	7.5	18.2	2.9	0.017	2.878	0.084	0.942		I
Solea solea	C	53	23.9	20.0	33.2	2.8	0.006	3.055	0.181	853	0.042	I
	F	46	24.1	20.2	33.2	2.8	0.004	3.077	0.195	0.846		I
	M	6	23.7	20.0	26.5	2.7	0.089	2.885	0.152	0.998		I
Buglossidium luteum	C	55	12.0	8.4	15.1	1.6	0.005	3.016	0.150	0.901	0.038	I
	F	30	12.6	10.4	15.0	0.9	0.054	2.637	0.201	0.838		I
	M	7	13.7	12.6	15.1	0.8	0.002	3.027	0.549	0.876		I
Eutrigla gurnardus	C	633	15.2	10.1	25.6	2.7	0.007	3.051	0.032	0.933		I
Trigloporus lastoviza	C	44	12.5	5.5	18.0	2.6	0.049	2.567	0.065	0.971		A-
Chelidonichthys lucerna	C	352	19.4	10.5	56.0	5.0	0.009	3.000	0.025	0.976		I
Lepidotrigla cavillone	C	143	9.9	5.9	14.2	1.7	0.033	2.631	0.096	0.840		A-
Trigla lyra	C	27	22.4	16.5	32.3	4.3	0.012	2.830	0.152	0.932		I

*For *R. clavata*, measurements of disk width from one wing tip to the other were used. P: probability result of ANOVA that indicates significance of the parameter *b* between sexes, G: growth type, I: isometric, A+: positive allometry, A-: negative allometry.

Table 2. Comparison of the WLR results with previous studies.

Species	Present study				Eryılmaz and Meriç, 2005				Atasoy et al., 2006				Keskin and Gaygusuz, 2010				Bok et al., 2011			
	Entire sea				Western part				Northeastern part				Southwestern part				Northwestern part			
	n	*b*	SE	G	n	*b*	SE	G	n	*b*	SE	G	n	*b*	SE	G	n	*b*	SE	P
Raja clavata	170	2.420	0.10	A-													24	2.867	-	I
Merlangius merlangus	234	2.836	0.05	A-					920	3.140	-	-					166	3.149	-	A+
Merluccius merluccius	715	2.886	0.03	A-													319	3.369	-	A+
Lophius piscatorius	15	2.846	0.38	I													40	2.491	-	A-
Callionymus lyra	99	2.554	0.08	A-													87	2.832	-	I
Trachurus trachurus	156	2.951	0.16	I													307	3.128	-	A+
Cepola macrophthalma	20	1.193	0.12	A-													17	1.510	-	A+(?)
Gobius niger	83	3.129	0.1	I													286	2.980	-	I
Mullus surmuletus	354	3.179	0.05	A+									17	3.382	0.15	I	142	2.717	-	A-
Mullus barbatus	94	3.004	0.21	I													99	3.326	-	A+
Pomatomus saltatrix	17	2.770	0.31	I													290	2.527	-	A-
Serranus hepatus	379	2.623	0.08	A-									5	3.002	0.21	I	111	2.706	-	A-
Diplodus annularis	81	3.432	0.23	A+									7	3.112	0.24	I	15	2.957	-	I
Uranoscopus scaber	49	3.061	0.12	I													82	3.154	-	A+
Arnoglossus laterna	328	2.785	0.06	A-									7	2.672	0.44	I	58	3.016	-	I
Solea solea	53	3.055	0.18	I													55	3.171	-	I
Buglossidium luteum	55	3.016	0.15	I													27	2.619	-	A-
Eutrigla gurnardus	633	3.051	0.03	I													67	2.962	-	I
Chelidonichthys lucerna	352	3.000	0.03	I	224	3.019	-	I					17	2.902	0.24	I	90	2.982	-	I
Trigla lyra	27	2.830	0.15	I													96	3.047	-	I

Table 3. Weight–length characteristics of 11 species that were not evaluated due to low sample size (n < 15).

Species	Sex	n	Length (cm)			
			Mean	SE	Min.	Max.
Mustelus asterias	C	8	68.4	13.5	45.5	139.0
Mustelus mustelus	C	1	72.1	-	-	-
Raja ocellata	C	3	32.5	4.7	25.5	30.5
Oxynotus centrina	C	5	39.9	6.5	22.1	55.0
Squalus acanthias	C	9	51.9	2.4	45.0	68.0
Torpedo marmorata	C	4	20.0	3.0	14.5	28.5
Pagellus erythrinus	C	6	15.7	0.6	13.5	17.5
Trachinus draco	C	2	18.4	0.1	18.2	18.5
Microchirus variegatus	C	4	9.7	0.8	7.5	11.2
Lepidorhombus boscii	C	6	16.7	0.2	16.0	17.4
Zeus faber	C	4	31.1	7.6	8.3	39.5

salinity and temperature (Sparre et al., 1989; Tıraşın, 1993; Moutopoulos and Stergiou, 2002; Froese, 2006; Gerritsen and McGrath, 2007). In addition, the Sea of Marmara showed different patterns in temperature, salinity, and the disturbance level of marine life due to urbanization, industrialization, and marine traffic from south to north and from west to east. Our results represent the first WLR data on 16 fish species for the entire Sea of Marmara region, and these are a significant source of comparable results.

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