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Length-Weight Relationships of 34 Fish Species from the Sea of Marmara, Turkey

[1]Tomris Deniz Bok, [1]Didem Gokturk, [1]Abdullah Ekrem Kahraman, [1]Tugrul Zahit Alicli, [2]Tan Acun and [3]Celal Ates
[1]Department of Fisheries Technology, Faculty of Fisheries, Istanbul University, Ordu Cad. No: 200, Laleli, 34470 Istanbul, Turkey
[2]Department of Fisheries, Institute of Sciences, Istanbul University, Bozdogan Kemeri Cad.No: 6 Vezneciler, Istanbul, Turkey
[3]Armutlu Vocational School, Yalova University, 77500 Armutlu-Yalova, Turkey

Abstract: Length-weight relationships were estimated for 34 coastal fish species of the Sea of Marmara namely *Arnoglosus laterna*, *Atherina boyeri*, *Blennius ocellaris*, *Buglossidium luteum*, *Callionymus lyra*, *Callionymus risso*, *Cepola macrophthalma*, *Chelidonichthys lucerna*, *Diplodus annularis*, *Eutrigla gurnardus*, *Gaidropsarus meditrraneus*, *Gobius niger*, *Lesueurigobius friesii*, *Lophius piscatorius*, *Merluccius merluccius*, *Merlangius merlangus euxinus*, *Mullus barbatus*, *Mullus surmuletus*, *Pomatomus saltatrix*, *Raja astarias*, *Raja clavata*, *Sardinella aurita*, *Scorpaena porcus*, *Serranus cabrilla*, *Serranus hepatus*, *Solea kleinii*, *Solea solea*, *Spicara smaris*, *Squalus acanthias*, *Squalus blainvillei*, *Syngnathus acus*, *Trachurus trachurus*, *Trigla lyra* and *Uranoscopus scaber*. Samples were collected between November 2006 and March 2007 using bottom trawl and commercial beam trawl at depths ranging from 30-100 m. This research is the first reference on length-weight parameters of 21 species for the Sea of Marmara. The parameters of a and b of the equation $W = aL^b$ were estimated. The b values of the species caught ranged from 1.51 for *Cepola macrophthalma* to 3.485 for *Atherina boyeri*. Whenever possible, the b values for the species obtained both in this study and some of the previously reported in the Turkish waters were compared.

Key words: Length-weight relationships, coastal fish, allometric growth, Sea of Marmara, chondrichthyes, osteichthyes

INTRODUCTION

Length-Weight (L-W) and Length-Length (L-L) relationships have applied and basic uses for assessment of fish stocks and populations (Ricker, 1968). L-W relationship parameters can also be used as indices of fish condition for life history comparison of different regions (Petrakis and Stergiou, 1995; Thomas *et al*., 2003) as well as other applications in population dynamics as revised by Mendes *et al*. (2004). Many biological parameters are known to vary over small geographical ranges (Armstrong *et al*., 2004; Gerritsen *et al*., 2006). Nevertheless, for stock assessment purposes, length-weight relationships are often assumed to be uniform for an entire stock. Moreover, when data are sparse for a certain stock, length-weight relationships from neighboring stocks are occasionally applied (ICES, 2002). However, regional difference in the length-weight relationships and condition indices of fish are known to exist (Brodziak and Mikus, 2000; Ratz and Lloret, 2003).

There is little information on the continental ichthyofauna in the Sea of Marmara which is dominated by species of marine derivation (Keskin, 2007; Bilecenoglu *et al*., 2000; Tuncer *et al*., 2008). In the Northern Sea of Marmara, these habitats suffer intense fishing pressure from beam trawl and gill net fishery thus causing large quantities of the fish species inhabiting these systems to be captured (Gungor *et al*., 2007). Sea of Marmara provides a significant proportion of the overall marine fish production in Turkey and is considered as one of the most important fishery grounds (Anonymous, 2009). Sea of Marmara is also known as an important spawning and nursery ground for several fish species (Mater and Cihangir, 1990; Unsal and Oral, 1996). Information about the length-weight relationships of fish species in the Sea of Marmara is scarce and incomplete.

In the present study, parameter estimates are provided for 34 fish species collected in the Sea of Marmara. To the best the knowledge, this study presented the first reference on L-W relationships for 21

Corresponding Author: Tomris Deniz Bok, Department of Fisheries Technology, Faculty of Fisheries, Istanbul University, Ordu Cad. No: 200, Laleli, 34470 Istanbul, Turkey

species among them. There is not much studies concerned about length-weight relationships in the studied area as well as previous information on these species.

MATERIALS AND METHODS

The study was carried out in the Northern Sea of Marmara (Fig. 1). The samples were collected by trawl and beam trawl hauls at depths of 30-100 m. The sampling interval from November 2006 to March 2007 was done using research vessel R/V YUNUS-S (32 m length, 510 HP engine) and a commercial beam trawl DENIZ 1 (13 m length, 130 HP engine).

Fish were identified based on Whitehead *et al*. (1986) and fischer. Scientific names for each species were checked with the FishBase (Froese and Pauly, 2010). Samples were measured for Total Length (TL) to the nearest mm. Total Weight (TW) of each specimen was measured with a digital balance to an accuracy of 0.01 g. The estimation of the Length-Weight Relationship (LWR) was made by the adjustment of an exponential curve ($W = aL^b$) converted in to its logarithmic expression:

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

where, W is TW (g), L is TL, a is the intercept and b the slope. The null hypotheses of isometric growth (H_0, b = 3) were tested by the t-test (Sokal and Rohlf, 1987).

RESULTS AND DISCUSSION

During the 71 hauls with a total towing time of approximately 182 h, 3591 fish specimens that belonged to 39 fish species from 27 families were determined. The best represented families were Triglidae, Soleidae and Rajidae (3 species), distantly followed by Gadidae, Mullidae, Serranidae, Gobiidae, Callionymidae, Scorpaenidae and Squalidae (2 species). The remaining 18 families were represented by only one species. Out of the 22 listed in Table 1, length weight relationships were published for 12 species in the Sea of Marmara (Keskin and Gaygusuz, 2010). The sample size ranged from 8 individuals for *Squalus acanthias* to 580 for *Lesueurigobius friesii*.

The sample size and minimum and maximum of length and weight for each species are shown in Table 1 as well as the L-W relationships, the coefficient of determination (r^2), the Confidence Interval (CI) of b and the growth type. Length weight parameters for 5 species whose numbers were below 8 (by catch and discard) and where L-W relationships could not be calculated are also shown in Table 2. Previous studies providing L-W relationships for some of the species are shown Table 3 for comparative purpose.

The L-W relationships parameter b typically varies between 2.049 and 3.527, according to Froese and Pauly (2010). In the present study, the values of b ranged from 1.51 for the *Cepola macropthalma*, to 3.485 *Atherina boyeri*, corresponding to b median value of 2.971 whereas 50% of the values of b were in the interval between 2.619

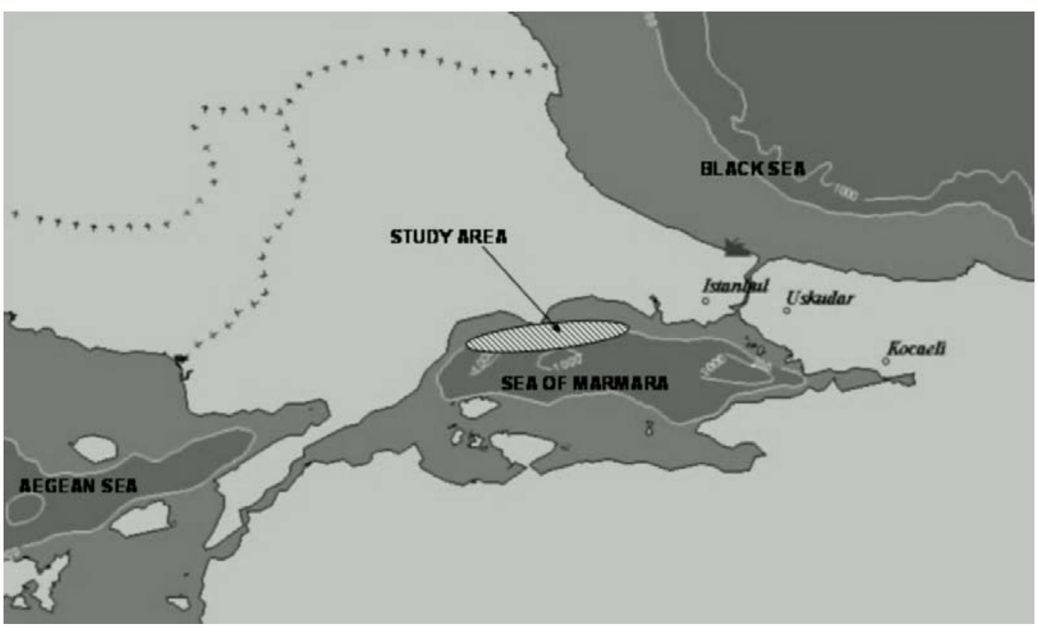

Fig. 1: The Sea of Marmara and the study area

Table 1: Length-weight relationships of 34 fish species collected in the Sea of Marmara, Turkey

			Total length (cm)		Total weight (g)		Regression parameters				
Family	Species	N	Min.	Max.	Min.	Max.	a	b	95% CI of b	r^2	Growth type
Atherinidae	*Atherina boyeri*	14	7.6	11.7	1.840	8.40	0.0015	3.485	3.265-3.705	0.992	I
Blenniidae	*Blennius ocellaris*	15	11.2	13.7	18.930	31.50	0.0381	2.562	2.275-2.651	0.994	A-
Bothidae	*Arnoglosus laterna*	58	6.8	20.0	2.150	53.28	0.0068	3.016	2.942-3.090	0.963	I
Callionymidae	*Callionymus lyra*	87	6.4	22.6	1.650	66.53	0.0087	2.832	2.745-2.919	0.966	I
	Callionymus risso	15	11.6	18.2	10.130	38.60	0.0079	2.929	2.866-2.992	0.999	I
Carangidae	*Trachurus trachurus*	307	8.0	16.4	3.070	33.99	0.0056	3.128	3.074-3.183	0.918	A+
Centracanthidae	*Spicara smaris*	403	5.9	17.7	3.530	78.30	0.0089	3.083	3.020-3.145	0.862	I
Cepolidae	*Cepola macrophthalma*	17	20.8	46.7	6.570	27.04	0.0934	1.510	1.212-1.808	0.837	A+
Clupeidae	*Sardinella aurita*	16	9.9	16.8	6.040	35.38	0.0333	2.272	1.846-2.696	0.877	I
Gadidae	*Merlangius merlangus euxinus*	166	7.6	24.2	2.700	121.40	0.0047	3.149	3.087-3.212	0.943	A+
	Gaidropsarus meditrraneus	56	8.2	14.3	1.300	11.75	0.003	3.179	2.917-3.441	0.794	I
Gobiidae	*Gobius niger*	286	6.9	15.0	3.490	33.30	0.0115	2.980	2.915-3.045	0.884	I
	Lesueurigobius friesii	580	4.2	10.7	0.500	7.30	0.016	2.530	2.485-2.575	0.848	A-
Lophiidae	*Lophius piscatorius*	40	36.0	54.0	800.000	2150.00	0.0001	2.491	2.315-2.667	0.877	A-
Merluccidae	*Merluccius merluccius*	319	8.9	44.8	3.800	753.68	0.0026	3.369	3.342-3.397	0.990	A+
Mullidae	*Mullus barbatus*	99	10.0	15.7	9.540	46.59	0.0049	3.326	3.218-3.434	0.916	A+
	Mullus surmuletus	142	11.0	18.0	11.480	60.80	0.024	2.717	2.631-2.802	0.886	A-
Pomatomidae	*Pomatomus saltatrix*	290	10.6	24.0	12.100	107.60	0.0325	2.527	2.466-2.591	0.856	A-
Rajidae	*Raja clavata*	24	12.2	70.0	0.015	2628.00	0.00001	2.867	2.656-3.079	0.893	I
	Raja astarias	30	43.0	79.0	0.440	3092.00	0.000002	3.242	3.135-3.348	0.971	I
Triglidae	*Chelidonichthys lucerna*	90	8.0	64.0	5.400	2400.00	0.01	2.982	2.93-3.0340	0.977	I
	Trigla lyra	96	4.5	51.0	0.720	1100.00	0.0062	3.047	3.016-3.078	0.992	I
	Eutrigla gurnardus	67	9.6	22.8	9.100	111.50	0.0105	2.962	2.882-3.042	0.962	I
Scorpaenidae	*Scorpaena porcus*	15	17.3	21.4	84.020	186.02	0.0067	3.343	2.525-4.161	0.944	I
Serranidae	*Serranus hepatus*	111	5.9	11.8	3.530	24.49	0.0319	2.706	2.596-2.745	0.874	A-
	Serranus cabrilla	15	6.9	11.7	4.400	23.67	0.0091	3.186	2.893-3.479	0.975	I
Sparidae	*Diplodus annularis*	15	7.0	16.7	6.800	94.38	0.022	2.957	2.868-3.066	0.994	I
Soleidae	*Solea solea*	55	6.9	16.0	2.280	31.50	0.0043	3.171	3.036-3.306	0.928	I
	Solea kleinii	20	4.6	25.9	1.600	115.88	0.0314	2.5	2.384-2.616	0.983	A-
	Buglossidium luteum	27	9.5	20.0	9.180	53.28	0.0195	2.619	2.506-2.731	0.973	A-
Squalidae	*Squalus acanthias*	8	41.0	52.0	500.000	950.00	0.00003	2.619	2.393-2.846	0.957	I
	Squalus blainvillei	18	38.0	56.0	350.000	852.00	0.00004	2.476	2.315-2.636	0.956	A-
Syngnathidae	*Syngnathus acus*	17	21.3	28.4	4.510	11.92	0.0003	3.115	2.721-3.508	0.926	I
Uranoscopidae	*Uranoscopus scaber*	82	10.7	24.6	21.100	378.24	0.0109	3.154	3.085-3.222	0.969	A+

n, sample size; a and b, parameters of length-weight relationships; 95% CL (b), 95% confidence intervals of b; r^2, coefficient of determination; I, Isometric, A^+, Positive allometric, A^-, Negative allometric

Table 2: Descriptive statistics for the five additionally elasmobranches species in the northern Sea of Marmara, Turkey

			Total length (cm)		Total weight (g)	
Family	Species	N	Min.	Max.	Min.	Max.
Rajidae	*Raja oxyrinchus*	2	85.0	100.8	2570	3050
Triakidae	*Mustelus mustelus*	2	10.5	26.5	4325	5838
Dasyatidae	*Dasyatis pastinaca*	12	15.0	69.0	905	6450
Torpedinidae	*Torpedo marmorata*	2	23.7	37.4	300	473
Oxynotidae	*Oxynotus centrina*	1	-	46.0	-	1250

N, sample size; Min., Minimum; Max., Maximum

and 3.154. The coefficient of determination (r^2) range from 0.7936 for the *Gaidropsarus meditterraneus*, to 0.9986 for the *Callionymus risso* with a median value of 0.9435; 23 out of a total of 34 regression presented r^2 values higher than 0.90. All linear regressions were highly significant ($p<0.005$) statistically.

Concerning the type of growth, 19 species (55.88% of the total species number) evidenced isometric growth (b = 3), 9 species (26.47%) showed negative allometry (b<3) and 6 species (17.65%) positive allometry (b>3) for pooled estimate relationships (Table 1).

In comparison terms, to the researchers best knowledge, this study presents the first references available on L-W relationships for 21 fish species for the Sea of Marmara (Table 1).

The results presented in the current study is to be an adequate estimation of length-weight relationship since, the parameter b falls within the expected range of 2.5-3.5 (Froese, 2006) and a minimum of 8 individuals were used to estimate these parameters and it is considered an adequate sample size.

Table 3: Comparison of length-weight relationship parameters for 34 fish species obtained by several researchers

	Present work		Sea of Marmara			Turkish coasts of Aegean and Mediterranean Aegean sea			Black sea		
Species	n	TL-W equation	n	TL-W equation	Ref	n	TL-W equation	Ref.	n	TL-W equation	Ref
Arnoglosus laterna	58	$W = 0.0068L^{3.016}$	7	$W = 0.0207L^{2.670}$	A	1078	$W = 0.0097L^{2.906}$	G			
Atherina boyeri	14	$W = 0.0015L^{3.4851}$	606	$W = 0.0045L^{3.215}$	A	138	$W = 0.0048L^{3.165}$	H			
Blennius ocellaris	15	$W = 0.0381L^{2.5615}$				204	$W = 0.0167L^{2.97}$	I			
Buglossidium luteum	27	$W = 0.0195L^{2.6186}$				862	$W = 0.0091L^{3.06}$	I			
Callionymus lyra	87	$W = 0.0087L^{2.8324}$									
Callionymus risso	15	$W = 0.0079L^{2.9292}$	42	$W = 0.01407L^{2.71}$	B						
Cepola macrophthalma	17	$W = 0.0934L^{1.51}$				136	$W = 0.03461L^{1.8533}$	J			
Chelidonichthys lucerna	90	$W = 0.01L^{2.9823}$	224	$W = 0.0092L^{3.019}$	C	121	$W = 0.0043L^{3.24}$	I			
Diplodus annularis	15	$W = 0.022L^{2.9572}$	7	$W = 0.0134L^{3.1104}$	A	372	$W = 0.0068L^{3.315}$	K			
Eutrigla gurnardus	67	$W = 0.0105L^{2.962}$				251	$W = 0.00250L^{3.4155}$	J			
Gaidropsarus meditrraneus	56	$W = 0.003L^{3.179}$	8	$W = 0.0068L^{3.010}$	A						
Gobius niger	286	$W = 0.0115L^{2.9803}$				272	$W = 0.0047L^{3.394}$	L	133	$W = 0.0113L^{3.00}$	P
Lesueurigobius friesii	580	$W = 0.016L^{2.5304}$				631	$W = 0.0079L^{3.013}$	G			
Lophius piscatorius	40	$W = 0.0001L^{2.4915}$				445	$W = 0.01239L^{3.0255}$	J			
M. merluccius	319	$W = 0.0026L^{3.3695}$				567	$W = 0.0046L^{3.152}$	L			
Merlangius merlangus euxinus	166	$W = 0.0047L^{3.1497}$	920	$W = 0.005L^{3.14}$	D	100	$W = 0.0092L^{2.944}$	H	904	$W = 0.0067L^{3.0248}$	Q
Mullus barbatus	99	$W = 0.0049L^{3.3261}$				451	$W = 0.0032L^{3.060}$	M	176	$W = 0.0111L^{2.9633}$	Q
Mullus surmuletus	142	$W = 0.024L^{2.7166}$	17	$W = 0.0045L^{3.385}$	A	601	$W = 0.0068L^{3.192}$	K			
Pomatomus saltatrix	290	$W = 0.0325L^{2.5287}$							14	$W = 0.003L^{3.336}$	R
Raja astarias	30	$W = 0.000002L^{3.2421}$				113	$W = 0.0013TL^{3.386}$	N			
Raja clavata	24	$W = 0.00001L^{2.867}$				77	$W = 0.0037L^{3.080}$	N	27	$W = 0.0019L^{3.24}$	P
Sardinella aurita	16	$W = 0.0333L^{2.2716}$	24	$W = 0.0031L^{3.439}$	A	50	$W = 0.0062L^{3.076}$	K			
Scorpaena porcus	15	$W = 0.0067L^{3.343}$	168	$W = 0.023L^{2.96}$	E	255	$W = 0.0215L^{2.915}$	K	136	$W = 0.0173L^{3.0337}$	Q
Serranus cabrilla	15	$W = 0.0091L^{3.186}$				41	$W = 0.0131L^{2.897}$	L			
Serranus hepatus	111	$W = 0.0319L^{2.7063}$	5	$W = 0.0153L^{2.998}$	A	584	$W = 0.0161L^{3.029}$	L			
Solea kleinii	20	$W = 0.0314L^{2.5}$									
Solea solea	55	$W = 0.0043L^{3.1714}$				74	$W = 0.0022L^{3.386}$	H			
Spicara smaris	403	$W = 0,0089L^{3.0827}$				130	$W = 0.0138L^{2.877}$	K	83	$W = 0.0063L^{3.1504}$	Q
Squalus acanthias	8	$W = 0.00003L^{2.6197}$				32	$W = 0.0031L^{3.11}$	O	176	$W = 0.0040L^{2.95}$	S
Squalus blainvillei	18	$W = 0.00004L^{2.4758}$				266	$W = 0.00345L^{3.0555}$	J			
Syngnathus acus	17	$W = 0.0003L^{3.1149}$	15	$W = 0.0004L^{3.069}$	A						
Trachurus trachurus	307	$W = 0.0056L^{3.1285}$	158	$W = 0.0115L^{2.9367}$	F	373	$W = 0.0128L^{2.810}$	M	1995		
Trigla lyra	96	$W = 0.0062L^{3.047}$				26	$W = 0.0170L^{2.74}$	I			
Uranoscopus scaber	82	$W = 0.0109L^{3.1541}$				92	$W = 0.0103L^{3.153}$	M	69	$W = 0.0150L^{3.05}$	P

Ref. is the refernce of different researchers: A-Keskin and Gaygusuz (2010), B-Ozen *et al*. (2009), C-Eryilmaz and Meric (2005), D-Atasoy *et al*.(2006), E- Alpaslan *et al*. (2007), F-Bostanci (2009), G-Ozaydin *et al*. (2007), H-Ozaydin and Taskavah (2007), I-Ilkyaz *et al*. (2008), J-Ismen *et al*. (2007), K-Karakulak *et al*.(2006), L-Cicek *et al*. (2006), M-Sangun *et al*.(2007), N-Yeldan and Avsar (2007), O-Filiz and Bilge (2004), P-Demirhan and Can (2007), Q-Kalayci *et al*. (2007), R-Ak *et al*. (2009), S-Avsar (2001)

According to Bagenal and Tesch (1978) the parameters of b generally do not vary significantly throughout the year, unlike parameters which may vary seasonally, daily and between habitats. In fact, L-W relationships are not constant over the whole year, varying according to factors such as food availability, feeding rate, gonad development and spawning period. However, the parameter b is characteristic of species and generally does not vary significantly throughout the year, unlike the parameter a which may vary daily, seasonally and between different habitats (Santos *et al*., 2002).

The L-W relationships estimated in this study are shown in Table 3, together with similar relationships for the same species previously obtained for the Turkish coast. Differences observed for regressions estimated from different areas were compared. The estimates for b values obtained in the present research are particularly high for *Atherina boyeri* and very low for *Cepola macropthalma*. On the contrary, for *Merlangius merlangius euxinus*, *Gobius niger* and *Uranoscopus scaber* both the allometric condition factor and the coefficient of allometry are similar to those obtained in previous studies carried out in the Sea of Marmara of the Mediterranean sea and in the Black sea by Atasoy *et al.* (2006) and Sangun *et al.* (2007).

This research is the new contribution on LWR parameters and new extended size range of *A. laterna*, *B. luteum*, *C. lyra*, *C. risso*, *C. macrophthalma*, *C. lucerna*, *E. gurnardus*, *G. mediterraneus*, *G. niger*, *L. friesii*, *L. piscatorius*, *M. merlangus euxinus*, *P. saltatrix*, *R. astarias*, *S. hepatus*, *S. kleinii*, *S. blainvillei* and *T. lyra* for the Sea of Marmara, Turkey. Moreover this study presents the first references on LWR for *C. lyra* and *S. kleinii* in the Turkish waters. Compared to the information available in Froese and Pauly (2010), this study produced new records of maximum total length for seven species: *A. laterna* (20.0 cm), *C. risso* (18.2 cm), *G. niger* (15.0 cm), *L. friesii* (10.7 cm), *T. lyra* (51.0 cm), *B. luteum* (20.0 cm) and *R. astarias* (79.0 cm).

The Sea of Marmara is one of the most important fishery and known as an important spawning and nursery ground under pressure of fishery. It is well known that LWR parameters are commonly used in fisheries management and fisheries biology applications.

CONCLUSION

The researchers believe that this study provides useful information on length-weight relationships in the Sea of Marmara in terms of the first parameters estimation for 21 fish species in the Sea of Marmara. It is also well known that length-weight relationship parameters are commonly used in fisheries management and fisheries biology applications. From this point of view, the related studies on L-W relationships among specimens caught in this area should be evaluated and developed in future.

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