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RESEARCH ARTICLE

Length-weight relationships for fourteen fish species collected by bottom trawl from the Eastern Black Sea coast, Turkey

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ABSTRACT

Length-weight relationships (LWR) were described for fourteen demersal and pelagic fish species; whiting (*Merlangius merlangus*), red mullet (*Mullus barbatus*), picarel (*Spicara maena*), scorpion fish (*Scorpaena porcus*), anchovy (*Engraulis encrasicolus*), sprat (*Sprattus sprattus*), horse mackerel (*Trachurus mediterraneus*), bluefish (*Pomatomus saltatrix*), *turbot (Scophthalmus maximus),* thornback ray (*Raja clavata*), shore rockling (*Gaidropsarus mediterraneus*) round goby (*Neogobius melanostomus*), black goby (*Gobius niger*) and stargazer (*Uranoscopus scaber*) caught with bottom trawl (12 mm mesh size) from the Eastern Black Sea. Samples were caught in depths from 10 m up to 60 m between April 2017 and March 2018 at monthly intervals. The minimum and maximum lengths and weights, length-weight relationships, parameters of *a* and *b*, ± 95% CI of *b*, r^2, growth type (isometric or allometric) of samples, and statistical analyses of the relationship were determined. Estimates for parameter *b* of the length–weight relationship ranged between 2.44 and 3.54.

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Introduction

The Black Sea is the world's largest land-locked inland sea (Bakan & Büyükgüngör, 2000). It has been exposed to environmental fluctuations and strong anthropogenic stresses (Bologa, 2001). In the Eastern part of the Black sea, the fishing grounds are quite different and the big rivers (Bzyb, Kodori, Inguri of Rio and Çoruh River) flows into the Black Sea from Georgia, which is close to the sampling area of the present study. The rivers change the physico-chemical properties parallel to the food spectrum of the environment (Berkün et al., 2010). This may play an important role in determining the nutrient composition, quantity and quality of the environment.

The length-weight relationship (LWR) has great importance in fish biology, physiology, ecology and fishery assessment (Gonçalves et al., 1997; Silva et al., 2013).

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Furthermore, the LWR allows fish condition to be estimated. The condition factor is frequently used in the analysis of ontogenetic changes (Safran, 1992) and for between-regions life-history comparisons (Weatherley & Gill, 1987). Length and weight parameters are also highly crucial for fisheries science, and stock assessment studies. It gives information about the growth type of fish, whether it is isometric or allometric (Ricker, 1975; Erzini, 1994). Previous studies about the length-weight relationships for fish species in the Black Sea coast of Turkey were performed by many researchers (Demirhan & Can, 2007; Kalaycı et al., 2007; Ak et al., 2009; Yankova et al., 2009; Özdemir & Duyar, 2013; Kasapoğlu & Düzgüneş, 2013; Çalık & Sağlam, 2017; Samsun et al., 2017). This study aims to provide data on the length-weight relationship for the 14 fish species captured by bottom trawl from the coastal waters of the Eastern Black Sea, Turkey.

Material and Methods

Study Area and Fish Sampling

The fishing operations were performed with the special permission of the Ministry of Agriculture and Forestry with the R/V Karadeniz Araştırma belongs to the Fishery Faculty of Recep Tayyip Erdoğan University due to the restriction of trawl fisheries in the study area. Depths of the surveys were started from 10 m up to 60 m and the operations were done between April 2017 and March 2018 (monthly) off the Rize coast in the south-eastern Black Sea. Samples were obtained by hauling an experimental bottom trawl net (12 mm mesh size) at a constant speed of 2.5-3 knots. Fishing took place within an area defined by the following coordinates: 40°59'29''N/40°19'52''E; 40°59'57''N/40°18'50''E; 40°01'32''N/40°22'53''E; 41°02'10''N/40°22'04''E (Figure 1).

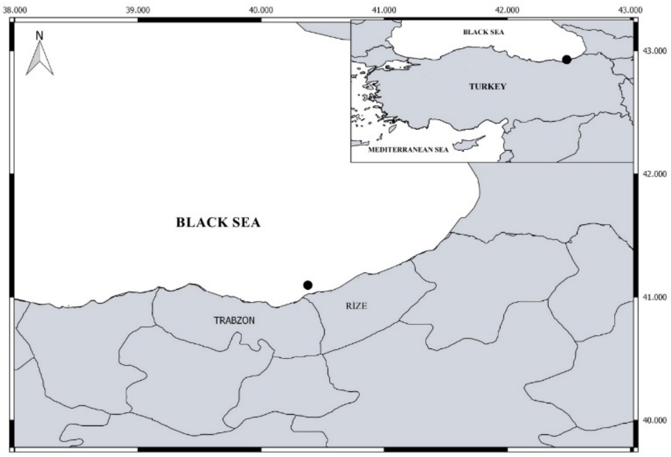

Figure 1. Study area (Iyidere coast)

Length- Weight Relationship (LWR)

All the yield was classified according to the fish species and identified. If the same species of fish were in a small amount all of the samples was measured. For fish species that were at a high number, the sub-sampling method was applied in order to measure the length and weight values. The fresh samples' total length (TL; cm) was recorded to the nearest 0.1 cm and total weight (W; g) was measured to the nearest 0.01 g. The length and weight relationship of fish were calculated using the exponential relationship (Ricker, 1973) (Equation 1) using the least-squares method:

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

where a is the intercept and b is the slope. The association degree between variables of W (total weight; g) and TL (total length; cm) was calculated by the determination coefficient (r^2). Additionally, 95% confidence limits of parameter b were estimated. The Student's t-test was used for comparison of the slopes (Zar, 1996). When the parameter 'b' is statistically equal to 3, the growth is called isometric, but the growth is positive allometric when the 'b' value is more than 3 and negative allometric when the 'b' value is less than 3 (Dutta et al., 2012).

Results and Discussion

In this research, length-weight relationships for 14 species were examined: *Sprattus sprattus* (Linnaeus, 1758*), Engraulis encrasicolus* (Linnaeus, 1758), *Scorpaena porcus* (Linnaeus, 1758), *Trachurus mediterraneus* (Steindachner, 1868), *Spicara maena* (Linnaeus, 1758), *Pomatomus saltatrix* (Linnaeus, 1766), *Merlangius merlangus* (Linnaeus, 1758), *Mullus barbatus* Linnaeus, 1758, *Gaidropsarus mediterraneus* (Linnaeus, 1758), *Raja clavata* Linnaeus, 1758, *Neogobius melanostomus* (Pallas, 1814), *Uranoscopus scaber* Linnaeus, 1758 and *Gobius niger* Linnaeus, 1758. For each species, the sample size, length ranges (minimum- maximum and average), parameters of length-weight relationships (a and b), 95% confidence intervals of b and the coefficient of determination (r^2) and growth type were given in Table 1. According to the results of this study, the "a" values ranged from 0.0013 to 0.169 while the "b" values varied between 2.4454 and 3.5474. The coefficients (r^2) ranged from 0.89 (*E. encrasicolus*) to 0.99 (*S. porcus*).

In this study, 7591 fish belonging to 14 families were examined. The most sampled species were *M. barbatus* (47%), *M. merlangus* (23.2%), *S. sprattus* (12.5%) respectively. Length-weight relationships for 14 species presented here were discussed deeply with previous studies from the Black Sea, Marmara, Aegean, Mediterranean and Adriatic Seas (Table 2).

Table 1. Length-weight relationships of 14 fish species caught from Eastern Black Sea, Turkey

Species	N	$L_{min-max}$	$W_{min.-max.}$	a	b	S.E. of b	95% CL of b	r^2
S. sprattus	780	5.7-16.6	0.79-33.54	0.0047	3.06	0.0012	3.13-2.99	0.90
E. encrasicolus	83	6.6-11.2	1.2-5.53	0.0043	3.04	0.0138	3.27-2.81	0.89
S. porcus	219	5.5-25.9	3.03-49.58	0.0145	3.11	0.0004	3.15-3.07	0.99
T. mediterraneus	581	7.3-18.4	2.26-51.18	0.0027	3.42	0.0019	3.51-3.33	0.91
S. maena	162	9.1-19.1	7.14-65.42	0.0081	3.08	0.0013	3.15-3.01	0.97
P. saltatrix	14	14.4-22	25.51-88.29	0.0118	2.89	0.0253	3.24-2.55	0.96
M. merlangus	1444	5.7-24.9	1.13-111.49	0.0063	3.04	0.0001	3.06-3.02	0.97
M. barbatus	2930	5.2-23.6	1.15-129.21	0.005	3.23	0.00007	3.25-3.21	0.98
S. maximus	18	22-69	400-6540	0.169	2.44	0.0117	2.67-2.21	0.96
R. clavata	478	24-97	40-6290	0.0027	3.20	0.0006	3.24-3.15	0.97
G. mediterraneus	22	14.2-26.6	15.87-134.95	0.0013	3.54	0.0130	3.78-3.31	0.97
N. melanostomus	169	9-24.6	8.83-250.34	0.0069	3.24	0.00091	3.30-3.18	0.98
G. niger	427	5.7-13.5	1.91-24.78	0.0112	2.97	0.0014	3.05-2.90	0.93
U. scaber	264	4.8-24.2	2.31-263.45	0.0178	2.96	0.00094	3.02-2.90	0.97

Table 2. Length-weight relationship parameters of 14 fish species estimated from other areas

Species	N	L_{min}-L_{max}	W_{min}-W_{max}	a	b	r^2	Region	References
S. sprattus	5087	5.6-12.6	3.34-47.37	0.008	2.86	0.88	Black Sea	Kalaycı et al., 2007
	134	4.3-7.9	0.37-3.18	0.004	3.35*	0.90	Aegean Sea	Moutopoulos & Stergiou, 2002
	423	5.6-10.7	1.08-8.14	0.006	2.92	0.91	East Black Sea	Kasapoğlu & Düzgüneş, 2013
	15016	5.5-12.5	2.54-9.41	0.002	3.46*	0.98	West Black Sea	Panayatova, 2001
	599	5.9-10.9	1.4-8.1	0.007	2.92	0.94	Black Sea	Özdemir & Duyar, 2013
	3060	6-11.5	1.32-7.99	0.01	2.70	0.95	West Black Sea	Yankova et al., 2011
E. encrasicolus	10062	5.5-14.5	0.9-17.4	0.008	2.86	0.89	Black Sea	Samsun et al., 2017
	4027	10.3-15.7	8.3-24.5	0.024	2.51	0.99	West Black Sea	Yankova et al., 2011
	696	8-13.6	3.5-16.4	0.018	2.62	0.88	Black Sea	Özdemir & Duyar, 2013
	1588	5.9-14.6	1.1-18.1	0.012	2.77	0.94	East Black Sea	Kasapoğlu & Düzgüneş, 2013
	575	8-14.7	2.85-19.14	0.017	2.60	0.85	Black Sea	Kalaycı et al., 2007
S. porcus	50	8.5-21	13-165	0.025	2.89	0.97	East Black Sea	Çalık & Sağlam, 2017
	351	5-34.2	2.1-406.1	0.009	3.27*	0.88	East Black Sea	Ak et al., 2009
	980	6.1-35.5	7-640	0.018	3.02*	0.97	Mediterranean	Morey et al., 2003
	98	8.2-26.4	-	0.012	3.18*	0.98	Aegean Sea	Karachle & Stergio, 2008
	15	17.3-21.4	84.2-186.02	0.006	3.34*	0.94	Marmara Sea	Bök et al., 2011
	136	8.5-29.2	13-508	0.017	3.03*	0.98	Black Sea	Kalaycı et al., 2007
T. mediterraneus	1432	7-18.4	4.5-55	0.005	3.17*	0.92	West Black Sea	Yankova et al., 2011
	526	9.4-15.3	4.6-25.2	0.003	3.3*	0.9	Black Sea	Özdemir & Duyar, 2013
	17	25.5-34.5	129-320	0.000	2.72	0.97	Adriaatic	Dulčić & Kraljević, 1996
	344	12-34.2	16.8-306.8	0.029	2.60	0.93	Mediterranean	Torres et al., 2012
	191	17.3-34.1	-	0.014	2.82	0.92	Aegean Sea	Moutopoulos & Stergiou, 2002

Note: * Studies showing similarities with this study

Table 2 (Continued). Length-weight relationship parameters of 14 fish species estimated from other areas

Species	N	L_{min}-L_{max}	W_{min}-W_{max}	a	b	r^2	Region	References
S. maena	528	8.3-24.2	3.51-29.4	0.009	3.00*	0.86	East Black Sea	Ak et al., 2009
	52	4.2-20.1	0.6-86	0.011	2.86	0.98	Mediterranean	Morey et al., 2003
	176	7.5-16.9	5.12-52.64	0.028	2.59	0.92	Mediterranean	Sangun et al., 2007
	118	7-18.5	-	0.009	2.99	0.96	Aegean Sea	Karachle & Stergio, 2008
	403	5.9-17.7	3.53-78.30	0.089	3.08	0.86	Marmara Sea	Bök et al., 2011
	83	11.2-20	14.24-87.67	0.006	3.15*	0.96	Black Sea	Kalaycı et al., 2007
P. saltatrix	820	16.1-27.5	32.5-227.9	0.005	3.25	0.95	Black Sea	Samsun et al., 2017
	14	11.6-21.2	12-131	0.003	3.34	0.96	East Black Sea	Ak et al., 2009
	207	12.2-24	15.4-127.2	0.005	3.25	0.98	Black Sea	Özdemir & Duyar, 2013
	25	12.5-20.2	16-75.2	0.009	3.01	0.87	East Black Sea	Kasapoğlu and Düzgüneş, 2013
	143	13.2-21.7	23.21-88.19	0.013	2.86*	0.92	Black Sea	Kalaycı et al., 2007
M. merlangus	140	10-27	9-118	0.013	2.77	0.91	East Black Sea	Çalık & Sağlam, 2017
	943	6.7-29.5	2.15-241.2	0.004	3.16*	0.98	East Black Sea	Ak et al., 2009
	44	14.1-29.1	-	0.004	3.18*	0.98	Aegean Sea	Karachle & Stergio, 2008
	166	7.6-24.2	2.7-121.40	0.004	3.14*	0.94	Marmara Sea	Bök et al., 2011
	1282	7.2-42.5	2-593	0.005	3.15*	0.98	Adriatic Sea	Bolognini et al., 2013
	3715	5.5-22.5	1.05-80.9	0.004	3.15*	0.99	West Balck Sea	Yankova et al., 2011
	432	6.8-14.6	-	0.005	3.24*	0.97	East Black Sea	Demirhan & Can, 2007
M. barbatus	22	17.3-24.7	60-180	0	3.12*	0	Adriaatic Sea	Dulčić & Kraljević, 1996
	76	12.5-22.3	-	0.004	3.27*	0.94	Aegean Sea	Karakulak et al., 2006
	2693	5.3-19	1.20-73-40	0.007	3.12*	0.96	East Black Sea	Kasapoğlu & Düzgüneş, 2013
	99	10-15.7	-	0.0049	3.32*	0.91	Marmara Sea	Bök et al., 2011
	714	6.1-21.9	2.08-161.14	0.007	3.13*	0.99	East Black Sea	Ak et al., 2009
	451	8.2-22	4.96-106.26	0.0032	3.06*	0.94	Mediterranean	Sangun et al., 2007
	432	6.8-18	-	0.0051	3.24*	0.97	East Black Sea	Demirhan & Can, 2007
S. maximus	16	37.5-70.5	925-7865	0.0113	3.11	0.93	East Black Sea	Çalık & Sağlam, 2017
	63	10--61	14.6-4494.4	0.007	3.24	0.98	Black Sea	Ak et al., 2009
	155	25-79	-	0.011	3.10	0.99	Adriatic Sea	Arneri et al., 2001
	97	32.5-80	444.2-9456	0.0069	3.37	0.93	Black Sea	Özdemir & Duyar, 2013
	50	44-71.7	1390-5960	0.001	3.27	0.84	West Black Sea	Yankova et al., 2011
R. clavata	24	56-79	1200-5500	0.001	2.30	0.96	West Black Sea	Yankova et al., 2011
	31	20.50-99	28.86-2614	0.0016	3.29*	0.93	Aegean Sea	Filiz & Mater, 2002
	52	34.3-95	170-5450	0.001	3.42*	0.91	East Black Sea	Demirhan et al., 2005
	27	10.7-95.2	-	0.0019	3.24*	0.99	East Black Sea	Demirhan & Can, 2007
G. mediterraneus	172	6.5-32	2.24-313.52	0.0114	3.08*	0.96	East Black Sea	Kasapoğlu & Düzgüneş, 2013
	8	4.2-20.7	-	0.0006	3.01*	0.99	Marmara Sea	Keskin & Gaygusuz, 2010
	56	8.2-14.3	1.3-11.73	0.003	3.18*	0.98	Marmara Sea	Bök et al., 2011
	15	8.5-14.5	-	0.0069	2.86	0.97	Aegean Sea	Karachle & Stergio, 2008
	164	4.5-23.6	0.25-95.30	0.0029	3.28*	0.98	West Black Sea	Van et al., 2019

Note: * Studies showing similarities with this study

Table 2 (Continued). Length-weight relationship parameters of 14 fish species estimated from other areas

Species	N	L_{min}-L_{max}	W_{min}-W_{max}	a	b	r^2	Region	References
N. melanostomus	99	8.6-19.1	-	0.0047	3.39	0.95	East Black Sea	Demirhan & Can, 2007
	172	6.5-32.0	2.24-313.52	0.0114	3.088	0.96	East Black Sea	Kasapoğlu & Düzgüneş, 2013
	3910	13.6-19.2	37.5-113	0.006	3.346	0.98	West Black Sea	Yankova et al.,2009
	73	9.1-35	8.58-381.42	0.01	3.033	0.89	East Black Sea	Ak et al., 2009
	758	3.6-13.3	-	0.0112	3.08	0.97	Caspian Sea	Abdoli et al., 2009
G. niger	113	7.6-13.2	-	0.0113	3*	0.91	East Black Sea	Demirhan & Can, 2007
	227	8.0-25.3	5.37-168.7	0.0166	2.86	0.96	Black Sea	Kalaycı et al., 2007
	286	6.9-19	3.49-33.3	0.0115	2.98	0.88	Marmara Sea	Bök et al., 2011
	447	7.7-16.5	-	0.0075	3.15*	0.97	Aegean Sea	Özaydın et al., 2007
	225	36-92	-	0.0123	2.97	0.96	Mediterranean	Verdiell-cubedo et al., 2006
U. scaber	30	12.4-28.4	-	0.007	3.22	0.98	Aegean Sea	Moutopoulos & Stergiou, 2002
	620	1.8-56.4	1.01-551.51	0.008	3.22	0.81	East Black Sea	Ak et al., 2009
	92	5.2-24.7	2.15-307.96	0.0103	3.15	0.99	Mediterranean	Sangun et al., 2007
	82	10.7-24.6	21.1-378.24	0.0109	3.15	0.96	Marmara Sea	Bök et al., 2011
	346	5.2-21.9	2-182.5	0.0167	3	0.99	East Black Sea	Demirhan et al., 2005

Note: * Studies showing similarities with this study

In the Black Sea *S. sprattus* and *E. encrasicolus* are not the target species of bottom trawling. However, these species were detected in the samplings. These common pelagic species migrate from offshore in the beginning of spring (Polat & Ergün, 2008). So this could be the reason for the presence of these species in the catch composition of the present study. It is remarked by Karakulak et al. (2006) that differences of *b* values for the same species are due to the differences in sampling methods, namely, the number of specimens and the differences in the length ranges of the species. These variations can also be arisen because of temporal variations of the sampling sites. In addition, in our study, it has been seen that the length range of the species is limited and mostly smaller fishes are dominant. On the coast of the Black Sea, an excessive fishing pressure exists (Knudsen et al., 2010). The high fishing mortality brings some changes to the biology of the species, such as a decrease in total length and first sexual maturity length (Jennings et al., 1999). Consequently, studies revealing variations in fish biology should be conducted continuously to monitor the recent situation of fish stocks (Ricker, 1975; Weatherley & Gill, 1987; Yankova et al., 2011). There is no doubt that fatness and shape of the species are initially stated according to the change on *b* values, but some factors such as food (size, quantity, and quality), salinity, sex, temperature, time of year, stage of maturity can change parameters of the length-weight relationship (Ricker, 1973).

Conclusion

The outcomes of this study have significant importance to make comparison with other studies. The results obtained will make a considerable contribution to the knowledge of fish populations in this special area. It is expected that fishermen and scientists take advantage of this study for future studies, especially about heavily exploited populations, as well as those under stock recovery plans or other management and conservation programs.

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Compliance with Ethical Standards

Authors' Contributions

Author GD designed the study, HO wrote the first draft of the manuscript, performed and managed statistical analyses. All authors read and approved the final manuscript.

Conflict of Interest

The authors declare that they have no conflict of interest.

Ethical Approval

For this type of study, formal consent is not required.

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