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Length-weight relationships of 28 fish species caught from demersal trawl survey in the Middle Black Sea, Turkey

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Abstract: This study provides updated the length-weight relationships and Fulton's condition factor of 28 fish species belonging to 23 families from the Black Sea. Samples were collected along the depths between 0-100 meters by demersal trawl surveys conducted seasonally from May 2017 to September 2019. A total of 83,885 specimens were collected. The length-weight relationships and Fulton's condition factor, minimum, maximum and mean lengths, total weights, descriptive statistics, and growth type were provided for all the species. The results indicate that LWR parameters of b varied from 2.2039 to 3.737 and Fulton's condition factor varied between 0.004 and 1.18. These findings could be useful for monitoring and management of sustainable fisheries and habitat health.

Key words: Length-weight relationship, Black Sea, Turkey, bottom trawl survey

1. Introduction

Length-weight relationship (LWRs) has great importance in fishery assessment studies to provide information about the growth of the fish and general conditions in a marine habitat through the fish condition factor (ICES, 2017). LWR is a significant standard method for fisheries science, to estimate length-frequency samples to total catch, or biomass and has great importance in fishery assessments (Froese, 2006). In addition to abovementioned importance, LWR is also a powerful tool that allows estimation of fish weight based on the known length, measurement of changes in population robustness health, and morphometric, interspecific, and intra-population comparisons. It also helps convert one variable into another (Kuriakose, 2017).

Geographic localities with different environmental conditions are resulting differences in weight–length relationships of the same species. The Black Sea is an internal semienclosed basin characterized by brackish and high productivity waters surrounded by huge rivers by six countries (Turkey, Russian Federation, Ukraine, Romania, Bulgaria, and Georgia). Therefore, the Black Sea has encountered ecological and environmental problems for the last 50 years (O'Higgins et al., 2014). These problems can be enumerable as illegal, unregulated, unreported fishing (IUU), overfishing, eutrophication, global climate change, coastal urbanization, solid waste discharges including micro and macro plastics and maritime oil transportation (Güneroğlu et al., 2019). The status of the Black Sea environment is very well documented about all aspects in the literature with myriad scientific papers (Demirhan and Can, 2007; Kalaycı et al., 2007; Ak et al., 2009; Erguden et al., 2011; Yankova et al., 2011; Kasapoglu and Duzgunes, 2014; Yeşilçiçek et al., 2015; Çalık and Sağlam, 2017; Türker and Bal, 2018; Yıldız et al., 2018).

Living organisms such as fish generally increase in size (in length and in weight) during their development. The factors that regulate the rate at which a fish can grow can be divided into exogenous factors imposed by the environment and endogenous factors related to the geotype and physiological condition of the fish (Wootton, 1998). The majority of the species that are the focus of this study have been investigated covering a different aspect of its biology and ecology including LWR. However, the variety of factors affecting the growth and hence length and weight and related parameters such as LWR and Fulton's condition factor (Fulton's K) and vary between

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seasons, localities and years, resulting in different weight–length relationships. Therefore, the main objective of the present work is to provide updated information on LWR and Fulton's K of the species most of which are either commercially or ecologically important (i.e. endangered or rare) in the southeastern Black Sea. This information would enhance management and conservation and allow future comparisons between populations of the same species.

2. Material and methods

The samples were collected within the scope of the national program of bottom trawl surveys carried two times a year from 2017 to 2019. This survey method was based on MEDITS protocol modified for the Black Sea and the research vessel R/V Sürat Araştırma-1 was used during the surveys. Sampling was carried out mainly in the littoral region between Sinop and Ordu in three depth strata (0-20 m, 20-50 m, and 50-100 m) (Figure). Length measurements were recorded as total length (L) from the mouth to the end of the caudal fin measured to the nearest 0.1 cm. The total weight (W) was measured using a digital balance with an accuracy of 0.01 g. LWR of the selected species was determined using the cube law proposed by Le Cren (1951), $W = aL^b$ where a = intercept and b = slope of the regression line. Prior to regression analysis length and weight data of individual specimen were log transformed. LWR of each fish species was arrived at by using the logarithmic transformation of cube law (Log W = Log a + b Log L) with a view to establishing a linear relationship. Outliers were removed by following Froese (2006). The coefficient of determination (R^2) was estimated in order to explore the degree of association between L and W. When applying the LWR formula on sampled fish, b may deviate from the "ideal value" of 3 that represents an isometric growth (Ricker and Carter, 1958) because of certain environmental circumstances or the condition of the fish themselves. When b is less than 3, fish become slimmer with increasing length, and growth will be negatively allometric. When b is greater than 3.0, fish become heavier showing positive allometric growth and reflecting optimum conditions for growth. Student's t-tests were applied for this. All statistical analyses were considered at a significance level of 95% ($p < 0.05$). The condition factor is used for comparing the condition, fatness, or well-being of fish based on the assumption that heavier fish of a given length are in better condition (Wootton, 1998). The Fulton's condition factor was calculated following the formula proposed by Fulton (1904) as, Fulton's K= 100 x W /L^3, where W = weight of the fish (g) and L = length of the fish (cm).

3. Results

The study presents LWRs for 28 species, representing 23 families and of which 13 are commercial and 15 are noncommercial. A total of 83,885 specimens were used.

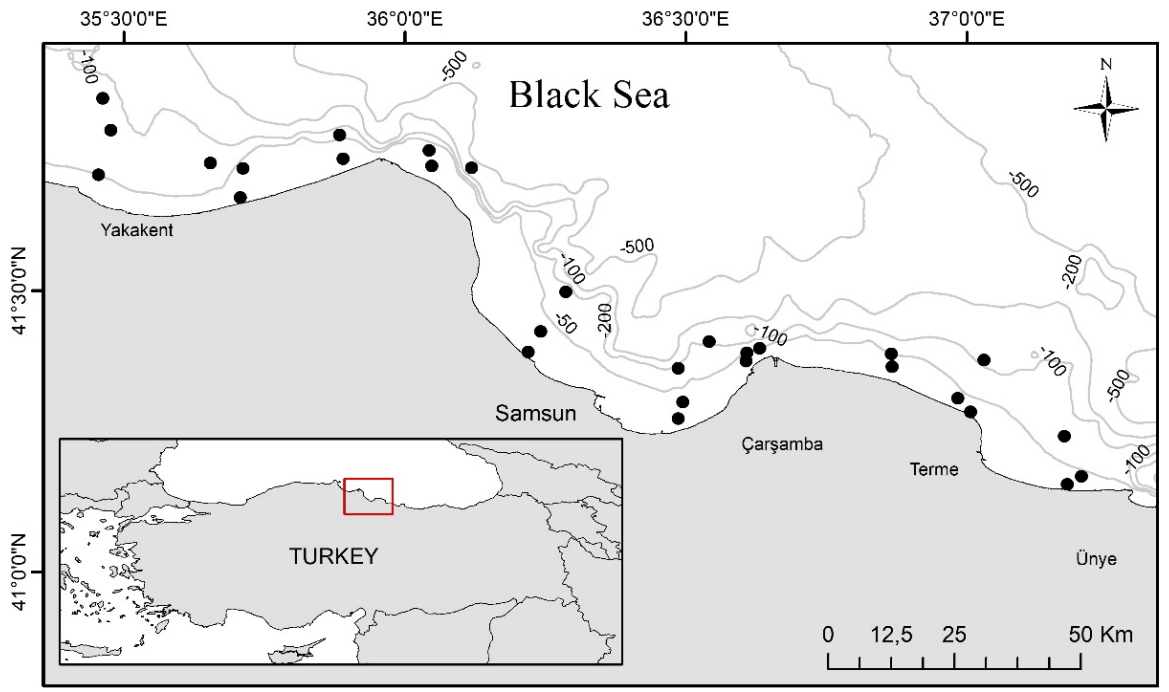


Figure. Map of Turkey showing the sampling sites in the Black Sea.

The number of samples per species, the length ranges (minimum and maximum), Fulton's K, parameters of length and weight relationships (*a* and *b*), 95% confidence intervals of *b*, the coefficient of determination (R^2) and associated statistics are given in the table. Majorty of regressions were highly significant ($p < 0.05$), with the coefficient of determination (R^2) ranging from 0.867 to 0.996 (Table). The values of a were ranged from 0.0004 to 0.0501 while the *b* varied between 2.2039 for *Hippocampus guttulatus* and 3.737 for *Dasyatis pastinaca* (Table). The most abundant species in the samples were *Merlangius merlangius* (by 32534 specimens) and followed by *Mullus barbatus*, *Sprattus sprattus,* and *Trachurus mediterraneus*. Besides, some species caught as little amount for example.

4. Discussion

This study covers recent information on the LWR and Fulton's K of 28 fish species that have been distributed in the Black Sea including the first recorded data of *Pomatoschistus marmoratus* from the Turkish Black Sea area. The LWR parameters for the species have been updated against ongoing environmental and ecological changes in the Black Sea (Shin et al., 2018) and economically and ecologically important species are discussed in more detail below.

Merlangius merlangus is one of the most economic demersal resources of the Black Sea (Dağtekin et al., 2019). Parameter *b* for *M. merlangus* in this study was the lowest calculated value in all the other studies conducted in the Black Sea (Samsun and Erkoyuncu 1998; Genç et al., 1998; Kalaycı et al., 2007; Yıldız and Karakulak 2018; Ak et al., 2009) apart from the work of Çalık et al. (2017) whose sample size was considered low. The *b* value of one of the most vulnerable and at the same time one of the most economically important species of the Black Sea namely *Scopthalmus maximus* was the lowest one compared to the rest of the researches conducted in the Turkish Black Sea coasts. This may be attributed to changing both biological and ecological conditions and intensive catch strategy by the fishers in the Black Sea (Kıdeyş, 2002). Another economically important species of the Black Sea is *M. barbatus* and the *b* coefficient was found similar to the results of Genç et al. (1998) and Ak et al. (2009) while it was slightly higher than the values reported by Genç et al. (2002), Kalaycı et al. (2007), Çalık and Sağlam (2017), and Dağtekin et al. (2019) for the same areas. In addition, Karakulak et al. (2006) and Özaydın et al. (2007) found a higher coefficient of *b* than this study. The reason for the high values may be attributed to the different biological and environmental conditions in the areas that studies conducted (Wootton, 1998; Froese 2006). *Engraulis encrasicolus* is the most dominant commercial species in the Black Sea. Mutlu (2000) and Samsun et al. (2004) found the *b* value to be less than 3. Compared with our study findings, Kalaycı et al. (2007), Özdemir et al. (2018), Kasapoglu and Duzgunes (2014), Genç et al. (2018) had similar results. *Spratus spratus* which has been represented by high biomass in the Black Sea like *Engraulis encrasicolus* showed positive allometry and together with the b value found by Şahin et al. (1999) it is the highest value observed in comparison to studies conducted in adjacent country areas of the Black Sea (Yankova et al., 2011; Özdemir and Duyar, 2013; Türker and Bal, 2018). In this study, *b* value was found to be lower than the values reported by Karakulak et al. (2006); Ak et al. (2009), Yankova et al. (2011), Aydın and Karadurmuş (2012) for *Trachurus mediterraneus* while it was higher than the values reported by Genç et al. (1998), Kayalı (1998), Şahin et al. (2009), Atılgan et al. (2012) and Ak et al. (2015). *Hippocampus guttulatus* showed isometric growth which corroborates with the results of the majority of the studies conducted in the Black Sea (Ak et al., 2009; Kasapoglu and Duzgunes, 2014).

Cartilaginous fish, an important part of the species studied in this study, namely *Raja clavata*, *Squalus acanthias*, and *Dasyatis pastinaca* are listed as either near threatened (Ellis et al. 2016) or vulnerable (Finucci et al 2020 and Jabado et al., 2021). The *b* value of the *Raja clavata* was found to be lower than in the other studies except the Yankova et al. (2011) and it is remarkable that the number of samples of this study is compared to the others. The *S. acanthias* except value was found higher than the others except the Avsar (2001). The calculated *b* values of *Dasyatis pastinaca* were lower than İşmen et al. (2007), Özaydın et al. (2007), Yeldan et al. (2008), İlkyaz et al. (2008) and Yığın and İşmen (2009) contrary to Filiz and Mater (2002), Morey et al. (2003), Filiz and Bilge (2004), Karakulak et al. (2006) and Kasapoglu et al. (2018).

The fish condition factor represents energy accumulated in a fish's body and can also offer useful information about a stock (Gücü et al. 2018). In addition, the condition factor is positively affected by various biological processes involved in reproduction such as fecundity (Ferrer-Maza et al. 2016). Strong stratification and great variance in hydrographic conditions, as well as high production, characterize the Black Sea. Migration and reproduction periods are thought to be effective in the change of the condition factor of the species (Gücü et al. 2018).

In conclusion, the results provided in this study are useful to fisheries biologists as it updated length-weight parameters for some species and "estimated these parameters for the first time for several species inhabiting the Black Sea" and provided updated information about the condition of species studied. The basic biological information, such as LWRs and Fulton's K, generated

Table. Length-weight relationships for 28 fish species from southeastern Black Sea (N is the sample size; mean, min, max, and SD are the mean, minimum, maximum, and standard deviation respectively; a and b are the parameters of the weight–length relationship; SE (b) is the standard error of parameter b; R^2 is the coefficient of determination; growth type is classified as negative (-) and positive allometric (+), and isometric (I).

				Length characteristics	Weightcharacteristics	Condition factor	Regression parameters							
Family	**Species**	**STATUS**	**N**	**Mean±SD (min-max)**	**Mean±SD (min-max)**	**Mean±SD (minimum-maximum)**	**a**	**b**	**R^2**	**SE (*b*)**	**Student t test of *b***	**±CI (0.95)**	**Growth type**	**P**
Dasyatidae	*Dasyatis pastinaca*	Non-commercial	224	42.94 ± 0.935 (30-113.5)	968.88 ± 159.029 (95-15706)	0.65 ± 0.015(0.22-1.69)	0.0004	3.7374	0.9132	0.077339	-9.5352	0.1555	+	p<0.05
Rajidae	*Raja clavata*	Prohibited	1408	54.38 ± 0.523 (10-93)	1441.92 ± 34.505 (5-6530)	0.62 ± 0.005(0.01-4.7)	0.0042	3.0937	0.9747	0.01704	-6.9922	0.0343	+	p<0.05
Squalidae	*Squalus acanthias*	Prohibited	108	51.86 ± 1.294 (30.2-80)	679.41 ± 47.874 (135-2485)	0.41 ± 0.007(0.3-0.81)	0.0068	2.87	0.9604	0.05656	2.2967	0.1137	-	p<0.05
Blenniidae	*Parablennius tentacularis*	Non-commercial	58	7.22 ± 0.156 (4.3-9.4)	4.12 ± 0.26 (0.77-9.57)	1.16 ± 0.149(0.76-9.62)	0.009	3.0545	0.9631	0.25432	-0.5899	0.5112	I	p>0.05
Bothidae	*Arnoglossus kessleri*	Non-commercial	226	6.02 ± 0.046 (4.4-9)	2.24 ± 0.054 (0.84-6.5)	0.99 ± 0.009(0.53-1.59)	0.0117	2.9034	0.875	0.08638	1.2867	0.1736	I	p>0.05
Carangiade	*Trachurus mediterraneus*	Commercial	6915	10.01 ± 0.032 (5.2-18.5)	8.81 ± 0.102 (1.23-66.77)	0.77 ± 0.003(0.11-5.06)	0.0058	3.1152	0.9555	0.01006	-10.9896	0.0202	+	p<0.05
Centracanthidae	*Spicara smaris*	Commercial	384	9.41 ± 0.098 (5.3-18)	9.53 ± 0.384 (1.46-63.77)	0.99 ± 0.005(0.56-1.74)	0.0086	3.0608	0.9725	0.02913	-2.3017	0.0586	+	p<0.05
Clupeidae	*Alosa immaculata*	Commercial	690	14.99 ± 0.109 (9.3-27)	24.97 ± 0.70 (4.25-182.65)	0.65 ± 0.003(0.44-1.32)	0.0043	3.1543	0.9664	0.02272	-6.8781	0.0457	+	p<0.05
	Sprattus sprattus	Commercial	11898	8.34 ± 0.015 (4.5-13)	3.77 ± 0.021 (0.57-13.44)	0.61 ± 0.001(0.33-1.02)	0.0039	3.2096	0.9576	0.00870	-24.0928	0.0175	+	p<0.05
Engraulidae	*Engraulis encrasicolus*	Commercial	1355	9.84 ± 0.05 7(4.7-14)	5.8 ± 0.087 (0.45-16.01)	0.55 ± 0.005(0.19-6.3)	0.006	2.954	0.9765	0.01296	3.6888	0.0261	-	p<0.05
Gadidae	*Merlangius merlangus*	Commercial	32534	9.23 ± 0.027 (5-23.5)	6.75 ± 0.082 (0.82-97.6)	0.73 ± 0.001(0.27-1.52)	0.007	3.0185	0.9873	0.00335	-5.5114	0.0067	+	p<0.05
Gobiidae	*Gobius niger*	Non-commercial	3642	8.33 ± 0.022 (3.3-21)	7 ± 0.066 (0.38-81.72)	1.11 ± 0.002(0.48-2.09)	0.0071	3.2095	0.9374	0.01237	-15.3308	0.0249	+	p<0.05
	Mesogobius batrachocephalus	Commercial	141	15.16 ± 0.407 (7.4-26.7)	41.37 ± 3.635 (4.22-195.78)	0.85 ± 0.013(0.58-1.35)	0.0055	3.1566	0.9743	0.04737	-3.5927	0.0952	+	p<0.05
	Neogobius melanostomus	Commercial	1356	10.35 ± 0.067 (4.1-18.5)	15.89 ± 0.358 (0.62-86.52)	1.17 ± 0.005(0.67-5.32)	0.0069	3.2249	0.9794	0.01541	-17.6089	0.0309	+	p<0.05
	Pomatoschistus marmoratus	Non-commercial	59	10.81 ± 0.484 (4-19.7)	14.36 ± 2.417 (0.42-77.8)	0.7 ± 0.016(0.55-1.04)	0.0029	3.3714	0.991	0.04246	-8.7276	0.0855	+	p<0.05
	Aphia minuta	Non-commercial	59	5.76 ± 0.082 (3.8-7.3)	1.85 ± 0.088 (0.36-4.1)	0.93 ± 0.018(0.66-1.26)	0.0046	3.3933	0.8783	0.16735	-2.3507	0.3364	+	p<0.05
Labridae	*Symphodus tinca*	Non-commercial	11	9.31 ± 0.591 (7-12.5)	14.35 ± 3.072 (4.41-33.81)	1.52 ± 0.058(1.29-1.75)	0.0046	3.5303	0.9958	0.16550	-6.4989	0.3327	+	p<0.05
Lotidae	*Gaidropsarus mediterraneus*	Non-commercial	49	13.7 ± 0.339 (8.2-18.1)	18.39 ± 1.327 (3.38-42.99)	0.66 ± 0.009(0.51-0.82)	0.006	3.0329	0.970	0.07751	-0.4229	0.1558	I	p>0.05
Mullidae	*Mullus barbatus*	Commercial	20238	8.48 ± 0.033 (4.7-20.4)	7.07 ± 0.125 (0.81-87.15)	0.97 ± 0.001(0.43-1.43)	0.0066	3.1694	0.9877	0.00460	-36.7679	0.0092	+	p<0.05
Pleuronectidae	*Platichthys flesus*	Commercial	75	18.23 ± 0.771 (6.6-35)	85.68 ± 9.948 (3.45-440)	1.01 ± 0.018(0.12-1.32)	0.0123	2.9351	0.9908	0.04953	1.9495	0.0996	I	p>0.05
Pomatomidae	*Pomatomus saltatrix*	Commercial	601	13.68 ± 0.103 (8.8-23.8)	25.65 ± 0.662 (5.44-123.01)	0.9 ± 0.004(0.63-1.23)	0.0074	3.0717	0.9712	0.02159	-3.3176	0.0434	+	p<0.05
Scophthalmidae	*Scopthalmus maximus*	Commercial	126	30.89 ± 0.865 (5.9-55)	627.24 ± 53.218 (5.15-3250)	1.62 ± 0.032(0.47-3.7)	0.0146	3.0207	0.9484	0.04879	-0.3306	0.0981	I	p>0.05
Scorpaenidae	*Scorpaena porcus*	Commercial	376	11.31 ± 0.169 (5.2-23.6)	38.07 ± 2.057 (2.7-345)	2.04 ± 0.023(0.19-4.51)	0.0194	3.0177	0.9691	0.04468	-0.6204	0.0898	I	p>0.05
Soleidae	*Pegusa nasuta*	Non-commercial	145	13.33 ± 0.38 (5-31.4)	30.52 ± 2.984 (1.27-345.36)	0.94 ± 0.01(0.7-1.25)	0.0105	2.9534	0.99	0.02487	1.8773	0.0499	I	p>0.05
Sparidae	*Diplodus annularis*	Non-commercial	135	8.25 ± 0.25 (4.3-18.2)	14.56 ± 1.719 (1.16-106.7)	1.72 ± 0.018(0.24-2.29)	0.0129	3.1409	0.9908	0.06446	-5.5515	0.1296	+	p<0.05
Syngnathidae	Hippocampus guttulatus	Non-commercial	24	7.59 ± 0.169 (6.3-9.6)	2.63 ± 0.127(1.7-4.56)	0.62 ± 0.142(0-3.78)	0.0289.	2.2039	0.9813	0.3971	23.1797	0.7982	-	p<0.05
Trachinidae	*Trachinus draco*	Non-commercial	234	13.83 ± 0.181 (8.5-24)	21.4 ± 0.986 (4.43-103.2)	0.04 ± 0.001(0.03-0.05)	0.0066	3.0297	0.9803	0.04472	-1.0379	0.0899	I	p>0.05
Uranoscopidae	*Uranoscopus scaber*	Non-commercial	770	11.94 ± 0.137 (3.3-24.8)	37.57 ± 1.299 (0.84-265.52)	0.71 ± 0.005(0.29-1.01)	0.0226	2.8824	0.9833	0.05004	7.8843	0.1006	-	p<0.05

from this study would be useful for further studies on fish populations and on fish stock assessment which in turn find its application in sustainable management measures of the commercially and ecologically important fish species. Also, the results of this study are useful for the assessment of the data-limited species in the Black Sea.

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