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Length-Weight Relationships (LWRs) of target fish turbot, *Scophthalmus maximus* (Pleuronectiformes: Scophthalmidae) and non-target fish thornback ray, *Raja clavata* (Rajiformes: Rajidae) caught by turbot gill net fishery in the Black Sea, Turkey

Sabri BILGIN[1] and Ozay KÖSE[2]
(1) *Sinop University Faculty of Fisheries and Aquaculture, TR57000, Sinop, Turkey*
(2) *Recep Tayip Erdoğan University Faculty of Fisheries and Aquaculture, TR53000, Rize, Turkey*
Corrosponding Author: sbrbilgin@hotmail.com

Abstract: The present study was conducted to determine the length weight relationships (LWRs) of turbot, *Scophthalmus maximus* and thornback ray, *Raja clavata* caught by bottom turbot gill net in the Black Sea, Turkey and to compare the LWRs parameters of *S. maximus* and *R. clavata* from different geographical locality for contributing fisheries management of these two fish species in the Black Sea. The LWR of *S. maximus* samples collected from the Rize coast in the Black Sea highlighted that *S. maximus* showed isometric growth characteristics for female and combined data (Pauly's test, $P > 0.05$) and negative allometric growth for male (Pauly' t test, $P < 0.05$). The LWR of *R. clavata* showed that *R. clavata* has positive allometric growth characteristics for female and combined data (Pauly's test, $P < 0.05$) and isometric growth for male (Pauly's test, $P > 0.05$). In addition to this, to compare the estimations calculated from the present study with other studies, log (a) values were plotted against values of b, proved to be consistent with previous studies data for *R. clavata* and *S. maximus*. This study provides basic information on the LWRs both *S. maximus* and *R. clavata* populations, in support of sustainable fisheries management of these two fish species and especially of the sea coastal waters in the Black Sea, Turkey.

Résumé : *Relations longueur-poids (LWRs) chez l'espèce cibe, le turbot*, Scophthalmus maximus *(Pleuronectiformes : Scophthalmidae) et chez l'espèce non cible, la raie bouclée* Raja clavata *(Rajiformes: Rajidae) capturées au filet de pêche en Mer Noire, Turquie.* La présente étude visait à determiner les relations longueur-poids (LWR) du turbot, *Scophthalmus maximus* et de la raie bouclée *Raja clavata* capturés par un filet maillant en Mer Noire, Turquie et à comparer les paramètres de LWRs de *S. maximus* et *R. clavata* de différentes régions géographiques pour contribuer à la gestion de pêche de ces deux espèces en Mer Noire. Les LWR des échantillons de *S. maximus* récoltés sur la côte de Rize en Mer Noire ont montré que *S. maximus* présentait des caractériques de croissance isométrique pour les femelles et les données combinées (test de Pauly, $P < 0,05$) et une croissance allométrique negative pour les males (test de Pauly, $P > 0,05$). En complément, pour comparer les estimations calculées à partir de la présente étude avec d'autres études, les valeurs de log (a) ont été comparées aux valeurs de b, qui se sont révélées cohérentes avec les données d'études précédentes de *R. clavata* et *S. maximus*. Cette étude fournit des informations de base sur les LWR des deux populations de *S. maximus* et *R. clavata*, en appui de la gestion de pêche durable de ces deux espèces de poissons, en particulier dans les eaux côtières de la Mer Noire en Turquie.

Keywords: Length-weight-relationships (LWRs) ● *Scophthalmus maximus* ● *Raja clavata* ● Gill net ● Black Sea

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Introduction

According to Froese & Pauly (2017); turbot, *Scophthalmus maximus* (Linnaeus, 1758), distribution is northeast Atlantic: throughout the Mediterranean and along the European coasts to Arctic Circle; also found in most of the Baltic Sea. Subspecies *Psetta maxima maeotica* (Pallas, 1814) in the Black Sea (Froese & Pauly, 2017). Adults live on sandy, rocky or mixed bottoms; rather common in brackish waters. Feed mainly on other bottom living fishes such as gobies and also, to a lesser extent, on larger crustaceans and bivalves. Spawning season is between April and August in the Black Sea (Aydın & Şahin, 2011; Eryılmaz & Dalyan, 2015; Froese & Pauly, 2017). Legal turbot fisheries with turbot gill nets are conducted during the one year period except for between 15 April and 15 June (Anonymous, 2017) in the Turkish Seas. However, in the last few years, the turbot natural stocks have been gradually exhausted, e.g. while turbot productions were 2,700 tons in 2000, total turbot fishing productions were decreased down to 769 tons in 2007, 528 tons in 2008, 383 tons in 2009, 295 tons in 2010 and 221 tons in 2016 in the Turkish Seas.

The thornback ray, *Raja clavata* Linnaeus, 1758 distribution is eastern Atlantic: Iceland, Norway, North Sea and the western Baltic southward to Morocco and Namibia, including the Mediterranean and the Black Sea (Froese & Pauly, 2017). Found on mud, sand and gravel bottoms, rarely on rougher bottoms. Feeds on anchovy, horse mackerel, whiting, goby, shrimp and crab species in the Black Sea (Demirhan et al., 2005). The thornback ray is one of the most abundant elasmobranch species landed by the Black Sea fishery as by catch during the turbot bottom gill net, bottom trawl, trammel net and bottom longline fisheries. This species utilized fresh and frozen (Frimodt, 1995).

Knowledge on biological features such as length-weight relationships (LWRs), growth characteristics, etc. of fish species are important tools for marine biologist and fisheries managers. The LWRs have many applications in fish stock assessments and ecological studies. These are also useful for fisheries research because they allow estimating the condition and food and feeding, life histories of certain species such as reproduction activities and spawning (Stergiou & Moutopoulos, 2001). The LWRs are very useful for fisheries research because they: (*i*) allow the conversion of growth-in-length equations to growth-in-weight for use in stock assessment models; (*ii*) allow the estimation of biomass from length observations; (*iii*) allow an estimate of the condition of the fish; and (*iv*) are useful for between region comparisons of life histories of certain species (Stergiou & Moutopoulos, 2001). Moreover, the WLRs parameters can be applied in different factors such as age, gonad activities, amount of food and feeding, sea water temperature, seasons etc. (Weatherley, 1972). The present study was conducted to determine the weight length relationships of target fish turbot, *S. maximus* and non-target fish thornback ray, *R. clavata* caught by bottom turbot gill net fishery in the Black Sea, Turkey and to compare the LWRs parameters of *S. maximus* and *R. clavata* from different geographical locality for contributing for marine biologist and fisheries managers to fisheries management of these two fish species in the Black Sea.

Materials and Methods

Sample Collection

Turbot gill net fishing operations surveys were conducted between March 2010 and September 2011 on the Rize coasts of the southeastern Black Sea (Fig. 1). Turbot gill net sets that belonging to commercial turbot gill nets fisherman were used for samplings. Characteristics of these net as: equipped length of one turbot gill net was 72 m (about 40 fathom length) and one set was consist of 5-7 added equipped net (0.36-0.504 km). Sampling operations was conducted with these set nets with the characteristics as mesh size (320 mm), mesh depth (7 mesh), thickness of the twine (210 d / 2x3 no) and hanging ratio (E = 0.36). A total of 224 individuals of *S. maximus* and 117 of *R. clavata* were collected from commercial landing at Rize coast, in the Black Sea, Turkey.

Length-Weight Relationships (LWRs)

The total length (*TL*) and the wet body weight (*W*) of two fish species (turbot and thornback ray) were measured after

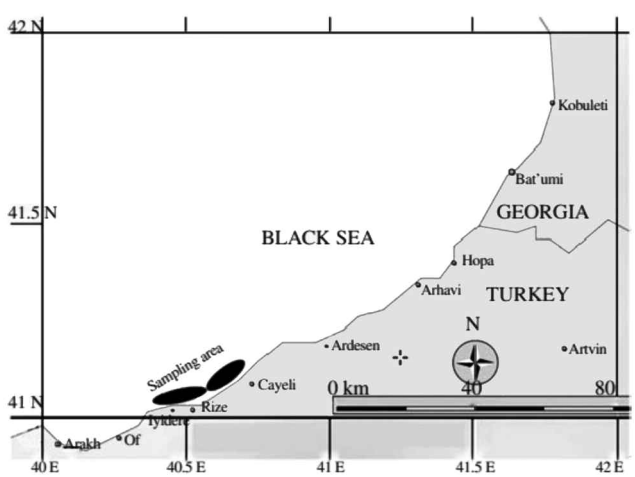


Figure 1. Turbot gill net fishing operations sampling area on the Rize coasts in the southeastern Black Sea.

blot drying with a piece of clean towel. All specimens were measured to the nearest 0.1 cm and weighed to the nearest 0.1 g. The LWRs, parameters were calculated and analyzed using MS Excel software. However to compare the length-weight relation results both turbot and thornback ray obtained in this study with the results of previous studies, the *Log (a)* values were drawn against *b* values. The weight length relationship was estimated as:

$$W = aTL^b \quad (1)$$

where *W* is the body weight (g), *TL* is the total length (cm), *a* is the intercept, and *b* is the slope of the regression line. Comparison of the difference of slope value from *b* = 3 (isometric growth) for all seasons, Pauly's *t*-test was performed (Pauly, 1984). Pauly's *t*-test statistic was calculated as below:

$$t = \frac{Sd_{\log TL} \mid b-3 \mid}{Sd_{\log W}\sqrt{1-r^2}}\sqrt{n-2} \quad (2)$$

where Sd_{logTL} is the standard deviation of the log *TL* values, Sd_{logW} is the standard deviation of the log *W* values, n is the number of specimens used in the computation. The value of *b* is different from *b* = 3 if calculated *t* value is greater than the tabled *t* values for n-2 degrees of freedom (Pauly, 1984). The comparisons between the slopes of the log-transformed regression lines between males and females were carried out using analysis of covariance (ANCOVA) (Mc Donald, 2014.). Comparison of the difference of correlation coefficient (*r*) from zero *t*-test (Snedecor & Cochran, 1989) was calculated as follow:

$$t = \frac{r^* \sqrt{(n-2)}}{\sqrt{(1-r^2)}} \quad (3)$$

where *n* is the number of fish used in the computation and *r* is the correlation coefficient. The value of correlation coefficient is different from zero if *t* value is greater than the tabled *t* values for n-2 degrees of freedom. T test to compare the means between the different sexes in PAST ver 1.75b software package (Hammer et al., 2001). Differences were considered statistically significant when $P < 0.05$.

Results

A total of individuals belonging to two species were examined in this study. Mean total length of *S. maximus* was calculated between 25.0-74.0 cm (mean: 49.5 ± 0.88 cm, n = 110) in combined data (female + male), between 40.5–74.0 cm (mean: 55.9 ± 1.52 cm, n = 42) in female, and between 25.0-69.0 cm (mean: 45.5 ± 0.73 cm, n = 68) in male. The mean total length of females was statistically longer than males (t test; $P < 0.001$).

The LWRs results and statistics of *S. maximus* between male, female and combined sex showed below and in Fig. 2. The slope of the length - weight relationship was significantly (ANCOVA, $P < 0.05$) different between sexes. Therefore, this relationship was investigated separately for each sex. The relationship for females, male and combined data was: $W = 0.0168TL^{3.0424}$, $r^2 = 0.9474$, $Sd_{logL} = 0.076493$, $Sd_{logW} = 0.23909$, n = 42, Pauly's test = 0.3741, $P > 0.05$, isometric growth (female). $W = 0.1299TL^{2.4774}$, $r^2 = 0.8786$, $Sd_{logL} = 0.058687$, $Sd_{logW} = 0.15511$, n = 68, Pauly's test = 4.6954, $P < 0.05$, negative allometric growth (male). $W = 0.0185TL^{3.0008}$, $r^2 = 0.9309$, $Sd_{logL} = 0.078172$, $Sd_{logW} = 0.24313$, n = 110, Pauly's test = 0.01014, $P > 0.05$, isometric growth (combined data). The LWR of *S. maximus* samples collected from the Rize coast in the Black Sea were showed that *S. maximus* showed isometric growth characteristics for female and combined data (Pauly's test, $P > 0.05$) and negative allometric growth for male (Pauly's test, $P < 0.05$). However, in order to comparison of the difference of correlation coefficient (*r*) from zero *t*-test (Snedecor & Cochran, 1989) was applied and the values of (*r*) for female (*r* = 0.9733, t test: 26.8411), for male (*r* = 0.9373, t test: 21.8549), for combined data (*r* = 0.9648, t

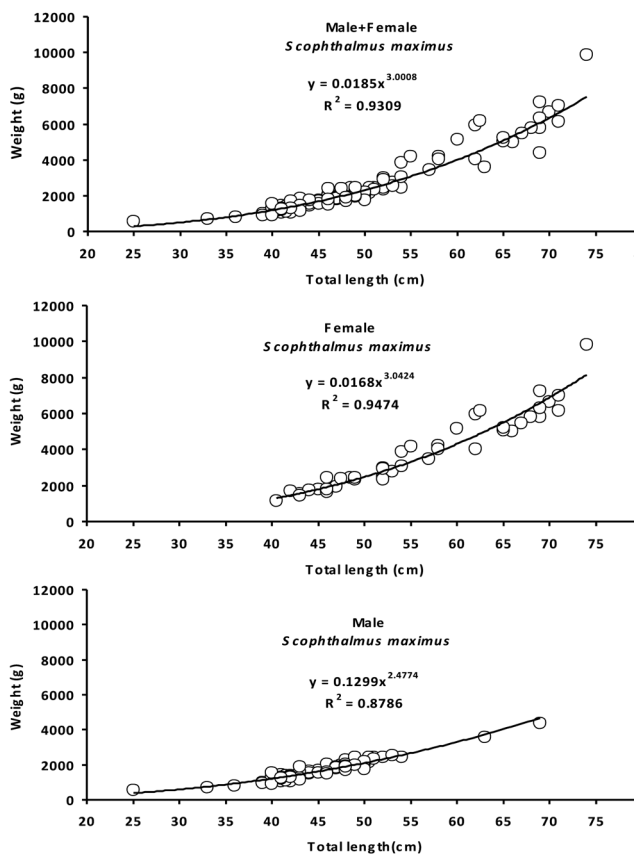


Figure 2. *Scophthalmus maximus.* Length weight relationships (LWRs) of turbot, caught by turbot gill net from eastern Black Sea, Turkey.

Table 1. *Scophthalmus maximus.* The length-weight relationships (LWRs) parameters of turbot, from different geographical locality. TL: total length (cm), a: intercept, b: slope, n: number of samples.

a	*b*	Sex	Length range (cm)	Length type	r^2	n	Locality	References
0.129	2.656	Combined	17.5-68.8	TL	0.952	-	Black Sea	Anonymous (1988)
0.0179	3.020	Combined	9.0-56.0	TL	0.973	2953	Baltic Sea, sub-divisions	Froese & Sampang (2013)
0.01508	3.090	Combined	-	TL	-	242	not specified (ICES division)	Bedford et al. (1986)
0.011	3.104	Combined	25.0-79.0	TL	0.990	155	Adriatic Sea	Arneri et al. (2001)
0.0128	3.127	Combined	4.5-72.5	TL	0.983	944	North Sea / 1993-2007	Wilhelms (2013)
0.0085	3.158	Combined	14.0-70.0	TL	0.989	-	south-western Black Sea coast	Eryilmaz & Dalyan (2015)
0.0105	3.168	Combined	2.0-80.0	TL	0.998	394	Bay of Biscay	Dorel (1986)
0.0105	3.173	Combined	5.0-59.0	TL	0.994	124	East and West Channel	Dorel (1986)
0.007	3.248	Combined	10.0-61.0	TL	0.977	63	Eastern Black Sea	Ak et al. (2009)
0.00802	3.260	Combined	20.0-60.0	TL	0.982	101	North Sea	Froese & Sampang (2013)
0.001	3.278	Combined	44.7-71.7	TL	0.840	50	Black Sea	Yankova et al. (2011)
0.0044	3.386	Combined	50.0-75.0	TL	-	40	Buchan	Coull et al. (1989)
0.0185	**3.001**	**Combined**	**25.0-74.0**	**TL**	**0.931**	**110**	**Eastern Black Sea**	**Present study**
0.02102	2.930	Female	3.0-25.0	TL	0.992	158	Sète, Grau-du-Roi and Saintes-Marie-de-la-Mer	Robert & Vianet (1988)
0.0168	2.930	Female	3.0-48.0	TL	0.980	283	Gulf of Lion	Vianet et al. (1989)
0.013	3.110	Female	-	TL	-	-	southern North Sea	van der Hammenand & Poos (2012)
0.0112	3.170	Female	22.5-63.5	TL	0.966	184	North Sea	Wilhelms (2013)
0.0168	**3.042**	**Female**	**40.5-74.0**	**TL**	**0.947**	**42**	**Eastern Black Sea**	**Present study**
0.0218	2.920	Male	3.0-45.0	TL	0.980	290	Gulf of Lion	Vianet et al. (1989)
0.0219	2.920	Male	3.0-47.5	TL	0.980	171	Sète, Grau-du-Roi and Saintes-Marie-de-la-Mer	Robert & Vianet (1988)
0.022	2.950	Male	-	TL	-	-	southern North Sea	van der Hammenand & Poos (2012)
0.0138	3.099	Male	20.5-56.5	TL	0.952	221	North Sea	Wilhelms (2013)
0.1299	**2.477**	**Male**	**25.0-69.0**	**TL**	**0.879**	**68**	**Eastern Black Sea**	**Present study**

tets: 38.1425) are different from zero ($P < 0.05$), indicated that *S. maximus* has higher correlation in LWR equations. In addition to this, to compare the estimations calculated from the present study with other studies (Table 1), log (a) values were plotted against values of b (Fig. 3), proved to be consistent with previous studies data for *S. maximus*.

Mean total length of *R. clavata* was calculated between 52.0-94.5 cm (mean: 79.0 ± 0.78 cm, n = 117) in combined data (female + male), between 63.0-94.5 cm (mean: 81.5 ± 0.79 cm, n = 66) in female, and between 52. -91.5 cm (mean: 75.8 ± 1.37 cm, n = 51) in male. The mean total length of females was statistically longer than males (t test; $P < 0.001$).

The LWRs results and statistics of *R. clavata* between male, female and combined sex showed below and in Fig. 4. The slope of the length - weight relationship was significantly (ANCOVA; $P < 0.05$) different between sexes. Therefore, this relationship was investigated separately for each sex. The relationship for females, male and combined data was: $W = 0.0032TL^{3.1706}$, $r^2 = 0.9480$, $Sd_{logL} = 0.0354$, $Sd_{logW} = 0.1152$, n = 66, Pauly's test = 1.837, $P < 0.05$, positive allometric growth (female). $W = 0.0051TL^{3.057}$, $r^2 = 0.9813$, $Sd_{logL} = 0.1000$, $Sd_{logW} = 0.2000$, n = 51, Pauly's test = 1.456, $P > 0.05$, isometric growth (male). $W = 0.0039TL^{3.1253}$, $r^2 = 0.9730$, $Sd_{logL} = 0.0506$, $Sd_{logW} = 0.1603$, n = 117, Pauly's test = 2.585, $P < 0.05$, positive allometric growth (combined data). The LWRs of *R.clavata* samples collected from the Rize coast in the Black Sea were showed that *R. clavata* showed positive allometric growth characteristics for female and combined data (Pauly's test, $P < 0.05$) and isometric growth for male (Pauly's test, $P > 0.05$).

However, in order to comparison of the difference of correlation coefficient (*r*) from zero *t*-test (Snedecor &

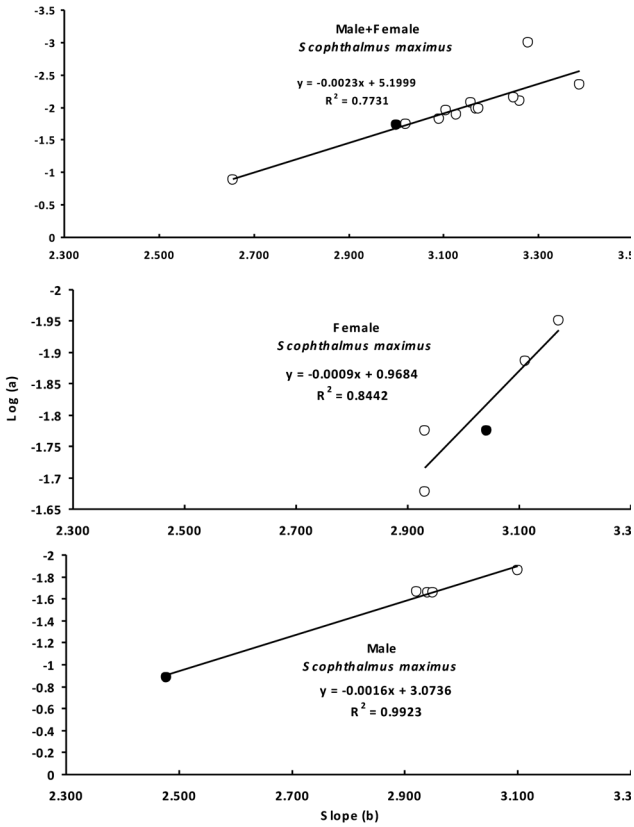


Figure 3. *Scophthalmus maximus.* Test plot of log (a) against b for different LWRs. Black dot = present study parameters (male + female n = 13; male n = 5 and female n = 5), white dot = estimated parameters of other studies showed in Table 1.

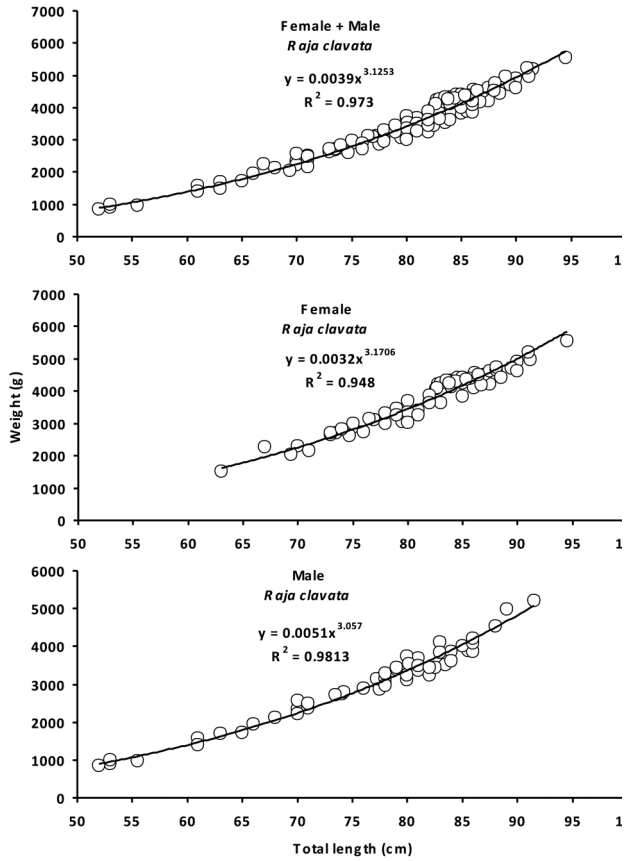


Figure 4. *Raja clavata.* Length weight relationships (LWRs) of thornback ray, caught by turbot gill net from eastern Black Sea, Turkey.

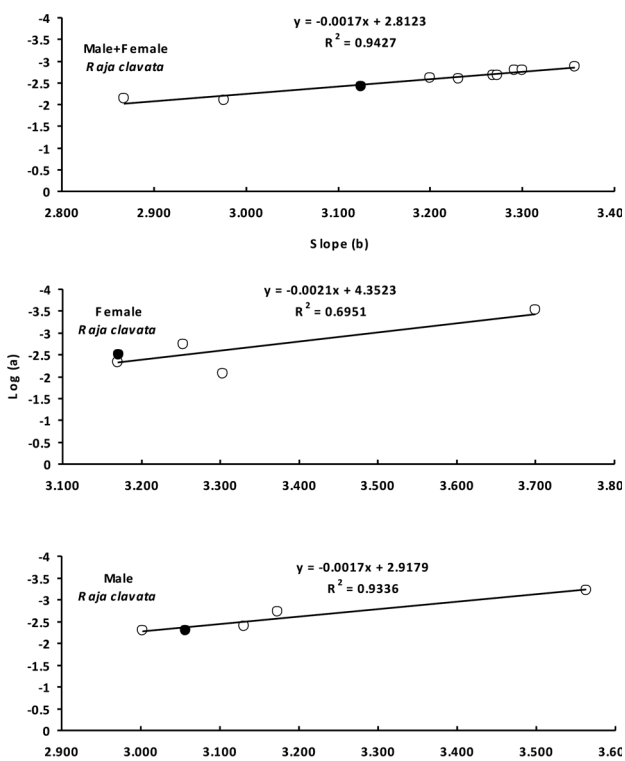
Cochran, 1989) was applied and the values of (*r*) for female (*r* = 0.974, t test: 34.163), for male (*r* = 0.9906, t test: 50.615), for combined data (*r* = 0.986, t test: 64.383) are different from zero ($P < 0.05$), indicated that *R. clavata* has higher correlation in LWRs equations. In addition to this, to compare the estimations calculated from the present study with other studies (Table 2), log (a) values were plotted against values of b (Fig. 5), proved to be consistent with previous studies data for *R. clavata*.

Discussion

According to Froese et al. (2011), based on the slope (*b*) of the relation between weight and length, one can check whether the growth of a fish species is isometric (*b* = 3, all fish dimensions increase at the same rate), hypo-allometric (*b* < 3, a fish increases less in weight than predicted by its increase in length, i.e., it becomes more elongated as it grows; also termed negative allometric) or hyper-allometric (*b* > 3, a fish increases more in weight than predicted by its increase in length, i.e., it becomes less elongated or more roundish as it grows; also termed positive allometric). Our data fit the regression for the species *S. maximus* excellently and growth parameters are highly similar to previous study results. Namely, *b* values of *S. maximus* were estimated as between 2.656 and 3.386 (mean: 3.085 ± 0.32608, n = 20) for *S. maximus* in twenty LWRs studies according to achieved previous study and present study results showed in Table 1. The *b* values of the LWRs showed that female (*b* = 3.042) have isometric growth type, while male (*b* = 2.477) have negative allometric growth type. The *b* value of female obtained from the present study is very similar with the results of the previous study showed in Table 1. But in contrast to females, *b* value of males was lower in to the previous study. In contrast to *S. maximus*, the *b* value of *R. clavata* showed that females (*b* = 3.174) have positive allometric growth type, while males (*b* = 3.057) have isometric growth type. The *b* value of both female and male of *R. clavata* obtained from the present study is very similar with the results of the previous study showed in Table 2. However, the correlation coefficient (*r*) both females and males for two fish species (*R. clavata* and

Table 2. *Raja clavata.* The length-weight relationships (LWRs) parameters of Thornback ray, from different geographical locality. TL: total length (cm), a: intercept, b: slope, n: number of samples.

a	*b*	Sex	Length range (cm)	Length type	r^2	n	Locality	References
0.0074	2.867	Combined	12.2-70.0	TL	0.893	24	Northern Sea of Marmara	Bok et al. (2011)
0.0081	2.976	Combined	9.5-95.5	TL	0.984	73	North Sea	Wilhelms (2013)
0.0024	3.200	Combined	14.5-38.1	TL	0.996	18	Balearic Islands	Merella et al. (1997)
0.0025	3.231	Combined	30.6-86.2	TL	0.927	63	Nazaré to St André	Mendes et al. (2004)
0.0022	3.268	Combined	-	TL	-	74	not specified (ICES division)	Bedford et al. (1986)
0.0021	3.273	Combined	15.3-95.2	TL	0.990	86	Gulf of Cadiz	Torres et al. (2012)
0.0016	3.291	Combined	20.5-99.0	TL	0.872	29	North Aegean Sea	Filiz & Mater (2002)
0.0016	3.300	Combined	20.5-99.0	TL	0.940	37	North Aegean Sea	Filiz & Bilge (2004)
0.0014	3.357	Combined	13.7-54.0	TL	0.980	13	Algarve	Borges et al. (2003)
0.0039	**3.125**	**Combined**	**52.0-94.5**	**TL**	**0.973**	**117**	**Eastern Black Sea**	**Present study**
0.0030	3.170	Female	18.4-91.6	TL	0.990	-	Caernarfon Bay, north Wales	Whittamore & McCarthy (2005)
0.0018	3.253	Female	20.5-99.0	TL	0.861	21	North Aegean Sea	Filiz & Mater (2002)
0.0084	3.303	Female	-	TL	0.984	1124	Carmarthen Bay, British Isles	Ryland & Ajayi (1984)
0.0003	3.700	Female	34.3-88.2	TL	0.940	-	Eastern Black Sea	Demirhan et al. (2005)
0.0032	**3.174**	**Female**	**63.0-94.5**	**TL**	**0.948**	**66**	**Eastern Black Sea**	**Present study**
0.0050	3.002	Male	48.0-95.0	TL	0.960	-	Eastern Black Sea	Demirhan et al. (2005)
0.0040	3.130	Male	26.9-77.8	TL	0.990	-	Caernarfon Bay, north Wales	Whittamore & McCarthy (2005)
0.0019	3.173	Male	-	TL	0.984	1019	Carmarthen Bay, British Isles	Ryland & Ajayi (1984)
0.0006	3.563	Male	29.7-67.0	TL	0.968	8	North Aegean Sea	Filiz & Mater (2002)
0.0051	**3.057**	**Male**	**52.0-91.5**	**TL**	**0.981**	**51**	**Eastern Black Sea**	**Present study**



S. maximus) have higher correlation in the LWRs equations and also *log* (*a*) values were plotted against values of *b* values for *S. maximus* (Fig. 3) and for *R. clavata* (Fig. 5) proved to be consistent with previous studies data.

The LWRs can be used for converting lengths into biomass, determining fish condition, comparing fish growth among areas, and as a complement to species-specific reproduction and feeding studies (Froese, 1998 & 2006) Thus, they are an important component of fisheries biology and when properly calculated they can be very useful to fisheries management. This study provides basic information on the LWRs both *S. maximus* and *R. clavata* populations, in support of sustainable fisheries management of these two fish species and especially of the sea coastal waters in the Black Sea, Turkey.

Figure 5. *Raja clavata*. Test plot of log (a) against b for different LWRs. Black dot = present study parameters (male + female n = 10; male n = 5 and female n =5), white dot = estimated parameters of other studies showed in Table 2.

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