ACTA ZOOLOGICA BULGARICA

Acta Zool. Bulg., 73 (3), September 2021: 417-423
Published online 16 August 2021
http://www.acta-zoologica-bulgarica.eu/2021/002454

Aquatic Ecology
Research Article

Seasonal Variations in the Length-weight Relationships of the Thornback Ray *Raja clavata* L., 1758 (Chondrichthyes: Rajidae) from the Turkish Black Sea Coast

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Abstract: Data on seasonal variations of the length-weight relationships of the threatened thornback ray *Raja clavata* L., 1758 from the Black Sea coastal areas of Turkey are presented. The study was carried out along the Sinop coasts between September 2015 and August 2016. Twelve trammel nets (32 mm, 36 mm and 40 mm mesh size) and 30 turbot gillnets (320 mm mesh size) were used. Totally, 430 thornback rays were analysed to calculate their length-weight relationship. The mean length of all thornback rays was 60.88±0.91 cm. The values of parameter *b* were 3.3450, 3.1496 and 3.2525 for females, males and all individuals, respectively. Positive allometric growths (t-test, $p < 0.05$) were recorded in all groups. The seasonal length-weight relationship of thornback rays was determined as $W = 0.0029L^{3.1675}$ ($R = 0.9533$, $N = 323$) for summer, $W = 0.003L^{3.1505}$ ($R = 0.9955$, $N = 20$) for autumn, $W = 0.003L^{3.1612}$ ($R = 0.9967$, $N = 16$) for winter and $W = 0.0022L^{3.2412}$ ($R = 0.9866$, $N = 71$) for spring.

Key words: Rajiformes, *Raja clavata,* length-weight relationship, Black Sea

Introduction

The thornback ray *Raja clavata* L., 1758 (Chondrichthyes: Rajidae) is distributed in the Eastern Atlantic: from Iceland, Norway, North Sea and the western Baltic Sea, southwards to Namibia as well as in the Mediterranean Sea and the Black Seas (McEachran & Dunn 1998). It is found on mud, sand and gravel bottoms, rarely on rougher bottoms. The thornback ray is a demersal and carnivore species. It feeds on anchovy, horse mackerel, whiting, goby, shrimp and crab species in the Black Sea (Demirhan et al. 2005). This species is of primary importance for the Mediterranean Basin. It is the most abundant skate in the Mediterranean Sea and is the dominant species in commercial landings (Kadri et al. 2014). Elasmobranch catches are up to c. 1.1 % of the total landings in the Mediterranean Sea (Lteif et al. 2016). These fish populations decline due to the direct fishing pressure and bycatch in the Mediterranean Sea (Başusta et al. 2012). Commercially, the thornback ray is of secondary importance along the Bulgarian coast of the Black Sea. However, it is one of the most abundant bycatch species of commercial fisheries in other Black Sea countries (e.g. Russia, Turkey and Ukraine) when using demersal trawl, turbot set nets and other gillnets fishing (Demirhan et al. 2007, Raykov & Yankova 2013, Kasapoğlu & Düzgüneş 2017).

IUCN Red List status of the thornback ray is near threatened (Ellis 2016). Therefore, it is nec-

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essary to provide protection of this species and carry out studies on its biology, reproduction, age, growth and population parameters. Fisheries management and research often require the use of biometric relationships to transform data collected in the field into appropriate indices (Mendes et al. 2004). The length-weight relationships (LWR) are important tools in fish biology, physiology, ecology, population assessments and management (Kohler et al. 1995, Gonçalves et al. 1997, Borges et al. 2003, Yankova et al. 2011). However, due to its variations, it will be more correctly to examine this relationship seasonally or even monthly, since it has been shown to change monthly or seasonally (Ak et al. 2009, Özdemir et al. 2015, 2018).

The present study was carried out to determine the seasonal length-weight relationships of discard thornback rays caught by small-scale fisheries at various localities along the Black Sea coast of Turkey.

Materials and Methods

The study was carried out along the Sinop coasts of the Black Sea in September 2015 – August 2016 (Fig. 1). The region of Sinop is an important fishery centre for the Black Sea. Fishermen use turbot set nets, gillnets and trammel nets in coastal fisheries. Target fish species are turbot, red mullet and whiting. The most important bycatch species when using these fishing gears are thornback ray, scorpion fish, stargazer and crabs. Twelve trammel gillnets (32 mm, 36 mm and 40 mm mesh size) and 30 turbot gillnets (320 mm mesh size) were used. The nets were set at 15-60 m depth. All samples were taken to the laboratory and were measured to the nearest 0.1 cm (total length), weighted (wet weight) to the nearest 0.01 g and sexed. The sex of fishes was determined based on the presence of the clasper organs (O'Shaughnessy et al. 2015; Fig. 2).

Length-weight relationships were estimated by fitting an exponential curve $W = aL^b$ to the data (Ricker 1975, Pauly 1984). Parameters a and b of the exponential curve were estimated using a linear regression over log-transformed data: Log W = Log a + b Log L, where W was the total weight (g), L was the total length (cm), a was the intercept and b was the slope, using the least-squares method. The association between variables W and L was estimated using the coefficient of determination (R^2). Additionally, 95% confidence limits of the parameter *b* were estimated.

The Student's t-test was used for comparison of the slopes (Zar 1996):

$$t = \frac{Sd_{logL}}{Sd_{logW}} \frac{|b-3|}{\sqrt{1-r^2}} \sqrt{n-2},$$

where Sd_{logTL} was the standard deviation of the log TL values, Sd_{logW} was the standard deviation of the log W values, n was the number of specimens used in the computation. The value of b is different from b = 3 if the calculated t value is greater than the tabled t values for n^{-2} degrees of freedom (Pauly 1984).

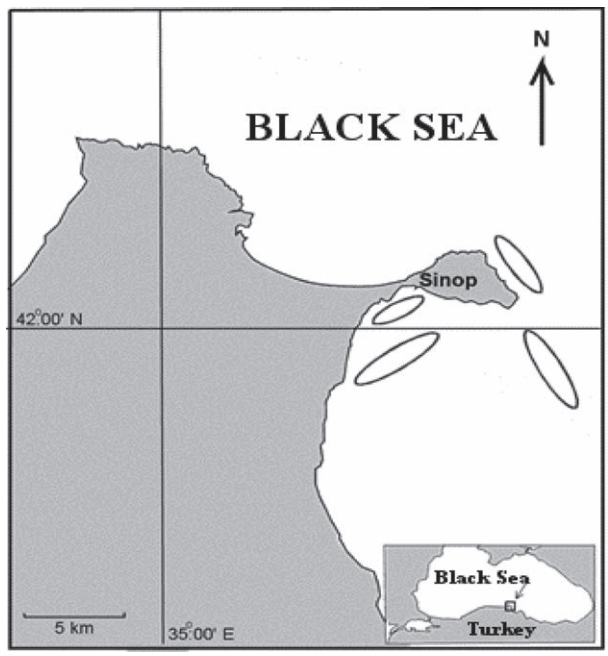

Fig. 1. The sampling area of the present study.

Table 1. Seasonal data on length (cm) and weight (g) of thornback ray

Seasons	Female (♀)		Male (♂)	
	Total Length (Min – Max – Mean)	Weight (Min – Max)	Total Length (Min – Max – Mean)	Weight (Min – Max)
Summer	25.2–88.0–66.2±1.32	14.5–4245.5	16.8–84.7–55.5±1.59	14.5–4258.8
Autumn	27.4-75.0–51.2±4.52	134.7–2488.4	27.4–78.1–47.3±5.07	119.3–2615.3
Winter	15.0–65.3–42.9±5.81	13.9–1665.8	27.6–77.9–50.4±7.43	130.5–2630.2
Spring	19.3–86.7–66.9±2.37	32.5–4462.7	39.7–87.0– 67.4±2.03	279.3–3572.2
All	15.0–88.0–60.9±1.07	13.9–4462.7	16.8–87.0–57.5±1.29	14.5–4258.8

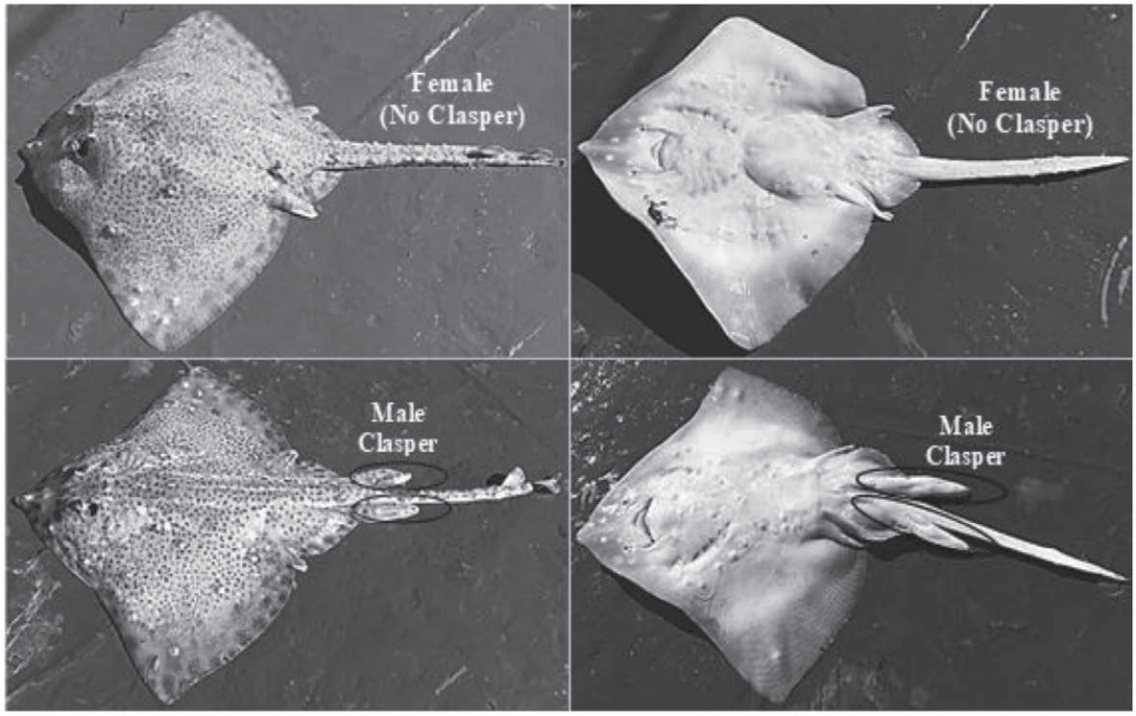

Fig. 2. Sex identification of thornback rays based on the present of clasper organs.

When the parameter '*b*' is equal to 3, the growth is called isometric. 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). Differences were considered statistically significant when $P < 0.05$.

Results

Totally, 430 thornback rays were measured to calculate length-weight relationships. Most fishes were caught in summer (75.12 %) and only few were caught in winter (3.72 %). The length and weight of the fishes varied between 15.0 and 88.0 cm, and 14.5 and 4258.8 g, respectively. The minimum length was recorded in winter and the maximum length was in summer. The mean length of female and male fishes was 60.9±1.07 cm and 57.5±1.29 cm, respectively. Seasonal length and weight data exhibited variations (Table 1).

Most fishes of the 80-cm size class were caught in spring and summer. During the autumn and winter, the majority of fishes were within the 50-cm size class. Among fishes caught in summer, autumn and winter, the majority were with a maximum weight of 500 g. Fig. 3 shows the seasonal length and weight frequency of thornback rays off Sinop.

The values of parameter *b* were calculated as 3.3450, 3.1496 and 3.2525 for females, males and all individuals, respectively. Positive allometric

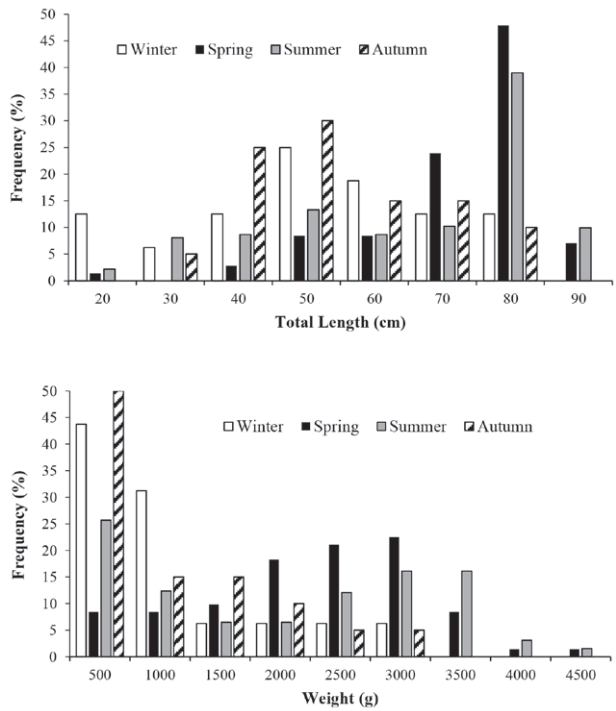

Fig. 3. Seasonal length and weight frequency distribution of thornback rays.

growths (t-test, $p < 0.05$) were obtained for all individuals. Seasonal length-weight relationships of the thornback ray were determined as $W = 0.0029L^{3.1675}$ ($R = 0.9533$, $N = 323$) for summer, $W = 0.003L^{3.1505}$ ($R = 0.9955$, $N = 20$) for autumn, $W = 0.003L^{3.1612}$ ($R = 0.9967$, $N = 16$) for winter and $W = 0.0022L^{3.2412}$

Table 2. Analysis of LWR parameters of thornback ray *Raja clavata.*

Seasons a		Parameters					
		95% CI (a)	b	SE(b)	95% CI (b)	test (b)	
Summer	♀	0.0012	0.0009-0.0017	3.2644	0.0334	3.1983-3.3405	P<0.05
	♂	0.0028	0.0021-0.0036	3.1282	0.0319	3.1005-3.2013	P<0.05
	Both	0.0029	0.0015-0.0034	3.1675	0.0298	3.2046-3.3124	P<0.05
Autumn	♀	0.0026	0.0013-0.0052	3.1877	0.0768	3.0104-3.3649	P<0.05
	♂	0.0033	0.0011-0.0099	3.1250	0.1244	2.8381-3.4119	P<0.05
	Both	0.0030	0.0017-0.0053	3.1505	0.0707	3.0021-3.2989	P<0.05
Winter	♀	0.0022	0.0013-0.0037	3.2309	0.0584	3.0926-3.3692	P<0.05
	♂	0.0069	0.0016-0.0094	2.9653	0.1448	2.5821-3.3266	P>0.05
	Both	0.0030	0.0017-0.0052	3.1612	0.0680	3.0152-3.3072	P<0.05
Spring	♀	0.0017	0.0009-0.0032	3.2967	0.0729	3.1482-3.4452	P<0.05
	♂	0.0031	0.0021-0.0086	3.1482	0.1171	2.9102-3.3855	P<0.05
	Both	0.0022	0.0012-0.0036	3.2412	0.0646	3.1121-3.3702	P<0.05
All	♀	0.0014	0.0011-0.0017	3.3481	0.0281	3.2926-3.4036	P<0.05
	♂	0.0033	0.0024-0.0044	3.1334	0.0404	3.0537-3.2131	P<0.05
	Both	0.0032	0.0025-0.0037	3.2525	0.0232	3.2016-3.2902	P<0.05

Table 3. Comparison of LWR parameters of thornback ray (*Raja clavata*) from various studies

Authors	Region/Country	n	a	b	R^2	Growth
Merella et al. (1997)	Baleric Islands	18	0.0024	3.20	0.99	+Allometry
Dorel (1986)	Manche-French	211	0.0033	3.18	0.99	+Allometry
Düzgüneş et al. (1999)	Trabzon-Turkey	-	0.0030	3.18	-	+Allometry
Erdem et al. (2001)	Sinop-Turkey	54	0.0026	3.20	0.98	+Allometry
Filiz & Mater (2002)	İzmir-Turkey	29	0.0016	3.29	0.93	+Allometry
Borges et al. (2003)	Algarve-Portugal	13	0.0014	3.36	0.98	+Allometry
Filiz & Bilge (2004)	İzmir-Turkey	37	0.0016	3.30	0.94	+Allometry
Mendes et al. (2004)	Portugal Coasts	63	0.0025	3.23	0.96	+Allometry
Demirhan et al. (2005)	Rize-Turkey	52	0.0010	3.42	0.91	+Allometry
Başçınar & Sağlam (2005)	Trabzon-Turkey	193	0.0023	3.24	0.96	+Allometry
Yeldan & Avşar (2007)	Adana-Turkey	77	0.0037	3.08	0.98	+Allometry
Demirhan & Can (2007)	Trabzon-Turkey	27	0.0019	3.24	0.99	+Allometry
İşmen et al. (2007)	Çanakkale-Turkey	112	0.0013	3.12	1.00	+Allometry
Yeldan et al. (2008)	Adana-Turkey	90	0.0034	3.10	0.99	+Allometry
Yığın & İşmen (2009)	Çanakkale-Turkey	226	0.0016	3.32	0.99	+Allometry
Yankova et al. (2011)	Bulgaria Coasts	24	0.0010	2.30*	0.86	-Allometry
Bök et al. (2011)	Marmara Sea-Turkey	24	0.0001	2.86*	0.89	Isometric
Saygu (2011)	Antalya-Turkey	792	0.0018	3.25	0.96	+Allometry
Başusta et al. (2012)	İskenderun-Turkey	75	0.0023	2.64*	0.76	-Allometry
Torres et al. (2012)	Cadiz-Spain	86	0.0021	3.27	0.99	+Allometry
Özdemir & Duyar (2013)	Samsun-Turkey	102	0.0027	3.18	0.98	+Allometry
Kasapoğlu & Düzgüneş (2013)	Trabzon-Turkey	63	0.0010	3.29	0.97	+Allometry
Eronat & Özaydın (2014)	İzmir-Turkey	137	0.0016	3.52	0.96	+Allometry
Eronat & Özaydın (2015)	İzmir-Turkey	187	0.0049	2.80*	0.98	-Allometry
Lteif et al. (2016)	Lebanese Coasts	30	0.0015	3.33	0.91	+Allometry
Çalık & Erdoğan (2017)	Samsun-Turkey	10	0.0010	3.44	0.98	+Allometry
Özdemir et al. (2017)	Sinop-Turkey	259	0.0013	3.35	0.92	+Allometry
Adda-hanifi et al. (2017)	Algerie Coasts	563	0.0030	3.15	0.97	+Allometry
Bilgin et al. (2018)	Rize-Turkey	117	0.0039	3.13	0.97	+Allometry
Present Study	Sinop-Turkey	430	0.0032	3.25	0.96	+Allometry

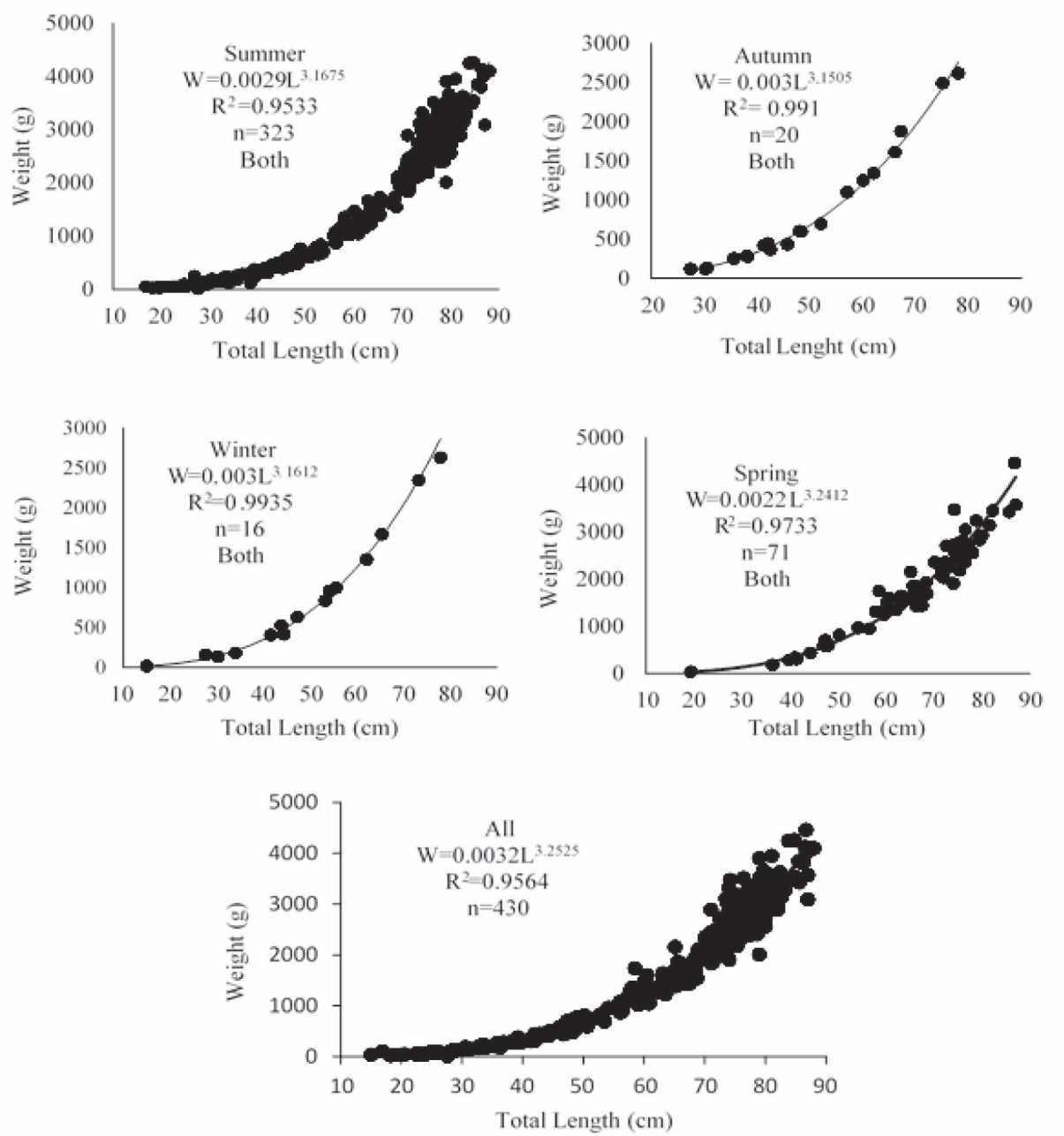

Fig. 4. Seasonal length-weight relationships (LWR) of thornback rays.

(R = 0.9866, N = 71) for spring (Fig. 4).

Seasonally, the coefficient of determination ranged from 0.9538 for females to 0.9977 for males; all regressions were highly significant. The growth was positive allometric for female and male fishes all season except for male fishes in winter (P < 0.05). In our findingsudy, the "*a*" values ranged from 0.0012 (♀ in summer**)** to 0.0069 (♂ in winter), while the "*b*" value ranged from 2.9653 (♂ in winter) to 3.2967(♀ in spring). Table 2 shows the seasonal LWR parameters of thornback rays (male, female and combined).

Discussion

Our results demonstrate positive allometry for the thornback rays in the region of Sinop (Table 2). Our data fit the regression for the thornback ray and LWR parameters are similar to those reported in previous studies, though b values show differences from some of them (Table 3). Our results differ from the population data for the Bulgarian coasts of the Black Sea (Yankova et al. 2011), Marmara Sea (Bök et al. 2011), the East Mediterranean coasts (Başusta et al. 2012) and the Aegean Sea coasts (Eronat & Özaydin 2015), which exhibit negative allometry or isometry (Table 3).

In the fishery studies, length-weight relations are very important because these relations enable the comparison of growth differences between the same species or different fish species in the different habitats and (or) regions (Gonçalves et al. 1997). The reason for the different parameters obtained by us compared to those by other researchers could be owing to growth-performance differences or to the non-homogenous samples related to the fishing equipment and fishing time (Yankova et al. 2011). Besides, differences of growth might have been affected by several factors, such as growth increment and differences in age and stage of maturity as well as differences in the sampling periods, feeding, quality and quantity of the food as well as environmental conditions, temperature, salinity and seasonality (Ricker 1975).

In conclusion, changes in the Black Sea ecosystem affect the biomass, stock structure, distribution, growth, biology, feeding, population and reproduction features of many fish species. Populations of some fish species have been significantly reduced due to extreme fishing pressure and pollution on the Turkish part of the Black Sea (Bat et al. 2007). On the other hand, overfishing in the Black Sea waters caused many fish species to become threatened (Öztürk et al. 2013), including the thornback ray *Raja clavata*. Therefore, studies on protected species and their population dynamics should continue.

Acknowledgements: We thank technical personal of R/V Seydi Ali Reis, Ismail Karakan, Murat Yilmazer, Ali Gördük, Vehbi Dağdelen and Aydın Çetin (in our heart) for their help in the sea trials. This research has been supported by the Sinop University Scientific Research Projects Coordination Unit. Project Number: SUF-1901-14.06, 2017.

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Received: 08.05.2020
Accepted: 03.12.2020