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Length-Weight, Length-Length Relationships and Condition Factor of Picarel, *Spicara smaris* (Linnaeus, 1758) Sampled from Aegean Sea and Black Sea

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Abstract

In this study, length-weight relationship (LWR), length-length relationship (LLR), and condition factor (K) of *Spicara smaris* (Linnaeus, 1758) collected from Aegean Sea and Black Sea during 2023-2024 fishing season were determined. A total of 116 samples (Aegean Sea N=56, Black Sea N=50) were obtained from commercial fishermen. The mean (±SD) total length and weight of samples varies between 15.47±0.98 cm, 34.82±6.45 g, and 12.35±1.40 cm, 20.01±8.93 g for Aegean and Black Sea, respectively. The slopes (b values) of the total length–weight regressions indicated (-) negative allometric growth to (+) positive allometric growth in localities. In addition, LLRs were calculated by using the linear regression model. LLRs were also highly significant (P<0.001) with coefficient of determination (R^2) ranging from 0.748 to 0.975. The Fulton's condition factor was calculated according to localities and sex, separately, and when the two localities were compared in terms of condition factors, a significant difference was found between them (F=7.699, P=0.007).

Key Words: Picarel, length-weight relationship, length-weight relationship, condition factor, Türkiye

Ege Denizi ve Karadeniz'den Örneklenen İzmarit, Spicara smaris (Linnaeus, 1758)'in Boy-Ağırlık, Boy-Boy İlişkileri ve Kondisyon Faktörü

Öz

Bu çalışmada, 2023-2024 av sezonunda Ege Denizi ve Karadeniz'den örneklenen *Spicara smaris* (Linnaeus, 1758)'in boy-ağırlık ilişkisi (LWR), boy-boy ilişkisi (LLR) ve kondisyon faktörü (K) belirlenmiştir. Toplamda 116 (Ege Denizi N=56, Karadeniz N=50) örnek ticari balıkçılardan temin edilmiştir. Örneklerin ortalama (±SD) total boyları ve ağırlıkları Ege ve Karadeniz için sırasıyla 15,47±0,98 cm, 34,82±6,45 g ve 12,35±1,40 cm, 20,01±8,93 g arasında değişmektedir. Boy-ağırlık regresyonlarının eğimleri (b değerleri), lokalitelerde (-) negatif allometrik büyümeden (+) pozitif allometrik büyümeye kadar değişmiştir. Ayrıca doğrusal regresyon modeli kullanılarak LLR'ler hesaplanmıştır. Ayrıca boy-boy ilişkileri 0,748 ile 0,975 arasında değişen belirleme katsayılarına (R^2) bağlı olarak önemli bulunmuştur (P<0,001). Fulton'un kondisyon faktörü lokalitelere ve cinsiyete göre ayrı ayrı hesaplanmış ve iki lokalite kondisyon faktörleri açısından karşılaştırıldığında aralarında anlamlı fark bulunmuştur (F=7,699, P=0,007).

Anahtar Kelimeler: İzmarit, boy-ağırlık ilişkisi, boy-boy ilişkisi, kondisyon faktörü, Türkiye

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1. INTRODUCTION

Picarel, *Spicara smaris* (Linnaeus, 1758), a marine and commercial fish species is found in the Mediterranean and Black seas, as well as the Atlantic from Portugal to Morocco and the Canaries. It lives on seagrass beds and muddy bottoms at depths of between 15 and 100 meters. (Tortonese 1986). In addition, it feeds on mainly zooplankton. It is a protogynous hermaphrodite and a total spawner from August to October (Froose and Pauly 2023) also spawns on detritic sandy bottoms, where the nests are excavated (Tsangridis and Filippousis 1992). During the reproductive stage, picarel entirely exhibits sexual dimorphism (Zei 1949; Tortonese 1975). These actions were the primary causes of the systematic confusion within the family Centracanthidae that lasted until at least 1970. However, male *S. smaris* was classified as a distinct species, while male *S. flexuosa* was occasionally mistaken for a male *S. smaris* (Pollard and Pinchot 1971; Dulčić et al. 2003). Unfortunately, this confusion occurs in many studies. At this point, it is an undeniable fact that both molecular and morphometry studies should be used together. For this reason, it is very important to identify the species correctly in the studies and to create an effective management plan by calculating the population parameters accordingly.

Fish have a special place among all vertebrates, particularly when considering growth patterns and behaviors. Growth is generally described as a living system's constant rise in quantity over time. The growth performance of organisms is the primary determinant of the economic return in commercial aquaculture facilities (Lugert et al. 2016). Fish growth underlies a wide range of positive or negative impacting factors. In fish, growth mainly depends on feed consumption and quality (Slawski et al. 2011), stocking density (Li et al. 2021); biotic factors such as sex (Imsland and Jonassen 2003) and age (Yılmaz et al. 2015; Lugert et al. 2016; Paladin et al. 2023); food (Weatherley and Gill 1987; Rahman et al. 2008); genetic variation; abiotic factors such as water chemistry, temperature (Abd El-Hack et al. 2022; Crouse et al. 2022), photoperiod (Imsland and Jonassen 2003) and oxygen level (Brett 1979). Overall health and growth indicators for fish could provide comprehensive information on the effects of the aquatic environment (Zapfe and Rakocinski 2008). Studies on population dynamics and species management have been the main applications for these indicators (Ortiz de Zárate and Babcock 2016; Zambrano et al. 2023) to compare different habitat qualities (Brázová et al. 2021).

For stock assessment studies, the associations between fish length-length (LLRs) and length-weight (LWRs) are valuable tools (Froese 2006). Many studies have emphasized the significance of figuring out LWRs and condition factor (K), as it offers details regarding growth trends, health, habitat circumstances, life history, and morphological traits of fish (Schneider et al. 2000; Sinovčić et al. 2004; Froese 2006; Hossain 2010; Giarrizzo et al., 2015; Özpiçak et al., 2017; Jisr et al. 2018; Özpiçak et al. 2018; Saygın et al. 2018; Park et al. 2021; Şalcıoğlu and Sönmez 2022; Ginting and Huang 2023; Şimsek et al., 2024). In addition, season and habitat, as well as gonadal development, sex, food, stomach fullness, health, and preservation techniques, all impact LWR (Froese 2006). However, to comprehend the most popular tools for fisheries data and the rational management of fishing resources, fisheries biologists have to get LWR data (Yedier et al. 2019). In addition, length-weight relationship parameters constitute a very important part of population dynamics studies by estimating the fish's weight from its length, calculating the condition index, and comparing the populations and life processes of the fish in different habitats. Furthermore, the condition factor is a numerical measure of fish health that will impact current and future population success through growth, reproduction, and survival. It also evaluates seasonal trends in each fish's physical condition. (Le Cren 1951; Froese 2006). The condition of a fish reflects recent physical and biological circumstances and fluctuates by interaction among feeding conditions, parasitic infections, and physiological factors (Le Cren 1951). Furthermore, LLRs are significant because they enable growth studies that compare various fish body length measurements (Moutopoulos and Stergiou 2002). Various length measurements as total length (TL), fork length (FL), and standard length (SL) are also used for comparative growth patterns between taxonomically similar species (Huh et al. 2017; Park et al. 2021), and/or size converting between various body measurements when one of the body parts are damaged during sampling procedures (Froese 2006).

In the literature, there are some studies about LWR, LLR and condition factor of different *Spicara* species (Ismen 1995; Vidalis and Tsimenidis 1996; Dulčić et al. 2000; Dulčić et al. 2003; Karakulak et al. 2006; Çiçek et al. 2007; Kalaycı et al. 2007; Şalcıoğlu and Sonmez 2022). Also, there is no study about the comparisons of LLR, LWR and K of *S. smaris* from different seas of Türkiye. This study aims (i) to provide data of LWR, LLR and K of *S.smaris,* and (ii) compare these relationships between Aegean and Black Sea.

2. MATERIAL AND METHOD

2.1. Sampling and Biological Studies

S. smaris samples were obtained from commercial fishermen from Aegean (N=56) and Black Seas (N=50). Before the laboratory process, all samples were checked for morphologic misidentification based on previous studies in the literature (Minos et al. 2013; Şalcıoğlu et al. 2021).

The total length (TL), fork length (FL) and standard length (SL) of each sample were measured to ± 0.1 cm, and weighted (±0.01 g) using electronic balance. The gonads were examined by macroscopically.

2.2. LWR, LLR and Condition Factor

In fish, weight (W) is exponentially related to its length (L), according to the potential model:

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

Logarithmic transformation was applied to arrive at a linear relationship in the form of

$$\log W = \log a + b \log TL \quad (2)$$

according to Le Cren (1951) and Ricker (1975). All LLRs of *S. smaris* were computed using linear regression analysis (Zar 1999) and estimated separately according to localities.

In addition, Fulton's condition factor (K) was calculated according to the following formula;

$$K = (W/TL^3) \times 100 \quad (3)$$

(Le Cren 1951).

2.3. Statistical Analysis

The differences in mean values of TL, W and K between the sexes were checked by appropriate tests. Chi-square test was performed to test whether the observed sex ratio between females to males is deviated from the expected ratio of 1:1. In order to ascertain whether there were any appreciable variations in the slopes between the sexes, ANCOVA was employed (Zar 1999). Minitab, Microsoft Excel, and SPSS Statistics version 21.0 were used for the statistical analyses.

A total of 116 samples (Aegean Sea N=56, Black Sea N=50) were obtained from commercial fishermen. The mean (±SD) TL and W of samples varies between 15.47±0.98 cm, 34.82±6.45 g, and 12.35±1.40 cm, 20.01±8.93 g for Aegean and Black Sea, respectively (Table 1). In addition, the sex ratio (female: male) was calculated as 1:0.7 and 0.8:1 for Aegean and Black Sea; these results did not deviate significantly from 1:1 (x^2 = 0.045; P>0.05). Fish body anatomical changes associated with isometry and allometry are established during ontogeny and continue until sexual maturity.

3. RESULTS

Table 1. Descriptive statistics of TL and W for picarel (N: number of specimens)

Locality	Variable	N	Mean	SE	SD	Min.	Max.
Aegean Sea	TL	56	15.47	0.913	0.98	13.70	17.60
	W		34.82	0.86	6.45	22.72	48.96
Black Sea	TL	50	12.35	0.20	1.40	9.50	17.50
	W		20.01	1.26	8.93	7.38	64.16

3.1. LWRs and LLRs for *S. smaris*

There is no difference in TL and W between male and female individuals in both locations (Independent samples t test, P>0.05). Additionally, there is no difference in total length (F=3.851, P=0.520) and weight (F=0.698, P=0.405) between Aegean and Black Seas. The LWRs for *S. smaris* according to localites were shown in Figure 1 and Figure 2. The LWRs were significantly important (P<0.001, R^2> 0.83). The growth type of LWR was changed between (-) allometry to (+) allometry in picarel according to results of this study (Table 2).

Table 2. Growth types and LWR parameters for *S. smaris*

Locality	Sex	*a*	*b*	R^2	95% Confidence Interval	Growth Type
Aegean Sea	♀	0.015	2.827	0.900	1.963-2.611	(-) Allometry
	♂	0.016	2.807	0.881	2.343-3.397	Isometry
	♀+♂	0.013	2.870	0.863	2.579-3.111	Isometry
Black Sea	♀	0.004	3.420	0.986	3.138-3.697	(+) Allometry
	♂	0.005	3.303	0.891	2.861-3.745	Isometry
	♀+♂	0.004	3.365	0.963	3.138-3.591	(+) Allometry

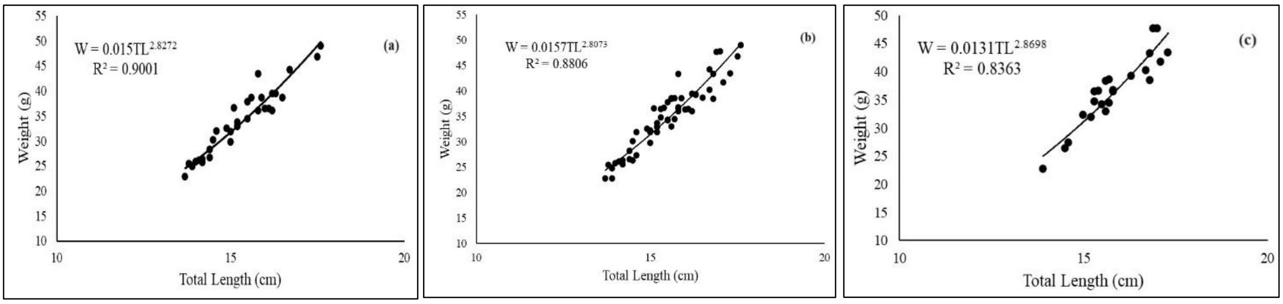

Figure 1. LWRs for *S. smaris*; (a) female, (b) male, (c) whole population from Aegean Sea

Additionally, in two locations, the slopes of LWRs for both sexes were not found to be statistically significant. (ANCOVA, P>0.05).

To calculate LLRs, the linear regression model was utilized. LLRs were also highly significant (P<0.001) with ranging from 0.748 to 0.975 (Table 3). All of the relationships were found significant according to locations (P<0.001). According to analysis, there was no significant difference in condition factor between sexes in both localities (Independent samples t-test, P> 0.05). However, when the two localities were compared in terms of condition factors, a significant difference was found between them (F=7.699, P=0.007).

Table 3. Length-weight relationships and growth type in different *Spicara* species

Locality	a	b	R^2	P
Aegean Sea	1.265	0.839	0.922	<0.001
	0.697	0.844	0.889	<0.001
	2.262	0.676	0.748	<0.001
Black Sea	0.618	0.966	0.958	<0.001
	0.715	0.838	0.975	<0.001
	0.059	0.822	0.959	<0.001

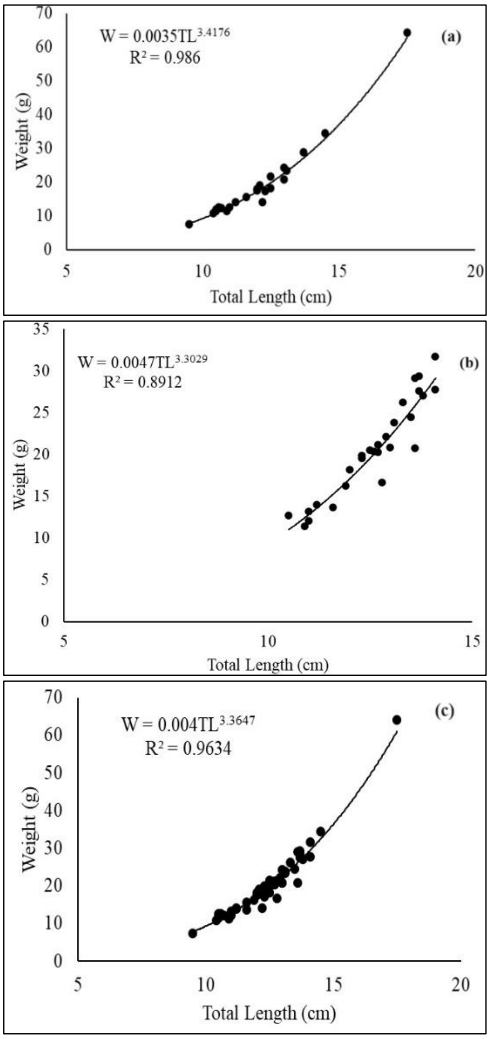

Figure 2. LWRs for *S. smaris*; (a) female, (b) male, (c) whole population from Black Sea

3.2. Fulton's Condition Factor

The Fulton's condition factor for *S. smaris* is shown in Table 4.

Table 4. Condition factor values of *S.smaris* according to localities.

Locality	Sex	Mean	SE	SD	Min.	Max.
Aegean	♀	0.938	0.010	0.057	0.847	1.099
Sea	♂	0.923	0.013	0.061	0.811	1.017
	♀+♂	0.932	0.008	0.059	0.811	1.099
Black	♀	1.004	0.020	0.096	0.775	1.197
Sea	♂	1.008	0.018	0.093	0.793	1.157
	♀+♂	1.006	0.013	0.093	0.775	1.197

4. DISCUSSION AND CONCLUSION

This work provides LWR, LLR, and K for *S.smaris* from Aegean and Black Seas in Türkiye. The LWRs are affected by a series of factors including season, habitat, gonad maturity, sex, diet, stomach fullness, health and preservation techniques (Tesch 1971; Bagenal and Tesch 1978). Furthermore, the physiological parameters of the sea, such as salinity and temperature, as well as the quality of the water and food sources, affect the regional variance in fish growth (Moutopoulos and Stergiou 2002; Gerritsen and McGrath 2007; Şalcıoğlu and Sönmez 2022).

According to results of present study, both LWR and LLRs were found significantly important in both localities ($P<0.001$). The regression coefficient values obtained from both LWRs and LLRs are high ($R^2 > 0.83$). When the literature was examined, studies were found examining the length-weight relationships and growth types of different *Spicara* species (Table 5).

Table 3. Length-weight relationships and growth type in different *Spicara* species

Locality	Species	*a*	*b*	R^2	Growth Type	Reference
Greece (Aegean Sea)	*S. maena*	0.00008	2.663	0.90	-	Petrakis and Stergiou (1995)
Greece (Aegean Sea)	*S. maena*	0.01040	3.096	0.88	-	Moutopoulos and Stergiou (2002)
Croatia	*S.smaris*	0.0122	2.955	0.99	Isometric	Dulčić et al. (2003)
Mediterranean Sea	*S.smaris*	0.01975	2.695	0.97	Isometric	Valle et al. (2003)
Northern Aegean Sea-Türkiye	*S.smaris*	0.0138	2.877	0.72	Isometric	Karakulak et al. (2006)
Turkey	*S. maena*	0.0076	3.137	0.98	(+) Allometric	Çiçek et al. (2007)
Black Sea-Türkiye		0.0063	3.1504	0.96	(+) Allometric	Kalaycı et al. (2007)
Central Aegean Sea	*S.smaris*	0.0137	2.962	0.96	Isometric	Özaydın et al. (2007)
Eastern Black Sea-Türkiye	*S.smaris*	0.009	3.008	0.86	Isometric	Ak et al. (2009)
Aegean Sea- Türkiye	*S. maena*	0.011	3.020	0.96	-	Soykan et al. (2010)
Central Aegean Sea	*S. smaris*	0.00001	2.88	0.96	(-) Allometric	Kapiris and Klaoudatos (2011)
Central Aegean Sea	*S. flexuosum*	0.000005	3.13	0.97	(+) Allometric	Kapiris and Klaoudatos (2011)
Northern Aegean Sea (Türkiye)	*S. maena*	0.002	3.34	0.94	(+) Allometric	Cengiz and Paruğ (2021)
Black Sea-Türkiye	*S. flexuosum*	0.0118	2.972	0.94	(-) Allometric	Dalgıç et al. (2021)
Black Sea-Türkiye	*S. flexuosum*	0.0694	2.297	0.96	(-) Allometric	Şalcıoğlu and Sönmez (2022)
Black Sea-Türkiye	*S.smaris*	0.004	3.365	0.963	(+) Allometric	Present study
Black Sea-Türkiye	*S.smaris*	0.013	2.870	0.863	Isometric	Present study

It was observed that the results obtained from this study were similar to the literature, on the other hand, some differences were observed, too (Table 5). The differences in b values could be results of these factors. Our results showed that the b values for the LWRs varied from two to four, as demonstrated by Tesch (1971). Associated with these results, the Aegean Sea, semi-enclosed basin of the eastern Mediterranean Sea, is a region of special interest for the Mediterranean oceanographic community, as one of the dense-water formation sites of the Mediterranean, driving its thermohaline circulation (Zervakis et al. 2004). Nonetheless, the largest land-locked inland sea in the world is the Black Sea. It receives drainage from nearly one-third of continental Europe. In the past 30 years, the ecosystem of the Black Sea has been severely degraded by waterborne trash from 17 different countries. The subhalocline waters of the Black Sea are anoxic due to natural sources. The Black Sea has historically provided food supplies, a scenic environment for travel and recreation, and even a place to dispose of garbage, including nuclear wastes, all while serving humankind well despite this natural shortcoming (Bakan and Büyükgüngör 2000). These structural differences observed between seas have caused the fish living in them to exhibit different characteristics.

In addition, the sex ratio were caculated as 1:0.7 and 0.8:1 for Aegean and Black Sea, these results did not deviate significantly from 1:1 ($x^2 = 0.045$; $P > 0.05$). The sex ratio (F:M) of *Spicara smaris* was reported as 1.59:1 (Şahin and Genç, 1999), 1:4.1 (Dulčić et al. 2000), and 4:1 (Kalaycı et al. 2007). The likely reason for the differences in reported sex ratios of the species could be as a result of protogynous hermaphroditism, sampling size or season.

LLRs are also beneficial for conversion when compared to values found in the literature, data on growth patterns, and ultimately, fish biomass estimation (Aburto-Oropeza et al. 2011). Additionally, LLRs give more details, especially with respect to growth pattern and will be beneficial for fishery management and fish biology studies. Karachle and Stergiou (2008) investigated LLRs of *S.smaris* from North Aegean Sea and found highly significant relationships (R^2>0.99, P<0.001). In this study, LLRs were significantly important for two localities, too (P<0.001) and coefficient of determination (R^2) ranged from 0.74 to 0.97.

Additionally, K is a crucial factor that determines whether any fish are healthy or not (Yılmaz and Sakallı, 2020). Numerous factors influence the condition factor, including as age, season, habitat, and reproductive time (Williams 2000), too. In this study, mean K were calculated as 0.932±0.008 and 1.006±0.013 for Aegean Sea and Black Sea, respectively. (Table 4). As opposed to males, females have high condition factors for both localities (Table 4). It is observed in this study, K could be influenced by gonadal maturity. Şahin and Genç (1999) were calculated K between 0.696-1.229 for female and 0.721-1.439 for male. However, the weight of the fish will be higher during the spawning season. For this reason, it is possible that the condition factor, which shows the relationship between the weight and length of the fish, is higher during the spawning season due to gonad development (Yaşar and Genç 1999). The differences encountered in the studies should be evaluated by taking this situation into consideration.

In conclusion, *Spicara smaris* is a marine and commercial fish species. Therefore, it is very important to create correct management plans for economically important fish species. In conclusion, present study has provided basic information on the LWR, LLR, and K of picarel that would be useful for fishery biologists/managers to impose adequate regulations for sustainable fishery management in the Aegean Sea and Black Sea.

CONFLICT OF INTEREST

There is no conflict of interest between the authors.

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