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Seasonal Variation in Length, Weight, and Sex Distribution of Turbot (*Scophthalmus maeoticus* Pallas, 1811) in the Sinop Region (Black Sea) of Turkey

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Abstract: The length, weight and sex distribution of turbot caught by bottom turbot gill nets were investigated in relation with seasons in the Sinop region. The size ranges were 23.9-69 cm and 31.8-81 cm for male and female turbot, respectively. Mean total length and weight were 50.37 ± 0.42 cm and 2483.2 ± 74.7 g for females, 45.93 ± 0.26 cm and 1711.2 ± 31.2 g for males, and 47.79 ± 0.24 cm and 2034.6 ± 38.5 g for all individuals. Significant differences were found both in length and weight values of turbot between seasons. The highest mean length and weight values were 49.56 ± 0.35 cm and 2286.5 ± 59.6 g in the spring, respectively. The length frequencies of turbot differed significantly between spring and other seasons ($P < 0.001$). Significant differences were found for sex ratios of turbot in spring. The length-weight relationship was estimated as $W = 0.0074\ L^{3.22}$.

Key Words: Turbot, *Scophthalmus maeoticus*, length, weight, sex ratio, seasonal variation

Türkiye'nin Sinop Bölgesi'ndeki (Karadeniz) Kalkan (*Scophthalmus maeoticus* Pallas, 1811) Balıklarının Boy, Ağırlık ve Cinsiyet Dağılımının Mevsimsel Değişimi

Özet: Sinop bölgesinde kalkan solungaç ağlarıyla avlanan kalkan balıklarının, boy, ağırlık ve cinsiyet dağılımı mevsimlere göre incelenmiştir. Erkek ve dişi kalkan balıklarının boyları 23,9-69 cm ve 31,8-81 cm arasında değişmiştir. Ortalama toplam boy ve ağırlıklar dişi; 50,37 ± 0,42 cm, 2483,2 ± 74,7 g, erkek 45,93 ± 0,26 cm, 1711,2 ± 31,2 g ve tüm bireyler için 47,79 ± 0,24 cm, 2034,6 ± 38,5 g olarak belirlendi. Kalkan balıklarının hem boy hem de ağırlık değerlerinde mevsimlere göre farklar önemli bulundu. En yüksek ortalama boy ve ağırlık değerleri 49,56 ± 0,35 cm ve 2286,5 ± 59,6 g olarak ilkbahardaydı. İlkbahar ile diğer sezonlar arasında boy frekans dağılımı açısından önemli fark vardı ($P < 0,001$). İlkbaharda kalkan balığının cinsiyet oranı farklı bulundu. Uzunluk ağırlık ilişkisi $W = 0,0074\ L^{3.22}$ olarak hesaplandı.

Anahtar Sözcükler: Kalkan, *Scophthalmus maeoticus*, uzunluk, ağırlık, cinsiyet oranı, mevsimsel değişim

Introduction

Total landings from marine fisheries in the world increased 5-fold in the 40-year period from 1950 to 1990. Recently, capture fisheries have not been able to keep pace with growing demand and many marine fisheries have already been overfished. Fish consumption increased by 31% while the supply from marine capture fisheries increased by only 9% from 1990 to 1997. This was intensified by the pressure on harvesters, which has translated into increased pressures on, and overfishing of, many commercial fisheries (Tidwell and Allan, 2001).

The Black Sea dominates the marine capture fisheries in Turkey and has accounted for 77.4% of the total catch. According to the Turkish Statistical Institute, 300 t of turbot were caught by the Turkish fishing fleet in 2003. Of this catch, 73% was reported to come from the Black Sea (Turkstat, 2005). Although the turbot landing was very low, its economic value is very important.

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Despite this importance, the landing values have been fluctuating and sharp reductions have been seen in recent years (Figure 1). Although turbot has a great commercial value, not only in Turkey but also in the Black Sea countries, it is hard to say that the stocks have been exploited rationally (Zengin and Düzgüneş, 2003).

Turbot gill net fishing is rather troublesome and tiring. Since turbot has great economic importance, the turbot gill net fishery is very popular for artisanal fishermen in the Sinop region of Turkey.

Turbot fishing in the Black Sea has mainly been carried out using bottom gill nets by 72% (Zengin and Düzgüneş, 2003). Gill nets are widely used for sampling on many fish populations, determination of biological characteristics, and stock assessments in commercial fishing (Reiger and Ribson, 1966).

The aim of the present study was to determine the length, weight and sex distribution, according to seasons, of turbot caught by bottom turbot gill nets in the Sinop region of Turkey, which is one of the most intensive turbot gill nets fishing areas of the Black Sea.

Materials and Methods

This study was conducted between Gerze Köşk Cape, Sinop (41° 47' 50'' N, 35° 12' 30'' E), and Sarıkum, Sinop (42° 01' 15'' N, 34° 54' 30'' E), between January and December 2001. Trawl fishing has been forbidden in this region by fisheries legislation for decades. Therefore, turbot fisheries were conducted using turbot gill nets.

Turbot samples were collected from commercial artisanal fishermen and the fishermen cooperative. Fishermen use single-walled tangle nets (from 280 mm to 370 mm, but mainly 320 mm mesh size), and 3-walled tangle nets (inner wall of 800 mm mesh size, 2 sides walled with 280 mm mesh size) for turbot fishing in Sinop (Samsun and Kalaycı, 2004). The total length (TL) and body weight (W) were measured to the nearest 0.1 cm and 1 g in fresh samples, respectively. Fish were sexed by visual observation of the gonads. The length-weight relationship was determined for males and females according to the equation $W = aL^b$, where W is the weight at time t, and a and b are the coefficients of the functional regression between W and L (Ricker, 1973).

The observed differences were evaluated statistically using one-way ANOVA and Student's t-test. A chi-square (χ^2) test was used to detect differences in the sex ratios. Comparisons of length frequency distributions among seasons were carried out using the Kolmogorov-Smirnov test (Zar, 1999)

Results

A total of 1011 turbot were measured in 2001. The size ranges were 23.9-69 cm and 212.1-5400 g, and 31.8-81 cm and 435.5-9500 g for male and female turbot, respectively. The mean total length and weight were 50.37 ± 0.42 cm and 2483.2 ± 74.7 g for females (n = 424), 45.93 ± 0.26 cm and 1711.2 ± 31.2 g for males (n = 587), and 47.79 ± 0.24 cm and 2034.6 ± 38.5 g for all individuals. The percentage of individuals smaller than 47 cm in length and 1800 g in weight was 50% and large turbot were very scarce (Figures 2 and 3).

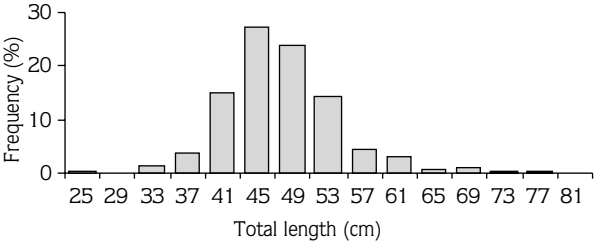

Figure 2. Length distribution of turbot in pooled sex data.

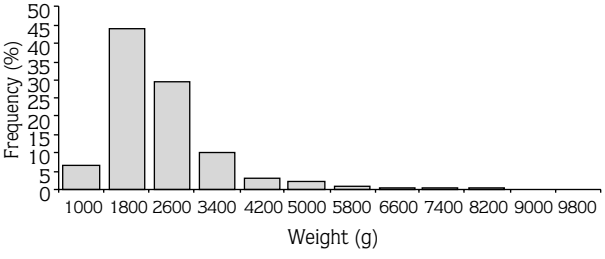

Figure 3. Weight distribution of turbot in pooled sex data.

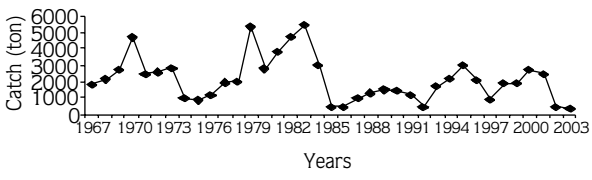

Figure 1. Turbot catch in Turkey from 1967 to 2003.

The catch frequencies were 19%, 60%, 9.5%, and 11.5% for winter, spring, summer, and autumn, respectively (Figure 4). The fish that were 67-81 cm in length and 5400-8600 g in weight were abundant in winter and spring while no fish larger than 57 cm and heavier than 3000-3800 g were found in summer and autumn (Figures 5 and 6). There were significant differences in length between seasons, except autumn and winter ($P < 0.05$). Moreover, there were significant

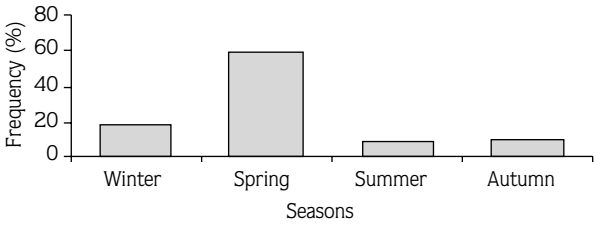

Figure. 4. Catch-frequency distribution of turbot according to seasons in 2001.

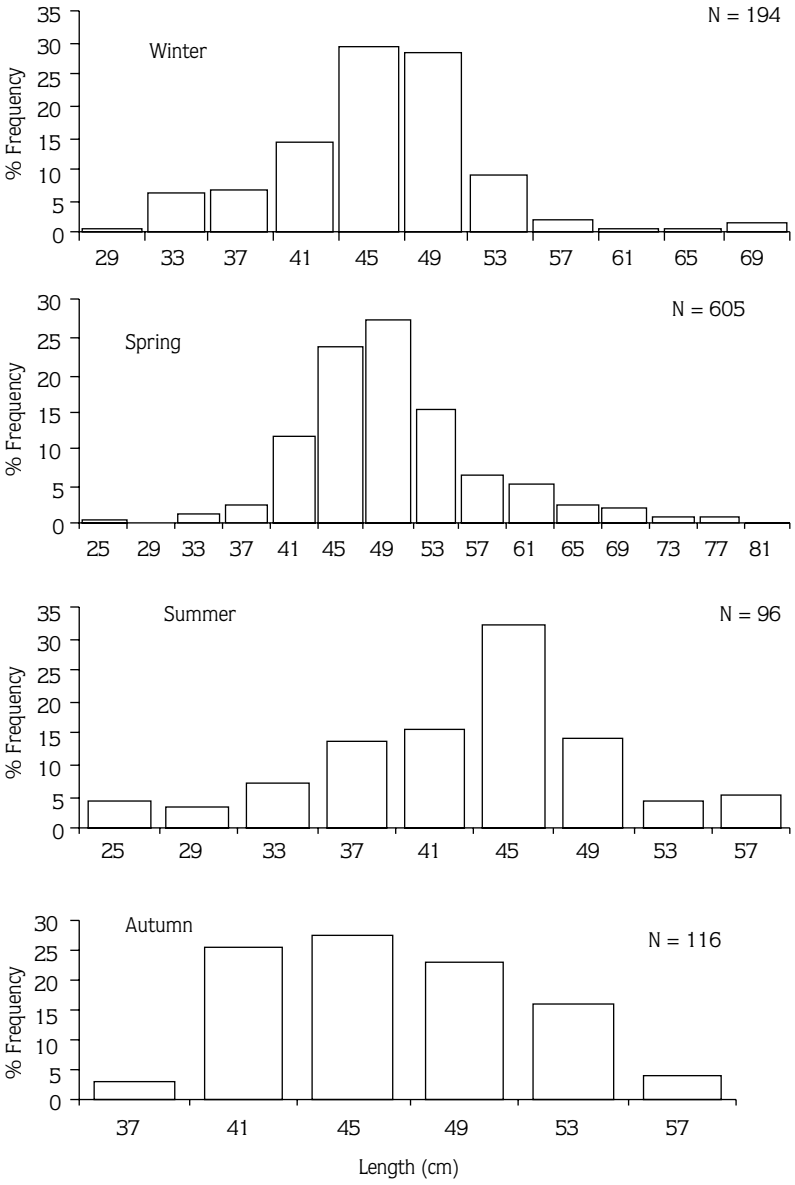

Figure 5. Length distribution of turbot caught according to seasons in 2001.

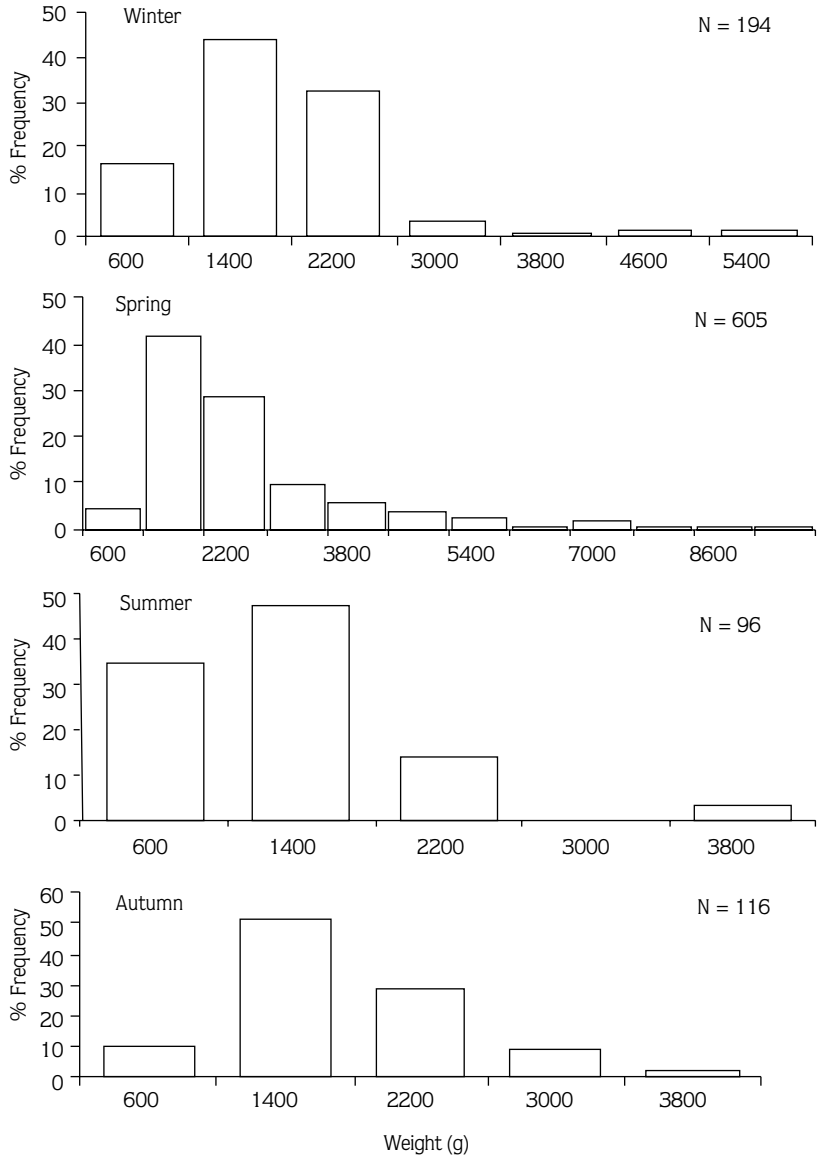

Figure 6. Weight distribution of turbot caught according to seasons in 2001.

differences in weight between spring-summer, spring-autumn, and spring-winter ($P < 0.05$). The highest mean length and weight were 49.56 ± 0.35 cm and 2286.5 ± 59.6 g in spring (Table 1). The length and weight of turbot differed significantly between the sexes ($P < 0.05$) (Figures 7 and 8). The Kolmogorov-Smirnov test indicated that the length frequencies of turbot differed significantly between spring and the other seasons ($P < 0.001$).

The female-male ratios of turbot were 52%-48%, 38%-62%, 42%-58%, and 45%-55% in winter, spring, summer, and autumn, respectively (Table 1). There were significant differences between the sex ratios in spring in favor of males ($P < 0.05$).

The length-weight relationship is shown in Table 2. The value of b was higher than 3 ($b \neq 3$, $P < 0.05$) and it was 3.22, 3.13, and 3.22 for female, male, and all samples, respectively. According to the results, growth of turbot was positive allometric. ANCOVA test showed significant differences between the sexes for length-weight relationship ($P < 0.05$) as the regression coefficient (b) was significantly higher in females (Table 2).

Table 1. Mean, minimum, maximum values of length and weight and sex ratio of turbot for seasons.

	Winter	Spring	Summer	Autumn
Female-Male	1.1:1	1:1.6 (P < 0.05)	1:1.4	1:1.2
TL ± SE (cm)	45.48 ± 0.52b	49.56 ± 0.35a	42.15 ± 0.82c	46.23 ± 0.51b
Min-Max	29.1-68	26.1-81	23.9-56.2	38.1-58.5
W ± SE (g)	1728.6 ± 67.1b	2286.5 ± 59.6a	1323.7 ± 85.7b	1766.1 ± 65.6b
Min-Max	400-5700	224.5-9500	212.1-3493	680-3300

a, b, c: Mean values in same rows with different letters are significantly different (P < 0.05 one way ANOVA)

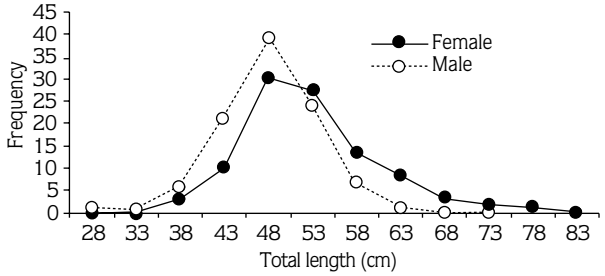

Figure 7. Length distribution of turbot for female and male turbot caught in Sinop region.

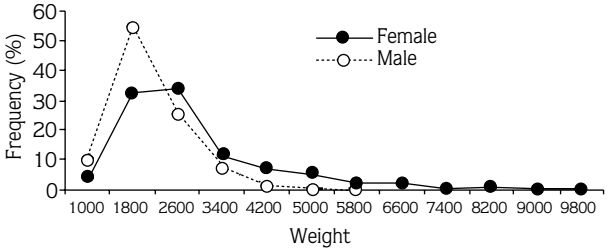

Figure 8. Weight distribution of turbot for female and male turbot caught in Sinop region.

Table 2. The length-weight relationship and growth coefficient of turbot.

	a	b	95% confidence limits of b	Growth	r
Female	0.0073	3.22	3.1329-3.3149	+ allometric	0.97
Male	0.0102	3.13	3.0420-3.2172	+ allometric	0.95
Overall	0.0074	3.22	3.1571-3.2783	+ allometric	0.96

Discussion

Throughout the sampling period, 9% of the turbot were smaller than 40 cm, a rate 5% higher than fishery legislation permits. Several researchers have reported different lengths of turbot in the Black Sea. The average lengths reported were 41.4 cm, 45.41 cm, 29.81 cm, and 35.36 cm, by Kutaygil and Bilecik (1979), Karadeniz (1990), and Samsun (1995) and Zengin (2000), respectively. However, both Karadeniz (1990) and Zengin (2000) reported turbot lengths smaller than 40 cm, specifically, 17% and 63.3% of those sampled, respectively. The average lengths for turbots caught by different types of fishing gear were 44.4 cm (71.8%), using bottom gill nets; 40.1 cm (26.1%), using trawl nets; and 21.8 cm (2.1%), using purse seines (Zengin, 1998). Turbots caught in the East Black Sea by single-walled tangle nets of different mesh sizes (340, 350, 360, 370, and 380 mm) had a minimum length of 38 cm, a maximum length of 72 cm, and an average length of 52.77 cm (Kara et al., 2004). In addition, the average total length of turbot decreased from 45.3 cm to 40.7 cm between 1991 and 1995 (Zengin, 1998). More

specifically, the average length of turbot in the Black Sea caught by trawl nets decreased from 41.9 cm to 37.6 cm between 1990 and 2000 (Zengin and Düzgüneş, 2003). Erdem (1996) reported that various percentages of turbot caught by turbot gill nets of different mesh sizes showed lengths less than 40 cm as follows: 90.4% (214 mm), 78.4% (214 mm), 65.9% (214 mm), 44.9% (333 mm), 19.9% (369 mm), and 4.4% (406 mm). Prodanov and Mikhailov (2003) found that 2- to 4-year-old turbot in Bulgarian waters were between 42 and 47 cm in length.

From March to June, turbot fishing intensifies when the temperature increases. During this period, an average of 64% is caught in the Black Sea. The maximum average turbot lengths were recorded in winter and spring. These numbers changed depending on the year and sea depths from 1990 to 1996 (Zengin, 2000). Sağıroğlu (1985) stated that turbot of longer lengths in the central Black Sea were mainly observed during April and May.

Furthermore, Ivanov and Beverton (1985) noted that turbot lived at depths of 14 to 50 m during the winter and 40-90 m in the summer. However, depending on the abundance of food, they swam toward shallow shores during the autumn, and less during the spring, to feed, similar to pelagic migrant species. Generally, in the spring, turbot lived at depths anywhere from 0 to 30 m, after having lived in deeper waters during winter (Zengin, 2000). In other words, turbot swam to shallow waters in the spring, remaining until early summer, and then moved to deeper waters in late summer; only a few smaller turbot swam toward shallow waters in autumn. This trend was clear when the samples were caught and their lengths recorded. In addition, the amounts caught during the autumn and winter were very low and the fish were small, both in weight and length.

Maximum turbot lengths vary according to years, species, and the areas studied. In other words, the maximum length for *Scophthalmus maximus* in the North Sea was 70 cm, 81.5 cm in Douarnenez Bay, 54 cm in Polish waters, and 50 cm in the Mediterranean Sea, according to Jones (1974), Deniel (1990), Draganik et al. (1996), and Robert and Vianet (1988), respectively. The maximum length of *Scophthalmus maotica* in the central Black Sea was 66 cm, 60 cm, and 74 cm; in the East Black Sea, 82 cm; and in Bulgarian waters, 75 cm (Sağıroğlu, 1985; Samsun, 1995; Erdem, 1996; Zengin, 2000, and Prodanov and Mikhailov, 2003, respectively). The recorded lengths for *S. maximus* were smaller than the lengths for *S. maeoticus,* Deniel's study in 1990 being the only exception. The maximum length of 81 cm in the present study was similar to Zengin's results in 2000, namely, 82 cm. Komakhıdze et al. (2003) observed that turbot could reach a length of 85 cm and a weight of 9 kg, and that even some could reach 100 cm length and 15 kg weight. In addition, female turbot weighing 20.2 kg and 19.9 kg were caught in 1983 along with male turbot weighing 16 kg caught in 1990, using gill nets in the Sinop region of Turkey (Interview with Görduk, A., artisanal fisherman in Sinop). Turbot weighing 19 to 20 kg were caught in 1983. At present, catching turbot longer than 82 cm or heavier than 9.5 kg is rare, which clearly indicates that overfishing has increased during this period.

Differences in growth between males and females were also observed in this study, with females significantly longer than males. Referencing many studies on turbot, females always had a higher growth rate and greater length, and they were older than males (Jones, 1974; Robert and Vianet, 1988; Deniel, 1990; Dragenik et al., 1996; Zengin, 2000; Arneri et al., 2001).

There is a well-known and significant correlation between the life history parameters, such as age at initial reproduction and natural mortality, and the growth rate of fish (Imsland et al., 1997). As such, fecundity increases with body size, and the relationship between somatic weight and fecundity supports rapid female growth after reaching a certain size at maturity, not seen in males (Roff, 1982). Rjinsdorp and Ibeling (1989) reported that the total increase in somatic weight and gonad weight of both males and females matches their increase to a particular size, but, after reaching that size, female flatfish have greater surplus energy than males. Devauchelle et al. (1988) found that female turbot growth exceeded male growth after attaining maturity.

The highest percentage of male turbots was determined to be 62% in the spring, significantly favoring males over females with a higher percentage. In a recent study the female ratio in the Black Sea was documented as 64% (Kutaygil and Bilecik, 1979), 33% (Sağıroğlu, 1985), 54% (Karadeniz, 1990), 44% (Erdem, 1996), 58% (Avşar, 1999), 50% (Zengin, 2000), and 55% (Genç, 2002). Sağıroğlu (1985) and Erdem (1996) found the male ratio to be higher in the samples caught using turbot gill nets. Although gender ratios in the spawning

population in different age and size groups vary according to species, reflecting the relationship of that species to its environment, the overall gender ratio is close to 1:1 in many species. However, the male ratio may be higher during the spawning period, as determined by Nikolskii (1980). The highest male ratio was 62%, which occurred naturally in the spring during spawning.

The value of b was found to be higher than 3 for all samples, which indicated that turbot growth had positive allometry. In fact, some studies show positive allometry in different seas, namely the Black Sea (Ivanov and Beverton, 1985), Central Black Sea (Samsun, 1995; Erdem, 1996), the Polish and Lithuanian Seas (Draganik et al. 1996), East Black Sea, (Avşar, 1999; Zengin, 2000), and the Adriatic Sea, (Arneri et al., 2001).

Turbot has an important place in the Turkish fishing industry, especially for the Black Sea fisheries. However, the latest statistics and landing data demonstrate that the average total lengths are decreasing. To preserve and maintain these valuable stocks, harvesting turbot smaller than 40 cm, the minimum legal fishing size, must be prevented. At the same time, fishermen must comply with the seasonal limitations (e.g., the spawning period) and net regulations.

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