Various aspects of the distribution and biology of turbot in the Black Sea

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Abstract. The present study aims to address various aspects of the biology and distribution of turbot based on isometric data from landings at authorized ports during the period 2017-2022. By synthesizing and analyzing data from turbot fishing, we gain insights into the species' history, distribution, and life cycle, which is crucial for science and beneficial for fisheries management. The study focuses on: distribution, length-weight relationship, and condition factor of turbot. Data were collected from authorized Bulgarian ports in the Black Sea during 2017-2022. Samples were taken from 4719 fish. The average total length and weight of the fish were 52.63±6.12 cm and 2600±910 g, respectively. The length-weight relationships were determined using the following equations: 2017: $W = 0.02L^{2.98}$, n = 566 ($R^2 = 0.88$); 2018: $W = 0.04L^{2.80}$, n = 783 ($R^2 = 0.85$); 2019: $W = 0.34L^{2.25}$, n = 713 ($R^2 = 0.71$); 2020: $W = 0.02L^{2.90}$, n = 926, (R2=0.89); 2021: $W = 0.02L^{2.93}$, n = 928, (R^2 =0.88); 2022: $W = 0.002L^{3.55}$, n = 803, (R^2 =0.86); 2017-2022: $W = 0.05L^{2.76}$, n= 4 719, (R^2 =0.74). The reproductive period of turbot in the Black Sea is between April and June. The condition factor during the period 2017-2022 varied as follows: 1.74, 1.86, 1.75, 1.74, 1.74, 1.91. The overall average value of the Fulton's condition factor during the study years was above one, indicating the good status of the turbot population (Psetta maxima) in the Bulgarian waters of the Black Sea.

1 Introduction

The turbot, Psetta maxima [1], is a flatfish belonging to the family Scophthalmidae. It is widely distributed in the northern part of the Atlantic Ocean, the Mediterranean Sea, and the Black Sea. This species inhabits European coastal waters in the northern Atlantic, ranging from Norway to Morocco, including the Baltic, Mediterranean, and Black Seas [2]. It is a benthic marine species that dwells on sandy and muddy bottoms in the shallower parts of the continental shelf, up to depths of approximately 110 meters [3]. Turbot is a highly valued commercial species [4], and in the Republic of Bulgaria, it is caught using anchored gillnets (GNS) with a mesh size of 400 mm.

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The turbot stock in the Black Sea is estimated to be approximately 2000 tons [5]. For the Republic of Bulgaria, as an EU member, a fishing quota has been established, increasing from 43 to 75 tons per year during the examined period.

2 Materials and methods

The study was conducted between latitudes 42°05' and 43°45' N and longitudes 27°55' and 29°55' E along the eastern Black Sea coast of Bulgaria. A total of 4719 individuals were investigated, caught using anchored gillnets with a mesh size of 400 mm between 2017-2022. Monthly investigations were carried out based on fishing logs from vessels landing turbot at regulated ports. The depths of capture ranged from 20 to 100 meters. The total length (L) was measured from the tip of the closed mouth to the extended tip of the caudal fin, with an accuracy of 0.1 cm. Body weight was measured to an accuracy of 0.1 g using an electronic scale after removing adhering water and particles from the body surface. Sexes were determined post-dissection by simple visual observation of the gonads' physical appearance [6]. Gonad weight was measured to the nearest 0.001 g after blotting blood and water.

The relative value of the degree of variation was determined using the formula (1) [7]. The standard deviation (σ) is calculated as follows:

$$\sigma = \sqrt{\frac{\sum (x_i - \overline{x})^2 \; f}{\sum f}} \tag{1}$$

where: σ – standard deviation; x_i – i- data element; $\bar{x}$ – mean of the data; f – number of elements.

The absolute measure of dispersion is computed using the coefficient of variation, as defined by [7] (Formula 2):

$$V_\sigma = \frac{\sigma}{\bar{x}} \; 100 \tag{2}$$

where: V_σ – coefficient of variation; σ – standard deviation; $\bar{x}$ – mean of the data

The universal growth equation is calculated using the formula (3) [8]:

$$W = a \; L^b \tag{3}$$

where: W – weight (g); L – total length (cm); a – constant; b – growth exponent.

The condition factor [9] is calculated by the formula (4):

$$K = 100 \; \frac{W}{L^3} \tag{4}$$

where: W – weight (g); L – total length (cm).

Observed differences are statistically evaluated using Microsoft Excel. The minimum significant level for the respective Student's t-test is determined at ($P < 0.05$).

3 Results and discussion

Biological data for the period were collected from 217 landings at ports: Durankulak, Krapets, Shabla, Kavarna, Balchik, Varna, Byala, Nessebar, Pomorie, Sozopol, and Tsarevo. The results of this study regarding the number of fish are shown in Table 1.

Table 1. Data on fish landed at ports for the period 2017-2022.

unloaded	Year						Total
	2017	2018	2019	2020	2021	2022	
number of fish	566	783	713	926	928	803	4 719
kg	1385	2046	1928	2769	2786	2215	13 129

During the period 2017-2022, 217 landings of turbot were observed, with most of them registered at the northern ports. This is because the fishing boats holding individual quotas for turbot catches from Varna and Dobrich outnumber those registered in Burgas [10].

A total of 4719 turbot specimens (Psetta maxima) were examined, with catch depths varying between 20 and 90 meters, depending on the season. On average, 23 fish and 64 kg were caught per vessel. The maximum number was 111 specimens, and the minimum was 2 turbot. The length varied between 45.10 and 82.00 cm, with an average total length (L, cm) of 53.77 cm. Weight values ranged from 1.25 to 9.75 kg. Data on the size and weight of turbot by year are presented in Table 2.

Table 2. Summary data on turbot length and weight by year.

period	n	W (kg)			L (cm)		
year		min	max	average ± SD	min	max	average ± SD
2017	566	1.25	6.60	2.45±0.79	45.10	70.00	52.05±4.90
2018	783	1.33	6.80	2.62±0.96	45.10	61.50	52.07±6.05
2019	713	1.40	6.80	2.70±0.93	45.50	82.00	53.59±7.17
2020	926	1.40	9.75	2.99±1.99	45.50	78.00	55.61±6.63
2021	928	1.60	9.75	3.00±1.21	45.50	78.00	55.66±6.52
2022	803	1.41	7.50	2.76±1.36	45.50	74.00	52.38±5.74
Total	4719	1.25	9.75	2.78±1.13	45.10	82.00	53.77±6.42

The average values of the total length and weight of women are higher than those of men, and the differences are statistically significant ($P < 0.05$). To establish the differences in the study concerning the characteristics of "size" and "weight" of the heel, the standard deviation was used. The size-weight characteristic shows relatively little variation in weight (W) - 4% and little variation in length (L), which is approximately 2%.

The relationship between size and weight of turbot for 2017 is expressed by the equation: $W = 0.02L^{2.98}$, $n = 566$ ($R^2 = 0.88$).

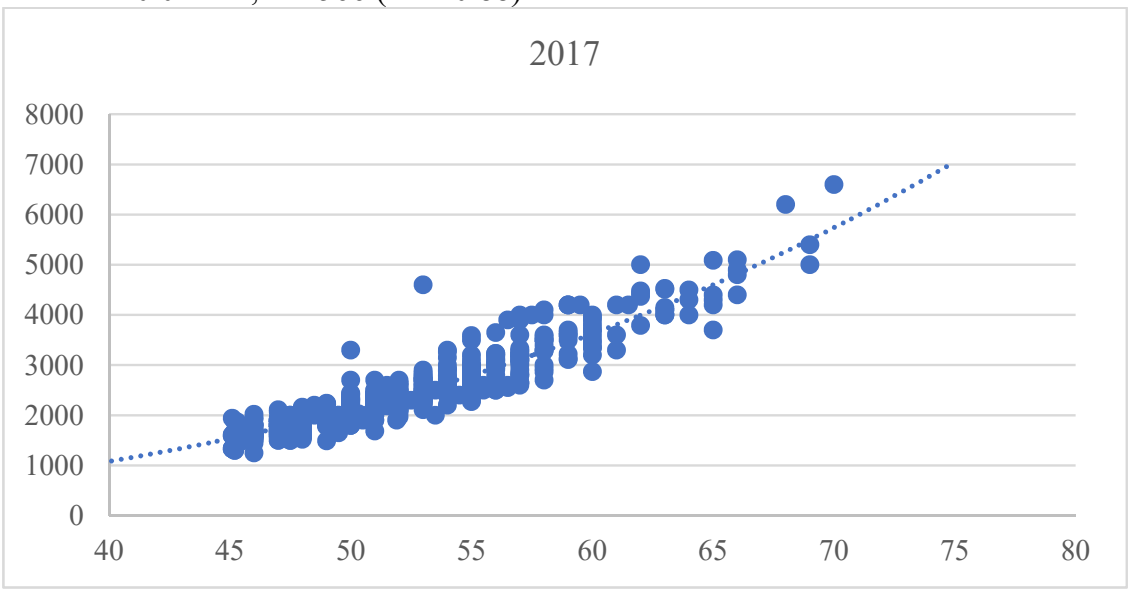

Fig. 1. Relationship between size and weight of turbot, n=566, 2017.

The relationship between size and weight of turbot for 2018 is expressed by the equation: $W = 0.04L^{2.80}$, n = 783 ($R^2 = 0.85$) (Figure 2).

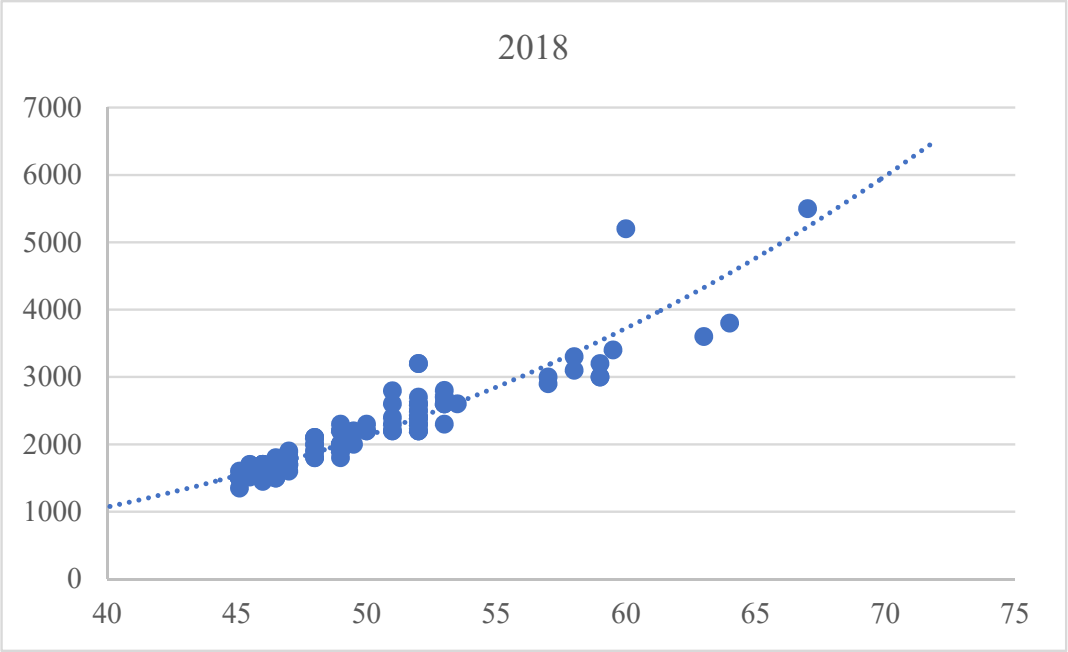

Fig. 2. Relationship between size and weight of turbot, n=783, 2018.

The relationship between size and weight of turbot for 2019 is expressed by the equation: $W = 0.34L^{2.25}$, n = 713 ($R^2 = 0.71$), (Figure 3).

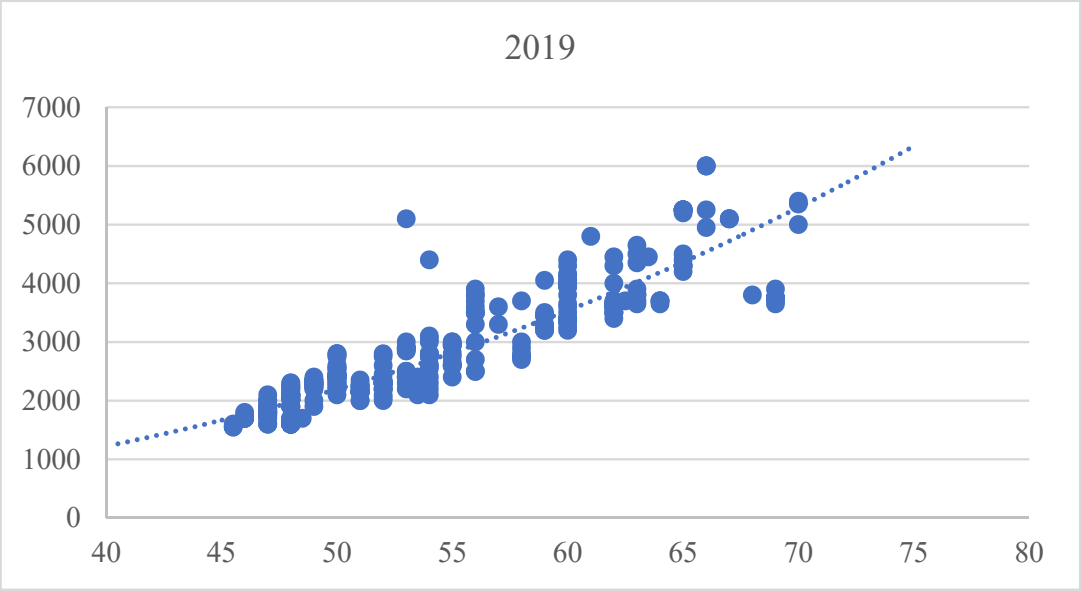

Fig. 3. Relationship between size and weight of turbot, n=713, 2019.

The relationship between the size and weight of turbot for the year 2020 is expressed by the equation: $W = 0.02L^{2.90}$, n = 926, (R^2=0.89); (Figure 4).

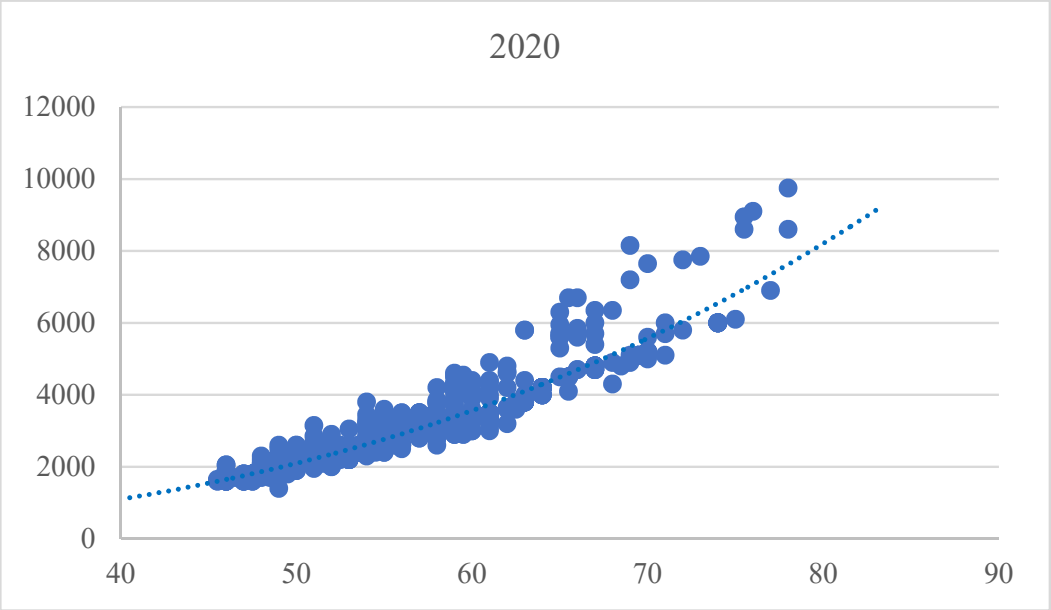

Fig. 4. Relationship between size and weight of turbot, n=926, 2020.

The relationship between the size and weight of turbot for the year 2021 is expressed by the equation: 2021: $W = 0.02L^{2.93}$, n = 928, (R^2 =0.88); (Figure 5).

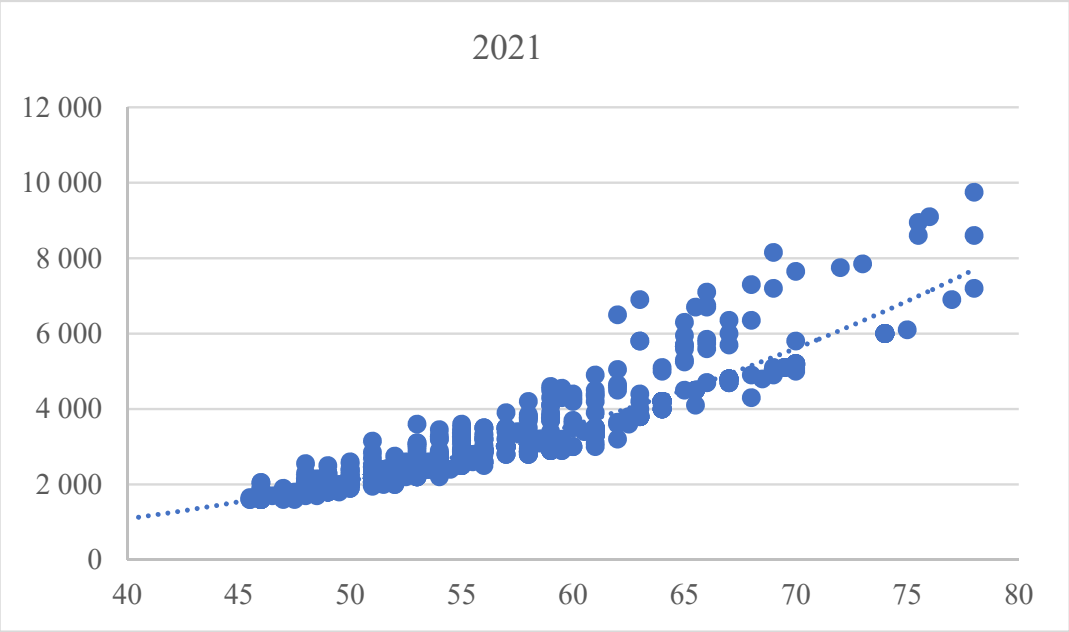

Fig. 5. Relationship between size and weight of turbot, n=928, 2021.

The relationship between the size and weight of turbot for the year 2022 is expressed by the equation: 2022: $W = 0.002L^{3.55}$, n = 803, (R^2 =0.86); (Figure 6).

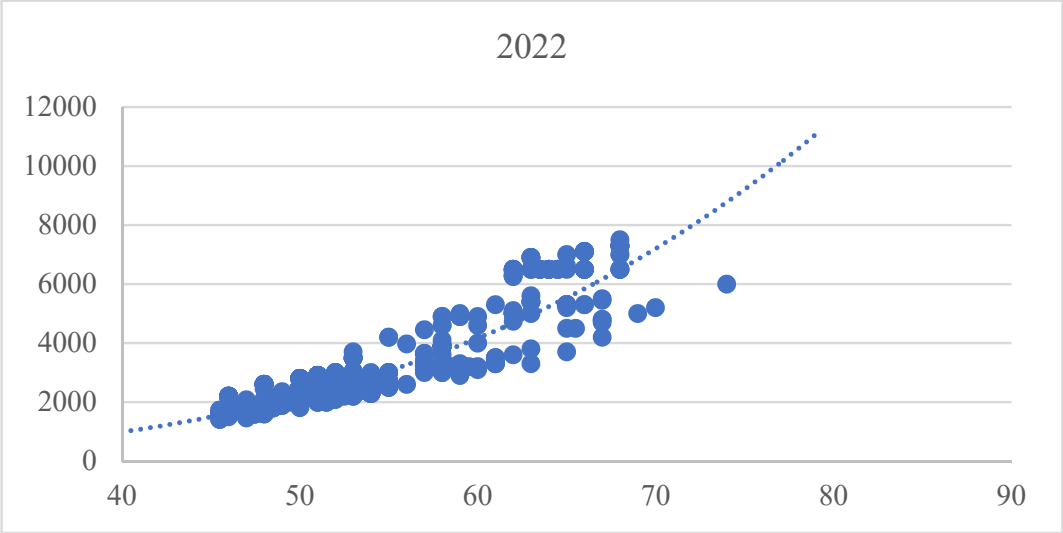

Fig. 6. Relationship between size and weight of turbot, n=803, 2022.

The relationship between the size and weight of turbot for the period 2017-2022 is expressed by the equation: 2017-2022: $W = 0.05L^{2.76}$, n= 4 719, (R^2 =0.74) (Figure 7).

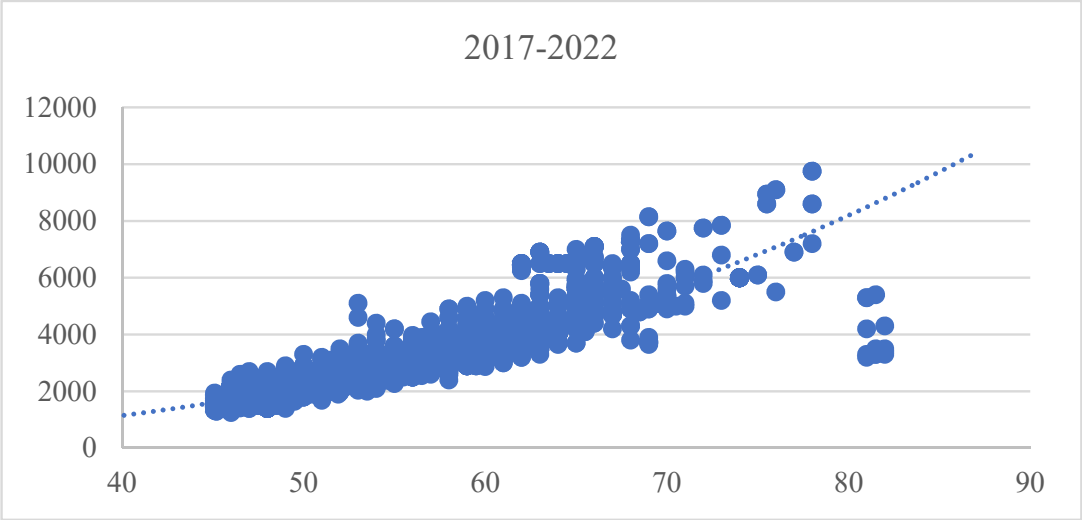

Fig. 7. Relationship between size and weight of turbot, n=4719, 2017-2022.

The universal growth equations and corresponding coefficients are presented in Table 3, with the b values ranging from 2.25 to 3.55 for the studied periods.

Table 3. Coefficients in the growth equations for the period 2017-2022.

year	N	a	b	R^2
2017	566	0.02	2.98	0.88
2018	783	0.04	2.80	0.85
2019	713	0.34	2.25	0.71
2020	926	0.02	2.80	0.89
2021	928	0.02	2.93	0.88
2022	803	0.002	3.55	0.86
Total	4719	0.05	2.76	0.74

As the fish grow in length, they also increase in weight. As seen from the growth equations, the relationship between weight and length is described by a power function. The exponent “b” is around 3 for most species.

The coefficient “a” varies across different periods. If the exponent “b” is greater than three, there is a tendency for relatively faster weight growth compared to length, meaning the weight increases more rapidly than the girth of the turbot. These conclusions are made with a high degree of correlation.

The Fulton's condition factor (K) is a quantitative parameter that provides information on the fish's condition, reflecting feeding conditions, health, and the impact of environmental factors [10]. This factor varies depending on physiological factors and the various stages of development [11-15].

We calculate the Fulton's condition factor using the formula (4), using the data for weight and length for the respective year (Table 4).

Table 4. Fulton's condition factors for the period 2017-2022.

Period	N	W (g)	L (cm)	K
2017	566	2450	52.05	1.74
2018	783	2620	52.07	1.86
2019	713	2700	53.59	1.75
2020	926	2990	55.61	1.74
2021	928	3001	55.66	1.74
2022	803	2758	52.38	1.91
Total	4719	2782	53.77	1.79

Calculations show that the fish in the study are in good condition, as the overall average value of K is higher than one.

4 Conclusions

Through biological monitoring of turbot catches along the Bulgarian coast of the Black Sea, we obtain necessary information for analysis and for creating a database to track catch structure over the years. This study aims to enhance current knowledge about distribution and track catch structure. It addresses some commercial and fishing aspects of turbot catches in the Bulgarian waters of the Black Sea.

A total of 4719 turbot specimens were examined. The average catch depth is 50 meters, which aligns with similar studies. Sahin and Gunes claim that turbot (Psetta maxima) is widespread in the coastal zone at depths of 20-60 meters.

This study found that on average, 22 fish were caught per vessel, with a maximum of 111 and a minimum of 2. The total length varied from 45.10 to 82 cm, with an average total length (TL, cm) of 53.77 cm. Weight values ranged from 1.25 to 9.75 kg.

The length-weight relationship (L-W) for the period 2017-2022 is of the form: $W = 0.05L^{2.76}$. The exponent (b) in the growth equation varies between 2.25 and 3.55. The value of (b) is between 2 and 4 for most fish. In this study, the values of (b) are around 3. The robustness of the turbot population is also confirmed by the Fulton's condition factor values. The fish in the study have an overall average K value higher than one. In conclusion, the study proves that turbot (Psetta maxima) are in good condition in the Bulgarian waters of the Black Sea.

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