Mar. Sci. Tech. Bull. (2023) 12(4): 483-494
e–ISSN: 2147–9666
info@masteb.com

dergipark.org.tr/en/pub/masteb
www.masteb.com
DOI: 10.33714/masteb.1369086

Marine Science and Technology Bulletin

https://prensip.gen.tr/

RESEARCH ARTICLE

Some population parameters of picked dogfish (*Squalus acanthias* L. 1758) incidentally captured in commercial fisheries in southern Black Sea shores and a first record of angular roughshark (*Oxynotus centrina*, L. 1758) for Black Sea

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ARTICLE INFO

Article History:
Received: 30.09.2023
Received in revised form: 31.10.2023
Accepted: 06.11.2023
Available online: 25.12.2023

Keywords:
Shark
By-catch
Fishing gears
Population characteristics
Black Sea

ABSTRACT

The study, which aimed to determine some population parameters of picked dogfish (*Squalus acanthias* L. 1758) distributed in the Black Sea, was carried out in the five fishing seasons (between 2016 and 2023 years). The sharks draw attention as a bycatch for all fishing gear used in the Black Sea. In the study, total length (cm), weight (g) and sex (female/male) data were obtained from the sharks captured with all fishing gears (demersal trawl, midwater trawl, gillnets purse seine, turbot gillnets, trammel nets and bottom) used in commercial fishing activities in the Black Sea of Türkiye. A total of 576 specimens were collected all fishing gears during the sampling period. Length-weight relationship (LWR) was founded as $W=0.0097L^{2.8521}$ (R^2 =0.9854) for all the picked dogfish. Also, mean total length 48.9±0.707 cm respectively. In addition, the first record of the angular roughshark (*Oxynotus centrina*, L. 1758) species was given for the Black Sea coasts, which originated in the western Atlantic, was seen in the Mediterranean, Aegean Sea and the Marmara Sea of Türkiye. The shark, which was accidentally caught with a purse seine net, measured as 33.5 cm in total length and weighed 585 g.

Please cite this paper as follows:

Özdemir, S., Özsandıkçı, U., & Duyar, H. A. (2023). Some population parameters of picked dogfish (*Squalus acanthias* L. 1758) incidentally captured in commercial fisheries in southern Black Sea shores and a first record of angular roughshark (*Oxynotus centrina*, L. 1758) for Black Sea. *Marine Science and Technology Bulletin*, *12*(4), 483-494. https://doi.org/10.33714/masteb.1369086

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Introduction

Cartilaginous fish, class Chondrichthyes, are a very large and diverse group that includes subclasses of Elasmobranchii and Holocephali and contain approximately 1100 species in total (Compagno, 1990; Compagno et al., 2005). They are one of the major parts of marine ecosystem (Cortes, 2000) and have a cartilaginous skeleton unlike Osteichthyes or bony fishes with a bony skeleton (Bonfil, 1994). Cartilaginous fishes are main components of marine communities (Cortes, 2000) and they play an important role in the marine ecosystems contributing to the regulation of low trophic level organisms since the majority of them are predators (Myers & Worm, 2005; Coll et al., 2013).

Chondrichthyans face various threats that can be examined under three main groups: targeted fishery (direct exploitation), bycatch (indirect exploitation), habitat loss and degradation (Stevens et al., 2005). Sharks and rays appear to be particularly vulnerable to over-exploitation because of their K-selected life-cycles strategy. Cartilaginous fishes were characterized by slow growth, late attainment of sexual maturity, long life spans, low fertility, and natural mortality, and a nearby relationship between the number of young produced and the size of the breeding bio-mass (Stevens et al., 2000). As a result of these main threats, it is estimated that nearly one quarter of the cartilaginous species are classified as threatened (Dulvy et al., 2014).

The commercial value of cartilaginous fish is relatively low compared to other bony fishes caught in the Mediterranean basin. Currently the amount of cartilaginous fish harvested annually on a Mediterranean basin scale represent nearly 1.15 % of the reported total catch (Bradai et al., 2018; FAO, 2020). However, it is estimated that roughly 50% of the total catch of elasmobranch species remain unreported due to various issues (Bonfil, 1994). Türkiye with Italy and Tunisia contributed 76% of the total elasmobranch catches within the Mediterranean during the 1980–2008 period (Bradai et al., 2012). However, incidental catch of cartilaginous fish appears as a more important problem in the Mediterranean basin. It is suggested that almost all cartilaginous fish living in the Mediterranean are affected by the bycatch problem. In order of importance, trawls, purse seine, longlines, driftnets, gillnets, trammel nets and dredge are the main fishing gears which cause incidental catch of these fish in the Mediterranean basin (Cavanagh & Gibson, 2007).

Mediterranean Sea including Black Sea and Sea of Azov is home to probably 84 chondrichthyan species representing 8% of the total number of species of this group in the world although entire Mediterranean basin covers less than 1% of the total area of World seas (Serena, 2005). According to Bilecenoğlu et al. (2014), there are 65 chondrichthyan species belong to classes of Elasmobranchii (64 sp.) and Holocephali (1 sp.) in the Türkiye marine fish fauna and 10 of these elasmobranch species can be found in the Turkish coasts of the Black Sea. The most widely known cartilaginous fish in the Black Sea is the thornback ray (*Raja clavata*). Thornback rays are often caught as bycatch by various fishing gears (such as purse seine, demersal trawl, pelagic trawl, dredge, gillnets and trammel nets) along the Black Sea coasts (Kasapoğlu & Düzgüneş, 2013; Özdemir et al., 2021).

Besides, the picked dogfish (*Squalus acanthias*) is the most important shark species living in the Black Sea. The picked dogfish has slow growth and late maturity feature (Tserkova et al., 2022). The IUCN status of picked dogfish in the Black Sea countries were reported LC - least concerned for Georgia; NT-near threatened for Romania; EN- endangered for Türkiye (Radu & Maximov, 2012). However, IUCN Red List status of picked dogfish is vulnerable species (Fordham et al., 2016). A demersal, inshore and offshore sharks of the continental and insular shelf and upper slopes. Usually near the bottom, but also in midwater and at the surface occurs mainly between 10-200 m depth (Ebert et al., 2010).

There are few detailed scientific studies on the sharks of the Black Sea. In this study, some population parameters and length-weight relationships of picked dogfish captured as a by-catch in trawl nets (demersal and pelagic), set nets (turbot gillnets, trammel nets and bottom gillnets) and purse seine used in the southern Black Sea coasts of Türkiye were determined. Also, a new shark species (Angular roughshark, *Oxynotus centrina*) were given first record for Black Sea shores.

Material and Method

The study was conducted out in the Black Sea coasts of Türkiye at by using commercial fishing gears. Active fishing gears were otter demersal trawls, pelagic trawls (01 September 2018 – 15 April 2023) and purse seine (01 September 2022 – 15 April 2023). Passive fishing gears were turbot gillnets, trammel nets and bottom gillnets (01 September 2016 – 15 June 2023). The sampling areas were southern Black Sea shores of Türkiye (Survey areas: Samsun-SA1 Sinop-SA2, Kastamonu-SA3 and Zonguldak-SA4). These regions are an important migration point and direction of pelagic and demersal fish shoals in the Black Sea coasts of Turkey. The nautical chart of the survey area is shown in Figure 1.

Table 1. Mesh size of set nets (passive fishing gears) used on sea trials

Fishing gear	Material	Mesh Size
Turbot gillnets	Multifilament	320 mm, 340 mm, 360 mm, 400 mm
Trammel nets	Multifilament	32 mm, 36 mm, 40 mm, 44 mm, 48 mm, 52 mm
Bottom gillnets	Multifilament	32 mm, 36 mm, 40 mm, 44 mm

Figure 1. Survey areas in the study (SA1: Samsun coasts, SA2: Sinop coasts, SA3: Kastamonu coasts, SA4: Zonguldak coasts)

Samples were collected with trawl nets, purse seine and set nets (turbot gillnets, trammel nets and bottom gillnets) at depths ranging from 15 m to 120 m. Traditional demersal trawl nets used from three different fishing region (40 mm, 42 mm and 44 mm codend mesh size) in the survey. Tow duration of trawl nets was to 60-120 minutes.

A total of 120 hauls for demersal trawl, 60 hauls for pelagic trawl, 60 fishing operations for bottom gillnets and trammel nets, 60 fishing activities for turbot gillnets and 8 fishing operation for purse seine were conducted during the study period. Also, while the turbot nets used in the research were left in the sea for an average of 10 days, the bottom gillnets and trammel nets remained in the sea for 24 hours. Mesh size of passive fishing gears (set nets) used on the study were given Table 1.

Angular roughshark were captured incidentally on 24 December 2022 at a depth of 42 meters by the purse seine in Zonguldak-Ereğli (SA4) offshore of Southern Black Sea, (41°25'18" N – 31°33'09" E, coordinates). After determining the size measure and sex of the shark, it was released back to the sea alive (Figure 2). The sharks were defined by considering the morphological and biological characteristics of species. The sex of the sharks was established by the macroscopic investigate of the gonads, clasper or not clasper (Compagno, 1984; Froese & Pauly, 2023a, 2023b). Incidentally captured picked dogfishes were registered to the nearest 1 mm (total length) and weight to the nearest 5 g (Figure 2).

Female/male ratio of picked dogfish was analyzed by Chi-square test (X^2). Fulton's condition factors (CF) were fixed by the Equation 1:

Figure 2. Measurement of the length of sharks

$$CF = \frac{W}{L^3} \times 100 \quad (1)$$

Length-weight relationships were predicted by fitting an exponential curve ($W=aL^b$) to the data (Pauly, 1984). Parameters "a" and "b" of the exponential curve were estimated by linear regression analysis over log-transformed data (Equation 2):

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

where, W is the total weight (g) and L is the total length (cm), "a" is the intercept and "b" is the slope, using the least-squares method.

The association-degree between variables of W and L was calculated by the determination coefficient (R). Additionally, 95% confidence limits of the parameter b were estimated. The Student's "t test" was used for comparison of the slopes (Zar, 1996).

When the parameter 'b' is statistically equal to 3, the growth is called isometric, but 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).

Results

A total of 576 picked dogfish were collected all fishing gears during the sampling period (Figure 3). The more sharks were incidentally caught with active fishing gear than with passive fishing gear in the study. While the most sharks were caught by demersal trawls (338), the least were caught by purse seine (5). A total of 40 sharks were caught accidentally by midwater trawls. Totally 193 sharks were caught incidentally with passive fishing gear (turbot gillnets: 54, trammel nets: 87 and gillnets: 52).

It was determined that 54.9% of the samples were females (N=316), 45.1% males (N=260). The shortest individual, 27.2 cm (TL) was obtained in May 2022 and the longest 111.8 cm (TL) in November 2019. The values of picked dogfish examined, mean length and weight, standard error, minimum and maximum size and weight for sexes were given in Table 2. Sex ratio was 1 female: 0.67 male in the examined fishes. Statistical analysis using the Chi-square test (X^2) is significant for the species ($p<0.05$).

The length-weight relationships (LWRs) of picked dogfish were calculated as $W=0.0098L^{2.8561}$, $W=0.0103L^{2.8283}$ and $W=0.0112L^{2.8521}$ for females, males and all individuals, respectively (Figure 4). Length-weight relationships of sharks were highly significant ($p<0.005$) and presented in Table 3.

Fulton's condition factors were founded as 0.801±0.009 for all individuals. Mean condition factor of female was higher than male individuals (0.769±0.013 and 0.919±0.012).

In the study, angular roughshark was recorded the first time in the Black Sea. The total length and weight of the shark caught accidentally with a purse seine net was measured as 33.5 cm and 585 g. Also, sex of shark was determined as female (Figure 5).

Figure 3. Incidental shark catches for fishing gears used on southern Black Sea coasts

Table 2. Some meristic features of captured picked dogfish

Gender	Total Length (cm)			Total Weight (g)		
	Max	***Min***	***Mean***	***Max***	***Min***	***Mean***
Male	94.2	30.5	43.8±0.801	2988	199.5	315.0±13.111
Female	111.8	27.2	55.5±0.569	5235	255.5	326.5±14.369
All	111.8	27.2	48.9±0.707	5235	199.5	321.5±16.257

Table 3. LWR parameters of captured picked dogfish

Parameters	Female	Male	All
N	316	260	576
a	0.0098	0.0103	0.0097
b	2.8561	2.8283	2.8521
SE of b	0.05433	0.05117	0.04485
Coefficient of a 95%	0.0041-0.0169	0.0077-0.0188	0.0037-0.0157
Coefficient of b 95%	2.681-3.111	2.678-3.107	2.686-3.115
R^2	0.9871	0.9823	0.9854
Growth	Negative Allometric	Negative Allometric	Negative Allometric
p value	<0.005	<0.005	<0.005

Note: SE: Standard error

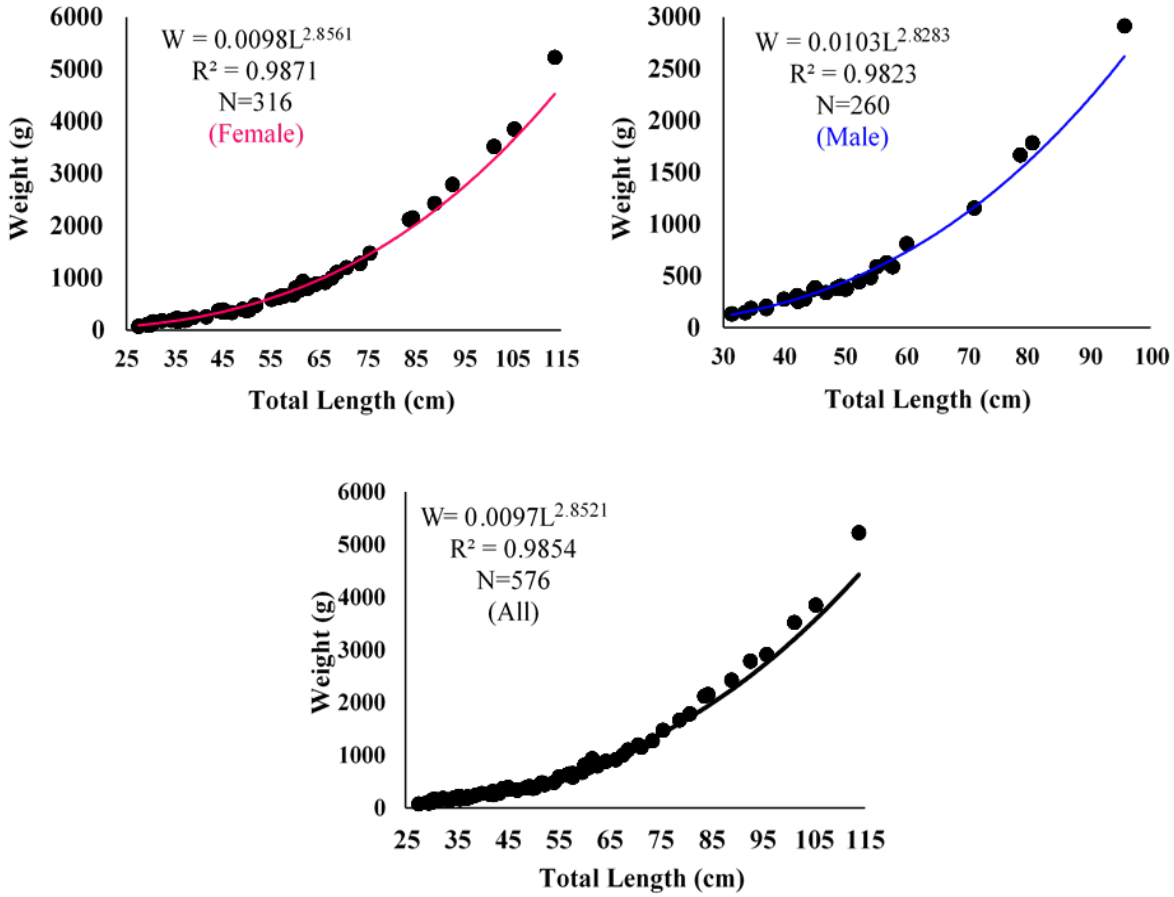

Figure 4. LWR graphics of picked dogfish (Female, male and all)

Discussion

Picked dogfish is assumed to be the most abundant living shark species (Dutta et al., 2012). While there are comprehensive studies on the species in the Aegean Sea, Mediterranean and Marmara Sea, research on the biology and population parameters of the species in the Black Sea is very limited.

In the Black Sea the largest catches of picked dogfish are along the coasts of Türkiye, although this fish is not a target species of fisheries, being yielded as by-catch in trawl nets and purse seine operations in the commercial fishing seasons. In the 1989 annual catches of Türkiye are 14558 tons. In subsequent years, they have decreased about 26.5 tons in 2011. It is stated that this decrease and rapidly collapse in picked dogfish stocks was caused by excessive and uncontrolled over-fishing pressure until the 2000s (Düzgüneş et al., 2005). Nowadays, commercial fishing of the species is prohibited in Turkey (Anonymous, 2020). Considering the slow growth and late maturity of the picked dogfish need to be protected and supported with

detailed study and precautions in order to maintain their existence in the marine ecosystem.

In this study, length-weight relationships of picked dogfish, the most important shark species of the Black Sea, were determined. Picked dogfish has been found to be negative allometric (b<3) growth (t test. p<0.005). The length-weight relationships parameter "b" typically varies between 2.0 and 3.5 (Froese et al., 2011).

There are a number of factors that may result in a high variability in the weight at length for any given fish species, including sex (e.g., one sex may have a wider length range, ovarian weight is usually larger than the weight of the testes), maturity stage and gonad size, weight of stomach contents, liver weight, parasite load, as well as the overall condition of the fish. Seasonal sampling and gear selectivity may result in different length and weight ranges observed for some species between the surveys (Silva et al., 2013).

Growth type of picked dogfish was established negative allometric in the studies except for Düzgüneş et al. (2005) in the southern Black Sea coasts of Türkiye. Likewise, it is stated that the majority of shark species for the Bulgarian coast of the Black Sea are female (Radu & Maximov, 2012). Also, the growth type was reported positive allometric in the Black Sea coasts of Bulgaria by the Yankova et al. (2011). Tserkova et al. (2022), found that the "b" value for male and female individuals of the species varies seasonally. Additionally, it was determined that growth was negative allometric for autumn and positive allometric for spring. Previous studies providing LWRs for picked dogfish Türkiye seas and other localities are shown in Table 4 to compare.

There are no studies on the condition factor of the picked dogfish have been found in the Black Sea. For this reason, a comparison could not be made for the Black Sea. In our study, similar results were obtained with values of condition factor of picked dogfish found from study in Marmara Sea. The average, minimum and maximum values of condition factor were reported for Marmara Sea 0.74, 0.63 and 1.00, respectively (Karadurmuş, 2022).

Studies conducted in the northwestern region of the Black Sea show that males are dominant (Maximov et al., 2008, 2010; Radu, 2016; Tserkova et al., 2022). While female (68%) appears to be dominant in the southeastern Black Sea coasts, the ratio of female to male is 2.1:1 (Düzgüneş et al., 2005). Demirhan & Seyhan (2007) reported that females dominated the samples, with 86.3% females (n=141) and 13.7% males (n=24). Likewise, it was stated that the majority of picked dogfish for the Bulgarian coasts of the Black Sea was female (Radu & Maximov, 2012). Similarly, it was determined that females were dominant in our study (1:0.67).

While previously there were new species entering the Black Sea through ship ballast water, in recent years, due to climate change and global warming, new species have been introduced to the Black Sea from other seas. Many species that have completed their adaptation period are rapidly spreading throughout the Black Sea (Bat et al., 2007, 2011; Üstün & Birinci-Özdemir, 2019; Radulescu, 2023). When it becomes an invasive species, it can cause the biological and ecological balance in the sea to be disrupted and biodiversity to change.

Figure 5. New shark for southern Black Sea coasts (Angular roughshark, *Oxynotus centrina*)

Table 4. LWR parameters from previously study of various authors for picked dogfish

Sex	N	$L_{Min-Max}$	a	b	Location	Author(s)
F+M	-	25.2-142.7	0.0153	2.757	Black Sea-RU	Anonymous (1988)
F	-	-	0.0059	2.889	Atlantic Coasts	Coull et al. (1989)
M	-	-	0.0057	2.889		
F+M	327	22.3-141	0.0022	3.141	Black Sea-TR	Samsun et al. (1995)
F	16	27-70.5	0.0112	2.775	Aegean Sea-TR	Filiz & Mater (2002)
M	16	38-56.5	0.0023	3.282		
F+M	32	27-70.5	0.0031	3.106		
F+M	32	27.0-70.5	0.0031	3.110	Aegean Sea-TR	Filiz & Bilge (2004)
F+M	535	49.4-101.5	0.0021	3.163	Pacific Coasts	O'Driscoll & Bagley (2004)
F+M	421	19.1-117.3	0.0020	3.150	Adriatic Sea-HR	Pallaora et al. (2005)
F+M	267	36.5-141.5	0.0090	3.342	Black Sea-TR	Düzgüneş et al. (2005)
F	312	17.1-115.0	0.0027	3.128	Aegean Sea-TR	İşmen et al. (2009)
M	253	20.8-87.5	0.0072	2.867		
F+M	565	17.1-115	0.0037	3.047		
F+M	22	112-144	0.0010	3.153	Black Sea-BG	Yankova et al. (2011)
F+M	8	41-52	0.00003	2.619	Marmara Sea-TR	Bök et al. (2011)
F	108	24.5-115.5	0.0015	3.249	North Sea	Wilhelms, (2013)
M	127	25.5-97.5	0.0041	2.984		
F	346	17.1-117.5	0.0075	2.860	Aegean Sea-TR	Yığın & İşmen (2013)
M	274	20.8-121.6	0.0030	3.110		
F+M	345	20-116	0.0017	3.208	British Islands	Silva et al. (2013)
F+M	2	36.5-75.5	0.0034	3.000	Mediterranean-ES	Barría et al. (2015)
F	176	-	0.00009	3.210	Adriatic Sea-IT	Bargione et al. (2019)
M	150	-	0.00009	3.200		
F	40	45-68	0.0070	2.990	Aegean Sea-TR	Cabbar & Yığın (2021)*
M	8	41-48.1	0.0053	3.050		
F+M	48	41-68	0.0048	3.080		
F	19	67-154	0.3939	2.113	Black Sea-RO (Autumn)	Tserkova et al. (2022)
M	143	29-131	0.0082	2.867		
F+M	162	29-154	0.0122	2.791		
F	7	105-143	0.0017	3.203	Black Sea-RO (Spring)	
M	9	37-120	0.0031	3.079		
F+M	16	37-143	0.0028	3.097		
F+M	22	17.6-71.2	0.0073	2.892	Marmara Sea-TR	Karadurmuş (2022)
F+M	108	30.2-80	0.0068	2.870	Black Sea-TR	Dağtekin et al. (2022)
F	**316**	**27.2-111.8**	**0.0098**	**2.856**	**Black Sea-TR**	**This study (2023)**
M	**260**	**37.5-94.2**	**0.0103**	**2.828**		
F+M	**576**	**27.2-111.8**	**0.0097**	**2.852**		

Note: **Fork length, TR: Türkiye, RO: Romania, BG: Bulgaria, HR: Croatia, ES: Spain, IT: Italy, RU: Russia.*

Many species such as rapa whelk, angler fish, puffer fish, sand steenbras, *Mnemiopsis leidyi, Beroe ovata,* Pacific oyster, starfish, Korean rockfish, which entered the Black Sea (Daskalov & Rätz, 2011; Sümer et al., 2016; Bilecenoğlu & Öztürk, 2018; Aydın & Gül, 2021; Birinci-Özdemir, 2022; Aydemir-Çil et al., 2023; Bilecenoğlu et al., 2023) are negatively affect ecological life and commercial fishing activities. For examples; reproduction, nutrition, prey-predator relationship, protection, shelter, habitat competition, decrease in target fish stocks, increase in bycatch species, work, time and income loss, damage and breakdown of fishing equipment.

Angular roughshark has most recently been assessed for The IUCN Red List of Threatened Species in 2020. The species is listed as endangered under criteria A2d (Finucci et al., 2021). There are many studies on the angular roughshark in the Mediterranean, Aegean Sea and Marmara Sea.

It is noteworthy that the number of individuals in these studies was low. It has been determined that female individuals are more dominant than male individuals. There are length, weight and gender data for the species, obtained from the Marmara Sea in 1960 but unpublished (Kabasakal & Özbek, 2022). The maximum length for the species was determined as 80 cm in Adriatic Sea, while the smallest size was reported as 29 cm in Aegean Sea (Dragičević et al., 2009; İşmen et al., 2009).

It is stated that the Atlantic-origin angular roughshark was last seen in the Türkiye seas during a diving observation in the Marmara Sea. In the study where the swimming behavior of the species was monitored, the total length of the species was recorded as 60 cm and female, recorded with an underwater camera (Kabasakal, 2009).

Angular roughshark, which was first recorded for the Black Sea in this study, is one of them. The serious increase in the water temperature of the Black Sea due to climate change accelerates the entry of many new species into the Black Sea and also allows them to adapt easily. It is not known what the effect of the angular roughshark will be when it enters the food chain in the Black Sea and its numbers increase.

Conclusion

Consequently, it is very important to conduct more detailed study on the picked dogfish, which is an important part of the Black Sea ecosystem and is considered in the vulnerable species category. In order to ensure biodiversity balance and sustainable fishing with maximum yield, new species entering the Black Sea should be quickly identified investigated and examined.

Acknowledgements

We would like to thank the commercial fishermen (small-scale fishery and large-scale fishery) in the Black Sea coasts of Türkiye for their contributions to the collection of fish samples and their support in the field studies.

Compliance With Ethical Standards

Authors' Contributions

SÖ: Designed the study, participated in marine field studies, collected the data, examined the samples, size and weight measurement of sharks, wrote the first draft of the manuscript, data curation, software, visualization, performed and managed statistical analyses, writing-review and editing, writing-review and editing, checked final of manuscript.

UÖ: Participated in sea experiments, collected the data, size and weight measurement of sharks, writing-review and editing, checked final of manuscript.

HAD: Participated in sea experiments, collected the data, checked final of manuscript.

All authors read and approved the final manuscript.

Conflict of Interest

The authors declare that there is no conflict of interest.

Ethical Approval

For this type of study, formal consent is not required.

Data Availability Statement

All data generated or analyzed during this study are included in this published article.

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