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Research Article

Catch Composition of Different Bottom Trawl Cod-ends in the Western Black Sea

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ABSTRACT

Across the Mediterranean and the Black Sea, an improvement in technological adoption which optimizes the environmental benefits of fisheries is needed. The testing of quality standards in trawl fishing is one of the essential components. In an experiment, we tested four bottom trawl cod-ends in the western Black Sea to determine the characteristics of the catch composition. Fishing trials were conducted by 40 mm diamond (40D), 44 mm diamond (44D), 40 mm square (the 40S), and 40 mm 90-degree turned (40T) mesh cod-ends for 31 bottom trawling hauls. The multivariate analysis of catch composition indicated a significantly higher differentiation between 40D and 40T cod-ends, mainly characterized by five species: *Merlangius merlangus*, *Mytilus galloprovincialis*, *Trachinus draco*, *Mullus barbatus*, and *Uranuscopus scaber*. The difference in the shape of cod-end meshes reflected the variation in the catchability and catch composition. However, the 40S and 40T showed 80% similarity in catch composition. Among cod-ends, 40T yielded in lowest catch per unit effort for both commercial and other species. Adoption of gear specially made to catch more target species can help bottom trawl fisheries further improve their ecological and economic sustainability.

Keywords: Black Sea, Bottom trawl, catch composition, cod-end

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INTRODUCTION

Bottom trawling, globally, is an essential fishing technique used today. Approximately 22% of the landed catch in the world originates from trawl fishery (Kelleher, 2005). However, it has always been the controversial fishing gear in the Black Sea and the Mediterranean Basin. This fishing method has used cutting-edge technology to boost its efficacy ever since the beginning of the industrial era (Sacchi, 2008). The trawl technique has an important position in Turkish demersal fishery and there is a bottom trawler fleet including 820 trawlers in suitable shelf areas except for the eastern Black Sea (TÜİK, 2022). In Turkish waters, the most suitable areas for trawling in the Black Sea are between İğneada and Kefken in the western part and between the provinces of Sinop, Samsun, and Ordu in the eastern part. The littoral zone outside these areas is highly fractured and unsuitable for trawling (Kutaygil & Bilecik, 1973; Kara, 1980). On the Turkish Black Sea coast, the Central and Western Black Sea coasts are significant trawling areas (Kaykaç, Zengin, Özcan-Akpınar, & Tosunoğlu, 2014; Sağlam & Samsun, 2018).

The bottom trawl fishery is one of the essential fishing activities in the western Black Sea, regarding the volume of landings and the economic value and demersal resources have traditionally provided economically significant catches for human consumption (Yildiz, 2016; Yıldız & Karakulak, 2018a). The demersal resources in the Black Sea were exploited by 196 trawl vessels fleet (TÜİK, 2022). In the Black Sea, the catch composition of bottom trawl nets is composed of a complex of fishes and invertebrates (Yildiz & Karakulak, 2017; Öğreden & Yağlıoğlu, 2017). Whiting (*Merlangius merlangus*), red mullet (*Mullus barbatus*), and one flatfish species turbot (*Scophthalmus maximus*) are the main target species (Başkaya, 2012; Yildiz, 2016). About 96% of annual landings of demersal fish stocks have been made up of whiting and red mullet, and bottom trawlers account for the majority (90%) of those catches in the western Black Sea (TÜİK, 2022).

As a result of management failures, the stock size of many demersal resources has decreased in the last decades. The overcapacity of the bottom trawl vessels, together with management problems with the illegal design (using two cod-ends-Yildiz, 2016) and functioning of the bottom trawls are the major contributor to the discarding of the demersal fish resources in the Black Sea (Ceylan, Şahin, & Kalaycı., 2014; Yildiz & Karakulak, 2017). High discarding rates (Başkaya, 2012; Ceylan et al., 2014; Yildiz, 2016; Öğreden & Yağlıoğlu; Yıldız and Karakulak, 2018b) and landing of small-sized specimens (Başkaya, 2012; Yildiz, 2016; Yıldız & Karakulak, 2018b) by bottom trawling have led the governments and regional commissions to apply more selective mesh sizes and mesh shapes (GFCM, 2009). According to the current management, the mesh size of the trawl cod-end in the Black Sea cannot be less than 40 mm square mesh, and after 1 September 2024, the 44 mm rhombic mesh cod-end will be permitted to use (BSGM, 2020) On the other hand, since 2008, European Union members in the Mediterranean Basin have been allowed to use and onboard only one of the 40 mm square mesh or 50 mm rhombic mesh cod-ends (COUNCIL REGULATION (EC) 1967/2006; GFCM/33/2009/2).

In Turkey and all over the world, demersal resources have been fished less than pelagic stocks, however, these species have a relatively high economic return (Genç, 2000). All species also have a significant impact on the resiliency and evolution of the ecosystem. Hence, to make optimum use of and protect fish stocks, management actions should be determined by scientific research. However, there are selectivity studies for different mesh sizes in the Black Sea (Özdemir, Erdem & Erdem, 2012; Zengin, Akpınar, İ., Kaykaç, & Tosunoğlu, 2019), but no study evaluates the catch composition of the different codends. Catch composition means species diversity is defined as species' variety and relative abundance (Winston B et al., 2019). Investigating how fishing affects marine ecosystems involves whole systems. For the first time in the Black Sea, this study provides new insights into the catch composition of the bottom trawl nets equipped with different mesh cod-ends configurations as 40 mm diamond (40D), 44 mm diamond (44D), 40 mm square (the 40S) and 40 mm 90-degree turned (40T).

MATERIAL AND METHODS

Study plan and data collection

This study was conducted in the coastal area between Kıyıköy/Kırklareli and Kefken/Kocaeli (Figure 1). Operations were carried out between 21 and 28 July 2019 with the R/V Yunus S research vessel, 32 m long, and 500 HP engine power. The coordinates

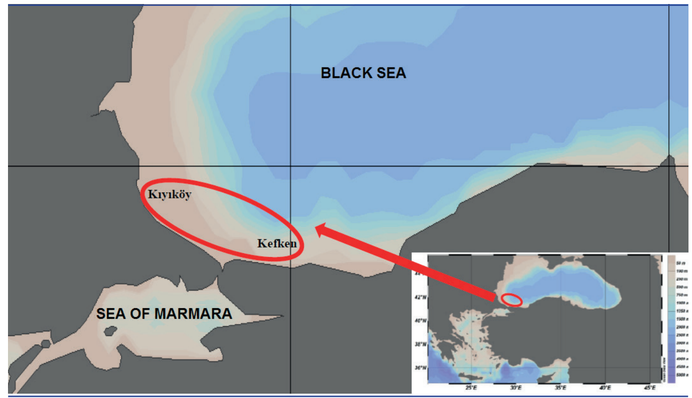

Figure 1. A general map of the sampling area.

and depth (m) data of the areas for each trawl operation were recorded. Haul durations were kept short of adequate sampling by four test cod-ends as 30 minutes and a constant speed of 3 miles/hour. The depth ranges of the stations varied between 19 m and 61 m.

A 900-mesh bottom trawl net, widely used by a commercial trawler, was employed. A 40 mm diamond (40D) mesh, legally used by trawlers, and three alternative cod-ends were tested. A 44 mm diamond (44D) mesh size was allowed for the Black Sea in bottom trawl fishing in fishery management (BSGM, 2020). Cod-ends have traditionally been constructed using diamond netting oriented with its normal direction in-line with the towing direction, also known as the T0 orientation - oriented 0° in the transversal or towing direction. However, this same netting can be installed in such a way that the mesh is rotated 45° (T45) or 90° (T90) in the transversal direction and improving size selectivity (Einarsson, Cheng, Bayse, Herrmann & Winger, 2021). In addition, the 40 mm mesh size of the square (the 40S) and 90-degree turned mesh (40T) cod-end were assessed. The length of all trawl cod-ends used in the study is 5 m. With the 40D, 44D, and 40S trawls, eight hauls were made; the 40T trawl cod-end produced seven hauls. For each species maintained, the total weights for each haul were recorded. The total weights and numbers were directly recorded when the catch was low; otherwise, a subsample was taken and sorted into the lowest taxonomic level.

Data analysis

The average catch per unit effort for the species caught in the four-trawl cod-ends was calculated using the following formula (Phiri & Shrikihara, 1999). The amount of catch per hour (kg. hour^{-1}) was calculated and standardized for each trawling.

$$CPUE = \frac{\Sigma\, Ci/Nh}{t/Nh}$$

Ci: The amount of catch per trawling (kg), t: Haul duration, Nh: Number of operations

The statistical significance of the difference between the CPUE values was checked with the One-Way ANOVA Test by using the "aov" function in the"ggpubr" package through R Studio version 4.2.1 (R Core Team, 2022). Before this test, it was checked whether the data were in the normal distribution or not and whether the variances were homogeneous with the Levene test. Log(x+1) transformations were applied if data didn't fit the normal distribution (Zar, 1999; Ozdamar, 2009).

CPUE data were matrixed by the Bray-Curtis Similarity matrix for similarity tests in various cod-ends, and cluster analysis was compared (Bray & Curtis, 1957; Everitt, 1980). The data were transformed using the logx+1 transformation before the cluster analysis (Field et al., 1982). Transformed data were used for cluster analysis and nonparametric multidimensional scaling (nMDS). The "analysis of similarity percentages (SIMPER)" test was used to determine the species that caused the difference in trawl cod-ends by using the Primer 6 statistical package program (Clarke & Warwick, 2001; Quinn & Keough, 2002). Species number (S), species richness (d), species diversity, Shannon-Weaver diversity index (H'log2), Pielou's equation index (J'), and Simpson Dominance-Diversity index (1-λ) were calculated by using abundance values.

RESULTS

Catch composition

64104 individuals (701.13 kg) belonging to 33 species were obtained by 31 bottom trawling operations. The catch composition of four different trawl cod-ends was given in Table 1. While the highest number of species was taken in the 40D (28 species) and

Table 1. Species and catches (kg) in examined cod-ends.

			Cod-ends					
	Species	**Value**	**44D**	**40D**	**40S**	**40T**	**TOTAL**	**%**
Chordata	*Dasyatis pastinaca*	NC	14.75	0.50	1.50	0	16.75	2.39
Chordata	*Raja clavata*	NC	0.55	0	1.50	0	2.05	0.29
Chordata	*Arnoglossus kessleri*	NC	0.03	0.12	0.04	0	0.18	0.03
Chordata	*Callionymus risso*	NC	0	0.10	0	0	0.10	0.01
Chordata	*Chelidonichthys lucerna*	C	0	0.15	0.08	0.13	0.35	0.05
Chordata	*Gaidropsarus mediterraneus*	NC	0.17	0	0	0	0.17	0.02
Chordata	*Gobius niger*	NC	0.50	4.72	0.96	0.61	6.78	0.97
Chordata	*M. merlangius euxinus*	C	64.76	114.98	20.12	12.10	211.96	30.23
Chordata	*Mesogobius batrachocephalus*	NC	1.95	0.64	0.05	0.05	2.69	0.38
Chordata	*Mullus barbatus*	C	19.30	6.40	0.33	0.12	26.14	3.73
Chordata	*Neogobius melanostomus*	NC	0.23	4.25	0.96	0.42	5.85	0.83
Chordata	*Parablennius tentacularis*	NC	0	0.05	0.02	0	0.07	0.01
Chordata	*Pegusa nasuta*	C	0.98	0	0.37	0	1.35	0.19
Chordata	*Platichthys flesus*	C	0.02	0.06	0.14	0.18	0.40	0.06
Chordata	*Scophthalmus maximus*	C	1.25	4.14	1.06	0.43	6.87	0.98
Chordata	*Scorpaena porcus*	NC	0.88	0.19	0.12	0.01	1.19	0.17
Chordata	*Sprattus sprattus*	C	0.30	4.06	0.54	1.34	6.22	0.89
Chordata	*Syngnathus abaster*	NC	0	0.06	0.01	0	0.07	0.01
Chordata	*Trachinus draco*	NC	0.82	7.46	1.59	0.26	10.12	1.44
Chordata	*Trachurus mediterraneus*	C	0.24	0.03	0	0	0.27	0.04
Chordata	*Uranoscopus scaber*	NC	7.56	15.02	12.24	4.75	39.57	5.64
Arthropoda	*Crangon crangon*	NC	0	0.04	0	0	0.04	0.01
Arthropoda	*Liocarcinus depurator*	NC	42.45	93.00	74.60	44.36	254.40	36.28
Arthropoda	*Liocarcinus navigator*	NC	0.05	0.36	0.11	0.25	0.77	0.11
Arthropoda	*Eriphia verrucosa*	NC	0.50	1.63	1.56	1.17	4.86	0.69
Mollusca	*Anadara inaequivalvis*	NC	0	0.08	0	0	0.08	0.01
Mollusca	*Mytilus galloprovincialis*	C	23.80	0.42	39.51	21.93	85.66	12.22
Mollusca	*Chamelea gallina*	C	0	0.13	0	0	0.13	0.02
Mollusca	*Rapana venosa*	C	0.98	0.21	0.35	0.12	1.66	0.24
Mollusca	*Acanthocardia deshayesii*	NC	0.01	0.01	0	0.05	0.07	0.01
Echinodermata	*Stereoderma kirschbergi*	NC	0.01	0	0	0	0.01	0.00
Tunicata	*Corella eumyota*	NC	0	7.90	3.17	3.12	14.19	2.02
Porifera	*Suberites domuncula*	NC	0.14	0	0.01	0.04	0.19	0.03
	TOTAL		182.20	266.64	160.88	91.41	701.13	

C:Commercial; NC: Non-commercial

the lowest was in the T90 (20 species). The maximum number of individuals was taken from 40D with 25199, followed by 44D with 15879, the 40S with 13865, and 40T with 9161. The same trend was observed in terms of catch amount.

The most dominant species were *Liocarcinus depurator* (55.5 %), *Merlangius merlangus euxinus* (23.42%), *Mytilus galloprovincialis* (% 8.78), *Mullus barbatus* (3.63%), *Sprattus sprattus* (3.02%), *Uranoscopus scaber* (1.46%) by numbers (Figure 2). The most dominant species by weight were *Liocarcinus depurator* (36.28%), *Merlangius merlangus euxinus* (30.23%), *Mytilus galloprovincialis* (12.22%), *Uranoscopus scaber* (5.64%), *Mullus barbatus* (3.73%) and *Dasyatis pastinaca* (2.39%) (Table 1).

Catch per unit effort (CPUE)

The minimum, maximum, mean, standard deviation, and standard error values of CPUE were given in Table 2 and Figure 3. The p-value of the cod-end variable is low ($p<0.05$), so it appears that the type of cod-end used has a real impact on the CPUE. The highest CPUE value was obtained in the 40D as 66.66±13.00 kg. hour^{-1}and followed by 44D with 45.55±7.34 kg. hour^{-1}, 40S with 40.22±6.04 kg. hour^{-1} and 40T with 26.12±3.60 kg. hour^{-1}. Among commercial fish (Table 1), whiting had the highest CPUE value of 28.75±15.56 kg. hour^{-1} with 40D cod-end ($p<0.05$) and the highest CPUE of red mullet was caught in 44D cod-end with 4.83±2.62 kg. hour^{-1} ($p<0.05$).

The similarity in catch composition

According to the Bray-Curtis similarity index, the 40D formed a single group (Fig 4 and 5), while the other three cod-ends formed a separate group. The 40S and 40T were at 83% similarity level, while 44D was 67% and 40D was at 60% similarity levels. Table 3 lists the species that contribute to the difference and their rates of contribution according to SIMPER analysis. Table 3 demonstrates that the 40D and 40T had the most significant difference (mean dissimilarity = 42.40).

Ecological indexes

The number of species ranged from 22 to 26, the species richness ranged from 2.668 to 3.017, and the Shannon-Wiener diversity index ranged from 1.171 to 1.327 (Table 4). The highest number of species was observed in 40D, while the lowest was in 40T.

DISCUSSION

This study compared the catch composition, CPUE, and species diversity of 40D, used in commercial bottom trawling in the Black Sea, and alternative cod-ends (44D, the 40S, and 40T).

Bottom trawlers are used extensively to catch demersal species on the Turkish coast. The number of species caught in Turkish waters by bottom trawlers is more than 50 (Tosunoğlu, Özbilgin & Özbilgin, 2003), even 84 species were recorded in the Aegean Sea (Sokyan et al., 2016). Another study revealed that as depth climbed, the number of species rose to 200. (Soykan et al., 2019). However, commercial trawlers in the Black Sea with 40 mm diamond mesh have captured anywhere between 18 and 34 species (Aksu, 2012; Başkaya, 2012; Yıldız, 2016). Bony fishes were the main category, according to Aksu (2012), Başkaya (2012), and Yıldız (2016), who identified 11, 25, and 22 species, respectively. According to Yıldız, Zengin, Karakulak, Uzer & Özcan Akpınar

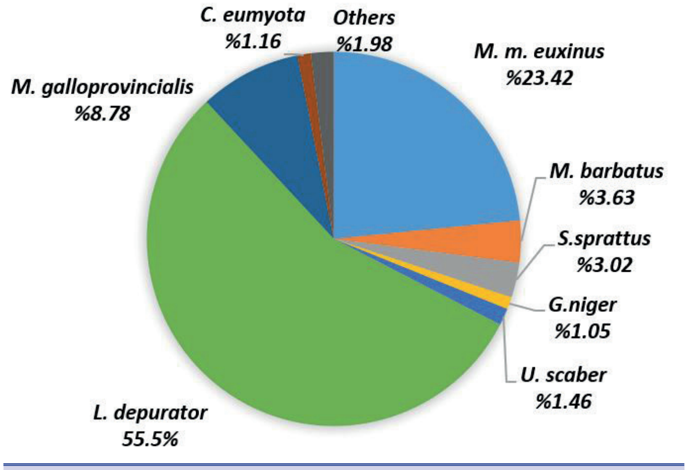

Figure 2. Numerical distribution of species obtained from bottom trawl trials.

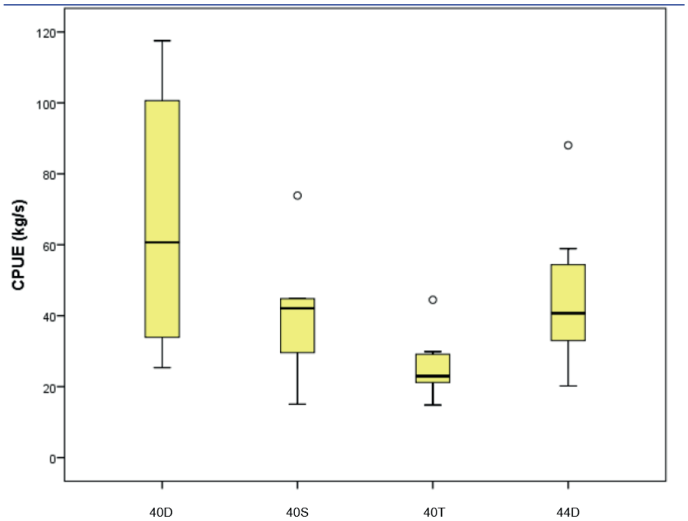

Figure 3. Variation of CPUE values obtained in trawl cod-ends.

Table 2. CPUE values of examined codends

Cod-ends	No. hauls	Min.	Max.	Mean	SD	SE
44D	8	20.20	88.05	45.55	20.76	7.34
40D	8	25.35	117.55	66.66	36.78	13.00
40S	8	15.05	73.86	40.22	17.08	6.04
40T	7	14.81	44.47	26.12	9.51	3.60

Table 3. Average dissimilarity rates between trawl cod-ends and the species that contributed to the difference.

44D & 40D (Average dissimilarity = 40.45)					
	44D	**40D**			
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Cont. %**	**Cum.%**
M. galloprovincialis	1.94	0.10	6.32	15.63	15.63
D. pastinaca	1.55	0.12	4.90	12.12	27.75
C. eumyota	0	1.09	3.75	9.27	37.02
T. draco	0.18	1.05	2.99	7.40	44.42
M. barbatus	1.76	0.96	2.78	6.88	51.30
L. depurator	2.45	3.19	2.54	6.27	57.58
G. niger	0.11	0.78	2.30	5.67	63.25
N. melanostomus	0.06	0.72	2.29	5.66	68.91
S. sprattus	0.07	0.70	2.17	5.37	74.28
M. m. euxinus	2.84	3.39	1.89	4.67	78.95
U. scaber	1.06	1.56	1.71	4.23	83.19
S. maximus	0.27	0.71	1.53	3.77	86.96
M. batrachocephalus	0.40	0.15	0.86	2.13	89.09
P. nasuta	0.22	0	0.77	1.90	90.99
44D & 40S (Average dissimilarity = 30.71)					
	44D	**40S**			
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Cont. %**	**Cum.%**
M. barbatus	1.76	0.08	6.64	21.63	21.63
D. pastinaca	1.55	0.32	4.82	15.69	37.32
M. m. euxinus	2.84	1.80	4.13	13.44	50.76
C. eumyota	0	0.58	2.29	7.47	58.23
L. depurator	2.45	2.98	2.07	6.75	64.98
M. galloprovincialis	1.94	2.39	1.77	5.75	70.73
M. batrachocephalus	0.40	0.01	1.53	4.99	75.72
U. scaber	1.06	1.40	1.34	4.36	80.08
E. verrucosa	0.12	0.33	0.82	2.66	82.73
R. clavata	0.13	0.32	0.75	2.45	85.19
S. porcus	0.20	0.03	0.67	2.17	87.36
N. melanostomus	0.06	0.22	0.62	2.01	89.37
T. draco	0.18	0.34	0.61	1.98	91.35
40D & 40mmS (Average dissimilarity = 35.51)					
	40D	**40S**			
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Cont. %**	**Cum.%**
M. galloprovincialis	0.10	2.39	8.49	23.91	23.91
M. m. euxinus	3.39	1.80	5.94	16.72	40.63
M. barbatus	0.96	0.08	3.27	9.20	49.84
T. draco	1.05	0.34	2.66	7.48	57.32
S. sprattus	0.70	0.12	2.14	6.03	63.35
G. niger	0.78	0.22	2.10	5.91	69.26
N. melanostomus	0.72	0.22	1.89	5.32	74.58
C. eumyota	1.09	0.58	1.88	5.30	79.88
S. maximus	0.71	0.23	1.79	5.05	84.93
R. clavata	0	0.32	1.20	3.37	88.31
L. depurator	3.19	2.98	0.78	2.20	90.51

Table 3. Continue.

44D & 40T (Average dissimilarity = 34.79)					
	44D	**40T**			
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Cont. %**	**Cum.%**
M. barbatus	1.76	0.03	7.65	22.00	22.00
D. pastinaca	1.55	0	6.82	19.61	41.61
M. m. euxinus	2.84	1.50	5.96	17.12	58.74
C. eumyota	0	0.64	2.81	8.08	66.81
M. batrachocephalus	0.40	0.01	1.72	4.93	71.75
S. sprattus	0.07	0.32	1.12	3.23	74.98
P. nasuta	0.22	0	0.99	2.83	77.81
U. scaber	1.06	0.86	0.89	2.57	80.38
S. porcus	0.20	0	0.88	2.52	82.90
R. venosa	0.22	0.03	0.85	2.46	85.36
L. depurator	2.45	2.62	0.72	2.07	87.43
E. verrucosa	0.12	0.29	0.72	2.07	89.50
S. maximus	0.27	0.11	0.69	1.99	91.49
40D & 40T (Average dissimilarity = 42.40)					
	40D	**40T**			
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Cont. %**	**Cum.%**
M. m. euxinus	3.39	1.50	7.86	18.53	18.53
M. galloprovincialis	0.10	1.98	7.78	18.34	36.87
T. draco	1.05	0.07	4.07	9.60	46.48
M. barbatus	0.96	0.03	3.83	9.04	55.52
U. scaber	1.56	0.86	2.90	6.83	62.35
G. niger	0.78	0.16	2.58	6.08	68.43
N. melanostomus	0.72	0.11	2.52	5.95	74.38
S. maximus	0.71	0.11	2.48	5.86	80.24
L. depurator	3.19	2.62	2.37	5.60	85.83
C. eumyota	1.09	0.64	1.87	4.41	90.25
40S & 40T (Average dissimilarity = 16.66)					
	40S	**40T**			
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Cont. %**	**Cum.%**
U. scaber	1.40	0.86	2.64	15.88	15.88
M. galloprovincialis	2.39	1.98	1.97	11.84	27.71
L. depurator	2.98	2.62	1.77	10.62	38.33
D. pastinaca	0.32	0	1.57	9.43	47.76
R. clavata	0.32	0	1.57	9.43	57.18
M. m. euxinus	1.80	1.50	1.47	8.83	66.01
T. draco	0.34	0.07	1.31	7.87	73.88
S. sprattus	0.12	0.32	0.97	5.85	79.72
S. maximus	0.23	0.11	0.57	3.45	83.17
N. melanostomus	0.22	0.11	0.50	2.98	86.15
P. nasuta	0.09	0	0.42	2.52	88.67
G. niger	0.22	0.16	0.28	1.70	90.37

Av.Abund: Avearge abundance; Av.Diss: Avearge Dissimilarity; Cont. %: Contribution percentage; Cum.%: Cumulative contribution percentage

Table 4. Ecological index values for the examined trawl codends.

Cod-ends	S	d	J'	H'(log_e)	1-λ
44D	26	3.017	0.3865	1.259	0.616
40D	28	3.086	0.3952	1.317	0.6186
40S	25	2.944	0.3636	1.171	0.5636
40T	22	2.668	0.4294	1.327	0.6256

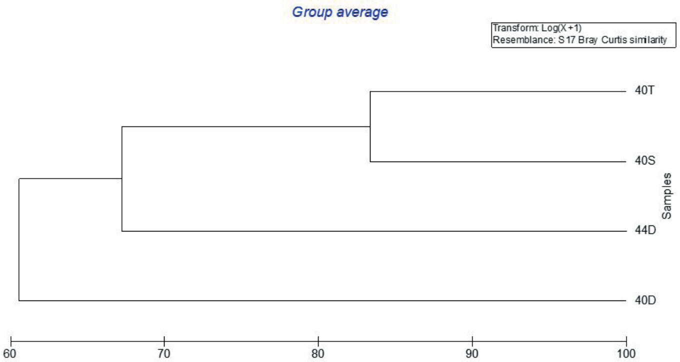

Figure 4. Clustering dendrogram based on Bray-Curtis similarity analysis of species caught in examined trawl cod-ends.

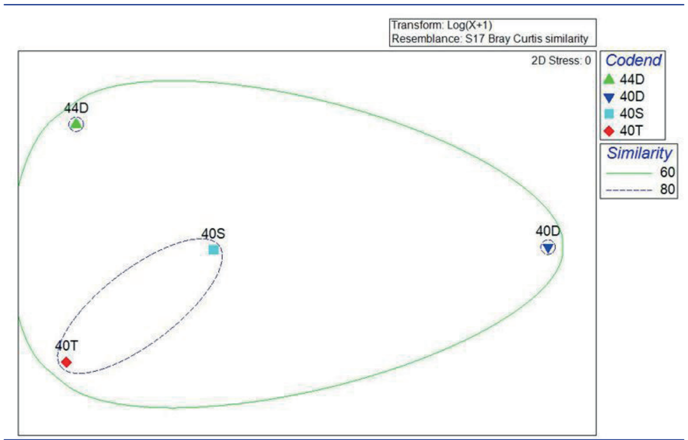

Figure 5. nMDS (Multidimensional scaling) analysis of species caught in examined trawl cod-ends.

(2019), depth is statistically the most influential factor determining the ordination of the faunal zonation in the study area. The species richness ranged from 2.668 to 3.017, and the Shannon-Wiener diversity index ranged from 1.171 to 1.327 during the study period. The species richness index value calculated by previous studies in the Western Black Sea Region was found between 0.177 and 2.156 in 2016 (ÇŞB, TUBITAK MAM, 2017) and between 0.691 and 1.809 in 2019 (ÇŞB, TUBITAK MAM, 2021). The Black Sea species diversity is relatively low compared to the Aegean Sea and the Mediterranean Sea. The species diversity varies according to the season, depth, behavior of the species, the duration of light during the day, the experiment period and time, the bottom structure, and the water's physical characteristics. The presence of fish or other species in the prey-predator status and their abundance are two additional dependent and independent variables that can alter the composition of the catch (Özbilgin & Ferro 1997; Özbilgin & Wardle 2002).

Gönener and Bilgin (2010) reported that red mullet, whiting, and turbot rank first in stock sizes, according to the data they obtained with their calculations covering two fishing seasons in the Black Sea. They noted that the changes in fish stock density in commercial trawling fishing areas might vary daily, monthly, or seasonally. Catch density of other species in the fishing area, and bioecological and physicochemical properties of waters can also affect this change.

CPUE is a proximal measure of a target species' abundance. To determine changes in the target species' abundance, CPUE changes were calculated. Overfishing is indicated by a decrease in CPUE values, whereas sustainable fishing is shown by a constant CPUE value (Puertas & Bodmer, 2004; Skalski, Ryding & Millspaugh, 2005). CPUE values were calculated as 241.63 kg. hour^{1} in autumn and 29.64 kg. hour^{1} in spring in 2010/2011 fishing season in bottom trawl fisheries in the Western Black Sea (Başkaya, 2012). Yıldız (2016) found that CPUE values as 100.4 kg. hour^{1}in the autumn and 27.9 kg. hour^{1} in the spring in the fisheries seasons of 2012/2013 and 2013/2014. Similarly, in other studies conducted in the Mediterranean and Black Seas, it has been reported that CPUE values are higher at the beginning of the trawling season, while CPUE values decrease throughout the season (Machias et al., 2001; Çiçek, 2006; Aksu, 2012). In this summer study, the average CPUE value was calculated for 44D as 40.22±6.04 kg. hour^{1}, for 40D as 66.66±13.00 kg. hour^{1}, for 40S as 45.55±7.34 kg. hour^{1}, for 40T as 26.12±3.60 kg. hour^{1}. The highest CPUE value of whiting, one of the commercial fish, was 28.75±15.56 kg. hour^{1} 40D and the highest CPUE value of red mullet was detected in 44D as 4.83±2.62 kg. hour^{1}. The difference between CPUE values 40D for whiting between 40D -the 40S and 40D - 40T was significant. In addition, the difference between 44D-40T and 40D-40T for red mullet and the total catch was significant.

The most efficient trawl cod-end in terms of catch rates, and the number of species obtained in this study is the diamond mesh with 40D. When we examine the ratios and CPUE values of red mullet and whiting determined as the target species in the catch composition, these ratios were found to be higher for 44D and 40D but relatively low for the 40S and 40T. It was found that the amount of whiting decreases by half when the mesh size increases from 40 mm to 44 mm for the diamond mesh shape. Considering the economic concerns (profits) of the fishers, the catch efficiency of square mesh and T90 trawl cod-ends in the Western Black Sea region is relatively low. It is clear from these results that there are pros and cons to each of these cod-ends. To prevent illegal fishing, new fisheries management policies need to be more moderate and accepted by fishermen. Better regulation of the double cod-end usage ban is required for a sustainable fishery.

The Mediterranean General Fisheries Commission (GFCM), responsible for the Mediterranean fisheries management, has decided to apply 40 mm square nets or 50 mm diamond mesh cod-ends for all trawling activities in the Mediterranean basin since 2009. The immediate implementation of the square mesh types advised by the scientific committee (GFCM/33/2009/2) will improve the protection of juveniles of different species and develop the selectivity of 40 mm diamond mesh cod-ends in bottom trawling fishing vessels and multi-species fisheries. Similarly, the European Union has made it mandatory to use 40 mm square or 50 mm diamond mesh cod-ends instead of 40 mm rhombic for bottom trawl nets used in the European Union waters of the Mediterranean basin. According to Turkish fisheries legislation, 44 mm diamond mesh is used in bottom trawl nets in the Aegean Sea and the Mediterranean Sea, and 40 mm diamond is employed in the Black Sea. It is stated that after 1 September 2020, rhombic-eyed trawl nets will be applied as 44 mm in the Black Sea in the communiqué, Fisheries No. 2016/35 (BSGM, 2016). Since the fishermen's organizations stated that this practice would adversely affect the fishing activities in the Black Sea, it has not yet entered into force (BSGM, 2020) and is to be after 1 September 2024.

It has been reported that fish in 40 mm square mesh trawl codend were injured during the removal process from the net, and therefore fishers were not satisfied with square mesh nets (Dogru, 2014). It is also known that square mesh cod-ends are not used in bottom trawl fishing in Turkey. The reasons for this are the economic loss of fish, no production of rhombic mesh nets by the fishing net factories, and the need for more labor as species are compressed and crushed in the cod end meshes.

It has been stated that 28mmD trawl cod-end is harmful in terms of species diversity, demersal stocks, and commercial/non-commercial species (Stergiou, Politou, Christou & Petrakis, 1997). In Greek waters, 40mm diamond mesh cod-end is more effective than 40mm square mesh with regard to commercial/non-commercial species ratios (Stergiou et al., 1997). It has been determined in the Western Black Sea that the 40D trawl cod-end is more efficient than the other trawl cod-ends from the fishers' perspective.

Comparing the Mediterranean and the Black Sea in terms of biodiversity, they are two very different seas. Only two commercial fish species—red mullet and whiting—are caught frequently in bottom trawl fisheries, despite the Black Sea's low biodiversity. The high-body-height fish species that are frequently found in bottom trawling in the Aegean and Mediterranean are missing from the Black Sea. Therefore, it is essential for sustainable fishing to adjust the characteristics of the fishing gear used according to the characteristics of the fish in the region. Decision-makers should take appropriate management steps for this region by taking into account the results of the present study and the outputs of socioeconomic research.

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REFERENCES

Aksu, H. (2012). Sinop Bölgesinde Dip Trolü Avcılığının Derinlik ve Bazı Meteorolojik Kriterlere Göre Av Verimi ve Kompozisyonunun Araştırılması, Doktora Tezi, Sinop Üniversitesi Fen Bilimleri Enstitüsü.

Başkaya, A. (2012). Batı Karadeniz'de Dip Trol Ağlarının Av Kompozisyonu ve Hedef Dışı Avın Belirlenmesi, Yüksek Lisans Tezi, İstanbul Üniversitesi Fen Bilimleri Enstitüsü

BSGM. (2016). Regulation for Commercial Fisheries in Seas and Inland Waters for 2016–2020 Fishing Period, number 4/1 (No: 2016/35). Ankara: General Directorate of Fisheries and Aquaculture (BSGM), Republic of Turkey Ministry of Food Agriculture and Livestock [In Turkish].

BSGM. (2020). Regulation for Commercial Fisheries in Seas and Inland Waters for 2020–2024 Fishing Period, number 5/1 (No: 2020/20). Ankara: General Directorate of Fisheries and Aquaculture (BSGM), Republic of Turkey Ministry of Food Agriculture and Livestock [In Turkish].

Ceylan, Y., Şahin, C. & Kalaycı, F. (2014). Bottom trawl fishery discards on the Black Sea coast of Turkey. *Mediterranean Marine Science*, 15, 156-164. https://doi.org/10.12681/mms.421

COUNCIL REGULATION (EC). (2006). 1967/2006 of 21 December 2006 concerning management measures for the sustainable exploitation of fishery resources in the Mediterranean Sea, amending Regulation (EEC) No 2847/93 and repealing Regulation (EC) No 1626/94. OJ L 409/11.

Çiçek, E. (2006). Karataş (Adana) Açıklarında Dip Trolleriyle Avlanan Ekonomik Potansiyele Sahip Türlerin İncelenmesi, Doktora Tezi, Çukurova Üniversitesi, Fen Bilimleri Enstitüsü.

ÇŞB, TÜBİTAK MAM (2017). Denizlerde Bütünleşik Kirlilik İzleme Programı 2014-2016 Karadeniz Özet Raporu, ISBN:978-605-5294-70-0, TÜBİTAK-MAM Matbaası Gebze/Kocaeli, 69 sy., Ankara.

ÇŞB, TÜBİTAK MAM (2021). Denizlerde Bütünleşik Kirlilik İzleme Programı 2014-2019 Karadeniz Özet Raporu, ISBN: 978-625-7076-21-0, TÜBİTAK-MAM Matbaası Gebze/Kocaeli, 69 sy., Ankara.

Einarsson, H.A., Cheng, Z., Bayse, S.M., Herrmann, B. & Winger, P.D. (2021). Comparing the size selectivity of a novel T90 mesh codend to two conventional codends in the northern shrimp (*Pandalus borealis*) trawl fishery. *Aquaculture and Fisheries*, 6(4), 382-392. https://doi.org/10.1016/j.aaf.2020.09.005

Erdoğan Sağlam, N & Samsun, S. (2018). An investigation on bottom trawl fishery in the Middle Black Sea. *Ege Journal of Fisheries and Aquatic Sciences*, 35(2), 189-193. https://doi.org/10.12714/egejfas.2018.35.2.12

Genç, Y. (2000). Bio-Ecological and Population Parameters for Red Mullet (*Mullus barbatus ponticus*, Ess. 1927) in the Eastern Black Sea Coastal Ph.D. thesis. Black Sea Technical University, Department of Fisheries Technology Engineering, Trabzon.

GFCM. (2009). On the minimum mesh size in the cod-end of demersal trawl nets. REC.CM-GFCM/33/2009/2

Kara, Ö.F. (1980). Fishery potential of Black Sea and Fish catching possibility in the region. Bank for the Development of Industry of Turkey, No. 32.

Kaykaç, M. H., Zengin, M., Özcan-Akpınar, İ., & Tosunoğlu, Z. (2014). Structural characteristics of towed fishing gears used in the Samsun coast (Black Sea). *Ege Journal of Fisheries and Aquatic Sciences*, 31(2), 87-96. https://doi.org/10.12714/egejfas.2014.31.2.05

Kutaygil, N. & Bilecik, N. (1973). Karadeniz Kıta Sahanlığı Trol Araştırmaları, E.B.K. Balıkçılık Müessesesi Mü-dürlüğü Araştırma Raporu.

Machias, A., Vasilopoulou, V., Vatsos, D., Bekas, P., Kallianotis, A., Papaconstantinou, C. & Tsimenides, N. (2001). Bottom trawl discards in the northeastern Mediterranean Sea. *Fisheries Research*, 53, 181–195. https://doi.org/10.1016/S0165-7836(00)00298-8

Öğreden, T. & Yağlıoğlu, D. (2017). Catch Composition of Bottom Trawl Fisheries in Düzce Coast, southwestern Black Sea. *Natural and Engineering Sciences*, 2(3), 158-167. https://doi.org/10.28978/nesciences.368342

Özbilgin, H. & Ferro, R.S.T. (1997). Seasonal Variation in Codend Selectivity of Haddock, Akdeniz Balıkçılık Kongresi. 9-11 April 1997, İzmir.

Özbilgin, H. & Wardle, C.S. 2002. Effect of Seasonal Temperature Changes on the Escape Behaviour of Haddock, *Melanogrammus aeglefinus*, from the Codend. *Fisheries Research*, 58(3), 323-331. https://doi.org/10.1016/S0165-7836(01)00394-0

Özdamar, E., Samsun, O., Kihara, K. & Sakuramoto, K. (1996). Stock assessment of whiting, *Merlangıus merlangus euxınus* along the Turkish coast of the Black Sea. *Journal of Tokyo University of Fisheries*, 82 (2), 135-149.

Özdemir, S., Erdem, Y. & Erdem, E. (2012). The Determination of Size Selection of Whiting (*Merlangius merlangus euxinus*) by Square Mesh Panel and Diamond Mesh Codends of Demersal Trawl in the Southern Part of Black Sea. *Turkish Journal of Fisheries and Aquatic Science*, 12, 407-410. https://doi.org/10.4194/1303-2712-v12_2_29

Phiri, H. & Shirakihara, K. (1999). Distribution and seasonal movement of pelagic fish in southern Lake Tanganyika. *Fisheries Research*, 41, 63-71. https://doi.org/10.1016/S0165-7836(99)00008-9.

Puertas, E.P. & Bodmer, R. (2004). Hunting Effort As A Tool For Communtiy-Based Wildlife Managment in Amazonia: Wildlife Consevation in South and Central Americ, People in Nature, https://doi.org/10.7312/12SILV12782-008

R Core Team (2022). R: A language and environment for statistical computing. R Foundation for

Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Richard Winston B, Phiri TB. & Singini W. (2019). Assessment of catch composition and economic analysis of monofilament and multifilament under-meshed gears (Ngongongo) at Likoma Island, Lake Malawi. *Journal of Fisheries Research*, 3(1),7-17. https://doi.org/10.35841/fisheries-research.3.1.7-17

Robert, M., Morandeau, F., Scavinner, M., Fiche, M. & Larnaud, P. (2020) Toward elimination of unwanted catches using a 100 mm T90 extension and codend in demersal mixed fisheries. *PLoS ONE* 15(7), e0235368. https://doi.org/10.1371/journal.pone.0235368

Sacchi J. (2008). The use of trawling nets in the Mediterranean. Problems and selectivity options. In: Basu rco B. (ed.). The Mediterranean fisheries sector. A reference publication for the VII meeting of Ministers of agriculture and fisheries of CIHEAM member countries (Zaragoza, Spain, 4 february 2008). Zaragoza : CIHEAM / FAO / GFCM, 2 008. p. 87 -9 6 (Option s Méditerranéenn es : Série B. Etu des et Recherches; n . 62)

Sánches, P., Sartor, P., Recasens, L., Ligas, A., Martın, J., De ranıerı, S. & Demestre, M. (2007). Trawl catch composition during different fishing intensity periods in two Mediterranean demersal fishing grounds. *Scienta Marina*, 71(4), 765-773. https://doi.org/10.3989/scimar.2007.71n4765

Skalski, J.R., Ryding, K.E. & Millspaugh, J.J. (2005). *Analysis of population indices*. Wildlife Demography: Analysis of Sex, Age, and Count Data. Academic Press. pp. 359–434. ISBN 978-0-12-088773-6.

Soykan, O. Z. A. N., Akgül, Ş. A., & Kınacıgil, H. T. (2016). Catch composition and some other aspects of bottom trawl fishery in Sığacık Bay, central Aegean Sea, eastern Mediterranean. Journal of Applied Ichthyology, 32(3), 542-547. https://doi.org/10.1111/jai.13042

Soykan, O., Bakır, K., & Kınacıgil, H. T. (2019). Demersal trawl discards with spatial and bathymetric emphasis in the Turkish coast of the Aegean Sea. Marine Biology Research, 15(1), 113-123. https://doi.org/10.1080/17451000.2019.1576902

Stergiou, K.I., Politou, C.Y., Christou, E.D. & Petrakis, G. (1997). Selectivity experiments in the NE Mediterranean: the effect of trawl codend mesh size on species diversity and discards. *ICES Journal of Marine Science*, 54(5), 774–786. https://doi.org/10.1006/jmsc.1997.0231

Tosunoğlu, Z., Özbilgin, Y.D. & Özbilgin, H. (2003). Body Shape and Trawl Codend Selectivity for Nine Commercial Fish Species. *Journal of the Marine Biological Association of the United Kingdom*, 83(6): 1309-1313. https://doi.org/10.1017/S0025315403008737

TÜİK. (2022). Fisheries statistics. Turkish Statistical Institute. https://biruni.tuik.gov.tr/medas/?kn=97&locale=tr

Yıldız T. & Karakulak F.S. (2017). Discard in Bottom-Trawl Fishery in the Western Black Sea (Turkey). *Journal of Applied Ichthyology,* 33(4), 689-698. https://doi.org/10.1111/jai.13362

Yıldız, T. (2016). Batı Karadeniz'de Ticari Demersal Balık Stokları Üzerine Trol Balıkçılığının Etkisi, Doktora Tezi, İstanbul Üniversitesi Fen Bilimleri Enstitüsü.

Yıldız, T. & Karakulak, F.S. (2018a). The catch composition of bottom trawl fishing in the Western Black Sea (Şile-İğneada). *Journal of Aquaculture Engineering and Fisheries Research,* 4(1), 20–34. http://dx.doi.org/10.3153/JAEFR18003.

Yıldız, T. & Karakulak, F.S. (2018b). General characteristics of bottom trawl fishery and effect of haul duration and total catch on discard in the Western Black Sea. *Ege Journal of Fisheries and Aquatic Sciences,* 35(1), 19-26. https://doi.org/10.12714/egejfas.2018.35.1.04

Yıldız, T., Zengin, M., Karakulak, F.S., Uzer, U. & Özcan Akpınar, İ. (2019). Community structure of demersal assemblages in the southwestern Black Sea. *Regional Studies in Marine Science,* 32, 100844. https://doi.org/10.1016/j.rsma.2019.100844

Zar, J.H. (1999). *Biostatiscal analysis*. 4th ed., New Jersey, Prentice Hall. USA, ISBN: 978-0321656865, 663 p

Zengin, M., Akpınar, İ. Ö., Kaykaç, M.H. & Tosunoğlu, Z. (2019). Comparison of selectivity of the trawl codends for whiting (*Merlangius merlangus euxinus*) in the Black Sea. *Ege Journal of Fisheries and Aquatic Sciences*, 36(3), 301-311. https://doi.org/10.12714/egejfas.2019.36.3.11