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## Bottom trawl fishery discards on the Black Sea coast of Turkey

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### Abstract

The purpose of this study is to determine the amount of bycatch and discards of fish caught by bottom trawlers operating along the Black Sea coasts of Turkey and discards changes depending on the depth. The study was conducted during the September 2009–April 2010 fishing season. Twenty-one bottom trawler operations were sampled and the catch composition was determined. A total of 26 species were caught, which included 22 species of fish, 2 species of arthropods, 1 gastropod and 1 bivalve. Two of these were target species (*Mullus barbatus*, *Merlangius merlangus*), while 25 species were discarded, including trash fish and specimens below the legal size. A total of 2142.76 kg of biomass was caught during the operations, of which 53.99 % was bycatch. The weighed discard rate was determined as 42.06% and two different groups were identified in discards (T1: 10-57 m, T2: 72-118 m) based on the depth. Significant differences were identified between these depth groups ( $p < 0.05$ ). It was determined that the biomass ( $\text{kg h}^{-1}$ ), the evenness index (J) ( $p < 0.05$ ), the average species number and species richness (D) ( $p < 0.01$ ) of the discards showed significant differences, but that the difference between species diversity (H) was negligible. No difference was found ( $p > 0.05$ ) between the ecological parameters of landings.

**Keywords:** Black Sea, bycatch, bottom trawl, discard, ecosystem.

### Introduction

By-catch has been a serious problem in worldwide fisheries (Zhou, 2008) and recently observed for the fishing industry in Turkey. Discards first attracted attention in the 1960s with the accidental death of dolphins caused by tuna fishing (Hall & Mainprize, 2005; Harrington *et al.*, 2005). In the study conducted by Kelleher (2005), the amount of discard worldwide was estimated at 7.3 million tons. In addition to the effects on fish stocks, commercial fishing also affects other marine organisms. One of the ecological effects of commercial fishing is the incidentally capture of non-target species. The increase in the amount of bycatch within the target catch affects not only the fishing industry but also other marine organisms (Alverson *et al.*, 1994; Hall, 1996; Hall *et al.*, 2000; Sanchez *et al.*, 2004). The marine ecosystem has been exposed to direct and indirect impacts by trawl fishing since trawl fishing collects huge amount of organisms and causes their death (Kumar & Deepthi, 2006). To determine these adverse effects and to maintain a sustainable fishing industry based on the ecosystem, it is essential that discard rates are estimated. Even though many countries and organizations have taken a number of measures to decrease the discard rate, political, fishery management, technical and economic problems were encountered with regards to their implementation (Hall, 1994; Allain *et al.*, 2003; Kelleher, 2005; Zollett, 2009). Shrimp and demersal finfish trawl fisheries account for over 50 percent of total

estimated discards while representing approximately 22 percent of total landings (Kelleher, 2005). Numerous studies have been conducted to develop new fishing gears that decrease bycatch and increase the chances of survival of discarded fish in bottom trawl fishing (Probert *et al.*, 1997; Hall *et al.*, 2000; Hannah & Jones, 2000; Stratoudakis *et al.*, 2001; Stobutzki *et al.*, 2001; Diamond, 2004; Beutel *et al.*, 2006; Zeeberg *et al.*, 2006; Chen *et al.*, 2007; Costa *et al.*, 2008). The high discard rate (0.5% - 83%) determined in studies conducted on bottom trawl fishing in various regions is an indication of this issue (Kelleher, 2005).

The Black Sea is one of the world's largest semi-enclosed seas. In Turkey, annual yield obtained by fishing activities is 477,658 tons and the Black Sea provides 77.92% of this yield (TUIK, 2012). While a large portion of this yield is obtained from seine nets and midwater trawls (anchovies, sprat, mackerel, bonito), the yield obtained from bottom trawling is far from negligible.

The Black Sea coasts of Turkey have a considerably narrow continental shelf, so some parts of this region are not suitable for bottom trawl fishing. In addition, the anoxic layer commences at depths of 150–200 m (Zaitsev & Mamaev, 1997; Badescu, 2007; Petrov *et al.*, 2011). These conditions limit both habitat and bottom trawl fishery along the Black Sea coasts. In some regions (West and Middle Coasts of the Southern Black Sea), bottom trawl fishing is performed throughout the fishing season.

In these regions, there are 470 fishing boats that are capable of bottom trawl fishing during a season (TUİK, 2012). Vessels can operate multiple fishing activities according to the Turkish licensing system. During some periods such as, lower income from bottom trawl fishing or in the seasons when Atlantic bonito is fished, fisherman can use other fishing gears (e.g. purse seine, drift net, mid-water trawl, hydraulic dredge). Therefore, it is not easy to estimate the fishing effort of trawl fisheries in this region. The bycatch and discard rate for the gears used for fishing in these regions is unknown. At the same time, no studies have been conducted to reduce bycatch (e.g. selection, modification of fishing gears).

The aim of this study was to determine the bycatch and discard rate of the traditional bottom trawls used in the Black Sea, their changes based on depth and also to serve as a reference for future studies to be conducted in this region.

## Material and Methods

### Sampling procedures

Samplings were performed in two-month periods on commercial fishing boats along the south-western coasts of the Black Sea between the beginning of the fishing season (September 2009) and the end of the fishing season (April 2010) (Fig. 1). The existence of the anoxic layer at depths greater than 150–200 m in the Black Sea causes organisms to condense at depths less than 150 m (Zaitsev & Mamaev, 1997; Badescu, 2007; Petrov *et al.*, 2011). Consequently, bottom trawl fishing is carried out in these regions.

Data regarding the operations (tow duration, depth, and time) were recorded. During the study, 21 fishing operations were performed at depths of 10 to 118 m, where fishing activities are the most intense. The study was conducted on three commercial trawl boats with different capacities (engine power and tonnage). The lengths of the vessels were 12, 14 and 21 m, respectively. The tow duration ranged between 0.45 and 2 h with tow speed ranging between 2.2–2.6 knots. There was no interference with the fishing activities of the crewmen.

All samplings were performed with the local fishermen's nets, which were not fitted with any equipment allowing for selectivity and their cod end diamond mesh size was 36 mm. Although no time limitations were effective in the study area, the operations began at dawn and continued throughout the day. The length of undersized species was measured according to the regulation of the Ministry of Food, Agriculture and Livestock of the Republic of Turkey. Following the selection of commercial species, the catch composition was determined, and the commercial and discarded catches were weighed on deck. It was not possible to use a digital balance because of lurching. Thus, weighing was carried out at the harbour. Species taxonomy was performed at the Recep Tayyip Erdoğan University Faculty of Fisheries laboratories. The composition of the discards and commercial catch by species used in the analysis was standardized as  $\text{kg}^{-1}$  superscript format. Trawl catch composition and definition of the terms used in the text are listed below.

**Target catch:** Catch of a species that is primarily sought by fishermen. Target species in some operations could be commercial bycatch in the other operations.

**Bycatch:** Total catch of non-target (discard and commercially valuable non-target species) animals.

**Discards:** Non-commercial species and commercial fish thrown back into the sea due to legal regulations (specimens below the minimum landing size and endangered species).

**Commercial bycatch:** Commercially landed species except for target (Walmsley *et al.*, 2007; Sartor *et al.*, 2003; Lobo *et al.*, 2010).

### Data analysis

The amount of discard in total yield and the rate of discard by weight were calculated according to the formulas below (Kelleher, 2005).

Components of total Fishing

$$D = C - L$$

C: Total catch

L: Landings

D: Discards

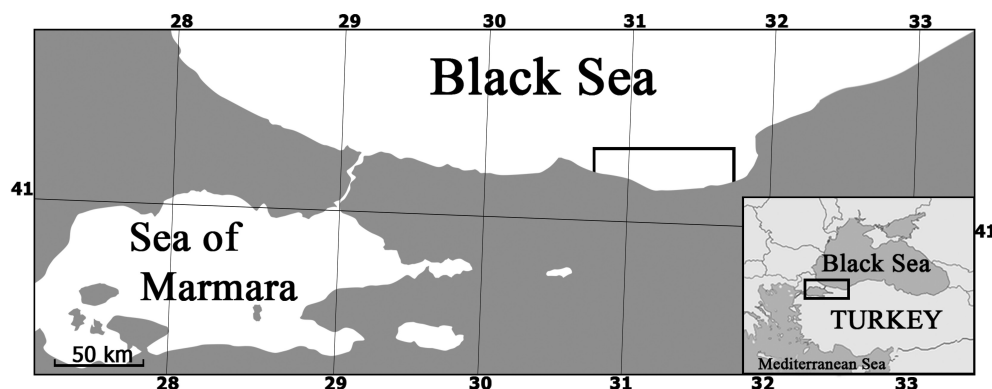


Fig. 1: Study area.

$$\text{Weighted discard rate} = \left( \frac{\Sigma D}{\Sigma D + \Sigma L} \right) \cdot 100$$

Similarity analysis of the discard species composition and amount obtained by the hauls was performed using the PRIMER 5 software package. Square root transformation linked with group average fusion was used for clustering the hauls. Multidimensional Scaling (MDS) analysis was performed according to the Bray-Curtis similarity matrix (Kruksal & Wish, 1978). Depth was used as a factor in both cluster and MDS analysis in order to categorize the hauls in terms of amount and species composition of discards. The ANOSIM test was performed on the hierarchical agglomerative clustering formed by the similarity matrix. To determine the contribution of each species to the dissimilarity rate (cut-off percentage = 90) observed between groups, Similarity Percentages (SIMPER) analysis was used (Clarke, 1993). To determine the effective use of total biomass caught in the depth groups, the EUE (Ecological Use Efficiency) of each haul and average of depth groups were calculated (Alverson & Huges, 1996).

$$\text{EUE} = \frac{\Sigma \text{Landed}}{\Sigma \text{Landed} + \Sigma \text{Discarded}}$$

The univariate indices of species richness (Margalef's  $D$ ), Shannon's index of diversity ( $H$ ) and Pielou's measure of evenness ( $J$ ), total number of species and biomass were calculated for each haul in the depth groups. These parameters were calculated separately for each haul corresponding to the landed and the discarded catch. Differences between the groups were determined with the Mann-Whitney test.

## Results

During the samplings, 26 species including 22 species of fish, 2 species of arthropods, 1 gastropod and 1 bivalve were caught. Only two species *Mullus barbatus*, *Merganlianus merlangus* were targeted, and these were the two species caught in greatest abundance. Twenty-five species were identified as discards. The total biomass was 2142.77 kg, of which 46.01 % (985.86 kg) were identified as the target, 53.99% (1156.91) as bycatch and the weighted dis-

**Table 1.** Total biomass of species caught in samplings.

	Species	Kg	%
<b>Targets</b>	<i>M. merlangus</i>	510.00	23.801
	<i>M. barbatus</i>	475.85	22.207
<b>Commercial bycatch</b>	<i>M. merlangus</i>	95.337	4.449
	<i>Pomotomus saltatrix</i>	91.3	4.261
	<i>M. barbatus</i>	37.36	1.744
	<i>Psetta maxima</i>	18.295	0.854
	<i>Alosa immaculate</i>	13.25	0.618
	<i>Trachurus mediterraneus</i>	0.156	0.007
<b>Discards</b>	<i>M. merlangus</i>	753.6037	35.170
	<i>Mytilus galloprovincialis</i>	34.585	1.614
	<i>Raja clavata</i>	25.126	1.173
	<i>Alosa immaculate</i>	19.319	0.902
	<i>Uronoscopus scaber</i>	9.322	0.435
	<i>Gobius niger</i>	8.4176	0.393
	<i>M. barbatus</i>	7.865	0.367
	<i>Trachinus draco</i>	7.669	0.358
	<i>T. mediterraneus</i>	6.114	0.285
	<i>Squalus acanthias</i>	5.3	0.247
	<i>Liocarcinus depurator</i>	5.211	0.243
	<i>Scorpaena porcus</i>	4.121	0.192
	<i>Rapana venosa</i>	3.74	0.175
	<i>Gaidropsarus mediterraneus</i>	2.746	0.128
	<i>Solea nasuta</i>	2.411	0.113
	<i>Chelidonichthys lucerna</i>	2.355	0.110
	<i>P. saltatrix</i>	1.4	0.065
	<i>Spicara smaris</i>	0.576	0.027
	<i>Ophidion barbatum</i>	0.521	0.024
	<i>Huso huso</i>	0.39	0.018
	<i>Platichthys flesus</i>	0.205	0.010
	<i>Hippocampus guttulatus</i>	0.1153	0.005
	<i>Crangon crangon</i>	0.0765	0.004
	<i>Blennius sp.</i>	0.018	0.0006
	<i>Signatus sp.</i>	0.008	0.0004

card rate was determined as 42.06% (Table 1). The rate of discard within the bycatch was determined as 77.89% (901.21 kg) of which 83.62% is constituted by *M. merlangus* below commercial size. The most abundant target, commercial bycatch and discard species caught was *M. merlangus*. Catch compositions and bycatch components are shown in Figure 2.

Following the selection of commercial catch, it was observed that nearly the whole discards thrown back to sea died and that most were consumed by sea birds. *Psetta maxima* was the only commercial species with no discarded fraction at all throughout the survey. During

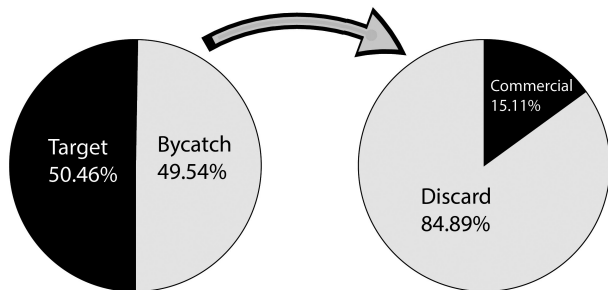


Fig. 2: Overall catch composition of the trawl.

one operation a single endangered *Huso huso* was immediately released alive by the fishermen.

According to cluster and MDS analysis, two groups ( $T_1$ ,  $T_2$ ) were identified (Fig. 3, 4).  $T_1$  consisted of trawl operations conducted between depths of 10-57 m, while the  $T_2$  group consisted of operations between 72-118 m. MDS stress value was 0.1. In addition, the ANOSIM test determined that the two groups are significantly different from one another ( $p < 0.05$ ).

According to SIMPER analysis, the species that contributed most to the distinction of the two groups were *M. merlangus* (36.09%), *Raja clavata* (13.52%), *Mytilus galloprovincialis* (7.02%) and *Uranoscopus scaber* (6.65%) (Table 2).

The amount of organisms and the number of species that were discarded varied considerably according to the depths at which the hauls were performed. While the target species in the  $T_1$  and  $T_2$  groups during 16 hauls was *M. barbatus*, the target species in the  $T_2$  group during 5 hauls was *M. merlangus*. The species and corresponding average landed and discard quantities ( $\text{kg h}^{-1}$ ) obtained during the sampling period are listed in Table 3.

Table 3 shows the mean hourly biomass of discard-

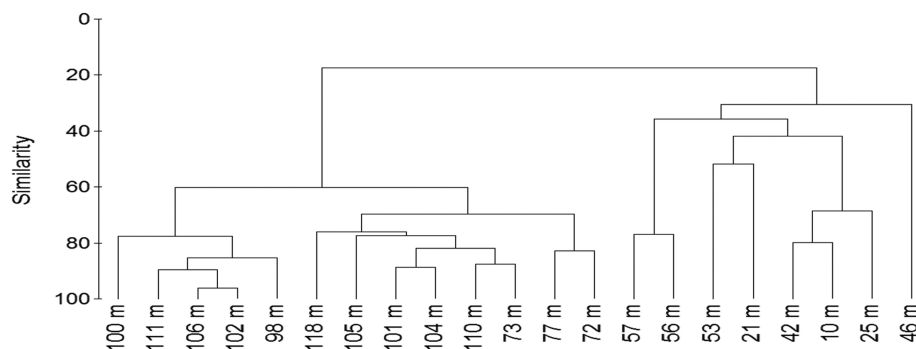


Fig. 3: Similarity dendrogram for discarded species composition based on trawl samples by depth.

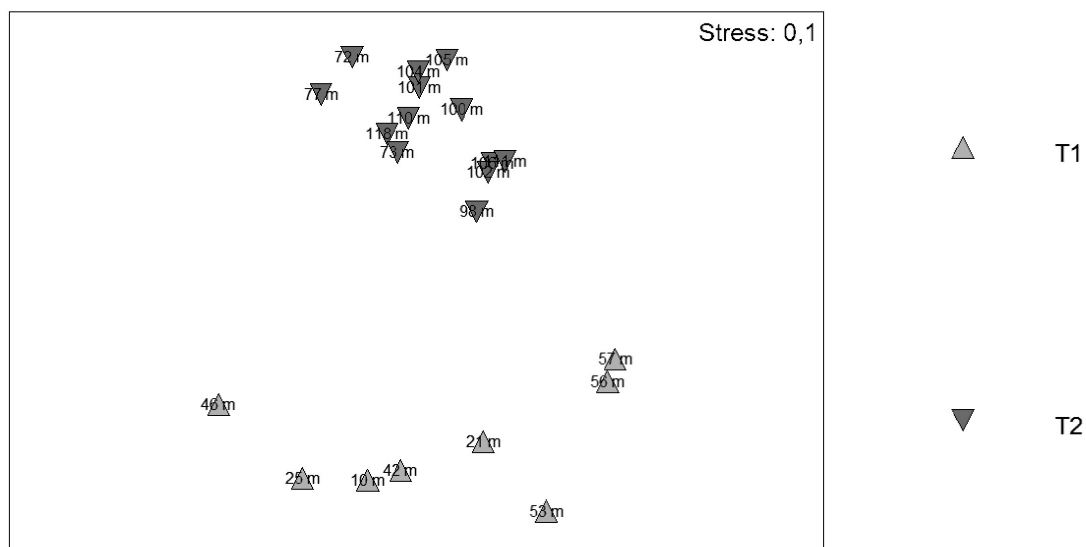


Fig. 4: Multidimensional scaling ordination of hauls of discarded catch for both groups  $T_1$  and  $T_2$ .

**Table 2.** SIMPER analysis of discards species abundance at the T1 and T2 groups. Average dissimilarity between groups = 93.13.

Species	Average Abundance T1	Average Abundance T2	Average Dissimilarity	Dissimilarity/ Standard Deviation	Contribution %	Cumulative %
<i>M. merlangus</i>	0.02	30.09	33.62	2.49	36.09	36.09
<i>R. clavata</i>	2.10	0.83	12.59	1.02	13.52	49.62
<i>M. galloprovincialis</i>	0.14	2.00	6.54	0.87	7.02	56.64
<i>U. scaber</i>	1.32	0.08	6.20	0.91	6.65	63.29
<i>T. draco</i>	0.83	0.25	4.63	0.80	4.97	68.26
<i>R. venosa</i>	0.69	0.00	4.50	0.63	4.83	73.09
<i>G. niger</i>	0.65	0.29	4.24	0.78	4.55	77.65
<i>M. barbatus</i>	0.76	0.20	3.84	1.72	4.12	81.77
<i>L. depurator</i>	1.16	0.00	3.22	0.51	3.46	85.23
<i>A. immaculata</i>	0.04	0.96	2.60	1.53	2.79	88.02
<i>G. mediterraneus</i>	0.32	0.01	2.32	0.71	2.49	90.51

**Table 3.** Mean hourly biomass of discarded and landed species in the depth groups.

Species in group T1	kg h <sup>-1</sup>	%	Species in group T2	kg h <sup>-1</sup>	%
<b>Landings</b>			<b>Landings</b>		
<i>M. barbatus</i>	32.76	69.10	<i>M. merlangus</i>	33.84	63.87
<i>P. saltatrix</i>	12.23	25.79	<i>M. barbatus</i>	18.25	34.45
<i>T. mediterraneus</i>	1.07	2.25	<i>P. maxima</i>	0.51	0.96
<i>P. maxima</i>	0.42	0.88	<i>A. immaculata</i>	0.39	0.73
<i>M. merlangus</i>	0.94	1.98			
<b>Discards</b>			<b>Discards</b>		
<i>R. clavata</i>	1.58	16.64	<i>M. merlangus</i>	34.35	87.47
<i>U. scaber</i>	1.06	11.21	<i>M. galloprovincialis</i>	2.00	5.10
<i>L. depurator</i>	0.87	9.21	<i>A. immaculata</i>	1.02	2.60
<i>T. mediterraneus</i>	0.72	7.61	<i>R. clavata</i>	0.96	2.45
<i>M. barbatus</i>	0.70	7.44	<i>G. niger</i>	0.30	0.76
<i>T. draco</i>	0.62	6.55	<i>T. draco</i>	0.29	0.74
<i>M. galloprovincialis</i>	0.60	6.34	<i>M. barbatus</i>	0.15	0.37
<i>G. niger</i>	0.54	5.65	<i>S. acanthias</i>	0.14	0.37
<i>S. porcus</i>	0.52	5.53	<i>U. scaber</i>	0.04	0.11
<i>R. venosa</i>	0.51	5.43	<i>S. smaris</i>	0.01	0.04
<i>M. merlangus</i>	0.38	4.01	<i>C. crangon</i>	0.001	0.002
<i>S. nasuta</i>	0.32	3.36			
<i>C. lucerna</i>	0.31	3.28			
<i>G. mediterraneus</i>	0.26	2.70			
<i>A. immaculata</i>	0.18	1.87			
<i>P. saltatrix</i>	0.12	1.23			
<i>H. huso</i>	0.07	0.69			
<i>O. barbatum</i>	0.06	0.63			
<i>P. flesus</i>	0.02	0.25			
<i>H. guttulatus</i>	0.01	0.15			
<i>S. smaris</i>	0.01	0.08			
<i>C. crangon</i>	0.01	0.05			
<i>Blennius</i> sp.	0.003	0.02			
<i>Sygnathus</i> sp.	0.001	0.01			

ed and landed species in the T1 and T2 groups. In both groups, the quantity of commercial species other than the target species is quite low. In the T1 group, *R. clavata* was the most discarded species (16.64%), while *Sygnathus* sp. (0.01%) was the least discarded species. In the T2 group, *M. merlangus* (87.47%) was the most discarded species, while *Crangon crangon* (0.002%) was the least discarded (Table 3).

The discard range of fishing operations in the T1 group was 5.2-18.9 kg h<sup>-1</sup>, with an average value of 9.47 ± 4.26 kg h<sup>-1</sup>. The weighted discard rate of T1 was 16.47%. The Ecological Use Efficiency (EUE) calculated for this group was between 0.7-0.88, and the average value of EUE was 0.814±0.06. The discard range for the T2 group was calculated as 4.7-235.6 kg h<sup>-1</sup>, and the average discard was 39.27±16 kg h<sup>-1</sup>. The weighted discard rate

of T2 was 48.82 %. The T2 group's EUE value ranged from 0.35 to 0.88 with an average value of  $0.574 \pm 0.166$ . The significance of the difference between the EUE values of the groups was determined (Table 4). In the T2 depth group, discards were found to be higher both in terms of proportion and quantity. There was no significant difference between the T1 and T2 groups in commercial biomass ( $p > 0.05$ ) (Table 4).

The total number of species discarded in the T1 depth group was found to be greater than the T2 group. Furthermore, in the T1 group, where the operations were performed in a shallower region, the average number of species was greater than that of T2. For the discarded species of both groups, significant differences were noted in the species richness ( $D$ ) and evenness ( $J$ ) indices, with the exception of the species diversity index ( $H$ ) (Table 5).

## Discussion

The demand for fish and sea food is increasing, while the supply of fish from wild capture fisheries has stagnated, (FAO, 2008). Hence effective use of marine resources is becoming increasingly important. When fisheries are categorized according to their exploitation, it is noted that

4% are under exploited, 25% are sustainably exploited, 47% are fully exploited, 18% are over-exploited, 9% face depletion and 1% are recovering (Mullon *et al.*, 2005; FAO, 2008). After a long period of overexploitation, increasing efforts to restore marine ecosystems and rebuild fisheries are under way. Efforts have been made considerably for the recovery of overexploited stocks in the world and the amount of fish stocks required to rebuild is 63%. Stocks should be harvested with lower exploitation rates to prevent the collapse of vulnerable species (Worm *et al.*, 2009). A similar evaluation of Turkey's fishery supplies is not possible due to the near absence of studies for determining supply size, the replenishment of these supplies, and the current fishing fleet's catch per unit effort (CPUE). However, fluctuations since 1988 in the production in Turkey, along with the increase of fishing fleets in terms of number, size, engine power, fish detecting devices and size of fishing tools in the same period are as much a cause for concern as the situation of supplies around the world. It is possible to say that these changes in fish supplies worldwide are caused by an increase in fishing capabilities, along with changes in the ecosystem caused by a sharp decrease in non-target species aside from the target species (Alverson *et al.*, 1994; Hall, 1996; Ye, 2002; Sanchez *et al.*, 2004; Kelleher, 2005; Kumar & Deepthi, 2006).

**Table 4.** Minimum, maximum and mean values of hourly yields estimated for the landed and discarded catch ( $\pm$ S.D.), discard rates of groups and EUE in the groups and statistical test results .

	T1			T2		
	Min.	Max.	Mean	Min.	Max.	Mean
<b>Landed (kg h<sup>-1</sup>)</b>	14.220	92.769	47.41 $\pm$ 27.87	9.882	195.110	52.98 $\pm$ 52.85
<b>Discard (kg h<sup>-1</sup>)</b>	5.292	18.972	9.47 $\pm$ 4.26*	4.66	235.560	39.27 $\pm$ 59.45*
<b>EUE</b>	0.704	0.884	0.814 $\pm$ 0.06*	0.354	0.880	0.574 $\pm$ 0.166*
<b>Discard rate (%)</b>		16.47			48.82	

\* $p < 0.01$ ; EUE: Ecological use of efficiency

**Table 5.** Calculated values of abundance, ecological parameters in the depth groups and statistical test results ( $\pm$  S.D.).

	T1 (10-57 m)	T2 (72-118 m)	Statistical test
Number of hauls	8	13	
<b>Landings</b>			
Total species	5	4	
Mean species	2.75 $\pm$ 0.97	2.23 $\pm$ 0.58	$U_{8,13}=40$
Mean biomass (kg h <sup>-1</sup> )	47.41 $\pm$ 27.87	52.98 $\pm$ 52.85	$U_{8,13}=45$
Mean species richness, $D$	0.48 $\pm$ 0.26	0.39 $\pm$ 0.23	$U_{8,13}=47$
Species diversity, $H$	0.66 $\pm$ 0.191	0.58 $\pm$ 0.27	$U_{8,13}=46$
Evenness index. $J$	0.76 $\pm$ 0.22	0.70 $\pm$ 0.28	$U_{8,13}=47$
<b>Discards</b>			
Total species	24	11	
Mean species	11.63 $\pm$ 3.77	5.23 $\pm$ 0.89	$U_{8,13}=7.5^{**}$
Mean biomass (kg h <sup>-1</sup> )	9.47 $\pm$ 4.26	39.27 $\pm$ 59.45	$U_{8,13}=23^*$
Mean species richness, $D$	4.86 $\pm$ 1.38	1.6 $\pm$ 0.83	$U_{8,13}=2^{**}$
Species diversity, $H$	1.7 $\pm$ 0.29	0.71 $\pm$ 0.41	$U_{8,13}=35$
Evenness index. $J$	0.72 $\pm$ 0.09	0.42 $\pm$ 0.23	$U_{8,13}=15^*$

\* $p < 0.05$ , \*\* $p < 0.01$

Trawls are one of the most important fishing gears used by the fishing industry for obtaining yield from the seas and are in widespread use for fishing benthic species in Turkey. Even though the Black Sea presents only limited regions suitable for bottom trawl fishing, it is used prominently in certain regions. In this context, the region where the Sakarya river flows into the Black Sea, which one of the regions where bottom trawls are used extensively was chosen as a station for this study. There are very few studies on selectivity, other management measures and catch composition in this area.

As is the case with this study, other studies conducted in Turkey and around the world on bottom trawls and other fishing gears similar to bottom trawls, revealed that the proportion of non-target species and discard is quite high. Similarly, the discard rate of bottom trawls was found to be 37% in the Bay of Izmir in the Aegean Sea; bycatch in shrimp trawls was found to be 29% in the Marmara Sea; and the bycatch of beam trawlers in the Marmara Sea for mesh size of 36 mm and 40 mm was found to be 28.9% and 27.8% respectively (Özbilgin *et al.*, 2006; Zengin & Akyol, 2009; Bök *et al.*, 2011). It was reported that the discard rate of bottom trawlers targeting different species of fish ranges between 19% - 64% in many studies conducted in the Mediterranean Sea (Tsagarakis *et al.*, in press). However, the discard rates of trawlers in different regions (e.g., Ireland, North-eastern Atlantic, USA) were found to be quite high (Allain *et al.*, 2003; Borges *et al.*, 2005; Harrington *et al.*, 2005). The discard rate in this study is similar to the results of other studies conducted in different seas. In light of these data, it was found that bottom trawl fishing in the world, just as in the Black Sea region, is characterized by a very high discard rate. This is because, this type of fishery retains large amounts of non-target species due to lack of selectivity.

It has been reported that the catch composition of trawls used for fish and benthic organisms, differ depending on the depth (Probert *et al.*, 1997; Sartor, *et al.*, 2003; Sanchez *et al.*, 2004; Gücü, 2012). In the current study, the depth was determined as a factor influencing the number of discards and the biomass of some species. While the number of discarded species in T1 was 24, it was 11 in T2 (Table 2). When considering the biomass, the discard ratio of *M. merlangus* in particular, which was dominant in the deeper area, was found to be higher. Additionally, a significant difference was noted between the discard rates of these two depth groups. EUE was applied to evaluate the impact of bycatch on total catch (Sartor, *et al.*, 2003). The significant differences ( $p < 0.05$ ) in discard rate and EUE values of these two depth groups show that depth affects the catch composition of bottom trawls (Table 4). It can be said that trawl fishing in T1 region affects a larger number of organisms than in T2 based on the mean number of species, average species diversity and the evenness index.

The difference observed in the T2 depth group with

regard to biomass is probably due to the presence of considerable *M. merlangus* stocks at this depth. In the studies that were performed, the number of species, bycatch, and discarded biomass showed considerable differences according to region, season and depth (Probert *et al.*, 1997; Stobutzki *et al.*, 2001; Sartor *et al.*, 2003; Sanchez *et al.*, 2004). In this context, bottom trawlers affect ecosystems differently according to depth.

As a result, the limited continental shelf size of the Turkish coasts in the Black Sea and the anoxic layer that commences at depths greater than 150-200m limit bottom trawl fishing in the region. Despite the limited area, extensive bottom trawl fishing activities have been carried out in Turkey's middle and western coasts of the Black sea. One of these regions is the area where the Sakarya River flows into the Black Sea. According to the legal regulation, trawl cod end mesh size has to be 40 mm in the Black sea but fishermen don't use this type of net. Therefore, the bycatch of traditional fish trawls used in the region is high and they lack the characteristics that would allow for sustainable stocks; this adversely affects both the fish stocks and the ecosystem. To minimize this negative effect, the traditional fishing gears need to be redesigned and new devices should be developed to reduce bycatch. For instance, the discard rate of *M. merlangus* could be reduced by using square mesh panel placed in the cod-end (Özdemir *et al.*, 2012). Mesh size should be determined according to the size of the target species; the cod end of the trawl must be standardized because, increasing cod end circumference negatively affects selectivity (Tokaç *et al.*, 2009). Fishing gears with these characteristics should be designed, and the most suitable gears for the region should be determined and recommended to local fishermen. Furthermore, fishing activities should be controlled. Despite these, it should be taken into account that discards into the sea constitute an easily available food resource for many scavengers such as seabirds and species living on the sea bottom (Valeiras, 2003).

Bycatch may be affected by several factors such as season, depth, region and characteristics of fishing gear. Thus, more comprehensive research should be designed in future. Moreover, a bycatch monitoring program should be developed to track changes in discarding and to gain a better understanding of the factors affecting bycatch.

On the other hand, selective fishing of only the target species is not necessarily useful to any of the target species, the by-catch species, or the ecosystem. Selectively and intensively taking out single species from an ecosystem will upset the existing relationships such as productivity of the species and sizes of fish in the ecosystem. Consequently, selectivity regulations are needed to balance the impact of all fisheries in an area (Zhou, 2008; Garcia *et al.*, 2012). Therefore, balanced harvesting method should be developed for sustainable fisheries in the area.



Bycatch in bottom trawlers constitutes a serious issue. As a significant factor contributing to population decrease and adversely affecting marine ecosystems, bycatch is considered by scientists, ecologists and politicians alike as being a significant problem. Therefore solving the problems of the fishing industry, or ensuring sustainable fishing, is inconceivable without taking bycatch into consideration (Hall *et al.*, 2000; Lewison *et al.*, 2004; Zhou, 2008; Davies *et al.*, 2009; Zollet, 2009). In this context, a fisheries management plan for the Turkish coasts of the Black Sea should be elaborated that accounts for bycatch in regions where bottom trawl fishing is employed.

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