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Effects of Depth, Season and Mesh Size on the Catch and Discards of Whiting (*Merlangius merlangus euxinus*) Gillnet Fishery in the Southern Black Sea, Turkey

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Abstract

In this study, factors (depth, season and mesh size) influencing the catch and discards of whiting (*Merlangius merlangus euxinus*) gillnet fishery on the Black Sea coasts of Turkey were investigated. A total of 19 species were identified and the target species, whiting (*Merlangius merlangus euxinus*), dominated 87.56% of the total catch and followed by red mullet (*Mullus barbatus*) with 6.32%. While 82.02% of the total catch had commercial value, 17.98% was discarded. The percentage of the discarded red mullet and whiting under MLS (<13 cm) were found to be 16.03% and 13.27%, respectively. The highest discard amount was observed in winter and the lowest one in summer. The discard rate was highest in the 55-74 m depth group and the 32 mm mesh size. One-way analysis of similarity (ANOSIM) showed that there were significant differences in the discard species compositions between spring and summer, as well as 32 and 40 mm, 32 and 44 mm mesh sizes (P<0.05). These results on the discard information in gillnet fishery can contribute to the literature on ecosystem-based sustainable fisheries management by highlighting relevant results on the protection of species and ecosystem.

Keywords: Whiting, discard, gillnet, multivariate analysis, Black Sea.

Güney Karadeniz'de Derinlik, Mevsim ve Ağ Göz Açıklığının Mezgit (*Merlangius merlangus euxinus*) Solungaç Ağı Avcılığında Av ve Iskarta Üzerine Etkisi

Özet

Bu çalışmada Türkiye'nin Karadeniz kıyılarında mezgit (*Merlangius merlangus euxinus*) solungaç ağı avcılığında, av ve ıskartayı etkileyen faktörler (derinlik, mevsim ve ağ göz açıklığı) incelenmiştir. Toplam 19 tür tanımlanmış ve hedef tür olan mezgit (*Merlangius merlangus euxinus*) %87,56'lık oranla toplam avın büyük bir kısmını oluşturmuş ve onu %6,32 ile barbunya (*Mullus barbatus*) izlemiştir. Toplam av miktarının %82,02'si ticari değer taşırken, %17,98'inin ise ıskarta olduğu belirlenmiştir. Asgari avlanabilir boy olan 13 cm altında bulunan ve ıskarta edilen barbunya ve mezgit av miktarları sırasıyla %16,03 ve %13,27 olarak bulunmuştur. En yüksek ıskarta miktarının kış mevsiminde, en düşük ıskarta miktarının ise yaz mevsiminde olduğu görülmüştür. 55-74 m derinlik grubunda ve 32 mm göz açıklığına sahip ağda ıskarta oranının en yüksek olduğu bulunmuştur. One-way analysis of similarity (ANOSIM)'e göre ilkbahar ve yaz mevsimleri arasında, 32-40, 32-44 mm göz açıklıklarına sahip ağların ıskarta tür kompozisyonları arasındaki farklılıkların önemli olduğu belirlenmiştir (P<0,05). Solungaç uzatma ağları balıkçılığında türleri ve ekosistemi korumak için ıskarta ile ilgili bu bilgilerin kullanılması, ekosisteme dayalı sürdürülebilir balıkçılık yönetimine katkı sağlayabilir.

Anahtar Kelimeler: Mezgit, ıskarta, solungaç ağı, multivariate analiz, Karadeniz.

Introduction

Despite that studies addressing the determination of effects of bycatch and discard on fishery have gained popularity in the recent years, the effects of discards on the ecosystem are still not fully understood (Kınacıgil *et al.*, 1999; Davies *et al.*, 2009). Due to these concerns, the ecosystem-based fisheries management model is developed and in this context, the protection of both the marine ecosystem and species, as well as ensuring the sustainability has become increasingly important. The regulations on fishery that only take catch in fishing into consideration are neither efficient nor sufficient. Further, for sustainable fishery some modifications in fishing gears are crucial in order to minimize bycatch and discard rates. As for fishing gears, in order to reduce bycatch and discard rates giving small

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individuals a chance to escape and non-target species to survive, many methods have been developed, including modifications such as using bycatch reduction devices and improvement of selectivity properties of nets.

For the management of a fish stock, it is essential to know about the quantity of bycatch and discard. In general, most fishing methods are considered to have high and variable discard rates (Alverson *et al*., 1994). According to Kelleher (2005) shrimp trawl fisheries have the highest weighted average discard rate of 62.3% with a range of discard rate (0-96%), Tuna and HMS longline 28.5% (0-40%) and dredge 23.8% (9-60%), however, gill and trammel nets are among the fishing gears having low discard rates with 0.5% (0-66%). While there are many studies on bycatch and discards in gillnets (e.g. GodØy *et al*., 2003; Gray *et al*., 2005; Bettoli and Scholten, 2006; Shester and Micheli, 2011), in Turkey, bycatch and discard studies were in general related to trammel nets (e.g. Aksu, 2006; Gökçe and Metin, 2007; Akyol, 2008; Metin *et al*. 2009). Only a limited number of studies (e.g. Aydin *et al*., 2008 with red mullet, *Mullus barbatus*; Tonay and Öztürk, 2003; with turbot, *Scophthalmus maeticus*) have been conducted on gillnets and there is no record of any studies on bycatch and discard rates of gillnets targeting whiting in the region.

Due to the ban on trawling in the region, whiting (*Merlangius merlangus euxinus* Nordmann, 1840) has been extensively caught with gillnets, as well as, occasionally with cast net. Whiting is a preferred species of fish in the region for consumption by its inhabitants. The catch quantity of marine fish in 2011 in Turkey was 432.246 tons and whiting accounted for 9454.8 tons (2.19%) of this amount. The majority of this catch is obtained from the Black Sea with 8.120 tons (85.88%) among the four catch regions, Marmara, Aegean, Mediterranean and Black Sea (TUIK, 2012).

Gillnets targeting whiting are used in almost all seasons especially in the eastern Black Sea region. Further, bottom-trawling ban in the area causes more efficient use of this type of fishing gear. In order to ensure the sustainability of the use of fishery resources and the reduction of non-target species, the determination of the effects of fishing gears on both species and ecosystem are very important. It is not possible to completely prevent the discard species and quantities in fishery, yet it is still crucial to minimize the discard and the implement of an appropriate management plan. Concerning the design of this plan, many measures such as the establishment of marine protected areas, seasonal catch and periodic depth restrictions, improvements in species and size selectivity of fishing gears will all help preventing the possible negative effects of discard on both species and the marine ecosystem.

The main objective of this study was to determine the catch composition and discard levels of gillnets used in whiting fishery on the eastern coasts of Turkey. This study provides data on the rates of small individuals (juvenile) among the quantities of the most important fish species. This data set will contribute to the assessment of effects of gillnets on the fish populations. Further, this study will allow analyzing the effects of depths, seasons and mesh sizes on discard species compositions and discards rates.

Materials and Methods

The study was conducted between June 2010 and June 2011 in the area between 41°01´ and 41° 03´ N latitudes and 40° 26´ and 40° 37´ E longitudes on the eastern Black Sea of the coast of Turkey. Experimental fishing trials (13 hauls) were monthly carried out during the study. The bottom structure of the fishing grounds were rocky, sandy, muddy and the depths varied from 35 to 95 m. Operational plans (e.g. setting, soaking and hauling times and determination of the fishing grounds) for the trials were based on the prior experience of fishermen in the region. Experimental fishing trials were undertaken on the R/V RIZESUAR (12 m long with an engine power of 140 HP) and also the gillnetter BEYTUL (6 m long with an engine power of 28 HP).

The experimental gillnet with a combination of five different mesh sizes (32, 34, 36, 40 and 44 mm) were tied together to compose a set. The nets were constructed with the same design and characteristics with those used by local fishermen. The nets were equipped with polypropylene Ø4 float line with plastic Ø4 floats (2.2 cm height; 11.68 g weight) and PP Ø6 lead line with 40 g lead sinkers. The nets consisted of polyamide multifilament netting made of 23 tex/2 and 50 meshes depth with a hanging ratio of 0.64. The gillnet had a total length of 635 m and was obtained using one sheet of each mesh size (each 127 m long). In each trial five sheets were randomly tied to each other. The nets were set with an anchor and buoy attached to each end.

Experimental Procedures

The nets tied to each other were deployed for a few hours before sunset and hauled at sunrise. For each fishing operation, setting locations, depths and fishing times (setting and retrieval times) were recorded. Also, geographical coordinates of all fishing operations were recorded using a GPS. Fishing operations were generally performed at suitable sea conditions. The soaking times of nets varied from 10 h to 22 h with an average of 16.1 h. At the end of fishing trials, all specimens with or without economic value taken from the nets were brought to the laboratory to be identified and sorted out by mesh sizes. The total length (L_T, mm) and total weight (0.1 g) have been recorded for all specimens.

Data Analysis

The amount of species discarded was estimated based on the total number of individuals. The estimated discard rate was calculated separately for each season, (autumn, winter, spring, summer), depth interval (D1: <54, D2: 55-74 m, D3: >75 m) and mesh size (32, 34, 36, 40 and 44 mm). All data recorded in a database have been standardised in the Catch Per Unit Effort (CPUE) expressed in numbers of species for 1000 m of net. The comparison of these variables between discard and target species was statistically analysed using CPUE values. CPUE was calculated using the following formula, CPUE = n / soak time (12 h) × length of the net (1000 m), where n represents the number of individuals. The species in the total catch with very low or without any marketable value and the individuals which are damaged or under the minimum landing size (MLS) were defined as discard. One-way analyses of similarity (ANOSIM) were used to test differences between seasons, depths and mesh sizes. Similarity percentage (SIMPER) analyses were used to identify the species that were most responsible for the similarity of catches within seasons, depths and mesh sizes (Clarke and Warwick, 2001). Multivariate analyses were performed with the software package PAST version 1.8 (Hammer *et al*., 2001). Statistical inference was based on the 95% significance level.

Results

Throughout the study, a total of 19 different species, 8 commercial and 11 discard, were obtained. Among the caught species, the target species of gillnets, whiting, was the most abundant one, accounting for 87.56% (n = 1816). Red mullet (n = 131; 6.32%) and the other 17 species (n = 127; 6.12%) were the other taxa that contributed most to the total catch. The total catch in number was 2074, comprising of 1701 individuals (82.02%) with commercial value and 373 discarded (17.98%). The number of whiting individuals, under MLS (13 cm) which considered to be discarded, was 13.27% (n= 241), while 86.73% (n=1575) of whiting catch consisted of commercially valuable individuals. Among the other caught species, 16.03% of red mullet and 8.33% of *Spicara maena* were discarded. Also, while *Uranoscopus scaber*, *Rapana venosa* and *Scapharca inaequivalvis* were entirely discarded, some species in very small numbers were fully commercially valuable, such as *Alosa fallax pontica*, *Engraulis encrasicolus* and *Trigla lucerna* (Table 1).

The number of individuals (CPUE) caught by gillnets was higher than the discard during each season. The catch amount by season varied considerably while the variance was highest in spring with a number of 1632 (±501.52) and lowest in summer with a minimum number of 290 (±109.70). However, the highest discard number was detected in winter with an amount of 327 (±163.29); and the lowest value in summer with 87 (±40.673). Except for spring, retained and discarded amounts showed a parallel change with each other. While the seasonal distribution of number of retained and discarded species was similar, the number of species reached its lowest value in autumn and highest in winter (Figure 1).

Retained and discarded amounts differed in magnitude by depths groups. The maximum detected

Table 1. Total number of individuals (N), percentage (%), numbers (n) of discard and commercial species caught by gillnet

Species	N	Commercial		Discard	
		n	%	n	%
Merlangius merlangus euxinus	1816	1575	86.73	241	13.27
Mullus barbatus	131	110	83.97	21	16.03
Gobius sp.	44	-	-	44	100
Uranoscopus scaber	21	-	-	21	100
Rapana venosa	20	-	-	20	100
Scapharca inaequivalvis	15	-	-	15	100
Spicara maena	12	11	91.67	1	8.33
Alosa fallax pontica	2	2	100	-	-
Engraulis encrasicolus	2	2	100	-	-
Squalus acanthias	2	-	-	2	100
Trachurus mediterraneus	1	-	-	1	100
Scorpaena porcus	1	-	-	1	100
Trigla lucerna	1	1	100	-	-
Ophidion barbatum	1	-	-	1	100
Solea solea	1	-	-	1	100
Dasyatis pastinaca	1	-	-	1	100
Hippocampus sp.	1	-	-	1	100
Syngnathus abaster	1	-	-	1	100
Crangon crangon	1	-	-	1	100
Total	2074	1701	82.02	373	17.98

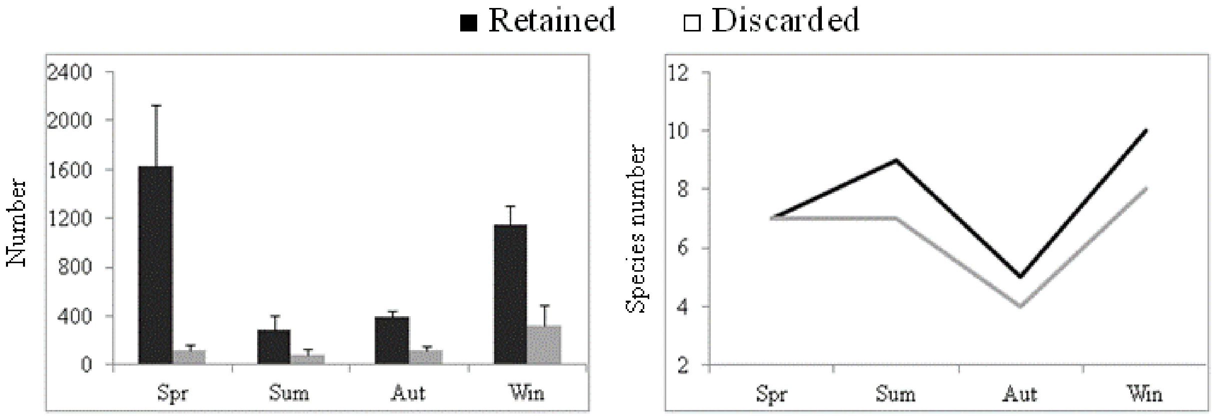

Figure 1. Mean value (+SE) and species number of retained and discarded catch per haul (CPUE) in each season (Spr: spring, Sum: summer, Aut: autumn, Win: winter).

retained amount was 627 (±641.99) in >75 m depths and minimum 565 (±163.19) in <54 m depths. There was an increase in catch amount with increasing depths. The discard reached its lowest value when the ratio of retained was 9.8% in > 75 m depth group. The number of retained and discarded species decreased depending on the increasing depth and was minimum (n = 4) in >75 m depth groups (Figure 2).

When considering mesh sizes, the highest number of fish was caught by 32 mm mesh size with 412 (±82.50) (CPUE), whereas 40 mm mesh size caught the lowest number of fish with 69 (±641.99). Also, the minimum discarded amount with 12 (±641.99) was detected for the 40 mm mesh size. The number of retained and discarded species by mesh sizes showed a similar distribution (Figure 3).

When the seasonal distribution of the target species of gillnets, whiting was analysed, the fishing efficiency was detected to have a maximum with 52.66% (n = 1576; n/12 h x 1000 m) in spring, and a minimum with 8.05% (n = 241; n/12 h x 1000 m) in summer (Figure 4). However, the catch amount of red mullet was found to reach its maximum in winter and minimum in spring.

Although whiting was found in all depth groups, a linear correlation between the catch amount and depth was detected. An increase in catch amount was observed to correlate positively with increasing depths. Whiting catch amount was found to have a maximum with 55.56% (n = 1538; n/12 h x 1000 m) in >75 m depth group, 27.07% (n = 749; n/12 h x 1000 m) in 55-74 m and a minimum with 17.33% (n = 479; n/12 h x 1000 m) in <54 m depth group. The catch amount of other species was observed to vary depending on the depth of the groups (Figure 5).

The catch amount of whiting decreased with increasing mesh sizes, with the exception of 40 mm. While the highest amount of fish was caught by the 32 mm mesh size with a value of 39.44% (n = 364, n/12 h x 1000 m), the minimum amount was obtained by 40 mm mesh size with a value of 6.60% (n = 61, n/12 h x 1000 m). Red mullet also displayed a similar pattern for all mesh sizes, as the catch amount decreased with increasing mesh size (Figure 6).

The difference among discarded species compositions by season was found to be significant (one-way ANOSIM; R = 0.4195, P= 0.0137). Further, species compositions of discard in spring were detected to be significantly different (ANOSIM; P< 0.05) from the compositions of summer with whiting and red mullet being the discriminating species. The two species that contributed most to the dissimilarities, together with their contribution ratios are displayed in Table 2.

The statistical analysis (ANOSIM) between discarded species compositions in depth groups showed no statistically significant difference (R = -0.0195, P< 0.4731) (Table 3).

Significant differences among discarded species compositions by mesh sizes were observed (ANOSIM; R = 0.0898, P=0.0076). These differences were detected between the 32-40 mm and 32-44 mm mesh sizes. The SIMPER analysis showed that the highest contribution to this dissimilarity was due to the species whiting and red mullet. The two species that contributed most to the dissimilarities and their contribution ratios are shown in Table 4.

Discussion

In this study, the catches obtained by whiting gillnets were calculated by evaluating commercial and discard catch. Due to the absence of earlier studies on the region, we have not been able to compare and contrast our results to a feasible benchmark. Throughout the study, while 82.02% of the caught species had commercial value, 17.98% of this species was discarded. Gray *et al.* (2005) reported the discard rate in gillnets as 6.2%. The differences in the results (discard rates) can be attributed to the species compositions resulting from regional differences, technical characteristics of nets and fishing strategies. The discard rate of individuals of target species whiting under minimum landing size (MLS) (13 cm total length) represented a large discard rate with 65% of total discard. Of all whiting catch, the rate of individuals under MLS with 13.27% was second only after red mullet (16.03%). This rate can be explained

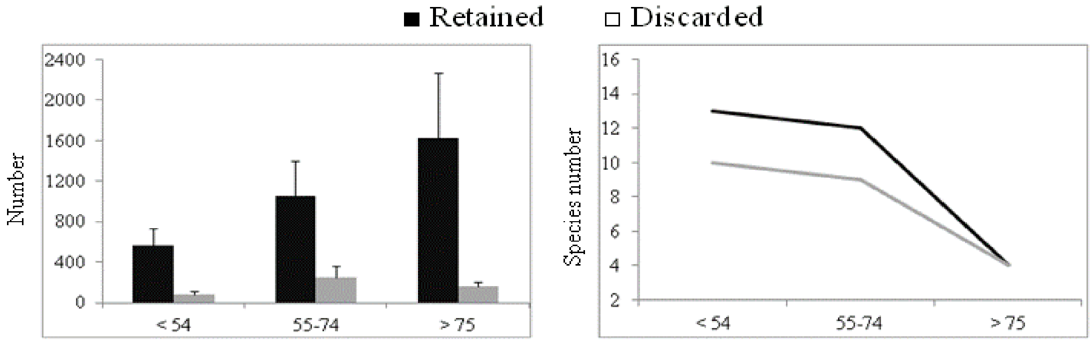

Figure 2. Mean value (+SE) and species number of retained and discarded catch per haul (CPUE) in each depth.

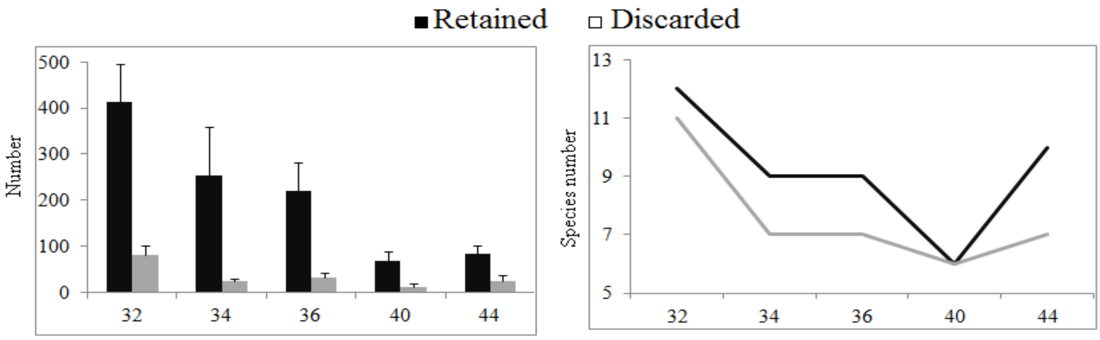

Figure 3. Mean value (+SE) and species number of retained and discarded catch per haul (CPUE) in each mesh size.

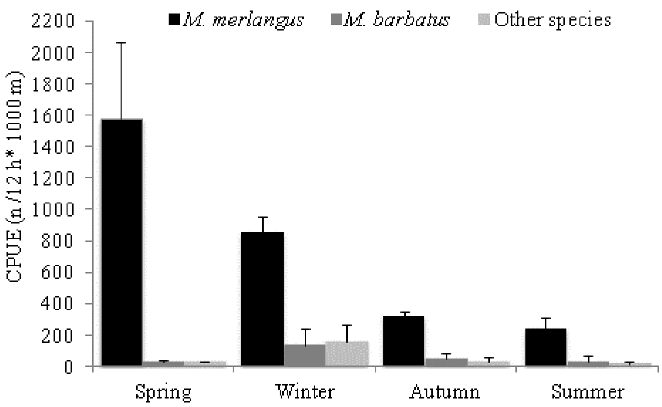

Figure 4. Relationship between CPUE (+SE) and season for the most important species in gillnets.

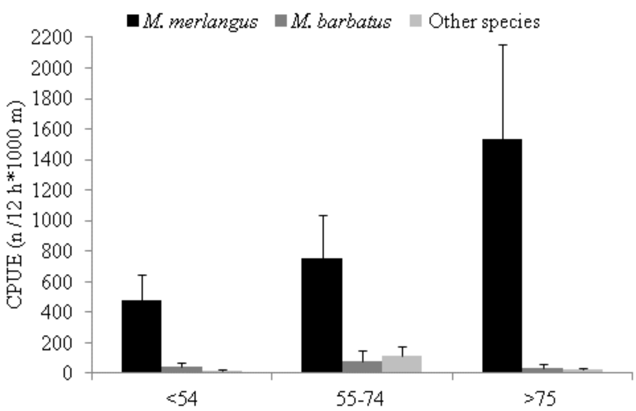

Figure 5. Relationship between CPUE (+SE) and depth for the most important species in gillnets.

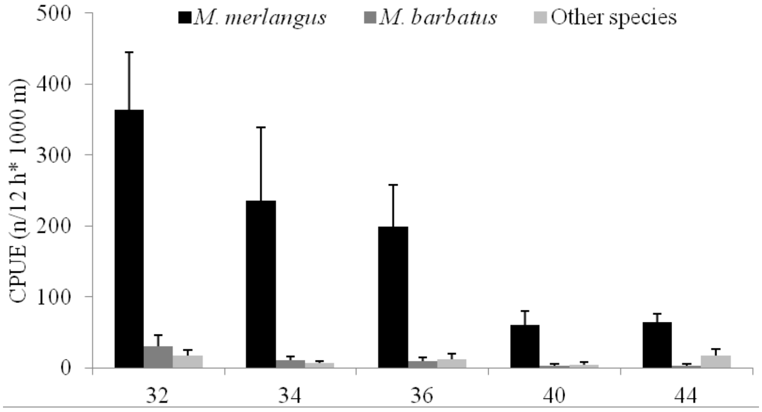

Figure 6. Relationship between CPUE (+SE) and mesh size for the most important species in gillnets.

Table 2. One-way ANOSIM results of discard species between seasons (*R* values and significance level, P). Global *R* = 0.4195, P (same) > 0.0137. SIMPER results showing the average dissimilarities (%), the two species contributing most to the dissimilarity and their contribution ratios to the average dissimilarities between seasons

	One-way ANOSIM		SIMPER		
Season	R value	P value	Average dissimilarity (%)	Discriminating species 1 (*M. merlangus*) Contribution of species 1 (%)	Discriminating species 2 (*M. barbatus*) Contribution of species 2 (%)
Spr-Win	0.0256	0.4012	38.22	72.01	11.95
Spr-Aut	0.5091	0.0967	58.14	90.83	4.267
Spr-Sum	0.6718	0.0177	67.41	92.43	3.577
Win-Aut	1.0000	0.0995	52.43	68.87	13.66
Win-Sum	0.8889	0.0979	64.48	70.52	12.80
Aut-Sum	-0.2500	0.7954	31.94	56.87	22.39

* Spr: spring, Win: winter, Aut: autumn, Sum: summer

Table 3. One-way ANOSIM results of discard species between depths (*R* values and significance level, P). Global *R* = -0.0195, P (same) < 0.4731. SIMPER results showing the average dissimilarities (%), the two species contributing most to the dissimilarity and their contribution ratios to the average dissimilarities between depths

	One-way ANOSIM		SIMPER		
Depth (m)	R value	P value	Average dissimilarity (%)	Discriminating species 1 (*M. merlangus*) Contribution of species 1 (%)	Discriminating species 2 (*M. barbatus*) Contribution of species 2 (%)
D1-D2	-0.1063	0.6547	48.78	69.96	13.76
D1-D3	0.1771	0.1460	49.93	89.78	5.68
D2-D3	-0.0938	0.6922	50.73	84.01	6.54

* D1: Depth <54 m, D2: Depth 55-74 m, D3: Depth >75 m

by smaller mesh sizes, especially capturing quite high amounts of small individuals. *Gobius sp*. and Atlantic stargazer were the major discarded species caught by the nets because of their morphological structure or being more abundant in these fishing grounds. However, *R. venosa* and *S. inaequivalvis* were also caught due to the entangles in the nets caused by the contacts with the sea ground. The quantity of other discard species was very low. Benthic fishes have very slow growth rates and fecundity (Clarke *et al*., 2001). In this context, it can be argued that high discard rates for benthic fishes as whiting and red mullet cause negative effects on the populations of the species.

While the variability of retained and discard CPUE values in gillnets differed with seasons, depths and mesh sizes, they were similar in terms of the number of species. In regards to the changes of seasonal discard in gillnet, the lowest value was observed in summer and highest in winter. The numbers of discard species were found to reach their maximum in winter and minimum in autumn. This variation may be caused by several factors, such as the conditions of the sea behaviour of discard species, bottom structures of fishing areas, fishing strategies and reproductive behaviours of the species. However, there was an important difference in the discard species compositions between spring and summer and it was also detected that whiting and red mullet were the important species that contributed to this

Table 4. One-way ANOSIM results of discard species between different mesh sizes (*R* values and significance level, *p*). Global $R = 0.0898$, p (same) < 0.0076. SIMPER results showing the average dissimilarities (%), the two species contributing most to the dissimilarity and their contribution ratios to the average dissimilarities between different mesh sizes

Mesh size (mm)	One-way ANOSIM		SIMPER		
	R value	P value	Average dissimilarity (%)	Discriminating species 1 (*M. merlangus*) Contribution of species 1 (%)	Discriminating species 2 (*M. barbatus*) Contribution of species 2 (%)
32-34	0.0580	0.1316	58.44	82.40	10.31
32-36	0.0505	0.1475	56.52	81.41	9.86
32-40	0.4025	0.0012	68.82	83.15	9.41
32-44	0.2792	0.0017	67.60	80.02	9.02
34-36	-0.0615	0.9739	53.94	82.42	8.26
34-40	0.0612	0.1379	55.88	82.66	9.25
34-44	0.0060	0.3355	57.71	76.62	8.23
36-40	0.1013	0.0727	56.39	81.98	7.28
36-44	0.0109	0.3105	56.11	76.00	6.62
40-44	0.0055	0.3367	52.43	70.44	7.47

difference. While in the 55-74 m depth group, the discard amount was the highest and in the <54 m depths it was the lowest there was no significant difference among depth groups of species composition. In addition, the number of discard species was observed to decrease with increasing depth. Depending on the mesh sizes, the discard amount had its maximum value in 32 mm and minimum in 40 mm. Gray *et al.* (2005) reported that retained and discard catches were lowest in the smallest mesh size and our findings are also in accordance with their results. The number of discard species by mesh sizes was highest in 32 mm and lowest in 40 mm.

The results of the study showed that the majority of discard in whiting gillnets consisted of whiting individuals under the MLS. Reducing this discard can be achieved by selectivity studies. Additionally, fishing in deeper waters where catch amount is high but discard is low and fishing without contact to the bottom can significantly reduce the discard. In this context, an improvement in the selectivity properties of gillnets for each target species and studies in order to prevent the capture of discard species must be continuously implemented. There are two ways of improving the reduction of bycatch in fishing technology. The first one is the species and size selectivity improvements in fishing gears and the second one is using bycatch reduction devices (Matsuoka, 2008). Discard, mostly perceived as a waste, can be effective on utilization of fish stocks in different ways, biomass and on the functions of ecosystems and productivity (Gray *et al*., 2004). In this context, a detailed evaluation of the issues regarding the discard that may have the potential to cause serious negative effects, including all the fishing gears, is essential.

In conclusion, this study will contribute to the estimation of discard species and rates of gillnets used in whiting fishery, understanding of the effects of gillnet fisheries on the ecosystem and hence protection and management of local fish stocks. In addition, this study is also important in addressing the determination of the role of depth, mesh sizes and seasons on discard species and rates, as well as in forming a basis for possible legal restrictions and measures be taken. Accordingly for policy recommendations, as individuals of target species under MLS (13 cm TL) constituted a large rate of the discard, gillnet mesh size should be at least 36 mm and the use of other mesh sizes less than should be strictly prohibited for the prevention of individuals under the MLS capture. Further, large fish caught by larger mesh sizes will have even higher economic value in the market. In light of all these considerations, we recommend performing long-term monitoring for the accurate determination of levels and for a better understanding of impacts of discard on marine organisms and ecosystems.

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