www.trjfas.org
RESEARCH PAPER ISSN 1303-2712
Turkish Journal of Fisheries and Aquatic Sciences DOI: 10.4194/1303-2712-v18_7_04

Can Shifting Codend Mesh Shape and Mesh Size Increase the Size Selectivity of Red mullet (*Mullus barbatus*) in the Black Sea?

M. Hakan Kaykac[1*], Mustafa Zengin[2], Zafer Tosunoglu[1]

[1] Ege University, Faculty of Fisheries, 35100, Bornova, İzmir, Turkey
[2] Central Fisheries Research Institute, Trabzon, Turkey
Phone: +90 530 2120505; Fax +90 232 3747450
E-mail: m.hakan.kaykac@gmail.com

Abstract

More than half of the landing (70%) of Red mullet (*Mullus barbatus*) in Turkey is provided from the Black Sea, which is almost all (96%) with bottom trawls. The effect of demersal trawl codend mesh shape and size on the selectivity of Red mullet in the Black Sea was investigated. Selectivity trials were conducted in August 2014 on a commercial trawl boat with conventional (40D), 36 and 40 mm square mesh (36S and 40S) and turned mesh codends (40T90). Data were collected using the covered codend method with a total of 21 valid hauls and selection parameters were obtained by fitting a logistic equation using maximum likelihood method. The L_{50} value was found to be very low at 9.79 cm in the 40D trawl codend, while the L_{50} value of 40S (11.89 cm) and 36S (10.59 cm) codends was obtained 21.5% and 8.2% better compared to the 40D, respectively. According to the traditional trawl codend, a L_{50} value increase of 5.1% was observed in 40T90 (10.29 cm). Although all these values are below the Minimum Landing Size of the species, changes to the traditional mesh, especially in the shape of the mesh, can lead to significant improvements in size selectivity.

Key words: The Black Sea, red mullet, codend selectivity, mesh shape**,** mesh size.

Introduction

Red mullet, among species of demersal fishery resources, is one of the most important commercial species preferred by the consumer. *Mullus spp*. and the other demersal species have been caught proportionally and effectively by bottom trawls. It has been recently noted that there is an over-catching and over-exploitation on red mullet stocks declared by General Fisheries Commission for the Mediterranean (GFCM) and therefore, it is recommended to change the design of fishing gears to reduce the overall fishing pressure and the percentage of undersized fish in the total catch (FAO, 2011; GFCM, 2011). For this reason, GFCM has encouraged the studies aiming to improve selectivity and reducing discards of the Mediterranean demersal trawl fleet (GFCM, 2010).

Among the countries in the Black Sea (Mediterranean sub-regional fisheries code: GSA 29 in the Mediterranean basin), Turkey was a significant producer with the 83% of total landing amount of *Mullus spp*. in 2014 (STECF, 2015). Therewithal, 70% of annual landing of *Mullus spp*. in Turkey was provided from the Black Sea in 2015 (Anonymous, 2016a). Therefore, the Black Sea coast of Turkey is of great importance for the catching of these species. Vast majority (96%) of the *Mullus spp*. on the Black Sea coast of Turkey has been caught with bottom trawls (Knudsen, Zengin, & Koçak, 2010). Two species of *Mullus spp*. have been caught with the trawls in this region. Striped red mullet (*Mullus surmuletus*) usually constitutes only a very small (4%) section of the total Red mullet fishing in and around the Istanbul Strait, whereas Red mullet (*Mullus barbatus*) is a commonly caught

www.trjfas.org
ISSN 1303-2712
DOI: 10.4194/1303-2712-v18_7_04

species in the whole Black Sea. These two species are easily distinguishable from each other morphologically. However, in some places, the red mullet's minors are also called as a "striped red mullet" (STECF, 2015) due to local Turkish naming errors and it is reported that there is no striped red mullet in Turkish coast of the Black Sea (Keskin, 2012; Gümüş and Zengin, pers.com.). There is no minimum landing size (MLS) for the *M. surmuletus* in the Black Sea regulated by European Union (EU), while in Turkey there are 13 and 11 cm MLS regulation for the red mullet and striped red mullet, respectively (Anonymous, 2016b). Currently, Turkish Fisheries Regulation (TFR, No. 4/1, 2016) define 40 mm minimum mesh size for the diamond mesh in the Black Sea, and 44 mm for both the Aegean and the Levantine Seas. The use of 40 mm square mesh has been left to the preference of the fisherman according the Turkish fisheries regulation. Beginning September 1, 2020, diamond mesh size of 44 mm in the trawl codend will be used in the Black Sea (Anonymous, 2016b).

It is observed that red mullet and whiting stocks in the Black Sea were under excessive pressure due to over and illegal bottom trawl fishery between 2005 and 2013, therefore market size of these species has fallen (Zengin et al., 2014). Genç (2014) stated that between 1982 and 2011, there was a steady decline in the total amount of red mullet production.

In general, the majority of mesh selection due to the structure of the trawl nets takes place in the codend (Wileman, Ferro, Fonteyne, & Millar, 1996). Allowing to escape the small fish and to catch on top of a certain size group in the trawl codend is the basic principle of mesh selection. All of the trawl nets in the Black Sea have been constructed by diamond mesh. The mesh tends to close in the net under the smallest force applied, which affects mesh selectivity negatively (Robertson & Stewart, 1988; Guijarro & Massuti, 2006). In the last quarter of a century, many selectivity studies have been conducted to increase codend selectivity in bottom trawl nets in order to ensure the sustainability of demersal fishery resources and to protect the fish stocks (Lök, Tokaç, Tosunoğlu, Metin, & Ferro, 1997; Tokaç, Lök, Tosunoğlu, Metin, & Ferro, 1998; Sala, Priour, & Herrmann 2006; Sala, Lucchetti, & Buglioni, 2007; Tosunoğlu, Aydın, & Özaydın, 2008; Tokaç, Özbilgin, & Kaykaç, 2010; Aydın, Tokaç, Ulaş, Maktay, & Şensurat, 2011; Özbilgin, Tokaç, & Kaykaç, 2012; Eryaşar et al., 2014; Sala, Lucchetti, Perdichizzi, Herrmann, & Rinelli, 2015; Özbilgin et al., 2015). In addition, the GFCM constantly encourages scientists to conduct selectivity studies for sustainable fisheries resource (GFCM, 2010).

Although the greatest amount of red mullet is provided from the Black Sea, there have been very few selectivity studies related to this species until today (Zengin, Genç, & Tabak, 1997; Genç et al., 2002; Özdemir, 2006). Some researchers have indicated that the mesh size, which must be used in legal regulations, is not preferred by a vast majority of fishermen (Ceylan, Şahin, & Kalaycı, 2014; Zengin, Gümüş, Kaykaç, Tosunoğlu, & Akpınar, 2017). This leads to an increase in the number of small individuals and by-catch rates. The size of red mullet landed in this region has decreased from 13.7 cm in 1990 to 10.5 cm in 2005 (Knudsen et al., 2010). In Eastern Black Sea, Genç (2000) reported that the first sexual maturity of the red mullet is attained at 10.2 cm in males and 11.3 cm in females. These declines in the length of the red mullet caught is a dangerous situation for these stocks when considering the length of the first maturity (LFM) and the minimum landing size (MLS) group.

Only one study was conducted on square mesh panel codend and the results showed that this panel was more selective than the diamond mesh (Özdemir, 2006). It is known that square mesh protects their openness under the physical load with respect to diamond mesh nets and therefore allows small individuals to escape (Wileman et al., 1996). It has been found that escapes are high when on the trawl codends are provided with mesh openings appropriate for the morphology of any species (Tosunoğlu, 2007; Tokaç et al., 2014; Tokaç et al., 2016). Although

RESEARCH PAPER
Turkish Journal of Fisheries and Aquatic Sciences
www.trjfas.org
ISSN 1303-2712
DOI: 10.4194/1303-2712-v18_7_04

the square mesh trawl codend in favour of red mullet selectivity gives positive results, it is known that it is not preferred by the fisherman due to the difficulty of construction and repair of the net (Graham, Kynoch, & Fyer, 2003). Because of the difficulties in design applications of square mesh trawl codend, scientists examined different trawl codends that could be preferred by the fisherman. T90 codend, in which the standard diamond mesh netting orientation is turned 90°, has more mesh opening than the standard diamond mesh and easy to apply and repair for the fishermen (Moderhak, 1995,1997,1999; Wienbeck, Hermann, Moderhak, & Stepputtis, 2011). There is no study in the Black Sea on the T90, which positively effects on the size selectivity of various fish species with different morphometrics.

In recent years, fishermen and consumers have confronted with largely small individuals of red mullet in catching stocks and on the market to a large extent. Scientists dealing with fisheries management are emphasizing that this problem is moving forward in two main ways. The over-fishing and illegal fishing have gradually increased since the beginning of the 2000s, and the other is the use of non-selective trawl codends suitable for MLS and LFM (Ulman et al., 2013; STECF, 2015). To avoid this situation, there is a need for more selective studies toward the target species in order to be a quick solution in practice. The lack of monitoring selectivity studies in that region in about last 10 years is of great importance to understand the current situation. The aim of this study was to determine the effect of different mesh shapes (square and T90) and mesh size (36 and 40 mm square and 40 mm diamond mesh codends) selectivity on the red mullet in the Black Sea demersal trawl fishery.

Material and Methods

The selectivity trials were carried out on-board the commercial trawler "*Malkoç Bey*" (31 LOA, 1300 HP main engine) from 20th to 27th August 2014 in the Western part of the Black Sea (Figure 1). All hauls were made at depths ranging from 15 to 30 m and muddy grounds. The towing duration was between 60 and 90 minutes, and the towing speed ranged from 2.8 to 3.0 knots (mean 2.9) as in commercial trawling. All tows were performed during daytime. The gear employed in the selectivity test was conducted using a conventional bottom trawl with 900 meshes around the mouth (Figure 2).

Trawling was carried out by using four different codends with a total of 21 valid hauls. The first one was the commercially used nominal 40 mm polythene (PE) codend with 300 meshes on its circumference (three seems of 100 meshes panels-40D). The second codend was made of nominal 40 mm PE material and turned 90º T-90 with 300 meshes on its circumference (three seems of 100 meshes panels-40T90). The third codend was constructed as constructed as 150 bars on its circumference full square mesh codend with nominal 36 mm PE netting (36S). Finally, the fourth one was150 bars on its circumference full square mesh codend with nominal 40 mm PE netting (40S) (Figure 3). All the codends were approximately 4-4.5 m in stretched lengths. They were attached to the end of the funnel which was 300 meshes in its circumference and made of 40 mm mesh size PE netting.

The hooped-covered codend method was used to collect selectivity data (Wileman et al., 1996). A 8.2 m long, and 24 mm mesh size knotless PA (polyamide) netting cover was used to collect the individuals that escaped. The cover was supported by two hoops (PVC Ø 1.6 m) to avoid the masking effect and to provide water flow between the codend and the cover. These hoops were mounted on the cover at distances of 2.2 and 5.2 meters from the attachment point at the end of the funnel.

www.trjfas.org
ISSN 1303-2712
DOI: 10.4194/1303-2712-v18_7_04

The mean mesh size of each codends was measured using a calliper rule. A 4 kg weight was tied vertically to the stationary jaw of the rule. A total of 60 meshes (3 lines of 20 meshes in the towing direction) near to the aft of each codend were measured (Table 1).

At the end of each tow, once the net was hauled onboard, the cover catch was first emptied, the catch was sorted by species, and then weighed. The same procedure was followed for the codend catch. Total lengths of full or subsamples of the target species were then measured to the nearest cm below. Selectivity data were collected using the covered codend method and selection curves of the individual hauls were obtained by fitting a logistic function:

$$r(l) = \exp(v_1 + v_2 l) / [1 + \exp(v_1 + v_2 l)]$$

where *r(l)* is the retained proportion of length class *l*, given that it entered the codend (Wileman et al., 1996), and $v=(v_1, v_2)T$ is the vector of the selectivity parameters. The values of L_{50} were estimated from the expressions:

$$L_{50} = \frac{-v_1}{v_2}$$

These parameters were calculated by maximum likelihood using the software CC 2000 (ConStat, 1995). For red mullet, mean selectivity curves using EC Model software (ConStat, 1995) were estimated by taking into account the between-haul variation of the selectivity parameters according to Fryer (1991).

A likelihood ratio test (McCullagh & Nelder, 1991) was carried out to evaluate if the selection curves estimated for the red mullet were statistically different for the two compared codends (see Campos, Fonseca & Henriques, 2003 and Deval, Bök, Ateş, Ulutürk, & Tosunoğlu, 2009).

Results

Mean values of totally 60 mesh measurements from 3 different lines of each codends were shown in table 1. 40D, 40T90, 36S and 40S codends on the same traditional trawl were carried out 4, 7, 6 and 4 valid hauls, respectively. A total of 21 valid hauls were performed during the trials. 6869.9 kg total catching was made by 4 trawl codends with different mesh shapes and sizes during 1595-minute haul duration. 33%, 17%, 21% and 29% of the total catch were gathered with 40D, 40T90, 36S and 40S codends, respectively. Weight of red mullet and its percentage in total catch were 2231.6 kg and 32% in all hauls. Catch per hour in all hauls was calculated 83.9 kgh^{-1} for the red mullet and 258.4 kgh^{-1} for total catch.

40 mm Diamond Mesh Codend (40D)

In the 40D trawl codend (used by fisherman), a total of weight 2277.4 kg was carried out in both codend and cover for 4 valid hauls. In terms of weight, 35.6% of the total catch was constituted by the red mullet and the species were caught totally 162.3 kgh^{-1} by 40D codend. In total, 47316 red mullets were counted 67.8 % in the codend and 32.2% in the cover. The numbers of red mullets both codend and cover for every hauls were in given table 3. About 87.6% of the total red mullet were constituted below the MLS value. 36.2% in the cover and 63.8% in the codend of the value were calculated for this trial. Percentage distribution of the codend by numbers was shown in table 2.

Figure 4 presents the length frequency distributions (ranged between 5 and 18 cm) of the red mullet that entered and escaped. Length frequency distributions showed bimodal with a major peak at about 6 cm and a minor peak at about 10 cm for the cover and a major peak at about 10 cm and a minor peak at about 12 cm for codend (Figure

Turkish Journal of Fisheries and Aquatic Sciences
RESEARCH PAPER
www.trjfas.org
ISSN 1303-2712
DOI: 10.4194/1303-2712-v18_7_04

4). Selectivity and regression parameters with their standard errors, variance matrix values and the number of the fish caught in the codend and cover in every single haul as well as mean curves (according to Fryer 1991) for each codend are given Table 3. Length at fifty percent retention (L_{50}) and Selection Range (SR) values were 9.8 (s.e. 0.35) and 2.2 (s.e. 0.11) cm for the codend, respectively (Table 3).

40 mm Turned Mesh Codend (40T90)

A total of 525-minute operation time was carried out 7 valid hauls during the experiment. A total of 13664 individuals were caught 8383 in the codend and 5281 in the cover. 22.2% of the total catch (1143 kg) in this codend comprised of this species. In this value (254.3 kg), a total red mullet of 30.1 kgh^{-1} was caught via 80% in the codend and 20% in the cover. Numbers of red mullets in both codend and cover for every hauls were given in table 3. 53.4% in the codend and 46.6% in the cover number of individuals below 13 cm were caught by 40T90 (Table 2). Only 9.8% of the individuals above the MLS value were detected in the cover.

The length frequency of distribution showed two peaks in the cover with a major peak at 6 cm and a minor peak at about 12 cm and unimodal in the codend with the mode at about 12.5 cm. Individual haul and mean selectivity curves are shown in figure 4. The mean L_{50} and SR values were 10.29 and 1.92 cm for the codend, respectively (Table 3). The 40T90 codend provided higher mean L_{50} and lower SR values than the commercial codend (40D). According to selectivity parameter values, about 5.1% better L_{50} value was detected with 40T90 codend. However, the L_{50} value of the 40T90 codend is still considerably lower than MLS.

36 mm Square Mesh Codend (36S)

A total of 6 valid hauls were carried out during the trial in 425 minutes. In totally 19967 red mullets were caught by 36S codend (Table 3). 31.1% of the total catch (1407 kg) was constituted by the red mullet. In terms of weight, 11.6% of the individuals were caught in cover. At the same time, 62.0 kg red mullet was caught in an hour. 74.3% in the codend and 25.7% in the cover of captured red mullet were determined to be below MLS value. 99.2% of the individuals above MLS value were retained in the codend. Only 0.8% of individuals above the MLS value were detected in the cover. Percentage distribution of the codend by numbers was shown in table 2.

The length of red mullets varied between 5 and 18.5 cm and showed a main peak at 12 cm in the codend and two peaks in the cover (a minor peak 6 cm and a major peak 10.5 cm). Individual haul and mean selectivity curves are shown in figure 4. Selectivity and regression parameters with their standard errors, variance matrix values and number of the fish caught in the codend and cover every single haul as well as mean curves (according to Fryer 1991) for each codend are given Table 3. Length at fifty percent retention (L_{50}) and Selection Range (SR) values were 10.59 (s.e. 0.09) and 1.11 (s.e. 0.03) cm for the 36S, respectively (Table 3). According to selectivity parameter values, about 8.2% better L_{50} value was detected with 36S codend. However, the L_{50} value of the codend is still considerably lower than MLS.

40 mm Square Mesh Codend (40S)

A total of 4 valid hauls were made in 345 minutes and 44179 individuals were caught in this trial. In terms of weight, the red mullet, about 35.7% of the total catch (728.6 kg), were caught totally 133.7 kgh^{-1} by 40S codend. Furthermore, nearly 64% of the species were weighted in the cover. The number of red mullets both in the codend and in the cover for every hauls was given in table 2. 83% of 39088 individuals below MLS value were determined

www.trjfas.org
ISSN 1303-2712
DOI: 10.4194/1303-2712-v18_7_04

in the cover. While 91.6% of the individuals above MLS value were escaped to from the codend, only 17% of the red mullet below MLS value was retained in the codend (Table 2).

The length frequency of distribution showed two peaks in the cover with a major peak at 6 cm and a minor peak at about 10 cm and unimodal in the codend with the mode at about 12.5 cm. Individual haul and mean selectivity curves are shown in figure 4. The mean L_{50} and SR values were 11.89 and 1.26 cm for the codend, respectively (Table 3). The 40S codend provided higher mean L_{50} values than the 40D codend. According to selectivity parameter values, about 21.5% better L_{50} value was detected with 40S codend. This codend was given the best L_{50} value of the codends used in the experiments. However, L_{50} value of the codend is still considerably lower than MLS.

According to the MLS value, the best of the mean selective curve was given to 40S trawl codend. Although L_{50} mean value of this codend was determined above the LM50 value, the opposite was true for the other trawl codends used in the trial (Figure 5).

The statistical comparison of the selections curves (36S, 40S and 40T90) compared to the 40D by the likelihood ratio test revealed significance at the 0.05 level for red mullet.

Discussion

In this study, we compared the effect of the codend mesh shape and mesh size on the selectivity of red mullet which is the most important species in the Black Sea trawl fishery. For this purpose, traditional trawl codend (40D), 90° turned mesh codend (40T90) and square mesh codends (36S and 40S) which have two different mesh sizes were tested for the species. It is the first selectivity study on the 36S, 40S and 40T90 trawl codends because of the mesh shape, size and overall application of the codend in the region. The results show that selectivity of commercial trawl codend (40D) used in the region is rather poor, whereas square mesh substantially increased overall selectivity for the red mullet.

There are limited studies on the size selectivity of the red mullet in the region (Zengin et al., 1997; Genç et al., 2002) (Table 4). Özdemir (2006) has revealed that the selectivity values he obtained in the determination of the location of the 36, 40 and 44 mm square mesh panels were higher compared to those of traditional trawl codends with 40 mm diamond mesh (L_{50} = 12.01 cm).

The previous studies and the results obtained in this study indicate that when the MLS values are taken into consideration, the size selectivity of the red mullet in the current commercial trawl codend is considerably low (Özbilgin & Tosunoğlu, 2003; Tosunoğlu, Özbilgin, & Özbilgin, 2003; Kaykaç, 2007; Sala, Lucchetti, Piccinetti, & Ferretti, 2008). Many researchers point out that in round shaped fish such as the red mullet, high selectivity values are obtained as a result of square mesh use in the codend (Stewart, 2002). Because diamond mesh nets tend to close under load compared to square mesh nets, hence reducing the escape area and accordingly, preventing the escape of small individuals (Robertson & Stewart, 1988; Guijarro & Massuti, 2006).

In Turkey, many researchers have been working on different mesh sizes, shapes and equipment for the selectivity of this species. The study results in table 4 indicate that the L_{50} value in the 40S trawl codend is quite high (Demirci, 2009; Ateş, Deval, Bök, & Tosunoğlu, 2010; Aydın et al., 2011; Özbilgin et al., 2015). At the same time Sala et al., (2008) reported that selectivity of red mullet in 40S trawl codend is significantly more selective than the others. In our results, although the 40S trawl codend gave higher L_{50} values compared to the trawl codends used in the experiment, it was significantly lower than the square-mesh codend results in other regions (Table 4). In the

www.trjfas.org
ISSN 1303-2712
DOI: 10.4194/1303-2712-v18_7_04

selectivity studies, it is stated that internal and external factors are effective on the selectivity values. O'Neill et al. (2016) has reported that the increase in bending stiffness of the rope used in the codend for Haddock reduced the value of L_{50}. The differences in square mesh results between these studies and our present studies might have been caused by towing duration, operation time and region, populations fished and properties of the fishing gears.

In the Black Sea, the total amount of fishing in each tow is quite large except for the target species during operation, and the majority of them consist of bycatch fishing and discards. Ceylan et al. (2014) stated that the bycatch fishing was about 54% in the trawls in this region. This may be thought to be also effective on the selectivity parameters, however, Sala and Luchetti (2011) reported that the L_{50} and SR values of codend fishing amount in the Mediterranean generally have no significant effect on the selectivity of the red mullet. However, it is also known that the garbage and non-target catch accumulated in the codend prevent the fish escapes by creating a load in the codend and closing the mesh holes.

Graham et al. (2003) reported that full square mesh cod-ends are unpopular with the fishing industry because they lack strength, the knots can be unstable and the nets are awkward to handle and repair. In addition to the aforementioned disadvantages of the use of the square mesh nets, the fact that it is excessively selective compared to the fisherman is also an important factor. So much so that, in our study, fishermen recommended us to try the 36S codend thinking that the 40S would be excessively selective. Although 36S is more selective than the 40D codend, it is well below the MLS value. In the 36 mm square panel application, as well, the selectivity values were found to be above 40D and below 40S (Özdemir, 2006). Red mullet is subjected to a MLS of 13 cm in Turkish territorial waters according to Turkish Fisheries Regulation to ensure contribution to the future stock before exploitation (Anonymous, 2016b).

In the model study he conducted, Tokaç et al. (2016) reported that mesh openness (OP) had a remarkable effect over L_{50} value in Red mullet size selectivity in both square mesh and diamond mesh nets. In the study, OP value is an important factor in the fact that the square mesh nets are more selective than diamond mesh nets. Obtaining low L_{50} values may result from the fact that the OP value cannot be fixed and many variable factors as mentioned above. Many studies have clearly demonstrated that square mesh codends capture fewer juveniles than diamond mesh codends because of OP (Sala et al., 2008; Aydın et al., 2011; Özbilgin et al., 2012, 2015; Tokaç et al., 2016; Tosunoğlu et al., 2003; Tosunoğlu, Aydın, Salman, & Fonseca, 2009). Therefore, TFR define a minimum mesh size of 44 mm diamond or 40 mm square mesh netting for demersal trawl codends used in the Mediterranean. TFR reports that 40 mm diamond mesh use is required for bottom trawls in the Black Sea, and 44 mm diamond mesh will be applied after 1 September 2020.

Fishermen do not prefer to use the square mesh application in the bottom trawl codends with the thought that they will bring extra work load for them (their being equipped and repaired). In terms of ease of use, it is known that trawl codends with diamond meshes are more advantageous than codends with square mesh (Wienback et al., 2011). It is also stated that square mesh application in the selectivity of laterally flattened fish indicates low selectivity (Lök et al., 1997; Sala et al., 2008). Some studies have demonstrated that T90 trawl codends, which are obtained by rotating a diamond mesh net by 90°, are more selective than the existing trawl codend (40D=T0) (Madsen, Herrmann, Frandsen, & Krag, 2012). In fact, it has been detected that the studies carried out on the T90 trawl codends in the Baltic Sea have improved the selectivity and contributed to the improvement of fish resources (Moderhak 1995;1999; Moderhak et al., 1999; Hansen, 2004; Digre, Hansen, & Erikson, 2010). With this study, T90 trawl codend was tested for the first time in the Black Sea. The results obtained indicated that the 40T90 trawl

www.trjfas.org
ISSN 1303-2712
DOI: 10.4194/1303-2712-v18_7_04

codend was more selective compared to the 40D trawl codend at red mullet selectivity. The use of trawl codends of the same net mesh size as T90 has been observed to have a positive effect on the selectivity of the red mullet in both experimental studies (Kaykaç, 2005) and in the model experiments (Tokaç et al., 2014).

In conclusion, changes in net mesh shape (square mesh and T90) and net mesh size (36S and 40S) were found to increase the length selectivity of the red mullet in the Black Sea compared to traditional trawl codends. In particular, it was observed that 40S codends selected larger size groups than the others. In recent years, escape mortality (due to skin injures and exhaustion) as well as selectivity of trawl codends is of great importance. In this context, it has been reported that 40S (26.3%) trawl codend for the red mullet gives the lowest escape mortality rate compared to the 44D (46.3%) and 50D (27.4%) trawl codends. However, it is stated that this condition is not related to the mesh size or shape (Düzbastılar, Laleli, Özgül & Metin, 2015; Düzbastılar et al., 2017). 40S codend contributes to the protection of stockpiles of the red mullet. There is a limited number of selectivity studies for sustainable fisheries in the Black Sea, which constitutes an important part in terms of red mullet production. However, it was reported that the use of 44 mm diamond will be started in 2020. At present, the current red mullet size groups are quite low. But the increase in the size groups put ashore can lead to even better pricing. More extensive and detailed selectivity studies are needed during commercial fishing to protect fisheries management and sustainable red mullet stocks in such an area where production is intensive.

Acknowledge

This work was financed by the European Project “BENTHIS (EU-FP7-312008)”. The authors would like to thanks and gratitude to the project leader Prof. Dr. Adrian RJINSDORP and Prof. Dr. Aysun GÜMÜŞ providing all kinds of support. Thanks are also due to Murathan ÖZDEMİR and all the project researchers for participating the sea trials.

References

Anonymous (2016a). Fishery Statistics 2015. State Institute of Statistics Prime Ministry Republic of Turkey. Retrieved from http://www.tuik.gov.tr/PreHaberBultenleri.do?id=21720

Anonymous (2016b). The Commercial Fish Catching Regulations in 2016–2020 Fishing Period (4/1 Notification No: 2016/35). Retrieved from http://www.tarim.gov.tr/BSGM/Duyuru

Ateş, C., Deval, M.C., Bök, T., & Tosunoğlu, Z. (2010). Selectivity of diamond (PA) and square (PE) mesh codends for commercially important fish species in the Antalya Bay, Eastern Mediterranean. *Journal of Applied Ichthyology*, 26, 465–471. https://dx.doi.org/10.1111/j.1439-0426.2010.01462.x

Aydın, C., Tokaç, A., Ulaş, A., Maktay, B., & Şensurat, T. (2011). Selectivity of 40 mm square and 50 mm diamond mesh codends for five species in the Eastern Mediterranean demersal trawl fishery. *Afr. J. Biotechnol.*, 10, 5037–5047. https://dx.doi.org/10.5897/AJB11.082

Ceylan, Y., Şahin, C., & Kalaycı, F. (2014). Bottom trawl fishery discards on the Black Sea coast of Turkey. *Medit. Mar. Sci.*, 15/1, 156-164. https://dx.doi.org/10.12681/mms.421

Campos, A., Fonseca, P., & Henriques, V. (2003). Size selectivity for four fish species of the deep ground fish assemblage off the Portuguese southwest coast: evidence of mesh size, mesh configuration and cod end catch effects. *Fish. Res.*, 63, 213–233. https://dx.doi.org/10.1016/S0165-7836(03)00060-2

ConStat, (1995). CC Selectivity. Granspaettevej 10, DK-9800 Hjjlarring, Denmark.

Demirci, S. (2009). *Selectivity of square and diamond mesh trawl codend for some fish species in north east Mediterranean* (PhD Thesis). University of Mustafa Kemal, Hatay, Turkey.

Deval, M. C., Bök, T., Ateş, C., Ulutürk, T., & Tosunoğlu, Z. (2009). Comparison of the size selectivity of diamond (PA) and square (PE) mesh codends for deepwater crustacean species in the Antalya Bay, eastern Mediterranean. *J. Appl. Ichthyol.*, 25, 372–380. https://dx.doi.org/10.1111/j.1439-0426.2009.01239.x

Digre, H., Hansen, U.J., & Erikson, U. (2010). Effect of trawling with traditional and ‘T90’ trawl codends on fish size and on different quality parameters of cod *Gadus morhua* and haddock *Melanogrammus aeglefinus*. *Fisheries Science*, 76(4), 549–559. https://dx.doi.org/10.1007/s12562-010-0254-2

Dinçer, A.C. (2014). Common method and gears used in the Turkish coast of The Black Sea (pp. 212-223). In: Düzgüneş, E., Öztürk, B., & Zengin, M. (Eds.), Turkish Fisheries in the Black Sea. Publication Number 40, İstanbul, Turkey, Published by Turkish Marine Research Foundation (TUDAV), 548 pp.

Düzbastilar, F.O., Breen, M., Aydın, C., Özbilgin, H., Özgül, A., Ulaş, A., Metin, G., Gül, B., & Lök, A. (2017). Seasonal variation in mortality of red mullet (*Mullus barbatus*) escaping from codends of three different sizes in the Aegean Sea. *Sci. Mar.,* 81(3), 339-349. http://dx.doi.org/10.3989/scimar.04600.19A

Düzbastılar, F.O., Laleli, T., Özgül, A., & Metin, G. (2015). Determining the severity of skin injuries of red mullet, *Mullus barbatus* (Actinopterygii: Perciformes: Mullidae), inflicted during escape from trawl codend. *Acta Ichthyol. Piscat.,* 45 (1): 75–83. http://dx.doi.org/10.3750/AIP2015.45.1.08

E.C., (2006). Council regulation (EC 1967/2006) 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. Off. J. Eur. Union 409, 75.

Eryaşar, A.R., Özbilgin H., Gökçe G., Özbilgin Y.D., Saygu I., Bozaoğlu A.S., & Kalecik, E. (2014). The Effect of Codend Circumference on Selectivity of Hand-Woven Slack Knotted Codend in the North Eastern Mediterranean Demersal Trawl Fishery. *Turkish Journal of Fisheries and Aquatic Sciences*, 14, 463-470. https://dx.doi.org/10.4194/1303-2712-v14_2_17

FAO, (2011). Review of the State of World Marine Fishery Resources. Retrieved from http://www.fao.org/docrep/015/i2389e/i2389e.pdf

Fryer, R. (1991). A model of the between-haul variation in selectivity. *ICES J. Mar. Sci.,* 48, 281–290. https://dx.doi.org/10.1093/icesjms/48.3.281

Genç. Y. (2000). Türkiye'nin Doğu Karadeniz kıyılarındaki barbunya (*Mullus barbatus ponticus* Ess., 1927) balığının biyo-ekolojik özellikleri ve populasyon parametreleri (PhD Thesis). Karadeniz Teknik Üniversitesi. Fen Bilimleri Enstitüsü. Trabzon, Turkey.

Genç, Y., Mutlu, C., Zengin, M., Aynın, İ., Zengin, B., & Tabak, İ. (2002). Doğu Karadeniz'deki av gücünün demersal balık stokları üzerine etkisinin tespiti. Trabzon Su Ürünleri Merkez Araştırma Enstitüsü, Sonuç Raporu Proje No: TAGEM/IY/97/17/03/006, 114 pp (In Turkish).

Genç, Y. (2014). Red mullet fisheries in the Black Sea (pp. 340-360). In: Düzgüneş, E., Öztürk, B., Zengin, M. (Eds.) Turkish Fisheries in the Black Sea. Publication Number 40, İstanbul, Turkey, Published by Turkish Marine Research Foundation (TUDAV), 548 pp.

GFCM, (2010). Report of the Transversal Workshop on Selectivity Improvement, By-Catch Reduction and Alternative Gears, Alexandria, Egypt, 25–27 October.

GFCM, (2011). Report of the SCSA Working Group on Stock Assessment of demersal species, Istanbul, Turkey, 18–23 October 2010. GFCM: SAC13/2011/Inf.19.

Graham, N., Kynoch, R.J., & Fryer, R.J. (2003). Square mesh panel in demersal trawls: Further data relating haddock and whiting selectivity to panel position. *Fish. Res.,* 62(3):361-375. https://dx.doi.org/10.1016/S0165-7836(02)00279-5

Guijarro, B., & Massuti, E. (2006). Selectivity of diamond and square mesh codends in the deepwater crustacean trawl fishery off the Balearic Island (western Mediterranean). *ICES J. Mar. Sci.,* 63, 52–67. https://dx.doi.org/10.1016/j.icesjms.2005.08.011

Hansen, U.J. (2004). Performance of a trawl made from 90º turned netting (T90) compared with that of traditional codends. Gydynia: ICES Fishing Technology and Fish Behaviour Working Group Meeting.

Kaykaç, M.H. (2005). *Geleneksel dip trol ağında torba ağ göz açılımını artırmaya yönelik çalısmalar* (PhD Thesis). Ege Üniversitesi Fen Bilimleri Enstitüsü, Izmir, Turkey.

Kaykaç, M.H. (2007). Selectivity of standard and narrow trawl codends for the red mullet (*Mullus barbatus* L., 1758) and annular sea bream (*Diplodus annularis* L.,1758). *Ege J. Fish. Aqua. Sci.,* 24, 261–266.

Keskin, Ç. (2012). A preliminary study on demersal fishes in the south-western Black Sea shelf (NW Turkey). *J. Black Sea/Mediterranean Environment,* 18(3), 341-349.

Knudsen, S., Zengin, M., & Koçak, M.H. (2010). Identifying drivers for fishing pressure. A multidisciplinary study of trawl and sea snail fisheries in Samsun, Black Sea coast of Turkey. *Ocean and Coastal Management,* 53, 252-269. http://dx.doi.org/10.1016/j.ocecoaman.2010.04.008

Lök, A., Tokaç, A., Tosunoğlu, Z., Metin, C., & Ferro, R.S.T. (1997). Effects of different cod-end design on bottom trawl selectivity in Turkish Fisheries of the Aegean Sea. *Fish. Res.,* 32, 149–156. https://dx.doi.org/10.1016/S0165-7836(97)00048-9

Madsen, N., Herrmann, B., Frandsen, R.P., & Krag, L.A. (2012). Comparing selectivity of a standard and turned mesh T90 codend during towing and haul-back. *Aquatic Living Resources,* 25, 231–240. https://dx.doi.org/10.1051/alr/2012021

McCullagh, P., & Nelder, J.A. (1991). Generalized linear models, 2nd edn. Monographs on Statistics and Applied Probability 37. Chapman & Hall, London, 511 pp.

Moderhak, W. (1995). On properties of codend meshes differently oriented with respect to direction of motion. ICES Fish Capture Committee, B:21, 1–9.

Moderhak, W. (1997). Determination of selectivity of cod codends made of netting turned through 90°. *Bulletin of the Sea Fisheries Institute,* 1(1), 3-14.

Moderhak, W. (1999). Investigations of the selectivity of cod codends with meshes turned through 90°. *Bulletin of the Sea Fisheries Institute,* Gdynia, 1(146), 39–55.

O'Neill, F.G., Kynoch, R.J., Blackadder, L., Fryer, R.J., Eryaşar, A.R., & Sala, A. (2016). The influence of twine tenacity, thickness and bending stiffness on codend selectivity. *Fish. Res.,* 176, 94–99. https://dx.doi.org/10.1016/j.fishres.2015.12.012

www.trjfas.org
ISSN 1303-2712
DOI: 10.4194/1303-2712-v18_7_04

Özbilgin, H., & Tosunoğlu, Z. (2003). Comparison of the selectivities of double and single codends. *Fish. Res.,* 63, 143–147. https://dx.doi.org/10.1016/S0165-7836(03)00005-5

Özbilgin, H., Tokaç, A., & Kaykaç, H. (2012). Selectivity of commercial compared to larger mesh and square mesh trawl codends for four fish species in the Aegean Sea. *J. Appl. Ichthyol.,* 28, 51–59. https://dx.doi.org/10.1111/j.1439-0426.2011.01916.x

Özbilgin, H., Eryaşar, A.R., Gökçe, G., Özbilgin, Y.D., Bozaoğlu, A.S., Kalecik, E., & Herrmann, B. (2015). Size selectivity and hand and machine woven codends and short term commercial loss in the Norteastern Mediterranean. *Fish. Res.,* 164, 73–85. https://dx.doi.org/10.1016/j.fishres.2014.10.022

Özdemir, S. (2006). *The effect of position and mesh size of square mesh panel applied in bottom trawl on catchability of different species* (PhD Thesis). Ondokuz Mayıs University, Science Institute, Samsun, Turkey.

Özdemir, S., Erdem, Y., Erdem, E., & Özdemir Z.B. (2009). Comparison of size composition and catch efficiency of Horse mackerel (*Trachurus trachurus* L.) and blue fish (*Pomatomus saltatrix* L.) caught by bottom trawl from different fishing areas (in Turkish with English abstract). Celal Bayar Üniversitesi, Fen Bilimleri Dergisi, 5, 19-26.

Robertson, J.H.B. & Stewart, P.A.M. (1988). A comparison of size selection of haddock and whiting by square and diamond mesh codends. *ICES J. Mar. Sci.,* 44,148–161.

Sala, A., Priour, D., & Herrmann, B. (2006). Experimental and theoretical study of redmullet (*Mullus barbatus*) selection in codends of Mediterranean bottom trawls. *Aquat. Living Resour.,* 19, 317–327. https://dx.doi.org/10.1051/alr:2007002

Sala, A., Lucchetti, A., & Buglioni, G. (2007). The influence of twine thickness on the size selectivity of polyamide codends in a Mediterranean bottom trawl. *Fish. Res.,* 83, 192–203. https://dx.doi.org/10.1016/j.fishres.2006.09.013

Sala, A., Lucchetti, A., Piccinetti, C., & Ferretti, M. (2008). Size selection by diamond and square mesh codends in multi-species Mediterranean demersal trawl fisheries. *Fish. Res.,* 93, 8–21. https://dx.doi.org/10.1016/j.fishres.2008.02.003

Sala, A., & Lucchetti, A. (2011). Effect of mesh size and codend circumference on selectivity in the Mediterranean demersal trawl fisheries. *Fish. Res.,* 110, 252–258. https://doi.org/10.1016/j.fishres.2011.04.012

Sala, A., Lucchetti, A., Perdichizzi, A., Herrmann, B., & Rinelli, P. (2015). Is square-mesh better selective than larger mesh? A perspective on the management for Mediterranean trawl fisheries. *Fish. Res.,* 161, 182–190. https://dx.doi.org/10.1016/j.fishres.2014.07.011

STECF, (2015). Scientific, Technical and Economic Committee for Fisheries (STECF) – Black Sea assessments (STECF-15-16). Publications Office of the European Union, Luxembourg, EUR 27517 EN, JRC 98095, 284 pp.

Stewart, P.A.M. (2002). A review of studies of fishing gear selectivity in the Mediterranean. FAO COPEMED, 57 pp.

Ulman, A., Bekişoğlu, Ş., Zengin, M., Knudsen, S., Ünal, V., Mathews, C., Harper, S., & Pauly, D. (2013). From bonito to anchovy: a reconstruction of Turkey's marine fisheries catches (1950-2010). *Mediterranean Marine Science*, 14(2), 309-342. https://dx.doi.org/10.12681/mms.414

Tokaç, A., Lök, A., Tosunoğlu, Z., Metin, C., & Ferro, R.S.T. (1998). Codend selectivities of a modified bottom trawl for three species in the Aegean Sea. *Fish. Res.,* 39, 17–31. https://dx.doi.org/10.1016/S0165-7836(98)00172-6

Tokaç, A., Özbilgin, H., & Kaykaç, H. (2010). Selectivity of conventional and alternative codend design for five fish species in the Aegean Sea. *J. Appl. Ichthyol.,* 26, 403–409. https://dx.doi.org/10.1111/j.1439-0426.2009.01379.x

Tokaç, A., Herrmann, B., Aydın, C., Kaykaç, H., Ünlüler, A., & Gökçe, G. (2014). Predictive models and comparison of the selectivity of standard (T0) and turned mesh (T90) codends for three species in the Eastern Mediterranean. *Fish. Res.,* 150, 76–88. https://dx.doi.org/10.1016/j.fishres.2013.10.015

Tokaç, A., Herrmann, B., Gökçe, G., Krag, L.A., Nezhad, D.S., Lök, A., Kaykaç, H., Aydın, C., & Ulaş, A. (2016). Understanding the size selectivity of red mullet (*Mullus barbatus*) in Mediterranean trawl codends: A study based on fish morphology. *Fisheries Research*, 174, 81-93. https://dx.doi.org/10.1016/j.fishres.2015.09.002

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 UK.,* 83, 1309- 1313. http://dx.doi.org/10.1017/S0025315403008737

Tosunoğlu, Z. (2007). Trawl codend design (44 mm diamond PE mesh) and the effect on selectivity for *Pagellus erythrinus* and *Pagellus acarne*, two species with different morphometrics. *Journal of Applied Ichthyology,* 23, 578-582. http://dx.doi.org/10.1111/j.1439-0426.2007.00859.x

Tosunoğlu, Z. Aydın, C., & Özaydın, O. (2008). Selectivity of a 50-mm diamond mesh knotless polyethylene codend for commercially important fish species in the Aegean Sea. *Journal of Applied Ichthyology*, 24, 311-315. http://dx.doi.org/10.1111/j.1439-0426.2008.01067.x

Tosunoğlu, Z., Aydın, C., Salman, A., & Fonseca, P. (2009). Selectivity of diamond, hexagonal and square mesh codends for three commercial cephalopods in the Mediterranean. *Fisheries Research*, 97, 95–102. http://dx.doi.org/10.1016/j.fishres.2009.01.006

Wienbeck, H., Herrmann, B., Moderhak, W., & Stepputtis, D. (2011). Effect of netting direction and number of meshes around on size selection in the codend for Baltic cod (*Gadus morhua*). *Fish. Res.,* 109, 80–88. https://dx.doi.org/10.1016/j.fishres.2011.01.019

Wileman, D., Ferro, R.S.T., Fonteyne, R., & Millar, R.B. (1996). Manual of methods of measuring the selectivity of towed fishing gear (ICES Coop. Res. Rep., No. 215). Copenhagen K., Denmark, 126 pp.

Zengin, M., Genç, Y. & Tabak, İ. (1997). Determination of the selectivity of bottom trawl. Republic of Turkey, Minister of Agriculture and Rural Affairs, (Project No: TAGEM/ IY/96/12/1/004) Project Report, Trabzon, 51 pp. [In Turkish.]

Zengin, M. (2006). Türkiye'nin Orta Karadeniz (Samsun: Kızılırmak-Yeşilırmak) Kıyılarındaki Ekosistem-Habitat Değişimleri Üzerine Genel Bir Değerlendirme. In E. Özhan (Eds.), *Türkiye'nin Kıyı ve Deniz Alanları VI. Ulusal Konferansı,* (pp. 275-278). Muğla, Turkey

Zengin, M., Gümüş, A., Süer, S., Rüzgar, M., Van, A., Özcan Akpınar İ., Tosunoğlu, Z., Kaykaç, M. H., Başçınar, S. N., Uzmanoğlu, M. S., Çelik, T., Osma, R., Sü, U., & Karadurmuş, U. (2014). The Fisheries Impact on the Benthic Ecosystem

RESEARCH PAPER
www.trjfas.org
ISSN 1303-2712
DOI: 10.4194/1303-2712-v18_7_04

of Samsun Shelf Area in the Turkish Black Sea Coast. In I. Aydın, & S. Yerli, *FABA International Symposium on Fisheries and Aquatic Sciences*, (pp. 54-55). Trabzon, Turkey, Harman Press.,580 pp.
Zengin, M., Gümüş, A., Kaykaç, H., Tosunoğlu, Z., & Akpınar, İ.Ö. (2017). The impact of towing gears on the benthic macro fauna: current status for Black Sea and the Sea of Marmara. *Turkish Journal of Aquatic Sciences*, 32(2): 76-95. http://dx.doi.org/10.18864/TJAS201707

Table 1. Characteristics of the codends used in the experiments.

Codend Name	*40D*	*40T90*	*36S*	*40S*
Nominal mesh length (mm)	40	40	36	40
Measured mesh opening (mm)	41.29	39.47	35.95	39.85
SE (mm)	0.39	0.09	0.12	0.08
N	60	60	60	60
Min. - Max. (mm)	39-52	38-41	34-38	39-42
Material (Knotted)	PE	PE	PE	PE
Circumference mesh number	300	300	150	150

Table 2. Total numbers and percentage values below and above MLS (Minimum Landing Size= 13 cm) of the red mullet in codend (retained) and cover (escape) according to 40D, 40T90, 36S and 40S.

MLS = 13 cm		**40D**		**40T90**		**36S**		**40S**	
		Codend	*Cover*	*Codend*	*Cover*	*Codend*	*Cover*	*Codend*	*Cover*
<MLS	n	26429	15027	5724	4991	11072	3830	6662	32426
	%	***63.8***	***36.2***	***53.4***	***46.6***	***74.3***	***25.7***	***17.0***	***83.0***
>MLS	n	5648	212	2659	290	5025	40	4662	429
	%	***96.4***	***3.6***	***90.2***	***9.8***	***99.2***	***0.8***	***91.6***	***8.4***
Total		32077	15239	8383	5281	16097	3870	11324	32855

Table 3. Selectivity parameter estimates and number of specimens in the codend and cover for red mullet in 36S, 40T90, 40D, and 40S codends [L_{50} (cm), length at 50% retention; SR (cm) selection range; SE standard error; v_1 and v_2 maximum likelihood estimators of selectivity parameters; R_{11}, R_{12}, and R_{22} variance matrix measuring within haul-variation; d.f. degrees of freedom]

Turkish Journal of Fisheries and Aquatic Sciences
RESEARCH PAPER
www.trjfas.org
ISSN 1303-2712
DOI: 10.4194/1303-2712-v18_7_04

	Haul no	L_{50}	(SE)	SR	(SE)	v_1	v_2	R_{11}	R_{12}	R_{22}	Deviance	d.f.	p-value	Codend	Cover
36S	1	**10.19**	(0.07)	**1.08**	(0.09)	-20.771	2.038	3.2137	-0.2993	0.0280	31.78	19	0.03	1721	324
	2	**10.37**	(0.10)	**1.21**	(0.09)	-18.852	1.818	2.2626	-0.1983	0.0175	75.39	21	0.00	5193	842
	3	**10.29**	(0.08)	**1.49**	(0.12)	-15.191	1.476	1.7357	-0.1575	0.0144	47.42	18	0.00	2055	513
	4	**11.57**	(0.05)	**0.97**	(0.07)	-26.189	2.264	3.3018	-0.2893	0.0254	34.38	15	0.00	798	1060
	5	**10.17**	(0.04)	**1.00**	(0.06)	-22.348	2.197	1.7820	-0.1656	0.0154	41.34	21	0.01	4420	683
	6	**10.79**	(0.08)	**1.02**	(0.12)	-23.257	2.155	7.8489	-0.7009	0.0628	80.81	16	0.00	1910	448
	Mean (Fryer)	**10.59**	(0.09)	**1.11**	(0.03)	-20.893	1.972	2.6232	-0.2017	0.0167				16097	3870
40T90	1	**8.92**	(0.16)	**1.62**	(0.12)	-12.143	1.361	0.9575	-0.0930	0.0094	46.21	20	0.00	1908	618
	2	**8.68**	(0.73)	**4.14**	(1.10)	-4.605	0.531	2.5418	-0.2243	0.0199	22.55	11	0.02	595	136
	3	**11.07**	(0.07)	**1.83**	(0.11)	-13.275	1.199	0.6884	-0.0592	0.0051	9.63	12	0.65	881	399
	4	**10.07**	(0.53)	**3.96**	(0.93)	-5.582	0.555	2.2082	-0.1903	0.0169	727.35	23	0.00	2070	1048
	5	**10.45**	(0.13)	**1.88**	(0.17)	-12.250	1.172	1.5294	-0.1334	0.0117	4.53	12	0.97	591	133
	6	**10.61**	(0.09)	**1.28**	(0.10)	-18.163	1.712	2.3775	-0.2106	0.0188	56.39	24	0.00	1551	712
	7	**11.56**	(0.15)	**2.58**	(0.27)	-9.864	0.853	1.0606	-0.0920	0.0081	109.42	20	0.00	787	2235
	Mean (Fryer)	**10.29**	(0.12)	**1.92**	(0.08)	-10.851	1.055	2.9099	-0.2624	0.0250				8383	5281
40D	1	**10.76**	(0.21)	**2.26**	(0.37)	-10.471	0.974	3.1706	-0.2856	0.0261	1265.32	22	0.00	5188	4920
	2	**10.83**	(0.10)	**1.84**	(0.16)	-12.938	1.194	1.3556	-0.1230	0.0113	232.99	22	0.00	2593	3421
	3	**9.01**	(0.20)	**2.14**	(0.32)	-9.243	1.026	2.2336	-0.2256	0.0231	460.26	20	0.00	4040	1922
	4	**7.97**	(0.23)	**2.75**	(0.25)	-6.370	0.799	0.4811	-0.0483	0.0051	1026.71	21	0.00	20256	4976
	Mean (Fryer)	**9.79**	(0.35)	**2.20**	(0.11)	-9.714	0.992	2.4339	-0.1478	0.0094				32077	15239
40S	1	**12.36**	(0.12)	**1.81**	(0.19)	-14.998	1.213	2.1864	-0.1848	0.0157	174.47	18	0.00	1200	3460
	2	**11.93**	(0.03)	**0.35**	(0.03)	-74.935	6.284	38.8766	-3.2506	0.2720	46.63	18	0.00	2737	7525
	3	**11.60**	(0.06)	**1.65**	(0.10)	-15.471	1.335	0.9127	-0.0788	0.0068	119.69	20	0.00	2950	4686
	4	**11.67**	(0.10)	**1.33**	(0.11)	-19.279	1.652	2.1752	-0.1968	0.0179	480.1	16	0.00	4437	17184
	Mean (Fryer)	**11.89**	(0.08)	**1.26**	(0.17)	-30.625	2.575	204.6551	-17.1415	1.4361				11324	32855

Table 4. Results of previous selectivity studies and the current work for red mullet in Turkey.

References	Material	Mesh Size	Mesh Shape	L_{50}(cm)	SR (cm)	Study Area
Zengin et al., (1997)		36	D	12.54	2.34	Black Sea
		40	D	13.22	3.18	
		44	D	13.79	3.23	
Genç et al., (2002)		28	D	10.03		Black Sea
		40	D	10.91		
Özbilgin and Tosunoğlu, (2003)	PE	40	D	9.00	2.30	Aegean Sea
		40	D	10.10	2.30	
Özdemir, (2006)	PE	40	D	12.01	3.50	Black Sea
		32	SMP	11.64	2.93	
		36	SMP	12.32	3.21	
		40	SMP	12.91	3.20	
		44	SMP	13.37	3.94	
Kaykaç, (2007)	PE	40	D	11.80	3.00	Aegean Sea
		40	N	13.90	2.40	
		40	T90	15.20	1.80	
		40	RC	14.40	1.70	
Demirci, (2009)	PE	44	D	13.80	2.50	Eastern Mediterranean
		40	S	14.00	3.20	
		50	D	17.60	7.20	
Ateş et al., (2010)	PE	40	S	14.20	3.10	Eastern Mediterranean
Aydın et al., (2011)	PE	40	S	14.30	2.30	Aegean Sea
		50	D	15.30	4.40	
Özbilgin et al., (2015)	PE	44	DH	7.10	6.70	Eastern Mediterranean
	PE	40	S	14.10	2.60	
		44	D	8.40	5.20	
		50	D	12.10	4.70	
Current paper	**PE**	**40**	**D**	**9.79**	**2.2**	**Black Sea**
		40	**T90**	**10.29**	**1.92**	
		36	**S**	**10.59**	**1.11**	
		40	**S**	**11.89**	**1.26**	

[L_{50} (cm), length at 50% retention; SR (cm) selection range; PE, polythene; D, Diamond mesh codend; S, Square mesh codend; SMP, Square Mesh top Panel codend; N, Narrow codend; T90, 90° Turned-mesh codend; DH, diamond hand-woven codend; RC, Rigging Codend]

Turkish Journal of Fisheries and Aquatic Sciences
RESEARCH PAPER
www.trjfas.org
ISSN 1303-2712
DOI: 10.4194/1303-2712-v18_7_04

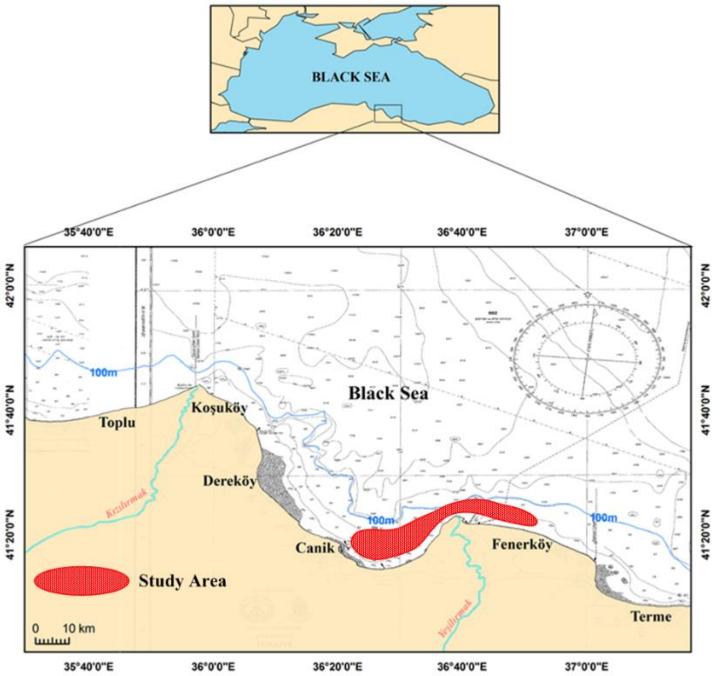

Figure 1. Study area in the Western part of the Black Sea.

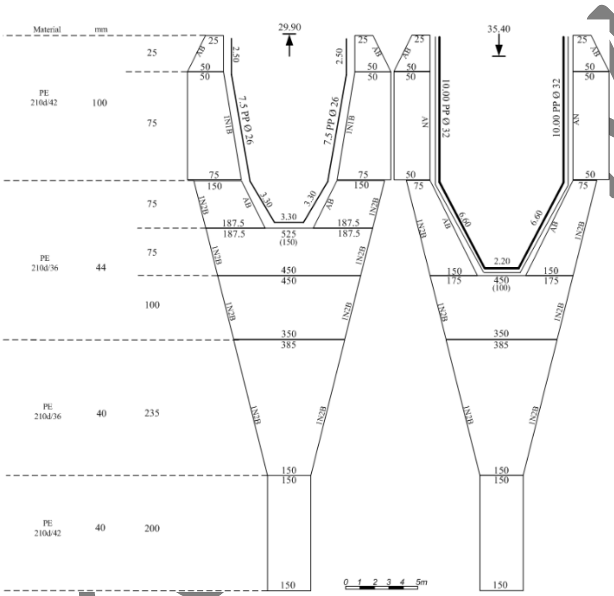

Figure 2. Technical drawing of 900 meshes in conventional bottom trawl.

Turkish Journal of Fisheries and Aquatic Sciences
www.trjfas.org
ISSN 1303-2712
DOI: 10.4194/1303-2712-v18_7_04

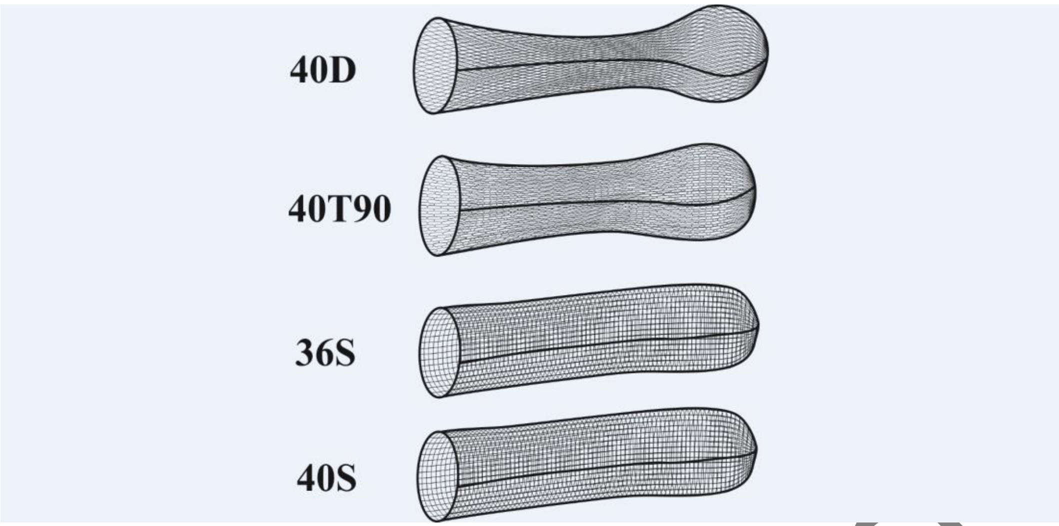

Figure 3. Illustration of trawl codends used in the experiments: 40 mm diamond mesh (40D), 40 mm 90° turned-mesh (40T90), 36 mm square mesh (36S), and 40 mm square mesh (40S).

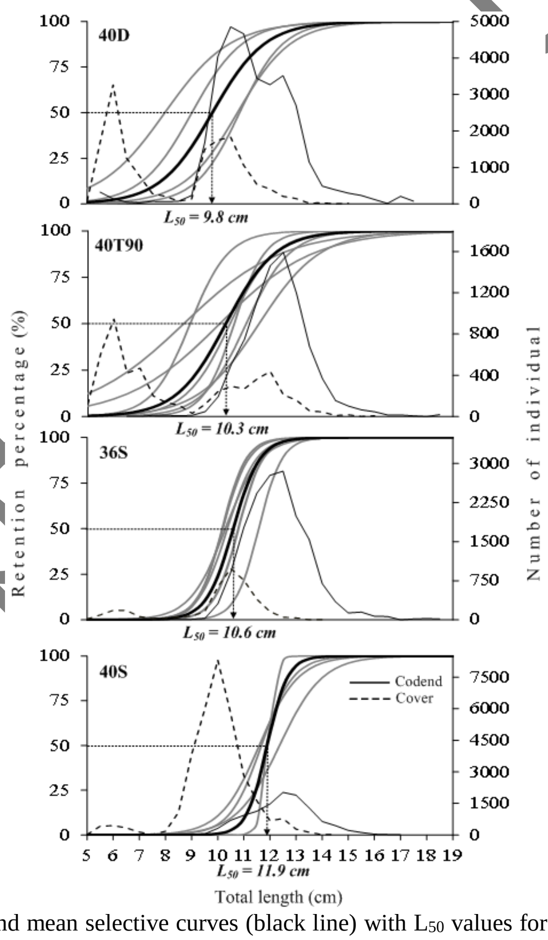

Figure 4. Individual (grey line) and mean selective curves (black line) with L_{50} values for all codends, and length frequency distributions of red mullet in codend and covers.

Turkish Journal of Fisheries and Aquatic Sciences
RESEARCH PAPER
www.trjfas.org
ISSN 1303-2712
DOI: 10.4194/1303-2712-v18_7_04

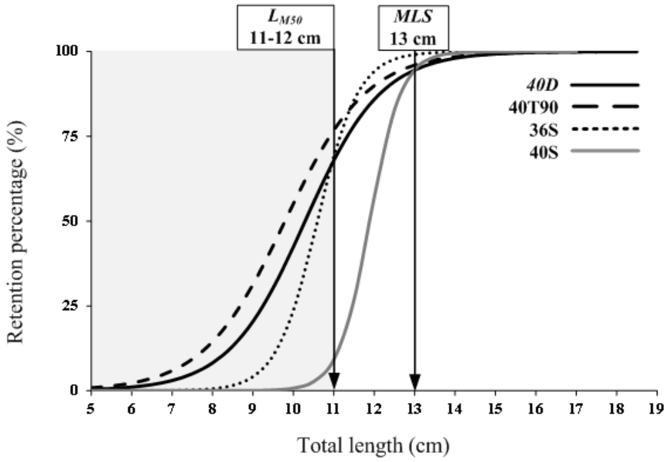

Figure 5. Mean selective curves in all codends. Minimum Landing Size (MLS) and Length of the first maturity (L_{M50}) values are shown in the figure.