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RESEARCH ARTICLE **ARAŞTIRMA MAKALESİ**

Selectivity of turned meshes codends for Deepwater Rose Shrimp (*Parapenaeus longirostris*), Horse Mackerel, (*Trachurus trachurus*) and European Hake (*Merluccius merluccius*) in the Aegean Sea

Ege Denizi'nde Derinsu Pembe Karidesi (*Parapenaeus longirostris*), İstavrit (*Trachurus trachurus*) ve Bakalyaro için (*Merluccius merluccius*) döndürülmüş ağ gözü torba seçiciliği

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Abstract: More than fifty published on demersal trawl codend selectivity studies have been carried out in the Mediterranean waters of Turkey since the mid-1980s. In this study, in an attempt to enhance the size selectivity of three species in the Aegean Sea trawl fisheries, three 90° turned meshes codens were investigated. Experiments were carried out in the Kuşadası Bay of the Eastern Mediterranean, between 19 January and 29 March 2015 with commercial stern trawler. The meshes of tested codends were turned 90°, two of them have 44 mm mesh size with 300 and 150 meshes around codend circumferences (44T300 and 44T150). The other has 40 mm mesh size with 165 meshes around codend circumferences (40T165). Individual hauls and mean selectivity parameters were estimated by using the CC2000 and EC-Modeller softwares, respectively. The mean L_{50} values of 44T300, 44T150 and 40T165 were 17.5 ± 0.2 mm, 18.6 ± 0.1 mm and 17.1 ± 0.2 mm carapace length for shrimp, 16.4 ± 0.4 cm, 17.1 ± 0.4 cm and 14.8 ± 0.2 cm total length for horse mackerel, respectively. The pooled L_{50} values of, 12.8 ± 0.5 cm, 13.2 ± 0.6 cm and 12.1 ± 0.1 cm total length for hake. While there are no differences between L_{50} values of 40T165 and 44T300 for deepwater rose shrimp ($p>0.05$), there are significant differences for horse mackerel ($p<0.05$). The likelihood ratio test results showed that there were no significant differences among all codends for European hake. In conclusion, any effort such as using square mesh, turned mesh codends or halved the number of meshes in the codend to release immatures of some species, is probably to cause the loss of marketable sizes of other species in the Mediterranean. This economical loss of revenues is the essential concern of fishermen that prevents them using alternative codend designs, though such designs are technically applicable. Consequently, the losses of income caused by using T90 mesh codend and halving the number of meshes around codend circumference should also be investigated in future studies.

Keywords: *Demersal trawl, turned meshes, deepwater rose shrimp, horse mackerel, European hake, Aegean Sea*

Öz: Türkiye'nin Akdeniz sularında 1980'lerin ortalarından beri demersal trol torba seçiciliği üzerine elliden fazla çalışma yürütülmüştür. Bu çalışmada Ege Denizi trol balıkçılığında 3 türün boy seçiciliğini geliştirmek için 3 farklı döndürülmüş ağ göz torbaları araştırılmıştır. Denemeler Doğu Akdeniz'de bulunan Kuşadası Körfezi'nde 19 Ocak ve 29 Mart 2015 tarihleri arasında ticari trol teknesiyle gerçekleştirilmiştir. Deneme torbalarının ağ gözleri 90° döndürülmüş olup ikisi 44 mm ağ göz boyunda, 300 ve 150 torba çevre göz sayısına sahiptir (44T300 ve 44T150). Diğer torba 165 çevre göz sayısına sahip 40 mm ağ göz boyundadır. Bireysel çekimler ve ortalama seçicilik parametreleri sırasıyla CC2000 ve EC-Modeller yazılımları kullanılarak hesaplanmıştır. Derinsu pembe karidesinin 44T300, 44T150 ve 40T165 torbalarında ortalama L_{50} değerleri sırasıyla 17,5 ± 0,2 mm, 18,6 ± 0,1 mm ve 17,1 ± 0,2 mm karapas boyu, istavritin 16,4 ± 0,4 cm, 17,1 ± 0,4 cm and 14,8 ± 0,2 cm total boydur. Bakalyaronun birleştirilmiş L_{50} değerleri 12,8 ± 0,5 cm, 13,2 ± 0,6 cm ve 12,1 ± 0,1 cm total boydur. Derinsu pembe karidesi için 40T165 ve 44T300'den elde edilen L_{50} değerleri arasında fark yokken ($p>0,05$), istavrit için önemli fark vardır ($p<0,05$). Olabilirlik oran test sonuçları bakalyaro için tüm torbalar arasında istatistiksel olarak önemli bir fark bulunamamıştır. Sonuç olarak Akdenizde bazı türlerin jüvenillerini serbest bırakmak için kare gözlü, döndürülmüş gözlü torba kullanma veya torba etrafındaki göz sayısını yarıya düşürme gibi çabalar, pazarlanabilir boydaki diğer türlerin kaybına neden olabilmektedir. Alternatif torbalar teknik olarak uygulanabilir olmalarına rağmen, ekonomik gelir kaybı balıkçıların torbaları kullanmalarını önleyen esas kaygıdır. Bu nedenle, T90 torba ve torba çevre göz sayısının yarıya indirilmesinin sebep olacağı gelir kayıpları gelecek çalışmalarda araştırılmalıdır.

Anahtar kelimeler: *Demersal trol, döndürülmüş torba, derinsu pembe karidesi, istavrit, bakalyaro, Ege Denizi*

INTRODUCTION

More than fifty scientific papers have been published on demersal trawl codend selectivity in the Mediterranean waters of Turkey since the mid-1980s (Stewart, 2002). The studies show that conventional mesh codends selectivity results are rather poor (Tokaç et al., 1998; Tosunoğlu et al., 2003; Tokaç et al., 2004, 2010; Özbilgin et al., 2012; Aydın et al., 2011). In order to improve selectivity, scientists have been made effort. One of these works is T90 mesh codends. T90 codend obtained by turning 90° of standard diamond mesh and can create important improvements in size selectivity (Madsen, 2007; Wienbeck et al., 2011). T90 codend was first tested by Moderhak (1997) for cod (*Gadus morhua*) fishery and then scientific interest have been increasing all around the world (Arkley, 2008; Hansen, 2004; Herrmann et al., 2007; Wienbeck et al., 2011, 2014; Madsen et al., 2012; Gorman and Dixon, 2015; Herrmann et al., 2013; Madsen et al., 2015; Stepputtis et al., 2016). It has been introduced in 2006 the legislation (EU Regulation no. 2187/2005) for the Baltic Sea cod fishery (EU, 2005; Herrmann et al., 2007). On the otherhand, few studies have been conducted on selectivity of T90 codend in the Mediterranean. Kaykaç (2005) has investigated the selectivity of 40 mm turned meshes in Aegean Sea for *Mullus barbatus,* and *Diplodus annularis*. Tokaç et al. (2014) have compared the size selectivity of T0 and T90 codends with three different mesh sizes for *Mullus barbatus, Pagellus erythrinus* and *Diplodus annularis*. Aydın and Tokaç (2015) have compared the size selective properties of the same mesh size of 90° turned mesh codend and square mesh codend for *Parapenaeus longirostris* and *Phycis blennoides.* Deval et al. (2016) estimated the selectivity of the same mesh size (50 mm) of T0 and T90 codends in deep water demersal trawl fisheries for *P. longirostris, Plesionika martia, Aristaeomorpha foliacea* and *Aristeus antennatus*. Dereli and Aydın (2016) gave selectivity results of four codends; two different mesh sizes of diamond mesh codends, square mesh codend and turned mesh codend for *M. barbatus, Merluccius merluccius, Trachurus trachurus* and *Dentex moroccanus.* İlkyaz et al. (2017) studied the selectivity of 90º turned meshes of three different mesh size codends for bogue (*Boops boops*) in the Eastern Mediterranean.

Turkish Fishery Regulations (TFR) define a minimum mesh size of 44 mm diamond or 40 mm square mesh netting for demersal trawl codends used in Aegean Sea (Anonymous, 2016), However, Fishers widely use 40 mm diamond mesh netting in trawl codends, accept in practice as legal as it usually measures about 43 mm with a wedge gauge (Özbilgin et al. 2012). On the other hand, studies with the same mesh size codends have shown that the selectivity can be improved by reducing the meshes around the codens (Reeves et al., 1992; Broadhurst and Kennelly, 1996; Lök et al., 1997; Broadhurst et al., 2004; Özbilgin et al., 2005; Sala and Luchetti, 2011; Eryaşar et al., 2014). Since August 2013, there was the provision that “the number of meshes around codend can’t be more than half of the number of meshes of tunnel” (Anonymous, 2012). However, this provision is not present in the TFR which came into force in September 2016.

This study aimed to investigate the selectivity of 90° turned meshes of 44 mm mesh sizes with 300 meshes around codend circumferences (44T300), 44 mm meshes size with 150 meshes around codend circumferences (44T150) and 40 mm mesh size with 165 meshes around codend circumferences (40T165) for the deepwater rose shrimp (*P. longirostris*), horse mackerel (*T. trachurus*) and European hake (*M. merluccius*) which have high economical value but different body shape. Selectivty results for hake firts time presented from the study.

MATERIALS AND METHODS

Experiments were carried out in the commercial fishing grounds of the Kuşadası Bay (Aegean Sea) during the period 19-24 January and 25-29 March 2015 on board a commercial stern trawler “Efsane G” (LAO: 19.85 m 500 HP engine power). A modified 900 meshes fishing circle demersal trawl net was used for all experiments (Şensurat, 2015). The water depth ranged from 65 to 215 m (average: 115.5 m). The average towing duration was 178.1 min. (110-250 min). All hauls were carried out during daytime.

All tested codends are same material (380d / 21 no) made of knotted polyethylene netting and 5 m in length. The implementation of a T90 mesh where the diamond codend mesh (T0) is turned 90º (Wienbeck et al., 2011). Characteristics of the experimental codends are as follows:

(1) 44T300: nominal 44 mm (45.4 mm ± 0.11) 300 meshes on its circumference.

(2) 44T150: nominal 44 mm (45.4 mm ± 0.11), 150 meshes on its circumference.

(3) 40T165: nominal 40 mm (40.4 mm ±0.10), 165 meshes on its circumference.

The end of the tunnel consisted of 44 mm mesh size of 300 meshes in circumferences (44 x 300= 13200 mm). According to the EC regulation (Anonymous, 2006), the square mesh codend in particular, the circumference of the rear most part of the trawl body, and the extension piece should be from 2 to 4 times the circumference of the front end of the codend. We used the codends circumferences tested in the study considering the EC regulation as square mesh codend circumferences ((13200 mm / 40 mm) / 2= 165 meshes) and 90º turned meshes ((13200 mm /40 mm/ 2 = 165 meshes).

Full mesh sizes of the codends (four lines of 20 consecutive meshes in the towing direction) were measured while the netting was still wet after the tows by using OMEGA mesh gauge at 50 N. Each codend was attached to end of the tunnel, which had 300 meshes in circumference made of 48 mm knotless PE netting. A protective bag, 5.5 m in length and knotted polypropilen material with 100 mm mesh size, was used around the codend whereby the protective bag was laced around the codend. Aft ends of the codend and the protective net were tied together. The main characteristic of the codends are given in Table 1.

Table 1. Codend specifications

Codend features	Tested Codends		
	44T300	44T150	40T165
Nominal mesh size (mm)	44	44	40
Measured mesh size (mm)	45.4	45.4	40.4
Number of measurements	80	80	80
Twine thickness	380d/21 no	380d/21 no	380d/21 no
Materieal	PE knotted	PE knotted	PE knotted
Circumference mesh number	300	150	165

The selectivity of the codends was estimated using the hooped covered codend method described by Wileman *et al*. (1996). The cover was made of knotless polyamide (PA) netting with a nominal mesh size of 24 mm and supported by hoops, that 1.9 m in diameter. The hoops were made of 5 cm diameter PVC material. Supporting hoops were used to avoiding the masking effect of the cover on the codend meshes.

At the end of each tow the cover catch was first removed. If necessary, random sub-sampling of an appreciable amount for all hauls was made from the codend and the cover. The investigated species separately sorted from the rest of the catch and weighed. Meantime, crews sorted the marketable codend catch by species and left the discards on deck. Three species were deepwater rose shrimp, horse mackerel and hake, collected for selectivity analyses. Full or sub-samples were taken and weighed separately from marketable catch and discards.

Length measurements were obtained to the nearest cm for horse mackerel and European hake. Sub-samples were taken from the cover and codend for the deepwater rose shrimp. The length class frequencies were then estimated by raising the sub-sampled frequencies obtained by the ratio of the total weight to the sub-sample weight. The length class frequencies for the shrimps in the codend and cover were estimated by multiplying the measured frequencies in the subsamples by the inverse of the sampling proportion. The carapace length (from the orbital sinus to the internal posterior margin of the carapace) was measured to the nearest mm for the deep-water rose shrimp by using digital calipers. When the numbers of individuals retained and escaped were insufficient for individual haul estimation, data were pooled over all hauls to estimate the selection curve for only European hake. The length distributions of the discarded individuals were added to the codend's distribution for the selectivity analysis.

To compare the retention rates of immature specimens between the different codend, a 13 and 20 cm total length (TL) minimum landing sizes (MLS) were used for Atlantic horse mackerel and European hake given by Anonymous (2016), respectively. MLS regulation does not given in TFR for deepwater rose shrimp. Therefore, 20 mm carapace length (CL) MLS were used for rose shrimp given by EU (2005).

Selectivity parameters for individual hauls were obtained by using the CC2000 software (ConStat, 1995). The data were analized using a logistic equation with the maximum likelihood method (Wileman *et al*., 1996) as $\mathrm{S(l)} = \exp(\mathrm{v1}+\mathrm{v2l})/[1+\exp(\mathrm{v1}+\mathrm{v2l})]$, where the parameters v_1 and v_2 are the intercept and slope of the linear logistic function, respectively. The mean selectivity of the individual hauls was calculated by taking into account between-haul variation according to Fryer (1991) using the ECModeller software (ConStat, 1995) which adopts the REML method (residual maximum likelihood). The values of L_{50} were estimated from the expression:

$$L50 = (-v1/v2)$$

Selection Range (SR, difference between the 75% and 25% retention lengths) was estimated with the equation:

$$SR = L75 - L25$$

Fryer (1991) model was used to test between-haul variation of the selectivity parameters v_1 and v_2 by mesh configuration, allowing the estimation of mean curves for the three different mesh codends by using the software ECModeller (ConStat, 1995) which utilizes the REML (Residual Maximum Likelihood) approach. The model of Fryer (1991) was also used to investigate the significance of catch size, mesh configuration on the selectivity parameter estimates. Some of the explanatory variables effect on the L_{50} and SR values such as the mesh configuration, mesh numbers of codend circumference, the codend catch, the species catch and the haul duration were tested.

The statistical significance among pooled selection curves for the European hake was evaluated with a likelihood ratio test (e.g. Campos et al. 2003).

RESULTS

A total weight of 5.02 tonnes was caught in the codend and cover during 100.9 h, in 34 hauls (11 hauls 44T300, 11 hauls 44T150 and 12 hauls 40T165). The total catch was composed of 0.93 t with 44T300, 2.36 t with 44T150 and 1.73 t with 40T165. Deepwater rose shrimp (*P. longirostris*), Horse mackerel (*T. trachurus*) and European hake (*M. merluccius*) accounted for the majority of the total catch by weight (Table 2).

Table 2. The total catch and percentage of catch by species in codend and cover as caught from 44T300, 44T150 and 40T165 codends

	44T300			44T150			40T165		
	Codend	Cover	Total	Codend	Cover	Total	Codend	Cover	Total
Weight (kg)	750.5	182.2	932.7	2138.0	219.3	2357.3	1398.4	336.4	1734.8
Deepwater rose shrimp (%)	5.9	16.5	7.9	0.6	5.3	1.0	3.3	9.0	4.6
Horse mackerel (%)	8.7	16.8	10.2	3.1	19.9	4.6	20.1	30.9	23.5
European hake (%)	11.1	0	8.9	2.5	0.2	2.3	4.0	0.1	3.2
Others (%)	74.3	66.7	73.0	93.8	74.6	92.1	72.6	60.0	68.7

Deepwater rose shrimp (*Parapenaeus longirostris* Lucas, 1846)

In total, 51 276 deepwater rose shrimp were caught from 33 valid hauls. While 52.4% (26 888) specimens retained, 47.6% (24 388) was escaped.

Total number of specimens, captured and escaped percentage and their minimum and maximum sizes in codends are given in Table 3. Length-frequency distributions show their size ranges between 7 to 32 mm for all tested codends, with a main peak at 15-17 mm CL (Figure 1, right side). A total of 43.6, 56.1 and 32.9% of the specimens were found above MLS in the 44T300, 44T150 and 40T165 codend, respectively.

Table 3. Total number of deepwater rose shrimp specimens, captured and escaped percentage and their minimum and maximum sizes in codends

	Total number of specimens	Captured (%)	Size ranges (mm)		Above MLS (%)	Escaped (%)	Size ranges (mm)		Above MLS (%)
			Min	Max			Min	Max	
44T300	21333	54.7	7	32	43.6	45.3	6	27	12.6
44T150	7030	43.4	10	32	56.1	56.6	7	27	15.6
40T165	22913	53.1	9	31	32.9	46.9	8	28	13.6

Selectivity estimates for individuals and mean curves (according to Fryer, 1991) of rose shrimp are given in Table 4 and Figure 1. Table 4 also presents numbers of shrimp in codends and covers. The mean L_{50} and SR values were 17.5 and 5.7 mm for 44T300, 18.6 and 5.1 mm for 44T150 and 17.1 and 6.0 mm for 40T165. An inspectation of the fit statistics indicated problems using a logistic curve to describe the selection data for all hauls ($p < 0.05$), except for hauls no. 3, 4, 7 and 10 for 44T300, no. 1, 2, 3, 7, 10, 11 for 44T150 and no. 4, 5, 6, 7 and 10 for 44T165. Inspection of the deviance residuals indicated structural problems when using the logistic curve to model the experimental data in these hauls. Lack of fit does not certainly refer that the fitted selection curve is not a good model of the selection of the species. If a plot of residuals vs. length shows no clear structure, then the lack of fit is due to over-dispersion (McCullagh and Nelder, 1989; Deval et al., 2016), that is, the failure of the assumption that fish behave independently (Wileman et al., 1996).

Significant differences were found only between 44T150 and the other two codends. On the other hand, there were no significant differences between SR values between the codends ($p > 0.05$). Explanatory variables results which affect selectivity parameters are also given in Table 5.

Horse mackerel (*Trachurus trachurus* Linnaeus, 1758)

A total number of 13 562 horse mackerel were caught with 30 valid hauls. While 63.5% (8617) specimens retained, %36.5 (4945) was escaped. Total number of specimens, captured and escaped percentage and their minimum and maximum sizes in codends are given in Table 6. Length-frequency distributions show their size ranges as 12.5 to 31 cm for all tested codends. All of the captured specimens in the 44T300 and 44T150 codends, 99.7% of the specimens were found above MLS in 40T165 codend (13 cm, Anonymus, 2016).

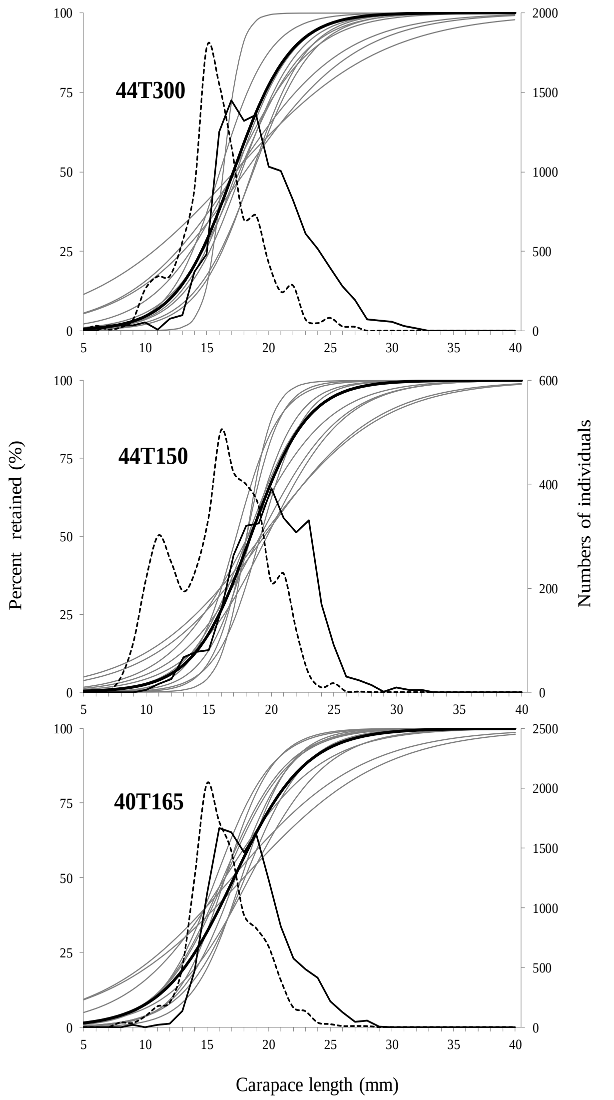

Figure 1. The selection curves and length distribution of the deepwater rose shrimp (*P. longirostris)*. Y-axis left: percentage retained for the selection curves of: 44T300, 44T150 and 40T165 (thick drawn lines; mean selection curve (Fryer 1991), thin drawn lines; individual selection curves). Y-axis right: normalized length-frequency distribution, drawn lines: codend specimens, broken lines; and cover specimens.

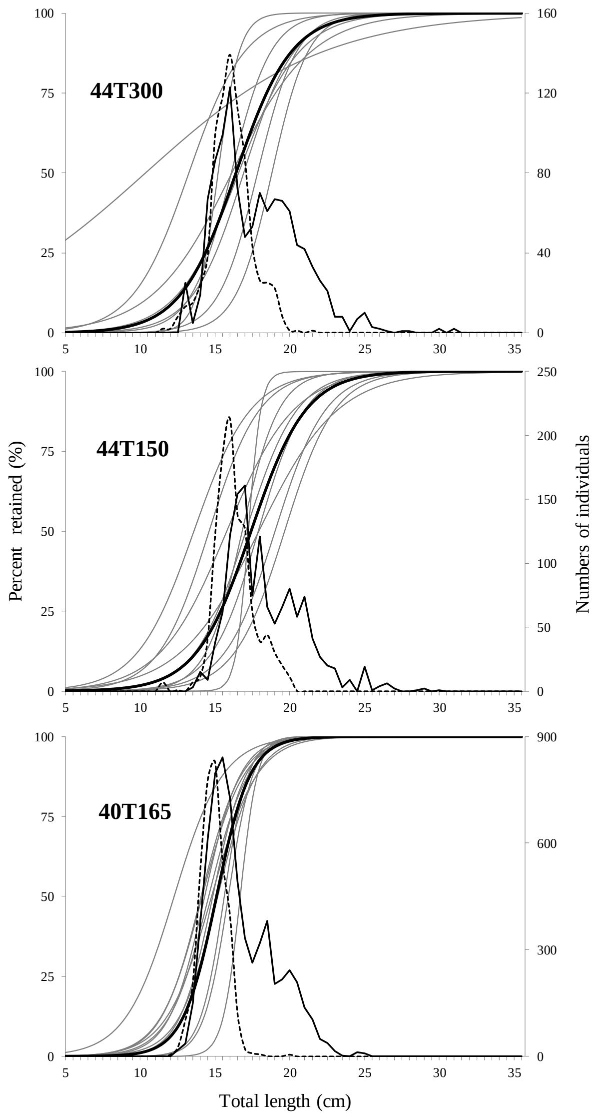

Figure 2. The selection curves and length distribution of the horse mackerel (*T. trachurus)*. Y-axis left: percentage retained for the selection curves of: 44T300, 44T150 and 40T165 (thick drawn lines; mean selection curve (Fryer 1991), thin drawn lines; individual selection curves). Y-axis right: normalized length-frequency distribution, drawn lines: codend specimens, broken lines; and cover specimens

Table 4. Estimated selectivity parameters of individual and mean hauls (according to Fryer, 1991) for deepwater rose shrimp in 44T300, 44T150 and 40T165

Codends	H.N	L_{50}	CI low-CI high	SR	CI low-CI high	v_1	v_2	R_{11}	R_{12}	R_{22}	deviance	dof	pvalue	NCd	NCv
44T300	1	18.7	18.0-19.5	5.3	3.8-6.9	-7.707	0.411	1.061	-0.057	0.003	96.22	14	0.00	914	1035
	2	17.6	16.8-18.5	5.9	3.9-8.0	-6.525	0.370	1.222	-0.067	0.004	143.99	21	0.00	820	667
	3	16.1	15.5-16.7	4.5	3.1-5.8	-7.930	0.494	1.209	-0.075	0.005	22.11	13	0.05	133	143
	4	18.7	17.7-19.7	4.9	3.1-6.7	-8.388	0.449	2.416	-0.124	0.007	15.14	18	0.65	79	64
	5	17.2	15.5-18.9	13.1	5.6-20.7	-2.878	0.167	0.645	-0.037	0.002	1070.21	23	0.00	5083	5146
	6	16.3	16.0-16.6	1.6	1.3-1.9	-22.377	1.372	4.854	-0.286	0.017	97.01	23	0.00	2371	896
	7	17.1	16.3-18.0	6.9	4.8-9.0	-5.441	0.317	0.689	-0.038	0.002	11.74	19	0.90	294	144
	8	17.4	16.5-18.2	9.6	7.0-12.1	-3.980	0.229	0.286	-0.015	0.001	88.81	21	0.00	1155	999
	9	17.4	16.6-18.2	5.1	3.8-6.3	-7.568	0.435	0.876	-0.047	0.003	59.54	20	0.00	469	325

	10	17.8	16.5-19.1	5.2	3.2-7.1	-7.567	0.425	2.212	-0.113	0.006	12.17	18	0.84	94	40
	11	18.1	15.9-20.3	10.1	4.2-15.9	-3.944	0.218	1.341	-0.068	0.004	79.88	17	0.00	258	204
	F	***17.5***	***17.3-17.7***	***5.7***	***5.3-6.1***	***-7.309***	***0.426***	***21.479***	***-1.337***	***0.084***	***17.00***	***17***	***0.00***		
44T150	1	18.1	17.2-19.0	5.1	3.1-7.1	-7.768	0.429	2.086	-0.114	0.006	16.3	17	0.50	76	80
	2	17.2	15.9-18.5	3.8	2.1-5.4	-9.988	0.581	4.948	-0.262	0.014	10.9	14	0.69	84	23
	3	18.0	16.1-19.9	3.0	0.1-5.9	-13.369	0.742	32.045	-1.736	0.095	7.2	7	0.41	11	10
	4	18.2	16.9-19.5	7.1	3.8-10.4	-5.587	0.308	1.517	-0.081	0.005	109.4	15	0.00	511	513
	5	18.4	17.9-18.9	4.0	3.1-4.9	-10.095	0.549	1.258	-0.065	0.003	48.9	18	0.00	705	414
	6	19.1	18.2-20.1	7.2	4.9-9.5	-5.685	0.307	0.784	-0.041	0.002	93.7	19	0.00	603	753
	7	19.1	18.5-19.8	3.9	2.7-5.0	-10.904	0.570	2.428	-0.129	0.007	14.2	20	0.82	85	134
	8	19.7	18.4-20.9	6.9	4.4-9.4	-6.293	0.320	0.989	-0.054	0.003	166.8	17	0.00	474	1020
	9	19.2	16.9-21.5	10.5	5.2-15.9	-4.002	0.208	0.728	-0.042	0.003	145.9	19	0.00	387	739
	10	18.0	17.4-18.7	2.2	1.5-3.0	-17.775	0.986	6.822	-0.403	0.024	10.6	17	0.88	48	203
	11	19.4	17.7-21.1	9.8	5.5-14.1	-4.354	0.224	0.804	-0.041	0.002	14.8	18	0.68	70	84
	F	***18.6***	***18.5-18.7***	***5.1***	***4.7-5.5***	***-8.040***	***0.438***	***9.165***	***-0.488***	***0.026***	***17.00***	***17***	***0.00***		
40T165	1	16.5	15.8-17.2	8.5	6.1-10.9	-4.266	0.259	0.352	-0.020	0.001	329.9	19	0.00	5487	4697
	2	18.0	17.0-19.0	12.4	7.9-17.0	-3.181	0.177	0.295	-0.016	0.001	119.8	17	0.00	2014	2142
	3	18.5	17.7-19.3	6.9	4.7-9.1	-5.844	0.317	0.738	-0.040	0.002	98.6	17	0.00	927	1088
	4	18.1	17.7-18.5	5.4	4.4-6.5	-7.303	0.404	0.467	-0.025	0.001	23.2	15	0.08	391	346
	5	16.5	16.1-16.8	4.3	3.6-5.0	-8.398	0.510	0.475	-0.027	0.002	24.2	15	0.06	634	331
	6	17.3	16.0-18.6	5.0	2.1-7.9	-7.640	0.441	4.499	-0.253	0.014	8.3	13	0.83	40	37
	7	15.7	14.9-16.6	5.0	3.7-6.3	-6.876	0.437	0.688	-0.044	0.003	23.0	16	0.11	110	136
	8	17.0	15.7-18.4	11.6	6.1-17.2	-3.217	0.189	0.603	-0.033	0.002	83.3	18	0.00	779	655
	9	16.3	15.8-16.9	5.7	4.3-7.1	-6.280	0.385	0.553	-0.032	0.002	85.0	18	0.00	1417	1053
	10	17.8	16.8-18.8	4.4	2.6-6.2	-8.915	0.501	3.061	-0.169	0.010	10.0	15	0.82	60	56
	11	16.5	15.5-17.5	5.8	3.8-7.7	-6.263	0.380	1.121	-0.063	0.004	51.2	18	0.00	305	208
	F	***17.1***	***16.9-17.3***	***6.0***	***5.7-6.3***	***-5.938***	***0.345***	***2.915***	***-0.166***	***0.010***	***17***	***17***	***0.00***		

L_{50}: 50% retention length (mm); CI: confidence interval; SR: selection range; v_1 and v_2: regression parameters; dof: degree of freedom; R: variance matrix measuring the within-haul variation; NCd: Number of specimens in Codend; NCv: Number of specimens in Cover

Table 5. Explanatory variables affected on selectivity parameters

Parameters	Estimate	SD	t-value	dof	p-value
P. longirostris					
Mesh (L_{50})	-16.053	1.418	-11.331	35	0.000
Mesh (SR)	-4.565	1.543	-2.958	35	0.006
Codend species catch (L_{50})	-0.000	0.000	-2.317	35	0.027
Duration (L_{50})	0.020	0.007	2.777	35	0.009
Circumference (L_{50})	15.293	1.224	12.492	35	0.000
Circumference (SR)	5.142	0.691	7.442	35	0.000

L_{50}: 50% retention length, SR: selection range, SD: standart deviation; dof: degree of freedom

Table 6. Total number of horse mackerel specimens, captured and escaped percentage and their minimum and maximum sizes in codends

	Total number of specimens	Captured (%)	Size ranges (mm)		Above MLS (%)	Escaped (%)	Size ranges (mm)		Above MLS (%)
			Min	Max			Min	Max	
44T300	1365	67.4	13.5	31.0	100	32.6	11.5	21.5	98.0
44T150	2367	55.3	13.5	30.0	100	44.7	5	20	99.1
40T165	9830	65.0	12.5	25.0	99.7	35.0	10	20	99.2

Thirty valid hauls provided data to obtain selection curves for all codends. Selectivity estimates for individuals and mean curves (according to Fryer, 1991) of horse mackerel are given in Table 7 and Figure 2. The mean L_{50} values for 44T300, 44T150 and 40T165 were 16.4, 17.1 and 14.8 cm, respectively. SR values of these three codends were 2.7, 3.4 and 2.5 cm, respectively. Inspection of the fit statistics (p-value and model deviance vs. df) indicated that there were no problems using a logit curve to describe the selection data for any haul (p>0.05), except for hauls no. 5, 6 and 10 for 44T150, and no. 1, 2, 4, 5, 6, 8, 9 and 11 for 44T165. There were significant differences between L_{50} values of 40T165 and the other two codends (p< 0.05). Explanatory variables which affect on selectivity parameters are given in Table 8.

Table 7. Estimated selectivity parameters of individual and mean hauls (according to Fryer, 1991) for horse mackerel in 44T300, 44T150 and 40T165

Codends	H.N	L_{50}	CI low-CI high	SR	CI low-CI high	v_1	v_2	R_{11}	R_{12}	R_{22}	deviance	dof	p value	NCd	NCv
44T300	1	15.2	14.5-16.0	1.6	0.7-2.5	-21.271	1.398	37.867	-2.344	0.146	7.08	18	0.99	170	11
	2	16.9	14.7-19.2	3.7	0.4-7.1	-0.954	0.588	14.070	-0.907	0.059	11.91	14	0.61	8	24
	3	16.1	12.8-19.5	2.9	-1.1-7.0	-12.044	0.748	41.922	-2.774	0.187	5.51	7	0.60	3	9
	4	16.6	15.6-17.6	4.5	2.7-6.4	-8.077	0.487	2.971	-0.164	0.009	19.96	23	0.65	113	49
	5	13.3	10.7-15.8	4.1	1.6-6.6	-7.042	0.531	7.020	-0.405	0.024	14.59	21	0.84	192	16
	6	10.4	5.1-15.6	13.2	0.9-25.4	-1.731	0.167	1.326	-0.083	0.005	22.77	14	0.06	316	124
	7	18.8	18.1-19.5	2.7	1.8-3.6	-15.486	0.823	5.361	-0.304	0.017	24.01	15	0.07	48	159
	8	17.9	17.2-18.5	2.9	1.7-4.1	-13.553	0.759	7.511	-0.419	0.024	10.46	25	1.00	62	46
	9	16.1	12.6-19.7	5.8	-7.9-19.6	-6.066	0.376	34.868	-2.134	0.132	6.71	6	0.35	8	7
	F	***16.4***	*16.0-16.8*	***2.7***	*2.5-2.9*	***-8.785***	***0.536***	***16.607***	***-0.779***	***0.038***		***13***	***0.00***		
44T150	1	17.2	14.6-19.9	0.9	-0.9-2.7	-41.512	2.407	1005.21	-62.892	3.938	3.07	7	0.88	1	55
	2	19.0	18.3-19.7	3.7	2.8-4.7	-11.205	0.589	1.503	-0.088	0.005	32.44	25	0.15	112	341
	3	17.9	17.3-18.5	3.4	2.2-4.7	-11.457	0.640	3.570	-0.204	0.012	15.82	18	0.61	81	107
	4	15.8	14.9-16.7	4.9	2.4-7.5	-7.011	0.444	3.288	-0.195	0.012	17.43	16	0.36	134	79
	5	19.6	18.6-20.7	3.7	2.2-5.2	-11.661	0.593	4.183	-0.233	0.013	32.52	20	0.04	69	234
	6	13.6	11.7-15.5	4.2	1.7-6.6	-7.138	0.525	5.993	-0.359	0.022	47.16	18	0.00	510	81
	7	14.6	13.3-16.0	3.7	2.0-5.4	-8.623	0.590	4.903	-0.284	0.017	29.06	18	0.05	324	54
	8	17.9	16.6-19.2	5.8	2.1-9.5	-6.779	0.378	3.897	-0.226	0.013	11.37	17	0.84	47	63
	9	17.1	15.7-18.5	3.8	0.4-7.1	-9.917	0.581	15.573	-0.947	0.058	9.86	15	0.83	22	26
	10	16.8	14.3-19.4	2.7	-2.3-7.7	-12.682	0.813	102.155	-6.385	0.401	15.25	7	0.03	9	18
	F	***17.1***	***16.7-17.5***	***3.4***	***3.2-3.6***	***-9.415***	***0.541***	***2.862***	***-0.055***	***0.001***		***15***	***0.00***		
40T165	1	14.2	13.6-14.7	3.1	2.1-4.1	-10.050	0.710	2.809	-0.181	0.012	43.0	16	0.00	953	288
	2	15.6	15.1-16.1	1.8	0.1-2.5	-19.352	1.238	12.648	-0.811	0.052	155.7	19	0.00	685	375
	3	15.9	15.6-16.2	1.8	1.3-2.4	-19.178	1.206	8.137	-0.511	0.032	18.7	18	0.41	150	90
	4	16.7	16.4-17.0	1.3	0.9-1.6	-28.753	1.722	13.927	-0.866	0.054	47.3	19	0.00	188	524
	5	15.2	14.7-15.7	2.9	1.4-4.4	-11.625	0.765	7.101	-0.476	0.032	56.0	11	0.00	385	496
	6	14.9	14.4-15.3	2.5	1.4-3.6	-13.239	0.891	8.214	-0.534	0.035	33.6	13	0.00	272	155
	7	14.8	14.3-15.3	3.4	2.1-4.6	-9.667	0.654	3.014	-0.197	0.013	20.4	16	0.20	143	87
	8	14.6	14.0-15.1	3.0	1.8-4.1	-10.855	0.744	4.616	-0.297	0.019	71.7	14	0.00	1033	406
	9	14.3	13.9-14.8	2.6	1.7-3.6	-11.961	0.835	4.654	-0.309	0.021	97.4	14	0.00	1374	619
	10	12.3	10.3-14.2	3.6	1.3-5.9	-7.491	0.610	7.513	-0.495	0.033	15.3	13	0.29	230	33
	11	14.1	13.6-14.6	3.0	1.9-4.0	-10.421	0.740	3.600	-0.239	0.016	76.7	19	0.00	975	369
	F	***14.8***	***14.6-15.0***	***2.5***	***2.4-2.6***	***-13.328***	***0.793***	***30.492***	***-1.628***	***0.087***		***17***	***0.00***		

L_{50}: 50% retention length (mm); CI: confidence interval; SR: selection range; v_1 and v_2: regression parameters; dof: degree of freedom; R: variance matrix measuring the within-haul variation; NCd: Number of specimens in Codend; NCv: Number of specimens in Cover

Table 8. Explanatory variables affected on selectivity parameters

Alpha parameters	Estimate	SD	t-value	dof	p-value
T. trachurus					
Codend catch (SR)	0.000	0.000	10.661	32	0.000
Codend species catch (L_{50})	-0.000	0.000	-2.230	32	0.033
Duration (L_{50})	0.099	0.005	18.795	32	0.000

European hake (*Merluccius merluccius* Linneaus, 1758)

A total number of 1978 European hake were caught. While 93.5% (1850) specimens retained, 6.5% (128) was escaped. Total number of specimens, captured and escaped percentage and their minimum and maximum sizes in codends are given in Table 9. Length-frequency distributions show their size ranges as 10 to 58 cm for all tested codends. A total of 60.5, 59.6 and 74.0% of the specimens were found above MLS in the 44T300, 44T150 and 40T165 codend, respectively (20 cm, Anonymus, 2016).

For European hake the data structure did not allow for a haul-by-haul analysis, but selection curves could be estimated for all codends based on pooled data. Selectivity estimates for pooled mean curves of European hake are given in Table 10 and Fig 3. The pooled L_{50} values and SR in 44T300, 44T150 and 40T165 were 12.8 and 4.6 cm; 13.2 and 4.0 cm; and 12.1 and 1.7 cm, respectively. The likelihood ratio test results showed that there was no significant difference between codends.

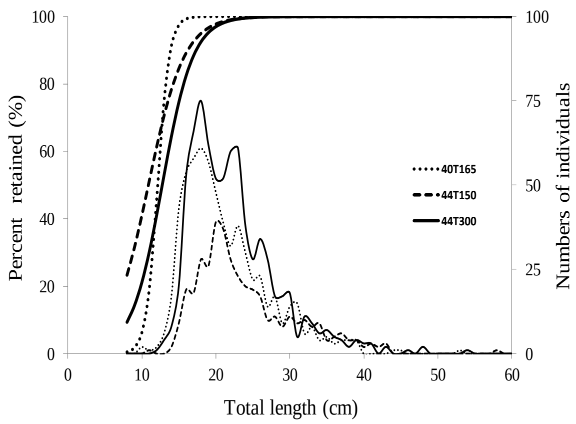

Figure 3. Mean selection curves for European hake based on pooled data with observed retention in the three codends. Thin lines correspond to length frequency in codends. Y-axis left: percentage retained for the selection curves of: a; 44T300, 44T150. Y-axis right: normalized length-frequency distribution.

Table 9. Total number of European hake specimens, captured and escaped percentage and their minimum and maximum sizes in codends

	Total number of specimens	Captured (%)	Size ranges (mm) Min	Max	Above MLS (%)	Escaped (%)	Size ranges (mm) Min	Max	Above MLS (%)
44T300	837	94.0	12	48	59.6	6.0	15	19	0
44T150	413	95.9	11	58	74.0	4.1	15	19	0
40T165	728	91.6	10	63	53.1	8.4	8	16	0

Table 10. Estimated selectivity parameters of pooled and stacked for European hake in 44T300, 44T150 and 40T165.

C		L_{50}	CI low-high	SR	CI Low-high	v_1	v_2	R_{11}	R_{12}	R_{22}	deviance	dof	pvalue	NCd	NCv
44T300	**P**	12.8	12.3-13.3	4.6	4.2-5.0	-6.115	0.479	0.529	-0.463	0.506	27.64	31	0.64	787	50
44T150	**P**	13.2	12.6-13.8	4.0	3.5-4.5	-7.243	0.547	4.638	-0.268	0.016	11.39	30	0.99	396	17
40T165	**P**	12.1	12.1-12.2	1.7	1.6-1.8	-15.385	1.267	0.076	-0.018	0.051	6.88	33	1.00	667	61

C= Codends L_{50}= fifty percent retention length, CI= confidence interval, SR= selection range; v_1 and v_2 regression parameters, R_{11}, R_{22} and R_{22}= variance matrix values, dof= degree of fredom

DISCUSSION

This study presents selectivity of three turned mesh codends in the Aegean Sea demersal trawl fishery. To deal with the multi-species characteristics of this fishery, the investigation focused on the main three commercial species (*P. longirostris*, *T. trachurus* and *M. merluccius*) of this area. T90 selectivty results for hake first time determimed in the study.

There were many selectivity studies carried out with 40 mm diamond (Özbilgin et al., 2005, 2012; Kaykaç et al., 2009), 44 mm diamond (Aydın et al., 2009; Lucchetti, 2008; Sala et al., 2008; Aydın and Tosunoğlu, 2010) and 40 mm square mesh codends (Guijaro and Massuti, 2006; Lucchetti, 2008; Tosunoğlu et al., 2008b; Deval et al., 2009; Aydın and Tokaç, 2015) for three investigated species (Table 11). Some of these studies have been indicated that the selectivity of 40 mm diamond mesh codend are rather poor (Tokaç et al., 1998; Tokaç et al., 2004, 2010; Özbilgin et al., 2012; Aydın et al., 2011). Wienbeck et al. (2011) reported that both turning the neting direction 90° and halving the number of meshes around codend circumferences had an important and possitive effect on the size selection of cod. Thus, we tested T90 codends instead of 40 and 44 mm diamond mesh codends. Among our three codends, the highest results were obtained from 44T150, in which both factors were applied together.

In order to increase rose shrimp selectivity, many studies have been carried out with different mesh sizes in the range of 39-60 mm (Guijaro and Massuti, 2006; Deval et al., 2006, 2009; Sala et al., 2008). However, T90 codend was used in just two studies for rose shrimp in Mediterranean. One of these studies, Aydın and Tokaç (2015) were estimated L_{50} value of 14.8±0.1 mm for deepwater rose shrimp with 40 mm turned mesh with 330 meshes on its circumference. This value was lower than our findings especialy 40T165 coded which is same mesh size with theirs. This difference could be the number of meshes around codend circumference because it is well known that decreasing number of meshes around codend, increase the L50 values. On the other hand Deval et al. (2016) investigated the selectivity of an experimental 50 mm diamond (T0) and 90° turned mesh (T90) codends, the researchers reported L_{50} value 21.4 and 22.6 mm for *P. longirostris,* respectively. These results are higher than our findings due to the using large meshes. L_{50} value obtained in their study present a statistically significant increase with a change in the same mesh size codens from T0 to T90 for four commercial shrimp species including *P. longirostris*.

Sala et al. (2008) also reported that mesh configuration affect L_{50} values of rose shrimp. Guijarro and Massuti (2006) obtained in the Western Mediterranean an increase the L_{50} value for rose shrimp from 17.2 to 20.6 mm with a change in mesh configuration from 40 mm diamond to 40 mm square. Deval et al. (2009), using 40 mm square mesh codend found the same L_{50} value (18.6 mm) as our results of 44T150 codend. The results of this study show that 44T150 codend better than the others, but none of them was adequate for the 20 mm MLS of deepwater rose shrimp. On the other hand, there is no MLS regulation in TFR. However, Manaşırlı and Avşar (2008) and Dereli (2010) studied on 50% maturity size of the *P. longirostris*, first maturity size (CL_{M50}) of female deepwater rose shrimps were found as 18.2 mm and 24.56 mm, respectively. Dereli (2010) also estimated CL_{M50} of male shrimp as 12.9 mm. Given by the results MLS regulation will be implemented by the TFR for the sustainable fishery of the rose shrimp.

Table 11. Some of the selectivity studies in Mediterranean demersal trawl fisheries

Species	References	EsM	Area	MSh	MS	CC	L_{50}	SR
P. longirostris	Guijaro and Massuti, (2006)	P	WM	S	40	180	20.2	2.1
	Aydın *et al.* (2009)	F	EM	D	44	400	12.0	4.0
	Aydın and Tosunoğlu, (2009)	F	EM	S	40	200	16.7	6.5
		F	EM	H	40	200	17.4	6.2
	Deval *et al.* (2009)	P	EM	S	40	100	18.6	6.0
		P	EM	D	44	200	16.6	4.4
	Kaykaç *et. al.* (2009)	F	EM	D	40	300	14.5	5.6

		F	EM	D	48	275	16.1	6.5
		F	EM	S	40	150	16.3	4.3
	Aydın *et al.* (2014)	P	EM	D	44	*50	16.3	6.7
		P	EM	D	44	*215	16.8	6.9
	Aydın and Tokaç, (2015)	F	EM	S	40	165	15.5	5.4
		F	EM	T90	40	330	14.8	7.4
	Deval *et al.* (2016)	F	EM	D	50	300	21.4	9.3
		F	EM	T90	50	300	22.6	8.3
	Present study	F	EM	T90	44	300	17.5	5.7
		F	EM	T90	44	150	18.6	5.1
		F	EM	T90	40	165	17.1	6.0
T.trachurus	Tosunoğlu *et al.* (2008a)	F	EM	D	50	400	15.6	5.5
	Aydın and Tosunoğlu, (2010)	F	EM	D	44	400	14.7	4.6
		F	EM	S	40	200	15.9	5.6
		F	EM	H	40	200	17.1	5.0
	Aydın *et al.* (2014)	F	EM	D	44	*50	16.3	5.5
		F	EM	D	44	*215	16.7	6.2
	Dereli and Aydın, (2016)	F	EM	D	44	300	16.2	3.1
		F	EM	D	50	264	14.2	4.2
		F	EM	S	40	165	15.3	3.2
		F	EM	T90	40	330	17.1	2.1
	Present study	F	EM	T90	44	300	16.4	5.7
		F	EM	T90	44	150	17.1	5.1
		F	EM	T90	40	165	14.8	6.0
M. merluccius	Özbilgin *et al.* (2005)	F	EM	D	40	100	14.3	3.4
	Bahamon *et al.* (2006)	P	NWM	D	40	230	10.1	3.1
		P	NWM	S	40	140	16.0	3.2
	Guijaro and Massuti, (2006)	P	WM	D	40		11.6	3.1
		P	WM	S	40	180	15.3	2.2
	Lucchetti, (2008)	F	CM	S	40	310	13.0	3.7
	Tosunoğlu *et al.* (2008a)	F	EM	D	50	400	11.4	4.1
	Aydın and Tosunoğlu, (2010)	F	EM	D	44	400	10.4	3.1
		F	EM	S	40	200	14.4	4.8
		F	EM	H	40	200	11.0	4.3
	Sala and Lucchetti, (2011)	F	CM	D	48	280	11.5	5.6
		F	CM	D	56	240	16.3	7.8
	Özbilgin *et al.* (2012)	F	EM	D	40	300	10.5	3.8
		F	EM	D	48	275	12.8	3.7
		F	EM	S	40	150	15.2	4.7
	Aydın *et al.* (2014)	P	EM	D	44	*50	9.7	7.2
		P	EM	D	44	*215	10.4	4.2
	Dereli and Aydın, (2016)	F	EM	D	44	300	12.3	1.6
		F	EM	D	50	264	14.4	6.3
		F	EM	S	40	165	14.3	3.4
	Present study	**P**	**EM**	**T90**	**44**	**300**	**12.8**	**4.6**
		P	**EM**	**T90**	**44**	**150**	**13.2**	**4.0**
		P	**EM**	**T90**	**40**	**165**	**12.1**	**1.7**

NWM, North western-;WM,western-;EM, eastern-; CM, central Mediterranean; EsM, method for estimation of selectivity (F, Fryer's; P, pooled); MSh, mesh shape (D, diamond-; S, square-; H,hexagonal-;T90, 90 ° turned mesh); MS, mesh size; L_{50}, mean value of retention length at 50%; SR, selection range

To the best of our knowledge, there is only one study about T90 turned mesh codends for horse mackerel in the Aegean Sea (Dereli and Aydın, 2016). Among three different mesh configurations, the highest L_{50} value (17.1 cm) for horse mackerel was obtained from T90 codend by researchers. Although their T90 codend has both smaller mesh size and wider codend than our 44T300 codend, L_{50} values were obtained equal. Our results of 44 mm turned mesh codends are higher than 44 mm diamond mesh codends given by same fishing grounds (Aydın and Tosunoğlu, 2010). They are estimated a L_{50} value of 14.7 cm for the 44 mm diamond mesh with 400 meshes around codend circumference. This value (14.7 cm) is close to just our 40 mm turned mesh codend. This closeness may be resulted of using narrower codend in our study according to the other. Morphological and behavioural characters may also explain the higher L_{50} values for *T. trachurus*. Tosunoğlu et al., (2008a) indicate that most horse mackerel individuals showed continuous stronger swimming ability in the belly section of the trawl until the trawl was hauled up. For this reason, L_{50} values of the codend for mackerel is 20% higher than the MLS (13 cm), thus allowing for the escapement of most the juveniles.

Studies that carried out different mesh shape, size and material, ranging from 28 to 70 mm mesh size in Mediterranean (Özbilgin et al., 2005, 2012; Guijaro and Massuti, 2006; Lucchetti, 2008; Tosunoğlu et al., 2008a; Aydın and Tosunoğlu, 2010) for hake. However, due to the differences in the mesh size and material, mesh configuration and number of meshes at the codend circumference, results of most of these studies are not comparable to those found in the existing findings (Tosunoğlu et al., 2008a; Sala and Lucchetti, 2010). Their results show that the use of larger diamond mesh codend increases the L_{50} values for *M. merluccius*. Furthermore, the analysis of selectivity presented that square mesh codend positively affected L_{50} of hake; this codend increased the size of escapement in the Mediterranean (Guijarro and Massuti, 2006; Ordines et al., 2006; Lucchetti, 2008; Aydın and Tosunoğulu, 2010; Özbilgin et al., 2012; Dereli and Aydın, 2016). But none of them mentioned T90 codends. The present study for the first time presents selectivty parameters of T90 for hake. The results of L_{50} (13.2 cm) value of the 44T150 codend is higher than the values for 44T150 and 40T165 codends. However, these L_{50} values are still very low compared to the 20 mm MLS (Anonymous, 2016). On the otherhand, Our 40 mm turned mesh size codend (40T165) selectivity results are higher than those reported by Bahamon et al. (2006), Guijarro and Massuti (2006) and Tosunoğlu et al. (2008a) who determined L_{50} values for 40 mm nominal mesh sizes as 10.1 cm, 11.6 cm and 11.4 cm, respectively. From the Table 11, no investigations were adequate release the under 20 cm individuals.

Sala and Lucchetti (2011) reported that the codend circumference plays a role which is as important as mesh size for *M. merluccius*, *M. barbatus* and *Alloteuthis media*. An increase in mesh size from 48 mm to 56 mm could be made futile by an increase in codend circumference of only 13-17%. Tosunoğlu et al. (2008a) and Sala and Lucchetti (2011) also found that selectivity increases with larger mesh size but also decreases with wider codends. These results showed that it is not sufficient to increase selectivity in multi-species fisheries only by setting a minimum mesh size, account must also be taken of the effects of the other factors such as the codend circumference, mesh configuration.

In conclusion, the change from 300 to 150 number of meshes around the codend circumference, increase L_{50} from 17.5 to 18.6 mm (6.3%) for deepwater rose shrimp, from 16.4 to 17.1 cm (4.3%) for horse mackerel and from 12.8 to 13.2 cm (3.1%) for hake. However, these values no adequate for the MLS of deepwater rose shrimp and European hake. Therefore, an option of reducing the number of meshes around codend circumference with a larger turned mesh should be researched in future studies for obtaining optimal 50% retention length values. It is known that any efforts such as using square mesh, turned mesh codends or halved the number of meshes in the codend to release immatures of some species, is probably to cause the loss of marketable sizes of other species in the Mediterranean. This economical loss of revenues is the essential concern of fishermen that prevents them using alternative codend designs, though such designs are technically applicable. Consequently, the losses of income caused by using T90 mesh codend and halving the number of meshes around codend circumference should also be investigated in future studies.

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