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The Effect of Codend Circumference on Selectivity of Hand-Woven Slack Knotted Codend in the North Eastern Mediterranean Demersal Trawl Fishery

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Abstract

Poor selectivity and high discard rate of hand-woven slack knotted codend is a serious problem for north eastern Mediterranean demersal fish stocks. This study investigates the effect of codend circumference on bottom trawl selectivity for red mullet (*Mullus barbatus*), bogue (*Boops boops*), goldband goatfish (*Upeneus moluccensis*), Randall's threadfin bream (*Nemipterus randalli*) and picarel (*Spicara smaris*). A total of 18 valid hauls were conducted using covered codend method between 08 October and 26 December 2012 in Mersin Bay. Results show that selectivity of commercially used standard codend (300 meshes around its circumference) is rather poor and the narrow codend (150 meshes around its circumference) significantly increases selectivity for tested species. However, it is not selective enough to avoid the individuals of five commercial species under the MLS or FMS.

Keywords: Narrow codend, trawl selectivity, hand-woven slack knotted codend, Mersin Bay.

Kuzey Doğu Akdeniz Demersal Trol Balıkçılığında Torba Çevresinin El Örmesi Gevşek Düğümlü Torba Seçiciliğine Etkisi

Özet

El örmesi gevşek düğümlü torbanın zayıf seçiciliği ve yüksek ıskarta oranı Kuzey Doğu Akdeniz demersal balık stokları için ciddi bir problemdir. Bu çalışmada torba çevresindeki göz sayısının dip trol seçiciliği üzerine olan etkisi barbun (*Mullus barbatus*), kupes (*Boops boops*), Nil barbunyası (*Upeneus moluccensis*), merbun (*Nemipterus randalli*) ve izmarit (*Spicara smaris*) için araştırılmıştır. Mersin Körfezi'nde 08 Ekim ve 26 Aralık 2012 tarihleri arasında örtü torba yöntemi kullanılarak toplam 18 çekim gerçekleştirilmiştir. Sonuçlar test edilen türler için ticari olarak kullanılan standart torbanın (çevresinde 300 göz olan) seçiciliğinin çok zayıf olduğunu ve dar torbanın (çevresine göz sayısı 150 olan) seçiciliği önemli ölçüde arttırdığını göstermektedir. Bununla birlikte, dar torba beş ticari tür için minimum yakalanma boyu veya ilk üreme boyunun altındaki bireyleri kaçırmada yeterince seçici değildir.

Anahtar Kelimeler: Dar torba, trol seçiciliği, el örmesi gevşek düğümlü torba, Mersin Körfezi.

Introduction

Mediterranean fisheries are remarkable for the large number and variety of commercially important species caught and the wide range of fishing methods employed, from artisanal to industrial (Stewart, 2002). Management of fishing stocks in the Mediterranean Sea is mainly based on defining closed areas and seasons, Minimum Landing Sizes (MLS), Minimum Mesh Sizes (MMS) and limiting effort (Sala and Luchetti, 2010; Tokaç *et al*., 2014).

Trawl catches contribute 90% of the total landing in the Turkish demersal fishery (Metin *et al.*, 2004). Presently Turkish Fisheries Regulations (TFR) defines a minimum codend mesh size of 40 mm for the Black Sea, 44 mm for the Aegean Sea and the Mediterranean for demersal trawls. Additionally, the use of 40 mm square mesh codend is left to fishermen's preference (Anonymous, 2012). Many studies published during the last decade have clearly shown that the selectivity of commercially used codends are rather poor in Turkish demersal trawl fisheries (Tosunoğlu *et al.*, 2007; Ateş *et al.*, 2010; Tokaç *et al.*, 2010; Aydın *et al.*, 2011; Özbilgin *et al.*, 2012).

In order to improve fish stocks and reduce fishing mortality, from August 2013 TFR also defines a new regulation for codend circumference that number of the codend meshes shall not be more than half of the number of meshes around the tunnel (Anonymous, 2012). In general, for the same mesh size, reducing the number of mesh around the codend might improve codend selectivity (Reeves *et al.*, 1992; Broadhurst and Kennelly, 1996; Lök *et al.*, 1997; Broadhurst *et al.*, 2004; Özbilgin *et al.*, 2005; Sala and Luchetti, 2011). Because during the haul, when the codend fills, diamond meshes elongate under tension, the end meshes are blocked, water flow is diverted and the codend forms a typical bulge which expands to a maximum diameter (Robertson and Stewart, 1988). Underwater observations show that most of the fish mainly escape through open meshes just in front of the bulge and meshes ahead of these are partially or totally closed along the length of the codend, which leads to retention of juveniles of round-bodied fish (Özbilgin *et al.*, 2005). Narrow codends should expand to form a smaller bulge and it takes less time to achieve the maximum diameter (Sala and Luchetti, 2011). As a result of this, with reduced number of meshes around the codend, the individual meshes should be more open during the tow (Robertson and Emslie, 1985).

Forty four mm mesh size hand-woven slack knotted codend is commercially used in Mersin Bay (north eastern Mediterranean) demersal trawl fleet. Özbilgin *et al.* (2013) reported that selectivity of this codend is extremely poor for almost all the commercial species. Underwater observations conducted in Mersin Bay trawl operations show that fish mainly try to escape from the fabricated codends in the end of the tow when towing speed is reduced and the meshes are relatively slacker. However, knots of commercially used codends are deliberately left slack, so the meshes stay less open when no force is applied on them. The potential escape chance is thus relatively reduced especially for juveniles.

To predict potential effect of the new regulation about codend circumference in Mersin Bay demersal trawl fishery, present study compares the selectivity's of a hand-woven 300 mesh slack knotted codend with 150 mesh narrow codend for five marketable fish species.

Materials and Methods

Selectivity trials were carried out onboard the commercial trawler "Aynur 33" (21 LOA, 480 HP main engine) in legal trawling grounds of Mersin Bay of the north eastern Mediterranean (Figure 1) between 08 October and 26 December 2012. All hauls were performed at depths ranging from 30 to 78 m. The towing durations were between 120 and 180 min, and the average towing speed was 2.7 knots (ranging between 2.5 and 2.9 knots). To minimise the effects of spatial and temporal differences on selectivity due to the changes of population structure, the codends were changed as often as possible.

Selectivity of standard (300 meshes on its circumference) and narrowed (150 mesh) codends were tested with a total of 18 valid hauls (two hauls had to be canceled due to tears on the standard cod end). Both the cod ends were 5.5 m in stretched length and made of the same multi-monofilament hand-woven polyethylene (PE) material with 44 mm nominal mesh size (Figure 2). They were attached to the end of the funnel, which had 300 meshes around its circumference, and was made of 44 mm mesh size PE netting. Codends were tested with a protective bag which was made of 3.5 mm diameter PP twine with a nominal 110 mm diamond mesh and 80 meshes on its circumference. The mean mesh size of each codends was measured with an OMEGA mesh gauge (Fonteyne *et al.*, 2007) at 50 N when the netting was wet.

Selectivity data was collected by using commercial demersal trawl gear of the vessel with the covered codend technique for five commercial species: red mullet (*Mullus barbatus*); bogue (*Boops boops*); goldband goatfish (*Upeneus moluccensis*); Randall's threadfin bream (*Nemipterus randalli*);

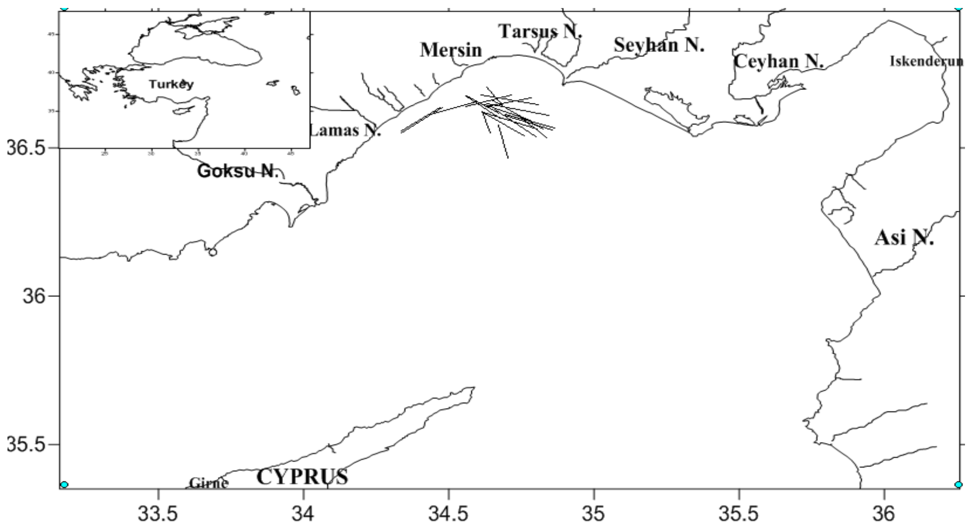

Figure 1. Study area and the position of trawl hauls.

picarel (*Spicara smaris*). The cover with a nominal 24 mm mesh size was supported by two 1.3 m diameter hoops to minimize masking effect of the cover netting on codend mesh openings (Wileman *et al.*, 1996). The data were pooled to calculate selectivity parameters of each codend due to insufficient retention numbers in majority of the individual hauls. Selectivity parameters were estimated using the "ccfit" function in the "Trawl functions" programs for R (Miller *et al.*, 2004). Selection curves were obtained by fitting a logistic equation that is modeled as $r(l)=\exp(v_1+v_2l)/[1+\exp(v_1+v_2l)]$ by means of maximum likelihood method. In the logistic equation, r(l) is the probability that a fish of length *l* is retained given that it entered the codend (Wileman *et al.*, 1996), and $v = (v_1, v_2)^T$ is vector of the selectivity parameters. A likelihood ratio test (McCullagh and Nelder, 1991) was carried out to determine whether the selection curves estimated for two codends were statistically different from each other (Campos and Fonseca, 2003).

Results

The mean values of 60 mesh (three lines of 20 meshes near the aft) measurements were: 47.57 mm (ranging between 41-55 mm) for standard codend and 43.88 mm (ranging between 41-49 mm) for narrow codend. The catch per hour values were found as 43.13 kg for standard codend in 8 valid hauls with total towing duration of 1113 min, 42.45 kg for narrow codend in 10 valid hauls with total towing duration of 1350 min.

The collected data allowed analysis of the selectivity for five commercial species: red mullet; bogue; goldband goatfish; Randall's threadfin bream; picarel. Estimated selectivity parameter and number of individuals retained in codend and cover for these species were given in Table 1. Figures 3-7 show selection curves of codends for each species.

Red mullet was the most abundant fish species entered the codends. Their lengths varied between 7 and 21.5 cm and showed a main peak at 10 cm (Figure 3). The Minimum Landing Size (MLS) defined by the Turkish Fisheries Regulations (TFR) is 13 cm for this species (Anonymous, 2012) and more than 70% of individuals below 13 cm were retained in each codend. Lengths at fifty percent retention (L_{50}) values for red mullet were found as 5.82 cm in the standard codend and 6.71 cm in the narrow codend. Selection Range (SR) values were 2.42 cm and 2.16 cm, respectively. The selection curves of standard and narrow codends are found to be significantly different ($P<0.05$).

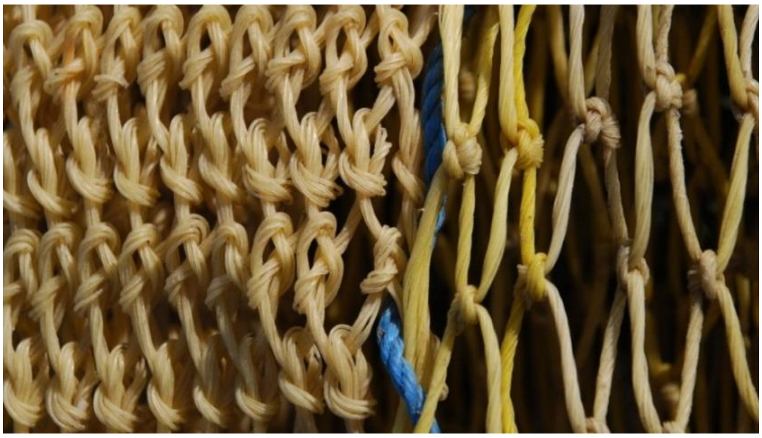

Figure 2. Hand-woven (left) and machine-woven (right) codends.

Table 1. Results of selectivity parameter estimates with number of species in codend and cover for two codends

Species	Codend	L50 (SE)	SR (SE)	SF	V_1	V_2	R_{11}	R_{12}	R_{22}	Codend	Cover
Red mullet	Standard	5.82 (0.67)	2.42 (0.37)	1.22	-5.29	0.91	1.985	-0.195	0.019	3949	42
	Narrow	6.71 (0.17)	2.16 (0.13)	1.53	-6.82	1.02	0.320	-0.034	0.004	8972	299
Bogue	Standard	6.81 (1.25)	3.06 (0.78)	1.43	-4.88	0.72	4.413	-0.377	0.033	725	11
	Narrow	7.56 (0.52)	3.49 (0.37)	1.72	-4.76	0.63	0.669	-0.054	0.004	2530	80
Goldband goatfish	Standard	2.04 (7.18)	6.54 (5.64)	0.43	-0.69	0.34	9.020	-0.869	0.084	286	17
	Narrow	8.37 (0.09)	1.76 (0.13)	1.91	-10.45	1.25	0.735	-0.080	0.009	661	209
Randall's thread fin bream	Standard	2.01 (1.32)	8.16 (2.01)	0.42	-0.54	0.27	0.228	-0.030	0.004	288	52
	Narrow	5.92 (0.11)	2.28 (0.22)	1.35	-5.71	0.96	0.356	-0.054	0.008	419	202
Picarel	Standard	7.82 (0.35)	4.65 (0.84)	1.64	-3.69	0.47	0.592	-0.065	0.007	194	88
	Narrow	10.18 (0.25)	3.76 (0.42)	2.32	-5.95	0.58	0.348	-0.037	0.004	161	250

***L50** (50% retention length) and SR (selection range) with standard errors (SE); SF (selection factor (calculated by using measured mesh sizes)); V_1 and V_2 (maximum likelihood estimators of the selectivity parameters); R_{11}, R_{12} and R_{22} (variance matrix values).

In total, 3346 bogue entered the codends. The length distribution was between 8 and 20.5 cm and showed a peak at 14 cm (Figure 4). L_{50} and SR values were found as 6.81 and 3.06 cm for standard codend, 7.56 and 3.49 cm for narrow codend. Selection curves of each codends are also found to be significantly different (P<0.05). According to TFR there is no MLS for bogue (Anonymous, 2012). However, sexual maturity size of females was found as 13 cm by Kınacıgil *et al.* (2008) in the Aegean Sea. According to this value both the codends tested in the present study are rather unselective.

Goldband goatfish was the most abundant lessepsian species migrated from Red Sea, and a total of 1173 specimens captured in the codends. The lengths of individuals varied between 6.5 and 17.5 cm and showed a peak at 10 cm (Figure 5). In present study, L_{50} increased from 2.04 cm to 8.37 cm when narrow codend replaced the standard codend. SR values were found as 6.54 cm for standard and 1.76 cm for narrow codend, and selection curves of two codends were significantly different (P<0.01). The MLS for goldband goatfish is 10 cm (Anonymous, 2012). Although the narrow codend was found to be more selective, its L_{50} value is still under the MLS.

Randall's threadfin bream was the second most abundant lessepsian species after goldband goatfish in the present study. Their lengths ranged between 3.5 and 25 cm and showed a peak at 6 cm (Figure 6). The MLS of Randall's threadfin bream is not specified in the TFR, and to our knowledge there is no information available about first maturity size (FMS) of this species. Change from the standard to narrow codend increased the L_{50} values from 2.01 cm to 5.92 cm, and decreased SR values from 8.16 cm to 2.28 cm. Selection curves of the two codends were found to be significantly different (P<0.01).

During the study, a total of 693 picarel entered

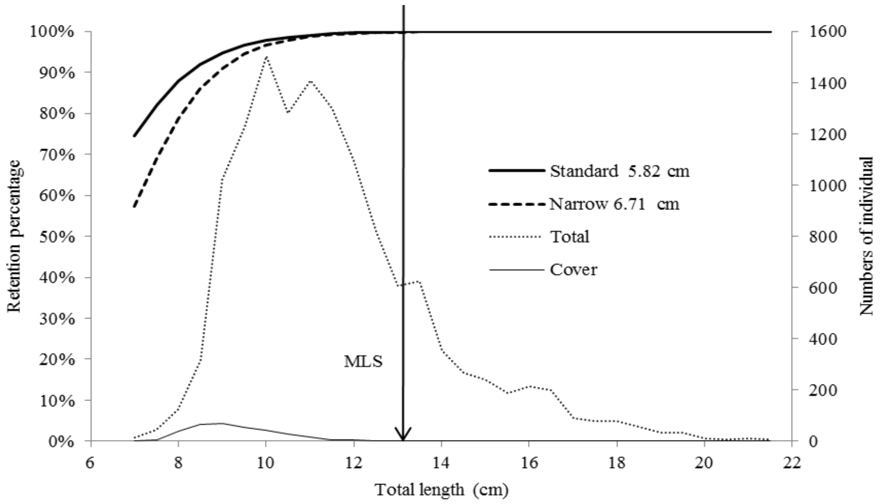

Figure 3. *Mullus barbatus*. Selection curves with L_{50} values for two codends, and length frequency distributions of fish that entered the codends and escaped. The MLS (13 cm) for red mullet (Anonymous, 2012) is also shown in the figure.

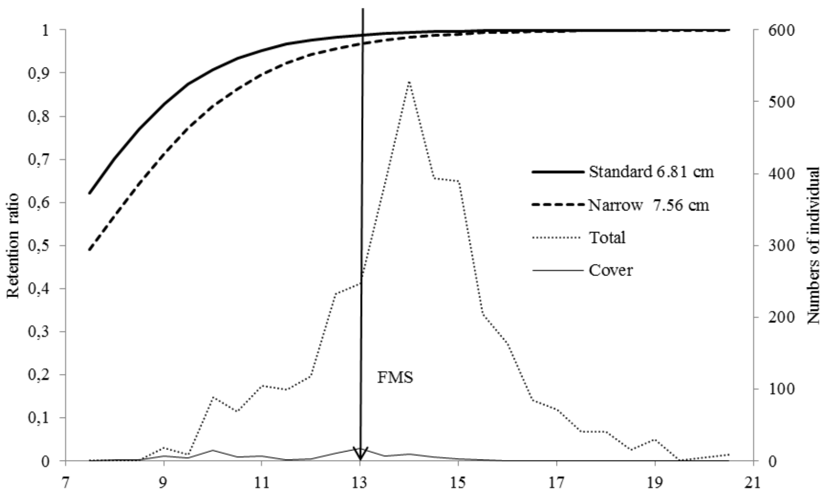

Figure 4. *Boops boops*. Selection curves with L_{50} values for two codends, and length frequency distributions of fish that entered the codends and escaped. The FMS (13 cm) for female bogue (Kınacıgil et al., 2008) is also shown in the figure.

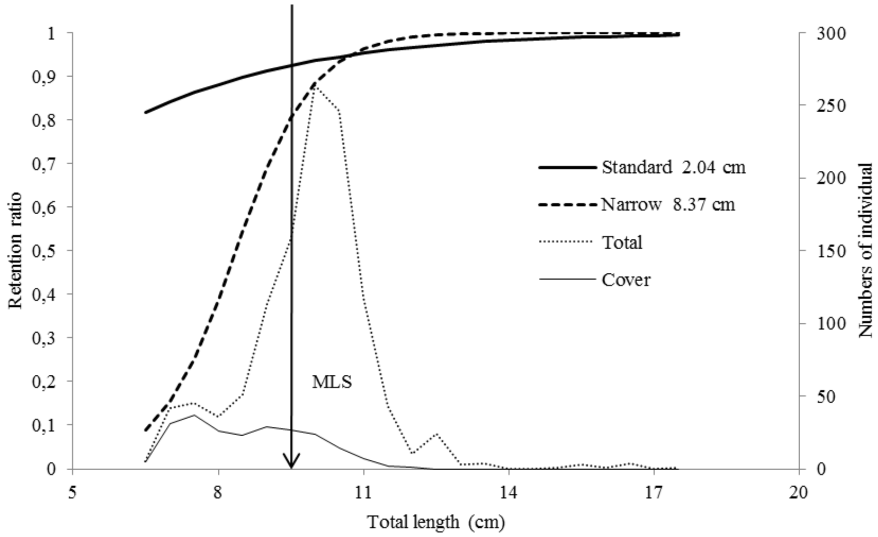

Figure 5. *Upeneus moluccensis*. Selection curves with L_{50} values for two codends, and length frequency distributions of fish that entered the codends and escaped. The MLS (10 cm) for goldband goatfish (Anonymous, 2012) is also shown in the figure.

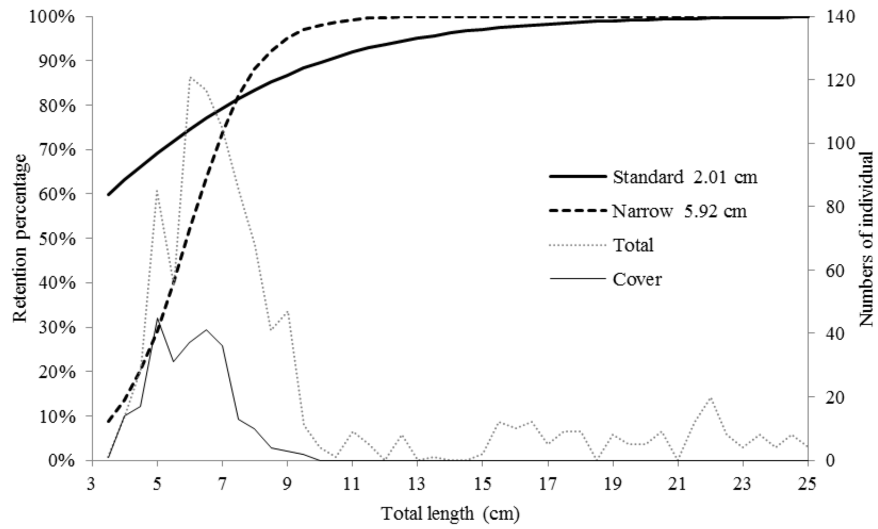

Figure 6. *Nemipterus randalli*. Selection curves with L_{50} values for two codends, and length frequency distributions of fish that entered the codends and escaped.

the codends. The length distribution varied between 7 and 17.5 cm, and showed a peak at 8 cm (Figure 7). The MLS of picarel is not specified in TFR. However, Kınacıgil *et al.* (2008) reported that females of this species reach sexual maturity at 12 cm length in the Aegean Sea. Although narrow codend (L_{50} = 10.18 cm, SR = 3.76 cm) was found to be more selective than standard codend (L_{50} = 7.82 cm, SR = 4.65 cm), L_{50} values of both the codends are below sexual maturity size. Selection curves of the two codends are also statistically different from each other (P<0.01).

Discussion

Present study is the first of its kind to demonstrate the effect of circumference on selectivity of hand-woven slack knotted trawl codend used by trawl fleet in Mersin Bay. Results clearly show that selectivity of previously used commercial codend is rather poor for mentioned species, and the narrow codend is significantly more selective. This finding is consistent with the results of the other studies conducted in the Mediterranean waters (Lök *et al.*, 1997; Özbilgin *et al.*, 2005; Sala *et al.*, 2006; Kaykaç, 2007; Sala and Luchetti, 2010; 2011). The only common species between the present and the other studies (Lök *et al.*, 1997; Sala *et al.*, 2006; Kaykaç, 2007; Sala and Luchetti, 2011) is the red mullet for which all the investigations clearly conclude that the narrow codend has higher L_{50} values. However, because of the differences in the mesh material, mesh size, mesh diameter, presence and types of knots, number of meshes around the codend and tunnel, towing duration and populations fished, the results of

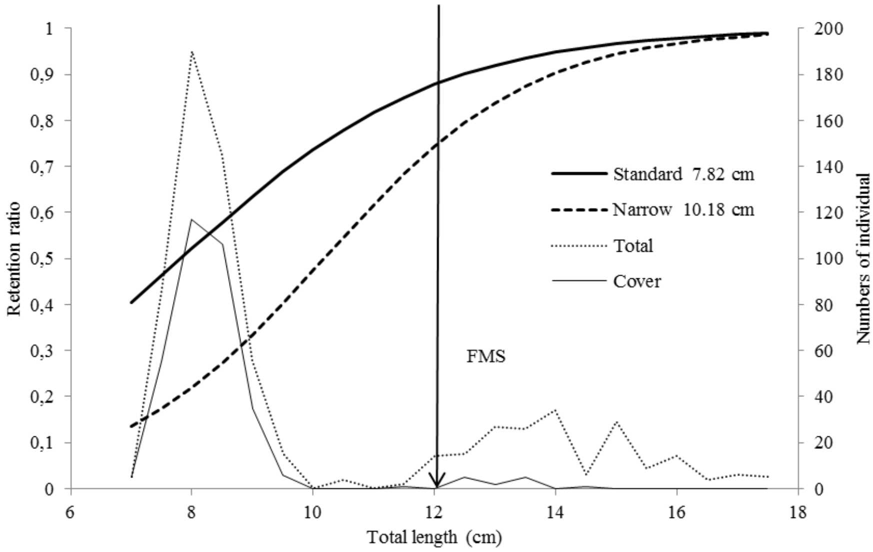

Figure 7. *Spicara smaris***.** Selection curves with L_{50} values for two codends, and length frequency distributions of fish that entered the codends and escaped. The FMS (12 cm) for female picarel (Kınacıgil *et al.,* 2008) is also shown in the figure.

the present study and the other investigations on the effect of codend circumference on selectivity are not directly comparable in terms of selection parameters. The observed increase of L_{50} value for narrow codend may be explained by the meshes remaining more open during the tow. Robertson and Emslie (1985) reported that 60 mesh narrow codend was seen to be more open than 120 mesh conventional codend in underwater observations in the Scottish North Sea trawl fishery.

Although produced from the same package of netting, mean mesh size of the narrow codend (43.9 mm) was smaller than that of the 300 mesh codend (47.6 mm). The difference measured here is likely to be caused by process of net making by hand. However, despite having about 8 % smaller mean mesh size, the narrow codend was still significantly more selective than the commercial codend. To take the difference in measured mesh sizes into account, selection factors (SF) are calculated and presented in Table 1. SF values of narrow codend are found to be 0.31, 0.29, 1.48, 0.93 and 0.68 higher for red mullet, bogue, goldband goatfish, Randall's threadfin bream and picarel, respectively.

The current study was carried out in the first half of the fishing season when water temperature is relatively higher and the fish are expected to be in their best condition after summer feeding (Özbilgin *et al.*, 2007), so specimens are expected to be more active to escape from the codends (Özbilgin and Wardle, 2002). This finding is supported by another study using the same commercial codend (300 diamond meshes around its circumference) in the second half of the season, when almost all of marketed species found no chance to escape (Özbilgin *et al.*, 2013) to a degree that even the selection parameters could not be estimated. Therefore, selectivity of these codends for the second half of the season, when the water temperature is relatively lower and the most of fish are at their spawning stages, is expected to be even poorer than that reported in this study (Özbilgin *et al.*, 2007; 2011; 2012).

In conclusion, this study demonstrates that reducing the number of meshes around the codend circumference increases selectivity of hand-woven slack knotted trawl codend used in Mersin Bay. However, this improvement in selection is not sufficient enough to release juveniles of commercial species under the MLS or FMS for a sustainable fishery. In addition, selectivity is expected to be even worse in the second half of the fishing season when narrow codend might not be effective because of the scarce catch size (Özbilgin *et al.*, 2013) which does not allow the meshes remain open (Sala and Luchetti, 2010). Therefore, the new regulation enforcing reduced codend circumference (Anonymous, 2012) in Turkish bottom trawl fisheries is not likely to be efficient on its own for sustainable fisheries in the north eastern Mediterranean. The other factors that affect selectivity such as twine material (Tokaç *et al.*, 2004), twine diameter (Sala *et al.*, 2007; Graham *et al.*, 2009), and construction method of nets must also be considered when policy makers aim to make a new arrangement. Finally, authors suggest that due to high discard rate (Özbilgin *et al.*, 2013) and non-selective characteristic, commercially used hand-woven slack knotted codends should be banned to reduce the negative impacts of trawling on fish stocks in the region. Özbilgin *et al.* (2013) reports that selectivity of the same mesh size machine-woven codend is better than that of hand-woven codend for seven commercial species studied in Mersin Bay. Enforcement of codends that has meshes staying open during trawling is essential to improve size selectivity in this fishery. Meanwhile, it also has to be taken into account that demersal trawling in Mersin Bay has a multi-species character, with more than 130 species involved (Özbilgin *et al.*, 2013). Thus, any efforts to release juveniles of some species, is likely to cause the loss of marketable sizes of many other species, due to the differences in their morphologies (Tosunoğlu *et al.*, 2003), and behaviour (Özbilgin *et al.*, 2013). Such commercial loss of revenues (Özbilgin *et al.*, un published) are the main concern of the fleet that prevents them using more selective codends, although they are technically available.

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