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Full Length Research Paper

Selectivity of 40 mm square and 50 mm diamond mesh codends for five species in the Eastern Mediterranean demersal trawl fishery

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The aim of this study was to determine the selectivity of 40 mm square (40S) and 50 mm diamond (50D) mesh codend for five species, red mullet (*Mullus barbatus*), annular sea bream (*Diplodus annularis*), common Pandora (*Pagellus erythrinus*), axillary sea bream (*Pagellus acarne*) and blotched picarel (*Spicara maena*) in the Eastern Mediterranean. Selectivity data were collected by the covered codend method and analyzed. Mean selection curves were analyzed and compared using the between haul variations model for red mullet and annular sea bream. Pooled data were used for common Pandora, axillary sea bream and blotched picarel. In total, 22 valid hauls, 10 with 40S and 12 with 50D codends were carried out. The 50% retention lengths (L_{50}) of 40S and 50D codend were found as 14.5 and 15.3 cm for red mullet, 9.5 and 11.3 cm for annular sea bream, 13.1 and 15.0 cm for common Pandora, 14.4 and 15.3 cm for axillary sea bream, 14.5 and 17.2 cm for blotched picarel, respectively. This study showed that codends with 40S and 50D L_{50} results improve the selectivity when considering commercially used 40 mm nominal diamond mesh codend in Turkish seas for given species. However, in multi-species, it seems likely that a separation of species system would potentially be of more value than size-selective systems. Therefore, different selective techniques such as grid and separation panel and behaviour of the species against the gear need to be investigated.

Key words: Codend selectivity, 40 mm square mesh, 50 mm diamond mesh, Eastern Mediterranean, demersal trawl.

INTRODUCTION

The minimum mesh size has been used as an important management tool in many trawl fisheries around the world. Ideally, the minimum mesh size should be determined in relation to the minimum legal landing size and the selection property of the codend. This would require different codends for different species because of differences in the maturity size, marketable size, growth rate and other biological features of the target fish (He, 2007).

Turkish fisheries regulation (TFR) allows trawlers to use a minimum of 40 and 44 mm codend diamond mesh size in the Black Sea and in the remaining Turkish waters, respectively. In addition, the use of 40 mm square meshes codend was adopted in September 2008 as an alternative for the 44 mm diamond mesh codend (Anonymous, 2008). On the other hand, according to council regulation (EC 1967/2006) of the European commission concerned with sustainable exploitation of fishery resources in Mediterranean Sea, demersal trawl codends should be made of 40 mm square mesh instead of diamond mesh or at the duly justified request of the ship owner, which is 50 mm diamond mesh.

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Abbreviations: L_{50}, 50% retention lengths; **40S,** 40 mm square mesh codend; **50D,** 50 mm diamond mesh codend; **TFR,** Turkish fisheries regulations; **MLS,** minimum landing sizes; **FML,** first maturity length.

There are many selectivity studies carried out with different mesh size, material and shape in Turkish seas. Recent studies have shown that the selectivity of diamond mesh codend used commercially by Turkish demersal trawlers is rather poor (Özbilgin and Tosunoğlu, 2003; Tosunoğlu et al., 2003a, b; Tokaç et al., 2004). On the one hand, there are few selectivity studies conducted on 40 mm square mesh and 50 mm diamond codend. Polyethylene (PE) 40 mm square mesh codend selectivity studies explored some crustaceans, cephalopods (Aydin and Tosunoğlu, 2009; Deval et al., 2009; Tokaç et al., 2009) and polyamide (PA) 40 mm for red mullet and annular sea bream (Tokaç et al., 1998). On the other hand, PE 50 mm mesh codend selectivity was investigated for hake (*Merluccius merluccius*), horse mackerel (*Trachurus trachurus*), anglerfish (*Lophius piscatorius*), John Dory (*Zeus faber*) and deep water rose shrimp (*Parapeaneus longirostris*) by Tosunoğlu et al. (2007, 2008). No available information with PE 50 mm diamond and 40 mm square mesh codend for red mullet (*Mullus barbatus*), annular sea bream (*Diplodus annularis*), common Pandora (*Pagellus erythrinus*), axillary sea bream (*Pagellus acarne*) and blotched picarel (*Spicara maena*) which have high commercial values.

The aim of this study was to determine the selectivity of 40 mm square (40S) and 50 mm diamond (50D) mesh codend. The criterion of the codend studied here is compatible with the council regulation for five species: red mullet, annular sea bream, common Pandora, axillary sea bream and blotched picarel which are commercially important species.

MATERIALS AND METHODS

Fishing trials were carried out on R/V 'EGESÜF' (27 m LOA, 500 HP main engine) in the Central area of Izmir Bay, in the Eastern Aegean Sea between 05 and 27 November, 2008. Twenty two (22) valid hauls were carried out; ten with 40 mm square (40S) and twelve with 50 mm diamond (50D) mesh codends. The towing duration was 60 min for all the hauls and the average towing speed was 2.4 knots (between 2.1 and 2.8 knots).

A modified bottom trawl, 900 meshes round the fishing circle, (Tosunoğlu and Aydin, 2007, for drawing) was operated. Two different mesh codends, 40S and 50D were tested. Due to the nature of Turkish nets, makers do not provide nets of the same material. That is why for both mesh types, 40S was made of knotted PE, whereas 50D was a knotless PE material. Both codends were about 5 m in length having 100 bars around codend circumference in 40S and 200 meshes in 50D. On the other hand, number of meshes around funnel was 200 meshes. To determine the mean mesh size of each codend, a total of 60 stretched mesh openings were measured near the aft (3 lines of 20 meshes in towing direction) using a calliper rule with 4 kg weight vertically tied to stationary jaw of the rule. The mean mesh sizes of the codends were 40.8 ± 0.14 mm and 50.1 ± 0.08 mm for 40S and 50D, respectively.

Selectivity data were collected for the three species by using hooped covered codend method (Wileman et al., 1996). The cover used was 7.5 m in length and made of 24 mm nominal mesh size knotless PA netting. It was supported by two hoops in 1.6 m diameter. The hoops were made of 4 cm diameter PVC material and mounted to the cover at distances of 1.4 and 4 m from the attachment point which was at the end of the funnel.

After each haul, catches from codend and cover were separately emptied on the deck, sorted by species and weighed. For the common Pandora and axillary sea bream, the whole catches were always measured as the numbers of individuals were not sufficient for calculating selectivity by haul and pooled data had to be used. For blotched picarel, there are sufficient data for calculating individual 50% retention length (L_{50}) results in 40S; however, there are no individuals in most hauls of 50D. Thus, in order to compare codend selectivity curves of 40S and 50D, we used the pooled data for this species. For red mullet and annular sea bream which were captured in large numbers per hauls, random samples were taken from total catches. The length class frequencies were then estimated by scaling up the sub-sampled frequencies obtained by the ratio of the total weight to the sub-sample weight. Total lengths of all species were measured to the nearest cm.

To compare the retention rates of immature specimens between the different codend, a 13 and 15 cm total length (TL) minimum landing sizes (MLS) were used for red mullet and common Pandora given by TFR. According to TFR, regulations do not have any MLS for annular sea bream, axillary sea bream and blotched picarel. Therefore, 10.5, 14 and 12 cm first maturity length (FML) values reported with the same fishing ground study by Kinacigil et al. (2008) were taken into consideration as a MLS for annular sea bream, axillary sea bream and blotched picarel.

Selectivity curves of the individual hauls were obtained by fitting the logic function: $r(l)=\exp(v_1+v_2l)/[1+\exp(v_1+v_2l)]$ by means of maximum likelihood method as given in Wileman et al. (1996) where the parameters v_1 and v_2 are the intercept and slope of the linear logistic function, respectively. Selectivity parameters for individual hauls and pooled data were estimated by using the CC2000 software (*ConStat*, DK). The mean selectivity of individual hauls was found by taking into account between-haul variation (Fryer, 1991) using the ECModeller software (*ConStat*, DK). The model of Fryer (1991) was also used to investigate the significance of catch size on the selectivity parameter estimates.

A likelihood ratio test (McCullagh and Nelder, 1991) was carried out because the pooled selection curves estimated in the two different cod ends were statistically different from each other. The in-likelihoods resulting from fitting independent selection curves for each pair of contiguous mesh sizes were summed up, and then a single curve was fitted to the data of both mesh sizes and the corresponding in-likelihood was assessed. W2 = 2(in-likelihood (mesh size A)+in-likelihood (mesh size B)−In-likelihood (mesh sizeA+mesh sizeB)) is approximately χ2 (α,df), where df is given by the change in the number of parameters estimated when fitting the curves, if the null hypothesis H_0 of no differences between curves is correct. The derivation of log-likelihoods was done with stacking (that is piling) individual hauls instead of pooling by length class (Millar et al., 2004).

RESULTS

In total 22 hauls, 10 with 40S and 12 with 50D codends were performed. A total weight of about 1 911.7 kg, 885.5 kg in 40S and 1 026.2 kg in 50D was caught. Red mullet was the dominant species in 40S, with 35% (309.3 kg) and in 50D with 39% (400.4 kg). Annular sea bream was the second species in both codends (22% in 40S, 27% in 50D) followed by blotched picarel, common Pandora and axillary sea bream (Figure 1). Remaining species (fish and invertebrates) contributed to 32% (279.4 kg) of the

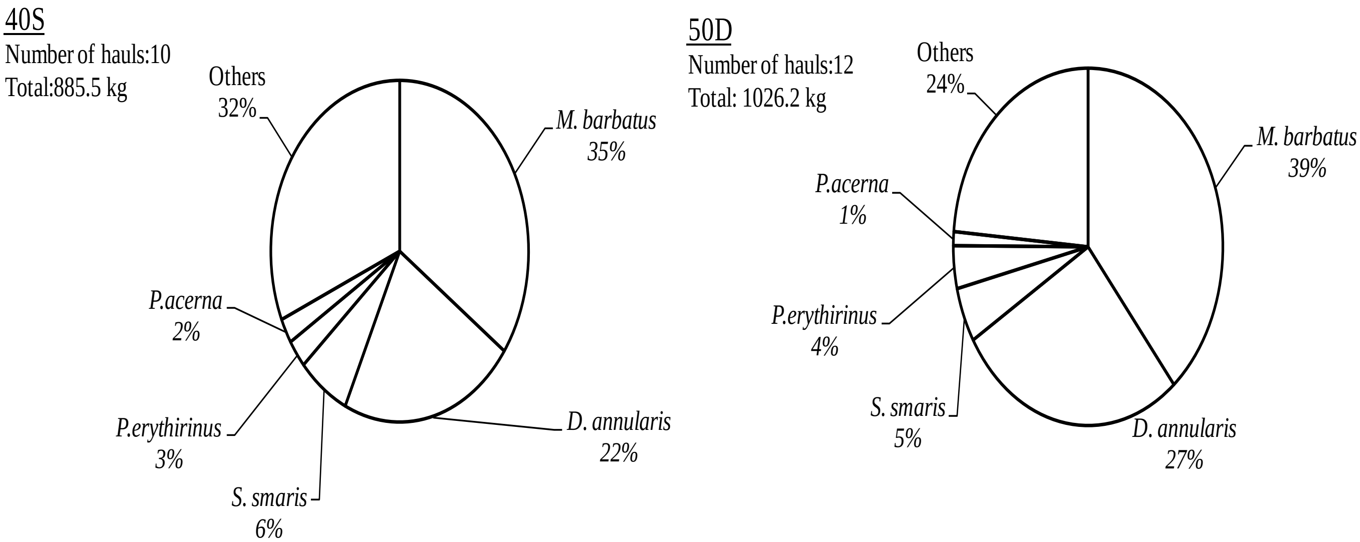

Figure 1. Catch composition of 40 mm square (40S) and 50 mm diamond (50D) mesh codends.

40S and 25% (260.5 kg) of the 50D.

Red mullet

A total number of 10 759 red mullet was caught in the 40S. While 25% (2,686) of the specimens was retained with sizes ranging from 9 to 21 cm, 75% (8,073) escaped ranging from 7 to 16 cm. In 50D, a total number of 11 847 specimens were caught: 28% (3,355) with a size range from 9 to 21 cm, and 72% (8,492) escaped from 7 to 18 cm (Figure 2). Figure 2 shows (Y-axis right) normalized length frequency distributions in the codend and cover calculated as a percentage of red mullet in each length class and selection curves of 40S and 50D (Y-axis left). As seen in the figure, the size ranges of red mullet (both those escaped and were captured) from both codends were similar. A total of 64 and 55% specimens were found below MLS in the 40S and 50D, respectively. The retention percentages of individuals below the MLS were 13% in 40S and 20% in 50D codends. However, the percentage of individuals below MLS in the cover was determined as 81 and 69% for 40S and 50D, respect-tively.

Selectivity estimates and curves for individual and mean curves (according to Fryer, 1991) of red mullet are given in Table 1 and Figure 2, respectively. Table 1 also shows L_{50} values of pooled data, selection ranges (SR), with their confidence intervals and regression parameters and some variable details of 40S and 50D. The mean L_{50} values of 40S and 50D were 14.5 ± 0.27 and 15.3 ± 0.03 cm, respectively. When SRs were compared, the values for 40S and 50D were 2.2 ± 0.05 and 4.4 ± 0.12 cm, respectively. Significant differences were found between L_{50} and SR values of 40S and 50D ($p < 0.05$). However, total codend and species catch did not have any significant effect on the L_{50} and SR values ($p > 0.01$).

Annular sea bream

A total number of 7,671 annular sea bream was caught in the 40S. While 87% (6 699) of the specimens was retained with sizes ranging from 8 to 18.5 cm, 13% (972) escaped with sizes ranging from 7 to 11.5 cm. In 50D, a total number of 9,137 specimens was caught: 35% (3 156) with a size range of 8.5 to 17.5 cm; and 65% (5 981) escaped from 7.5 to 13.5 cm. Figure 3 shows (Y-axis right) normalized length frequency distributions in the codend and cover calculated as a percentage of annular sea bream in each length class and selection curves of 40S and 50D (Y-axis left). As seen in the figure, the size ranges of annular sea bream (both those that were captured and those that escaped) from both codends are completely different. A total of 21 and 45% specimens were found below FML in the 40S and 50D, respectively. The retention percentages of individuals below the FML were 11% in 40S and 12 % in 50D codends. However, the percentage of individuals below FML in the cover was determined as 93 and 62% for 40S and 50D, respect-tively.

The mean L_{50} values 40S and 50D were 9.5 ± 0.03 cm and 11.3 ± 0.03 cm, respectively. When SRs were com-pared, the values for 40S and 50D were 0.8 ± 0.00 cm and 1.5 cm ± 0.03, respectively (Table 1). Significant differences were found between L_{50} and SR values of 40S and 50D ($p < 0.05$). However, total codend and species catch did not have any significant effect on the

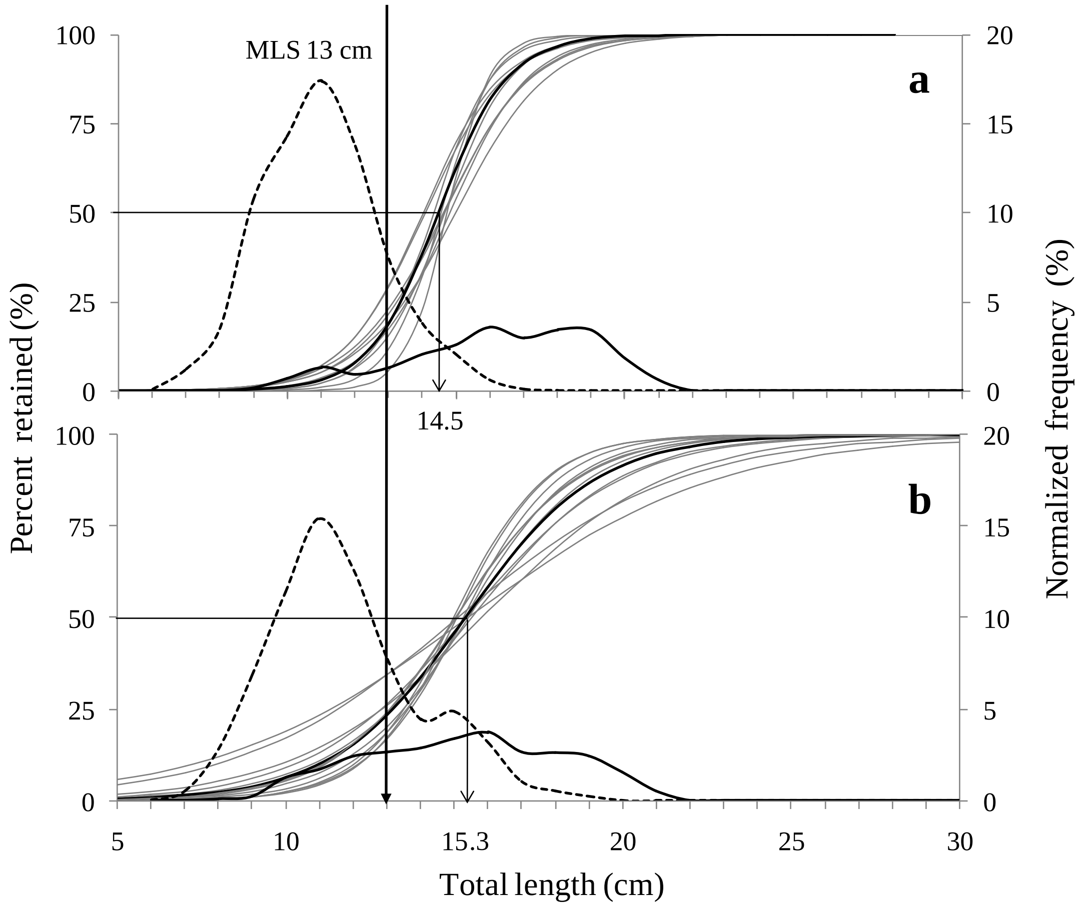

Figure 2. Selection curves and length distribution of red mullet (*M. barbatus*). Y-axis left: percentage retained for selection curves of: a; 40 mm square and b; 50 mm mesh codends (thick drawn lines; mean selection curve (Fryer, 1991), thin drawn lines; individual selection curves). Y-axis right: normalized length-frequency distribution, drawn lines: codend specimens, broken lines; cover specimens. Vertical lines; first maturity length (FML).

L_{50} and SR values ($p > 0.05$).

Common Pandora

A total number of 370 common Pandora was caught in the 40S. While 91% (338) of the specimens was retained with sizes ranging from 13 to 26 cm, 9% (32) escaped, with sizes ranging from 6 to 14 cm. In 50D, a total number of 541 specimens were caught: 55% (296) with a size range of 11 to 26 cm and 45% (245) escaped, from 8 to 17 cm. Figure 4 shows (Y-axis right) normalized length frequency distributions in the covers calculated as a percentage of common pandora in each length class and selection curves of 40S and 50D (Y-axis left). As seen in the figure, common Pandora specimens that escaped from 50D were higher than those of 40S. A total of 25 and 40% specimens were found below MLS in the 40S and 50D, respectively. The retention percentages of individuals below the MLS were 18% in 40S and 15% in 50D codends. However, the percentage of individuals below MLS in the cover was determined as 100 and 70% for 40S and 50D, respectively.

The pooled data L_{50} values 40S and 50D were 13.1 ± 0.11 and 15.0 ± 0.15 cm, respectively. When SRs were compared, the values for 40S and 50D were 0.7 ± 0.14 and 2.0 ± 0.24 cm, respectively (Table 1). The selection curves of 40S and 50D codends are found to be significantly different ($p < 0.05$).

Axillary sea bream

A total number of 591 axillary sea bream was caught in 40S. While 55% (268) of the specimens was retained with sizes ranging from 12 to 20 cm, 45% (323) escaped, with sizes ranging from 11 to 16 cm. In 50D, a total number of 306 specimens were caught: 22% (67) with a

Table 1. The 50% retention length (L_{50} cm) and SR (cm) values of investigated species.

Species		S/N		95% CI for		95% CI for			Catch weight (kg)			Number in	
			L_{50}	L_{50}	S.R.	S.R.	v_{i1}	v_{i2}	Total	Codend	Species	Codend	Cover
Red mullet	40S	1	14.6	13.8-15.4	2.9	2.1-3.8	-10.98	0.75	57.8	33.5	11.3	206	836
		2	14.0	13.6-14.4	2.6	2.3-3.1	-12.07	0.86	74.0	53.7	14.5	299	754
		3	14.1	13.5-14.6	2.7	2.0-3.3	-11.67	0.83	53.4	34.1	13.7	291	920
		4	14.7	14.3-15.0	2.2	1.7-2.6	-14.96	1.02	142.6	115.7	7.2	121	358
		5	14.9	14.0-15.9	3.0	2.0-4.1	-10.91	0.73	144.0	74.7	16.3	315	2034
		6	14.8	14.0-15.7	2.6	1.7-3.4	-12.76	0.86	70.7	44.9	14.0	294	530
		7	14.1	13.7-15.2	2.8	2.1-3.5	-11.14	0.79	124.0	115.2	36.0	216	1460
		8	14.3	14.0-14.6	1.9	1.6-2.2	-16.36	1.14	96.9	74.7	15.0	268	963
		9	14.7	14.4-15.0	1.4	1.1-1.7	-23.72	1.61	68.3	46.2	18.5	237	524
		10	14.5	14.2-14.9	1.7	1.2-2.1	-19.28	1.33	46.8	27.6	13.0	294	549
		P	14.4	14.1-14.8	2.5	2.1-2.9	-12.67	0.88					
		F	14.3	13.7-14.9	2.3	2.2-2.4	-14.06	0.98					
	50D	1	15.5	14.4-16.3	5.1	3.6-6.6	-6.65	0.43	99.2	42.3	19.1	466	1270
		2	14.9	13.6-16.6	7.2	4.0-10.3	-4.63	0.31	108.5	75.7	11.8	390	704
		3	15.3	14.7-15.9	3.5	2.7-4.3	-9.65	0.63	98.0	47.7	17.0	426	1323
		4	15.4	14.3-16.5	8.2	5.5-10.8	-4.15	0.27	67.8	38.5	15.1	354	615
		5	15.6	14.4-16.7	4.8	3.2-6.4	-7.18	0.46	73.1	30.0	13.0	307	1129
		6	15.2	14.2-15.9	3.9	2.7-5.1	-8.49	0.56	119.4	66.2	10.5	195	420
		7	15.8	15.0-16.7	6.0	4.5-7.4	-5.83	0.37	70.4	34.7	6.5	131	296
		8	15.2	14.8-15.8	3.1	2.5-3.7	-10.81	0.71	70.4	31.7	6.4	115	363
		9	15.1	14.6-15.6	2.9	2.3-3.5	-11.32	0.75	91.6	50.6	28.4	218	910
		10	15.4	14.9-15.9	3.9	3.2-4.6	-8.62	0.56	82.3	36.1	7.7	174	558
		11	15.0	14.2-15.9	4.0	2.8-5.1	-8.25	0.55	65.9	46.7	9.5	181	322
		12	15.0	14.2-15.8	3.0	1.9-4.0	-11.13	0.74	84.7	50.3	18.5	321	580
		P	15.2	14.9-15.5	4.4	4.0-4.9	-7.61	0.50					
		F	15.3	15.2-15.4	4.4	4.1-4.7	-7.80	0.51					
Annular sea bream	40S	1	9.1	9.0-9.3	0.6	0.5-0.8	-31.65	3.49	57.8	33.5	15.0	503	62
		2	9.6	9.5-9.9	0.6	0.5-0.8	-33.76	3.50	74.0	53.7	18.0	595	78
		3	9.2	9.0-9.5	0.6	0.4-0.9	-31.04	3.39	53.4	34.1	12.5	421	21
		4	9.4	9.2-9.7	0.7	0.5-0.8	-31.86	3.37	142.6	115.7	16.8	579	44
		5	9.5	9.4-9.6	0.6	0.5-0.7	-36.49	3.82	144.0	74.7	33.0	1144	336
		6	9.8	9.7-10.1	0.6	0.5-0.8	-34.15	3.50	70.7	44.9	8.2	846	87
		7	9.4	9.2-9.8	0.8	0.6-1.0	-26.00	2.77	124.0	115.2	23.0	684	40
		8	9.4	9.2-9.7	0.9	0.7-1.0	-24.21	2.57	96.9	74.7	30.0	1170	192
		9	9.1	8.9-9.4	1.2	0.9-1.5	-16.92	1.86	68.3	46.2	14.6	456	49
		10	8.9	8-7-9.3	1.3	1.0-1.7	-14.45	1.62	46.8	27.6	7.6	321	63
		P	9.5	9.4-9.6	0.8	0.7-0.9	-25.52	2.69					
		F	9.4	9.3-9.6	0.8	0.8-0.9	-26.98	2.88					
	50D	1	11.1	10.9-11.3	1.6	1.3-2.0	-15.01	1.35	99.2	42.3	11.0	369	888
		2	11.2	11.0-11.4	2.1	1.6-2.6	-11.70	1.04	108.5	75.7	34.5	300	321
		3	10.9	10.7-11.1	1.3	1.1-1.5	-18.52	1.70	98.0	47.7	17.7	455	680
		4	11.0	10.8-11.3	1.2	0.9-1.5	-20.56	1.86	67.8	38.5	8.2	306	345
		5	10.9	10.6-11.1	1.6	1.1-2.0	-15.19	1.40	73.1	30.0	9.9	101	155
		6	11.2	11.0-11.4	0.9	0.7-1.2	-26.15	2.33	119.4	66.2	22.8	243	495
		7	11.3	11.0-11.6	1.8	1.4-2.3	-13.49	1.19	70.4	34.7	9.2	300	678
		8	11.2	11.0-11.3	1.7	1.3-1.9	-14.71	1.32	70.4	31.7	6.9	250	570

Table 1. Continue

		9	11.9	11.6-12.1	1.5	1.2-1.9	-16.86	1.42	91.6	50.6	10.3	99	450
		10	11.9	11.7-12.1	1.7	1.4-2.0	-15.45	1.29	82.3	36.1	6.1	189	570
		11	11.1	10.9-11.3	1.7	1.3-2.1	-14.05	1.27	65.9	46.7	12.6	168	289
		12	11.1	10.9-11.4	1.3	1.0-1.7	-18.33	1.65	84.7	50.3	14.3	366	540
		P	11.2	11.0-11.3	1.5	1.4-1.7	-15.97	1.42					
		F	11.2	11.1-11.3	1.5	1.4-1.6	-16.09	1.44					
CP			13.1	12.9-13.4	0.7	0.4-1.0	-39.33	2.99			23.2	338	32
AS	40S	P	14.4	14.0-14.8	4.0	2.2-5.8	-7.93	0.55	878.4	620.1	8.5	268	323
BP			14.4	14.1-15.0	2.6	1.9-3.3	-12.27	0.85			12.6	411	1467
CP			15.0	14.7-15.3	2.0	1.5-2.5	-16.32	1.09			14.3	296	245
AS	50D	P	15.3	14.6-16.0	2.4	1.2-3.5	-14.23	0.93	1031.2	550.4	2.6	67	239
BP			17.2	15.4-19.1	7.1	4.0-10.2	-5.33	0.31			6.3	195	698

*CI, Confidence interval; P, pooled data; F, Freyer (1991); CP, common Pandora; AS, axillary sea bream; BP, blotched picarel.

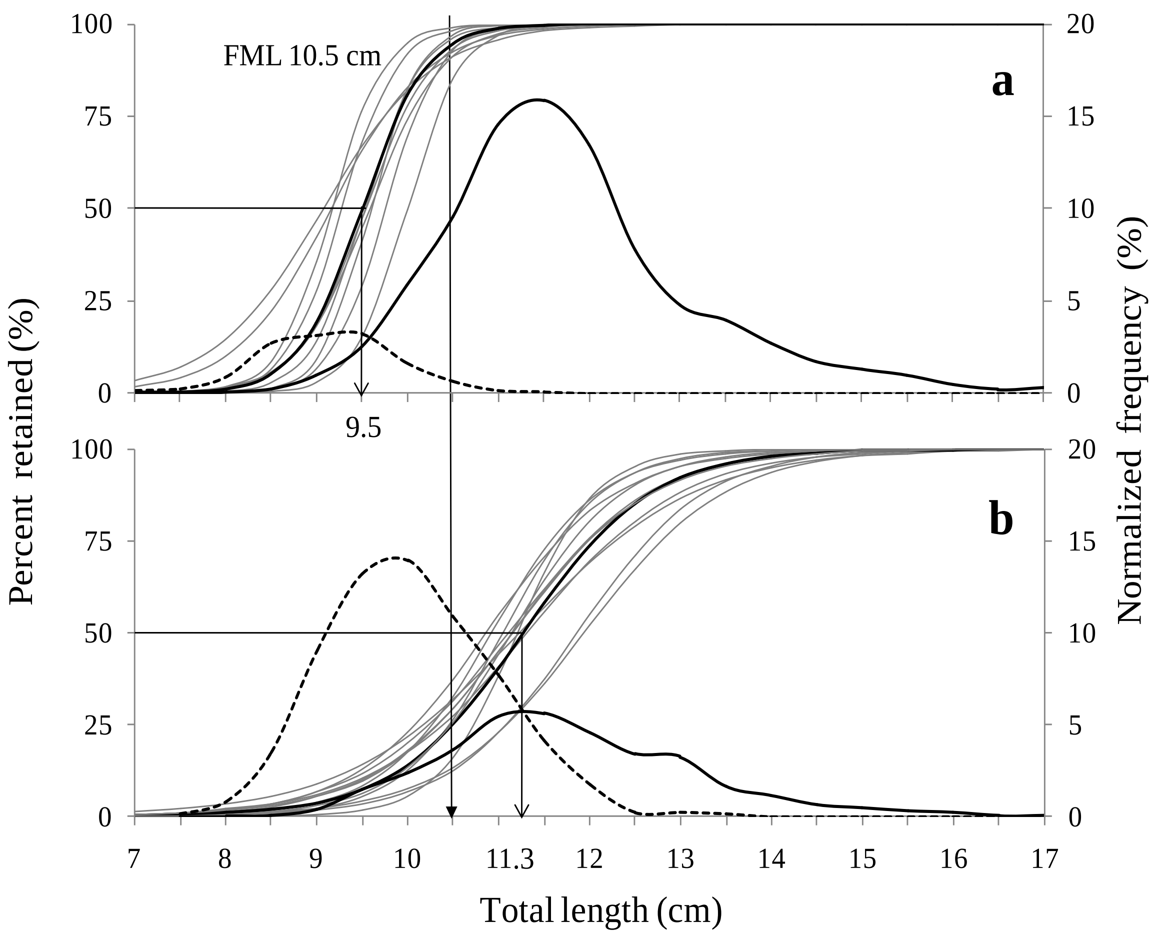

Figure 3. Selection curves and length distribution of annular sea bream (*D. annularis*). Y-axis left: percentage retained for selection curves of: a; 40 mm square and b; 50 mm mesh codends (thick drawn lines; mean selection curve (Fryer, 1991), thin drawn lines; individual selection curves). Y-axis right: normalized length-frequency distribution, drawn lines: codend specimens, broken lines; cover specimens. Vertical lines; first maturity length (FML).

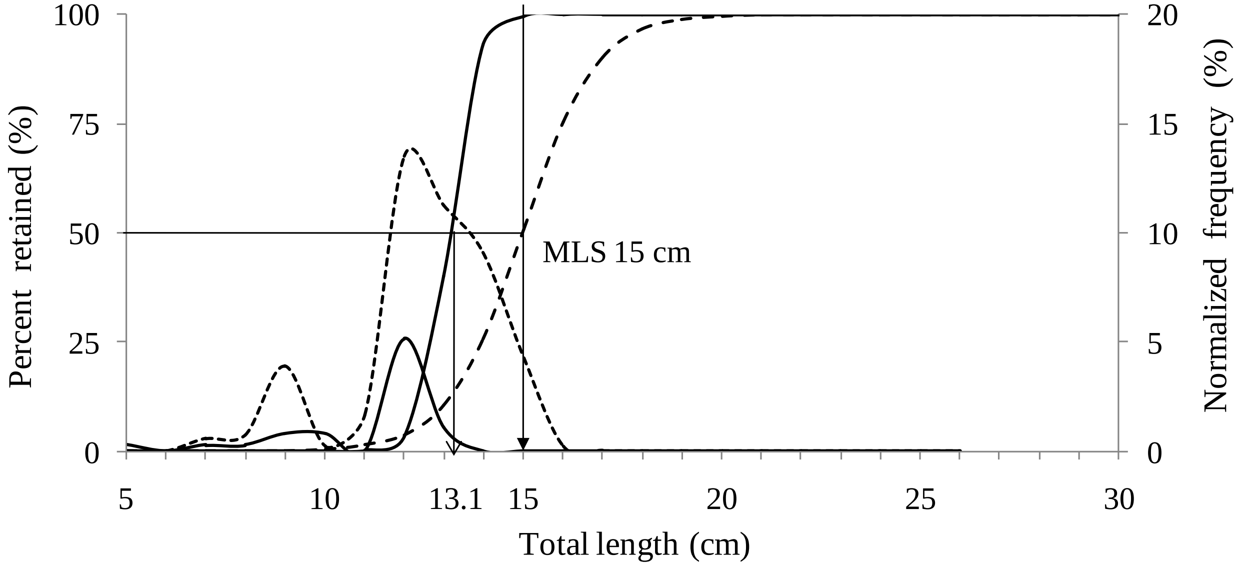

Figure 4. Selection curves and length distribution of common Pandora (*P. erythrinus*). Y-axis left: pooled data mean selection curve of 40 mm square (drawn line), 50 mm diamond mesh codend (broken line). Y-axis right: normalized length-frequency distribution of covers of 40 mm square (drawn line) and 50 mm diamond mesh codend (broken line). Vertical lines; minimum landing size (MLS).

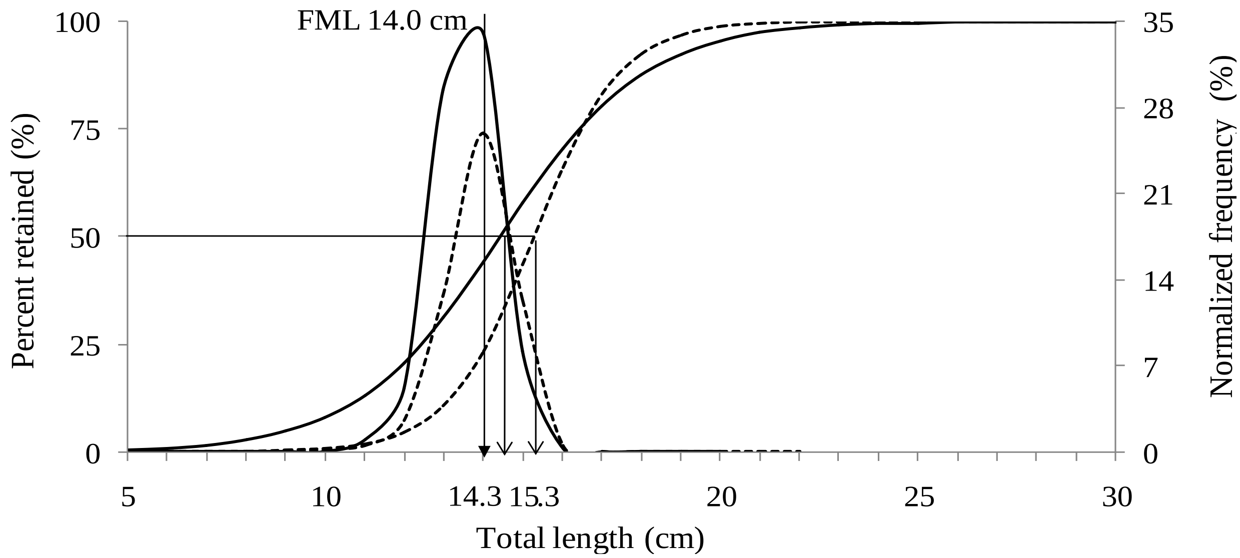

Figure 5. Selection curves and length distribution of axillary sea bream (*P. acerna*). Y-axis left: pooled data mean selection curve of 40 mm square (drawn line) and 50 mm diamond mesh codend (broken line). Y-axis right: normalized length-frequency distribution of covers of 40 mm square (drawn line) and 50 mm diamond mesh codend (broken line). Vertical lines; first maturity length (FML).

size range from 13 to 17 cm and 78% (239) escaped, from 11 to 17 cm. Figure 5 shows (Y-axis right) normalized length frequency distributions in the covers calculated as a percentage of axillary sea bream in each length class selection curves of 40S and 50D (Y-axis left). As can be seen in the figure, the size ranges of axillary sea bream that escaped from both codends are similar. A total of 21 and 41% specimens were found below SMS in the 40S and 50D, respectively. The retention percentages of individuals below the SMS were 12% in 40S and 24% in 50D codends. However, the percentage of individuals below SMS in the cover was determined as 29 and 46%

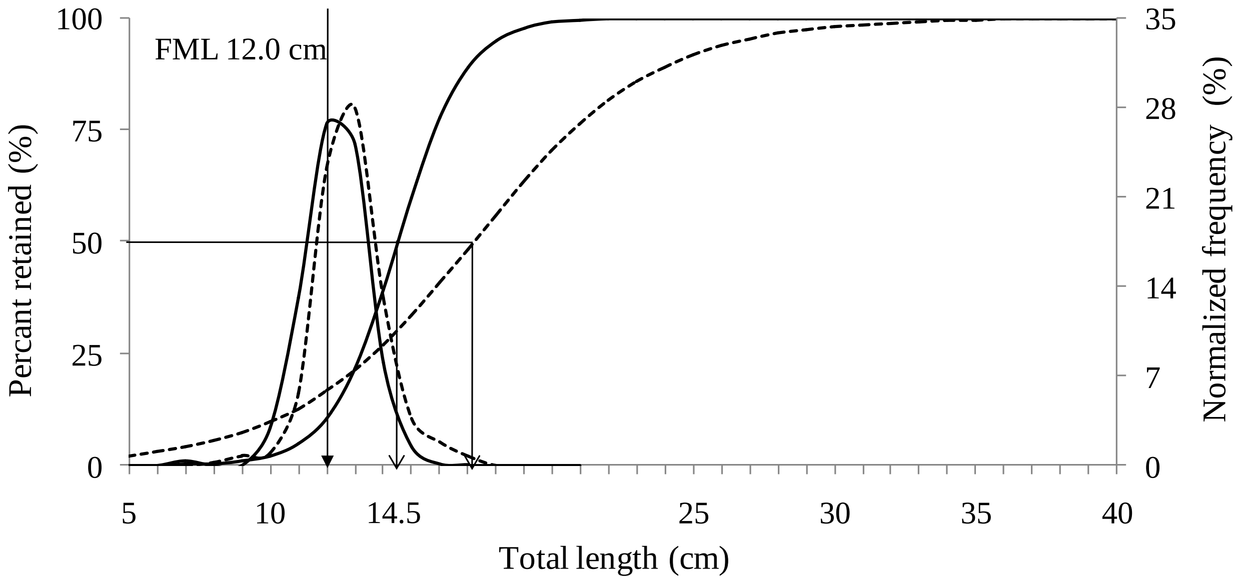

Figure 6. Selection curves and length distribution of blotched picarel (*S. maena*) Y-axis left: pooled data mean selection curve of 40 mm square (drawn line) and 50 mm diamond mesh codend (broken line). Y-axis right: normalized length-frequency distribution of covers of 40 mm square (drawn line) and 50 mm diamond mesh codend (broken line). Vertical lines; first maturity length (FML).

for 40S and 50D, respectively.

The pooled data L_{50} values 40S and 50D were 14.4 ± 0.11 and 15.3 ± 0.28 cm, respectively. When SRs were compared, the values for 40S and 50D were 4.0 ± 0.14 and 2.4 ± 0.24 cm, respectively (Table 1). The selection curves of 40S and 50D codends are found to be significantly different ($p < 0.05$).

Blotched picarel

A total number of 1878 blotched picarel was caught in the 40S. While 22% (411) of the specimens was retained with sizes ranging from 11 to 20 cm, 78% (1467) escaped, with sizes ranging from 7 to 17 cm. In the 50D, a total number of 893 specimens were caught: 22% (195) with a size range from 11 to 18 cm and 78% (698) escaped, from 8 to 17 cm. Figure 6 shows (Y-axis right) normalized length frequency distributions in the covers calculated as a percentage of blotched picarel in each length class selection curves of 40S and 50D (Y-axis left). As seen in the figure, the size ranges of blotched picarel that escaped from both codends are similar. A total of 17 and 12% specimens were found below SMS in the 40S and 50D, respectively. The retention percentages of individuals below the SMS were 5% in 40S and 7% in 50D codends. However, the percentage of individuals below SMS in the cover was determined as 21 and 13% for 40S and 50D, respectively.

The pooled data L_{50} values 40S and 50D were 14.5 ± 0.11 and 21.5 ± 0.28 cm, respectively. When SRs were compared, the values for 40S and 50D were 4.0 ± 0.14 and 2.4 ± 0.24 cm, respectively (Table 1). The selection curves of 40S and 50D codends are found to be significantly different ($p < 0.05$).

DISCUSSION

In this study, we have investigated and compared the selectivity of the 40 mm square mesh and 50 mm diamond mesh codend which is compatible with the council regulation. 50D results are for the first time presented on investigated species from Turkish demersal trawl. In addition, blotched picarel selectivity results are initially presented from both codends.

It is well established that various factors affect the selectivity, for example twine material (Tokaç et al., 2004) and thickness (Lowry and Robertson, 1996; Herrmann and O'Neill, 2006; Sala et al., 2007), catch weight (Erickson et al., 1996; Campos et al., 2003; Herrmann 2005) and especially codend circumference (Reeves et al., 1992; Broadhurst and Millar, 2009; Graham et al., 2009). This is because the number of mesh around codend circumference ensured mesh opening and provided selectivity. To ensure the mesh opening, we conducted the ratio between the number of meshes in funnel and codend circumferences, 2:1 for 40S and 1:1 for 50D. However, this ratio is generally employed by trawlers, with 1:1.5 or more (Tosunoğlu et al., 2008) as their use is not prohibited in the fishery circular (Anonymous, 2008).

Data concerning the effects of explanatory variables other than mesh size on the selectivity of Mediterranean bottom trawls are scarce (Sala et al., 2008). We also propose novel selectivity models for the red mullet and annular sea bream. However, the proposed models require further investigation, because our study was primarily designed to estimate the effects of total, codend and species catch on codend and not to assess the effects on towing duration and towing speed. Long towing duration increased catch size as the catch builds up altered the codend geometry and degree of mesh opening (Campos et al., 2003). Thus, selectivity negatively (Suuronen et al., 1991; Madsen et al., 1998) or positively (O'Neill and Kynoch, 1996) affected the different species. The effects of this variable on codend selectivity may become more evident when analysing commercial catches and there is therefore a need for the analysis of commercial data before any final conclusions concerning the effects of this variable on selectivity parameters can be drawn. On the other hand, towing speed is another key factor that affected codend selectivity. A decrease of haddock selectivity by increased towing speed in one data set was equalled by an increase of cod selectivity in another (Dahm et al., 2002). O'Neill (1997) has shown how an increase of towing speed can lead to an increase of the lateral mesh opening and increase of cod-end selectivity. Alternatively, an increase of towing speed may accelerate swimming fish, reducing their ability to escape and thereby, leading to a decrease of cod-end selectivity. In further experiment, effect on selectivity of different towing speed needs to be investigated.

Square mesh codend gave higher 50% retention length than diamond mesh at the same mesh size for round fish as red mullet (Stewart, 2002). We found from experiment results that 40S improved the selectivity when compared with the nominal 40 mm diamond shape of PE codend given by Tosunoğlu et al. (2003a) and Özbilgin and Tosunoğlu (2003). Tokaç et al. (1998) estimated L_{50} of 40 mm square mesh size of PA knotted material for red mullet as 13.2 cm fork length corresponding to 15.0 cm TL (Tosunoğlu et al., 2003b) which is higher than our 40S and close to 50D results . They used a codend made of thinner PA netting, both of which should increase selectivity compared to our study (Tokaç et al., 2004). On the other hand, knotless PA 39 mm square mesh codend was determined as 10.9 cm (Sala et al., 2008). In case of 44 mm PA diamond, L_{50} result has been found as 8.9 cm (Sala et al., 2006). This difference may be due to twine thickness and material of codend, study area, experiment period, depth, gear construction, etc.

Results of the selectivity analysis indicate that the commercially used 40 mm nominal mesh size PE codend (although, the legal mesh size is 44 mm) is rather unselective for annular sea bream (Tosunoğlu et al., 2003b; Özbilgin et al., 2005) in the Aegean Sea. From the experimental results, although, 50D clearly improved the selectivity of annular sea bream, 40S is still unselective for the species when considering FML. This is mostly related to body shape because studies demonstrated that square-meshes codend were found to be unsuitable for deep-bodied or flat fish such as annular sea bream (Guijarro and Massuti, 2006; Sala et al., 2008). On the other hand, and alternatively, sorting grid can be used to improve the annular sea bream selectivity. Aydın et al. (2008) emphasize that annular sea bream could easily pass the vertical bars because of its compressed body shape. For common pandora L_{50} and SR of the trawl codend commercially used in the Eastern Aegean Sea varied between 10.3 and 12.4 cm and 2.0 and 3.2 cm, respectively (Tosunoğlu et al., 2003a, b; Özbilgin and Tosunoğlu, 2003; Tosunoğlu, 2007). The estimated L_{50} for common pandora with the 50 mm diamond mesh codend (15.0 cm) is equal to the current minimum landing size (MLS= 15 cm) and significantly higher than that of 40mm square mesh codend (13.1 cm). Clearly, the 50 mm diamond mesh codend would represent a marked improvement in the harvesting pattern of this commercially important species. However, it is notable that common Pandora is a protogynic hermaphrodite species, where females become males in their third year at sizes of about 17–18 cm in the Aegean Sea (Stergiou et al., 1997; Kinacigil et al., 2008). Hence, a substantially higher mesh size than 50 mm in the diamond mesh codend would be required if the spawn-at-least-once rule was to be satisfied for this species.

As no literature on the trawl selectivity of blotched picarel could be found, the results obtained in this study could not be compared. Apparently this is the first study reporting the trawl selection for this species from Turkish seas. The observed L_{50} values of the 50D (18.6%) are higher than that of 40S. From the other point of view, the codends tested in this study gave higher selectivity for the species compared with given FML.

Axillary sea bream gives the impression of being a strong swimmer and easily penetrates (more active escape behaviour) the codend meshes while the trawl is being towed (Campos and Fonseca, 2003). Therefore, selectivity of the species is high. However, from the studies, various L_{50} and SR values for different mesh sizes and shape were found by different authors. Tosunoğlu (2007) estimated L_{50} and SR values of 44 mm PE codend from Aegean Sea as 13.6 cm and 1.9 cm. Campos and Fonseca (2003) calculated L_{50} and SR values as 13.9 and 7.4 cm for 80 mm diamond and 19.6 and 3.6 cm for 65 mm square mesh codend from the shallow ground fish assemble off the south-west coast of Portugal. Moreover, it was found that while 40 mm square mesh codend gave higher L_{50} value than that of diamonds with same size, L_{50} value of 44 mm PA diamond codend was more than the mesh square in the Aegean Sea having the same size (Tokaç et al., 1998).

Our L_{50} values of 40S and 50D are appropriate for size selection of axillary sea bream considering FML.

This work clearly shows that 40S and 50D L_{50} results improve the selectivity when considering commercially used 40 mm nominal diamond mesh codend in Turkish seas for given species. However, it has to be taken into account that demersal trawling in the Aegean Sea has a multi-species character, with more than 50 species encountering the gear (Petrakis and Stergio, 1997). Due to the differences in body shape and size of caught species, a mesh codend mesh size appropriate for one species will not be suitable for many others (Stergiou et al., 1997; Ordines et al., 2006; Sala et al., 2008). Therefore, in multi-species, it seems likely that a species separation system might potentially be of more value than size-selective systems (Stewart, 2002). Therefore, different selective techniques such as grid and separation panel and behaviour of the species against the gear need to be investigated.

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