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SELECTIVITY OF 40 MM SQUARE- AND 90º TURNED-MESH CODEND FOR THE DEEPWATER ROSE SHRIMP, *PARAPENAEUS LONGIROSTRIS* (CRUSTACEA), AND GREATER FORKBEARD, *PHYCIS BLENNOIDES* (ACTINOPTERYGII: GADIFORMES: PHYCIDAE), IN THE EASTERN MEDITERRANEAN

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Background. Bottom trawling is an important fishing technique for catching demersal fish, and selectivity is one of the most important tools for fishery management. This study aimed to determine the selectivity of 40 mm square- (40S) and 90º turned-mesh (40T90) codend for the deepwater rose shrimp, *Parapenaeus longirostris*, and greater forkbeard, *Phycis blennoides* (Brünnich, 1768).
Material and methods. Fishing experiments were conducted on the international waters of the Aegean Sea by using a commercial vessel between 24 August and 13 September 2012. The hooped covered codend technique was employed for the estimated codend selectivity. The selectivity parameters were estimated by using CC 2000 software.
Results. Nineteen successful hauls, 11 with 40S, and 8 with 40T90 codends, were performed. The mean L_{50} values (50% retention length) of 40S and 40T90 were found to be a 15.5 ± 0.1 mm and 14.8 ± 0.1 mm carapace lengths for the rose shrimp, and 15.3 ± 0.1 cm and 12.2 ± 0.1 cm total lengths for the greater forkbeard, respectively.
Conclusion. In conclusion, 165 square meshes in a codend circumference with 40 mm mesh sizes provided higher L_{50} values than the 40 mm turned meshes, and 330 meshes around the codend circumference. Halving the number of meshes in the codend with larger turned mesh and different modifications should be investigated for further studies in order to appropriate the L_{50} values.

Keywords: bottom trawl, responsible fisheries, size selectivity, mesh type

INTRODUCTION

The size and shape of the mesh in the trawl codend have been demonstrated as the main factors influencing the selectivity of trawl catches (e.g., Robertson and Stewart 1988, Reeves et al. 1992). Conventionally used diamond-mesh codend in trawl nets stretches during the trawling operation, and the meshes have a tendency to close when the codend is filled up; thus, reducing its effective selectivity compared with square mesh (Robertson and Stewart 1988, Guijarro and Massutí 2006). To improve trawl selectivity, square-mesh codends have been investigated for fish species by many authors (Stewart 2002). Those studies revealed that the same mesh sizes of square-mesh codends gave higher values of 50% retention length (L_{50}) than those of the diamond-mesh codends, at least for fish species round in cross section. However, knots of the full square-mesh codends can be easily unstable and the nets are difficult to handle and repair (Graham et al. 2003). Therefore, they have not been preferred by fishermen. On the other hand, T90 codends, in which standard diamond-mesh netting is turned 90º, could potentially improve the size selective properties compared with traditional codends made of the same netting. As standard conventional netting can be used, a T90 codend is a very simple way to potentially improve the size selectivity of the fishing gear (Madsen 2007). T90 mesh codend was initially tested for determination of selectivity of cod (Moderhak 1997) and has been the focus of increased scientific interest in recent years. It was included in the legislation for the fishery of Baltic Sea cod, *Gadus morhua* Linnaeus, 1758, in 2006 (Anonymous 2011).

Turkish fisheries regulations allow trawlers to use a minimum of 40 and 44 mm codend diamond-mesh size in the Black Sea and the Turkish territorial waters in the Aegean Sea and Mediterranean Sea, respectively. In addition, the use of 40 mm square-mesh codend was adopted in September 2008 as an alternative for the 44 mm diamond-mesh codend (Anonymous 2008). There are many selectivity studies carried out with conventional trawl codend 40 and 44 mm diamond-mesh studies that have demonstrated that both 40 and 44 mm diamond-mesh codend give poor selectivity parameters (Tokaç et al. 1998, Özbilgin and Tosunoğlu 2003, Tosunoglu et al. 2003a,

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Tosunoğlu et al. 2003b, Tokaç et al. 2004). On the other hand, square-mesh codend provides higher selectivity parameters especially for round fish and crustaceans than the same mesh size of 40 and even 44 mm diamond-mesh codend. T90 selectivity studies are very scarce (Tokaç et al. 2014) and there is no published study related to rose shrimp and greater forkbeard in the Mediterranean.

The deepwater rose shrimp, *Parapenaeus longirostris* is one of the main target species in Turkish bottom trawl fishery. The biology and fishery of the rose shrimp are well documented. Selectivity was considered in those studies to be the most useful management tool for this resource (Sobrino et al. 2005). There is no minimum landing size (MLS) for this species in Turkey, while there is a 20 mm carapace length (CL) restriction in Europe. Although the greater forkbeard, *Phycis blennoides* (Brünnich, 1768), also has a high market value, there is no MLS regulation for the species in Turkish and Mediterranean seas. Bahamon et al. (2007) previously used 26 cm as a guidance value for sexual first maturity (LFM) size.

The objective of this study was to compare the size selective properties of the same mesh size (40 mm) and twine thickness of 90º turned-mesh codend (40T90) with those of a square-mesh (40S) codend for deepwater rose shrimp, *Parapenaeus longirostris*, and greater forkbeard, *Phycis blennoides*, which have high economic value, but different morphology.

MATERIAL AND METHODS

The fishing experiments were conducted on the international waters of the Aegean Sea by using a commercial vessel FV *Hapuloğlu*, (23.83 m LOA and 522 kW main engine) between 24 August and 13 September 2012 (Fig. 1). The water depth of the trawled areas varied between 280 and 470 m (mean 373 m). The towing duration and speed ranged from 120 to 345 min and 2.4 to 2.5 knots, respectively as in commercial trawling. Trawl doors with a dimension of 190 × 90 cm, weighing 160 kg each, made of wood and steel, were used. A 1200 meshes modified conventional bottom trawl (Fig. 2) was used in all the trawl hauls. The end of the tunnel consisted of 44 mm mesh size of 300 meshes in circumferences (44 × 300 = 13 200 mm). According to the EC regulation (Anonymous 2006), the square-mesh codend in particular, the circumference of the rearmost 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 ((13 200 mm · 40 mm^{-1})$^{-2}$ = 165 meshes) and 90º turned meshes (13 200 mm · 40 mm^{-1} = 330 meshes). The two codends of a 40 mm nominal mesh size, but different mesh shapes, were tested. Both codends were of the same material (knotted PE, 380d/21 no) and 5 m in length. The specifications of the codends are given in Table 1. A protective bag was laced around the codend (made of 5.0 mm PP twine, 115.2 ± 1.2 mm mean mesh sizes, 65 meshes on its circumference, and about 5 m in stretched length). The aft ends of the codends and protective net were tied together. A total of 60 stretched mesh openings (3 lines of 20 meshes in towing direction) were measured to determine the mean mesh size of each codends by using a calliper rule with a 4 kg weight vertically tied to the stationary jaw of the rule.

They were attached to the 300 meshes around the circumference, and made of 44 mm mesh size of knotless PE. The hooped covered codend technique was employed for the estimated codend selectivity (Wileman et al. 1996). The cover was knotless polyamide netting with a nominal mesh size of 24 mm and 7.5 m in length. To prevent masking, a 5.0 m circumference hoop, made from a 40 mm diameter high-density polyethylene pipe, was rigged. The hoop was mounted at a distance of 2.5 m and 5.0 m from the ends of the funnel.

After each haul, the catches from the codend and cover were separately emptied on the deck. Deepwater rose shrimp and greater forkbeard were taken out from the cover and then the remaining items were weighed. Meanwhile, the crew of the fishing vessel manually sorted the marketable codend catch by species and left the discards on deck. After that, all species were weighed with respect to the investigated species, marketable catch, and discards. Whole catches of greater forkbeard were measured as total lengths to the nearest cm. Two kg sub-samples of the deepwater rose shrimp were taken from the cover and the codend. The length class frequencies for the species in

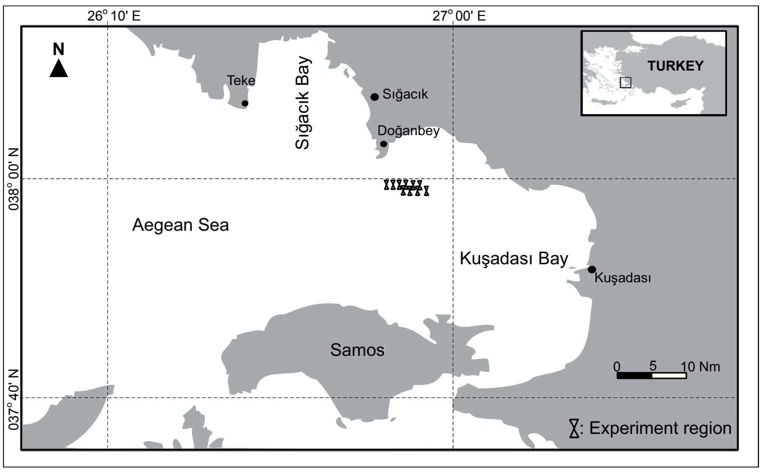

Fig. 1. Study area in the south-eastern Aegean Sea, Turkey

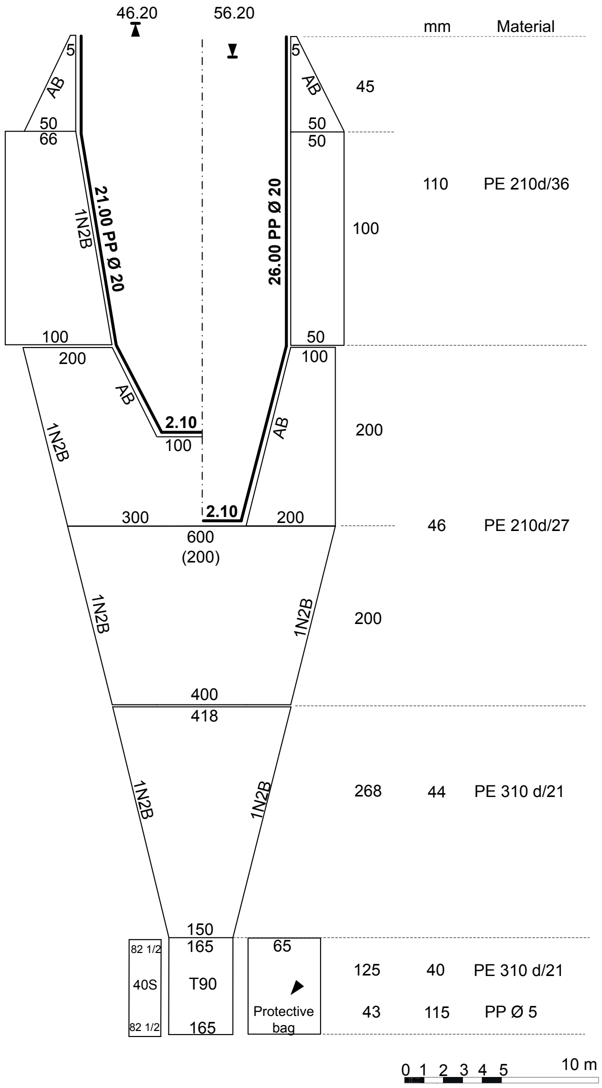

Fig. 2. Trawl net diagram used in experiment

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 1 mm for the deepwater rose shrimp by using digital callipers. The length distributions of the discarded species (disregarded during selection and damaged) were added to the codend catches for the selectivity analysis. The selectivity parameters of 40S and 40T90 meshes for the individual hauls and the pooled data, were estimated by using the logistic equation with the maximum likelihood method (Wileman et al. 1996):

$$(l) = \exp(v_1 + v_2 xl) \cdot [1 + \exp(v_1 + v_2 xl)]^{-1}$$

where the parameters v_1 and v_2 are the intercept and slope of the linear logistic function, respectively. These parameters were estimated by using CC 2000 software. The mean selectivity of the individual hauls was determined by taking into account the between-haul variation (Fryer 1991) using the ECModeller software which adopts the REML method (residual maximum likelihood) presented by Fryer (1991).

The parameters for each haul υ_i are independent and have a multivariate normal distribution: $\upsilon_i \sim N(\alpha, R_i + D)$, with mean expected value (Fryer 1991) defined as:

$$E\left(v_i\right) = E\begin{pmatrix} v_i 1 \\ v_i 2 \end{pmatrix} = \begin{pmatrix} \alpha_1 \\ \alpha_2 \end{pmatrix}$$

and variance matrix $R_i + D$, where the variance matrix $[R_i]$ measures the within-haul variation and $[D]$ measures the between-haul variation in the parameters $[\upsilon_i]$. Then the selectivity data were modelled according to Fryer (1991) by estimating the individual contribution of some explanatory variables to the selectivity parameters. Under these conditions $\upsilon i \sim N(X_i\alpha, R_i + D)$ with expected mean value:

$$E\left(v_i\right) = E\begin{pmatrix} v_i 1 \\ v_i 2 \end{pmatrix} = X_i \alpha$$

Where X_i is the design matrix of the q explanatory variables for haul i:

$$X_i = \begin{pmatrix} x_{i11} & x_{i12} \ldots x_{i1q} \\ x_{i12} & x_{i22} \ldots x_{i2q} \end{pmatrix}$$

and $(\alpha_1, \alpha_2, \ldots, \alpha_q)^T$ is the vector that determines the direction and magnitude of the influence of these variables on selectivity parameters (Sala et al. 2007).

Table 1

Codend specifications

Codend features	Tested codends 40S	Tested codends 40T90	Protective bag
Nominal mesh size [mm]	40	40	88
Measured mesh size [mm]	40.6 ± 0.1	40.6 ± 0.1	115.2
No. of measurements	60	60	60
Twine thickness	380d/21	380d/21	5 mm Ø
Material	PE knotted	PE knotted	PP hand woven
Width	165 meshes/bars	330 meshes	65 meshes
Length	125 meshes	125 meshes	50 meshes

40S = 40 mm square-mesh codend, 40T90 = 40 mm and 90° turned-mesh codend.

The selectivity parameters as functions of the explanatory variables the total catch size (codend and cover), the codend catch size, the species catch in the codend, and the towing duration were tested. The choice of the model best fitting the data was based on the lowest value for Akaike's Information Criterion-AIC (Fryer and Shepherd, 1996), defined to be

$$\text{AIC} = -2 \log \text{likelihood} + 2\ \text{np}$$

where np is the number of parameters. The choice of the model best fitting the data was based on the lowest value for the Akaikes Information Criterion (AIC) (Akaike 1974) defined as:

$$\text{AIC} = -2 \log (\text{maximum likelihood}) + 2k$$

Where k is the number of independently adjusted parameters.

RESULTS

In all 19 successful hauls, 11 with 40S codend (a total of 50.41 h) and 8 with 40T90 codend (a total of 28.75 h) were performed. A 61.9% of 40S and 69.5% of 40T90 total catch was composed of deepwater rose shrimp, *Parapenaeus longirostris*; broadtail shortfin squid, *Illex coindettii*; hake, *Merluccius merluccius* (Linnaeus, 1758); greater forkbeard, *Phycis blennoides*; angler fish, *Lophius piscatorius* Linnaeus, 1758; and blue whiting, *Micromesistius poutassou* (Risso, 1827). The reaming species (fish and invertebrates) and unspecified debris in the total catch consisted of the 38.1% in 40S and 30.5% in 40T90 (Table 2).

The selectivity parameters were analysed for the two species: deepwater rose shrimp, *Parapenaeus longirostris*, and greater forkbeard, *Phycis blennoides*. The broadtail short fin squid and angler fish consisted of 14.9% and 4.5% in the total catch of 40S, and 19.7% and 3.9% in the total catch of 40T90. There were no individuals escaping from the codends, and due to the insufficient data for each haul for hake and blue whiting, the selection parameters were not estimated.

The results of the selectivity analysis of each codend for the investigated species are given in Table 3, which summarizes the 50% retention length (L_{50}), selection ranges (SR), and regression parameters, with their 95% confidence interval for the individual and pooled data.

Deepwater rose shrimp. *Parapenaeus longirostris* was the most abundant species in both codends. A total number of 160 936 deepwater rose shrimp were caught in the 40S. While 82% (131 215) of the specimens were retained with sizes ranging from 8 to 37 mm, 18% (29 731) escaped ranging from 8 to 28 mm. In the 40T90, a total number of 123 096 specimens were caught: 76% (93 399) with a size range from 8 to 36 mm, and 24% (29 697) escaped, from 6 to 30 mm. Fig. 3 (right *Y*-axis) shows the length of the frequency distribution of the rose shrimp caught in 40S and 40T90 codends and covers, respectively. As can be seen in Fig. 3, the size ranges of the rose shrimp retained by both codends are very similar. While the codends length distributions show a peak at about 22 mm, the covers displayed at a 15 mm for both codends.

The selectivity estimates and curves for the individual and mean curves (according to Fryer 1991) of rose shrimp are given in Table 3 and Fig. 3. The 40S codend provided higher mean L_{50} values (15.5 ± 0.1 mm) than 40T90 (14.8 ± 0.1 mm). When the SRs were compared, the estimated values for the rose shrimp increased from 5.4 ± 0.1 mm in 40S to 7.4 ± 0.2 mm in 40T90. The model demonstrated that while the mesh configuration and towing duration were affected, the L_{50} and SR values (Table 4), total, codend, and species catch were not ($P < 0.05$).

Greater forkbeard. Fig. 4 shows (right *Y*-axis) normalized length frequency distributions in codend and cover specimens calculated as a percentage of *Phycis blennoides* in each length class. As can be seen in the figure, the size ranges of greater forkbeard are different. A total number of 4345 greater forkbeard was caught in the 40S codend. While 23% (1000) of the specimens were retained with sizes ranging from 9 to 43 cm, 77% (3345) escaped ranging from 7 to 17 cm. In the 40T90, a total number of 3004 specimens were caught: 52% (1552) with a size range from 9 to 42 mm, and 48% (1452), from 6 to 18 cm.

Table 2

The total catch [kg] and percentage of catch by species in codend and cover as obtained from the experiments with 40S and 40T90

Catch composition	40S			40T90		
	Total	Codend	Cover	Total	Codend	Cover
Weight of catch [kg]	2423.1	1903.6	519.6	1847.1	1495.4	351.7
Deepwater rose shrimp [%]	29.8	34.1	13.9	31.3	33.1	23.7
Broadtail shortfin squid [%]	14.9	19.0	0.0	19.7	23.1	5.0
European hake [%]	4.9	4.9	5.0	2.5	3.0	0.5
Greater forkbeard [%]	5.3	4.5	8.5	3.6	3.5	4.0
Anglerfish [%]	4.5	5.7	0.0	3.9	4.8	0.0
Blue whiting [%]	2.5	0.5	9.8	8.6	6.0	20.0
Others [%]	38.1	31.3	62.8	30.5	26.6	46.9

40S = 40 mm square-mesh codend, 40T90 = 40 mm and 90° turned-mesh codend.

Table 3

Selectivity parameters of 40S and 40T90 codend meshes for *Parapenaeus longirostris*

M	NH	L_{50} [mm]	95% CI	SR [mm]	95% CI	df	Deviance	Catch [number]			Fixed effect			
								Codend	Cover	Total	Total catch [kg]	Codend catch [kg]	Species catch [kg]	Towing time [min]
40S	1	14.8	13.4–16.3	7.7	5.6–9.9	22	630.6	8417	2175	10592	163.9	111.2	47.7	240
	2	17.7	17.1–18.3	3.9	3.2–4.5	23	124.1	5376	594	5970	196.1	175.4	38.7	190
	3	14.4	13.6–15.2	5.9	4.8–6.9	23	320.7	10967	1845	12812	287.7	239.0	67.3	330
	4	15.6	14.6–16.5	4.8	3.7–5.8	24	178.9	6813	516	7329	138.6	131.1	41.5	330
	5	16.1	15.3–16.8	5.3	4.2–6.5	23	328.7	4525	1647	6172	259.4	181.2	41.2	225
	6	16.5	16.0–17.1	4.0	3.3–4.8	19	133.3	3283	938	4221	100.5	78.9	21.7	120
	7	15.0	14.3–15.7	4.8	4.1–5.6	23	350.6	18352	2233	20585	185.5	154.4	97.5	255
	8	14.7	14.1–15.5	7.8	6.8–8.8	25	478.5	32807	8085	40892	326.0	254.7	75.9	345
	9	15.4	14.7–16.0	5.3	4.3–6.4	23	816.5	13065	4914	17979	309.6	203.9	64.1	330
	10	15.2	14.5–15.9	5.6	4.5–6.8	23	1039.5	19649	6049	25698	232.2	177.5	107.4	330
	11	14.6	13.5–15.7	5.0	3.9–6.1	25	331.8	7951	735	8686	220.7	193.5	46.1	330
	PP	15.2	14.9–15.5	6.0	5.6–6.3	30	659.3	131205	29731	160936	2420.2	1900.6	649.1	3025
	F	15.5	15.3–15.7	5.4	5.1–5.6	17								
40T90	1	14.1	13.3–15.0	7.9	6.5–9.2	21	407.9	15470	4696	20166	198.6	166.5	74.9	255
	2	16.7	15.8–17.6	6.4	5.2–7.6	19	222.3	8068	1738	9806	267.5	201.7	50.4	210
	3	16.2	14.9–17.5	11.4	8.4–14.4	22	664.3	9097	5148	14245	131.8	95.9	42.8	210
	4	13.4	12.1–14.8	9.0	7.0–11.1	24	428.7	10836	2596	13432	181.9	155.0	57.9	240
	5	14.0	12.0–16.0	8.1	5.4–10.9	25	1156.4	9480	2170	11650	255.8	221.5	51.8	195
	6	15.6	14.9–16.3	6.6	5.5–7.7	26	983.1	15250	7700	22950	266.6	213.9	85.8	210
	7	14.4	13.4–15.3	6.3	5.0–7.5	24	626.1	14495	3087	17582	293.2	265.1	64.2	210
	8	13.7	12.5–14.9	6.0	4.4–7.6	25	919.4	10703	2562	13265	248.6	172.9	66.9	195
	PP	14.7	14.4–15.1	7.6	7.1–8.1	28	560.0	93399	29697	123096	1844.1	1492.4	494.7	1725
	F	14.8	14.5–15.1	7.4	7.0–7.8	11								

40S = 40 mm square-mesh codend, 40T90 = 40 mm 90º turned-mesh codend, M = mesh type, NH = number of hauls, L_{50} = 50% retention length, SR = selection range, CI = confidence interval, df: degrees of freedom, *F* = mean parameters according to Fryer, PP = pooled parameters, Species catch = catch of *Parapenaeus longirostris* in codend.

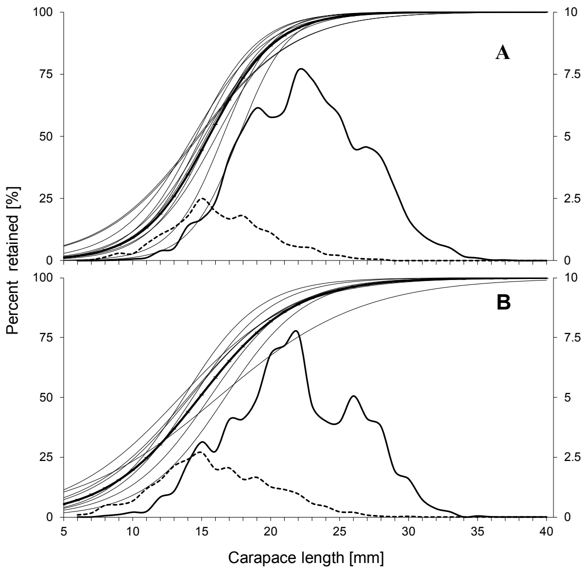

Fig. 3. Selection curves and length frequency distribution of the deepwater rose shrimp (*Parapenaeus longirostris*) in the square-mesh (**A**) and 90º turned-mesh codends (**B**); *Y*-axis left: percentage retained for the selection curves (Thick solid lines are mean selection curve and confidence band thin solid lines are individual selection curves), *Y*-axis right: normalized length-frequency distribution (Solid lines represent codend specimens, dashed lines represent cover specimens)

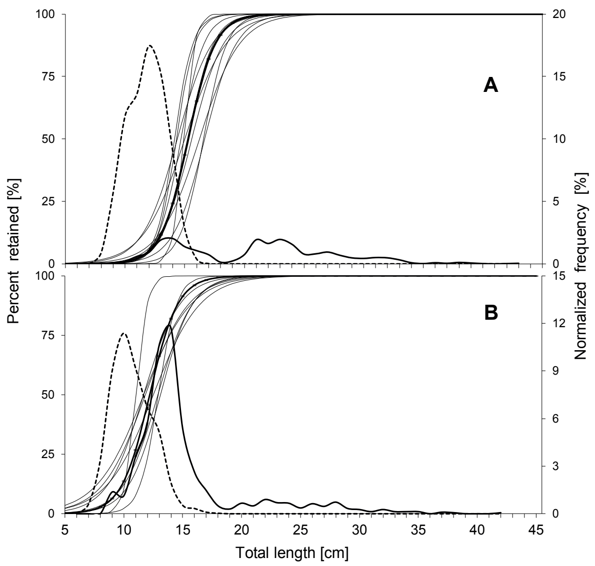

Fig. 4. Selection curves and length frequency distribution of greater forkbeard (*Phycis blennoides* in the square-mesh (**A**) and 90º turned-mesh codends (**B**); *Y*-axis left: percentage retained for the selection curves (Thick solid lines are mean selection curve and confidence band thin solid lines are individual selection curves), *Y*-axis right: normalized length-frequency distribution (Solid lines represent codend specimens, dashed lines represent cover specimens)

Table 4

Explanatory variables affected on selectivity parameters for deepwater rose shrimp, *Parapenaeus longirostris* and greater forkbeard, *Phycis blennoides*

Species		Intercept	Mesh	Total catch	Codend catch	Species catch	Towing duration
Parapenaeus longirostris	L_{50}	$P < 0.05$ ($P = 0.00000$)	$P < 0.05$ ($P = 0.03030$)	$P > 0.05$	$P > 0.05$	$P > 0.05$	$P < 0.05$ ($P = 0.00815$)
	SR	$P < 0.05$ ($P = 0.02780$)	$P < 0.05$ ($P = 0.00025$)	$P > 0.05$	$P > 0.05$	$P > 0.05$	$P < 0.05$ ($P = 0.03396$)
Phycis blennoides	L_{50}	$P < 0.05$ ($P = 0.00000$)	$P < 0.05$ ($P = 0.00000$)	$P > 0.05$	$P > 0.05$	$P > 0.05$	$P > 0.05$
	SR	$P < 0.05$ ($P = 0.00000$)	$P > 0.05$	$P > 0.05$	$P > 0.05$	$P < 0.05$ ($P = 0.01234$)	$P > 0.05$

L_{50} = 50% retention length, SR = selection range.

Individual hauls and the mean selectivity curves of greater forkbeard are presented in Fig. 4 (left *Y*-axis). The 40S (15.3 ± 0.1 cm) mesh codend had provided 25% higher L_{50} values than 40T90 (12.2 ± 0.1 cm) mesh codends (Table 5). When SRs were compared, the estimated values for greater forkbeard increased from 2.3 ± 0.1 mm in 40S to 2.8 ± 0.1 mm in 40T90. The model presented that while mesh configuration is affected by L_{50}, codend species catch is affected by SR values (Table 4). Other investigated fixed effect did not significant on both L_{50} and SR values.

DISCUSSION

In this study we have compared the selectivity of the 40 mm square- and 90º turned-mesh codend used for commercial demersal trawl fishery in the eastern Mediterranean. The L_{50} values for the 40 mm square-mesh codend were higher than those obtained for 40 mm 90º turned-mesh codend for both investigated species. These differences might be due to the number of meshes in the codend circumferences. Wienbeck et al. (2011) indicated that halving the number of meshes in the codend circumference of T90 had a significant and positive effect on the size selection of cod. Sala and Lucchetti (2011) reported the number of meshes around codend circumferences af-

Table 5

Selectivity parameters of 40S and 40T90 codend meshes for *Phycis blennoides*

M	NH	L_{50} [mm]	95% CI	SR [mm]	95% CI	df	Deviance	Catch [number]			Fixed effect			
								Codend	Cover	Total	Total catch [kg]	Codend catch [kg]	Species catch [kg]	Towing time [min]
40S	1	16.2	15.0–17.5	3.7	2.4–5.0	20	6.97	63	271	334	163.9	111.2	4.7	240
	2	16.7	15.5–17.9	2.9	2.0–3.8	26	8.2	91	320	411	196.1	175.4	13.4	190
	3	14.1	13.7–14.5	1.7	1.2–2.1	25	32.1	138	534	672	287.7	239.0	11.2	330
	4	16.6	15.9–17.2	2.1	1.6–2.7	26	8.0	195	464	659	138.6	131.1	22.4	330
	5	15.3	14.5–16.0	2.3	1.7–3.0	24	11.6	130	608	738	259.4	181.2	10.6	225
	6	14.3	13.5–15.2	1.7	0.5–2.9	10	11.2	17	27	44	100.5	78.9	0.6	120
	7	15.0	14.0–16.0	3.8	2.1–5.5	16	8.6	57	139	196	185.5	154.4	4.1	255
	8	15.6	14.6–16.6	2.9	1.8–4.0	16	8.5	34	221	255	326.0	254.7	3.4	345
	9	14.9	14.6–15.3	1.0	0.6–1.4	19	2.4	40	448	488	309.6	203.9	5.9	330
	10	14.4	13.9–14.8	3.2	2.3–4.1	20	19.9	126	208	334	232.2	177.5	4.1	330
	11	14.7	13.7–15.7	2.1	0.9–3.3	23	1.7	109	104	213	220.7	193.5	5.1	330
	PP	15.5	15.3–15.7	2.6	2.4–2.9	34	42.5	1000	3344	4344	2420.2	1900.6	85.2	3025
	F	15.3	15.1–15.5	2.3	2.1–2.5	17								
40T90	1	11.0	10.9–11.2	1.1	0.9–1.2	27	11.9	511	372	883	198.6	166.5	14.0	255
	2	12.9	12.7–13.2	1.7	1.3–2.1	26	48.8	263	386	649	267.5	201.7	11.7	210
	3	12.9	12.5–13.3	3.2	2.5–4.0	22	12.1	191	216	407	131.8	95.9	9.2	210
	4	12.5	11.6–13.4	4.4	2.8–6.0	23	14.9	109	123	232	181.9	155.0	9.2	240
	5	13.1	11.3–14.9	3.0	0.7–5.3	14	5.7	20	13	33	255.8	221.5	2.5	195
	6	11.8	10.9–12.7	4.0	2.2–5.9	13	27.1	150	99	249	266.6	213.9	3.3	210
	7	11.7	10.1–13.3	4.4	1.2–7.7	13	87.4	157	122	279	293.2	265.1	3.4	210
	8	11.7	11.0–12.4	3.4	1.7–5.0	18	40.2	151	121	272	248.6	172.9	4.1	195
	PP	12.2	12.0–12.3	2.7	2.4–3.0	31	50.4	1552	1452	3004	1844.1	1492.4	57.3	1725
	F	12.2	12.0–12.4	2.8	2.4–3.0	11								

40S = 40 mm square-mesh codend, 40T90 = 40 mm 90º turned-mesh codend, M = mesh type, NH = number of hauls, L_{50} = 50% retention length, SR = selection range, CI = confidence interval, df: degrees of freedom, *F* = mean parameters according to Fryer, PP = pooled parameters, Species catch = catch of *Phycis blennoides* in codend.

fected the selectivity parameters. In this study, 40S had 165 square meshes in circumference, 90º turned meshes (40T90) had 330 meshes in circumference.

There were several selectivity studies conducted on 40 mm and 44 mm PE diamond-mesh codend in the Mediterranean (Petrakis 1997, Lucchetti 2008, Sala et al. 2008, Aydın and Tosunoglu 2010). The selectivity of 40 mm diamond-mesh codend has been reported to be rather poor because a large proportion of the codend catch is immature and smaller than the minimum landing size or first maturity size. Therefore, we did not test 40 and 44 mm diamond-mesh codend. Our L_{50} values obtained from 40S and T90 are comparable to previous studies conducted in the Mediterranean and adjacent waters.

Selectivity was considered to be the most useful management tool for rose shrimp. Therefore, there are many studies conducted on codend mesh selectivity for this crustacean. As it is evident from the previous studies, the mesh shape is a significant factor influencing codend selection and the square-mesh codend provided higher L_{50} values for this species. In the presently reported study, the square-mesh codend L_{50} value was just 5 percentage points higher than that determined for T90. Selectivity studies for deepwater rose shrimp in other parts of the Mediterranean with 40 mm diamond-mesh codends reported similar results (Sala et al. 2008, Aydın et al. 2009, 2014, Kaykaç et al. 2009). On the other hand, Ragonese and Bianchini (2006) suggested that the range of 50.2–70.3 mm is a “biologically-sound mesh size” referring to the size at 50% maturity ranges of 20–22 mm for rose shrimp for Italian waters. Guijarro and Massutí (2006) also reached the L_{50} values of 20.2 mm using PA 40 mm square-mesh codend in the Balearic Islands. Only Tosunoglu et al. (2007) extrapolated 20 mm 50% maturity size (19.6 mm L_{50} values) with 49.4 mm diamond-mesh codend in in the Aegean Sea.

Different L_{50} values were obtained from different seas and seasons for greater forkbeard. Tokac et al. (2010) founded the highest L_{50} values (20.88 cm) with 41.5 mm PE square-mesh top panel codend in August. While Bahamon et al. (2006) calculated the lowest L_{50} value of 9.8 cm with 40.3 diamond PE mesh codend. Our L_{50} values of 40S (15.3 cm) approximates the L_{50} values obtained for 40 mm PE square-mesh codend obtained by other authors: 15.0 cm (40.3 mm mesh) (Bahamon et al. 2006); 15.8 cm (for 42.4 mm square-mesh codend) (Aydın et al. 2010); and 16.9 cm (42.9 mm) (Ozbilgin et al. 2012). On the other hand, a T90 L_{50} value determined in the course of the presently reported study (12.2 cm) is comparable to the previously reported value of 12.5 cm (Tokac et al. 2010, Ozbilgin et al. 2012), determined for diamond-mesh codend of 42.4 and 42.2 mm, respectively. Also Aydın et al. (2010) found the same L_{50} values with 44.7 cm diamond-mesh codend.

We determined that 165 square meshes in the codend circumference, with 40 mm mesh sizes, provided higher L_{50} values than 40 mm turned meshes, with 330 meshes around the codend circumference. An option of halving the number of meshes in the codend with a larger turned mesh and different modifications should be investigated in future studies for finding optimum L_{50} values.

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