[Turkish Journal of Veterinary & Animal Sciences](https://journals.tubitak.gov.tr/veterinary)

Volume 29 | Number 4 Article 4

1-1-2005

Selectivity of Standard, Narrow and Square Mesh Panel Trawl Codends for Hake (Merluccius merluccius) and Poor Cod (Trisopterus minutus capelanus)

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Turk J Vet Anim Sci
29 (2005) 967-973

Research Article

Selectivity of Standard, Narrow and Square Mesh Panel Trawl Codends for Hake (*Merluccius merluccius*) and Poor Cod (*Trisopterus minutus capelanus*)

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Received: 10.11.2003

Abstract: The selectivity of 3 trawl codends, (1) a commercially used standard codend, (2) a narrow codend (100 meshes on its circumference instead of 200) and (3) a square mesh top panel codend, was tested for hake (*Merluccius merluccius*) and poor cod (*Trisopterus minutus capelanus*) between 8 and 24 October 2003, in the Aegean Sea. Data were collected using the covered codend technique, and analysed by means of a logistic equation with the maximum likelihood method.

The results show that the commercially used standard codend (40 mm mesh size PE codends, 200 meshes on its circumference) retains all the hake that enter and releases only a few specimens of poor cod. The narrow codend has better selectivity than the standard codend (L_{50} = 14.28 cm for hake and 14.11 cm for poor cod). The selectivity of the square mesh top panel codend was higher than that of the narrow codend for hake (L_{50} = 15.25 cm), while it was similar for poor cod (L_{50} = 14.25 cm).

Key Words: Trawl selectivity, narrow codend, square mesh panel, hake (*Merluccius merluccius*), poor cod (*Trisopterus minutus capelanus*), Aegean Sea.

Standart, Dar ve Karegöz Panelli Trol Torbalarının Bakalorya (*Merluccius merluccius*) ve Tavuk Balığı (*Trisopterus minutus capelanus*) için Seçiciliği

Özet: Ege Denizi'nde 8 ve 24 Ekim 2003 tarihleri arasında bakalyaro (*Merluccius merluccius*) ve tavuk balığı (*Trisopterus minutus capelanus*) için (1) ticari olarak kullanılan standart torba, (2) dar torba (çevresinde 200 göz yerine 100 göz olan) ve (3) üst paneli kare gözlü torba olmak üzere üç trol torbasının seçiciliği test edilmiştir. Veriler örtü torba tekniği kullanılarak elde edilmiş ve 'En Yüksek Olabilirlik Yöntemi' ile lojistik denklem kullanılarak analiz edilmiştir.

Sonuçlar ticari olarak kullanılan standart torbada (çevresi 200 göz olan 40 mm göz açıklığında PE torba) tüm bakalyaroların kaldığı sadece bir kaç tavuk balığının kaçtığını göstermektedir. Dar torbanın seçiciliği standart torbaya göre nispeten yüksek bulunmuştur (L_{50} bakalyaro için 14,28, tavuk balığı için 14,11 cm). Üst paneli kare gözlü torbanın seçiciliği bakalyaro (L_{50} = 15,25 cm) için dar torbadan daha yüksek bulunurken, tavuk balığı (L_{50} = 14,25 cm) için benzer bulunmuştur.

Anahtar Sözcükler: Trol seçiciliği, dar torba, kare göz panel, bakalyaro (*Merluccius merluccius*), tavuk balığı (*Trisopterus minutus capelanus*), Ege Denizi.

Introduction

Recent studies have shown that the selectivity of the 40 mm PE netting diamond mesh codend used commercially by Turkish demersal trawlers is rather poor (1-5). Therefore, significant amounts of immature fish are either discarded or illegally marketed. Information on the selectivity of trawl codends is essential for managing demersal fisheries, as trawling is the main capture method for harvesting demersal species in Turkey (6). Moreover, to protect the juveniles, to reduce the discards and to maximise the yield per recruit, the use of selective gears and methods has to be enforced. Commercial trawl codend selectivity studies carried out in Turkish waters concentrated on the selection of red mullet (*Mullus barbatus*), annular sea bream (*Diplodus annularis*), picarel (*Spicara smaris*), common pandora (*Pagellus erythrinus*), axillary sea bream (*Pagellus acarne*), and whiting (*Gadus merlangus exinus*) (7). The selectivity of the commercial trawl codends for many other target and bycatch species is unknown.

This study investigated the selectivity of a conventional and 2 modified trawl codends for hake (*Merluccius merluccius*) and poor cod (*Trisopterus minutus capelanus*). Hake is commercially one of the most important demersal species in Turkish waters, with 20,810 t of catch reported in 2001 (8). According to Turkish Fisheries Regulations there is a 25 cm minimum landing size (MLS) limitation for this species (9). Poor cod also has a high market value. However, there are no catch records in the State Statistics (8), or MLS in Turkish Fisheries Regulations (9) for this species. Nevertheless, Politou and Papaconstantinou (10) reported that length at 50% maturity for poor cod is 14 cm.

Tosunoğlu et al. (4) estimated that the 50% retention length (L_{50}) and selection range (SR) of the trawl codend commercially used in the Eastern Aegean Sea for hake were 10.6 (se. 0.36) and 2.8 cm (se. 0.30), respectively. These values show that the selectivity of presently used codends, which are made of 40 mm polyethylene (PE) material diamond mesh netting, approximately 5 m in stretched length and 200 or 300 meshes on their circumference, is rather poor. At the codend-tunnel attachment area of this gear, circumference was measured as 186 cm by divers (A. Ulaş, personal communication). When 200 meshes of 40 mm netting are rigged to 186 cm circumference, codend meshes are not expected to remain open. Moreover, during the haul, as the catch accumulates, diamond meshes elongate under tension, the end meshes are obstructed, water flow is diverted and the codend becomes bulbous (11). Underwater observations show that most of the fish escape through open meshes just in front of the bulb. Meshes ahead of these are usually closed, which leads to retention of juveniles of round-bodied fish such as hake.

Conventionally, selectivity has been regulated by means of a legally defined minimum mesh size for the codend (12). However, it has become apparent that many other aspects of gear design can also influence gear selectivity (13). Amongst these, square shaped meshes and reduced number of meshes around the codend, which remains relatively open during the tow, are well documented (For example 1,11,14-16 for square mesh, and 12,17-19 for reduced number of meshes). Within this study, the selectivities of a conventional and 2 modified codends, one with a reduced number of meshes around the circumference (narrow) and the other with a square mesh top panel (SMP), were tested for hake and poor cod. The main aim of testing these modified codends was to determine their efficiencies in releasing immature specimens and reducing by-catch in demersal trawl fisheries in the Eastern Aegean Sea.

Materials and Methods

Fishing trials were carried out on board the R/V Egesüf (27 m LOA, 500 HP main engine) in the central area of İzmir Bay, in the Eastern Aegean Sea, between 8 and 24 October 2003. Water depth of the fishing area varied between 40 and 50 m. A standard of 200 m warp length was used for this depth range. The towing duration was 40-45 min for all the hauls and the average towing speed was 2.5 knots (ranging between 2.3 and 2.7).

Three codends made of nominal 40 mm PE netting were tested in a total of 15 valid hauls. All the codends tested were 5 m in stretched length. Numbers of the meshes around the codends varied in 3 configurations:

(1) Commercially used standard codend: 200 diamond meshes on its circumference

(2) Narrow codend: 100 diamond meshes on its circumference

(3) Square mesh top panel (SMP) codend: a combination of 50 square meshes on the top and 100 diamond meshes on the bottom panel, in total 150 meshes on its circumference.

The codends were tested on a traditional, 600 meshes (40 mm) around the mouth, bottom trawl commonly used by commercial fishermen on the eastern coast of the Aegean Sea. The technical specifications of the trawl net used in this study are given in Tokaç et al. (1). The covered codend method with 2 hoops, and the same rigging as described in Özbilgin and Tosunoğlu (2) was used to catch the fish escaping from the codend. At the end of each tow, the catches in the codend and cover were sorted and weighed, and the total lengths of hake and poor cod were measured to the nearest half a centimetre. Selectivity parameters for individual hauls for hake and combined hauls for poor cod were calculated in a program file prepared by Tokai (20) for analysing the covered codend data. This program was run by the Solver facility of MS-Excel. Codend selectivity curves were obtained in the program file by fitting a logistic equation by means of the maximum likelihood method (21). The selectivity of codends was determined from the relationship between the probability p of a fish entering the codend and fish length l. This relationship is described by the logistic function

$$p(l) = \frac{\exp(a + bl)}{1 + (\exp(a + bl))}$$

where the parameters a and b are the intercept and slope of the linear logistic function.

$$\mathrm{Ln}\left(\frac{p}{1 - p}\right) = a + bl$$

Consequently, the values of L_{50}, L_{25} and L_{75} can be estimated from the expressions

$$L_{50} = -\frac{a}{b}$$

$$L_{25} = \frac{(-\mathrm{Ln}(3) - a)}{b}$$

$$L_{75} = \frac{(\mathrm{Ln}(3) - a)}{b}$$

and

$$SR = L_{75} - L_{25}$$

For hake, parameters of the mean curves and between haul variations (22) were calculated by ECModel (Con-Stat).

Results

A total of 15 valid hauls (2 with standard, 7 with narrow and 6 with SMP codends) were carried out. Total numbers of hake caught were 4835 in all 3 codends and 196 in the cover. Total numbers of poor cod were much lower than those of hake: 224 in the codends and 101 in the cover. The number of hauls with the standard codend is lower than that of the others. It retained all the hake (650 specimens) that entered, and released only 2 individuals of poor cod. As a result, selection parameters could not be estimated for the standard codend. Therefore, the test of this codend was terminated after the second haul.

Table 1 presents the estimated selectivity and regression parameters (with their standard errors and variance matrix values) of individual and mean curves of narrow and SMP codends for hake. Selection parameters could not be estimated for the standard codend as it retained all the individuals. Individual and mean selectivity ogives and length-frequency distributions of the hake that entered and escaped from the narrow and SMP codends are given separately in Figures 1 and 2, respectively. L_{50}s and MLS (vertical broken line at 25 cm) are also shown in

Table 1. Selection parameters of hake (*Merluccius merluccius*) in narrow and square mesh panel (SMP) codends; Fifty percent retention lengths (L_{50}), selection ranges (SR), regression parameters (a and b), their standard errors (in brackets), variance matrix values (R_{11} R_{12} and R_{22}) and numbers of fish in the codend and cover for individual hauls and mean curves according to Fryer (22).

Codend	Haul	L_{50} (SE)	SR (SE)	a (SE)	b (SE)	R_{11}	R_{12}	R_{22}	Numbers of fish in Codend	Cover
NARROW	08 October 1	13.86 (0.79)	4.38 (0.71)	-6.95 (1.49)	0.50 (0.08)	2.213	-0.119	0.007	549	37
	08 October 3	12.25 (0.58)	3.43 (0.55)	-9.12 (1.77)	0.64 (0.10)	3.138	-0.180	0.010	404	27
	15 October 3	14.38 (1.35)	3.10 (1.20)	-10.21 (4.85)	0.71 (0.28)	23.484	-1.333	0.076	152	6
	16 October 3	12.86 (2.13)	3.91 (1.50)	-7.22 (3.91)	0.56 (0.22)	15.324	-0.838	0.046	265	7
	17 October 1	14.02 (0.98)	3.33 (0.75)	-9.24 (2.65)	0.66 (0.15)	7.040	-0.388	0.022	429	12
	17 October 2	14.47 (1.15)	3.11 (0.96)	-10.23 (3.92)	0.71 (0.22)	15.353	-0.854	0.048	240	10
	17 October 3	15.31 (0.74)	2.74 (0.60)	-12.27 (3.19)	0.80 (0.17)	10.148	-0.553	0.030	451	13
	Mean curve	14.28 (0.31)	3.42 (0.07)	-8.78 (0.33)	0.62 (0.02)	1.003	-0.057	0.003	2490	112
SMP	23 October 1	15.79 (0.58)	2.70 (0.54)	-12.84 (2.95)	0.81 (0.16)	8.699	-0.476	0.026	320	17
	23 October 2	14.13 (1.13)	3.81 (0.92)	-8.16 (2.56)	0.58 (0.14)	6.535	-0.534	0.019	298	12
	24 October 1	14.91 (1.26)	2.48 (1.16)	-13.23 (7.13)	0.89 (0.42)	50.783	-2.950	0.173	91	3
	24 October 2	15.46 (0.58)	2.16 (0.50)	-15.72 (4.13)	1.02 (0.24)	17.016	-0.971	0.056	371	10
	24 October 3	13.84 (1.13)	4.25 (0.98)	-7.16 (2.20)	0.52 (0.12)	4.827	-0.261	0.014	350	18
	24 October 4	16.62 (0.29)	1.89 (0.35)	-19.33 (3.74)	1.16 (0.21)	13.952	-0.798	0.046	265	24
	Mean curve	15.25 (0.50)	2.87 (0.15)	-11.51 (0.77)	0.751 (0.04)	4.188	-0.225	0.012	1695	84

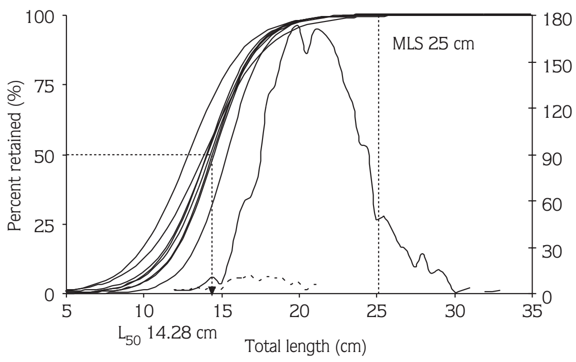

Figure 1. Selection curves and length frequency distributin of hake (*Merluccius merluccius*) in the narrow codend. Individual (thin straight line) and mean (bold straight line) selection curves and length frequency distribution of the population entering the codend (thick straight line) and escaping from the codend (thin broken line). Mean L_{50} value and minimum landing size (MLS) are also shown in the figure.

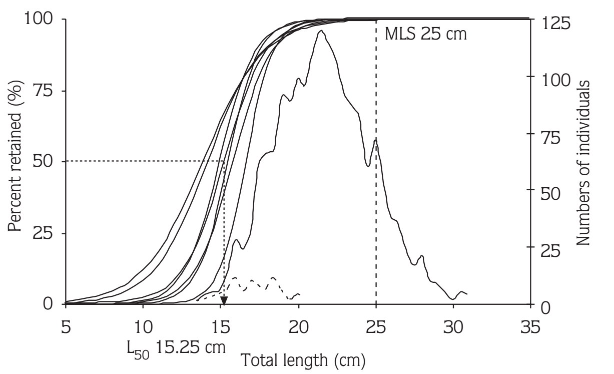

Figure 2. Selection curves and length frequency distribution of hake (*Merluccius merluccius*) in the square mesh panel (SMP) codend. Individual (thin straight line) and mean (bold straight line) selection curves and length frequency distribution of the population entering the codend (thick straight line) and escaping from the codend (thin broken line). Mean L_{50} value and minimum landing size (MLS) are also shown in the figure.

the figures. It can be seen in both the figures and the tables that the SMP codend releases more juveniles than the narrow codend. L_{50} values of the mean curves for hake were 14.28 cm (se. 0.31) in the narrow and 15.25 cm (se. 0.50) in the SMP codends. SRs were 3.42 cm (se. 0.07) and 2.87 cm (se. 0.15), respectively.

Selectivity and regression parameters (with their standard errors and variance matrix values) of the narrow and SMP codends for poor cod are given in Table 2. The results presented in the table were obtained by pooling the data due to insufficient numbers of specimens in individual hauls. Selectivity ogives and length frequency distributions of the total fish that entered and escaped from the narrow and SMP codends are given separately in Figures 3 and 4, respectively. Selection parameters could not be obtained for the standard codend as it released only a few specimens. The results show that for poor cod, the selectivities of the narrow and SMP codends are very similar. L_{50} values of these codends were 14.11 cm (se. 0.19) and 14.25 cm (se. 0.17), respectively. SRs were 1.69 cm (se. 0.33) for the narrow and 1.61 cm (se. 0.27) for the SMP codends.

Discussion

The results of this study demonstrate that a 40 mm nominal mesh size PE codend with 200 meshes on its circumference does not release any hake and releases only a few specimens of poor cod. This codend, which is presently used by commercial fleets, is rather unselective to a degree that even the selection parameters could not be obtained due to the insufficient amount of escapes. Therefore, the test of this codend was terminated after the second haul. However, Tosunoğlu et al. (4) estimated the selection parameters of this codend for hake by pooling 6 hauls in the same area in August 2002. L_{50} and SR values reported by these researchers are 10.6 and

Table 2. Selection parameters of poor cod (*Trisopterus minutus capelanus*) obtained from pooled data in narrow (7 hauls) and square mesh panel (SMP) codends (6 hauls); Fifty percent retention lengths (L_{50}), selection ranges (SR), regression parameters (a and b), their standard errors (in brackets), variance matrix values (R_{11} R_{12} and R_{22}) and numbers of fish in the codend and cover.

Codend	Dates	L_{50} (SE)	SR (SE)	a (SE)	b (SE)	R_{11}	R_{12}	R_{22}	Numbers of fish in Codend	Numbers of fish in Cover
NARROW	8-17 October 2003	14.11 (0.19)	1.69 (0.33)	-18.38 (3.61)	1.30 (0.25)	13.033	- 0.907	0.063	89	44
SMP	23-24 October 2003	14.25 (0.17)	1.61 (0.27)	-19.49 (3.40)	1.37 (0.23)	11.549	- 0.793	0.055	120	55

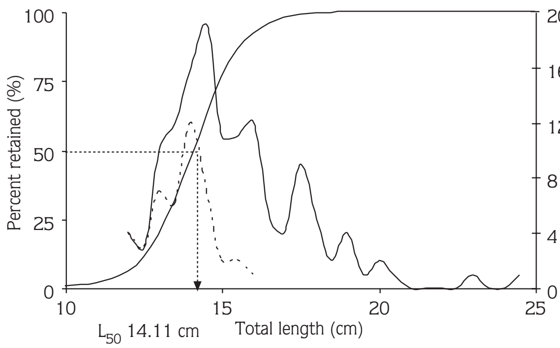

Figure 3. Selection curve and length frequency distribution of poor cod (*Trisopterus minutus capelanus*) in the narrow codend. Pooled selection curve (straight line) and length frequency distribution of the population entering the codend (thick straight line) and escaping from the codend (thin broken line). L_{50} value is also shown in the figure.

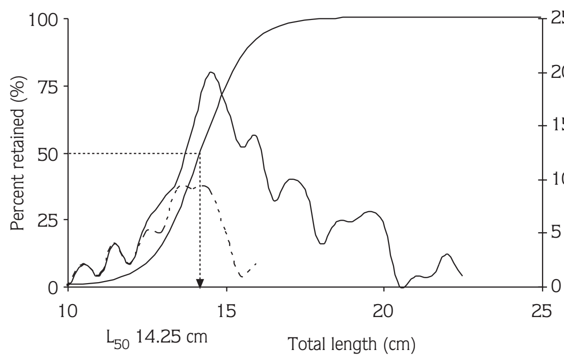

Figure 4. Selection curve and length frequency distribution of poor cod (*Trisopterus minutus capelanus*) in the square mesh panel (SMP) codend. Pooled selection curve (straight line) and length frequency distribution of the population entering the codend (thick straight line) and escaping from the codend (thin broken line). L_{50} value is also shown in the figure.

2.84 cm, respectively. When normalised length-frequency distributions of the populations entering the codends in these 2 studies (Figure 5) are investigated, it can be seen that smaller specimens (10-15 cm) existed in August 2002. The difference in the selectivity of the same codend between these 2 studies is thought to be mainly caused by the variation in the size structures of populations entering the codends.

In the literature there are several studies investigating codend selectivity for hake and poor cod (4,14-16,23-26). However, due to the differences in the gear constructions, mesh sizes, netting materials, and populations fished, the results of most of these studies are not comparable to those found in the present

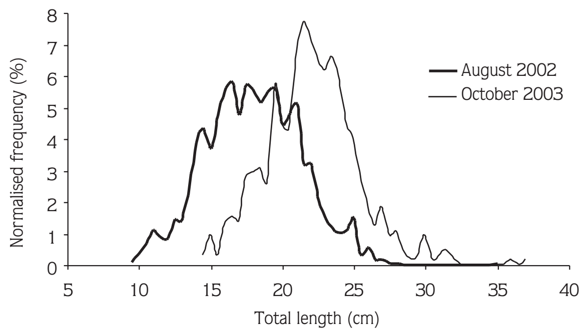

Figure 5. Normalised length frequency distributions of hake (*Merluccius merluccius*) entering the conventional trawl codend in August 2002 and October 2003.

experiments. However, it can be concluded that in both this study and others (14-16), the use of square shaped meshes in the codend results in higher L_{50} values for hake. This is expected as it is a round bodied species with a body height to body width ratio of 1.21 (SE ± 0.003) (4). On the other hand, for poor cod, Petrakis and Stergiou (14) reported lower L_{50} values using a square mesh codend than using a diamond mesh codend, whereas in this study the L_{50} value of the SMP codend is slightly higher than that of the narrow diamond mesh codend (Table 2). The absence of such a difference in this study might be due to the existence of both diamond and square shaped meshes in the SMP codend. A very significant positive effect of using a square mesh on L_{50} is not expected for poor cod as its body height to body width ratio is 2.14 (SE ± 0.009) (4). In other words, the body cross-section of this species is not as round as that of hake.

In the present study, reducing the number of meshes around the codend significantly increased the escape of juveniles of both species. This is known to be an effective way of increasing the selectivity of codends for many species. However it has been demonstrated for poor cod for the first time in the present study, and is in agreement with the results presented by Fiorentini and Leonori (26) for hake. Using a narrow codend in the present study was not a problem as the maximum catch with this codend was 139.7 kg. However, attention has to be paid to larger catch sizes as reducing the number of meshes also reduces the strength of the codend. Therefore, the minimum number of meshes should be calculated by taking the maximum catch size in commercial fishing into account.

In conclusion, commercially used trawl codends are unable to release immature specimens of hake and poor cod in the Eastern Aegean Sea. Using narrow or SMP codends significantly increases selectivity. However, with the present mesh size, if present in the population, the capture of undersized hake is inevitable. Therefore, enforcement of larger mesh size by ensuring the mesh opening during hauling is essential to release immature hake. Nevertheless, 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 (4,14). Therefore, any effort to release undersized hake (smaller than 25 cm) is likely to cause loss of marketable sizes of many other species, such as red mullet, picarel and poor cod. The authors of this study suggest that measures to ensure better mesh opening during trawling have to be taken immediately. Moreover, if at the same length the release of juveniles of one species and the retention of marketable specimens of others are aimed, behavioural studies leading to species separation in trawling have to be performed.

Acknowledgements

The authors would like to thank the captain and crew of the R/V Egesüf. Thanks are also due to Dr. Ali Ulaş, İlker Aydın, Ozan Soykan, Yeliz D. Özbilgin and Semih Leblebici for their help in fish measurements and gear handling, to Prof. Dr. T. Tokai for providing the program files used in the estimation of the selectivity parameters, and to the Deanship of the Ege University Fisheries Faculty and E.U. Scientific Research Foundation (Project no 2003/SÜF/007) for their financial support.

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