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Mortalities of fish escaping from square and diamond mesh codends in the Aegean Sea

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ABSTRACT

We investigated the survival of red mullet (*Mullus barbatus*), annular seabream (*Diplodus annularis*), and blotched picarel (*Spicara maena*) escaping from 40 mm square and 40 mm diamond mesh codends in the Aegean Sea. A low mortality for red mullet and blotched picarel was observed, and annular seabream had no mortality for two different codends. Red mullet mortality for diamond mesh codends was greater than square mesh codends. The estimate of the mean survival rate of square mesh codends for red mullet was 95.1%, while diamond mesh codends were 81.2%. For blotched picarel, the mean proportion surviving in the 3 square mesh codends was 96.5%, whereas it was 91.2% for diamond mesh codends. Mean survival percentages of brown comber (*Serranus hepatus*) were 96.7 and 94.6 for square and diamond mesh codends, respectively. Mortalities of scaldfish (*Arnoglossus laterna*) and survival rates of common pandora (*Pagellus erythrinus*) were 100.0% for all the cages.

1. Introduction

Many experiments conducted in the last two decades have shown that at least some fish do not survive the rigours of capture even if they ultimately escape from the gear. Unless most of the fish released from the gear survive, conservation regulations specifying new designs and minimum mesh sizes for codends are of little value (Sangster et al., 1996). If there are significant numbers of fish dying after escape from fishing gears, the use of traditional gear selectivity measures, such as minimum mesh size to protect the pre-spawning biomass, may not be appropriate (Chopin and Arimoto, 1995).

Poor selectivity of trawl codends has been an important issue in Turkish fisheries since the mid 1980s. As a result, more than 50 published studies to better understand and improve trawl selectivity (such as Petrakis and Stergiou, 1997; Lök et al., 1997; Stergiou et al., 1997; Tokaç et al., 2009; Tosunoğlu et al., 2003a, 2009; Özbilgin and Tosunoğlu, 2003; Özbilgin et al., 2005, 2007; Metin et al., 2005; Deval et al., 2006; Aydın and Tosunoğlu, 2010; Kaykaç et al., 2009) have been conducted in the Aegean and Black Seas. However, until now, there have been only a few studies (Metin et al., 2004; Tokaç et al., 2006; Düzbastılar et al., 2010) investigating the survival rates of fish escaping from trawl codends in the Mediterranean. Therefore, there is a large gap in our knowledge of the real effect of the changes in codend mesh size and shape regulations aiming for sustainable exploitation of the fish stocks.

European Commission regulations (EC, 1967/2006) require minimum mesh sizes of 40 mm square or 50 mm diamond (Tosunoğlu et al., 2008) mesh for trawl codends used in EU Mediterranean waters. As Turkey aims to be a member of the European community, it is important to consider the potential implications of these regulations upon Turkish fisheries. Presently Turkish Fisheries Regulations allows the use of 40 mm square mesh as an option to 40 mm diamond mesh codend in the Black Sea or 44 mm diamond mesh codend in the Aegean Sea and the Mediterranean (Anonymous, 2008). However, in practice most the trawlers use 40 mm diamond mesh codend in the Aegean Sea as this netting is usually measured about 43 mm with the wedge gauge (Tokaç et al., 2010).

Additionally, there have been several studies on the selectivity of these codends in Turkish waters (Aydın and Tosunoğlu, 2010; Kaykaç et al., 2009). The General Fisheries Commission for the Mediterranean (GFCM) and the Working Group on Fishing Technology and Fish Behaviour (WGFTFB) recommend more research be carried out in this topic in the Mediterranean (FAO/GFCM Report, 2007), and such selectivity studies should be supported by experiments to investigate the survival of escaping fish (ICES-FAO

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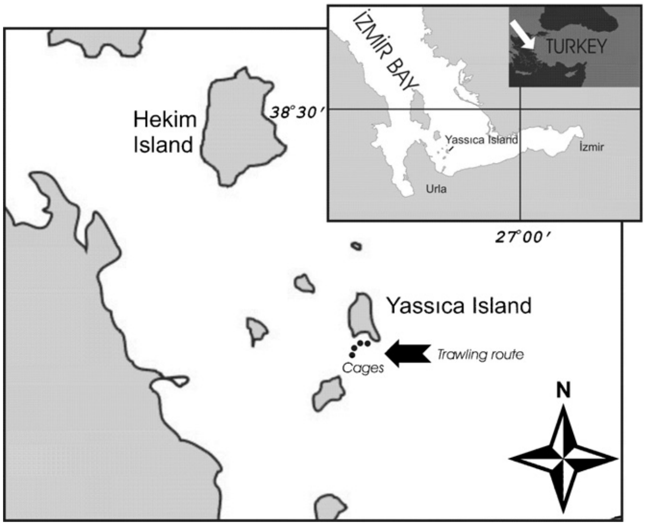

Fig. 1. Fishing ground and cage locations in İzmir Bay.

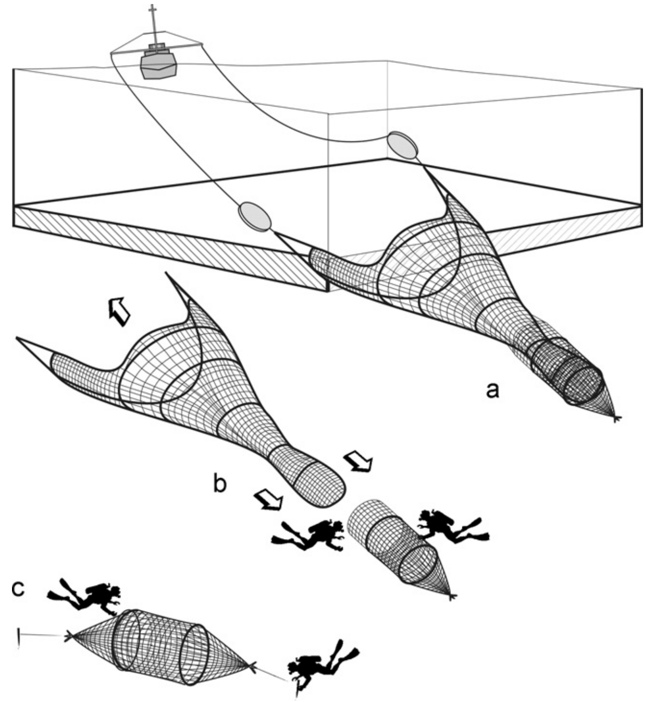

Fig. 2. Detachment of covers from the codend as an observation cage: (a) trawl hauling, (b) detaching the cover, (c) installing the cover.

WGFTFB, 2007). No information on the mortality of fish escaping from square mesh codends for commercial species has been reported so far in the Mediterranean.

The present study was performed in October 2009 under very similar conditions to experiments reported by Metin et al. (2004) and primarily compares the escape mortality for three commercial species, red mullet (*Mullus barbatus*), annular seabream (*Diplodus annularis*) and blotched picarel (*Spicara maena*), escaping from 40 mm square and diamond mesh codends in the Aegean Sea. Besides of those species, survival results belonging to other species (*Serranus hepatus*, *Arnoglossus laterna* and *Pagellus erythrinus*) were presented.

2. Material and methods

The experiments were performed aboard the R/V Egesüf (26.8 m length, ~372 kW engine) off the southern coast of Yassıca Island (38°23′56″N 26°48′20″E and 38°24′21″N 26°47′49″E) in the İzmir Bay (Fig. 1). A total of 6 15-min tows, starting from 25 to 30 m and terminating at 5–12 m in depth (where the cages were located), were carried out on 22nd October, 2009. The mean towing speed was 1.18 ms^{-1} (~2.29 knot).

Fishing gear was a tailored bottom trawl with 700 meshes around the fishing circle. The survival of fish escaping from 40 mm square (100 bars around the circumference and 5 m in length) and 40 mm diamond mesh polyethylene (PE) codends (200 meshes around the circumference and 5 m in length) was compared. To determine the mean mesh size of the square codend, a total of 60 stretched mesh openings (3 lines of 20 consecutive meshes in the towing direction) near to the aft part of the codend were measured using calliper with a 4 kg weight tied vertically to the stationary jaw. Mean value of the 60 meshes measured for 40 mm square mesh codend was found 39.99 mm ± 0.1. The PE material for 40 mm diamond mesh codend used in this experiment is the same as the material measured by Tokaç et al. (2010). 40 mm diamond was measured about 43 mm with the wedge gauge (Tokaç et al., 2010). However, in Tosunoğlu et al. (2003a), the 60 codend meshes which are 40 mm nominal stretched mesh size, measured by using a caliper rule with 4 kg weight vertically tied to the stationary jaw and an average value of 41.9 mm (SE ± 0.13) was found. The mean mesh size of the codend which has PE material (0.40*10) varies depending on many reasons.

Codend covers were constructed to retain escaping fishes. The covers were made with knotless polyamide (PA) netting that had a diamond mesh size of 24 mm (7 m in length and 450 meshes around the circumference at the maximum diameter). They were supported by 2 high-density polyethylene (HDPE) hoops 1.6 m in diameter. A 1 m long zipper was mounted on the cover netting between the 2 large hoops to collect the mortalities from the cages and to feed the survivors. The experimental protocol for collecting and monitoring fishes escaping from codends is the same as that used in the Aegean Sea by Metin et al. (2004). At the end of each tow (15 min), the covers were detached (Fig. 2) from the codends and horizontally deployed to the sea bottom by divers to be used as observation cages at shallow depths. The anchoring depths allowed the divers to monitor the cages securely with a long bottom time for sampling. To prevent anoxia by providing the maximum possible cage volume, the cages were stretched from one end to the other using ropes and wooden rods by divers.

To sample the fish population homogeneously, codends were changed at the end of each haul. The observations continued for seven days during which the cages were visited by divers three times per day; live fish were fed and dead fish were collected. Total (*TL*) and standard lengths (*SL*) of the mortalities were measured to the nearest mm. If a fish had a slightly damaged tail, *SL* was used to calculate *TL*. In some circumstances, neither *TL* nor *SL* could be measured due to loss of significant body parts. To enable length-based survival analyses for each of these mortalities, an approximate length was assumed by taking the head size into account.

At the end of the 7-day observation period, the cages were retrieved on the morning of the 29th of October. The fishes were counted, and their total and standard lengths were measured. For some survivors, *TL* could not be measured due to the loss of tail fins, in which case *SL* was measured, and equations of $TL = 1.2075 \times SL + 0.0861$ ($R^2 = 0.9861$) for red mullet, $TL = 1.1367 \times SL + 0.8583$ ($R^2 = 0.9076$) for annular seabream, and $TL = 1.1256 \times SL + 0.4975$ ($R^2 = 0.9132$) for blotched picarel were used for length conversion. These equations were obtained from the survivors in the cages and fishes retained in the codend. Survival percentage (S_p) was calculated as $S_p = 100\ (n_s/n)$, where n_s is the number of survivors, and n is the total number of fishes in a cage (dead fishes + survivors). Mortalities are shown with the symbol n_m. The Mann–Whitney *U* test was used to determine whether there is a significant difference between the observed mean survival percentages of the test cages. To determine differences in survival rates in length groups between the fish escaping from the square and the diamond mesh codends, nonparametric (Kolmogorov–Smirnov) statistical analyses were conducted. On the Turkish trawl codend, there is a protective or strengthening bag similar in the whole Mediterranean (Tosunoğlu et al., 2003b). In some circumstances this gear change the selectivity estimates. But in this study there is no effect on the selectivity of most Med. fish species. So this study should be mentioned, because in the survival experiments such protective bag was not used.

3. Results

3.1. Behavioural observations and fish composition

The observation cages were fixed to a hard bottom partially covered by meadows between 5 and 12 m deep. The sea condition was calm, and water temperature was 21 °C along the water column in the study field. During the first observation after installation of the cages, red mullet and annular seabream swam actively in groups, and some of the blotched picarel were usually observed to remain inactive in the upper and lower parts of the cages and remote from the other fishes. Some injured red mullet individuals swam in a head-up vertical position. Despite the fact that some species, such as annular seabream, two-banded seabream (*Diplodus vulgaris*), common pandora and brown comber, were seen to be quickly adapted to their new habitat, specimens with damaged scales of blotched picarel, red mullet, and black goby (*Gobius niger*) remained apart from the shoal. In the following days, the tails, fins and heads of the wounded fishes were eaten by healthy specimens of brown comber, annular seabream and two-banded seabream. In addition, the predation effect of brown comber, which is a carnivorous fish, increased in the last few days. Red mullet did not show much interest in the baits (bivalves, gastropods, pellets, etc.). However, they exhibited food-searching behaviour with their barbells on the sea bottom. Following few days, red mullet, which are demersal species, swam upward from the base of the cage and fed on settled detritus on the upper and lateral meshes of the cages. Flatfishes and black goby kept closer to the bottom of the cages and usually actively moving around. Individuals of red bandfish (*Cepola macrophtalma*) partly penetrated into the meshes with their tail fin. Blotched picarel showed routine swimming and feeding activities after few days. The predation affected that measurements of some mortality (i.e. flatfishes) could not be taken owing to loss of major body parts.

In total, 39 species belonging to 25 families were caught (Table 1). Of these, 32 bony fishes belonging to 17 families and 2 cartilaginous fishes represented by *Raja radula* and *Torpedo marmorata* were captured. The other five species were *Octopus vulgaris*, *Loligo vulgaris*, *Sepia officinalis*, *Squilla mantis*, and *Penaeus kerathurus*. In the study, 33 species were caught in the codend and 23 species were caught in the cover. In the catch composition, in terms of numbers of individuals, red mullet (1548) was the most abundant species, followed by annular seabream (991), blotched picarel (695), brown comber (460), scaldfish (398), European squid (*L. vulgaris*) (366), European pilchard (*Sardina pilchardus*) (226), two-banded seabream (122), and Atlantic spotted flounder (*Citharus linguatula*) (85).

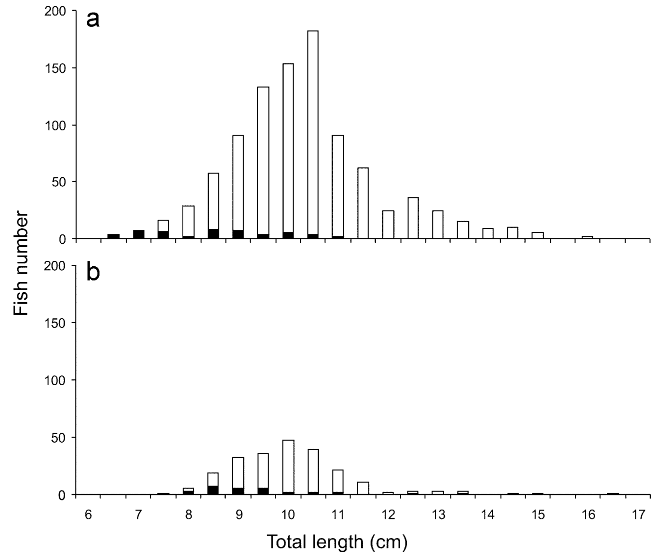

Fig. 3. Red mullet. Numbers of mortalities (black) and survivors (white). (a) Square mesh codend cages, (b) diamond mesh codend cages.

3.2. Post-escape mortality of red mullet

The total numbers of red mullet that escaped from square and diamond codends were 950 and 225, respectively (Fig. 3, Table 2). The size of these fish ranged between 6.8 and 16.3 cm. The square mesh codend cages had a greater mean survival rate than that of the diamond mesh codend cages. Survival percentages were 95.4%, 95.8% and 94.1% in the 3 square mesh codend cages. The mean proportion surviving in these cages was 95.1%. For 3 diamond mesh codend cages, these values were 71.7%, 94.6% and 77.4% (mean 81.2%). Survival rates among the observation cages showed an insignificant difference ($p > 0.05$). However, there was a significant difference in survival rates in length groups between the fish escaping from the square and the diamond mesh codend cages ($p < 0.05$).

3.3. Survival of annular seabream

The total number of annular seabream that escaped from the codends was 82. For all individuals of the annular seabream size ranges, the mean, minimum and maximum lengths and s.d. of the mean sizes are given in Table 3 for each cage. The size of the annular seabream ranged between 6.0 and 13.7 cm, and all the escaping fish from both the square and diamond mesh codends showed 100% survival.

3.4. Post-escape mortality of blotched picarel

The total numbers of blotched picarel in 3 square and 3 diamond mesh codends cages were 460 and 174, respectively (Fig. 4, Table 4). The sizes of the fish ranged between 8.8 and 16.0 cm in the population of 6 cages. Survival percentages of the fish escaping from square mesh codends in 3 tows were 96.4%, 96.3%, and 96.7%, resulting in a mean value of 96.5%. These values for the diamond mesh codend were 80.4%, 98.9% and 94.4% (mean 91.2%). There was a significant difference in survival rates in length groups between the square and the diamond mesh codend cages ($p < 0.05$).

3.5. Mortality rate during the monitoring period

Most of the mortalities occurred in the earlier days of the observation period. For red mullet, 55.3% of the mortalities in the square

Table 1
Distribution and number of species in codends and covers for each haul.

Species	Family	Codend						Cover					
		S1	S2	S3	D1	D2	D3	S1	S2	S3	D1	D2	D3
Raja radula	RAJIDAE				1								
Torpedo marmorata	TORPEDINIDAE	1											
Conger conger	CONGRIDAE							1					
Trachurus trachurus	CARANGIDAE	1				8							
Sardina pilchardus	CLUPEIDAE								185	2	1	8	30
Serranus hepatus	SERRANIDAE	1		1				95	100	137	23	81	22
Serranus cabrilla			1	1	1	6	2						
Serranus scriba			1		4	6		1	2	1			
Cepola macrophthalma	CEPOLIDAE						3	5	11	19		4	
Mullus barbatus	MULLIDAE	22	25	20	41	219	46	410	237	303	46	148	31
Diplodus annularis	SPARIDAE	117	102	293	92	144	161	13	7	14	5	4	39
Diplodus vulgaris		14	12	16	31	18	10	7			7	1	6
Lithognathus mormyrus				2		2	2						
Dentex macrophthalmus				1									
Pagellus erythrinus						2		15	10	10	3	4	4
Sparus aurata			6	3		4	2						
Boops boops		2	2	11	1		7						1
Mugil sp.	MULLIDAE			1									
Spicara maena	CENTRACANTHIDAE	8	3	6	6	22	17	168	82	209	46	92	36
Uranoscopus scaber	URANOSCOPIDAE	1		1	2								
Gobius niger	GOBIIDAE			1	2	7	1	13	12	7	5	4	2
Lesueurigobius friesii											1		
Coris julis	LABRIDAE										1		
Symphodus tinca			1		3	8			1		3		
Scorpaena notata	SCORPAENIDAE	1											
Trachinus draco	TRACHİNİDAE							1	1				
Lepidotrigla cavillone	TRIGLIDAE	2				1	2	1	5	7			1
Trigla lucerna		11	5	3	2	4	3						
Trigla lyra		1	10			2							
Citharus linguatula	CITHARIDAE	22		10	8	6	9	7	4	6	1	6	6
Arnoglossus laterna	BOTHIDAE	20	6			5	12	105	57	48	23	72	50
Arnoglossus thori		1			5					2	1		
Buglossidium luteum	SOLEIDAE							8	16	13	10	2	3
Solea solea			2	2	1	1	1						1
Octopus vulgaris	OCTOPODIDAE						1						
Loligo vulgaris	LOLIGINIDAE	4	72	127	62	96	5						
Sepia officinalis	SEPIIDAE	5	6	8	1	4	6						
Squilla mantis	SQUILLOIDEA	1	2	6	3	4	1						1
Penaeus kerathurus	PENAEIDAE	7	4		1	7	1						
Number of individuals in the observation cages		242	260	513	267	576	292	850	730	778	176	426	233

Table 2
Red mullet. Summary data of fish escaping from square (S) and diamond (D) mesh codends.

	S1	S2	S3	D1	D2	D3
n_m	19	10	18	13	8	7
n_s	391	227	285	33	140	24
N	410	237	303	46	148	31
S_p (%)	95.4	95.8	94.1	71.7	94.6	77.4
TL_{mean} (cm)	10.2	10.7	10.6	10.5	9.9	11.1
TL_{min} (cm)	7.3	8.0	6.8	7.5	8.1	9.1
TL_{max} (cm)	15.2	16.0	14.8	14.4	13.0	16.3
s.d. of TL_{mean}	1.48	1.39	1.35	1.52	0.86	1.69
Cage depth (m)	8.5	6.6	11.1	5.1	8.6	11.7

Table 3
Annular seabream. Summary data of fish escaping from square (S) and diamond (D) mesh codends.

	S1	S2	S3	D1	D2	D3
n_m	0	0	0	0	0	0
n_s	13	7	14	5	4	39
N	13	7	14	5	4	39
S_p (%)	100.0	100.0	100.0	100.0	100.0	100.0
TL_{mean} (cm)	8.9	9.8	8.9	7,1	8.3	11.9
TL_{min} (cm)	7.2	8.1	6.8	6.0	6.8	8.3
TL_{max} (cm)	10.2	12.3	10.5	8.8	9.5	13.7
s.d. of TL_{mean}	0.89	1.59	0.81	1.04	1.12	1.10

Table 4
Blotched picarel. Summary data of fish escaping from square (S) and diamond (D) mesh codends.

	S1	S2	S3	D1	D2	D3
n_m	6	3	7	9	1	2
n_s	162	79	202	37	91	34
N	168	83	209	46	92	36
S_p (%)	96.4	96.3	96.7	80.4	98.9	94.4
TL_{mean} (cm)	11.6	12.0	11.9	11.4	11.8	12.1
TL_{min} (cm)	8.8	8.8	9.4	9.0	9.5	10.8
TL_{max} (cm)	16.0	14.0	14.1	13.2	15.2	14.3
s.d. of TL_{mean}	1.08	0.89	0.82	1.08	1.11	0.81

mesh codend cages and 64.2% of the mortalities in the diamond mesh codend cages took place in the first 48 h following escape (Fig. 5). For blotched picarel, 38.0% of the mortalities in the square mesh codend cages and 67.0% of the mortalities in the diamond mesh codend cages took place in the first 48 h following escape (Fig. 6).

3.6. Post-escape mortality of other fishes

The total numbers of brown comber in 3 square and 3 diamond mesh codends cages were 332 and 126, respectively. The sizes of the fish ranged between 6.1 and 10.7 cm in the population of 6 cages. Survival percentages of the fish escaping from square mesh codends in 3 tows were 100.0%, 93.0%, and 97.1%, resulting in a mean value of 96.7%. These values for the diamond mesh codend were 100.0%, 97.5% and 86.4% (mean 94.6%). There was no significant difference in survival rates in length groups between the square and the diamond mesh codend cages ($p > 0.05$). The total numbers of scaldfish in 3 square and 3 diamond mesh codends cages were 210 and 145, respectively. Mortalities of scaldfish were 100.0 for all the cages. Simply 35 and 11 common pandora individuals were captured in 3 square and 3 diamond mesh codends cages, respectively. Survival rates of common pandora were 100.0% for all the cages.

4. Discussion

This is the first study reporting on the survival ratios of the fish escaping from square mesh codends in the Mediterranean. Present results show that both red mullet and blotched picarel survive in significantly higher ratios after escape from a square mesh codend in comparison to escape from a same mesh size diamond mesh codend. Work on the subject is rather limited in the literature, and those by Main and Sangster (1990, 1991) report that haddock and whiting escaping through a square mesh codend have lower mortality than those escaping from a diamond mesh codend of the same mesh size. Clearly, many fish, at least fusiforms, may escape through open square meshes with less injury than through conventional diamond meshes because the latter may become almost closed, owing to net tension during tow (Suuronen, 2005).

Metin et al. (2004) reported an average of 6.8% mortality for red mullet escaping from 40 mm nominal mesh size PE codends in the experiments conducted on September 1–7, 2002. In our study, the mortality of red mullet for the same codend was greater (mean 18.8%). Seasonal factors, such as temperature, which was 3.5 °C higher in the previous experiments, fish condition and size structure of the fished population, might have caused such differences. The influence of such factors on escape mortality requires further investigations. Additionally, mortality rates in 3 diamond mesh codend cages varied between 5.4% and 28.3%. Such variable results have also been obtained for other species in the literature. For example, the mortality of haddock for 3 control cages was reported to be between 9.1% and 16.1% in experiments conducted in 2004, whereas it was between 32.5% and 52.1% in 2005 (Ingólfsson et al., 2007). Moreover, Suuronen et al. (2005) reported that the escape mortalities of cod were 8.3%, 25.0% and 48.2% in the same test cage category (standard 120 mm diamond mesh codend).

Tokaç et al. (2006) reported that annular seabream had no mortality after escape from the same diamond mesh codend that was

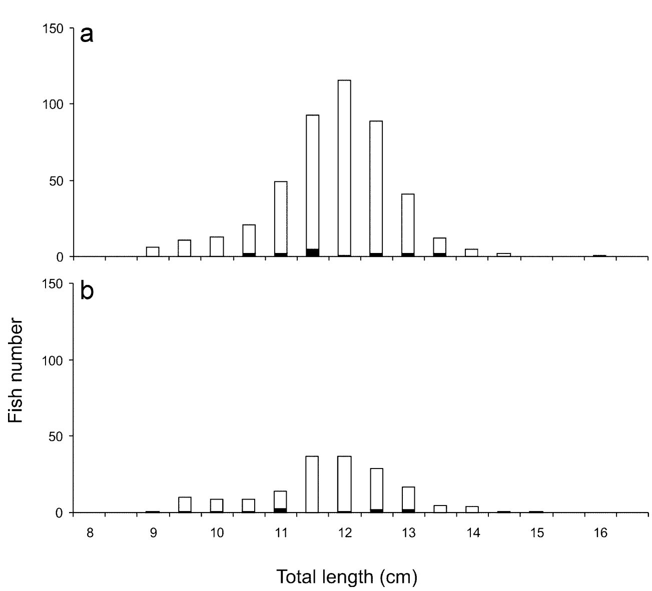

Fig. 4. Blotched picarel. Numbers of mortalities (black) and survivors (white). (a) Square mesh codend cages, (b) diamond mesh codend cages.

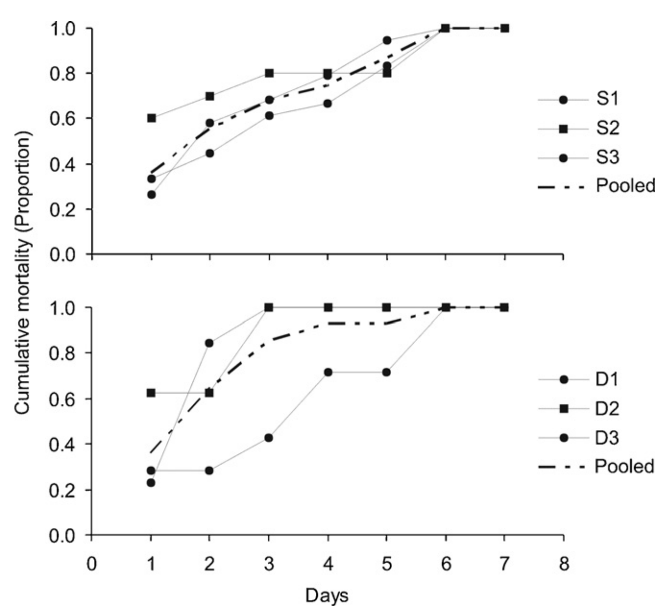

Fig. 5. Cumulative mortality of red mullet during the observation period for square (S1, S2, and S3) and diamond (D1, D2, and D3) mesh codend cages.

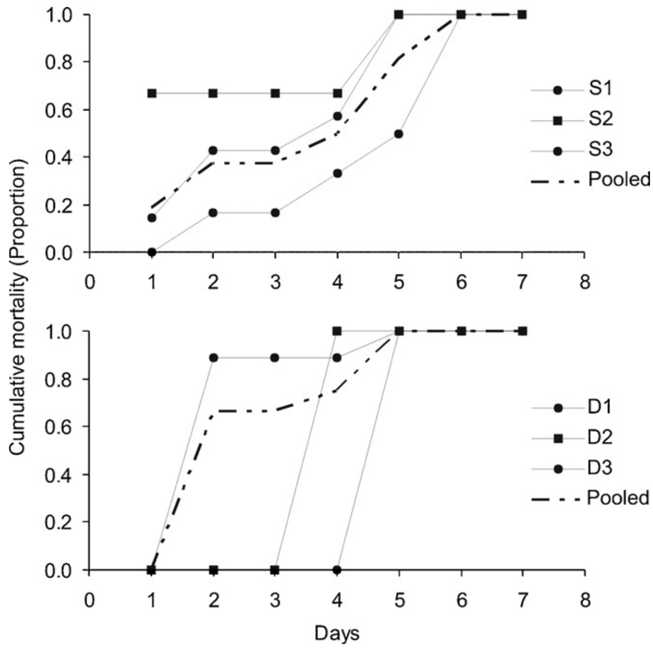

Fig. 6. Cumulative mortality of blotched picarel during the observation period for square (S1, S2, and S3) and diamond (D1, D2, and D3) mesh codend cages.

used in the present study. In the present study, annular seabream showed 100% survival after escape from both square and diamond mesh codends. For blotched picarel, no other data have been reported so far to our knowledge.

The mortality of brown comber, ranging in length from 6.1 to 10.7 cm (mean = 8.6 cm, s.d. = 0.57 cm), was negligible for all the test cages. Düzbastılar et al. (2010) were found average mortalities of brown comber for diamond mesh codend as 2.2% and 1.9% in 2007 and 2008 experiments, respectively. For square mesh codend, mean survival rate was 82.9% in the 2008 experiment. Escape mortalities of scaldfish and common pandora were 100.0 for all the cages. To our knowledge these are the first results for scaldfish and common pandora.

In the present study, a significant majority of the mortalities were observed in the first few days following capture (Figs. 5 and 6). Similar observations were made by Metin et al. (2004) for red mullet. Therefore, the observation period was limited to seven days, as in the methodology used by Metin et al. (2004).

The methodology used in the present experiment was developed in the early 2000s by the same team after several captivity systems were tested and preliminary results were obtained (Metin et al., 2004). Under the fishing conditions in the area and for the population fished, it was considered that the best results could be obtained by 15-min tows, this being the minimum duration required to reach an acceptable catch size. The main reason for limiting the towing duration to 15 min was to minimise fatigue caused by swimming after escape from the codends (Breen et al., 2002). In the present experiment, the main aim was to compare the survival ratios between the square and diamond mesh codend escapees. Therefore, work was focused on only these two codends, which were made of the same netting, but not on control groups. In the area, there is no capture methodology other than the open codend method to catch similar sizes of the target species as control fish. Metin et al. (2004), who collected the control group with this method, reported an even higher mortality of red mullet in the control than the test codend cages and hypothesised that this was due to a higher density of fish and the presence of predators in the control cage.

In conclusion, the results presented in this study support the decision on enforcement of the installation of square mesh codends in Mediterranean demersal trawl fisheries, as they provide significantly higher codend selectivity (as in Guijarro and Massuti, 2006; Ordines et al., 2006; Bahamon et al., 2006; Lucchetti, 2008; Kaykaç et al., 2009 for many species, with the exception of flat fish) and post-escape survival for red mullet and blotched picarel. This change is very likely to be a suitable technical solution to decrease the total fishing mortality for these two species. However, the effect of such technical measures on the total mortality of many other species, particularly flat fishes, in multi-species fisheries remains to be investigated.

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References

Anonymous, 2008. Notification 2/1 Regulating Commercial Fishing (Notification Number 2008-48) (in Turkish). SUR-KOOP, Su Urünleri Kooperatifleri Merkez Birliği, Pozitif Matbaa, Ankara, 112 pp.

Aydın and Tosunoğlu, 2010. Selectivity of diamond, square and hexagonal mesh codends for Atlantic horse mackerel *Trachurus trachurus*, European hake, *Merluccius merluccius*, and greater forkbeard *Phycis blennoides* in the eastern Mediterreanean. Appl. Ichtyol. 26, 71–77.

Bahamon, N., Sarda, F., Suuronen, P., 2006. Improvement of trawl selectivity in the NW Mediterranean demersal fishery by using a 40 mm square mesh codend. Fish. Res. 81, 15–25.

Breen, M., Sangster, G., O'Neill, B., Kynoch, R., Jones, E., Soldal, A., 2002. Evidence of sampling induced biases in mortality estimates from experiments investigating mortality in fish escaping from towed fishing gears. ICES CM 2002/V, 25.

Chopin, F.S., Arimoto, T., 1995. The condition of fish escaping from fishing gears—a review. Fish. Res. 21, 315–327.

Deval, M.C., Bök, T., Ateş, C., Özbilgin, H., 2006. Selectivity of PE and PA material codends for rose shrimp *Parapenaus longirostis* in Turkish twin rigged beam trawl fishery. Fish. Res. 81, 72–79.

Düzbastılar, F.O., Özgül, A., Aydın, İ., Gül, B., Soykan, O., 2010. A preliminary study on the survival of brown comber, *Serranus hepatus* (Actinopterygii, Perciformes, Serranidae), escaping from the codend of a bottom trawl. Acta Ichthyol. et Piscat. 40, 27–36.

EC, 1967/2006. Council Regulation (EC) No 1967/2006 of 21 December 2006 concerning management measures for the sustainable exploitation of fishery resources in the Mediterranean Sea, amending Regulation (EEC) No 2847/93 and repealing Regulation (EC) No 1626/94. Official J. Eur. Union, L 409/11.

FAO/GFCM, 2007. General Fisheries Commission for the Mediterranean Report Report, No. 31, FAO, Rome, Italy.

Guijarro, B., Massuti, E., 2006. Selectivity of diamond- and square-mesh codends in the deepwater crustacean trawl fishery off the Balearic Island (western Mediterranean). ICES J. Mar. Sci. 63, 52–67.

ICES WGFTFB Report, 2007. ICES Fisheries Technology Committee, ICES CM 2007/FTC:06, Ref. ACFM. Report of the ICES-FAO Working Group on Fish Technology and Fish Behaviour (WGFTFB) 23–27 April 2007, Dublin, Ireland.

Ingólfsson, Ó.A., Soldal, A.V., Huse, I., Breen, M., 2007. Escape mortality of cod, saithe, and haddock in a Barents Sea trawl fishery. ICES J. Mar. Sci. 64, 1836–1844.

Kaykaç, H., Tokaç, A., Özbilgin, H., 2009. Selectivity of commercial, larger mesh and square mesh trawl codends for deep water rose shrimp *Parapenaus longirostis* (Lucas, 1846) in the Aegean Sea. Sci. Mar. 73, 597–604.

Lök, A., Tokaç, A., Tosunoğlu, Z., Metin, C., Ferro, R.S.T., 1997. The effects of different codend design on bottom trawl selectivity in Turkish fisheries of the Aegean Sea. Fish. Res. 32, 149–156.

Lucchetti, A., 2008. Comparison of diamond- and square-mesh codends in the hake (*Merluccius merluccius* L. 1758) trawl fishery of the Adriatic Sea (central Mediterranean). Sci. Mar. 72, 451–460.

Main, J., Sangster, G.I., 1990. An assessment of the scale damage to and survival rates of young fish escaping from the codend of a demersal trawl. Scott. Fish. Res. Rep. 46, 90.

Main, J., Sangster, G.I., 1991. Do fish escaping from codends survive? Scott. Fish. Res. Rep. 18, 91.

Metin, C., Özbilgin, H., Tosunoğlu, Z., Gökçe, G., Aydın, C., Metin, G., Ulaş, A., Kaykaç, H., Lök, A., Düzbastılar, F.O., Tokaç, A., 2005. Effect of square mesh escape window on codend selectivity for three fish species in the Aegean Sea. Turk. J. Vet. Anim. Sci. 29, 461–468.

Metin, C., Tokaç, A., Ulaş, A., Düzbastılar, F.O., Lök, A., Özbilgin, H., Metin, G., Tosunoğlu, Z., Kaykaç, H., Aydın, C., 2004. Survival of red mullet (*Mullus barbatus* L., 1758) after escape from a trawl codend in the Aegean Sea. Fish. Res. 70, 49–53.

Ordines, F., Massuti, E., Guijarro, B., Mas, R., 2006. Diamond vs. square mesh codend in a multi-species trawl fishery of the western Mediterranean: effects on catch composition, yield, size selectivity and discards. Aquat. Living Resour. 19, 329–338.

Özbilgin, H., Tosunoğlu, Z., 2003. Comparison of the selectivities of double and single codends. Fish. Res. 63, 143–147.

Özbilgin, H., Tosunoğlu, Z., Aydın, C., Kaykaç, H., Tokaç, A., 2005. Selectivity of standard, narrow and square mesh panel trawl codends for hake (*Merluccius merluccius*) and poor cod (*Trisopterus minutus capelanus*). Turk. J. Vet. Anim. Sci. 29, 967–973.

Özbilgin, H., Tosunoğlu, Z., Tokaç, A., Metin, G., 2007. Seasonal variation in the trawl codend selectivity of blotched picarel (*Spicara smaris*). ICES J. Mar. Sci. 64, 1569–1572.

Petrakis, G., Stergiou, K.I., 1997. Size selectivity of diamond and square mesh codends for four commercial Mediterranean fish species. ICES J. Mar. Sci. 54, 13–23.

Sangster, G.I., Lehmann, K., Breen, M., 1996. Commercial fishing experiments to assess the survival of haddock and whiting after escape from four sizes of diamond mesh cod-ends. Fish. Res. 25, 323–345.

Stergiou, K.I., Petrakis, K., Politou, C.Y., 1997. Size selectivity of diamond and square mesh cod-ends for *Nephrops norvegicus* in the Aegean Sea. Fish. Res. 29, 203–209.

Suuronen, P., 2005. Mortality of fish escaping trawl gears. FAO Fisheries Technical Paper 478, Food and Agriculture Organization of the United Nations, Rome.

Suuronen, P., Lehtonen, E., Jounela, P., 2005. Escape mortality of trawl caught Baltic cod (*Gadus morhua*)–the effect of water temperature, fish size and codend catch. Fish. Res. 71, 151–163.

Tokaç, A., Lök, A., Metin, C., Özbilgin, H., Düzbastılar, F.O., Ulaş, A., Metin, G., Kaykaç, H., Aydın, C., Tosunoğlu, Z. 2006. Survival of red mullet (*Mullus barbatus* L., 1758), annular seabream (*Diplodus annularis* L., 1758) and axillary seabream (*Pagellus acarne* L., 1827) after escape from trawl codend in the Mediterranean. ICES CM 2006/FTC:06, REF. ACFM.

Tokaç, A., Özbilgin, H., Kaykaç, H., 2009. Alternative codend designs to improve size selectivity for Norway lobster (*Nephrops norvegicus*) and rose shrimp (*Parapenaus longirostis*) in the Aegean Sea. Crustaceana 82, 689–702.

Tokaç, A., Özbilgin, H., Kaykaç, H., 2010. Selectivity of conventional and alternative codend design for five fish species in the Aegean Sea. J. Appl. Ichthyol. 26, 403–409.

Tosunoğlu, Z., Özbilgin, Y.D., Özbilgin, H., 2003a. Body shape and trawl codend selectivity for nine commercial fish species. J. Mar. Biol. Assoc. UK 83, 1309–1313.

Tosunoglu, Z., Özbilgin, H., Tokaç, A., 2003b. Effects of the protective bags on the cod-end selectivity in Turkish bottom trawl fishery. Arch. Fish. Mar. Res. 50, 239–252.

Tosunoğlu, Z., Aydın, C., Özaydın, O., 2008. Selectivity of a 50 mm diamond mesh knotless polyethylene codend for commercially important fish species in the Aegean Sea. J. Appl. Ichthyol. 24, 311–315.

Tosunoğlu, Z., Aydın, C., Salman, A., Fonseca, P., 2009. Selectivity of diamond, hexagonal and square mesh codends for three commercial cephalopods in the Mediterranean. Fish. Res. 97, 95–102.