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Survival of fish after escape from a 40 mm stretched diamond mesh trawl codend in the Aegean Sea

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SUMMARY: This study aimed to determine the survival rates of three fish species, the brown comber (*Serranus hepatus*), black goby (*Gobius niger*) and annular seabream (*Diplodus annularis*), after their escape from a 40 mm stretched diamond mesh polyethylene (PE) codend. Experiments were carried out in the eastern Mediterranean in September 2007 using a conventional bottom trawl with 600 meshes around the mouth. A constant 15 min towing duration was used for all hauls. The towing speed varied between 2.0 and 2.5 knots. Codend covers, supported by two hoops, were used to retain escaping fish. At the end of each haul, these covers were detached from the codend, fixed to the sea floor at depths of 19 to 28 m, and then observed by the divers for a period of seven days. On the eighth day, all of the covers were lifted up and the survivors and mortalities were counted and measured. The mean survival percentages of open codend and experimental cages were found to be 97.1% and 98.3% for brown comber, 69.0% and 77.2% for black goby, and 97.5% and 98.6% for annular seabream respectively.

Keywords: survival rate, escapes, trawl codend, discard and by-catch, Aegean Sea.

RESUMEN: SUPERVIVENCIA DE PECES DESPUÉS DE ESCAPAR DE UNA RED DE ARRASTRE CON COPO DE 40 MM DE MALLA ROMBOIDAL EN EL MAR EGEO. – Este estudio tuvo como objetivo determinar las tasas de supervivencia de tres especies de peces, cherna afanecada o merillo (*Serranus hepatus*), chaparrudo (*Gobius niger*) y raspallón (*Diplodus annularis*), después de escapar de un copo con mallas de 40 mm romboidales de polietileno (PE). Los experimentos fueron realizados en el Mediterráneo Oriental, en septiembre de 2007 utilizando una red de arrastre de fondo convencional con 600 mallas alrededor de la boca. La duración estándar fue de 15 minutos de arrastre para todos los lances. La velocidad de arrastre varió entre 2.0 y 2.5 nudos. Los peces que escapaban del copo eran retenidos por un sobrecojo, el cual quedaba separado del copo mediante aros que facilitan el escape en buenas condiciones entre ambos paños. Al final de cada lance, las cubiertas del sobrecopo se separaban del copo y se fijaban al fondo del mar a profundidades entre 19 y 28 m y fueron observados por buceadores durante los siete días siguinetes. Al octavo día se contaron y midieron los sobrevivientes. Los porcentajes de supervivencia medios de control y en las jaulas experimentales resultaron ser del 97.1% y 98.3% para la cherna afanecada; 69.0% y 77.2% para el chaparrudo y 97.5% y 98.6% para el raspallón.

Palabras clave: tasa de supervivencia, escapes, red de arrastre, descartes y capturas acompañantes, mar Egeo.

INTRODUCTION

Bottom trawling is one of the most effective fishing methods for catching demersal fish species and has a high economic value. However, aside from the landed catch, this fishing gear can inflict considerable fishing mortality upon exploited stocks, which is unaccounted for (Suuronen, 2005). Modifying fishing gear to reduce the capture of juvenile fish has been one of the main management tools for sustainable fisheries (Suuronen, 2005; Bahamón *et al.,* 2007; Breen *et al.,* 2007). Improving the selectivity of trawls is an important conservation tool for minimising discards of unwanted and undersized fish and ensuring that fish reach their optimal size before harvesting (Main and Sangster, 1990).

Many selectivity studies have been carried out in the Mediterranean Sea. In order to improve selectivity some modifications of the codend, including the use of a square mesh codend (Lucchetti, 2008; Kaykaç *et al.,* 2009), lastridge rope (Lök *et al*., 1997) and the narrowed codend (Özbilgin *et al*., 2005), have been investigated. A few selectivity studies are also available for hexagonal mesh codends, but these are restricted to herring (Suuronen *et al*., 1991), crustacean (Aydın and Tosunoğlu, 2009) and cephalopod selectivity (Tosunoğlu *et al*., 2009), and no corresponding results are available for fish species in the Mediterranean demersal trawl fishery. A number of scientific works have been conducted on size selectivity with grids in the Mediterranean (Sardà *et al*., 2006).

As a consequence of selectivity during fishing, both target and non-target species may be injured when they escape from the gear usually by passing through the mesh of the codend (Wileman *et al.,* 1996) or from other instruments such as grids (Ingólfsson *et al.,* 2007) installed in the rear part of the codend. However, these selective devices will only work if escaping fish survive and grow to sustain the exploited population (Suuronen, 2005). Therefore, to ensure that selective fishing gears are working effectively, it is essential to demonstrate that escaping fish do actually survive (Ingólfsson *et al.,* 2007).

Several survival studies have been carried out over the past two decades on the northwest coast of Scotland, in the North Sea, the northern Baltic Sea and the Barents Sea (Main and Sangster, 1990; Sangster *et al.,* 1996; Suuronen *et al.,* 1996; Broadhurst *et al*., 2006; Ingólfsson *et al.,* 2007). However, information on the survival of released fish is limited for the Mediterranean. Information on survival rates is only available for red mullet (*Mullus barbatus*) (Metin *et al.,* 2004), annular seabream (*Diplodus annularis*) and axillary seabream (*Pagellus acarne*; Tokaç *et al.,* 2006). No information on survival rates for any other frequently discarded species has been reported so far. However, it is well known that Mediterranean demersal trawl fisheries catch a large number of species (Stergiou *et al*., 1997).

This study aimed to determine the survival rate of commercial annular seabream and for the first time the by-catch species, brown comber (*Serranus hepatus*) and black goby (*Gobius niger*), which have different body shapes and sizes.

MATERIALS AND METHODS

Trawling was conducted on the south coast of Yassıca Island (38º23'56''N 26º48'20''E and 38º24'21''N 26º47'49''E) in İzmir Bay in the eastern Mediterranean at depths of approximately 30 m on 11 September, 2007 (Fig. 1).

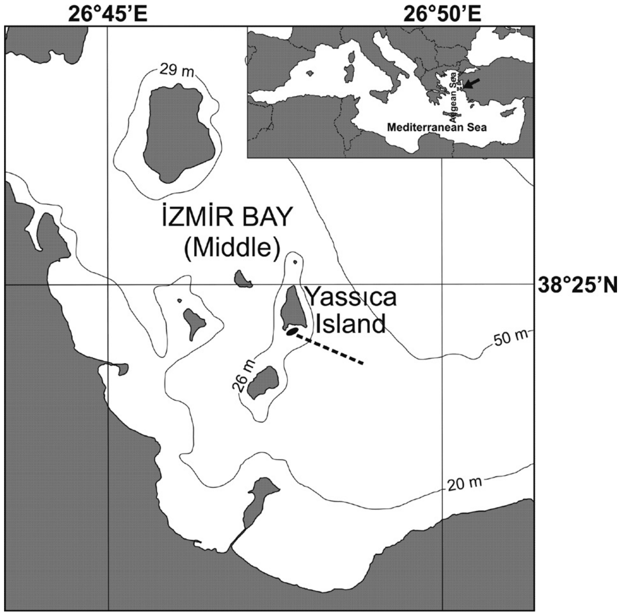

Fig. 1. – Study site: The ellipse and the dotted line indicate observation cages and the trawling route respectively.

Three open codend and three test hauls were carried out in one day with the R/V Egesüf (26.8 m length, 500 HP engine). The mean towing speed was 2.28±0.07 knots and a constant towing duration of 15 min was used for all hauls (in commercial trawling, the towing duration and speed vary between 1 and 6 h, and between 2.5 and 3.0 knots respectively). The fishing gear used was a conventional bottom trawl with 600 meshes around the mouth, a 40 mm stretched codend mesh size (200 meshes around the circumference) and a 5 m stretched length (see Metin *et al*., 2004 for a technical details). The twine material of the codend was polyethylene (PE) with a 1.27 mm diameter. Covers were used to retain escapees and as observation cages. The covers were made of knotless polyamide (PA) netting with a 24 mm stretched mesh size. They were 7.5 m in length and had a maximum circumference of 450 meshes. The covers were supported by two HDPE (High Density Polyethylene) hoops that were 1.6 m in diameter. A 1 m long zip was mounted on the cover netting between the two large hoops to collect deceased fish from the cages and to feed the survivors.

The trawl codend was left open to collect control fish. Thus, the fish that entered the codend also entered the cover without having to penetrate the codend meshes (OC). In the test hauls the cod line was tied like in the commercial fisheries, so all the escapees in these hauls had to penetrate the codend meshes (E). The experimental protocol for collecting and monitoring fish was similar to that previously used in the Aegean Sea by Metin *et al.* (2004). At the end of each tow, the cover was detached from the codend by cutting the rope connecting the cover and the codend, then it was attached horizontally to the sea bottom by divers (Fig.

2) for use as an observation cage at depths of 19 to 28 m (anchoring depths of experimental and control cages were as follows: E_1: 25 m; E_2: 22 m; E_3: 20 m; OC_1: 20 m; OC_2: 28 m; and OC_3: 19 m). To prevent anoxia by providing a maximum possible cage volume, the cages were stretched from one end to the other using ropes and wooden rods. After the cages had been installed, octopuses and rays were removed from the open codend cages by divers to minimise predation. The cages were observed by divers three times a day; the fish that were still alive were fed and the dead individuals were collected during the study period. Total (*TL*) and standard lengths (*SL*) of the mortalities were measured in 0.5 cm length groups.

Fish were monitored for 7 days, which may not have been long enough to demonstrate all the mortalities of some of the more fragile species. However, we chose an observation period of seven days as in a previous study carried out by Metin *et al.* (2004) because the majority of the deaths of the study species occurred within the first two to three days after capture (as in Sangster *et al*., 1996) and no behavioural or physical abnormalities were observed in the last days of the monitoring period. For this reason, the cages were lifted up on the eighth day, and fish were identified to the species level, and their *TL* and *SL* measurements were taken. The *SL* values of the specimens with damaged tail fins were converted to *TL*. In some cases, even the *SL* of some deceased fish could not be measured due to the significant loss of body parts.

The percentage of surviving fish (*S*p) was calculated as $Sp = 100\ (n_s / n)$, where n_s is the number of survivors and n is the total number of fish (dead fish + survivors) in an open or test codend cage. To determine differences in survival rates in the different length classes between the fish in the open and test codends, non-parametric (Kolmogorov-Smirnov) statistical analyses were conducted using the SPSS 13.0 software package (SPSS Inc, 2004).

RESULTS

Catch composition and behavioural observations

Six trawl hauls (three open codend and three test cages) were successfully performed. The weather conditions were variable (with a Beaufort scale of 1-7) during the observation period. The bottom temperature around the cages was approximately 24ºC throughout the monitoring period. In the experiments, 28 fish species belonging to 17 families were caught in the codend and 16 species belonging to 10 families were caught in the cover. Although 16 fish species escaped through the meshes during the study, here we focus on three species that had sufficient data for a statistical analysis. In terms of the number of fish, 31% of the catch consisted of the following three fish species: *S. hepatus* (12%), *G. niger* (11%) and *D. annularis* (8%).

During the first observation after the installation of the cages, annular seabream and brown comber actively swam in groups. Black goby kept closer to the bottom of the cages and were generally active. Brown comber individuals, which are carnivorous and are able to live in a variety of habitats, were found to adapt to

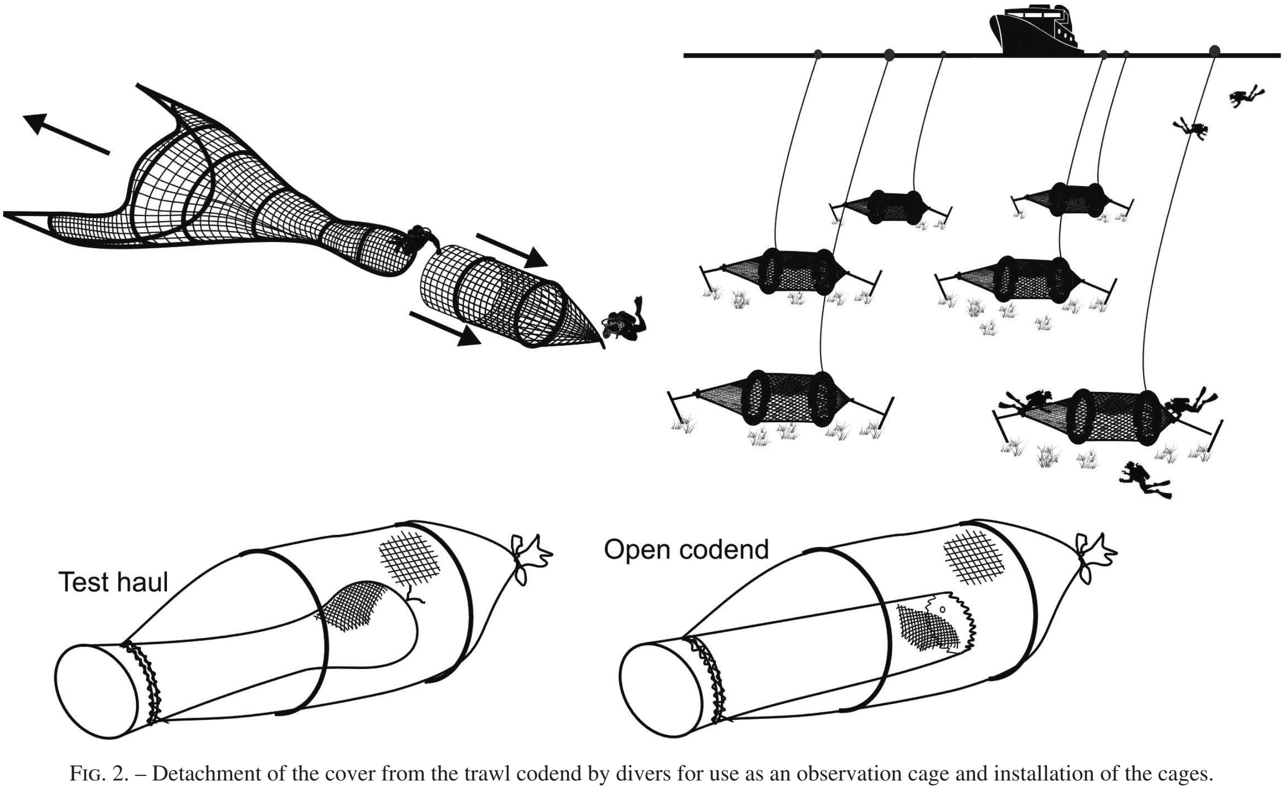

FIG. 2. – Detachment of the cover from the trawl codend by divers for use as an observation cage and installation of the cages.

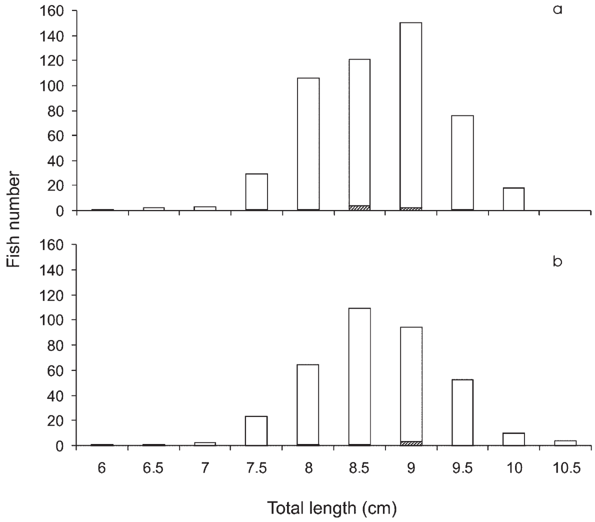

Fig. 3. – Numbers of dead (black) and surviving (white) brown combers (*Serranus hepatus*) in each length class for the combined data of the open codend (a) and test (b) cages (four fish in the open codend cage could not be measured).

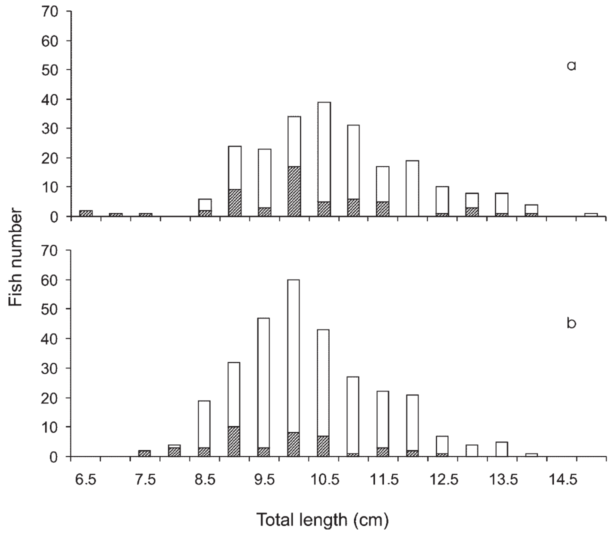

Fig. 4. – Numbers of dead (black) and surviving (white) black goby (*Gobius niger*) in each length class for combined data in the open codend (a) and test (b) cages (28 and 26 fish in the open codend and test cages respectively could not be measured).

their new medium earlier than the other fish. This species was found to be vigorous and aggressive in the cages, although it was smaller than the other captured fish. Some badly scaled fish were observed to remain apart from the shoal and in the following days, parts of these fish (tail, fin, head, etc.) were eaten by healthy specimens of brown comber, annular seabream, two banded seabream (*Diplodus vulgaris*) and cuttlefish (*Sepia officinalis*).

Brown comber

The total numbers of brown comber in the open codend and test cages were 510 and 360 respectively. Length measurements could not be taken of four individuals in the open codend cage due to the loss of significant body parts. The *SL* was measured and converted using the equation "$TL = 1.0633SL + 1.1569$". In the three experimental tows, 25 individuals were retained in the codend. Most of the individuals in the cages were in the 8.5 to 9.0 cm length groups (Fig. 3). The deceased fish found in the two test cages ranged from 8.0 cm to 9.0 cm in length: four were observed in E_2 and one in E_3. Survival rates were 100.0, 96.7 and 98.3% (mean, 98.3%; s.d. = 1.65) in the E_1, E_2 and E_3 test cages respectively (Table 1). The mean survival percentage for the three open codend cages was estimated to be 97.1% (s.d. = 2.18). Among the small fish (<9.0 cm) in the test cages, only a small number of brown comber died during the experiment, while mortalities were observed among the fish less than 9.5 cm in the three open codend cages. There was no significant difference in mean survival rates in the length groups between the open codend and test cages (p>0.05).

Table 1. – Total number (n) of brown comber, black goby and annular seabream, shown along with the number of mortalities (n_m) and the survival percentages (*S*p) for each cage.

Species		OC_1	OC_2	OC_3	E_1	E_2	E_3
Brown comber	n	202	125	183	176	124	60
	n_m	1	6	6	0	4	1
	*S*p	99.5	95.2	96.7	100.0	96.7	98.3
Black goby	n	81	75	100	97	130	93
	n_m	16	15	53	13	17	39
	*S*p	80.2	80.0	47.0	86.6	86.9	58.0
Annular seabream	n	103	8	115	24	9	1
	n_m	5	0	3	1	0	0
	*S*p	95.1	100.0	97.4	95.8	100.0	100.0

Black goby

The total numbers of black goby in the open codend and experimental cages were 256 and 320 respectively (Table 1). Length measurements could not be taken of 28 and 26 individuals in these cages respectively due to a significant loss of body parts. *SL* was measured and converted to *TL* using the equation "$TL = 1.226SL + 0.0134$". In the three experimental tows, a total of 230 individuals was retained in the codend. In the test cages, the highest number of individuals was in the 10.0 cm length group, whereas fish were between 10.0 and 10.5 cm in length in the three open codend cages (Fig. 4). Mortalities of fish ranging in length from 7.5 cm to 12.5 cm were found in the test cages: 13 were found in E_1, 17 in E_2 and 39 in E_3, resulting in survival rates of 86.6, 86.9 and 58.0% (mean, 77.2%, s.d. = 16.60) for black goby respectively (Table 1). The survival rate of E_3 was lower than that of E_1 and E_2, while the survival rate of OC_3 was lower than that of the two other open codend cages. The mean survival rate was 69% (s.d. = 19.11) for the three open codend cages. There was a significant difference between the control and test

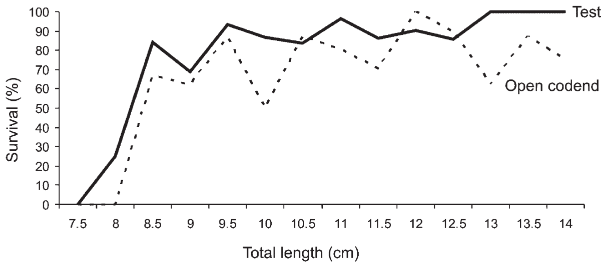

FIG. 5. – Black goby, relationship between fish length and the survival percentages of black goby in the open codend and experimental cages.

cages in terms of the mean survival rate in the different length groups (p<0.05). Figure 5 demonstrates the relationship between fish length and the survival percentages in the open codend and experimental cages.

Annular seabream

The total numbers of annular seabream in the open codend and experimental cages were 226 and 34 respectively. Length measurements could not be taken of one individual in the open codend cage due to a significant loss of body parts. A total of 366 individuals was retained in the three experimental tows. The mean survival rates for the three open codend and test cages were estimated as 97.5% (s.d. = 2.45) and 98.6%, (s.d. = 2.42) respectively. In Figure 6, (a) and (b) show the number of dead and surviving fish in each length class for the combined data of the open codend and test cages respectively. Table 1 shows the numbers of dead and surviving fish, as well as the survival percentages for the open codend and test cages separately. Although there were few data for the three test cages, the mortality was negligible among the small fish (<11 cm) in the open codend and test cages.

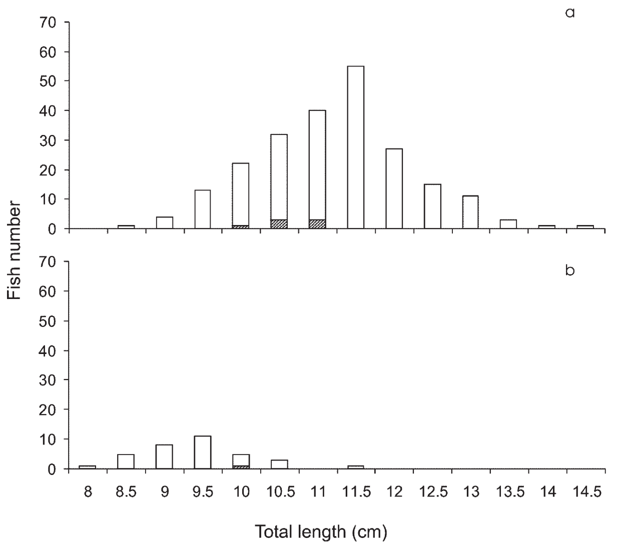

FIG. 6. – Annular seabream (*Diplodus annularis*), numbers of dead (black) and surviving (white) fish in each length class for the combined data of the open codend (a) and test (b) cages (one unmeasured fish was found in the open codend cage).

DISCUSSION

Measuring the survival of fish that have escaped from trawl codends under various and complex fishing conditions requires long term studies with a high survey effort (Suuronen, 2005; Suuronen *et al.,* 1996). Although methodologies have been improved and standardised to increase survival (Lehtonen *et al.,* 1998), the mortality of fish after they have escaped from trawl codends can be affected by factors such as mesh size and shape, fish species and fish size (Broadhurst *et al.*, 2006). In the present study, only one mesh size was used to estimate the survival of three fish species, two of which have never been studied in this context.

The methodology used in this experiment is the same as the methodology developed by this research team for a previous study in which the survival of red mullet was investigated (Metin *et al.,* 2004). Under the fishing conditions outlined in the Materials and Methods section and for the population fished, it was considered that the best results would be obtained with 15 min tows, as this is the minimum duration required to catch reasonable amounts of the target species. A longer towing duration would have led to more of the target species being caught; however, the sampling time for experiments to determine survival after escape is known to have a significant effect on the subsequent survival of the fish (Suuronen*,* 2005). Therefore, the main reason for limiting the towing duration to 15 min was to minimise the exhaustion caused by swimming after escape. In the present experiment, open-codend hauls were used to collect control fish. Although this technique itself is likely to cause additional injuries, due to the difficulty of obtaining similar size ranges of live target animals by any other fishing method, the control group had to be collected by trawling. Trawl-caught controls were also used by Ingolfsson *et al.* (2002) and significantly higher numbers of mortalities in comparison with trap-captured fish were reported. The most important advantage of trawl-caught control fish is that they experience all aspects of the experiment except for escaping from the codend. In addition, most biological characteristics, i.e. length, age, condition etc., would be very similar to the test cage population. In this experiment, the potential effect of the number of replicates (3 hauls) on the reliability of the results might be of concern. Three replicates are not much; however, because the survival was generally high, it can be regarded as sufficient.

Most studies of escape mortality have been performed for commercial fish escaping from the codend of demersal trawls (Sangster *et al.,* 1996; Suuronen *et al.,* 2005; Ingólfsson *et al.,* 2007).

The most studied group of fish are gadoids and in particular cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*) and whiting (*Merlangius merlan-*

gus), and in most studies the survival of these species has been relatively high although variable (Main and Sangster, 1990; Sangster *et al.,* 1996; Suuronen *et al.,* 2005; Ingólfsson *et al.,* 2007). Studies of species such as herring (*Clupea harengus*) suggest that the escape mortality of small pelagic fish may be high (e.g. Suuronen *et al.,* 1996). Species-specific variation in escape mortality has been reported by several researchers (Broadhurst *et al*. 2006; Ingólfsson *et al*., 2007).

Our results show that mortalities vary with the different fish species, although the exact causes of variation have not yet been explained. The mean mortalities of brown comber and annular seabream escaping from the 40 mm nominal stretched diamond mesh codend were less than 1.7 and 1.4% for the experimental cages respectively. In a previous study carried out in the Aegean Sea, the survival ratio of annular seabream was estimated as 100% for the same season (Tokaç *et al.,* 2006). The observed escape mortality of black goby was higher (mean 22.8%) than the two other species in the experimental cages.

Some fish have been reported to have a greater capacity to survive under many different conditions (skin damage, captivity stress, etc.) (Ryer *et al.,* 2004), which could not be investigated in the present study due to time constraints and needs to be studied in future works. In our experiment brown comber and annular seabream had a higher resistance to mortality in comparison to the black goby. Likewise, differences in mortality among three fish species (cod, haddock and saithe) were reported by Ingólfsson *et al.,* (2007). Mortality may differ considerably even for the same fish species in that experiment. In the present study, mortalities of brown comber and annular seabream were lower than 5% in both the open codend and experimental cages. However, differences in mortality amongst the experimental and open codend cages were between 13 and 53% for black goby. Survival depends on fish size in most studies (Suuronen, 2005). However, some experiments have found no significant relationship between fish length and mortality (Suuronen *et al.,* 2005). Nevertheless, many studies have shown an inverse relationship between skin injury and fish size. The general trend is that escape mortality is inversely related to fish length (Sangster *et al.,* 1996; Suuronen, 2005, Ingólfsson *et al.,* 2007). In the present study, this relationship was observed only for black goby, as there were very few mortalities for the other two species. A total of 576 black goby, ranging in length from 7.5 to 15.0 cm, were sampled during the experiments in all cages. Although length measurements of individuals could not be taken from 28 of the open codend fish and 26 of the fish in the experimental cages due to a significant loss of body parts, the percentage of mortality tended to be higher among the smaller fish (Figure 5).

During the experiments, 28 fish species were caught in the codend and 16 fish species were caught in the cover. Determining fish survival was not an easy task for all of the various species and size groups in the observation cages. Although divers removed predators such as *Raja clavata, Octopus vulgaris*, *Conger conger* as soon as possible after the open codend cages were deployed, predators caught in the trawl probably caused additional stress to the target fish species. The lower survival rate in the open codend cages may have resulted from differences in catch composition and the relatively high fish intensity in these cages in comparison to the experimental cages. In addition, the speed of water flow through the open codend is likely to have been higher than that in the test hauls and thereby fish in the open codend cages may have suffered more skin damage inside the trawl. This may explain part of the observed results.

The standard lengths of some of the deceased fish could not be measured because significant body parts had been eaten, and therefore these fish were only counted. Although this case does not affect the survival rate of fish, unmeasured fish could cause some problems in determining the differences in the survival rates of the length groups between the open codend and test cages. To avoid these problems in future studies, the number of observations per day could be increased. However, this would require more dive time and could cause additional stress to the caged fish.

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