A PRELIMINARY STUDY ON THE SURVIVAL OF BROWN COMBER, *SERRANUS HEPATUS* (ACTINOPTERYGII, PERCIFORMES, SERRANIDAE), ESCAPING FROM THE CODEND OF A BOTTOM TRAWL

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Background. Poor selectivity of trawl cod-ends has been a major problem of the modern-day fisheries, contributing to destruction of non-target organisms. It is expected that increased trawl selectivity can reduce bycatch and discards. This would only be true if significant numbers of the escaping fishes survive. The chances of survival of many species after escaping the trawl cod-end are still poorly known. This study was aimed at providing mortality estimates of brown comber, *Serranus hepatus*, escaping from two different demersal trawl cod-ends (40 mm diamond and square) in the Aegean Sea. We also looked at possible seasonal variation in the survival rate of escaped brown comber (diamond mesh).
Materials and Methods. Two experiments were conducted off the Yassıca Island, İzmir Bay (Aegean Sea, Turkish coast): in winter 2007 and summer 2008. Five hauls were performed in winter (January–February 2007), and nine hauls in late summer (September 2008). Sampling time was 15 min, except for a control cage in 2007 experiments.
Results. No significant difference in the mortality of brown comber for 40 mm diamond mesh cod-end was demonstrated between the winter (2.2 percentage points) and the summer (1.9 percentage points). Throughout each period of this experiment, the survival of escaping brown comber showed a length-dependent mortality, with the majority of dead fish being less than 8.8 and 9.4 cm in length for diamond and square test cages, respectively. The experiments carried out in 2008 demonstrated that the survival of brown comber for diamond and square test cages was generally very high (98.1% and 82.9%, respectively).
Conclusion. The escape mortality of brown comber was negligible for two different cod-ends and seasons.

Keywords: brown comber, *Serranus hepatus*, benekli hani, escape mortality, diamond cod-end, square cod-end, seasonal variation

INTRODUCTION

Demersal trawling in Turkish Coasts is performed on the grounds where more than 50 species encounter the gear (Tosunoğlu et al. 2003b). Similarly, it has been reported that trawl fisheries is generally multispecies in the Mediterranean Sea (Tudela 2004). A considerable amount of fishes such as annular seabream, (*Diplodus annularis*) (see Özbilgin et al. 2005), black goby (*Gobius niger*), red bandfish (*Cepola macrophthalma*) (see Lamprakis et al. 2003) end up as discard or bycatch in the bottom trawl fishery that targets the marketable demersal species. One of the reported discard fishes captured by bottom trawls (Lamprakis et al. 2003) is brown comber, *Serranus hepatus*, which is a species of a minor commercial (Froese and Pauly 2009). Minimum landing size (MLS), which is designed to allow escapement of undersized fish, for this species is not specified in the Turkish Fisheries Regulations (Anonymous 2008). Discard of trawl fisheries are commonly a result of conventional diamond mesh cod-ends regarding MLS of the target species (Graham and Kynoch 2001). In Turkish waters, large amount of bycatch and discard where reported by Tosunoğlu et al. (2003b) and Metin et al. (2005). According to the present legislation, minimum trawl cod-end mesh sizes are 40 mm for the Black Sea and 44 mm for the Aegean Sea and the Mediterranean Sea (Anonymous 2008). The fate of fish such as brown comber, in terms of unaccounted fishing mortality, is

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related with not only a potential source of discarding of unmarketable bycatch, but also escaping from fishing gear resulting in deaths (Breen 2004).

Poor selectivity of conventional trawl cod-ends has recently been a major problem in Turkish fisheries (Tosunoğlu et al. 2003b, Metin et al. 2005). Alternatively, improving the cod-end selectivity is a crucial conservation instrument to minimise bycatch and discard fish and ensure fish reach their optimal size before capture (Suuronen 2005). For that reason, a great number of studies have been conducted on trawl cod-end selectivity since the mid 1990s. Particularly, 40 mm nominal mesh size PE (Polyethylene) cod-end has been investigated in the Aegean Sea (Lök et al. 1997, Tokaç et al. 1998, 2004, Tosunoğlu et al. 2003b, Metin et al. 2005, Özbilgin et al. 2005). Only a few studies on other trawl cod-ends or improved cod-ends with escape panel (Metin et al. 2005) and sorting grids (Aydın et al. 2008) had been carried out in Turkish waters. Although those studies can find solutions to the poor selectivity of commercially used trawl cod-ends, to ensure that selective fishing gears are working efficiently, it is important to demonstrate that escaping fish can survive. These selectivity studies will only work if escaping fish survive and grow up to sustain the exploited fish population (Suuronen 2005).

A considerable amount of studies of escape mortality have been conducted over the past two decades (Main and Sangster 1990, Suuronen et al. 1995, Sangster et al. 1996, Ingólfsson et al. 2007). Among those works, mainly, the escape mortality has been observed with gadoids, particularly whiting (*Merlangius merlangus*) (see Sangster et al. 1996, Broadhurst et al. 1997), haddock (*Melanogrammus aeglefinus*) (see Sangster et al. 1996), Atlantic cod (*Gadus morhua*), and saithe (*Pollachius virens*) (see Ingólfsson et al. 2007).

Information on survival rates is only available for red mullet, *Mullus barbatus* (see Metin et al., 2004), annular seabream (*Diplodus annularis*), and axillary seabream, *Pagellus acarne* (see Tokaç et al., 2006). No information on survival rates for any other frequently discarded species has been reported so far.

The mortality levels of the fishes escaping from demersal trawl cod-end are predominantly affected by: species-related mortality, fish size, mesh size and shape, water temperature, and cod-end catch (load) (Suuronen 2005). A number of survival studies have been conducted, however, to particularly demonstrate a relation between the escape mortality and increasing mesh size (Sangster et al. 1996). Those studies demonstrated that the mesh shape had more effect on the fish mortality than the mesh size (Main and Sangster 1990). Despite, a great deal of survival studies performed in various seas, the effect of mesh size and shape poorly understood, at least for various demersal fish species.

Until now, the escape mortality of brown comber has not been studied in the Mediterranean. In the presently reported study the effects of season and cod-end mesh shape were investigated for this fish species. The prime goal of this study was to provide survival data to investigate the effect of seasonal variation of fish after escape from 40 mm diamond cod-end. Secondly we wanted to determine the effect of mesh shape on the mortality of brown comber, using two different PE cod-ends (40 mm diamond cod-end and 40 mm square mesh cod-end).

MATERIALS AND METHODS

Two experiments were conducted off the Yassıca Island (Fig. 1) in İzmir Bay (Aegean Sea, Turkish coast) during the periods 29 January–5 February 2007, and 11–18 September 2008. A research vessel, *R/V EGESÜF* (26.8 m length, ~372 kW engine) was used for trawling operations. A total of 14 hauls were done in 2007 and 2008, located between lat 38º23′–38º24′N and long 26º47′–26º48′E. Trawl route and trawl speeds (2.0–2.5 knots) were calculated from position fixes with a global positioning system (GPS). The trawl began fishing in water depths of approximately 25–30 m and then the operation was terminated in a depth of between 10–20 m. The first part of the experiment was carried using with two control cages and three test cages in winter. Two different tow durations (5 and 15 min) were performed to find appropriate sampling time which may have an affect on the survival probability of brown comber. The next year, three control and six test cages were used in the end of the summer. Escaping fish were sampled and retained for the total duration of the fishing tow, which was 15 min in all cases, except for the first control cage of the winter season. The cod-end catch from each test tow was sorted to species and weighed. The experimental protocol for collecting and monitoring fish after escape from a trawl cod-end was similar to the method used by Metin et al. (2004) (Fig. 1).

In the 2007 experiments, the fishing gear was a conventional bottom trawl with 600 meshes around the mouth and having a 40 mm nominal diamond mesh size (DM) cod-end (200 meshes around the circumference and 5 m stretched length) (Metin et al. 2004). A tailored bottom trawl with 700 meshes around the fishing circle was used in 2008. In the second experiments, two different PE cod-ends; 40 mm nominal diamond mesh size and 40 mm square mesh size (SM) cod-end (100 bars around circumference and 5 m in length) were tested. Cod-end covers were used to catch cod-end escapees. Cod-end was left open during the control hauls. The control group passed through the trawl and entered the cover. These covers were made of knotless polyamide (PA) netting in 24 mm mesh size. They were 7 m in length and 450 meshes around the circumference at the maximum diameter. The covers were supported by two HDPE (High Density Polyethylene) hoops in 1.6 m diameter. Three horizontal openings with a length of ~1 m were constructed on the cover netting to collect dead fish from the observation cages and feed the survivors. Each access opening was closed using a thin braided polyester (PES) rope woven through the netting meshes.

At the end of the haul, the cover was detached from the trawl by divers; a method that has been successfully employed in other studies (e.g., Sangster et al. 1996).

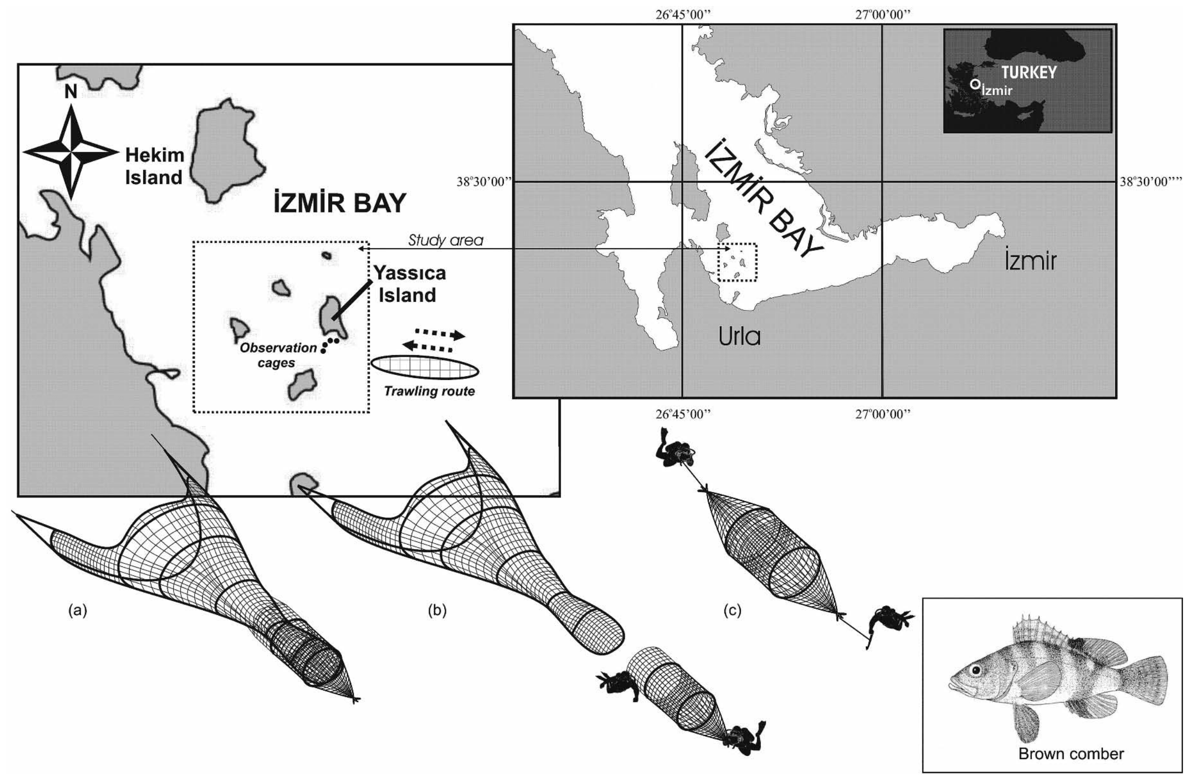

Fig. 1. The study area and a schematic diagram of a demersal trawl, illustrating the sampling processes: (a) A demersal trawl with codend cover attached; (b) Detaching the cover from the codend by divers; (c) Installing the cover as an observation cage

Also, the cover was moved slowly through the water to minimise enforced swimming among the already fatigued fish in the cover. Although it was observed that while detaching the cover fish made an effort to swim to the surface and head of net. To ensure the stability of the observation cages and maximise the volume of the containment area, the cages were stretched out on the seabed by using ropes and wooden rods. These installation rods were pounded into the soft bottom by divers using a hammer.

The observation period was set to 7 days, based on experience from earlier experiments (Metin et al. 2004). For the next seven days, the cages were observed by divers three times a day; dead fish were collected and any surviving fish were fed. All dead fish were transferred to the laboratory for measurement. During the first observation dive, octopuses and rays were removed from each cage to avoid injury and predation of the remaining fishes. At the end of the seven-day monitoring period (on the morning of day 8), the cages were retrieved and put on the deck of the research vessel, *R/V EGESUF*. Surviving individuals of brown comber, for which mortality was negligible, were counted and weighed. The number of fish along with information of their size ranges, mean length, and standard deviation (SD) of the size distribution are provided. Total body length of dead and live brown bomber was measured to nearest 0.1 centimetres. Survival probability were calculated as, $Sp = 100\ (n_s \cdot n^{-1})$ where n_s is the number of survivors, and n is the total number of fishes in a cage (dead fishes + survivors). Both parametric (Student's *t*-test and one-way ANOVA) and nonparametric (Kruskal–Wallis) statistical analyses were completed by using the SPSS 13.0/2004 software package (SPSS Inc.).

RESULTS

2007 experiments. Five trawl hauls (two control and three test cages) were successfully performed in winter experiments. All observation cages were retrieved on day 8 (5 February). The weather conditions were variable (wind: 1–7 Beaufort scale). Bottom temperature around the cages was recorded about 13ºC. During the first observation after installation of the cages, individuals of brown comber were seen swimming in groups vigorously (Fig. 2). However, in next day, they were seen to be adapted to their new medium and kept on swimming in groups actively. Following days some parts (tail, fin, head, eyes etc.) of badly injured fish were eaten by healthy individuals of brown comber, which are aggressive and carnivorous, in the cages. Fish behaviour was similar among observation cages.

In the experiments, a total of 28 fish species were caught in the cod-end and 16 species were caught in the cover. In the catch composition, in terms of numbers of individuals, red mullet was the most abundant species, followed by brown comber with 895 individuals. In the catch composition, as illustrated in Fig. 3, the highest number of fish was in the 9 cm length group. Dead fish ranging in length from 7.0 cm to 9.0 cm, were found in the test cages: 2 in DM1, 3 in DM2, and 1 in DM3, resulting in survival rates of 98.2%, 96.3%, and 98.9% for brown comber in those test cages, respectively (Table 1). There was no significant difference in survival rates among the test cages ($P > 0.05$). An average pooled mortality in the test cages was 2.2%.

The measurements of an individual of brown comber could not be taken due to loss of significant body parts. 5 min and 15 min hauls were conducted for two control cages. There was no difference between the survival rates of control cages for brown comber. Five fish, ranging in length from 8.5 cm to 9.5 cm, were found dead in the two control cages: 1 in C1-5 min and 4 in C2, resulting in survival rates of 98.9% and 98.3% for brown comber in those control cages, respectively. Fig. 4 shows the number of all fishes and dead individuals in the control and test cages. Lines indicate that the number of fish escaped but dead. The all observed mortality in the test cages occurred within the first 2 days. The mortalities of the control cages stopped at the end of the first 24 h. The negligible mortality of brown comber was observed among the small fishes (<8.8 cm) in the test cages (DM), while mortalities occurred amongst the small fishes less than 9.6 cm in the two control cages.

2008 experiments. All cages were retrieved on the morning of 18 September 2008. The sea condition was calm and water temperature was approximate 24ºC around the cages. The cages were fixed at water depths of approximately 10 m. During the first observation, no difference in fish swimming and behaviours was observed among the cages in 2007 and 2008 experiments.

In the study, 29 species were caught in the cod-end and 25 species were caught in the cover. In the catch composition, in terms of numbers of individuals, blotched picarel (*Spicara maena*) was the most abundant species, followed by red mullet, annular seabream, and brown comber (in total 925). As shown in Fig. 5, the highest number of individuals was captured in the length group of 8.5 cm among all the hauls. There were 4 dead brown comber in SM1, 13 in SM2, 9 in SM3, 3 in DM2, and 1 in DM3, resulting in survival rates of 93.1%, 81.4%, 74.3%, 94.8%, and 99.3% in those test cages, respectively (Table 2). A total of 18 brown comber, ranging in length from 6.0 cm to 9.1 cm, were found dead in the three control cages: 4 in C1, 11 in C2, and 3 in C3, resulting in survival rates of 97.3%, 80.0%, and 98.1% in those control cages, respectively.

The mean survival rate for test cages was higher (98.1%) for the diamond mesh than the square test cages (82.9%) and control cages (91.8%). The survival rates among the observed cages showed little variability. However, there was no significant difference in survival rates between the diamond test cages and the square test cages ($P > 0.01$). Fig. 6 demonstrates the number of all fishes and dead individuals in the three control and six test cages. Lines show the number of fish escaped but dead in length groups. The survival probability for brown comber in the test cages was positively associated with fish length shown in Fig. 7. It was concluded that the mortality of

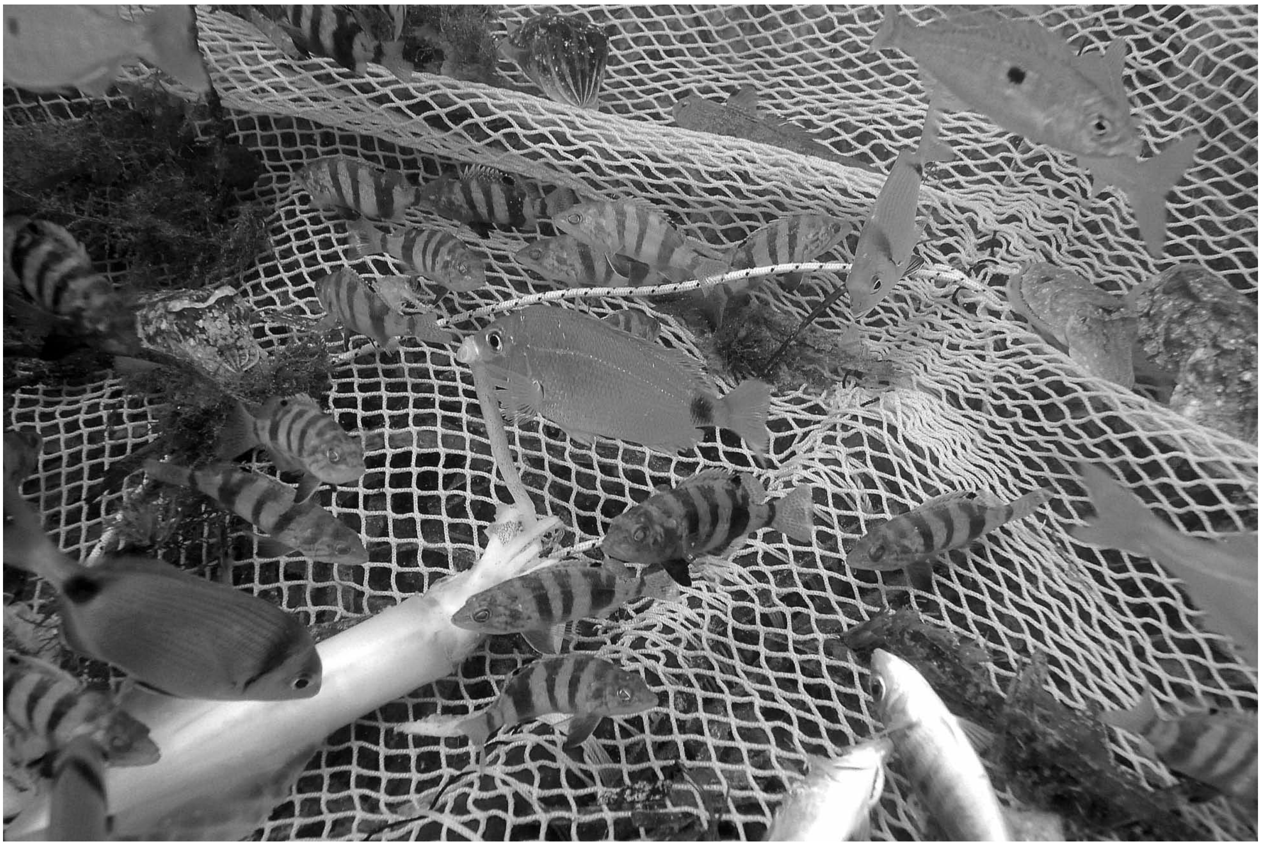

Fig. 2. An internal view of the control cage: during the observations, brown comber (*Serranus hepatus*) two banded seabream, (*Diplodus vulgaris*) individuals and some blotched picarel (*Spicara maena*) were swimming actively, whereas cuttlefishes (*Sepia officinalis*) were remaining on the bottom of knotless net. A specimen of annular seabream was feeding on a tentacle of dead squid (*Loligo vulgaris*) and few of picarel were dead

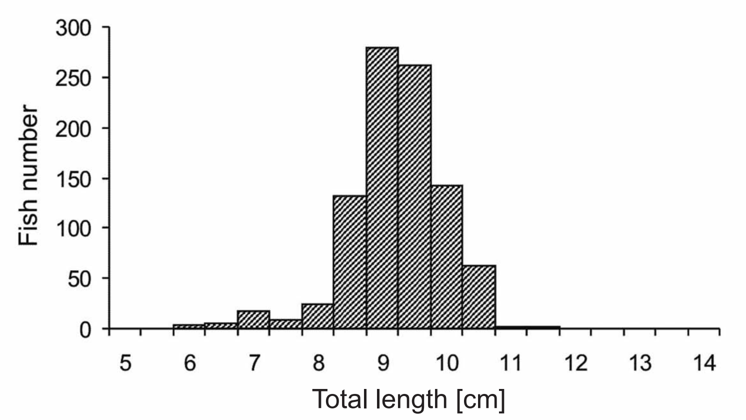

Fig. 3. Length frequency distribution of brown comber (*Serranus hepatus*) in winter (control and test cages)

Table 1

Number, survival rate and data of brown comber (*Serranus hepatus*) from the observation period in the survival experiment in 2007

	Control cages		Test cages		
	C1 – 5 min	C2	DM1	DM2	DM3
Number of mortalities*	1	4	2	3	1
Survivors (n_s)	94	234	109	77	86
Number of fish (n)	95	238	111	80	87
Survival (*Sp*, %)	98.9	98.3	98.2	96.3	98.9
Mean length [cm]	8.8	9.1	8.7	8.7	9.0
Min length [cm]	7.6	6.9	6.5	6.5	6.5
Max length [cm]	10.5	10.9	10.0	10.4	10.4
SD	0.46	0.81	0.70	0.86	0.79
~Anchoring depth [m]	18	17	19	24	26

*1 dead fish could not be measured in DM3.

brown comber in the diamond test cages for two experiments (2007 and 2008) was very low (mean 2.2% and 1.9%) and survival probability was unrelated to the seasonal variation ($P > 0.05$).

The mortality rate of fish generally decreased during the 7-day observation period. The highest mortality rate (between 50.0% and 100% of the total observed mortality) of brown comber was observed in the first day for most control cages. The tendency for high mortality in the first day was repeated in five of all the test cages (SM1, SM2, SM3, DM2, and DM3) resulting in 75.0%, 69.2%, 55.6%, 100%, and 100% mortality, respectively. The mortality of brown comber was observed predominantly among the small fishes (<9.4 cm) in the square test cages, while mortalities occurred amongst the fish smaller than 8.5 cm in the diamond test cages (Fig. 7). In the control cages, mortalities were observed among the fish smaller than 10 cm. The size-dependent mortality was observed among the test cages in both seasons.

DISCUSSION

Discarding of unmarketable bycatch is considered one of the most important potential sources of fishing mortality for various species, including those of major commercial and recreational fisheries (Suuronen et al. 1996b, Breen 2004). Improving the selectivity of fishing gear to reduce the bycatch and discards has been one of the main management tools for sustainable fisheries (Tosunoğlu 2003a, Suuronen 2005, Ingólfsson et al. 2007). Although in trawl fishery it is allowed that considerable amount of fish escape passing through trawl cod-ends, the process will only work effectively if escaping fish could survive (Breen 2004, Suuronen 2005). For this reason, investigating the survival probability of escaping fish is a vital to assess a part of unaccounted fishing mortality. The escape mortality of some commercial fish, particularly haddock (*Melanogrammus aeglefinus*) (see Main and Sangster 1990), whiting (*Merlangius merlangus*) (see Sangster et al. 1996) and Atlantic cod (*Gadus morhua*) (see Suuronen et al. 2005, Ingólfsson et al. 2007), had been studied over the past 15 years. The interaction between the observed mortality of those species and some factors (e.g., fish size, species, mesh size and shape, and water temperature) had been investigated (Main and Sangster 1990, Ingólfsson et al. 2007). However, such information is rather limited for the Mediterranean species such as brown comber, which is a minor commercial, presented in the study.

However survival methodology has been improved by Lehtonen et al. (1998), the mortality of fish after passing through and escaping from the trawl cod-ends can be affected by the main factors as mentioned above. In our study two different mesh shape cod-ends has been used

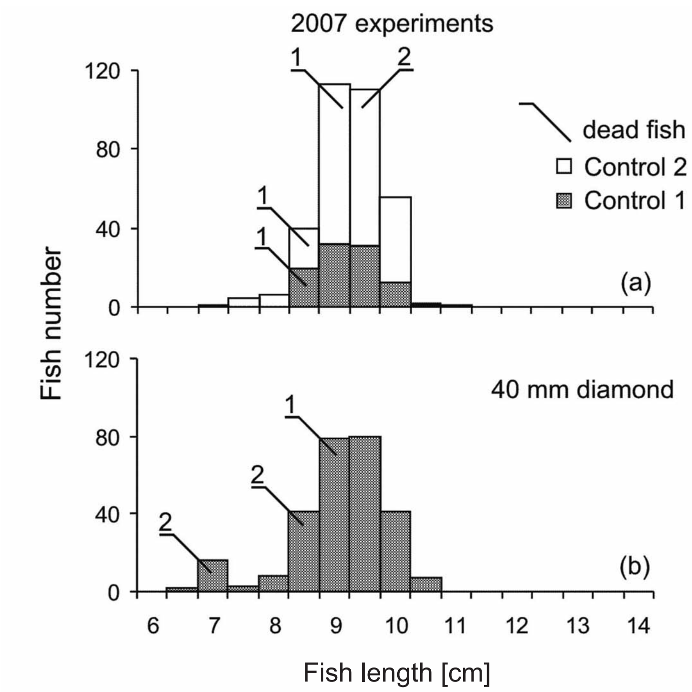

Fig. 4. Population of brown comber (*Serranus hepatus*) of the cod-ends and covers in 2007 experiments: (a) numbers of fish and dead in each length class for control 1 and 2 (b) numbers of fish and dead in each length class for combined data of test cages

Table 2

Number, survival rate and data of brown comber (*Serranus hepatus*) from the observation period in the survival experiment in 2008

	Control cages			Test cages					
	C1	C2	C3	SM1	SM2	SM3	DM1	DM2	DM3
Number of mortalities*	4	11	3	4	13	9	—	3	1
Survivors (n_s)	145	44	152	54	57	26	145	55	143
Number of fish (n)	149	55	155	58	70	35	145	58	144
Survival (*Sp*, %)	97.3	80	98.1	93.1	81.4	74.3	100	94.8	99.3
Mean length [cm]	8.5	9.1	8.5	9.0	8.9	8.8	8.5	8.6	8.2
Min length [cm]	7	7.8	6.0	7.7	7.1	7.9	7.1	7.3	7.1
Max length [cm]	10.2	12.7	10.8	10.2	10.4	10.0	10.6	10.2	10.0
SD	0.69	0.72	0.70	0.59	0.64	0.54	0.59	0.73	0.58
~Anchoring depth [m]	12	10	7	9	8	8	15	12	9

*1, 4, 2, and 2 dead fish could not be measured in C1, C2, SM2, and SM3, respectively.

different from Metin et al. (2004) to estimate the relationship among water temperature, mesh shape and the survival of brown comber data. It has been reported that some fish species have a greater capacity to survive many factors (injury, captivity stress, predation, etc.) (Ryer et al. 2004) like brown comber in the present study. Ingólfsson et al. (2007) also reported such differences of mortality among three fish species that although cod and saithe (*Pollachius virens*) were capable of surviving after their escape from the trawl, haddock was more vulnerable. It was clear that brown comber have high capability of surviving after escape from the cod-ends.

The mortality of brown comber in the test cages for two experiments (2007 and 2008) was very low and survival probability was unrelated to the seasonal variation. Likewise, the observed mortalities of brown comber were negligible in the control cages in the winter period. In the previous study, it was reported that the higher mortality was likely to be caused by the much higher density of the fish in the control cage (Metin et al. 2004). Although the different tow durations, the mortality of brown comber (C1–5 min; 1.1% and C2–15 min; 1.7%) was not affected by sampling time and the cod-end catch size. However, as reported by Breen et al. (2002), the sampling time in such experiments has a significant effect on the subsequent survival of the fish. It is concluded that the effect of tow duration on escape mortality should be surveyed in more detail. This mortality may be affected by some factors such as the cod-end catch size and composition, the towing speed, the netting material of the gear, and hauling and handling processes (Suuronen 2005).

As illustrated in Table 2, the mean mortalities of brown comber (17.1%) in the square test cages were

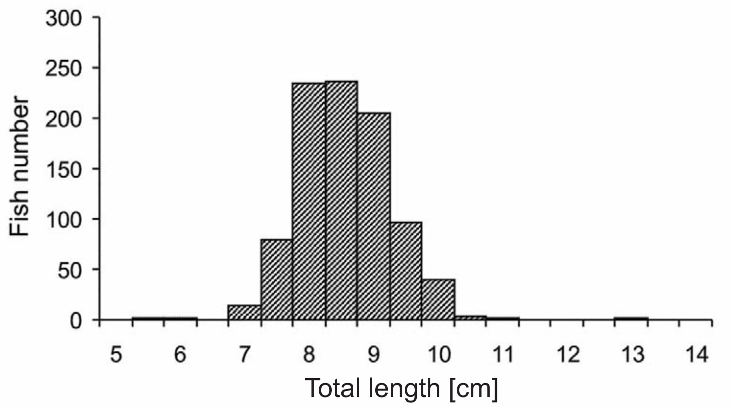

Fig. 5. Length frequency distribution of brown comber (*Serranus hepatus*) in summer (Control and test cages)

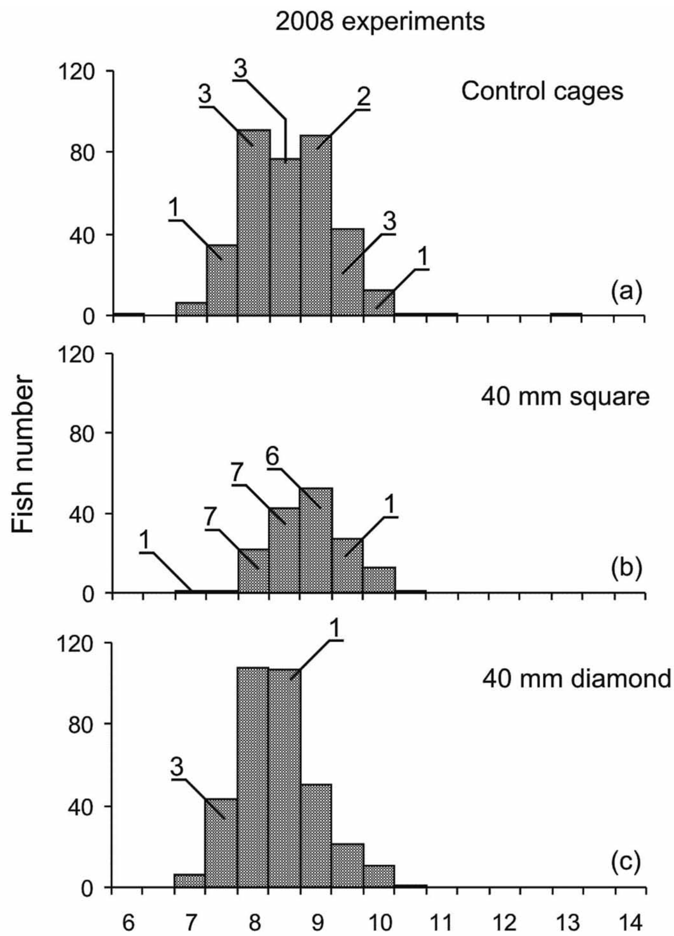

Fig. 6. Population of brown comber (*Serranus hepatus*) of the cod-ends and covers in 2008 experiments: Numbers of fish and dead in each length class for combined data of (a) control cages; (b) square test cages; (c) diamond test cages

greater than the control groups (8.2%) in 2008 experiments. On the other hand, the observed escape mortality of brown comber in the diamond mesh cages was very little lower (mean 1.9%) than those fish in the square mesh cages. The 2008 results showed that there was no significant difference between the cod-ends.

However, a few mortality cases were observed in the all cages in 2007 and 2008 experiments, the inverse relation was observed between mortality and fish length as illustrated in Fig. 7. It has been reported in the majority of the studies that fate of survival depends on fish size (Suuronen 2005). Mortality of brown comber was clearly size-dependent. The majority of mortalities for brown comber were in the fish length less than 9.4 cm for experimental cages in both 2007 and 2008. Although, some survival experiments showed no significant relation between fish length and mortality (Suuronen et al. 2005), it has been observed that the mortality rate tends to be higher among the smaller individuals in this study. Likewise, many studies have shown an inverse relation between skin

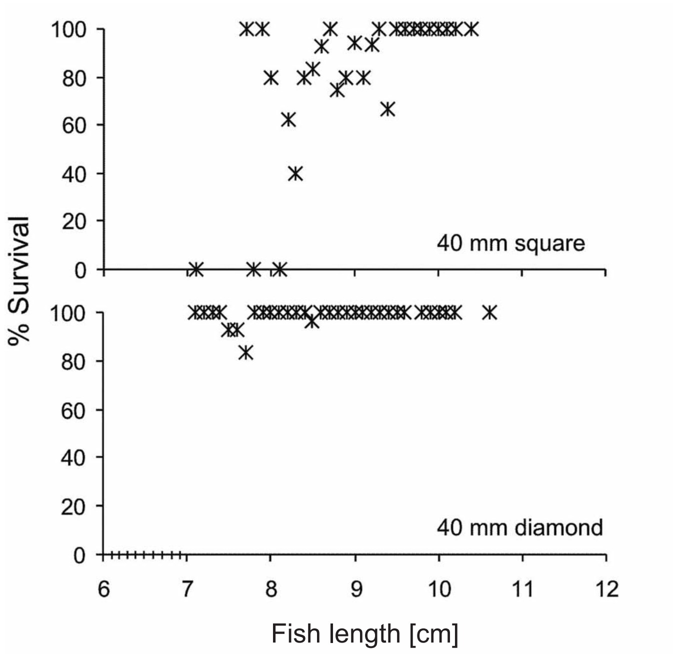

Fig. 7. The survival percentages of brown comber (*Serranus hepatus*) in the test cages are positively associated with fish length. Those fish in length groups are given in the 1 mm range

injury and fish size as our experiment (Sangster et al. 1996, Ingólfsson et al. 2007).

It is clear that the mortality of brown comber was not affected by the seasonal variation (water temperature) for the diamond mesh cod-end. The water temperature was 13 and 24ºC around the cages for winter and summer experiments, respectively. Although there was high variation between hauls, Suuronen et al. (2005) observed that lower mortality of cod was at lower water temperatures (<10°C), and higher mortality was at higher temperatures (>15°C). In common, low water temperatures may cause decreasing swimming ability and increasing the vulnerability to various capture stresses. The behavioural changes may also influence the ability of fish such as haddock to escape from trawl cod-ends as reported by Özbilgin and Wardle (2002). Our study showed that the low mortality of brown comber in water temperatures <13°C was consistent to the results in 2008 experiments (>24°C).

This study is the first experiment to investigate the survival rates of brown comber which may be influenced by the seasonal variation and mesh shape in the Mediterranean Sea. Our results show that brown comber has ability to withstand physical injury and fatigue associated with capture. However, during the sampling period about 30 species were caught in the cod-end, unfortunately, to obtain sufficient data were not easy task for all species as a result of difficultness of fish collecting from the observation cages in a short dive time, predation effect (Ingólfsson et al. 2007), decomposition (Suuronen et al. 1996a), and capture stress (Breen 2004) in multi-species ambient. Although monitoring duration was limited to 7 days, it may not have been long enough to demonstrate all mortalities of some fragile species. Therefore, we preferred to present survival data of brown comber of 2007 and 2008 experiments in this study. In addition, towing speed was between 2–2.5 knots during the survival experiments like the previous studies. It is known that towing speed has an effect on fish swimming capacity within the trawl and during escape from the trawl, and in this manner on mortality (Suuronen 2005). On the other hand, there are no published data on the effect of towing speed on survival probability (Suuronen 2005). Furthermore, our experiments may have not been completely representative of commercial fishing condition. Nevertheless, we concluded that the survival data of brown comber, resulted in low escape mortality, will obtain useful information for commercial bottom trawling fisheries in the Mediterranean Sea.

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REFERENCES

Anonymous 2008. 2/1 numaralı ticari amaçlı su ürünleri avcılığını düzenleyen tebliğ. [The announcement of commercial fishery regulations, no. 2/1.] Sirküler No. 2008/48. Ankara: Türkiye Cumhuriyeti, Tarım ve Köy İşleri Bakanlığı, Koruma ve Kontrol Genel Müdürlüğü. [Announcement

No. 2008/48. Ankara: Republic of Turkey, Ministry of Agriculture and Rural Affairs, General Directorate of Conservation and Inspection.] [In Turkish.]

Aydın C., Tosunoğlu Z., Tokaç A. 2008. Sorting grid trials to improve size selectivity of red mullet (*Mullus barbatus*) and annular sea bream (*Diplodus annularis*) in Turkish bottom trawl fishery. Journal of Applied Ichthyology **24** (3): 306–310. DOI: 10.1111/j.1439-0426.2007.01052.x.

Breen M. 2004. Investigating the mortality of fish escaping from towed fishing gears-a critical analysis. PhD thesis, University of Aberdeen, Scotland.

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.

Broadhurst M.K., Kenelly S.J., Barker D.T. 1997. Simulated escape of juvenile sand whiting (*Sillago ciliata*, Cuvier) through square-meshes: Effects on scale-loss and survival. Fisheries Research **32** (1): 51–60. DOI: 10.1016/S0165-7836(97)00037-4.

Froese R., Pauly D. (eds.) 2009. FishBase. [version 04/2009] http://www.fishbase.org.

Graham N., Kynoch R.J. 2001. Square mesh panels in demersal trawls: Some data on haddock selectivity in relation to mesh size and position. Fisheries Research **49** (3): 207–218. DOI: 10.1016/S0165-7836(00)00211-3.

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 Journal of Marine Science **64** (9): 1836–1844. DOI: 10.1093/icesjms/fsm150.

Lamprakis M.K., Kallianiotis A.A., Moutopoulos D.K., Stergiou K.I. 2003. Weight–length relationships of fishes discarded by trawlers in the north Aegean Sea. Acta Ichthyologica et Piscatoria **33** (2): 145–151.

Lehtonen E., Tschernij V., Suuronen P. 1998. An improved method for studying survival of fish that escape through meshes of trawl codends. Fisheries Research **38** (3): 303–306. DOI: 10.1016/S0165-7836(98)00163-5.

Lök A., Tokaç A., Tosunoğlu Z., Metin C., Ferro R.S.T. 1997. The effects of different cod-end design on bottom trawl selectivity in Turkish fisheries of the Aegean Sea. Fisheries Research **32** (2): 149–156. DOI: 10.1016/S0165-7836(97)00048-9.

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. Scottish Fisheries Research Report, 46/90.

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. Turkish Journal of Veterinary and Animal Sciences **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. Fisheries Research **70** (1): 49–53. DOI: 10.1016/j.fishres.2004.06.013.

Özbilgin H., Tosunoğlu Z., Tokaç A., Metin G. 2005. Seasonal variation in trawl Codend selectivity for annular sea bream (*Diplodus annularis* L., 1758). Turkish Journal of Veterinary and Animal Sciences **29**: 959–965.

Özbilgin H., Wardle C.S. 2002. Effect of seasonal temperature changes on the escape behaviour of haddock, *Melanogrammus aeglefinus*, from the codend. Fisheries Research **58** (3): 323–331. DOI: 10.1016/S0165-7836(01)00394-0.

Ryer C.H., Ottmar M.L., Sturm E.A. 2004. Behavioral impairment after escape from trawl codends may not be limited to fragile fish species. Fisheries Research **66** (2–3): 261–269. DOI: 10.1016/S0165-7836(03)00197-8.

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. Fisheries Research **25** (3–4): 323–345. DOI: 10.1016/0165-7836(95)00430-0.

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., Erickson D.L., Orrensalo A. 1996a. Mortality of herring escaping from pelagic trawl codends. Fisheries Research **25** (3–4): 305–321. DOI: 10.1016/0165-7836(95)00446-7.

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. Fisheries Research **71** (2): 151–163. DOI: 10.1016/j.fishres.2004.08.022.

Suuronen P., Perez-Comas J.A., Lehtonen L., Tschernij V. 1996b. Size-related mortality of herring (*Clupea harengus* L.) escaping through a rigid sorting grid and trawl codend meshes. ICES Journal of Marine Science **53** (4): 691–700. DOI: 10.1006/jmsc.1996.0088.

Suuronen P., Turunen T., Kiviniemi M., Karjalainen J. 1995. Survival of vendace (*Coregonus albula*) escaping from a trawl cod end. Canadian Journal of Fisheries and Aquatic Sciences **52** (12): 2527–2533. DOI: 10.1139/f95-843.

Tokaç A., Lök A., Tosunoğlu Z., Metin C., Ferro R.S.T. 1998. Cod-end selectivities of a modified bottom trawl for three fish species in the Aegean Sea. Fisheries Research **39** (1): 17–31. DOI: 10.1016/S0165-7836(98)00172-6.

Tokaç A., Özbilgin H., Tosunoğlu Z. 2004. Effect of PA and PE material on codend selectivity in Turkish bottom trawl. Fisheries Research **67**: 317–327. DOI: 10.1016/j.fishres.2003.10.001.

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, 2006/FTC: 06, REF. ACFM.

Tosunoğlu Z., Özbilgin Y.D., Özbilgin H. 2003a. Determination of the appropriate hanging ratios to ease the escape of juvenile red mullet (*Mullus barbatus* L., 1758) and annular sea bream (*Diplodus annularis* L., 1758) from a trawl codend. Turkish Journal of Veterinary and Animal Sciences **27**: 1193–1199.

Tosunoğlu Z., Özbilgin Y.D., Özbilgin H. 2003b. Body shape and trawl cod end selectivity for nine commercial fish species. Journal of Marine Biology Association of the United Kingdom **83**: 1309–1313. DOI: 10.1017/S0025315403008737.

Tudela S. 2004. Ecosystem effects of fishing in the Mediterranean: an analysis of the major threats of fishing gear and practices to biodiversity and marine habitats. UNEP Food and Agriculture Organization of the United Nations. General Fisheries Commission for the Mediterranean Studies and Reviews No. 74.

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