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Full Length Research Paper

Size selectivity of commercial (300 MC) and larger square mesh top panel (LSMTPC) trawl codends for blue whiting (*Micromesistius poutassou* Risso, 1826) in the Aegean Sea

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In the present study, size selectivity of a commercial (300 MC) and a larger square mesh top panel (LSMTPC) codend for blue whiting (*Micromesistius poutassou*) were tested on a commercial trawl net in the international waters between Turkey and Greece. Trawling, performed during daylight was carried out at depths ranging from 124 to 230 m, and towing speed changed between 2.2 and 2.3 knots for a 13-day sea trial in August 2005. Selectivity data were obtained by using the covered codend technique. Selection parameters were estimated by fitting a logistic equation using the maximum likelihood method. The results show that mean L_{50} values of 16.98 (s.e. 0.22) and 22.84 (s.e. 0.51) cm were estimated for 300 MC and LSMTPC, respectively. These values show that the LSMTPC codend has higher L_{50} values than the 300 MC codend. In view of the length value of blue whiting at first maturity (15 to 18 cm), mean L_{50} value of LSMTPC codend is remarkably higher than 300 MC codend.

Key words: Trawl selectivity, blue whiting, commercial codend.

INTRODUCTION

Blue whiting (*Micromesistius poutassou* Risso, 1826), a small fish species belonging to the Gadidae family, is widely distributed in the Barents Sea, Norwegian Sea and Mediterranean Sea. They appear on the continental slope and shelf from 150 to more than 1000 m depth, but, more commonly at 300 to 400 m (Cohen et al., 1990; Campos and Fonseca, 2007). Blue whiting, which spawns first at the age of 3 years, is considered a fast growing and long life span species with maximum age of about 20 years, and total body length reaching to 50 cm (Ha, 2008). This species has mostly been caught by bottom trawls. There is no catch statistics reported for blue whiting by Turkish State Statistical Institute. Whereas in international waters between Turkey and Greece, this species is fished, along with more than 50 species of fish, cephalopods and crustaceans by traditional Mediterranean trawls in seasonal closure for coastal trawling (within 6 miles from the cost). The trawl fishing in this region is performed with special permission during a part of the closed season. Turkish Fisheries Regulation permitted trawlers to use minimum mesh size of 44 mm in the Aegean Sea (Anonymous, 2008). However, most trawlers operating in this area use a small diamond mesh netting (mesh size 40 mm) in the codends which does not allow the escape of juvenile specimens (Stewart, 2002).

The capture and discarding of below length at first maturity (LFM) and minimum landing size (MLS) are unwanted situations in any fishery. More selective fishing gears are needed for sustainable fisheries management. The traditional Mediterranean trawls are generally made with non-selective netting and fishing boats which are involved in multi-species fisheries. But, improvement in selectivity in the multi-species fisheries is more troublesome due to differences in body shape and size at maturity (Stewart, 2002). For this reason, many selectivity studies for this gear have been carried out in the

Abbreviations: LFM, Length at first maturity; **MLS,** minimum landing size; **PE,** polyethylene; **PA,** polyamide; **LSMTPC,** large square mesh top panel codend; **SR,** selection range.

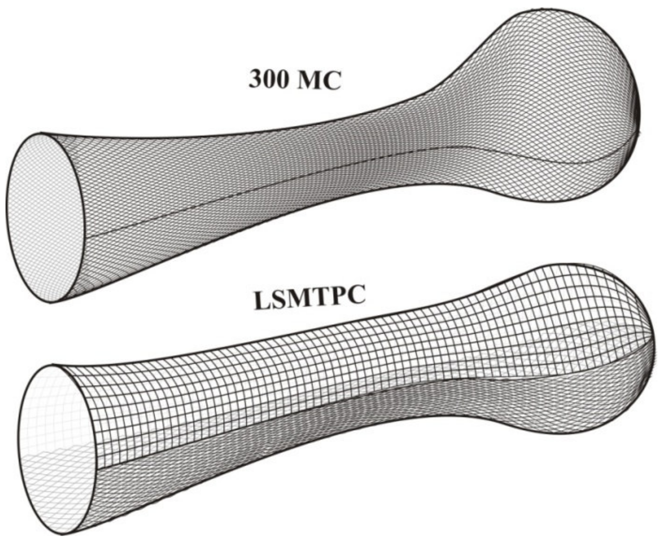

Figure 1. Illustration of the two tested codends.

Mediterranean Sea (Petrakis and Stergiou, 1997; Tokaç et al., 1998, 2004; Özbilgin and Tosunoğlu, 2003; Özbilgin et al., 2005, 2007; Bahamon et al., 2006; Tosunoğlu et al., 2007; Sala et al., 2008; Deval et al., 2009; Ateş et al., 2010). These studies in connection with practicality generally concentrated on the mesh size and mesh configuration. The use of a single mesh size is insufficient for the selectivity of all fish species existing in the Aegean Sea (Tokaç, 2001). At the same time, full square mesh codends are unpopular with the fishing industry because they lack strength, the knots can be unstable and the nets are awkward to handle and repair (Graham et al., 2003). Therefore, application of different mesh configurations in trawl codends may be useful for improving selectivity of the multi-species fishery by taking into consideration, fish with different body shapes. For this reason, some researchers used square mesh window and panel for by-catch and discard reduction in the trawl codend (Campos and Fonseca, 2004; Özbilgin et al., 2005; Tokaç et al., 2010).

Fishermen tend to use different fishing areas because of decreasing fishing stocks. At the same time, this reduction has led to appreciation of different species in trawl fishery. Although blue whiting is caught by trawl fishery in Turkish Seas and consumed by people, it is not a common commercial species when compared to other species in Turkey. However, it is a very important commercial species of Greek trawl fishery (Stergiou, 1999). Campos et al. (2003a) noticed that length of the species was depth-dependent, with smaller individuals from 20 to 25 cm caught at depths of 200 m, while the length range extends up to 30 cm which is suitable for commercial fishery at depths from 200 to 400 m. These lengths are suitable for commercial consumption of blue whiting in Turkey. For all these reasons, blue whiting is expected to be one of the major commercial species of trawl fishery in the future.

In this study, the selectivity results of the traditional bottom trawl codend (300 MC - 40 mm mesh size) used commercially by Turkish demersal trawl fleets is compared with a larger square mesh (LSMTPC - 24 mm bar length) on the top panel for blue whiting. Thus, the selectivity results of this study will be expected to contribute to other studies (biology, stock assessment, etc.) and legal arrangements in the future.

MATERIALS AND METHODS

The 26.2 m LOA, 294 KW commercial trawler "Niyazi Reis" was chartered for thirteen-day sea trial between 1st and 13th August 2005. Trawling, performed during daylight, was carried out in the international waters between Turkey and Greece, at depths ranging from 124 to 230 m (see Figure 1 in Kaykaç et al. (2009) for the map of the study area). Towing duration varied between 90 and 300 min, and towing speed change was between 2.2 and 2.3 knots. The trawl was a typical commercial bottom trawl used for demersal fishery in this fishing ground. Technical information of this gear (conventional bottom trawl with 900 meshes around the mouth) is described in detail by Tokaç et al. (2005).

Selectivity of two codends made of knotted polyethylene (PE) material was tested. The first one was the commercially used 40 mm PE codend with 300 meshes on its circumference (three seems of 100 meshes panels) (300 MC). Second codend was constructed as 150 diamond meshes of 40 mm PE netting on the lower, and 66 square meshes of 48 mm PE netting on the top panel (LSMTPC) (Figure 1). Both codends were approximately 5.5 m in stretched lengths. They were attached to the end of funnel which was 300 meshes in its circumference and made of 40 mm mesh size PE netting. A 10.2 m long, and 24 mm mesh size knotless PA (polyamide) netting cover was used to collect the escaped individuals. The cover was supported by two hoops (PVC Ø 1.9 m) to avoid the masking effect and to provide water flow between codend and the cover. These hoops were mounted to the cover at distances of 2 and 5 m from the attachment point, which was at the end of the funnel.

At the end of each tow first the cover catch was taken, blue whiting was separated from the rest of the catch and weighed. Meanwhile, the crew of the fishing boat sorted the marketable codend catch by species and left the discards on deck. Then full-samples was taken and weighed separately for marketable catch and discards. Length measurements were taken to the cm below.

Due to insufficient numbers of escapement in many hauls, selection parameters were calculated by using the 'stacked haul method' (Millar et al., 2004), which does not incorporate an explicit modeling of the between-haul variation. The method, however, accounts for this variation implicitly by keeping replicates of length classes from all hauls separately. Data from all hauls were stacked into a single dataset, which was then handled as a single (artificial) haul. Estimates were consequently obtained by fitting a logistic equation using the maximum likelihood method as in Wileman et al. (1996) by using CC 2000 software (ConStat, 1995). When the data showed over-dispersion due to unaccounted variability, the replication estimate of dispersion (REP statistic) was calculated to measure this, and that was automatically used for subsequent adjustment of the estimated variances in CC 2000. General statistical details can be found in McCullagh and Nelder (1989).

A likelihood ratio test (McCullagh and Nelder, 1989) was carried out to evaluate if the stacked data selection curves estimated for blue whiting in the 300 MC and LSMTPC codends were statistically different from each other (Campos et al., 2003b for *Lepidorhombus boscii*; Risso, 1810). The in-likelihoods resulting from fitting in-

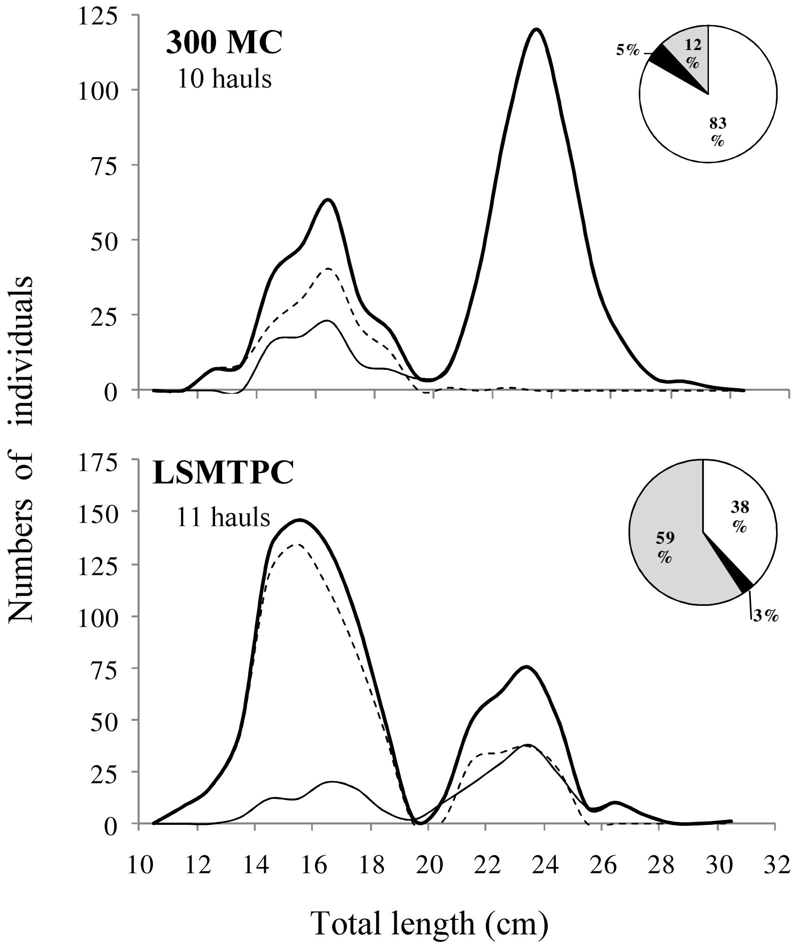

Figure 2. Size structure of the population indicated retaining (thin line), escaping (broken line) and entering (thick line) from the codends. Pie graphs inserted in figures demonstrate percentage of marketed (white), discarded (black) and escaped (gray) *M. poutassou* in terms of weight.

dependent selection curves for the two codends were summed up, and then a single curve was fitted to the data of both codends, and the corresponding ln-likelihood was assessed. $W^2 = 2$ [ln-likelihood (300 MC) + ln-likelihood (LSMTPC) - ln-likelihood (300 MC + LSMTPC)] is approximately $\chi^2(\alpha, df)$, where df is given by the change in the number of parameters estimated in the curves, if the null hypothesis H_0 of no differences between curves is correct.

RESULTS

Results of mean mesh size measured with caliper rule (42.15 to 49.80 mm) were partly lower than those with the Wedge gauge (42.58 to 51.17 mm). A total of 21 valid hauls with 10 for 300 MC and 11 for LSMTPC were carried out by using two different codends. In all trawling, operations produced a total catch biomass of 6030, 2523 kg with 300 MC and 3507 kg with LSMTPC, during 75.5 trawling hours. The catch was composed of more than 50 species of fish, cephalopods and crustaceans. A total of 1624 specimens were collected in 21 valid hauls.

Figure 2 presents the length frequency distributions of retained, entered and escaped fish both for 300 MC and LSMTPC. All length frequency distributions were bimodal with one peak at about 12 to 19 cm and another at about 20 to 28 cm. From Figure 2, it can be seen that a great majority of the first year classes are released from the codends. A great proportion of the species were retained in 300 MC with retention of 0.88 in terms of weight and 0.77 in terms of numbers. However, these ratios were fairly low values for LSMTPC.

The results of the estimate of the selectivity parameters are given in Table 1, and the mean selection curves are shown in Figure 3. The selection curves of the two codends are found to be significantly different ($p < 0.01$). L_{50} values of 16.98 (s.e. 0.22) and 22.84 (s.e. 0.51) cm were estimated for 300 MC and LSMTPC, respectively. These values demonstrate that the L_{50} of LSMTPC is 34.5% higher than that of the 300 MC codend. Selection ranges (SRs) of these codends are 3.47 and 7.32 cm, respectively (Table 1). Pie graphs in Figure 2

Table 1. Selectivity parameter estimates [L_{50} (cm), length at 50% retention; *SR* (cm), selection range; CI, confidence interval; v_1 and v_2, maximum likelihood estimators of selectivity parameters; R_{11}, R_{12}, and R_{22}, variance matrix measuring within-haul variation; *d.f.*, degrees of freedom] and number of specimens in codend and cover for 300 MC and LSMTPC.

Parameter	300 MC	LSMTPC
L_{50} (SE)	16.98 (0.22)	22.84 (0.51)
CI L_{50}	16.54-17.42	21.81-23.86
SR (SE)	3.47 (0.29)	7.32 (0.78)
CI SR	2.89-4.06	5.76-8.88
v_1	-10.747	-6.858
v_2	0.633	0.300
R_{11}	0.8794	0.4195
R_{12}	-0.0497	-0.0205
R_{22}	0.0029	0.001
Dev.	99.02	142.90
d.f.	98	78
p-value	0.45	0.00
Codend	475	215
Cover	144	690

Numbers in brackets are standard errors.

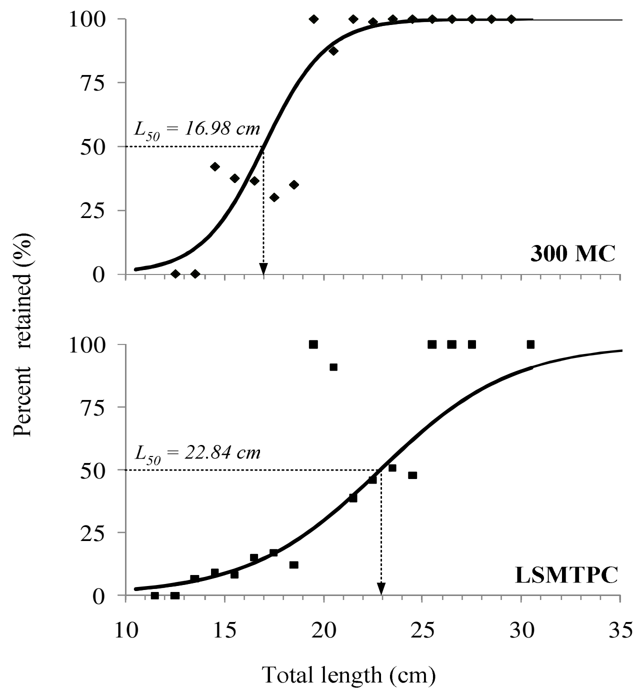

Figure 3. Selection curves and observed retention percentages as data points (filled diamonds are 300 MC and filled squares are LSMTPC). L_{50} values are indicated on the figures.

show that in terms of weight, similar discard percentages were observed for 300 MC (5%) and LSMTPC (3%). However, market percentage ratio of 300 MC (83%) was higher than LSMTPC (38%) (Figure 2).

DISCUSSION

In this study, selectivity results of the commercial codend (300 MC) used by Turkish demersal trawlers in international waters of the Aegean Sea and the large square mesh top panel codend (LSMTPC) have been compared for blue whiting. L_{50} increased from 16.98 cm for 300 MC codend to 22.84 cm for LSMTPC codend. Results of the LSMTPC codend in the present study show considerably higher mean L_{50} values than 300 MC codend for this species. Many studies indicated that the diamond mesh used in the trawl codends have rather poor selectivity than square meshes because square meshes, as opposed to diamond ones, remain open during towing (Robertson and Stewart, 1988; Petrakis and Stergiou, 1997; Tosunoğlu et al., 2003; Özbilgin et al., 2005; Guijarro and Massuti, 2006; Ordines et al., 2006; Sala et al., 2008; Deval et al., 2009; Tokac et al., 2010; Ateş et al., 2010). As a result of using diamond mesh codend, a significant proportion of the codend catch is immature and smaller than minimum landing size or length of the first maturity.

Blue whiting can be landed legally in Italy above 7 cm (Sala and Luchetti, 2010), while for Greece it was reported to be 10 cm (Petrakis and Stergiou, 1997). This species has been caught as by-catch and is sold together with other whiting. But it has not been recorded by Turkish Statistical Institute. Therefore, there is no minimum landing size defined for this species in the Turkish Fisheries Regulations (Anonymous, 2008). While length at first maturity of blue whiting is 15 to 18 cm in Greece (Papaconstantinou et al., 1989), 18.20 cm in Northern Spain and 19 cm in Portugal (Silva et al., 1996), MLS has been reported to be 10 cm (Petrakis and Stergiou, 1997) in Greece. In view of the length value of blue whiting at first maturity, mean L_{50} value of LSMTPC codend is remarkably higher than 300 MC codend.

Özbilgin et al. (2005) reported a significant increase in the L_{50}s of hake and poor cod by using a square mesh top panel codend in the relatively shallower waters of the Eastern Aegean Sea. In the same way, the square mesh top panel codend has relatively higher L_{50} than the commercial codend for four species in addition to blue whiting (Tokaç et al., 2010). These studies show that modifications of the square mesh top panel codends in general, improved the selectivity. At the same time the escape of fish above length at the first maturity is a cause for concern to trawl fishermen. For blue whiting, Tokaç et al. (2010) reached values of 19.42 cm by 40 mm square mesh top panel codend from the stacked data in international waters of Aegean Sea. With this study, L_{50} values of blue whiting increased by 18% when square mesh size is increased by 20%.

Sala and Luchetti (2010) notified that especially for this species, mesh configuration and fishing played a significantly positive effect on L_{50}. Result of the present study carried out in August is similar to the results of their studies in September. There may be minor differences in the L_{50} values due to differences in gear constructions, mesh material twine thickness, towing speed and duration, etc.

In conclusion, selectivity results of 48 mm square mesh top panel codend is more selective than the commercial one for blue whiting. Therefore, it is thought that usage of smaller than 48 mm square mesh on top panel will be suitable for commercial uses. At the same time, selectivity result of winter season need to be investigated for this species.

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