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Is square-mesh better selective than larger mesh? A perspective on the management for Mediterranean trawl fisheries

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ABSTRACT

Relatively little scientific work has been done to assess the selectivity of square-mesh codends in the highly variable multi-species conditions in the Italian trawl fisheries. Therefore this study was initiated to investigate the effect of using square-mesh and larger diamond-mesh codends on size selectivity of deepwater red shrimp (*Aristaeomorpha foliacea*) and red mullet (*Mullus barbatus*), with possible implication in future management measures. Four different codends were used in the sea trials. When size selection estimates are applied for management issues it is not sufficient only to consider the mean size selection parameters. It also needs to consider the effect of between-haul variations in the selection process. In the current study, potential consequences of the between-haul variation on the selection curves have been considered by applying a pooled curve with a double bootstrap approach. The results attained in the present study indicate that the use of 40 mm square-mesh codend results in a 50% retention length (L50) similar to that of the 50 mm diamond-mesh codend, but with a steeper selection range (SR). For red mullet, both 50 mm diamond-mesh and 40 mm square-mesh codends lead to an L50 that is higher than the minimum landing size (MLS, 11 cm). Deepwater red shrimp is not subject to any MLS and may always be landed legally. However, large amounts of juveniles of deepwater red shrimp have been retained in all codends. Council Regulation (EC) No. 1967/2006 called for a discard reduction policy in waters under the jurisdiction of the European Union. As demonstrated in the current paper, to simultaneously improve the size selectivity of fish and shrimp species can be difficult due to large differences in their morphological characteristics, therefore it may question whether more sophisticated alternative of selective devices, such as grids or square-mesh panels, could be implemented in some Mediterranean fisheries.

1. Introduction

Italian trawl fisheries land a large number and a variety of commercially important species using small diamond-mesh codends, which tend to retain almost all animals. In order to reduce fishing mortality and discards of dying marine organisms, the improvement of the trawl selectivity is therefore of prime importance. For example, Council Regulation (EC) No. 1967/2006 requested an increase of diamond-mesh size from 40 mm to 50 mm or the use of 40 mm square-mesh in the codend. The selectivity performance of Italian bottom trawls has been widely investigated (Lucchetti, 2008; Lucchetti and Sala, 2012; Sala et al., 2004, 2006, 2007a,b; Sala and Lucchetti, 2010, 2011), however relatively little scientific work has been done to assess the selectivity of square-mesh codends in the highly variable multi-species Italian trawl fisheries (Sala et al., 2008).

Deepwater red shrimp (*Aristaeomorpha foliacea*) are widely represented in the slope bottoms (400–800 m) of the South Tyrrhenian Sea and Strait of Sicily, and are actively fished by both Italian and foreign fleets, mainly from the Northern Africa countries. This deepwater fishery can be nearly considered as mono-specific, given that red shrimp represent the most abundant and valuable catch (Ragonese et al., 2002). Red mullet (*Mullus barbatus*) is one of the most important resources for shelf demersal fishery (down

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to 200 m) in the Mediterranean. The current investigation was restricted to the red mullet inhabiting the Sicilian side, because biological features of those living on the Tunisian shelf suggest that they belong to another population (Levi et al., 1994).

Most of the Mediterranean studies on the selectivity for deepwater red shrimp focus on diamond-mesh codends (Ragonese et al., 1994, 2002; D'Onghia et al., 1998; Carlucci et al., 2006). Currently there are only three studies that investigated the effect of square-meshes in the codend on the selectivity for shrimp species in Mediterranean. In these studies, selectivity parameters for the 40 mm square-mesh were estimated for *Aristeus antennatus*, *Parapenaeus longirostris* and *Plesionika martia* by Guijarro and Massutí (2006) for *P. longirostris* by Sala et al. (2008) and for *A. foliacea*, *A. antennatus*, *P. longirostris* and *P. martia* by Deval et al. (2009). The codend tested by Deval et al. (2009) was entirely made of knotted polyethylene (PE). No study has examined the effect of using knotless polyamide (PA) square-mesh codends on size selectivity for deepwater red shrimp. This study investigates the effect of using square-mesh netting and larger diamond-meshes in the codend on size selectivity of deepwater red shrimp and red mullet, two of the most important commercial species in this area, with possible implication on management measures for the fisheries.

2. Materials and methods

2.1. Sea trials

Selectivity trials were conducted on a commercial vessel on two different fishing grounds of the South Tyrrhenian normally exploited by local fishermen. The gear employed in the sea trials was a typical Italian commercial trawl net (Prat et al., 2008; Eigaard et al., 2011a) entirely made of knotless PA netting. All rigging components of the gear were identical with those commonly adopted in commercial practice in the Italian trawl fisheries (Dremière et al., 1999; Fiorentini et al., 1999, 2004; Sala et al., 2007c; Notti et al., 2013). Gear performance (i.e., door spread, horizontal and vertical net openings) was measured during all hauls using a SCANMAR system. A laptop automatically controlled data acquisition and provided for real time correct system functioning through a customized software (Brčić et al., 2014). The main goal of these measurements was to obtain for each haul detailed, real time data on gear performance.

Four different codends were used in the sea trials. The nominal mesh sizes tested were 44 mm and 54 mm and two different mesh configurations were associated with each mesh size: diamond- and square-mesh. The codend mesh sizes were measured using an ICES mesh gauge (ICES, 1962) with 4 kg tension while the netting was wet.

The actual mesh sizes of the four tested codends were: 45.15 ± 0.75 mm (DM44-320) and 45.95 ± 0.39 mm (SM44-160) for the 44 mm diamond- and square-mesh respectively; and 54.70 ± 0.86 mm (DM54-256) and 56.90 ± 0.45 mm (SM54-128) for the larger 54 mm diamond- and square-mesh respectively (Table 1). The four codends were designed to have almost the same circumference during fishing (approximately 3.5 m). Generally, underwater observations have shown the diamond-meshes in the codend of demersal trawls tend on average to open circumferentially only about 15–25% of the mesh size (Robertson, 1986, 1993). Therefore, the circumferential length during fishing, *clf* (mm), with a diamond-mesh codend would not be expected to exceed $clf_{DM} = 0.25 \times ms \times nmw$, where *ms* (mm) and *nmw* are the mesh size and the number of meshes in the codend circumference, respectively. On the other hand, the circumferential length of a square-mesh codend will be nearly $clf_{SM} = 0.50 \times ms \times nbw$, where *nbw* is the number of bars in the circumference. Notice we have used that the square-mesh bar length is half the diamond-mesh size. In order to accurately matching the circumference of the diamond- and square-mesh codends, we must therefore calculate the number of meshes in circumference (or bars) of the square-mesh codend to produce similar values for *clf* as for the diamond-mesh codends while accounting for the differences in circumferential openness of the meshes for these two codend types. Considering the mesh sizes and number of meshes in circumference of the two tested diamond-mesh codends (Table 1), we find:

$$clf_{DM44-320} = 0.25 \times 45.15 \times 320 = 3612\,\text{mm} \quad (1)$$

$$clf_{DM54-256} = 0.25 \times 54.70 \times 256 = 3501\,\text{mm} \quad (2)$$

Therefore, to find out the number of bars of the square-mesh codends to match at such circumferences, it is necessary to divide each *clf* of the diamond-mesh codends, (1) and (2), by the bar length of the square-mesh codends:

$$nbw_{SM44-160} = \frac{3612}{0.5 \times 45.95} = 157 \quad (3)$$

$$nbw_{SM54-128} = \frac{3501}{0.5 \times 56.90} = 123 \quad (4)$$

These numbers in (3) and (4) have been adjusted to 160 and 128, as reported in Table 1, in order to have identical rigging rules to those commonly adopted in commercial practices in the Italian demersal trawl fisheries.

Size selectivity data were collected using the covered codend technique (Fig. 1), where a cover with a nominal mesh size of 20 mm was supported by circular hoops to keep it clear of the codend and minimize masking effects (Wileman et al., 1996). The cover was approximately 1.5 times larger in circumference and longer than the codend, as recommended by Stewart and Robertson (1985).

For each haul, catches from trawl codend and cover were handled separately on board and weighed. Total length (TL, cm) for red mullet and carapace length (CL, mm) for deepwater red shrimp were measured respectively to the nearest 0.5 cm and 1.0 mm below in randomly selected sub-samples. The subsampling ratios were then calculated by dividing the sub-sample weight by the total weight in the codend and cover separately.

2.2. Estimation of mean selection curve

Analysis was conducted separately for deepwater red shrimp and red mullet following the procedure described in Annex I. The selectivity results for each species were derived only from the first or the second cruise within the same area.

When size selection estimates are to be applied for managements issues it is not sufficient just to consider the mean size selection obtained using the method described in Fryer (1991). One also needs to consider the effect of between-haul variations in the selection process (Frandsen et al., 2011). For example, even if mean SR is small (e.g. steep mean size selection curve) if there is a considerable between-haul variation in L50 then for the deployment over hauls hypothetically some hauls could lead to the catch of many small fish while others could lead to the loss of big fish. Such effect is not included in the Fryer mean size selection curve as it is represented by the between-haul variation matrix, see Fryer (1991) for details. Further different gear configurations can have different between-haul variations in selection process and for management questions it is also important to consider this effect when evaluating the benefit from applying a certain gear type (Wienbeck et al., 2011). One way to include the effect of between-haul variations into a single selection curve is to make what Millar (1993) called a "*fishery selection curve*" (Sistiaga et al., 2010; Herrmann et al., 2012). This can be obtained by pooling hauls, as described in Annex I and as in the current study it has been decided for estimating the selection