MINOUW

SFS-09-2014
RIA •634495

# Science, Technology, and Society Initiative to Minimize Unwanted Catches in European Fisheries

## WP2. Technological and social solutions
## Deliverable 2.8 Review of effectiveness of conventional by-catch reducing devices

Responsible beneficiary: 1 - CSIC
Contractual due date: month 16
Dissemination level: PUBLIC
Report Status: FINAL
Actual submission date: 22 August 2016 (month 18)

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Co-funded by the Horizon 2020 Framework Programme of the European Union

RESEARCH & INNOVATION

ID•634495

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# Deliverable 2.8 Review of effectiveness of conventional by- catch reducing devices

## 1. Summary (for non specialists)

This document reports the results of a desktop review of recent (last 10-15 years) experiments with conventional modifications to fishing gear aiming at reducing by-catch, or more generally, unwanted catches in south European waters. The results of the review show that most experiments focus on solutions to mitigate the poor selectivity of small meshed diamond codends in bottom trawls (e.g. Sala et al., 2008; Sala and Lucchetti, 2011, among many others). The available studies on other fishing gear are limited (Stergiou and Erzini, 2002; Erzini et al., 2006). The reason for this focus of research on bottom trawl is due to the widespread perception of it being a fishing gear of low species and size selectivity.

Most studies report only the effects of fishing gear modifications on the fishery target species, not on the entire catch composition. However, some works exceptionally report the effects of fishing gear modifications on the entire catch and provide preliminary data to assess ecosystem impacts (for instance, Stergiou et al., 1997; Ordines et al., 2006). Very few studies provide an assessment of short-term economic losses due to fishing gear change or modifications (Guijarro and Massutí, 2006; Samy-Kamal et al., 2015) or costs (Özbilgin et al., 2015).

The results of this review show also that the benefits of adopting new fishing gear or modifying existing gear are dependent not only on the type of gear itself (viz., trawl, trammelnet or gillnet), but also vessel characteristics, environment characteristics and species assemblage (Wileman et al., 1996; MacLennan, 1992). In many cases, the sea trials made by fisheries scientists or technologists under ideal and controlled conditions are not consistent with the results observed in commercial fisheries (Sobrino et al., 2000; STECF, 2012).

A consistent result of many sea experiments is that it is difficult to simultaneously improve the size selectivity in fisheries where taxa of different morphologies co-occur in the catch based only on mesh changes. For instance in mixed shrimp/fish fisheries, where small shrimp or juvenile fish are unwanted by-catch, changes to the size or configuration of the trawl codend mesh are insufficient. Alternative selective devices, such as grids or square-mesh panels should be considered for south European fisheries, especially in the case of bottom trawls operating on the continental shelf, which are the typical case of mixed fisheries (Aydin et al., 2011).

A second general result is that it is very difficult to design an appropriate mesh configuration for all species because a mesh size appropriate for one species could be unsuitable for many others (Stewart, 2002). As far as possible, species-specific trawls need to be promoted to progress towards rational exploitation patterns with low

impact on ecosystems. The results of the sea trials reviewed here should be assessed critically on a case-by-case basis in view of their adoption by commercial fleets, because what works well in one area or fishery may not work well in other areas. A fishery has developed through decades of trial and error by fishers and many factors can affect the efficiency of the fishing method and modifications to it.

Considering that the main fleet segments in south European fisheries continue to produce large quantities of unwanted by-catch and show poor selection patterns (in terms of species selectivity or size selectivity) it can be concluded that technical measures have been ineffectual. Additionally, regulations are sometimes inconsistent, or too complex to put in practice, or difficult to understand by industry or fisheries inspectors (STECF, 2012)

Adopting methods to reduce unwanted catches will help fishers comply with the Landings Obligation (art. 15 of the Common Fisheries Policy), decrease the environmental impact of fisheries and reduce sorting time. In the case of trawl, some modifications to the fishing gear (changing net mesh size or fitting by-catch reduction devices) may actually improve trawl performance and reduce fuel consumption, as well as decrease damage to the codend and improve catch quality. Most of the methods reviewed may reduce commercial catches in the short term, which should be compensated by increases in stock size and higher catches in the longer term. The catch of certain target species may be reduced in the long term also and industry should contemplate using alternative fish catching methods in some instances.

It is necessary to recall that even if technical modifications to the fishing gear allow to increase selectivity and bring the average size of first capture (L50) in line with regulated minimum sizes for many species, for many species the regulated minimum size defined (especially for Mediterranean species) is still far from the biologically meaningful average size at maturity (Lm50). This is of particular concern for important commercial species such as hake (Merluccius merluccius) or sole (Solea solea) which have a regulated minimum size of 20 cm TL, but mature at ca. 35 and 30 cm TL, respectively. Regulation mesh configurations currently in place are still insufficient to fulfill biologically based conservation goals.

## 2. Background

South European fisheries (Mediterranean sea and adjacent Atlantic: Gulf of Cadis and Algarve region in south Portugal) are characterized by inadequate exploitation patterns whereby fishing gear —particularly the most productive ones, trawl and purse seine— catch small sized, immature fish, with negative effects on the production potential of fisheries. This exploitation pattern has become the norm since the introduction of motorized fishing in the late 1920s and its general adoption in the late 1940s. The result of this decades-long exploitation pattern has led to general overexploitation of south European fisheries (in particular growth overexploitation), deteriorating fish stocks and the general conclusion that exploitation rates and patterns must change to ensure the ecological and economic sustainability of the fisheries (Colloca et al., 2013; Vasilakopoulou et al., 2014). Although the general diagnostic is widely accepted by fisheries managers, industry and scientists, and the situation of overexploitation has been recognised for a long time, it has not been possible to progress towards the solution(s) to the problem for many reasons, among which the variety of fisheries in the area, both in terms of species commercially exploited (several dozens) and types of fishing gear used (Lleonart, 2008) are of special relevance here.

Most studies identify bottom trawls fitted with small-mesh cod-ends as the most problematic fishing gear, due to their poor selectivity (Caddy, 1993; Lleonart, 2008; Colloca et al., 2013). For instance, cod-ends fitted with diamond meshes as small as 28 mm or 38 mm (stretched mesh) were used in Greece and Spain, respectively, until recently. Bottom trawls operating with cod-ends fitted to small diamond meshes retain practically all animals entering the trawl (Stergiou et al., 1997; Stewart, 2002).

Studies carried out in the last two decades showed that substantial improvements in size selectivity of commercially important species (and to a lower extend, species selectivity) can be achieved by changing conventional diamond mesh cod-ends to square mesh cod-ends (Bahamon et al., 2006; Ordines et al., 2006; Sala et al., 2008; among others). As a result of these studies, Council Regulation (EC) No. 1967/2006, regarding management measures for the sustainable exploitation of fishery resources in the Mediterranean sea, envisaged to make the use of 40-mm square-meshed netting mandatory or, alternatively, to proceed with increase in mesh size (50-mm diamond mesh) to reduce mortality rates of juveniles and discards of non-target marine organisms by trawlers.

Technical methods to reduce unwanted catches in fisheries can be classified broadly according to their intended objective, although clearly one technological solution can address more than one objective simultaneously:

Excluding “low productivity” or endangered species (turtles, elasmobranchs, etc.). Fitting turtle-excluding devices (TED) is one example of this solution, implemented in certain bottom trawl fisheries (Jenkins, 2012);

Protecting the fraction of the population with largest spawning potential, the so-called “BOFFFs” (big, old, fat, fecund females) (Hixon et al., 2014). This can be achieved by promoting fishing gear that have dome shaped selectivity, particularly set gears such as gillnets, trammelnets or longlines.

Protecting non-target by-catch by suitable gear modifications, such as cod-end mesh size or sorting grid panels in bottom trawl gear.

Protecting marine habitats by using low impact gear (Suuronen et al., 2012)

The objectives of this review are to assess the effectiveness of conventional technical methods to reduce unwanted catches in fisheries, focusing on the experiences in the case study areas of the project MINOUW.

## 3. Methodology

A review of the publications and project reports produced by fisheries scientists and technologists in South European waters was carried out, focusing on the areas covered by the MINOUW case studies (South Portugal; NE Spain; Italy, and Greece). We added the results of publications from researchers in Turkey because of the quality and relevance of their results. The review aimed at recent work (last 10-15 years) because previous reviews exist (Stewart, 2002). **Annex 1** provides the basic data on selectivity retrieved from this publications, see **Reference** section for list of publications.

# 4. Results

## 4.1. Modifications to fishing gear

Because the main problems of species or size selection are due to towed fishing gear, particularly bottom trawls, this is the fishing gear that has received more research attention by far. The number of studies and field trials with modifications of the design of the trawl is very large, but the different types of interventions reviewed can be summarized as:

1. increasing the mesh size of the cod-end to increase escapement in diamond mesh (DM) codends
2. changing the mesh orientation of the diamond mesh by turning 90º (nets known as T90: Digre et al. 2010) or 45º, obtaining a square mesh (SM, also known as T45)
3. introduction of square mesh panels to an otherwise diamond mesh codend in the top part of the codend towards the front.
4. modifying the codend circumference
5. changing material of the codend net
6. changing twine thickness
7. introduction of bycatch reduction devices (BRDs, see next section)
8. increasing lateral mesh openings to maximise size selection
9. modifications to the trawl wings or body, where some species or size selection does occur

Examples of the last two have not been found in the study area. An example of field trials for (8) has been reported in a penaeid shrimp fishery in Australia (Broadhurst et al., 2015).

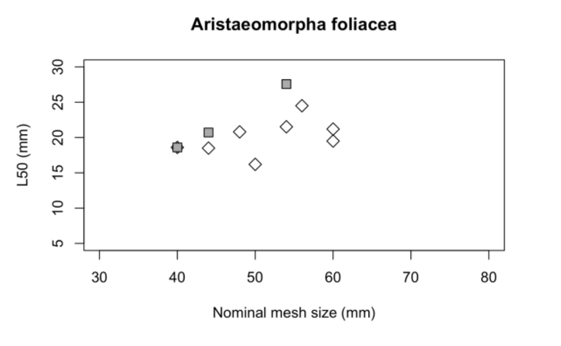
### 4.1.1. Increasing the mesh size in trawls

Earlier studies of codend selectivity compared diamond mesh codends of different sizes (Kennelly, 1995, Wileman et al., 1996, Broadhurst, 2000, Campos et al., 2002, 2003; Valdemarsen & Suuronen, 2003). In general, the results are consistent and document a larger escapement ratio for increasingly large diamond meshes, particularly evident in “round fish”, i.e. fish whose body section is approximately circular, such as hake or blue whiting. Increasing the mesh size in diamond mesh nets also contribute to escapement of low aspect (flat fishes) or high aspect fishes (for instance, sparids or John dory), but escapement in these type of morphologies is enhanced by square mesh netting (see next section).

It is reported that increasing the mesh size in diamond meshes produces a increase in 50% length at first capture ($L_{50}$) and also a concomitant increase in the selection range (SR) (Campos et al., 2002, 2003; Sala et al., 2008) resulting in a wider range of sizes caught and relatively higher proportion of under size fish.

The results of our review produced data of sufficient quality for meta-analysis by means of statistical analyses of selection patterns in 11 taxa (Mediterranean sea and Gulf of Cadis). In the following figures the effect of increasing mesh size on average size at first capture ($L_{50}$), selection range (SR) and selection factor (SF) is shown for diamond mesh studies. When the effect was statistically significant, a regression line is shown. The two types of net configuration (diamond / square) are shown on these figures also, and the statistical differences tested by ANOVA (results discussed in the next section).

Markers: empty diamonds correspond to diamond mesh; shaded square diamonds correspond to square mesh. Due to the low availability of data, some species where grouped in higher level taxa: the two horse mackerels (*Trachurus trachurus* and *Trachurus mediterraneus*, as *Trachurus sp.*), two flatfishes (*Lepidorhombus boscii* and *Arnoglossus laterna*) and three Sparidae (*Diplodus annularis*, *Pagellus acarne* and *Pagellus eryhtrinus*).



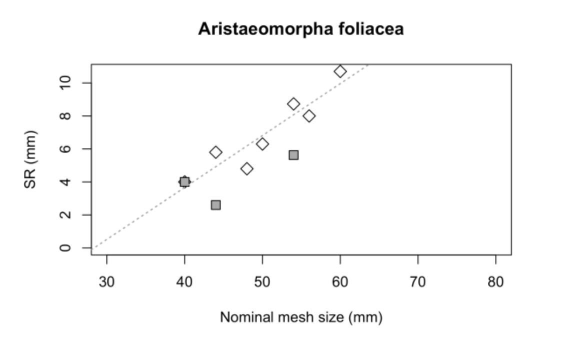
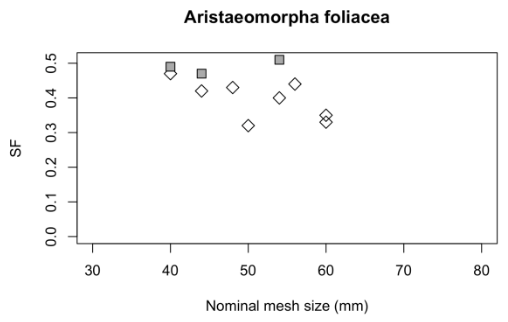



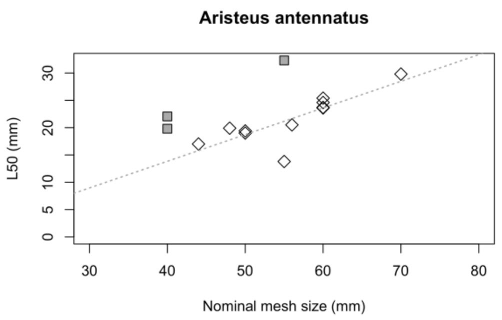

**Fig. 4.1.** Giant red shrimp *Aristaeomorpha foliacea*

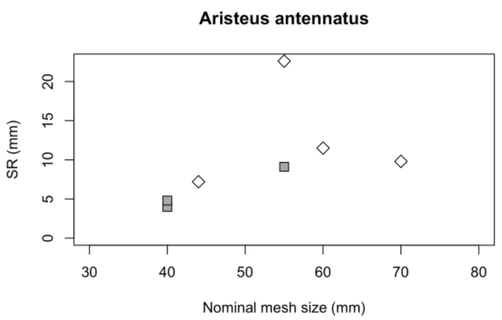
Mediterranean MLS: None

$L_{50}$ shows a statistically non-significant increase with mesh size. The increase in SR was significant (a=-8.92, b=0.315, p<0.01). No significant effect on SF of increasing mesh size.

Insufficient data to test the effect of mesh configuration (square 40 mm / diamond 40 mm) on $L_{50}$, SR, and SF.



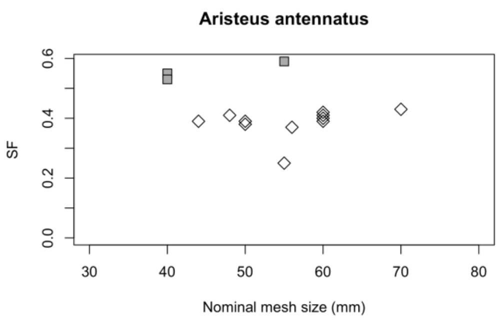




**Fig. 4.2** Blue and red shrimp *Aristeus antennatus*

Mediterranean MLS: None

$L_{50}$ is shown to increase significantly with mesh size (a=-5.6711, b=0.4879, p<0.01). No significant effect on SR or SF of increasing mesh size.

Insufficient data to test the effect of mesh configuration (square 40 mm / diamond 40 mm) on $L_{50}$, SR, and SF.

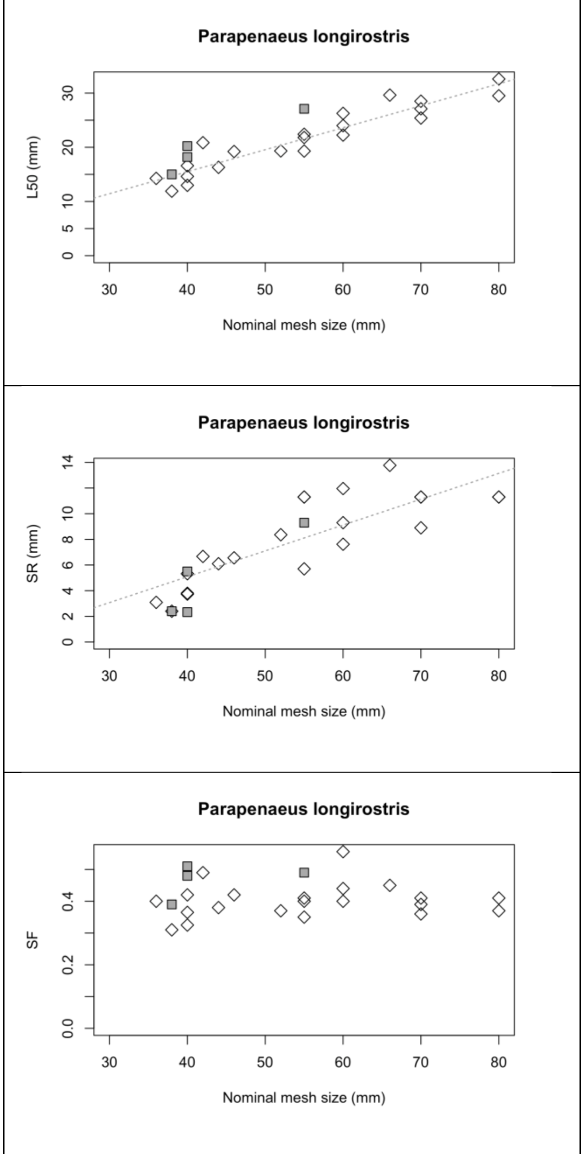



**Fig. 4.3** Deepsea rose shrimp *Parapenaeus longirostris*

Mediterranean MLS: 20 mm CL

Both L50 and SR significantly increasing with increasing mesh size (a=-0.73141, b=0.40566 and a=-2.97144, b=0.20145 respectively, both $p<0.0001$). No statistically significant effect on SF.

The $L_{50}$ of square 40-mm mesh codends (19.21 mm) was significantly higher than $L_{50}$ of diamond 40-mm mesh codends (14.73 mm), with $p<0.05$. No significant difference on SR or SF.

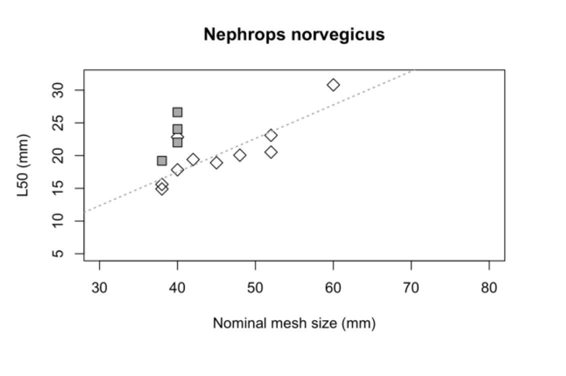
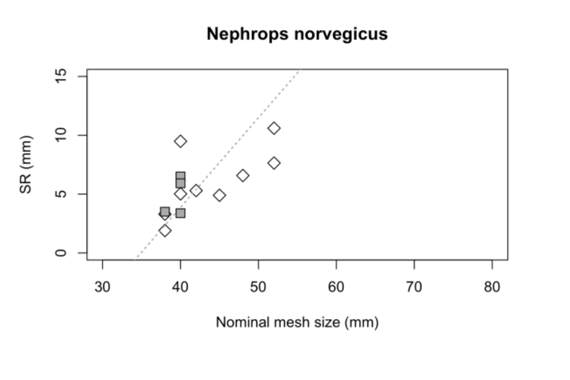
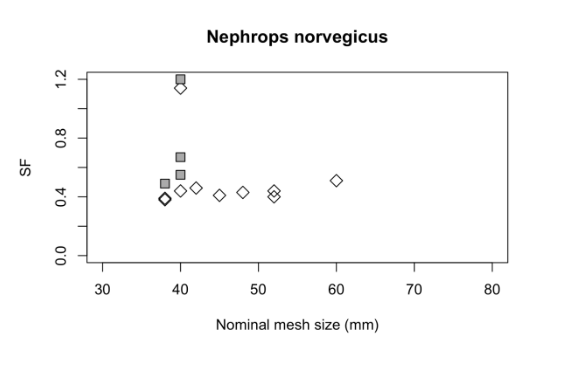



**Fig. 4.4** Norway lobster *Nephrops norvegicus*

Mediterranean MLS: 20 mm CL

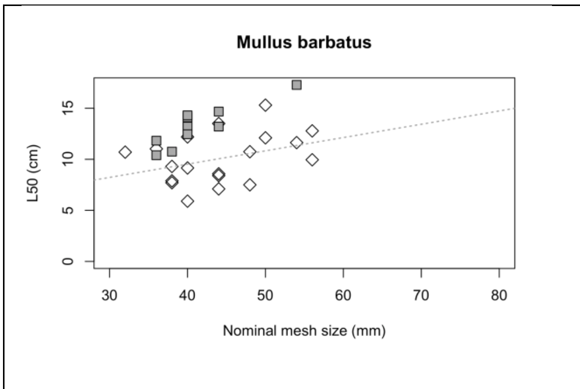
Both $L_{50}$ and SR significantly increasing




with increasing mesh size (a=-3.05, b=0.51 and a=-26.62, b= 0.76, respectively with $p<0.001$). No statistically significant effect on SF.

Square 40-mm mesh codends not significantly different from diamond 40-mm mesh codends on $L_{50}$, SR or SF.



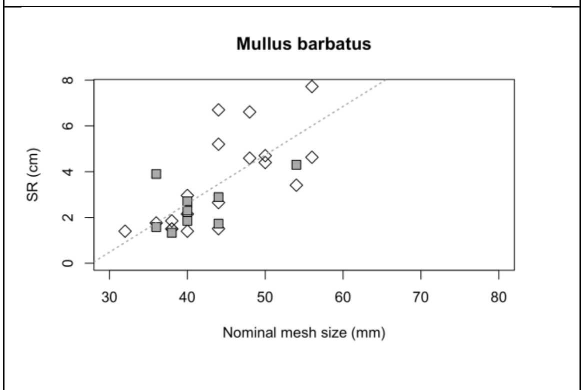
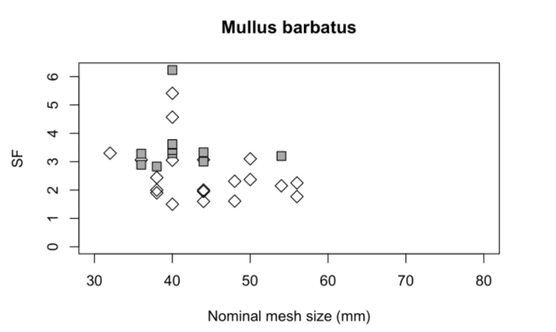



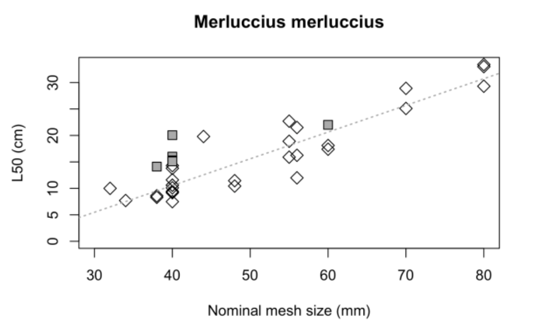

**Fig. 4.5** Red mullet *Mullus barbatus*

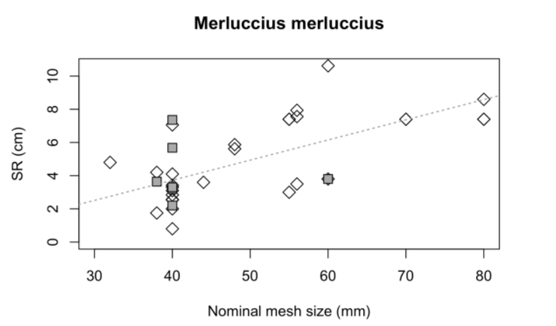
Mediterranean MLS: 11 cm TL

Both $L_{50}$ and SR significantly increasing with increasing mesh size (a=4.3233, b=0.1301 and a=-5.884, b=0.212, respectively $p<0.05$).

The $L_{50}$ of square 40-mm mesh codends (13.51 mm) was significantly higher than $L_{50}$ of diamond 40-mm mesh codends (9.08 mm), with $p<0.05$. No significant difference on SR or SF.



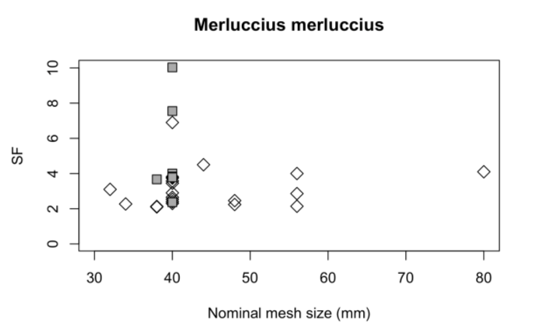




**Fig. 4.6** Hake *Merluccius merluccius*

Mediterranean MLS: 20 cm TL

Both $L_{50}$ and SR significantly increasing with increasing mesh size (a=-9.660, b=0.505 and a=-1.132, b=0.121, respectively with $p<0.001$). No statistically significant effect on SF.

The $L_{50}$ of square 40-mm mesh codends (16.33 mm) was significantly higher than $L_{50}$ of diamond 40-mm mesh codends (10.64 mm), with $p<0.05$. No significant difference on SR or SF.

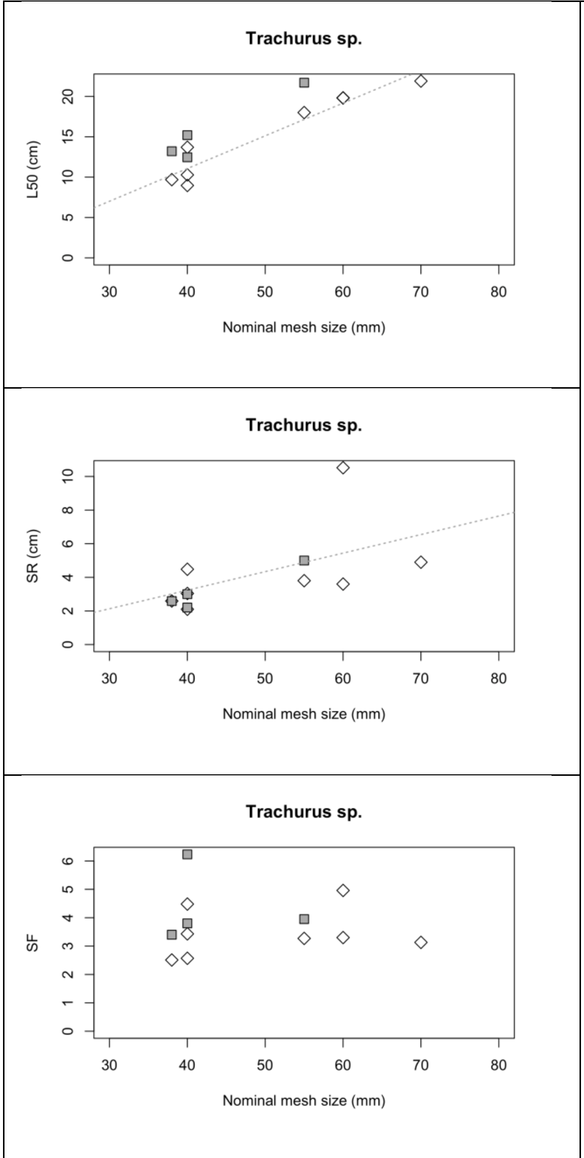



**Fig. 4.7** Horse mackerels *Trachurus* spp.

Mediterranean MLS: 15 cm TL

Both $L_{50}$ and SR significantly increasing with increasing mesh size (a=-5.141, b=0.4052 and a=-1.177, b=0.1103, respectively with p<0.001). No statistically significant effect on SF.

Square 40-mm mesh codends not significantly different from diamond 40-mm mesh codends on $L_{50}$, SR or SF.

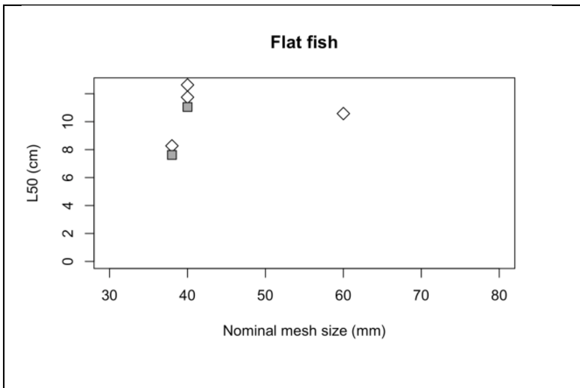
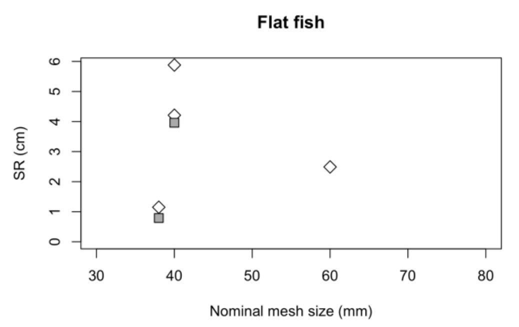
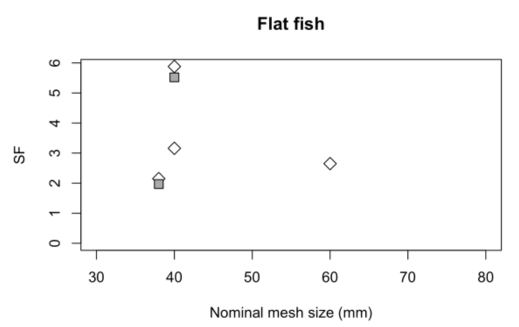



**Fig. 4.8** Two species of flatfish combined (*Lepidorhombus boscii* and *Arnoglossus laterna*)

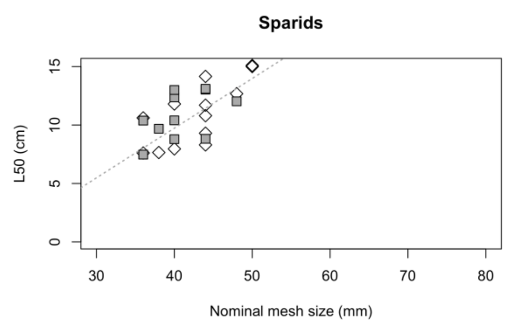
Mediterranean MLS: none




Insufficient data to test the effect of mesh size increase on $L_{50}$, SR, and SF.

Insufficient data to test the effect of mesh configuration on $L_{50}$, SR, and SF.



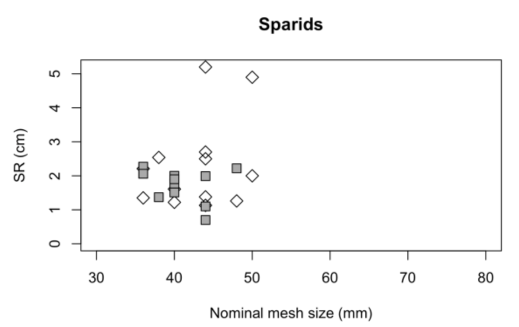
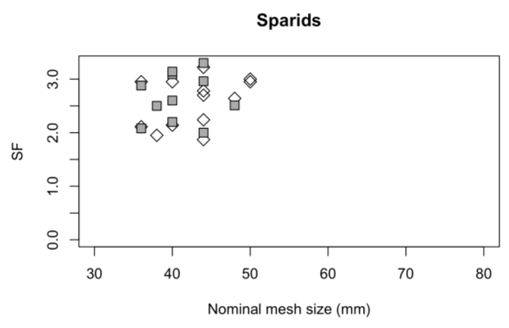




**Fig. 4.9** Three species of sea breams (Sparidae) combined *Diplodus vulgaris*, *Pagellus acarne* and *Pagellus erythrinus*

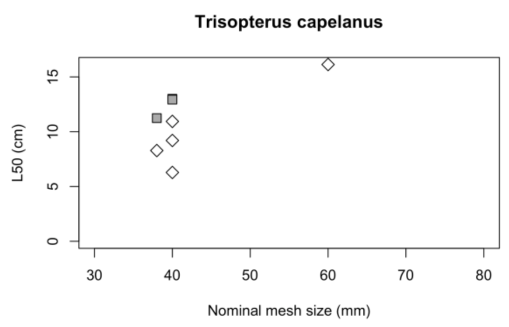
Mediterranean MLS: 12 cm (*Diplodus vulgaris*), 17 cm TL (*Pagellus acarne*), 15 cm TL (*Pagellus erythrinus*)

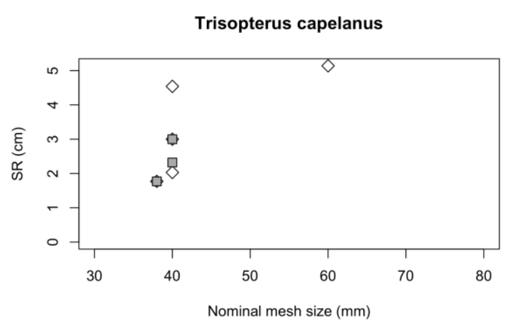
$L_{50}$ significantly increasing with increasing mesh size (a=-7.263, b=0.425 with $p<0.05$). No statistically significant effect on SF or SR.

No significant effect of square 40-mm mesh codends compared to diamond 40-




mm mesh codends.



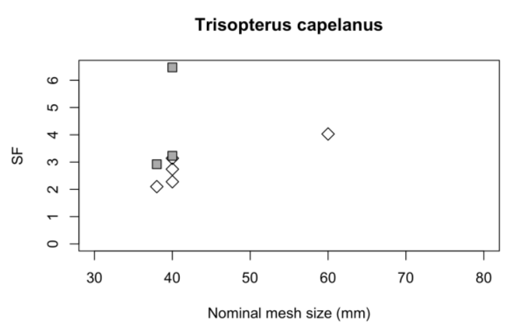




**Fig. 4.10** Poor cod (*Trisopterus capelanus*)

Mediterranean MLS: none

Insufficient data to test the effect of mesh size increase on $L_{50}$, SR, and SF.

Statistically larger $L_{50}$ in square 40-mm codends (12.97 cm TL) than in diamond 40-mm codends (8.81 cm TL) with $p<0.05$, but no effect on SR or SF.

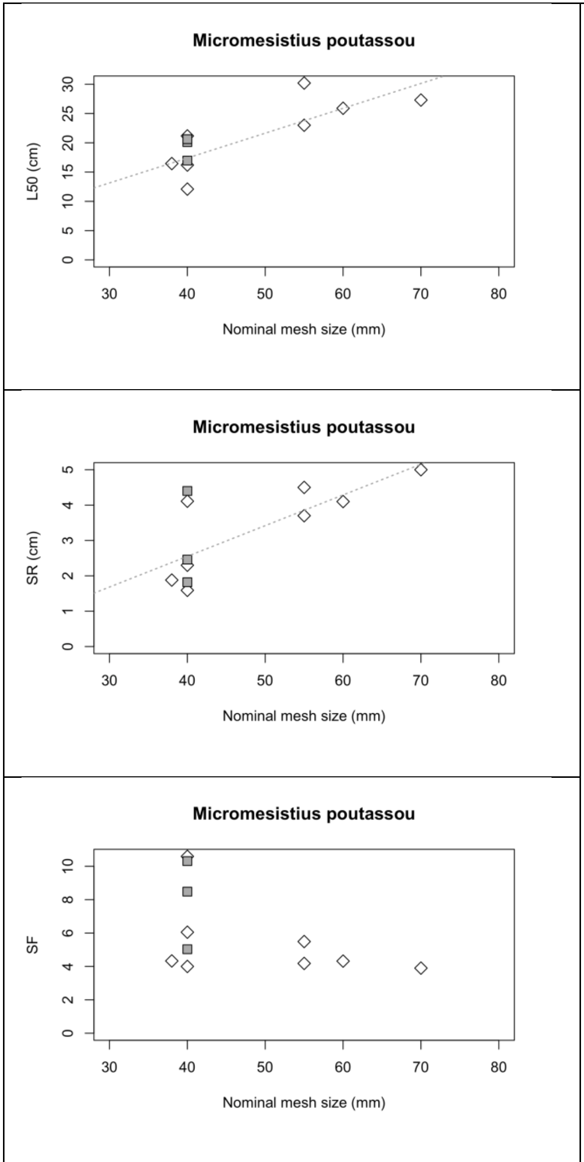



**Fig. 4.11** Blue whiting (*Micromesistius poutassou*)

Mediterranean MLS: none

Both $L_{50}$ and SR significantly increasing with increasing mesh size (a=0.403, b=0.4245 and a=-0.9208, b=0.087, respectively with $p<0.001$). No statistically significant effect on SF.

No effect on $L_{50}$, SR or SF of square 40-mm codends compared to diamond 40-mm codends.

Figs 4.1 to 4.4 show that increasing mesh size of diamond codends allows to increase $L_{50}$ and the selection range (SR) of the crustacean tested, which are the main crustacean resources in the Mediterranean, over the range of diamond meshes tested (40 to 60 mm stretched mesh). However, only codends with diamond meshes of 60 mm or higher would allow for $L_{50}$ higher than the MLS for those crustacean species that are regulated (*Parapenaeus longirostris* and *Nephrops norvegicus*).

Round fishes (red mullet Fig. 4.5, hake Fig. 4.6, blue whiting Fig. 4.11), horse mackerels (Fig. 4.7) and sea-breams (Fig. 4.9) showed increasing $L_{50}$ and SR with increasing mesh sizes in diamond mesh codends, over the range of diamond meshes tested (32 to 80 mm stretched mesh). Note that for hake only the larger meshes tested (60 mm and larger) would allow to obtain $L_{50}$ above MLS and only the largest mesh (80 mm) would allow to obtain near $L_{50}$ the mean size at maturity.

In the case of sea-breams, diamond mesh codends larger than 40 mm would produced $L_{50}$ above MLS for *Diplodus vulgaris*, but not for the other two species considered (*Pagellus acarne* and *P. erythrinus*) (Fig. 4.9).

### 4.1.2. From diamond to square meshes

Square mesh cod-ends have better properties in terms of $L_{50}$ (size at selection) or SR (selection range) than diamond meshes, according to the results of sea trials of numerous authors (see also recent review by Sala et al., 2015). For the same nominal mesh size, $L_{50}$ was larger and SR was smaller in square mesh than in diamond mesh in many studies. However, note that better size selectivity of square mesh is particularly evident for round fish (hake, red mullet) or shrimps and less so for flat fish or high-aspect fishes. Results by Campos et al. (2002, 2003) support the idea that increases in cod-end mesh size, but most importantly, changes in mesh configuration, from standard diamond to square mesh cod-ends, allows for the exclusion of a high proportion of undersized individuals, together with non-commercial by-catch. Also, Mallol (2005) reported that the number of fish escaping from a 40 mm square mesh codend was between 5 and 7 times greater than for a 40 mm diamond mesh codend for hake, poor cod, red mullet or mackerel in sea trials aboard a Spanish commercial trawler in the Gulf of Lions.

While square mesh is more selective than diamond mesh of similar size for roundfish (Robertson and Stewart, 1988), the opposite is the case with flatfish (Millar and Walsh, 1992). Square-meshes were found to be less selective for flat and/or deep-bodied fish as these escaped more readily from diamond-meshes in sea trials in southwest Portugal (Campos et al., 2003a), the Adriatic (Sala et al., 2008) and the Balearic islands (Guijarro and Massutí, 2006), among other examples.

For high-aspect fishes (e.g. Sparids) it would be expected that diamond mesh codends result in generally better size selectivity, but some studies did not find a significant difference between diamond mesh and square mesh codends (e.g. *Pagellus acarne*, *Diplodus annularis* in Tokaç et al., 1998). The behaviour of the species (shoaling, escape reaction, other) can also play a role in the selection process. In our data review process corresponding to Deliverable D1.1, Figs. A3 “Length frequency profiles” for GSA09, we found that horse mackerel (*Trachurus trachurus*) and poor cod (*Trisopterus capelanus*) show better selectivity with diamond mesh codends than with square mesh codends.

Our meta-analysis of the results of sea trials testing square mesh codends of 40 mm against similar sized diamond codends shows that using square mesh codends produced higher $L_{50}$ in the two crustaceans that had sufficient data for testing (clearly in deepwater rose shrimp, less so in Norway lobster, Figs. 4.3 and 4.4).

Round fishes (red mullet Fig. 4.5, hake Fig. 4.6, poor cod Fig. 4.10) showed higher $L_{50}$ in square mesh codends of 40 mm compared to diamond codends of the same size. In the case of red mullet, this increase is sufficient to bring $L_{50}$ in line with MLS in Mediterranean fisheries, but $L_{50}$ of hake would still be below regulation size.

No significant effect could be detected for horse mackerels, sea-breams or blue whiting (Figs 4.7, 4.9 and 4.11).

### 4.1.3. Introduction of square mesh panels

Square-mesh windows have been fitted to traditional diamond-mesh trawls in particular locations, such as on the top of the trawl main body, the trawl extension piece or near the bosom of the headrope. In Baltic fisheries a specific modification of the trawl using square-mesh windows (known as the BACOMA trawl) has become normative (STECF, 2012). Square mesh panels were tested both in the upper panel of the aft belly of the trawl (3 m in front of the codend) and in the top of the codend of crustacean trawls used off southwest Portugal. The windows were effective in excluding blue whiting and blue horse mackerel, but not boarfish, hake, horse mackerel or chub mackerel (Campos and Fonseca, 2004, 2007; Fonseca et al. 1998). Blue whiting and blue horse mackerel escapement was greatest (approximately 50% for both species) when the panels were placed on the top of the codend, but both panel locations resulted in an 11% loss of the target rose shrimp (Campos and Fonseca, 2007).

### 4.1.4. Modifying the codend circumference

Modifying the codend circumference (number of meshes) is equivalent to manipulating mesh opening angle (OA). Reducing the number of meshes results in a greater opening angle, providing enhanced opportunities for round fish species to escape. The number of available studies is limited (Özbilgin et al., 2005; Sala and Lucchetti, 2010, 2011; Sala et al., 2016; Tokaç et al., 2016) and the effectiveness of this modification is uncertain. Improved escape of juvenile hake (*Merluccius merluccius*) and poor cod (*Trisopterus capelanus*) has been documented when reducing codend circumference (Fiorentini and Leonori, 2002; Özbilgin et al., 2005). However, it is important to note that fishers can manipulate the codend circumference and offset the selectivity gains due to mesh size increase (Sala et al., 2006; Özbilgin et al., 2006).

### 4.1.5. Changing material of codend net

According to Bahamon et al. (2006) and Tokaç et al. (2004) the material of the codend (polyamyde, PA, or polyethylene, PE) is also important in improving selectivity, with PA nets producing larger $L_{50}$ than PE nets, although the quantity of studies is limited.

Experiments by Fonseca et al. (2007) in crustacean trawling evidenced this for rose shrimp (*Parapenaeus longirostris*), Norway lobster (*Nephrops norvegicus*) and blue and red shrimp (*Aristeus antennatus*). Deval et al. (2009) showed that for certain species of commercial crustaceans (e.g. *Parapenaeus longirostris*, *Aristaeomorpha foliacea*) codends made of PE allowed to produce higher $L_{50}$ than codends made of PA, for the same nominal size square mesh configuration.

### 4.1.6. Changing twine thickness

The number of experiments reporting the effect of twine thickness of codend nets on selectivity is limited for southern European waters. Sala et al. (2007a) show that $L_{50}$ decreased by as much as 20 to 31%, depending on the species, when increasing the twine thickness of polyamide nets from 2.38 to 2.89 mm. These results agree with similar sea trials elsewhere in Europe (Lowry and Robertson, 1996). Clearly, any regulation working only on mesh size increase can be offset by fishers by adjusting the twine thickness (Sala et al., 2007a; b).

## 4.2. By-catch reducing devices (BRD) in trawls

By-catch reducing devices (BRDs) are new structures inserted in fishing gears with the purpose of providing an escape route for unwanted species or sizes. Different combinations of flexible separator panels and square-mesh escapement panels were tested in the crustacean fishery in the south and southwest of Portugal, with the goal of promoting the escapement of semi-pelagic fish such as blue whiting and boarfish which are common bycatch in the fishery targeting the rose shrimp *Parapenaeus longirostris* and the Norway lobster *Nephrops norvegicus* (Campos and Fonseca, 2004). They are primarily conceived to take advantage of differences in behaviour between crustaceans and fish in order to reduce the by-catch fraction without significant loss of crustaceans.

The use of BRDs may significantly contribute to the exclusion of non-commercial by-catch through square mesh windows. Campos and Fonseca (2004) demonstrated that the addition of a separator panel was necessary to guide boarfish to the upper level of the trawl. Comparison of the data among experiments clearly demonstrates that the effectiveness of similar panels depends on the trawl in which they are used. Improved results were obtained in lower opening trawls, likely due to the increased probability for the different fish species to contact the square mesh escape panels.

Another type of bycatch reduction device for trawls is a sorting grid composed of spaced bars made of aluminum, steel or plastic and fitted to the extension piece immediately before the codend. These types of devices, the Nordmøre grid (Isaksen et al., 1992) being perhaps most popular example, are designed to separate species based on both their physical size and behavioural differences. The traditional Nordmøre grid was designed for northern European shrimp fisheries, based on the principle that large animals are guided upwards, towards an escape opening by the grid, while small animals (particularly shrimp) pass between the bars and end up in the cod end (Graham, 2003). A modification to obtain the contrary effect was tested to promote the escapement of small fishes or shrimp by Eayrs et al. (2007) in Vietnam. The SE Asian model (JTED "Juvenile and Trash Excluder Device") could be a potential solution in southern European fisheries, but the loss of marketable catch remains a problem.

Grids can be installed in their own short trawl section, allowing for easier maintenance and repairing. They also display more constant selection properties when compared to the flexible sorting panels, for which the performance varies according to the trawl geometry. Those specific properties have contributed to the commercial acceptance of grids, and their use is now mandatory in several crustacean fisheries in the North Atlantic, where in addition to minimizing discards they contribute to the reduction of sorting time on board and promote the quality of the target species.

For the Portuguese crustacean trawling, the separation of crustaceans (rose shrimp and Norway lobster) from fish, as well as the exclusion of small pelagic, low-valuable by-catch species such as the blue whiting and the boarfish, was addressed through the use of GCRUST1 (Fonseca et al., 2005), which is a modification of the original Nordmøre grid. The grid incorporated a lower bar-less section to allow the passage of crustaceans, mainly *Nephrops*, directly into the cod-end without being size-selected by the grid. Fish retained by the grid (i.e., not crossing the grid bars) escape through a triangular shaped hole, located just above the grid at the trawl upper panel.

A similar system was tested (Fonseca et al., 2006) with the purpose to separate crustacean from fish species while retaining the entire catch. In the latter system, the catch retained by the grid is not released, but instead guided to an upper codend section where it is kept. The results obtained in the experiments where sorting panels or grid systems (GCRUST1 and GCRUST2) were used, demonstrated successful sorting according to species. *Nephrops*, as well as rose shrimp, were directed into the cod-end, either passing between the grid bars or through the bar-less section at the bottom.. The passage of these species through the grid bars requires an adequate bar spacing to prevent losses. In GCRUST2, a considerable fraction of *Nephrops* was guided to the upper cod-end, due to decrease in bar- spacing from 25 to 20 mm.

An active escape behaviour was recorded for blue whiting in GCRUST1 (Fonseca et al., 2005), which is in agreement with what was previously observed by Campos and Fonseca (2004) when testing the selective properties of oblique panels and square mesh windows. More than 70% escaped from the trawl, being collected in a cover connected to the upper trawl section. The contact-probability with the grid, estimated from data, indicate that most blue whiting swam to avoid the grid bars. Hake, in contrast, displayed no avoidance reaction towards the grid, with all fishes contacting it.

A different grid system constructed entirely of polyurethane (GCRUST3) was tested in the crustacean trawl fishery (Fonseca et al. 2006). This system, unlike GCRUST1 and 2, is intended to be size-selective for both *Nephrops* and fish species, releasing immature individuals from the trawl through a grid section made in square meshes, while adults are guided to an upper opening section and retained in the cod-end.

Aydin et al. (2011) and Aydin and Tosunoglu (2012) showed that sorting grids can be efficient to separate fish from shrimps, especially in south European deepwater shrimp fisheries (*Parapenaeus longirostris*), but are not efficient for separating among different types of fishes or fish sizes due to problems with low aspect fishes, such as anglerfish, and clogging by shoaling species, such as horse mackerels (*Trachurus* spp.). Sardà et al. (2006) reported that sorting grids of 15 and 20 mm bar spacing were less size selective than a 36 mm square mesh codend in a continental shelf demersal mixed fishery, at least for the main species of that fishery (hake, red mullet, horse mackerel), with the notable exception of a flatfish that is bycatch of this fishery, *Citharus linguatula*, which showed higher $L_{50}$ with separating grids of 20 mm bar spacing.

Some studies show that in multispecies fisheries targeting a variety of fish species, bottom trawls fitted with sorting grids panels were not more size selective than regular bottom trawls with diamond meshes (Sardà et al., 2006). Bahamon et al. (2007b) reported that selectivity of a bottom trawl equipped with sorting grids was improved in several commercial species of the continental shelf and slope compared to trawls fitted with the traditional diamond mesh codends, but the difference was not significant when compared with square mesh codends.

Sorting grids can be rendered ineffective by marine litter, especially plastics, as shown by Eyasar et al. (2014), and marine litter is a pervasive problem on Mediterranean fishing grounds (Sánchez et al., 2013).

### 4.3. Passive or set fishing gear

Set nets (gillnets, trammel nets) or longlines used in southern Europe are inherently more size selective than bottom trawls. However, species selection is not guaranteed and the survival of by-catch likely low. In general, gillnets have better properties regarding species selection than trammel net.

Petrakis and Stergiou (1995; 1996) in sea trials with gillnets of four increasingly large mesh sizes (34 to 46 mm stretched mesh) showed that six target species of the Greek small scale fisheries had correspondingly higher $L_{50}$ as mesh sized increased.

As in trawl nets (Section 4.1 above), fishes with high aspect ratio, such as Sparids, may show lower $L_{50}$ than comparably sized round fish for a given gillnet mesh size (Petrakis and Stergiou, 1995; 1996).

Gillnets and trammel nets in use in Southern European fisheries generally range from 30 to 46 mm (stretched mesh) and retain fish above minimum landing size. Deliverable D1.1 of the MINOUW project (unpub. data) shows that trammel nets used in Catalonia produce catches of legal size for the majority of species, except for two species caught with sole trammel nets (regulation mesh size >=40 and <60 mm): Half of *Lithognathus mormyrus* and 31 % of *Solea vulgaris* captured are under the minimum landing size of 20 cm TL.

Stergiou and Erzini (2002) reported that bottom longlines used in the Aegean Sea had generally higher $L_{50}$ than gillnets targeting the same species. However, the small hooks of the bottom longlines trialled had high selection ranges and could effectively catch small size individuals of most sparid species studied. Scorpionfish (*Scorpaena porcus*) and comber (*Serranus cabrilla*) did not show this pattern and both fishing gear showed approximately the same pattern. In general, longlines will catch all fish above a certain size, while set nets catch fish only within a specific size window.

## 5. Analysis

### 5.1. Adverse economic effects

Short term loss of income due to the adoption of modifications to the fishing gear is to be expected and has been demonstrated (experimentally) in some cases (Ordines et al., 2006; Guijarro and Massutí, 2006). Modelling work for the northwest Mediterranean suggests a 10-20 % decrease in yield per recruit of hake, poor cod and greater forkbeard in the first year after replacement of 40 mm diamond mesh codends with 40 mm square mesh, but that yield per recruit would recover to pre-introduction levels by year two and increase by 55 % for hake and 20-30 % for poor cod and greater forkbeard after 4-5 years (Bahamon et al., 2007a). An analysis of the change from 40 mm diamond mesh to 40 mm square mesh or 50 mm diamond mesh in a bottom trawl fishery in SE Spain did not show any adverse income effects for fishers (Samy-Kamal et al., 2015). In any case, some studies with square-mesh codends show loss of small-bodied commercial species which may be a barrier to ‘buy in’ from fishers (Bahamon et al., 2006). The following table summarizes the estimates on loss of catch value produced for Mediterranean fisheries, mostly in the context of replacing 40-mm diamond mesh codends with 40-mm square mesh codends.

Table 1. Estimates of loss of income (catch value) from sea trials in Mediterranean bottom trawl fisheries.

| name in study | baseline net codend | modified net | study | study area | country | short term loss of commercial catch |
|---|---|---|---|---|---|---|
| **Deep water crustacean fishery** | DM40 | SM40 | Guijarro & Massutí 2006 | Balearic isl. | Sp | low (1.4-2.4%) |
| **continental shelf mixed fishery** | DM40 | SM40 | Bahamon et al. 2006 | Catalonia | Sp | high (14-34%) |
| **Deep water crustacean fishery** | DM40 | SM40 | Bahamon et al. 2006 | Catalonia | Sp | low (3-5%) |
| **continental shelf mixed fishery (shallow shelf)** | DM40 | SM40 | Ordines et al. 2006 | Balearic isl. | Sp | high (32%) |
| **continental shelf mixed fishery (deep shelf)** | DM40 | SM40 | Ordines et al. 2006 | Balearic isl. | Sp | low (3%) |
| **continental shelf mixed fishery** | DM44 | SM40 | Ozbilgin et al. 2015 | Mersin Bay (North Levant) | Tr | medium (17%) |
| **continental shelf mixed fishery** | DM44 | D40 | Ozbilgin et al. 2015 | Mersin Bay (North Levant) | Tr | low (9%) |
| **continental shelf mixed fishery** | DM44 | D50 | Ozbilgin et al. 2015 | Mersin Bay (North Levant) | Tr | high (21%) |
| **continental shelf mixed fishery** | DM44 | selection grids on DM44 | Aydin et al. 2011 | Aegean sea | Tr | high (23%) |
| **continental shelf mixed fishery** | SM44 | selection grids on SM44 | Aydin et al. 2011 | Aegean sea | Tr | high (25%) |
| **continental shelf mixed fishery** | DM40 | SM40 | Samy-Kamal et al. 2015 | SE Spain | Sp | none |
| **Deep water crustacean fishery** | DM40 | SM40 | Samy-Kamal et al. 2015 | SE Spain | Sp | none |
| **continental shelf mixed fishery** | DM40 | DM50 | Samy-Kamal et al. 2015 | SE Spain | Sp | none |
| **Deep water crustacean fishery** | DM40 | DM50 | Samy-Kamal et al. 2015 | SE Spain | Sp | none |

DM = Diamond Mesh SM = Square Mesh

Loss of income from adopting the current regulation 40-mm square mesh codend compared to the previous legal diamond mesh in Mediterranean continental slope mixed fisheries is estimated to be low (typically, less than 10%), while loss of income can be higher than 20% in continental shelf mixed fisheries. The loss of income from implementing selection grids can be high (Aydin et al., 2011; Bahamon et al., 2006). However, an analysis of sale bills at the fish market (Samy-Kamal et al., 2015), showed no difference in the income of trawl fleets in SE Spain before and after the official adoption of the new regulation square mesh.

As reported above, most of the studies on the modifications of fishing gears to increase selectivity assessed the change of the 40-mm diamond mesh codend by 40-mm square mesh codend or 50-mm diamond mesh codend as this change has been requested by Council Regulation (EC) No. 1967/2006. A number of research projects aimed at comparing the effects of different mesh sizes and types for trawlers were funded by MiPAAF (the Italian Ministry of Agricultural, Food and Forestry Policies) in the years before the issue of the Council Regulation (EC) No. 1967/2006 (D'Ambra, 2001; Belcari, 2005; Ferretti, 2006). Unfortunately, none of these studies analysed the change of the mesh from a cost perspective.

The economic evaluation carried out by these studies is generally limited to an estimate of the loss of income due to the landings compositions of the alternative meshes. Even in the economic analysis reported in D'Ambra (2001) it is explicitly assumed no variation in the costs structure. The impact on revenues is generally perceived as the most relevant, which is true in many cases, but changes in the fishing gears could affect also other important economic variables. The costs of adapting the fishing gear to comply with new regulations is typically borne by industry. Not many studies available, but there is evidence that short term losses in catch value can be mitigated by adopting new fishing gear that is cheaper, more efficient in terms of fuel consumption or that helps reduce sorting costs.

When technical adaptations for increasing selectivity require new investments, additional capital costs should be considered. A new investment would increase capital value affecting both depreciation costs and the opportunity costs of capital. The annual cost associated to the investment will be a function of the investment value and its lifetime, where the latter depends on the type of investment (hull, engine, electronics or other equipment). However, adaptations to increase selectivity do not necessarily require additional costs. In some cases, investments in selectivity can be done when a fishing gear or a part of it needs to be replaced anyway because damaged or worn.

Some technical modifications refer to parts of the fishing gear subjected to be frequently replaced. For instance, the codend and other pieces of the trawl net need to be changed frequently in some fisheries. In these cases, technical adaptations can be considered as repair or maintenance costs not affecting the capital costs. The new piece of the fishing gear could be at the same time more selective and cheaper than the old one, resulting in a benefit from an economic point of view. A study by Özbilgin et al. (2015) showed that the codends with the new square mesh of 40 mm were 6 times cheaper to build than the traditional diamond 44-mm mesh codends used in Turkey. Information from the Italian fishing sector says that a new mesh codend for a trawl net costs less than 150 Euro, including installation. This would suggest that costs (or benefits) from changing the mesh codend can be assumed as negligible if compared with the related loss of income.

This is confirmed also by a comparative study by Ünal and Tosunoglu on the economic impacts of 40 mm square and 44 mm diamond mesh shape in trawl fisheries in Turkey. The study, presented and discussed in GFCM (2010) within a review of selectivity studies on square mesh codend and grids applied to Mediterranean bottom trawls, suggests that changes of mesh shape do not incur any additional cost for fishers.

## 5.2. Positive economic effects

Fuel consumption, which represents the main cost for trawlers, could be affected by modifications in the mesh size. Indeed, one of the advantages of using larger mesh sizes in trawls is that they reduce drag and are more fuel-efficient. Although detailed studies are lacking in southern Europe, the study of Broadhurst et al. (2015) in an Australian penaeid shrimp fishery suggests that the short term loss of income could be partially offset by reduced fuel consumption of the fishing vessel. Suuronen et al. (2012), mentioning studies by Zúñiga et al. (2006), Rico-Mejía and Rueda (2007), Melo et al. (2008) and Heredia-Quevedo (2010), reports that technical modifications tested in bottom trawl fisheries in Mexico, Colombia and Chile to reduce by catch and fuel consumption show that reducing gear drag between 20 and 35% would produce fuel saving between 23 and 43%.

An aspect that has rarely been assessed is the savings in terms of manpower when using more selective fishing gear. By reducing unwanted catches, it is expected that sorting time would decrease in more selective fisheries, with corresponding savings in manpower or labour costs. The impact of more selective fishing gears on labour costs is expected to become even more relevant with the implementation of the landing obligation (Regulation (EU) No. 1380/2013). Indeed, the time spent to sort the product of each haul in fisheries with a relevant amount of discards may increase as a consequence of the new regulation. What could be discarded because not marketable, with the introduction of the new regulation should (at least partially) be stored, preserved in special boxes and brought to the ground. This could result in an increase of work on board and possibly in the number of employees.

## 5.3. Effectiveness

The review of the literature showed that, in general, increasing the mesh size of diamond nets, or adopting square mesh nets or fitting sorting grids are effective in improving the size or species selectivity of fishing gear, particularly bottom trawls. This general assertion needs to be qualified by the results of studies that show, for example, that 40-mm square mesh codends are not completely effective in avoiding the catch of undersize shrimp in bottom trawl fisheries targeting shrimp (Deval et al., 2009); to this end sorting grids are more effective (Aydin et al., 2011; Aydin and Tosunoglu, 2012). Sorting grids are highly effective in separating fish from shrimps in bottom trawl fisheries targeting shrimps (e.g. the deepwater rose shrimp *Parapenaeus longirostris*: Aydin and Tosunoglu, 2012). However, loss of income due to escapement of valuable fish by-catch can be expected. Also, sorting grids can be rendered ineffectual on bottoms with large amounts of marine litter (Eryasar et al., 2014).

The results of sea trials with different combinations of nets or bycatch reducing devices show often a degree of variability due to external factors such as the season, the type of net material (polyamide or polyethylene; knotted or knotless), small changes in rigging, bottom types, catch composition, etc.

With the exceptions of Stergiou et al (1997) and Ordines (2006), most studies only report on fishery target species, not on the entire trawl catch composition, so the ecosystem effects of changes in fishing gear selectivity cannot be assessed at the present time.

### 5.4. Uptake by industry

Legislative changes to regulations concerning fishing gear for fisheries conservation purposes are recurrent and to a large extent based on scientific studies. However, these changes are rarely monitored by fisheries scientists or technologists and the uptake of new nets by industry is rarely documented. For instance, 5 years after the 2011 mandatory introduction of square mesh codends in Mediterranean trawl fisheries it is not clear whether the measure has been universally adopted by industry.The effect on the commercial fisheries and on the conservation of resources of a series of increases in the minimum mesh size of bottom trawl codends in Spain (from diamond mesh of 38 mm before 2006 40 mm from 2006- 2010 and to square mesh of 40 mm since 2011 in Spain) has not been studied and, in general, the effectiveness of technical measures are not monitored over time. In general, data on how marine organisms and assemblages respond to technological changes in the fishing gear are poorly documented (Matić-Skoko et al., 2011). A recent study documenting a bottom trawl fishery in Alicante (SE Spain) could not detect any benefits or losses from adoption of the new fishing gear (from diamond mesh of 40 mm to square mesh of the same size, Samy-Kamal et al., 2015). The new nets could be hydrodynamically more efficient and allow to trawl faster, hence offsetting the short-term losses to be expected in the more selective nets. However, undetected manipulation of the new nets by fishers to offset the short-term losses could not be ruled out.

The successful use of technical measures depend to a large extent on their acceptance by industry and due to lack of short term financial incentives and lack of long-term perspective, vessel operators may try to circumvent technical measures whose implementation reduces their operating profit in the short term (Suuronen and Sardà, 2007b).

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# 7. Annex 1 – Selectivity parameters obtained during the review process, with source.

| species code | species | nominal mesh.size (mm) | mesh.id[1] | codend material[2] | L50[3] | SR[4] | SF[5] | source | area |
|---|---|---|---|---|---|---|---|---|---|
| **WHB** | Micromesistius poutassou | 38 | DM38 | | 16.45 | 1.88 | 4.33 | Del. 1.1 (from Project Discards 1) | GSA6 |
| **HKE** | Merluccius merluccius | 40 | DM40 | PE | 10.10 | 3.10 | 2.53 | Bahamon et al.. 2006 | GSA6 |
| **HKE** | Merluccius merluccius | 40 | SM40 | PE | 16.00 | 3.20 | 4.00 | Bahamon et al.. 2006 | GSA6 |
| **NEP** | Nephrops norvegicus | 40 | SM40 | PE | 22.00 | 6.50 | 0.55 | Bahamon et al.. 2006 | GSA6 |
| **WHB** | Micromesistius poutassou | 40 | SM40 | PA | 20.12 | 2.46 | 5.03 | Guijarro & Massutí 2006 | GSA05 |
| **ARA** | Aristeus antennatus | 40 | SM40 | PA | 22.05 | 3.99 | 0.55 | Guijarro & Massutí 2006 | GSA05 |
| **DPS** | Parapenaeus longirostris | 40 | DM40 | PA | 16.60 | 3.80 | 0.42 | Guijarro & Massutí 2006 | GSA05 |
| **DPS** | Parapenaeus longirostris | 40 | SM40 | PA | 20.22 | 2.33 | 0.51 | Guijarro & Massutí 2006 | GSA05 |

[1] type of mesh: (D)iamond; (S)quare

[2] PE: polyethylene; PA: Polyamyde

[3] Size at 50% selection: as cm TL for fishes and mm CL for crustaceans

[4] Selection Range: as cm TL for fishes and mm CL for crustaceans

[5] Selection factor, no units.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **NEP** | Nephrops norvegicus | 40 | SM40 | PA | 26.62 | 3.38 | 0.67 | Guijarro & Massutí 2006 | GSA05 |
| **HKE** | Merluccius merluccius | 40 | DM40 | PA | 11.60 | 0.80 | 2.90 | Guijarro & Massutí 2006 | GSA05 |
| **HKE** | Merluccius merluccius | 40 | SM40 | PA | 15.30 | 2.20 | 3.83 | Guijarro & Massutí 2006 | GSA05 |
| **MUT** | Mullus barbatus | 36 | DM36 | | 11.02 | 1.76 | 3.06 | Tokaç et al. 1998 | GSA22 |
| **MUT** | Mullus barbatus | 36 | SM36 | | 11.82 | 1.58 | 3.28 | Tokaç et al. 1998 | GSA22 |
| **MUT** | Mullus barbatus | 40 | DM40 | | 12.19 | 2.15 | 3.05 | Tokaç et al. 1998 | GSA22 |
| **MUT** | Mullus barbatus | 40 | SM40 | | 13.20 | 1.85 | 3.30 | Tokaç et al. 1998 | GSA22 |
| **MUT** | Mullus barbatus | 44 | DM44 | | 13.50 | 2.65 | 3.07 | Tokaç et al. 1998 | GSA22 |
| **MUT** | Mullus barbatus | 44 | SM44 | | 14.67 | 2.89 | 3.33 | Tokaç et al. 1998 | GSA22 |
| **SBA** | Pagellus acarne | 36 | DM36 | | 10.61 | 2.21 | 2.95 | Tokaç et al. 1998 | GSA22 |
| **SBA** | Pagellus acarne | 36 | SM36 | | 10.38 | 2.27 | 2.88 | Tokaç et al. 1998 | GSA22 |
| **SBA** | Pagellus acarne | 40 | DM40 | | 11.80 | 1.61 | 2.95 | Tokaç et al. 1998 | GSA22 |
| **SBA** | Pagellus acarne | 40 | SM40 | | 12.36 | 1.77 | 3.09 | Tokaç et al. 1998 | GSA22 |
| **SBA** | Pagellus acarne | 44 | DM44 | | 14.16 | 1.38 | 3.22 | Tokaç et al. 1998 | GSA22 |
| **SBA** | Pagellus acarne | 44 | SM44 | | 13.03 | 1.99 | 2.96 | Tokaç et al. 1998 | GSA22 |
| **ANN** | Diplodus annularis | 36 | DM36 | | 7.61 | 1.35 | 2.11 | Tokaç et al. 1998 | GSA22 |
| **ANN** | Diplodus annularis | 36 | SM36 | | 7.47 | 2.06 | 2.08 | Tokaç et al. 1998 | GSA22 |
| **ANN** | Diplodus annularis | 40 | DM40 | | 7.96 | 1.22 | 2.14 | Tokaç et al. 1998 | GSA22 |
| **ANN** | Diplodus annularis | 40 | SM40 | | 8.79 | 1.51 | 2.20 | Tokaç et al. 1998 | GSA22 |
| **ANN** | Diplodus annularis | 44 | DM44 | | 9.30 | 1.13 | 2.24 | Tokaç et al. 1998 | GSA22 |
| **ANN** | Diplodus | 44 | SM44 | | 8.82 | 1.10 | 2.00 | Tokaç et al. 1998 | GSA22 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | annularis | | | | | | | | |
| **ANN** | Diplodus annularis | 48 | DM48 | | 12.68 | 1.26 | 2.64 | Tokaç et al. 1998 | GSA22 |
| **ANN** | Diplodus annularis | 48 | SM48 | | 12.03 | 2.22 | 2.51 | Tokaç et al. 1998 | GSA22 |
| **HKE** | Merluccius merluccius | 48 | M48C280 | | 11.45 | 5.62 | 2.46 | Sala and Luchetti 2011 | GSA17 |
| **HKE** | Merluccius merluccius | 48 | M48C326 | | 10.43 | 5.87 | 2.24 | Sala and Luchetti 2011 | GSA17 |
| **HKE** | Merluccius merluccius | 56 | M56C240 | | 16.25 | 7.56 | 2.86 | Sala and Luchetti 2011 | GSA17 |
| **HKE** | Merluccius merluccius | 56 | M56C280 | | 11.99 | 7.94 | 2.14 | Sala and Luchetti 2011 | GSA17 |
| **MUT** | Mullus barbatus | 48 | M48C280 | | 10.74 | 4.59 | 2.31 | Sala and Luchetti 2011 | GSA17 |
| **MUT** | Mullus barbatus | 48 | M48C326 | | 7.50 | 6.61 | 1.61 | Sala and Luchetti 2011 | GSA17 |
| **MUT** | Mullus barbatus | 56 | M56C240 | | 12.78 | 4.63 | 2.25 | Sala and Luchetti 2011 | GSA17 |
| **MUT** | Mullus barbatus | 56 | M56C280 | | 9.95 | 7.72 | 1.77 | Sala and Luchetti 2011 | GSA17 |
| **MSF** | Arnoglossus laterna | 38 | DM38 | | 8.27 | 1.15 | 2.15 | Sala et al. 2008 | GSA17 |
| **MSF** | Arnoglossus laterna | 38 | SM38 | | 7.62 | 0.79 | 1.97 | Sala et al. 2008 | GSA17 |
| **SQM** | Illex coindettii | 38 | DM38 | | 4.89 | 0.97 | 1.27 | Sala et al. 2008 | GSA17 |
| **SQM** | Illex coindettii | 38 | SM38 | | 8.60 | 1.82 | 2.17 | Sala et al. 2008 | GSA17 |
| **HKE** | Merluccius merluccius | 38 | DM38 | | 8.30 | 1.75 | 2.13 | Sala et al. 2008 | GSA17 |
| **HKE** | Merluccius merluccius | 38 | SM38 | | 14.11 | 3.64 | 3.67 | Sala et al. 2008 | GSA17 |
| **MUT** | Mullus barbatus | 38 | DM38 | | 7.89 | 1.85 | 2.00 | Sala et al. 2008 | GSA17 |
| **MUT** | Mullus barbatus | 38 | SM38 | | 10.75 | 1.33 | 2.83 | Sala et al. 2008 | GSA17 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **NEP** | Nephrops norvegicus | 38 | DM38 | | 15.60 | 1.90 | 0.38 | Sala et al. 2008 | GSA17 |
| **NEP** | Nephrops norvegicus | 38 | SM38 | | 19.20 | 3.50 | 0.49 | Sala et al. 2008 | GSA17 |
| **PAC** | Pagellus erythrinus | 38 | DM38 | | 7.65 | 2.54 | 1.95 | Sala et al. 2008 | GSA17 |
| **PAC** | Pagellus erythrinus | 38 | SM38 | | 9.68 | 1.37 | 2.50 | Sala et al. 2008 | GSA17 |
| **DPS** | Parapenaeus longirostris | 38 | DM38 | | 11.90 | 2.40 | 0.31 | Sala et al. 2008 | GSA17 |
| **DPS** | Parapenaeus longirostris | 38 | SM38 | | 15.00 | 2.40 | 0.39 | Sala et al. 2008 | GSA17 |
| **HMM** | Trachurus mediterraneus | 38 | DM38 | | 9.69 | 2.59 | 2.51 | Sala et al. 2008 | GSA17 |
| **HMM** | Trachurus mediterraneus | 38 | SM38 | | 13.21 | 2.59 | 3.40 | Sala et al. 2008 | GSA17 |
| **POD** | Trisopterus capelanus | 38 | DM38 | | 8.28 | 1.77 | 2.10 | Sala et al. 2008 | GSA17 |
| **POD** | Trisopterus capelanus | 38 | SM38 | | 11.24 | 1.77 | 2.92 | Sala et al. 2008 | GSA17 |
| **HKE** | Merluccius merluccius | 40 | DM40 | | 10.60 | 3.30 | 3.45 | Ordines et al. 2006 | GSA05 |
| **HKE** | Merluccius merluccius | 40 | SM40 | | 15.20 | 3.30 | 3.78 | Ordines et al. 2006 | GSA05 |
| **HKE** | Merluccius merluccius | 40 | DM40 | | 13.79 | 7.06 | 6.90 | Petrakis & Stergiou 1997 | GSA22 |
| **HKE** | Merluccius merluccius | 40 | SM40 | | 15.10 | 5.68 | 7.55 | Petrakis & Stergiou 1997 | GSA22 |
| **WHB** | Micromesistius poutassou | 40 | DM40 | | 21.17 | 4.11 | 10.59 | Petrakis & Stergiou 1997 | GSA22 |
| **WHB** | Micromesistius | 40 | SM40 | | 16.96 | 4.40 | 8.48 | Petrakis & Stergiou 1997 | GSA22 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | poutassou | | | | | | | | |
| **MUT** | Mullus barbatus | 36 | SM36 | | 10.40 | 3.90 | 2.89 | Sardà et al. 2006 | GSA6 |
| **PAC** | Pagellus erythrinus | 40 | SM40 | | 10.40 | 2.00 | 2.60 | Ordines et al. 2006 | GSA05 |
| **HMM** | Trachurus mediterraneus | 40 | DM40 | | 13.70 | 2.10 | 3.43 | Ordines et al. 2006 | GSA05 |
| **HMM** | Trachurus mediterraneus | 40 | SM40 | | 15.20 | 3.00 | 3.80 | Ordines et al. 2006 | GSA05 |
| **MUR** | Mullus surmuletus | 40 | DM40 | | 4.50 | 5.80 | 1.13 | Ordines et al. 2006 | GSA05 |
| **POD** | Trisopterus capelanus | 40 | DM40 | | 9.20 | 3.00 | 2.28 | Bahamon et al. 2006 | GSA6 |
| **POD** | Trisopterus capelanus | 40 | SM40 | | 13.00 | 3.00 | 3.23 | Bahamon et al. 2006 | GSA6 |
| **ARS** | Aristaeomorpha foliacea | 44 | SM44-160 | | 20.71 | 2.60 | 0.47 | Sala et al. 2015 | GSA17 |
| **ARS** | Aristaeomorpha foliacea | 54 | DM54-256 | | 21.52 | 8.73 | 0.40 | Sala et al. 2015 | GSA17 |
| **ARS** | Aristaeomorpha foliacea | 54 | SM54-128 | | 27.57 | 5.63 | 0.51 | Sala et al. 2015 | GSA17 |
| **MUT** | Mullus barbatus | 44 | DM44-320 | | 8.58 | 1.51 | 1.95 | Sala et al. 2015 | GSA17 |
| **MUT** | Mullus barbatus | 44 | SM44-160 | | 13.20 | 1.73 | 3.00 | Sala et al. 2015 | GSA17 |
| **MUT** | Mullus barbatus | 54 | DM54-256 | | 11.63 | 3.41 | 2.15 | Sala et al. 2015 | GSA17 |
| **MUT** | Mullus barbatus | 54 | SM54-128 | | 17.28 | 4.30 | 3.20 | Sala et al. 2015 | GSA17 |
| **DPS** | Parapenaeus longirostris | 36 | DM36 | | 14.26 | 3.09 | 0.4 | Sobrino et al. 2000 | ICES IX (Gulf of Cadis) |
| **DPS** | Parapenaeus longirostris | 46 | DM46 | | 19.22 | 6.56 | 0.42 | Sobrino et al. 2000 | ICES IX (Gulf of Cadis) |
| **DPS** | Parapenaeus longirostris | 52 | DM52 | | 19.33 | 8.36 | 0.37 | Sobrino et al. 2000 | ICES IX (Gulf of Cadis) |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **DPS** | Parapenaeus longirostris | 42 | DM42 | | 20.85 | 6.67 | 0.49 | Sobrino et al. 2000 | ICES IX (Gulf of Cadis) |
| **DPS** | Parapenaeus longirostris | 60 | DM60 | | 26.26 | 7.62 | 0.44 | Sobrino et al. 2000 | ICES IX (Gulf of Cadis) |
| **DPS** | Parapenaeus longirostris | 66 | DM66 | | 29.63 | 13.77 | 0.45 | Sobrino et al. 2000 | ICES IX (Gulf of Cadis) |
| **DPS** | Parapenaeus longirostris | 40 | DM40 | | 14.6225 | 3.73 | 0.365 | Sobrino et al. 2000 | ICES IX (Gulf of Cadis) |
| **MUT** | Mullus barbatus | 44 | CD44 | | 7.10 | 6.70 | 1.60 | Özbilgin et al. 2015 | GSA24 |
| **MUT** | Mullus barbatus | 44 | D44 | | 8.40 | 5.20 | 2.00 | Özbilgin et al. 2015 | GSA24 |
| **MUT** | Mullus barbatus | 50 | D50 | | 12.10 | 4.70 | 2.37 | Özbilgin et al. 2015 | GSA24 |
| **MUT** | Mullus barbatus | 40 | SM40 | | 14.10 | 2.60 | 3.41 | Özbilgin et al. 2015 | GSA24 |
| **PAC** | Pagellus erythrinus | 44 | CD44 | | 8.30 | 2.50 | 1.87 | Özbilgin et al. 2015 | GSA24 |
| **PAC** | Pagellus erythrinus | 44 | D44 | | 11.70 | 5.20 | 2.78 | Özbilgin et al. 2015 | GSA24 |
| **PAC** | Pagellus erythrinus | 50 | D50 | | 15.10 | 4.90 | 2.95 | Özbilgin et al. 2015 | GSA24 |
| **PAC** | Pagellus erythrinus | 40 | SM40 | | 13.00 | 1.90 | 3.14 | Özbilgin et al. 2015 | GSA24 |
| **MUT** | Mullus barbatus | 40 | SM40 | | 14.30 | 2.30 | 3.60 | Aydin et al. 2011 | GSA22 |
| **MUT** | Mullus barbatus | 50 | DM50 | | 15.30 | 4.40 | 3.10 | Aydin et al. 2011 | GSA22 |
| **PAC** | Pagellus erythrinus | 44 | DM40 | | 10.8 | 2.70 | 2.70 | Tokaç et al. 2004 | GSA22 |
| **PAC** | Pagellus erythrinus | 44 | SM40 | | 13.10 | 0.70 | 3.30 | Aydin et al. 2011 | GSA22 |
| **PAC** | Pagellus erythrinus | 50 | DM50 | | 15.00 | 2.00 | 3.00 | Aydin et al. 2011 | GSA22 |
| **ARS** | Aristaeomorpha foliacea | 44 | DM44PA | PA | 18.50 | 5.80 | 0.42 | Deval et al. 2009 | GSA24 |

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|---|---|---|---|---|---|---|---|---|---|
| **ARS** | Aristaeomorpha foliacea | 40 | SM40PE | PE | 18.60 | 4.00 | 0.49 | Deval et al. 2009 | GSA24 |
| **ARA** | Aristeus antennatus | 44 | DM44PA | PA | 17.00 | 7.20 | 0.39 | Deval et al. 2009 | GSA24 |
| **ARA** | Aristeus antennatus | 40 | SM40PE | PE | 19.80 | 4.80 | 0.53 | Deval et al. 2009 | GSA24 |
| **DPS** | Parapenaeus longirostris | 44 | DM44PA | PA | 16.30 | 6.10 | 0.38 | Deval et al. 2009 | GSA24 |
| **DPS** | Parapenaeus longirostris | 40 | SM40PE | PE | 18.20 | 5.50 | 0.48 | Deval et al. 2009 | GSA24 |
| **ARS** | Aristaeomorpha foliacea | 60 | DM60 | | 19.50 | | 0.33 | D'Onghia et al. 1998a | GSA20 |
| **ARA** | Aristeus antennatus | 60 | DM60 | | 23.70 | | 0.40 | D'Onghia et al. 1998a | GSA20 |
| **MUT** | Mullus barbatus | 38 | DM38 | | 9.30 | 1.50 | 2.44 | Voliani and Abella 1998 | GSA09 |
| **HKE** | Merluccius merluccius | 34 | DM34 | | 7.70 | | 2.27 | Sbrana and Sartor (project FARWEST) | GSA09 |
| **ARS** | Aristaeomorpha foliacea | 40 | DM40 | | 18.60 | 4.00 | 0.47 | Ragonese et al. 2002 | GSA16 |
| **ARS** | Aristaeomorpha foliacea | 48 | DM48 | | 20.80 | 4.80 | 0.43 | Ragonese et al. 2002 | GSA16 |
| **ARS** | Aristaeomorpha foliacea | 56 | DM56 | | 24.50 | 8.00 | 0.44 | Ragonese et al. 2002 | GSA16 |
| **ARS** | Aristaeomorpha foliacea | 50 | DM50 | | 16.20 | 6.30 | 0.32 | Carlucci et al. 2006 | GSA19 |
| **ARS** | Aristaeomorpha foliacea | 60 | DM60 | | 21.20 | 10.70 | 0.35 | Carlucci et al. 2006 | GSA19 |
| **ARA** | Aristeus antennatus | 48 | DM48 | | 19.90 | | 0.41 | Ragonese et al. 1994 | GSA16 |
| **ARA** | Aristeus | 56 | DM56 | | 20.50 | | 0.37 | Ragonese et al. 1994 | GSA16 |

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|---|---|---|---|---|---|---|---|---|---|
| | antennatus | | | | | | | | |
| **ARA** | Aristeus antennatus | 50 | DM50 | | 19.00 | | 0.38 | D'Onghia et al. 2003 | GSA19 |
| **ARA** | Aristeus antennatus | 60 | DM60 | | 25.40 | | 0.42 | D'Onghia et al. 2003 | GSA19 |
| **ARA** | Aristeus antennatus | 50 | DM50 | | 19.40 | | 0.39 | Carlucci et al. 2006 | GSA19 |
| **ARA** | Aristeus antennatus | 60 | DM60 | | 23.60 | | 0.39 | Carlucci et al. 2006 | GSA19 |
| **HKE** | Merluccius merluccius | 44 | DM44PA | PA | 19.80 | 3.6 | 4.5 | Deval et al. 2007 | GSA28 |
| **HKE** | Merluccius merluccius | 56 | DM56PA | PA | 21.50 | 3.5 | 4 | Deval et al. 2007 | GSA28 |
| **HKE** | Merluccius merluccius | 80 | DM80PA | PA | 33.40 | 8.6 | 4.1 | Deval et al. 2007 | GSA28 |
| **HKE** | Merluccius merluccius | 40 | DM40PE | PE | 10.60 | 2.84 | 2.65 | Tosunoglu et al. 2003 (in Deval et al. 2007) | GSA28 |
| **HKE** | Merluccius merluccius | 40 | DM40PE | PE | 14.30 | 3.42 | 3.575 | Ozbilgin et al. 2005 (in Deval et al.. 2007) | GSA28 |
| **GUU** | Trigla lucerna | 44 | DM44PA | PA | 17.90 | 2.3 | 4.1 | Deval et al. 2007 | GSA28 |
| **GUU** | Trigla lucerna | 56 | DM56PA | PA | 17.70 | 3.8 | 3.3 | Deval et al. 2007 | GSA28 |
| **GUU** | Trigla lucerna | 80 | DM80PA | PA | 25.60 | 6.6 | 3.3 | Deval et al. 2007 | GSA28 |
| **HKE** | Merluccius merluccius | 40 | DM40 | | 7.49 | 2.54 | 3.74 | Mallol 2005 | GSA07 |
| **WHB** | Micromesistius poutassou | 40 | DM40 | | 12.09 | 1.59 | 6.05 | Mallol 2005 | GSA07 |
| **POD** | Trisopterus capelanus | 40 | DM40 | | 6.28 | 2.03 | 3.14 | Mallol 2005 | GSA07 |
| **MUT** | Mullus barbatus | 40 | DM40 | | 9.15 | 2.96 | 4.57 | Mallol 2005 | GSA07 |
| **LDB** | Lepidorhombus | 40 | DM40 | | 11.75 | 5.88 | 5.88 | Mallol 2005 | GSA07 |

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|---|---|---|---|---|---|---|---|---|---|
| | boscii | | | | | | | | |
| **HOM** | Trachurus trachurus | 40 | DM40 | | 8.97 | 4.48 | 4.48 | Mallol 2005 | GSA07 |
| **HKE** | Merluccius merluccius | 40 | SM40 | | 20.05 | 7.36 | 10.03 | Mallol 2005 | GSA07 |
| **WHB** | Micromesistius poutassou | 40 | SM40 | | 20.62 | 1.82 | 10.31 | Mallol 2005 | GSA07 |
| **POD** | Trisopterus capelanus | 40 | SM40 | | 12.93 | 2.32 | 6.47 | Mallol 2005 | GSA07 |
| **MUT** | Mullus barbatus | 40 | SM40 | | 12.45 | 2.71 | 6.23 | Mallol 2005 | GSA07 |
| **LDB** | Lepidorhombus boscii | 40 | SM40 | | 11.05 | 3.96 | 5.52 | Mallol 2005 | GSA07 |
| **HOM** | Trachurus trachurus | 40 | SM40 | | 12.46 | 2.2 | 6.23 | Mallol 2005 | GSA07 |
| **NEP** | Nephrops norvegicus | 38 | DM38 | | 14.90 | 3.3 | 0.39 | Sardà et al. 1993 | GSA06 |
| **NEP** | Nephrops norvegicus | 42 | DM42 | | 19.40 | 5.3 | 0.46 | Sardà et al. 1993 | GSA06 |
| **NEP** | Nephrops norvegicus | 45 | DM45 | | 18.90 | 4.9 | 0.41 | Sardà et al. 1993 | GSA06 |
| **NEP** | Nephrops norvegicus | 52 | DM52 | | 23.10 | 10.6 | 0.44 | Sardà et al. 1993 | GSA06 |
| **NEP** | Nephrops norvegicus | 60 | DM60 | | 30.80 | 25.9 | 0.51 | Sardà et al. 1993 | GSA06 |
| **NEP** | Nephrops norvegicus | 40 | DM40 | | 17.83 | 5.02 | 0.44 | Mytilineou et al. 1998 | GSA22 |
| **NEP** | Nephrops norvegicus | 48 | DM48 | | 20.06 | 6.58 | 0.43 | Mytilineou et al. 1998 | GSA22 |
| **NEP** | Nephrops norvegicus | 52 | DM52 | | 20.53 | 7.64 | 0.4 | Mytilineou et al. 1998 | GSA22 |

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|---|---|---|---|---|---|---|---|---|---|
| **NEP** | Nephrops norvegicus | 40 | DM40 | | 22.82 | 9.49 | 1.14 | Stergiou et al. 1997 | GSA22 |
| **NEP** | Nephrops norvegicus | 40 | SM40 | | 24.05 | 5.92 | 1.2 | Stergiou et al. 1997 | GSA22 |
| **ARY** | Argentina sphyraena | 40 | D40 | | 11.31 | 4.23 | 2.83 | Belcari et al. 2007 | GSA9 |
| **MSF** | Arnoglossus laterna | 40 | D40 | | 12.63 | 4.21 | 3.16 | Belcari et al. 2007 | GSA9 |
| **BRF** | Helicolenus dactylopterus | 40 | D40 | | 6.73 | 1.96 | 1.68 | Belcari et al. 2007 | GSA9 |
| **HKE** | Merluccius merluccius | 40 | D40 | | 9.17 | 2.56 | 2.29 | Belcari et al. 2007 | GSA9 |
| **GFB** | Phycis blennoides | 40 | D40 | | 11.95 | 3.17 | 2.99 | Belcari et al. 2007 | GSA9 |
| **HOM** | Trachurus trachurus | 40 | D40 | | 10.28 | 3.04 | 2.57 | Belcari et al. 2007 | GSA9 |
| **POD** | Trisopterus capelanus | 40 | D40 | | 10.94 | 4.54 | 2.74 | Belcari et al. 2007 | GSA9 |
| **EOI** | Eledone cirrhosa | 40 | D40 | | 4.60 | 3.62 | 1.15 | Belcari et al. 2007 | GSA9 |
| **SQM** | Illex coindetii | 40 | D40 | | 4.10 | 2.00 | 1.00 | Belcari et al. 2007 | GSA9 |
| **DPS** | Parapenaeus longirostris | 40 | D40 | | 12.98 | 5.32 | 3.25 | Belcari et al. 2007 | GSA9 |
| **ARY** | Argentina sphyraena | 60 | D60 | | 23.12 | 9.95 | 5.78 | Belcari et al. 2007 | GSA9 |
| **MSF** | Arnoglossus laterna | 60 | D60 | | 10.58 | 2.49 | 2.65 | Belcari et al. 2007 | GSA9 |
| **BRF** | Helicolenus dactylopterus | 60 | D60 | | 10.31 | 3.17 | 2.58 | Belcari et al. 2007 | GSA9 |
| **HKE** | Merluccius merluccius | 60 | D60 | | 18.10 | 10.62 | 3.02 | Belcari et al. 2007 | GSA9 |
| **GFB** | Phycis blennoides | 60 | D60 | | 17.23 | 5.38 | 4.31 | Belcari et al. 2007 | GSA9 |

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|---|---|---|---|---|---|---|---|---|---|
| **HOM** | Trachurus trachurus | 60 | D60 | | 19.83 | 10.52 | 4.96 | Belcari et al. 2007 | GSA9 |
| **POD** | Trisopterus capelanus | 60 | D60 | | 16.13 | 5.14 | 4.03 | Belcari et al. 2007 | GSA9 |
| **EOI** | Eledone cirrhosa | 60 | D60 | | 5.45 | 3.01 | 1.36 | Belcari et al. 2007 | GSA9 |
| **SQM** | Illex coindetii | 60 | D60 | | 7.92 | 3.93 | 1.32 | Belcari et al. 2007 | GSA9 |
| **DPS** | Parapenaeus longirostris | 60 | D60 | | 22.25 | 11.96 | 5.56 | Belcari et al. 2007 | GSA9 |
| **HKE** | Merluccius merluccius | 32 | DM32 | | 10.00 | 4.8 | 3.1 | Del 1.1 (pooled 1981-1983) | GSA06 |
| **MUT** | Mullus barbatus | 32 | DM32 | | 10.70 | 1.4 | 3.3 | Del 1.1 (pooled 1981-1983) | GSA06 |
| **HKE** | Merluccius merluccius | 40 | DM40 | | 9.30 | 4.1 | 2.3 | Del 1.1 (pooled 1995-1996) | GSA06 |
| **WHB** | Micromesistius poutassou | 40 | DM40 | | 16.20 | 2.3 | 4 | Del 1.1 (pooled 1995-1996) | GSA06 |
| **MUT** | Mullus barbatus | 40 | DM40 | | 5.90 | 1.4 | 1.5 | Del 1.1 (pooled 1995-1996) | GSA06 |
| **MUR** | Mullus surmuletus | 40 | DM40 | | 6.50 | 1 | 1.6 | Del 1.1 (pooled 1995-1996) | GSA06 |
| **HKE** | Merluccius merluccius | 40 | DM40 | | 9.43 | 2 | 2.4 | Del 1.1 (2001) | GSA06 |
| **HKE** | Merluccius merluccius | 38 | DM38 | | 8.60 | 4.2 | 2.1 | Del 1.1 (pooled 1993-1994) | GSA06 |
| **MUT** | Mullus barbatus | 38 | DM38 | | 7.70 | 1.5 | 1.9 | Del 1.1 (pooled 1993-1994) | GSA06 |
| **MUR** | Mullus surmuletus | 38 | DM38 | | 7.80 | 1.3 | 2 | Del 1.1 (pooled 1993-1994) | GSA06 |
| **NEP** | *Nephrops norvegicus* | 55 | DM55 | PE TR 2.5mm | 27.1 | 6.1 | 0.49 | Campos et al. 2002 | ICES Ixa Portuguese south coast |
| **NEP** | *Nephrops norvegicus* | 55 | SM55 | PE TR 2.0mm | 34.7 | 16.0 | 0.63 | Campos et al. 2002 | ICES Ixa Portuguese |

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|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | south coast |
| **NEP** | *Nephrops norvegicus* | 60 | DM60 | PE TR 2.5mm | 25.8 | 8.0 | 0.43 | Campos et al. 2002 | ICES Ixa Portuguese south coast |
| **NEP** | *Nephrops norvegicus* | 70 | DM70 | PE TR 2.5mm | 27.7 | 7.5 | 0.40 | Campos et al. 2002 | ICES Ixa Portuguese south coast |
| **NEP** | *Nephrops norvegicus* | 55 | DM55 | PA TR 3.0mm | 22.7 | 7.4 | 0.41 | Fonseca et al. 2007 | ICES Ixa Portuguese south coast |
| **NEP** | *Nephrops norvegicus* | 70 | DM70 | PA TR 3.0mm | 28.9 | 7.4 | 0.41 | Fonseca et al. 2007 | ICES Ixa Portuguese south coast |
| **NEP** | *Nephrops norvegicus* | 80 | DM80 | PA TR 3.0mm | 33.0 | 7.4 | 0.41 | Fonseca et al. 2007 | ICES Ixa Portuguese south coast |
| **NEP** | *Nephrops norvegicus* | 55 | DM55 | PE TR 4.5mm | 18.9 | 7.4 | 0.34 | Fonseca et al. 2007 | ICES Ixa Portuguese south coast |
| **NEP** | *Nephrops norvegicus* | 70 | DM70 | PE TR 4.5mm | 25.1 | 7.4 | 0.36 | Fonseca et al. 2007 | ICES Ixa Portuguese south coast |
| **NEP** | *Nephrops norvegicus* | 80 | DM80 | PE TR 4.5mm | 29.3 | 7.4 | 0.37 | Fonseca et al. 2007 | ICES Ixa Portuguese south coast |
| **NEP** | *Nephrops norvegicus* | 60 | SM60 | PE Euroline PremiumTR 2x3.5mm | 33.1 | 13.7 | 0.60 | Not published | ICES Ixa Portuguese south coast |
| **DPS** | *Parapenaeus longirostris* | 55 | DM55 | PE TR 2.5mm | 21.8 | 5.7 | 0.40 | Campos et al. 2002 | ICES Ixa Portuguese south coast |

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|---|---|---|---|---|---|---|---|---|---|
| **DPS** | *Parapenaeus longirostris* | 55 | SM55 | PE TR 2.0mm | 27.1 | 9.3 | 0.49 | Campos et al. 2002 | ICES Ixa Portuguese south coast |
| **DPS** | *Parapenaeus longirostris* | 60 | DM60 | PE TR 2.5mm | 24.0 | 9.3 | 0.40 | Campos et al. 2002 | ICES Ixa Portuguese south coast |
| **DPS** | *Parapenaeus longirostris* | 70 | DM70 | PE TR 2.5mm | 27.1 | 8.9 | 0.39 | Campos et al. 2002 | ICES Ixa Portuguese south coast |
| **DPS** | *Parapenaeus longirostris* | 55 | DM55 | PA TR 3.0mm | 22.4 | 11.3 | 0.41 | Fonseca et al. 2007 | ICES Ixa Portuguese south coast |
| **DPS** | *Parapenaeus longirostris* | 70 | DM70 | PA TR 3.0mm | 28.5 | 11.3 | 0.41 | Fonseca et al. 2007 | ICES Ixa Portuguese south coast |
| **DPS** | *Parapenaeus longirostris* | 80 | DM80 | PA TR 3.0mm | 32.6 | 11.3 | 0.41 | Fonseca et al. 2007 | ICES Ixa Portuguese south coast |
| **DPS** | *Parapenaeus longirostris* | 55 | DM55 | PE TR 4.5mm | 19.3 | 11.3 | 0.35 | Fonseca et al. 2007 | ICES Ixa Portuguese south coast |
| **DPS** | *Parapenaeus longirostris* | 70 | DM70 | PE TR 4.5mm | 25.4 | 11.3 | 0.36 | Fonseca et al. 2007 | ICES Ixa Portuguese south coast |
| **DPS** | *Parapenaeus longirostris* | 80 | DM80 | PE TR 4.5mm | 29.5 | 11.3 | 0.37 | Fonseca et al. 2007 | ICES Ixa Portuguese south coast |
| **ARA** | *Aristeus antennatus* | 55 | DM55 | PE TR 2.5mm | 13.8 | 22.6 | 0.25 | Campos et al. 2003 | ICES Ixa Portuguese south coast |
| **ARA** | *Aristeus* | 55 | SM55 | PE TR | 32.3 | 9.1 | 0.59 | Campos et al. 2003 | ICES Ixa |

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|---|---|---|---|---|---|---|---|---|---|
| | *antennatus* | | | 2.0mm | | | | | Portuguese south coast |
| **ARA** | *Aristeus antennatus* | 60 | DM60 | PE TR 2.5mm | 24.6 | 11.5 | 0.41 | Campos et al. 2003 | ICES Ixa Portuguese south coast |
| **ARA** | *Aristeus antennatus* | 70 | DM70 | PE TR 2.5mm | 29.8 | 9.8 | 0.43 | Campos et al. 2003 | ICES Ixa Portuguese south coast |
| **HKE** | *Merluccius merluccius* | 55 | DM55 | PE TR 2.5mm | 15.9 | 3.0 | 2.89 | Campos et al. 2003 | ICES Ixa Portuguese south coast |
| **HKE** | *Merluccius merluccius* | 55 | SM55 | PE TR 2.0mm | | | | Campos et al. 2003 | ICES Ixa Portuguese south coast |
| **HKE** | *Merluccius merluccius* | 60 | DM60 | PE TR 2.5 mm | 17.4 | 3.8 | 2.90 | Campos et al. 2003 | ICES Ixa Portuguese south coast |
| **HKE** | *Merluccius merluccius* | 70 | DM70 | PE TR 2.5 mm | | | | Campos et al. 2003 | ICES Ixa Portuguese south coast |
| **HKE** | *Merluccius merluccius* | 55 | DM55 | PA TR 3.0mm | 22.7 | 7.4 | 4.13 | Fonseca et al. 2007 | ICES Ixa Portuguese south coast |
| **HKE** | *Merluccius merluccius* | 70 | DM70 | PA TR 3.0mm | 28.9 | 7.4 | 4.13 | Fonseca et al. 2007 | ICES Ixa Portuguese south coast |
| **HKE** | *Merluccius merluccius* | 80 | DM80 | PA TR 3.0mm | 33.0 | 7.4 | 4.13 | Fonseca et al. 2007 | ICES Ixa Portuguese south coast |
| **HKE** | *Merluccius merluccius* | 55 | DM55 | PE TR 4.5mm | 18.9 | 7.4 | 3.44 | Fonseca et al. 2007 | ICES Ixa Portuguese |

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|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | south coast |
| **HKE** | *Merluccius merluccius* | 70 | DM70 | PE TR 4.5mm | 25.1 | 7.4 | 3.59 | Fonseca et al. 2007 | ICES Ixa Portuguese south coast |
| **HKE** | *Merluccius merluccius* | 80 | DM80 | PE TR 4.5mm | 29.3 | 7.4 | 3.66 | Fonseca et al. 2007 | ICES Ixa Portuguese south coast |
| **HKE** | *Merluccius merluccius* | 60 | SM60 | PE Euroline PremiumTR 2 x 3.5mm | 22.0 | 3.8 | 4.01 | Not published | ICES Ixa Portuguese south coast |
| **WHB** | *Micromesistius poutassou* | 55 | DM55 | PE TR 2.5mm | 23.0 | 3.7 | 4.18 | Campos et al. 2003 | ICES Ixa Portuguese south coast |
| **WHB** | *Micromesistius poutassou* | 55 | DM55 | PE TR 2.5mm | 30.2 | 4.5 | 5.49 | Campos et al. 2003 | ICES Ixa Portuguese south coast |
| **WHB** | *Micromesistius poutassou* | 60 | DM60 | PE TR 2.5mm | 25.9 | 4.1 | 4.32 | Campos et al. 2003 | ICES Ixa Portuguese south coast |
| **WHB** | *Micromesistius poutassou* | 70 | DM70 | PE TR 2.5mm | 27.3 | 5.0 | 3.90 | Campos et al. 2003 | ICES Ixa Portuguese south coast |
| **HOM** | *Trachurus trachurus* | 55 | DM55 | PE TR 2.5mm | 18.0 | 3.8 | 3.27 | Campos et al. 2003 | ICES Ixa Portuguese south coast |
| **HOM** | *Trachurus trachurus* | 55 | SM55 | PE TR 2.0mm | 21.7 | 5.0 | 3.95 | Campos et al. 2003 | ICES Ixa Portuguese south coast |
| **HOM** | *Trachurus trachurus* | 60 | DM60 | PE TR 2.5mm | 19.8 | 3.6 | 3.30 | Campos et al. 2003 | ICES Ixa Portuguese south coast |

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|---|---|---|---|---|---|---|---|---|---|
| **HOM** | *Trachurus trachurus* | 70 | DM70 | PE TR 2.5mm | 21.9 | 4.9 | 3.13 | Campos et al. 2003 | ICES Ixa Portuguese south coast |

# 8. Annex 2 – Definitions

CL (carapace length): Method of measuring length of crustaceans. For shrimps, the standard measure of carapace length is from the inside of the eye socket to the posterior margin of the carapace.

DM (diamond mesh): A mesh composed of four sides of the same length. When tension is applied to a diamond mesh it elongates in the direction of the tension and shortens in the direction perpendicular to the tension, reducing the mesh opening.

ER (exploitation rate): the proportion of fish that are removed from the population, a metric of fishing intensity or fishing pressure.

EP (exploitation pattern): how fishing pressure is distributed across the age profile of a species, how fishing intensity is applied across the demographic structure of the stock.

$L_{50}$ (size at selection): Length for which 50% of individuals of that size are retained by the fishing gear.

MLS (minimum landing size): Smallest size fish that it is legal to keep or sell. Varies by species.

SR (selection range): Range from length at which 25% of individuals are retained by the fishing gear to length at which 75% are retained ($L_{75}$ – $L_{25}$)

SF (selection factor): $L_{50}$ divided by mesh size. Provides a way to apply selectivity curve determined from one mesh size to other mesh sizes.

SM (square mesh): A diamond mesh turned 45 degrees such that adjacent sides are at right angles. Square mesh remains fully open even under tension.

TL (total length): Method of measuring fish in which length is measured from snout to farthest point on tail.

The MINOUW Consortium

Co-funded by the Horizon 2020
Framework Programme of the European Union

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