



**GENERAL FISHERIES COMMISSION  
FOR THE MEDITERRANEAN  
COMMISSION GÉNÉRALE DES PÊCHES  
POUR LA MÉDITERRANÉE**



SCIENTIFIC ADVISORY COMMITTEE

Sub-Committee on Marine Environment and Ecosystems (SCMEE)

Sub-Committee on Stock Assessment (SCSA)

Economic and Social Sciences (SCESS)

**Transversal workshop on selectivity improvement, by-catch reduction  
and alternative gears**

**Alexandria**, Egypt, 25–27 October 2010

**Review of selectivity studies on square mesh codend and  
grids applied to Mediterranean bottom trawls**

(Working document)

## Introduction

Considering the need to improve the trawl selectivity for a sustainable exploitation of Mediterranean fisheries and the primary results of selectivity studies carried out by some Mediterranean research teams, the GFCM has adopted during its **Plenary session** the Resolution GFCM/31/2007/3 inciting the Mediterranean countries to substitute, by 2010, the diamond meshes of the trawl codend by 40 mm square meshes .

Because the available information on 40 mm square meshes codend do not cover all the fisheries configurations existing in Mediterranean sea, the GFCM has encouraged the Mediterranean countries to develop more selectivity studies in various situations through studies cases including bio economical analysis.

To promote the GFCM resolution, 3 workshops on selectivity were organized on standardization for trawl selectivity studies, Atselmed 1; Sète (France), 9 – 11 February 2005 and on the gradual implementation of 40 mm square mesh cod-end to the Mediterranean bottom trawling fleet, Atselmed 2; Barcelona (Spain), 2-4 April 2007 and Atselmed 3; Sète (France), 2 - 4 July 2008.

The SAC-SCMEE transversal working group (document SAC11/2008/Inf. 16) on selectivity recommended the adoption by the SAC of the proposal “Urgently implement and enforce the use of a square mesh of at least 40 mm in the bottom trawl codend in accordance with GFCM regulation”. The SCSA also recommended during the SAC 11th session the enforcement of the 40 mm square mesh size in the codend of the bottom trawlers.

The SCESS recommended analysing the socio-economic impacts of the implementation. During their 11th Session, (Marrakech, Morocco, 1-5 December 2008) the SAC stated that “regarding the progress made to ensure follow up of the implementation of the 40-mm square mesh in bottom trawls, some delegates reiterated the need to undertake pilot surveys to identify the socio-economic effects of this measure.

The aim of this document is to make a review of the previous GFCM – ATSELMED and of 71 studies carried out on bottom trawl selectivity dealing either on comparison between small and large diamond mesh or between diamond and square mesh or on sorting grids. It was decided to pay attention on studies dealing on effects of material type (knotless, Polyethylene, etc.) or any physical device which may affect the mesh selectivity (i.e. cod-end circumference,).

The main inputs are presented in first on methodology and secondly on main important results.

# Methodology

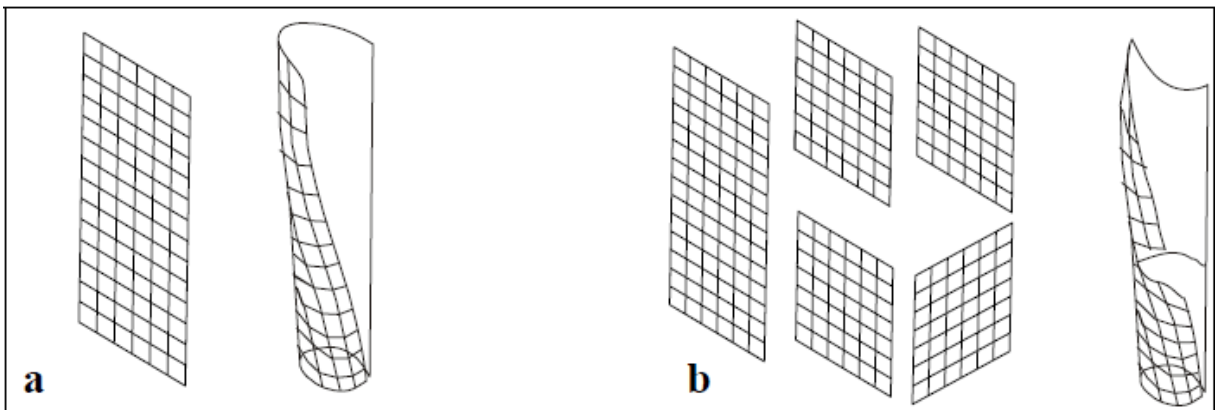
## Choice of selectivity devices

There are many types of Mediterranean trawls; these are different from one area to the other (inshore fishery is different from deep-sea fishery for instance); all these differences must be taken into consideration for a good management of the fisheries.

The choice of the selective devices is dictated by the will to stick to the professional fishing conditions and consequently fit to the trawl type.

3 ways are tested in Mediterranean sea improve the trawl selectivity and evaluated in the literature:

- to increase the mesh size codend
- to use square mesh codend



Different ways for mounting a square mesh codend from a conventional net panel (From GFCM-ATSELMED 2 Barcelona 2- 4 April, 2007)

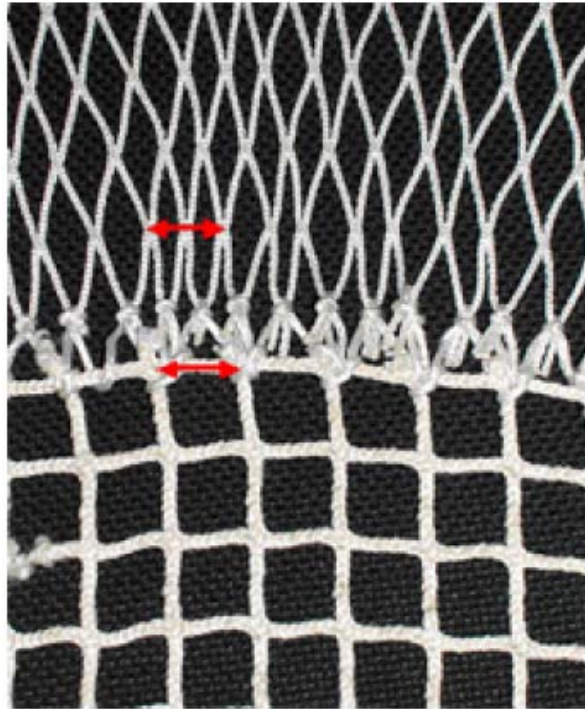
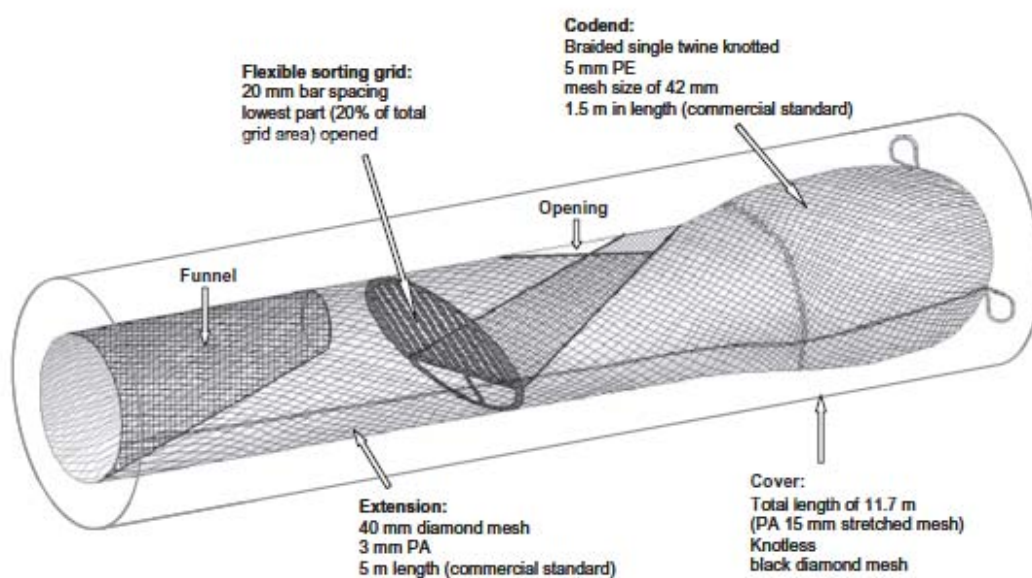


Figure 4: More care is required to establish the best joining rates between square meshes and diamond meshes panels. Here the horizontal rigging rate is of 2 diamonds for 1 square mesh (Piccinetti *et al.*; communication No. 2).

Recommendation for joining a square mesh panel to a diamond mesh panel.

- to use sorting grids



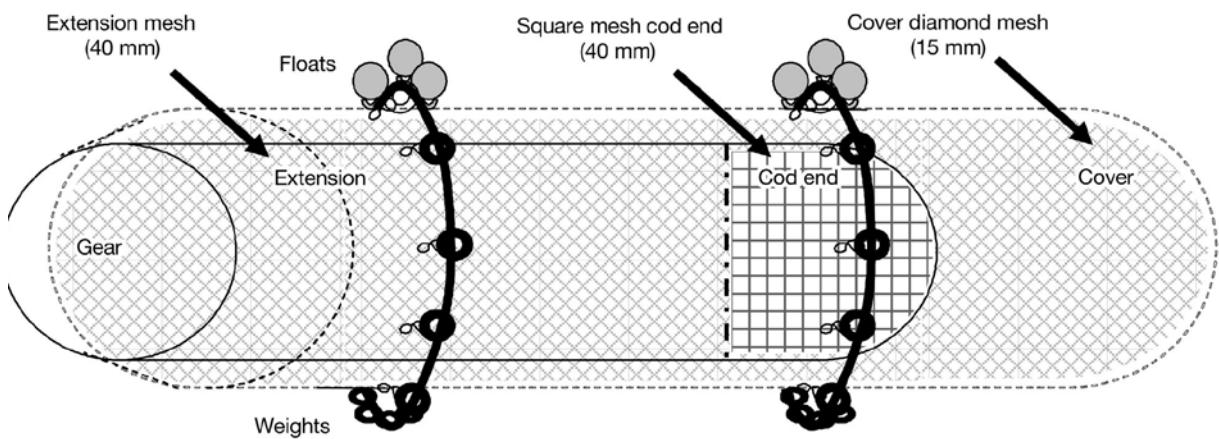
From Bahamon et al., 2007

If a square mesh configuration of the cod-ends mainly aims at keeping the meshes open, the square mesh panels, separating panels and grids are used to investigate the differences of behaviour; thus, the study strategies are different.

if the grids offer undeniable advantages in terms of selectivity for quite specific fisheries, their design, their mounting still present some disadvantages as their overall dimensions which clutter the deck of the small boats, their stability during trawling, their clogging by remains, these being as many elements to be taken into account under the experimental conditions. (GFCM-ATSELMED 1, Sète 2005).

### Choice of the experimental method

The most usual techniques to estimate the selectivity of a simple haul are that of the **cover cod-end** method, double devices method (i.e twin trawls) and alternate hauls method.



cover codend from Coll et al., 2008

They all have in common the capture of fish in two compartments one of which not being selective. They can be used for both the measurement of the selectivity of a simple selective device such as mesh, and the combination of several selective devices or multi-compartments. The statistical model SELECT seems to be a strict model changeable and general enough to be used for the analysis of a simple haul of all the types of gears.

The analysis of many hauls, which is inherent in any experimental process as reminded by the speaker, imposes to take into account the variability between the hauls; the model of Fryer (1991) satisfies perfectly this requirement, as it can take into account the fixed or random effects. If other statistical analysis software exists and if other methodologies remain to be explored, the methodological approach of a selectivity study rests on the respect of a number of fundamental steps. (GFCM-ATSELMED 1, Sète 2005).

The more their design is sophisticated, the more one is tempted to take into account all the elements but the more the risk of neglecting the usual conditions of operation of the trawls is high. Especially when using a cover cod-end, it is strongly recommended to make sure of the necessity to respect the ISO standards of representation of the physical parameters (trawls, power, etc).

If most of the various aspects of trawl selectivity are already largely detailed in the CIEM handbook, design of selectivity measurement devices

The most technique employed is the covered codend.

The remaining question is to know if the covered codend should or not cover the extension piece.

During the GFCM-ATSELMED 2 in Barcelona (2007) it was discussed whether an increase in minimum mesh size immediately should comprise the whole trawl or only the codend. In this context, it was brought forward that the normal procedure was to first regulate only the codend and at the same time fix a transition period (a normal lifetime of a trawl) after which also the whole trawl should comply with the new minimum mesh size. In this way, the fishing industry would not need to discard new or usable trawl already made with the previous minimum mesh size, and as more than 90% of the selection happens in the codend, the conservation difference would not be significant anyway.

### **Standardization of the procedures**

the GFCM-ATSELMED 1 in Sete (2005) recommended to use as much as possible the type of trawls used by the fishing industry, with the same parameters in order to be as close as possible to the professional fishing conditions.

To use also ICES caliper or Omega caliper, for the measurement of the mesh opening. Unfortunately, this gauge does not allow to measure meshes lower than 25 -30 mm, like those of the trawls used by small pelagic

For grids must be measured at the opening of the wet mesh.

It was also recommended to associate statisticians at the beginning of the project, this both to define an experimental plan and to answer the problem of the standardization of the results.

On the other hand the need for better definition of codend in terms of length, shape, etc. is urgent (GFCM-ATSELMED 2- Barcelona, 2 – 4 April, 2007).

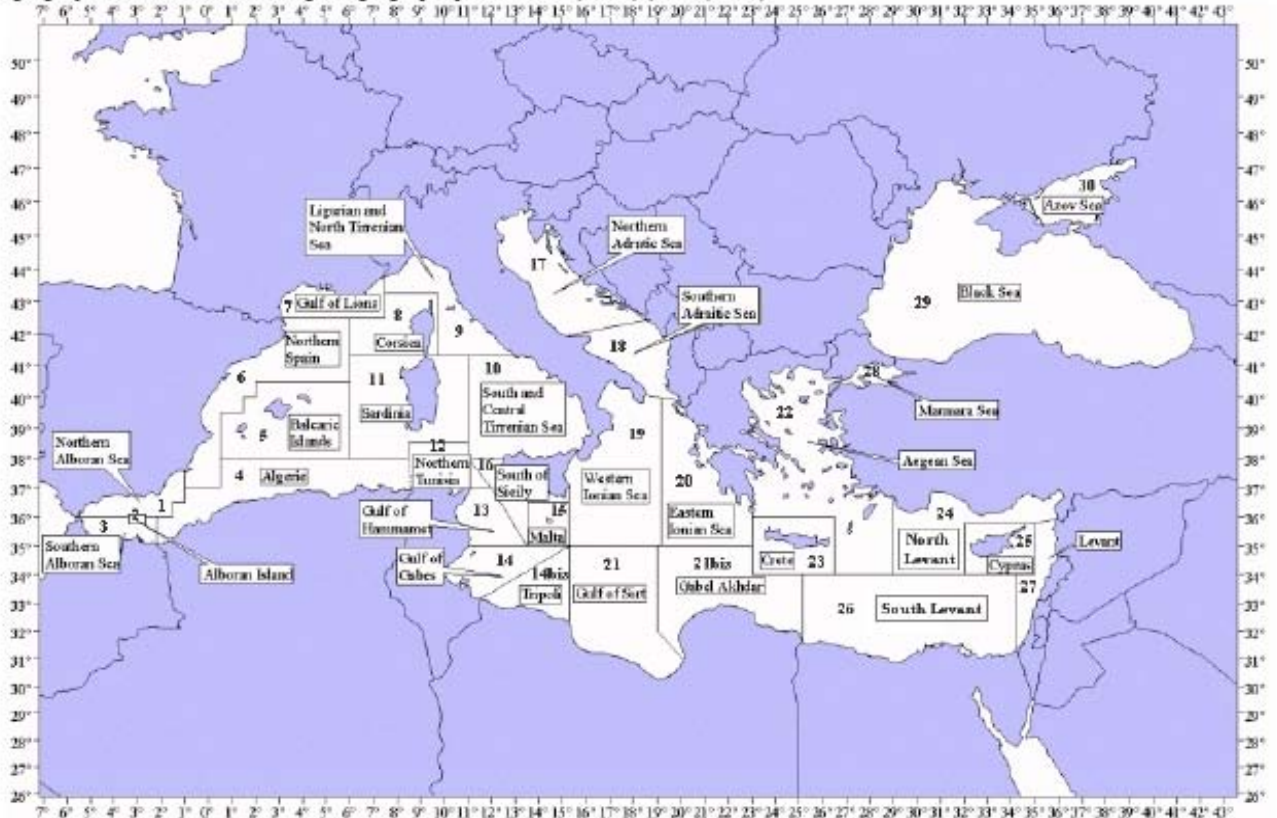
### **Selectivity parameters**

L50, Selection Factor, Selection Range, and percentage of retained individuals are the most frequent parameters given by the papers. They will be collected and registered in the selectivity database by GSA and by species (medselectivity.xls) .

# Results

## Studies by GSA

SAC geographical sub-areas/ Sous-régions géographiques du CSC (GSAs) (Rome, 2006)



Main GSA where selectivity were carried out during the ten recent years

GSA 1 ?, GSA 5, GSA 6, GSA 9, GSA 13 ?, GSA 17, GSA 20, GSA 22, GSA 24

Projects for GSA 3, GSA 4, GSA 7

## Studies by area

Through the great variability of the trawl characteristics given, it is possible to distinguish at least two commonly widespread fishing strategies around the Mediterranean basin: the trawling on the continental shelf without particular target species and the trawling of the slope targeting deep crustaceans. Complementary information should be able to make it possible to better reveal the technical differences characterizing these strategies (catch composition, duration and haul, etc.) and to identify the métiers for which the application of the square mesh would present some difficulties.

## **Species**

Effects of selectivity are examined for 28 species. Several references don't give in their abstract the whole species which were studied; Selectivity parameters are not always calculated for each species.

### **Deep bottom crustacean**

*Aristeomorpha foliacea*,

*Aristeus antennatus*,

*Parapenaeus longirostris*,

*Nephrops norvegicus*,

### **Coastal fish**

*Dentex macrophthalmus*,

*Diplodus annularis*,

*Diplodus vulgaris*,

*Mullus barbatus*,

*Mullus surmuletus*,

*Gobius niger*,

*Pagellus erythrinus*,

*Boops boops*,

*Spicara maena*,

*Spicara smaris*,

### **Shelf & Slope bottom fishes**

*Phycis blennoides*,

*Merluccius merluccius*,

*Micromesistius poutassou*,

*Pagellus acarne*,

*Helicolenus dactylopterus dactylopterus*,

*Cepola macrophthalma*,

*Trisopterus minutus capelanus*,



Zeus faber,

### **Flatfishes**

Arnoglossus laterna,

Lepidorhombus boscii,

Lophius piscatorius,

### **Mollusques**

Illex coindetii,

Loligo vulgaris,

Sepia orbignyana,

Trachurus trachurus,

Excepted for flatfishes, square mesh or grid are more selective than diamond mesh.

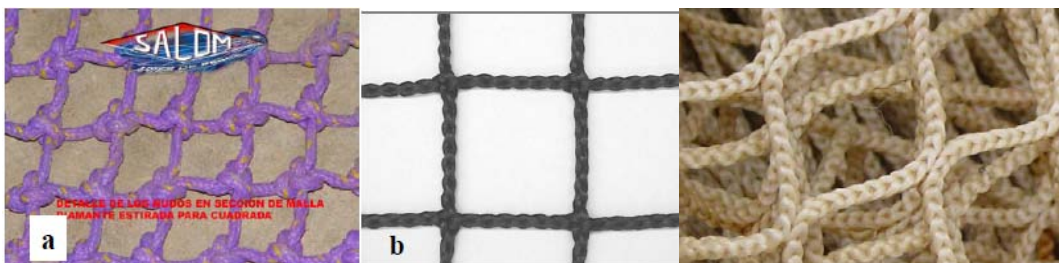
### **Mesh size**

From 28 mm to 60 mm without often any precision on the measurement mode (stretched or opening mesh).

40 mm is the most studied mesh size and compared to smaller mesh sizes or larger mesh sizes (29 references).

### **Mesh shape and Net panel type**

Mesh shape can be square, diamond or hexagonal (Raschel netting); 49 references for square-mesh.



a) knotted panel, b) knotless “Ultracross”, c) knotless “Raschel”.

### **Twine Material**

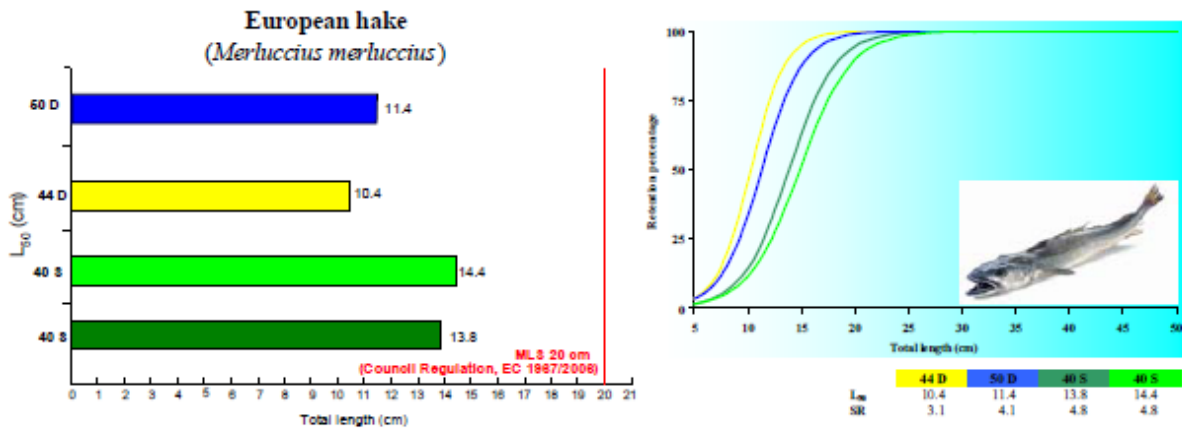
15 references dealing on the effects of twine material (PE or PA).

The comparison in Ionian sea between two types of bottom trawl codend, knotted and knotless, with 40 mm mesh size (stretched) do not show any differences regarding the L50, for 12 species of the 21 caught. The fact that the high cost of new materials used in Atlantic North (Polyéthylène

Ultracross) for the manufacture of the square mesh panels will constrain the majority of the Mediterranean fleets to adapt the netting usually employed for the construction of codend (knotted or knotless PE or knotted PA or knotless PA with Raschel system) with undeniable effects on the variability of the selectivity .

(Chilari, comm.. GFCM-ATSELMED 2, Barcelona 2007).

### Comparison between diamond and square mesh.



from Tokaç et al., 2007

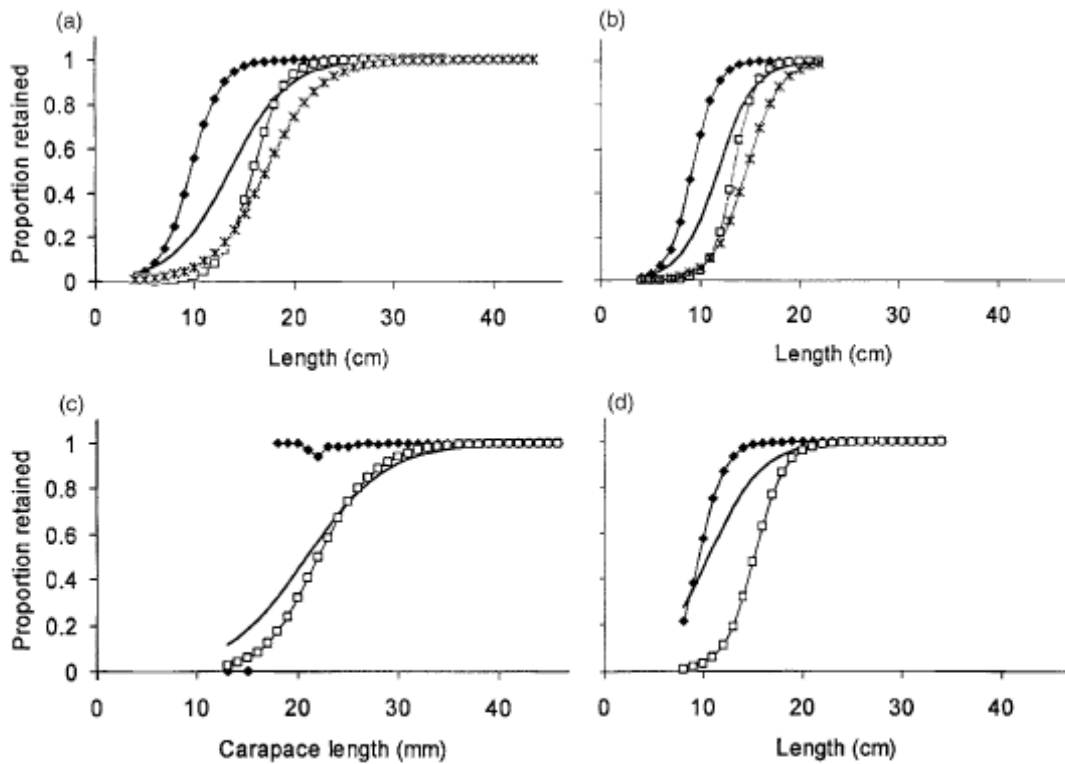
The main findings were demonstrated a better selectivity for the majority of species in the 40 mm square mesh codend than in a 40mm diamond mesh codend. But for most of species the results cannot allow to reach the minimum legal size.

### Grids

Few studies have assessed the efficiency of the sorting grid systems. 10 references for grids test were carried out in GSA 1, GSA 6, GSA 13, GSA 20, GSA 22.

These studies target the development of semi-rigid grids to reduce the by-catches of unwanted fish and juveniles. Comparison with the performance of 40-mm diamond(DM40) and square mesh (SM40) cod ends. Show that sorting grid selection ranges were broader than those estimated for DM and SM. Experience shows that the exchange of the DM for the SM and/or the introduction of SG20 can improve selectivity in the Mediterranean trawl but SM can be more efficient than SG20. The effect of a guiding funnel increase the selective performance of the grid.

## Comparison between selectivity devices



**Fig. 4** The 50% selection curves for (a) European hake, (b) poor cod, (c) Norway lobster and (d) greater forkbeard with 40-mm diamond mesh (◆, DM40) and 40-mm square mesh (□, SM40) cod ends (Bahamon *et al.*<sup>5</sup>), and 20-mm sorting grid with funnel (\*, BS20-f) and without funnel (solid line, BS20) from the present work. Diamond mesh cod end was not selective for Norway lobster; therefore, no selectivity curve was fitted (◆, observations).

From Bahamon et al., 2007

### Type of netting

6 references. Netting can be knotless or knotted. The “Raschel type” knotless netting gives an hexagonal shape to the mesh which may reduce the surface opening of the mesh when it is used as square mesh panel.

### Twine diameter

Nothing really identified in the selected reference.

### Others

2 references for Codend circumference. The objective of the studies was to investigate the effect on codend selectivity by increasing the codend mesh size or reducing the number of meshes in the codend circumference. The main results show that the reduction of number of meshes in the codend circumference will be more beneficial than increasing the mesh size.

## Economical analysis

The short-term economic losses of commercial species will be lower in the slope fishery than in the continental shelf for the fisheries switching from 40 mm diamond mesh to 40 mm square mesh codends

The potential economical consequences give some short terms and long terms possible effects on the socio economical characteristics of the exploitation including effects on prices, gear and maintenance costs and acceptability by the fishery sector .

A table of economical indicators to take into account in any economical analysis was built in the GFCM – ATSELMED 2 meeting.

INDICATORS	SHORT TERM	LONG TERM	OBSERVATIONS
Catch-landing	decrease or stable	increase	The improvement of selectivity suppose the reduction of catch of the small size individuals
Effect : price-quantities/quality	increase or equal	decrease or equal	The reduction of landing supposes the reduction of the supply and the increasing of the price
Costs :			The change of the gear supposes en initial investment that not affects other maintenance cost.
Gear cost	increase	equal	the increasing of the opening of the mesh supposes less resistance to water, less retention of biomass in the cod-end, in consequence less consumption of fuel. finally, the recover of the biomass allow in long term improve the quantity cached by fuel consumed
Maintenance cost	equal	equal	
Fuel cost	decrease	decrease	
costs per landing if biomass recover	increase	decrease	the initial reduction of the catch supposes increasing the cost per landing
added value	decrease	increase	the initial reduction of catches supposes the reduction of the added value, net profit and wages
Net Profit	decrease	increase	Idem

Wages	decrease	increases	Idem
Social effect (employment)	decrease	stable	initial reduction of the revenue supposes the of wages and a decrease of employment. in the long term, it could be observed an attraction to the metier as there is an increase of the wages and a net profit.
acceptability by the fishing sector	rejected	accepted	initial cost of the transition produces a resistance to change. When the biomass is recovered, the fishermen improve their profits and so they support the new regulation

To contribute to the analysis of a gear, the use of economic indicators can improve the decision criteria to the managers and fishers. Some of Socio-economic indicators were proposed:

A- Short Term Indicators. The short term indicators measure the immediate effect of the use of each fishing gear. They not take in consideration the effect of the recover of the stocks when a different system of production is implemented. It is proposed 5 short term indicators:

Physical Production (S-PP). Is the catch of each unit of effort of this gear can produce. Is expressed as the catch in a place (fishingground) in Kg. by species

Economic Productivity (S-EP). Is the average value produced in a fishingground by a unit of effort by the gear considered. In addition of the information (1), we need to know the average price per Kg of each specie catch by the gear.

Intensity of work (IW). Is the average number of hours workmen to develop one unit of effort of this gear.

Men Physical Production (S-MPP). Number of Kg of catch per year-men with this gear. (It is calculated from the data of S-PP and IW)

Men Productivity (S-MP). Euros produced by men per year-men (It is calculated from the data of S-EP and IW)

A- Long Term Indicators. The long term indicators measure the effect of the use of each fishing gear, when the stocks improve (or go down). They take in consideration the effect of the implementation of a different system of production over the fish stocks. Their estimation needs the use of bio-economic models (as MEFISTO), and are a statistical prevision. It is proposed 4 short term indicators, give that the intensity of work (IW), not change between short and long term by effort unit:

Physical Production (L-PP). It is the estimation of the long term catch of each unit of effort of this gear can produce. Is expressed as the catch in a place (fishing ground) in Kg by species

Economic Productivity (L-EP). It is the estimated long term average value produced in a fishing ground by a unit of effort by the gear considered. In addition of the information (6), we need to suppose the average price per Kg of each specie catch by the gear.

Men Physical Production (MPP). Long term estimation of the number of Kg of catch per year-men with this gear. It is calculated from the data of L-PP and IW.

Men Productivity (MP). Euros produced by men per year. It is calculated from the data of L-EP and IW.

### **Survival after escapement**

The problem of survival after escapement is then tackled showing that it is different according to the species, the animals with a carapace being by principle more resistant. Lastly, although few quantified elements are available either on square mesh or on grids (the animals that survive are in better state than with traditional meshes).

### **Environmental impact**

the reduction of the discards is significantly more important on the shelf than on the continental slopes.

Temporal dynamic simulations indicate that improvement of trawl selectivity would have noticeable and complex direct and indirect effects on target and non-target demersal species.

# Annexes

## Bibliography review

### Croatia

1. Alen Soldo. "Selectivity of bottom trawls used in Eastern Adriatic". GFCM -ATSELMED workshop Sète 9, 10 & 11 February 2005. The present study compares the selectivity of three types of cod-ends (mesh size 48 mm, 60 mm, and 60 mm equipped with a 60 mm square mesh panel), adapted to the principal trawls used in the East of the Adriatic, the "tartana" typical Mediterranean trawl and the double panel trawl, with larger opening. The experiments carried out onboard the R/V Bios required the use of (i) underwater video recording to observe the behaviour of the various selective devices; (ii) a system to control the geometry of the various trawls; (iii) a sonar to measure the spacing between the panels; (iv) dynamometers to record the tension of warps. Observations were thus carried out on the changes of horizontal and vertical openings, spacing between panels and the tensile strength (kN) of the trawls in relation to the trawling speed. The selectivity parameters for *Merluccius merluccius*, *Nephrops norvegicus* and *Mullus barbatus* were achieved using a heaving bag fitted with hoops made of composite rope and by adjusting the data to a logistic function. The comparison between the various results was completed by variance analysis. A comparison of the results of six various trawl structures for hake show significant differences. The main results show that the best conditions of selectivity were obtained with the double panel trawl, of 60 mm mesh size and fitted with a 60 mm square mesh panel.

2. Alen Soldo Underwater observations of different trawl constructions in the Eastern Adriatic **FTFB** «tartana» type of trawl is the main bottom trawl design in the Adriatic. It is used evenly on Croatian side as well as on Italian side of the Adriatic, but also in many other Mediterranean countries. Due to its construction and small mesh size, «tartana» bottom trawl is unselective and presumed as inadequate for works on subject of selectivity. Therefore, new designs of bottom trawl, based on double panel trawl designs, have been constructed in order to allow proper research on bottom trawl selectivity. During research, underwater video camera has been used and some technical parameters of trawls have been observed. Results of those observations, from four different trawl constructions, have been presented in this paper.

### Cyprus

3. Livadas, RJ., 1989. The selectivity of certain trawl cod-ends in Cyprus. FAO fisheries report. 1989. Mesh selectivity experiments on trawl cod-ends were carried out by the Department of Fisheries in September 1970 on a chartered commercial trawler. The purpose was to estimate the selectivity of two new trawl cod-ends, with a mesh opening greater than the one currently in use by the trawl fishery in Cyprus (32 mm). Average selection factor for the 34 mm cod-end for the 4

species: *Mullus barbatus*, *Mullus surmuletus*, *Pagellus erythrinus*, and *Spicara smaris* are in the range of 2.80-3.75 and for the 40 mm cod-end for *Spicara smaris* and *Mullus barbatus*, in the range of 3.40-3.88.

#### **France**

4. Potential effects of the implementation of square mesh codend to a traditional towed gear “gangui” 2010 Jacques Sacchi, Gildas Le Corre et Serge Mortreux (abstract not available).

#### **Greece**

5. Angeliki Adamidou et Argyris Kallionotis « Short presentation of the NETRASEL project concerning the Greek trials. GFCM -ATSELMED workshop Sète 9, 10 & 11 February 2005. The Norway lobster is an important commercial species for trawl fisheries in Greece. The separation of Norway lobster, shrimps and fish turns out to be almost feasible by using selective devices as demonstrated by the two tests achieved in the North of the Aegean Sea. The present paper, which was not presented, summarizes the selectivity experiments carried out within the framework of project NETRASEL (FAIR CT 98 4164) on the development of semi-rigid grids to reduce the by-catches of fish and juveniles of *Nephrops norvegicus*. These experiments were completed in 2000 in two different seasons with grids consisting of vertical bars at their upper part and of an opening at their lower part. A guiding panel was placed before the grid in order to make it easier for the shellfish to enter by the lower opening. Three grids with different bar spacing and opening width were tested. The comparison of the catches in the lower and higher cod-ends show that substantial proportions of Norway lobster and shrimps can be separated from fish.

6. Chilari Anna, Petrakis George, Kavadas Stefanos, Holst Rene., 2007. Selectivity trials with 40 mm knotted and 40 mm knotless cod end in Ionian Sea. GFCM- ATSELMED 2, Barcelona, 2 – 4 April, 2007. Selectivity experiments took place in the Eastern Ionian Sea during September 2003 and July 2004 in order to estimate the selectivity of two types of bottom trawl codend, knotted and knotless, with 40 mm mesh size (stretched). The covered cod end technique with hoops, was used. The mesh size of the cover was 20 mm. Four depth zones were defined for the analysis of data: 0-49 m, 50-99 m, 100-199 m and > 200 m. The ratios of escapees to retained (E/R) were 0.8, 1, 0.7 and 0.1 by weight and 2.1, 1.5, 1.4 and 0.4 by number for each zone, respectively. For hake, the ratio E/R, by weight, was generally low (< 0.1), whereas by number, was 0.3 in the 100-200 m depth zone and 0.7 in the >200 m depth zone. For red mullet, the ratio E/R by weight was 1.3 in shallow waters (where there is aggregation of juveniles), 0.5 in 50-100 m and 0.2 in deeper waters. The ratio E/R by number was 2.8 in shallow waters, 0.9 in 50-100 m and 0.5 in deeper waters. Selectivity parameters were estimated for 21 species (16 fish species, 4 cephalopods and 1 decapod). Regarding the estimated L50, for 3 species there were no differences between the two cod ends, whereas for other nine species higher values of L50 were estimated for the knotted cod end.



7. Petrakis, G; Stergiou, KI Size selectivity of diamond and square mesh codends for four commercial Mediterranean fish species ICES Journal of Marine Science [ICES J. Mar. Sci.]. Vol. 54, no. 1, pp. 13-23. 1997. In the present study, the size selectivity of the 14 mm (knot-to-knot) diamond-shaped codend (14D), presently used in Hellenic waters, is compared, with those of 20 mm square-shaped (20S) and 20 mm diamond-shaped (20D) codends for four commercially important demersal species (*Merluccius merluccius*, *Micromesistius poutassou*, *Trisopterus minutus capelanus capelanus* and *Lepidorhombus boscii*). Codend selectivity was estimated using the covered codend method. The results suggested that 14D was not selective for any of the target species and the proportion retained by 14D ranged between 0.88 and 1. In addition, only in the case of *M. merluccius* did the results suggest that 20S is significantly more selective and retains fewer under-sized fish than 20D. With the exception of *M. merluccius*, the direct estimation of the 14D  $L_{sub(50)}$  values was not possible, because of the small number of specimens retained by the cover codend of 14D. The  $L_{sub(50)}$  value of *M. merluccius* for 14D was lower than its currently enforced minimum landing size (MLS) and length at 50% maturity. In contrast, for 20S and/or 20D codends, even though the estimated  $L_{sub(50)}$  values were generally close to, or higher than, the species' MLS, the  $L_{sub(50)}$  value of 20S for *M. merluccius* and that of 20D for *L. boscii*, were much smaller than their lengths at 50% maturity, a fact indicating that even the use of 20S and 20D, respectively, provides small opportunities for reproduction. Hence, the appropriate mesh sizes for these two species must be greater than 20 mm and their MLS must be raised. In contrast, for *T. m. capelanus* and *M. poutassou*, the  $L_{sub(50)}$  values of 20D (but not of 14D) were close to their lengths at 50% maturity, a fact indicating that 20D is appropriate for these two species. The above mentioned facts clearly showed that: (1) 14D is harmful, in terms of size of landed fish, for the Hellenic demersal stocks and hence its use should be discontinued and (2) the use of a single appropriate mesh size for the Mediterranean trawl fishery as a whole is impossible because of its multispecies nature and the different body sizes of species involved. Since the majority of the individuals escaping through the meshes of 20D or 20S are immature and under-sized (i.e. their length is smaller than MLS), the replacement of 14D by either 20D or 20S, the former being the codend mesh size proposed by EU for the entire Mediterranean, will be accompanied by increased yield per recruit.

8. Sophronidis K., A. Kallianiotis & C. Radcliffe, 2001. Introducing selective devices in the Greek trawl fishery. 36th CIESM Congress, 23-27 October 2001, pp. Congress proceedings p. 326. (abstract missing).

9. Sofronidis, K., Kallianiotis, A., & Radcliffe, C., 2001. Introducing selective devices in the Greek trawl fisheries. *Rapp.Comm.int.Mer.Medit*, 36:326. (abstract missing).

10. Stergiou-KI; Petrakis-G; Politou-CY Size selectivity of diamond and square mesh cod-ends for *Nephrops norvegicus* in the Aegean Sea: Fisheries Research . Mar 1997; 29 (3): 203-209. Trawl cod-end mesh selection for *Nephrops norvegicus* was studied in two experiments in the western Aegean Sea using the covered cod-end method (cover: diamond-shaped, 10 mm). The following cod-end mesh sizes were used: 14 mm(knot-to-knot) diamond-shaped (14D), presently operated in the Hellenic commercial trawl fishery; 20 mm square-shaped(20s); 20 mm diamond-shaped (20D), this being the mesh size proposed by the European Union (EU) for the entire Mediterranean. Selectivity estimates were derived from pooling the data over all hauls and sampling dates. The results showed that the proportion of the population retained was higher for 14D than for 20D and 20s (0.99, 0.79 and 0.84, respectively). The direct estimation of the 50% retention length for 14D was not possible because of the very small number of specimens escaping through that cod-end. The results also suggested that 20s has a higher and sharper selectivity than 20D (higher 50% retention length and selection factor, lower selection range) and retains fewer undersized individuals than 20D. Yet, the 50% retention lengths for 20D and 20s were both lower than the length at 50% maturity, a fact indicating that even the use of 20s and 20D may provide little opportunity for reproduction.

#### **Israël**

11. Oren Sonin., 2007. Studies on square mesh panel selectivity and on the escaping fish out of the selective trawl done in Israel. GFCM-ATSELMED, Barcelona 2 – 4 April, 2007. The Israeli trawlers operate mainly bottom trawl and very seldom semi-pelagic trawl. It is a multi species fishery by definition. More than 170 species of fish, cephalopods, other molluscs and crustaceans were recorded in the Israeli trawl fishery throughout the past 10 years, some of them are Lessepsian migrants that become very important commercially for the Israeli fishery. Lessepsian migrants can exceed as much as 40% of commercial catch number. Those new species varies the diverted body shapes and sizes of fish that could already be fished in the Israeli trawl fishery. Therefore, East Mediterranean trawl fishery can serve as an utmost example for a multi species fishery. There are only two components in Israeli trawl fishery - commercial catches and discards- and consequently no-bycatch. Discards in the Israeli trawl fishery vary along the year and can reach as much as 90% of the commercial catch (numeral) sometimes in the summer months, right after the fingerlings are recruited into the trawl nets. Trawl selectivity studies had started in Israel at 1998, with trials of a small 50 mm square mesh panel connected to the first third of a 10 meter cod-end. The panel measurements were 50x50 centimetres. Experiments are conducted on-board commercial trawlers. A collecting net was designed to re-capture the escaping fish. A comparison between escaping and non-escaping fish is still being analysed; some of the raw data is presented in this paper. First analyses of the data collected until now suggest that as much as 35% of non-commercial fish can escape from the selective panel, while as much as 7% of commercial fish. Those first results suggest

that a smaller mesh size, could be used to favour the escapement of non-commercial fish from the trawls cod-ends. A pilot experimentation was made also to find out the survivability of the escaping fish. This experiment has involved the participation of 1 trawler, 2 boats, 17 crew men, including 3 divers and tested technical possibilities of moving the escaping fish from the collecting net into a cage, without causing more stress to the already very stress escapees. Therefore all the operation was done under the water. A movie was also made to take underwater pictures of the escaping fish. A larger scale experiment on fish mortality after escaping the selective device was not made due to budget deficiency. The survivability is very critical issue and can have biological, technological and economic consequences. While deciding on the implementation of the 40 mm square mesh cod-end we assume that the fish escaping the net, do survive. It could be that mortality rate of escaping fish from 40 mm square mesh is so high, that the implementation of 40 mm square mesh cod-end should be reconsider. There is not enough data regarding survivability of escaping fish in a multi species fishery. A frame work for the examination of the survivability of the escaping fish from 40 mm square mesh cod-ends must be prepared as soon as possible.

### **Italy**

12. Belcari P. & Cl. Viva., 2005. "Study on the effects of fitting square-mesh sections to the selectivity of demersal trawling in Northern Tyrrhenian Sea (western Mediterranean)". GFCM - ATSELMED workshop Sete 9, 10 & 11 February 2005. The square mesh panels used in the British and Irish Norway lobster fisheries definitely show capacities for releasing the small individuals, with negligible consequences on the value of the commercial landings. Experiments were thus achieved in the Northern Tyrrhenian sea, from the port of San Stefano, on trawling targeting deep pink shrimp, *Parapenaeus longirostris* between 100 and 300 m. These fisheries captures also other species of high commercial value, with mostly juveniles, especially of hake, blue whiting, which results in high rates of discards. The selective device, which was built by fisheries industrialists on the principles defined by Robertson (1993) consisted of a 3 m long x 6 m wide panel of 40 mm nominal size square meshes, placed ahead the cod-end at 6 m distance from the closing rope. The tests were carried out on board a professional fishing vessel from spring 2003 to spring 2004 included. The method consisted in measuring over a whole season by the cover cod-end method the selectivity of a commercial trawl with a 40 mm nominal size diamond mesh cod-end with that of an experimental trawl fitted with a square mesh panel of the same mesh size. All the hauls were completed in the same way; the date, position, depth, speed, the warp length were noted as well as the weights by species for a capture, for each of the hauls. The 50% retention rate (L50), the selection factor (SF) and the selection interval (SR) were obtained by adjusting the data to a logistic curve. The first results show that with the experimental trawl equipped with a square mesh panel, if the quantity of *P. longirostris* is around 10% less than that obtained with a commercial trawl, the

L50 of the individuals captured with the square mesh is approximately 20% higher. Although the analyses of the other species being in hand, for most of them the results remain similar.

13. Belcari P., De Ranieri S., Ligas A., Reale A., Sartor P., Viva C. 2006. Effects of fitting a square mesh section to the selectivity of demersal trawling in the northern Tyrrhenian Sea (Western Mediterranean). ICES 2006 Symposium, "Fishing Technology in the 21st Century: Integrating Fishing and Ecosystem Conservation" 30 October-3 November, 2006 Boston. (abstract missing)

14. Belcari, P; De Ranieri, S; Ligas, A; Reale, B; Sartor, P; Viva, C., 2007. Selectivity of two diamond mesh size cod-ends in the trawl fishery of the Northern Tyrrhenian Sea (Western Mediterranean) 38th CIESM Congress Proceedings. Rapport du 38ieme Congres de la CIESM. no. 38, p. 428. CIESM Congress Proceedings [CIESM Congr. Proc.]. 2007. Experimental fishing trials were carried out to compare the size selectivity of the 40 mm stretched diamond mesh size cod-end, commonly used in the Italian waters, and the 60 mm stretched diamond mesh size cod-end. In total, 24 tows were carried out in summer 2003 and spring 2004 between 20 and 350 m depth. Selection curves were estimated through the covered cod-end method. The experimental net was more selective for most of the commercial species, showing a reduction of the percentage of retained fraction and a consistent increase of the L sub (50) retention length.

15. Carlucci, R; D'Onghia, G; Sion, L; Maiorano, P; Tursi., 2006. Selectivity Parameters and Size at First Maturity in Deep-Water Shrimps, *Aristeomorpha foliacea* (Risso, 1827) and *Aristeus antennatus* (Risso, 1816), from the North-Western Ionian Sea (Mediterranean Sea) A SO: Source Hydrobiologia [Hydrobiologia]. Vol. 557, no. 1, pp. 145-154. Mar 2006. Selectivity experiments were carried out during trawling targeting deep-water shrimps *Aristeomorpha foliacea* (Risso, 1827) and *Aristeus antennatus* (Risso, 1816) (Crustacea, Decapoda, Aristeidae) in the North-Western Ionian Sea (Eastern-Central Mediterranean). Different criteria were employed to analyse maturity; however, the proportion at 50% of retained, mated and mature specimens was always used to indicate the size, expressed as Carapace Length (CL, mm), at first capture (CL sub(c)), mating (CL sub(sp)) and at first maturity (CL sub(m)), respectively. In order to estimate the size at 50% maturity (CL sub (m)) for females of both species, three criteria were adopted. In particular, CL sub m) was computed for the mature females not considering the presence of spermatophores, for the mature females with spermatophores and for the mature females intersected by the decreasing proportion with size of females without spermatophores. Three diamond stretched mesh codends of 40 mm, 50 mm and 60 mm were tested using a cover of 20 mm. The 40-mm stretched mesh size (European Union legal size in the Mediterranean) was not selective for the sampled population of each species. The size at first capture (CL sub(c)), calculated in both species for the two sexes combined, increased significantly with mesh size. Even for the mesh size of 60 mm, the size at first capture was still smaller than the sizes at 50% maturity, whatever the criterion adopted. Since the

differences between the size at first maturity and the sizes at first capture are greater in *A. foliacea* than *A. antennatus*, the former species appears in this respect to be more vulnerable to trawling than the latter.

16. D'Onghia, G; Carlucci, R; Maiorano, P; Panza, M., 2001. Discards from deep-water bottom trawling in the eastern-central Mediterranean Sea and effects of mesh size changes. Symposium on deep-sea fisheries: NAFO/ICES/CSIRO Symposium 3-14 September 2001. pp. 245-261. [J. Northwest Atl. Fish. Sci.]. Vol. 31. Data on discards were collected during deep-water bottom seasonal trawling surveys targeting red shrimps (*Aristeus antennatus* and *Aristeomorpha foliacea*) in the Ionian Sea. The performance of 3 codends, with stretched mesh sizes of 40, 50 mm and 60 mm, was tested. A cover with a stretched mesh of 20 mm was employed on each codend. The discarded catch constituted an important fraction of the total catch (20-50%). This was almost exclusively due to unwanted fish species, while discards of the target species and other commercial species were negligible. Discard rates increased with total catch and depth. No substantial differences were seen in the overall performance of the codends used. Differences were only detected in the biomass of the escaped fraction of the catch and in the size selectivity. The 40 mm mesh size was not selective in *Aristeus antennatus*. Larger mesh size codend (50 and 60 mm) allowed a higher number of small specimens to escape. The 50% retention sizes increased according to the mesh size in all examined species.

17. Ferretti M., Sala A., Piccinetti C., Ungaro N., 2005. Selettività di una rete a strascico con sacchi armati a losanga ed a maglia quadrata. Rapporto Finale al Ministero per le Politiche Agricole e Forestali, VI Piano Triennale della Pesca e dell'Acquacoltura (Progetto MIPAF n. 6-B-4).(abstract missing)

18. Fiorentino F., M. L. Bianchini, S. Ragonese, Brian Rosso, Alicia Mosteiro, Matthew Camilleri, P. Rinelli. "Experiences of trawl selectivity of diamond mesh cod-end-cod-ends in main target species of the Strait of Sicily and adjacent seas". GFCM -ATSELMED workshop Sète 9, 10 & 11 February 2005. This contribution is a review of the studies conducted on the selectivity of diamond mesh cod-ends of the trawls used in the Strait of Sicily and adjacent seas, in particular on *Aristeomorpha foliacea*, *Parapenaeus longirostris*, *Merluccius merluccius* and *Mullus barbatus*; the method of the cover cod-end being that the most used. An inventory of the principal parameters of these species was drawn up; the analysis of the literature shows the existence of a linear relation between mesh opening and L50 as well as SF; Fiorentino (1998) deduces an estimate of the relationship between it and the mesh size from different selectivity studies, in particular for hake.

19. Lucchetti A., 2008 Comparison of diamond- and square-mesh codends in the hake (*Merluccius merluccius* L. 1758) trawl fishery of the Adriatic Sea (central Mediterranean). Scientia Marina (Barcelona) [Sci. Mar. (Barc.)]. Vol. 72, no. 3, pp. 451-460. 2008. A traditional codend (40

mm diamond mesh) and an experimental codend (40 mm square mesh) made of 2.6 mm diameter knotless PA netting were tested on a commercial trawl net on a sandy-muddy bottom ( similar to 70 m depth) of the Adriatic sea in order to assess the size selectivity of European hake (*Merluccius merluccius*) and the reduction of the discards in a demersal multi-species trawl fishery. The catch was sorted as target species and bycatch and the selectivity with respect to European hake was investigated using the covered codend method. The square-mesh codend allowed a reduction of about 37% of the fraction discarded at sea. The mean catch obtained with the experimental codend was lower than that obtained with the traditional codend (about 14 kg per haul) but the short-term economic losses were low (similar to 3%). The square-mesh codend was also more selective than the traditional codend, giving the juveniles of European hake a good chance of escape: the mean selection length ( $L_{sub(50)}$ ) was 7.60 cm in DM and 3.98 cm in SM. Moreover, the mesh configuration did not affect the gear's performance. Thus, the square-mesh codend could be an easy, inexpensive and useful solution for a more sustainable management of the resources in Adriatic multi-species fishery.

20. Piccinetti C., Nicola Ungaro, Antonello Sala, Mario Ferretti. "Approach and methodology used in fishing experiments with square mesh cod-end in Adriatic Sea". GFCM -ATSELMED workshop Sète 9, 10 & 11 February 2005. The present paper presents the approach and methodology employed to measure the selectivity and the effectiveness of the square meshes applied to the type of trawl most commonly used at Adriatic Sea. Seventeen fishing experiments were completed to this end by the vessels of research DALLAPORTA and ANDREA. The selectivity of square mesh and diamond mesh shape bottoms were achieved separately by the use of a double 20 mm mesh size cod-end, equipped with plastic hoops to avoid masking the bottom tested. The adopted hanging ratio of square meshes panel is 25%. To compare the effectiveness of the two systems, the hauls were completed alternatively with one then the other type of cod-end, the yields expressed as a whole and by species being given in number and weight in kg/km<sup>2</sup>. The trawl geometry and efforts exerted on the trawl gear were constantly measured during each haul, using Scanmar equipment and tension sensors. The selectivity parameters were then calculated for each haul using software CC2000 while the average selectivity curves were obtained by the method of Fryer (1991). Compared with the observations obtained for diamond mesh bottoms of same dimensions, no significant difference was noted, neither between the vertical and horizontal openings, nor between the forces of resistance of the trawls. The specific composition is also identical but with weaker yields for the square mesh; for instance if one obtains a profit in weight of 64% for hake the total effectiveness is decreased by 20 %. In conclusion, the use of a square mesh bottom trawl involves a higher selectivity than with diamond meshes. This higher selectivity however involves an economic loss due to the youngest fraction of stock, as it is the case for the red mullet.

21. Sala A., Piccinetti C., Ferretti M., Buglioni G., Lucchetti A., Palumbo V., Ungaro N., 2005. Selectivity comparison of diamond and square mesh codends of Mediterranean bottom trawl. ICES CM 2005/B:04.

22. Sala, A; Priour, D; Herrmann, B., 2006. Experimental and theoretical study of red mullet (*Mullus barbatus*) selectivity in codends of Mediterranean bottom trawls. Aquatic living resources/Ressources vivantes aquatiques [Aquat. Living Resour./Ressour. Vivantes Aquat.]. Vol. 19, no. 4, pp. 317-327. 2006. The objective of this study was to investigate the effect on *Mullus barbatus* (red mullet) codend selectivity by increasing the codend mesh size or reducing the number of meshes in the codend circumference. This was performed through experimental sea trials and computer simulations. The sea trials were carried out in the Adriatic Sea using a polyamide codend in order to assess its selectivity, to record morphological (height, width and length) and population size structure parameters of red mullet (*Mullus barbatus*). The selectivity process in the codend was also simulated with an individual-based model (PRESEMO) and a finite element model (FEMNET) to calculate the codend shapes. By adjusting the behavioural description of red mullet in the simulation, the model results reached an agreement with the experimental results. Next these, behavioural parameters were used in the simulation model to predict the effect of changing mesh size and number of meshes around in new codend designs. The predicted effect and the benefit of enforcing these designs on catch efficiency below and above minimum landing size (MLS) were investigated. The results confirm that the reduction of number of meshes in the codend circumference will be more beneficial than increasing the mesh size.

23. Sala A., Alessandro Lucchetti, Corrado Piccinetti, Mario Ferretti., GFCM-ATSELMED 3 workshop Sète 2 – 4 July, 2008. Size selection by diamond- and square-mesh codends in multi-species Mediterranean demersal trawl fisheries The comprehensive study investigated by means of the covered codend method, the selectivity for eight common species in the Mediterranean demersal trawl fishery. A 38mm full square mesh codend was tested against a traditional Italian 38mm (40mm nominal) diamond mesh codend. Improved selectivity was demonstrated in the square mesh codend for all species except for scaldfish (*Arnoglossus laterna*). Good overall catches allowed for estimation of between haul variation which does not underestimate the variation normally obtained when pooling haul-data. The use of square 38mm (40 nominal) mesh codends as technical measure was strongly supported despite it does not give sufficient increase in selectivity for species I the multi-species fishery. Also in this study hake was one of the species who showed the largest improvement in selectivity using the square mesh configuration despite the improvement was not sufficient in relation to the minimum landing size. The WG discussed whether an increase in minimum mesh size immediately should comprise the whole trawl or only the codend. In this context it was brought forward that the normal procedure was to first regulate only the codend and at the same time fix a transition period (a normal lifetime of a trawl) after which also the whole

trawl should comply with the new minimum mesh size. In this way the fishing industry would not need to discard new or usable trawl already made with the previous minimum mesh size, and as more than 90% of the selection happens in the codend, the conservation difference would not be significant anyway.

24. Sala A., Lucchetti Alessandro, De Carlo Francesco, Palumbo Vito., 2007. Critical review of selectivity studies for *Mullus barbatus* (Red mullet) and *Merluccius merluccius* (European hake) in Mediterranean trawl fisheries. GFCM-ATSELMED 2, Barcelona 2-4 April, 2007). Given the importance of hake (*Merluccius merluccius*) and red mullet (*Mullus barbatus*) in the Mediterranean bottom trawl fisheries, the relationship between mesh size, L50, SR and SF was reviewed in this paper with the contributions of several scientists, with the main objective to estimate reference selection for different codend mesh size. Considering that the real processes are more complex, several Mediterranean fisheries scientists started to explore effects of other parameters (e.g. mesh size, mesh configuration, twine diameter, mounting ratio, etc.) on codend selectivity. This study presents an updated literature review of the Mediterranean bottom trawl selectivity, discusses and summarises the data and the work presented in several papers/reports. Advises on the experimental methodology and data analysis are provided for a better estimation of selection parameters. The review of the literature was undertaken during 2006 and further technical information on the gear characteristics were subsequently obtained contacting by correspondence the authors. The scarcity of review papers demonstrated the need for this review. In particular, between 1969 and 2007, only 20 and 28 relevant papers were found respectively for red mullet and hake, while only few for other demersal species. Updating of published literature is on going for these 2 species and needs to be extended to other main commercial species

25. Sala A., A. Lucchetti, 2010. The effect of mesh configuration and codend circumference on selectivity in the Mediterranean trawl *Nephrops* fishery. Fisheries Research (Amsterdam) [Fish. Res.]. Vol. 103, no. 1-3, pp. 63-72. Apr 2010. The Pomo pit area is both the main Adriatic nursery area for European hake (*Merluccius merluccius*) and Norway lobster (*Nephrops norvegicus*) and an important trawling ground for the Adriatic trawl fleet. The current paper is not only restricted to the escapement of Norway lobster but also takes note of the associated white fish community (European hake, blue whiting *Micromesistius poutassou* and poor-cod *Trisopterus minutus capellanus*) which makes an important contribution to the commercial catch of trawlers. This study was undertaken to analyse the effect on trawl selectivity of inserting first a 40mm square-mesh codend and second of increasing the circumference in the diamond-mesh codend. A traditional 40mm diamond-mesh codend, typical of the commercial trawl fisheries, was selected as a reference codend for the comparative analysis. The square-mesh codend was always more selective than the diamond-mesh codends, while the influence of codend circumference on diamond-mesh selectivity was less evident. In addition to mesh configuration and the number of meshes around the codend,



the selectivity data were modelled by estimating the individual contribution of catch size and season, but there was no evidence of a coherent effect on the selectivity of these two parameters. This study confirms that all the four investigated species make the best use of the square-mesh opening, either because of their body shape or because the form of the mesh facilitates forcing of the net. Results seem to suggest that for the main target species, Norway lobster, square-mesh codend would protect specimens under the 20mm of MLS (carapace length). Square-mesh also improves the L50 of European hake, but it seems not to be sufficient to avoid the catch of specimens under MLS of 20cm as fixed by the EC Reg. Nr. 1967/2006. In conclusion, enforcement of installation of square-mesh codends in Mediterranean trawl Nephrops fishing could contribute to decreasing the capture of individuals from the particular nursery area of Pomo pit.

26. Sala, A; Lucchetti, A; Piccinetti, C; Ferretti, M., 2008 Size selection by diamond- and square-mesh codends in multi-species Mediterranean demersal trawl fisheries. *Fisheries Research* (Amsterdam) [Fish. Res.]. Vol. 93, no. 1-2, pp. 8-21. 1 Sep 2008. Mediterranean demersal trawl fisheries traditionally operate using small diamond-shape meshes in the codend, which tend to retain almost all animals. We investigated the effect of mesh configuration on the size selectivity of nine species (the scadfish *Arnoglossus laterna*, the broad-tail shortfin squid *Illex coindetii*, the European hake *Merluccius merluccius*, the red mullet *Mullus barbatus*, the Norway lobster *Nephrops norvegicus*, the common pandora *Pagellus erythrinus*, the deepwater rose shrimp *Parapenaeus longirostris*, the Mediterranean horse mackerel *Trachurus mediterraneus* and the poor-cod *Trisopterus minutus capelanus*) commonly captured in the Mediterranean demersal trawls. Two codends having meshes with the same opening (ca. 38mm) but different mesh configuration (DM38: diamond-mesh and SM38: square-mesh configuration) were fished daily and alternately on the same trawl. They demonstrated a substantial improvement in selectivity with square-mesh. Selectivity was measured using the covered codend technique, the cover being supported by circular hoops. The results were analyzed taking into account the between-haul variation in selectivity. Two other important external variables were identified: the trawling depth and the codend catch, which for some species influenced between-haul variation, but there was no evidence of a coherent effect on selectivity parameters. The selectivity of 40mm diamond-mesh codend has been reported to be rather poor because a large proportion of the codend catch is immature and smaller than the minimum landing size (MLS) or first maturity size. With the exception of the flatfish (*A. laterna*), the effect of a change of mesh configuration from diamond- to square-mesh on size selectivity positively affected the retention length at 50% ( $L_{sub(5) sub(0)}$ ). However, square-meshes were found to be unsuitable for flat and/or deep-bodied fish as this one escape more readily from diamond-meshes. The Council Regulation (EC) No. 1967 /2006, concerning management measures for the sustainable exploitation of fishery resources in the Mediterranean, establishes the MLS of marine organisms. However, the increase in  $L_{sub(5) sub(0)}$  with square-mesh would not avoid

some of the existing contradictions in allowing the use of codend mesh which leads to lower L<sub>sub(5)</sub> than the MLS.

### **Morocco**

27. Benchoucha S., Malouli Idrissi M., Lahnine A., *Projet d'étude de la sélectivité du chalut à mailles carrées en Méditerranée marocaine Impact biologique et socio-économique de l'utilisation de ce type de chalut sur l'écosystème et sur la communauté des pêcheurs.* A draft project plan was presented for Moroccan experiments investigating selectivity for the newly legislated 50mm minimum codend meshsize and the 25-35mm diamond codends still in use. Impact of the new regulation on ecosystem, change in employment pattern and cost of catch would also be investigated. Support of COPEMED, IFREMER and FAO was requested to refine project plan and protocols. The WG recommended a firm plan with distinct phases to be developed for the project beginning with a gear survey to establish the trawl to be used in the trials. A protocol for the sea-trials should be developed with the assistance of technical experts. The group invited the final project plan with an indicative budget to be presented to the next meeting. A socioeconomic study assessing the impact of the changes to the new legislated meshsize should be conducted in parallel with the gear study. Strong interest from Egypt indicated the project frame could be extended to other regions.

### **Spain**

28. Bahamón, N., Sardà, F., Suuronen, P. 2006. Improvement of trawl selectivity in the NW Mediterranean demersal fishery by using a 40 mm square mesh codend. *Fisheries Research* 81:15-25 Commercial fishing trials with 40mm diamond (DM40) and square (SM40) mesh codends made of 5mm diameter knotted PE-netting were conducted in July 2005 on the continental shelf (~100 m) and upper slope (~400 m) of the Catalan Sea (NW Mediterranean) to assess the size selectivity of European hake (*Merluccius merluccius*), Norway lobster (*Nephrops norvegicus*), poor cod *Trisopterus minutus capelanus* ( ) and greater forkbeard (*Phycis blennoides*) in the demersal multi-species trawl fishery. In total, 28 tows were done using the standard covered codend method. For all four species, the SM40 showed a significantly higher mean selection length (L<sub>50</sub>) than the DM40. For hake the L<sub>50</sub> was 16.0 cm in SM40 and 10.1 cm in DM40; the corresponding figures were 13.0 cm versus 9.2 cm for poor cod and 14.9 cm versus 9.8 cm for greater forkbeard. For Norway lobster, DM40 did not show any size-selectivity whereas SM40 produced a L<sub>50</sub> of 22 mm. The selection range (SR) between DM40 and SM40 was not significantly ( $p > 0.05$ ) different for any of the three fish species. Our trials indicate that substantial improvement in size-selectivity for these commercially important species is achieved by switching from the conventional 40 mm diamond mesh codend to a 40mm square mesh codend. Our analysis also suggests that by using a 40mm square mesh codend the short-term economic losses of commercial species, compared to the losses

of 40mm diamond mesh codend, will be low in the slope fishery (less than ~5% of the total catch value), whereas in the continental shelf losses could be up to ~30% of the total catch value.

29. Bahamón, N., Sardà, F. Suuronen, P. 2007. Selectivity of a flexible size-sorting grid in the Mediterranean multi-species trawl fishery. *Fisheries Science* 2007 73: 331–340 The demersal multispecies trawl fishery in the western Mediterranean Sea has a poor selectivity; large numbers of juvenile fish are caught when using the legislated 40-mm diamond meshcod end. The selectivity of a flexible sorting grid with 20-mm bar spacing (BS20) installed in front the conventional trawl cod end was investigated. The standard covered cod end method was used. Data was adequate for analyzing the selectivity of European hake *Merluccius merluccius*, poor cod *Trisopterus minutus capellanus*, greater forkbeard *Phycis blennoides* and Norway lobster *Nephrops norvegicus*. The selectivity of the 20-mm sorting was compared with the performance of 40-mm diamond (DM40) and square mesh (SM40) cod ends. The effect of a guiding funnel on the performance of the grid (BS20-f) was also explored. Finally, the potential changes in yield per recruit (Y/R) and biomass per recruit (B/R) after implementing a sorting grid were explored. An overall improvement in the 50% selection length (L50) with all four species was substantial when comparing the BS20 to the DM40. Higher improvement in L50s was achieved when the grid was equipped with the guiding funnel. When comparing the performance of the BS20-f to the SM40, there was no marked difference in L50s. The Y/R and B/R, however, are substantially higher with BS20-f for poor cod and about the same for European hake. BS20 compared to SM40 achieved lower Y/R and B/R for all four species; the smallest difference was observed for Norway lobster. Further development is required if the sorting grid is to be introduced into commercial fisheries.

30. Bahamon, N; Sarda, F; Suuronen, P., 2007. Potential benefits from improved selectivity in the northwest Mediterranean multispecies trawl fishery. *ICES Journal of Marine Science* [ICES J. Mar. Sci.]. Vol. 64, no. 4, pp. 757-760. May 2007. The management scheme in the northwest Mediterranean multispecies demersal fishery is based largely on technical measures such as minimum mesh and landing sizes. However, selectivity of the trawls used is poor, and large numbers of juvenile fish are caught. We assess the consequences of improved gear selectivity for European hake, Norway lobster, poor cod, and greater forkbeard by assuming that the whole fleet would switch from the current 40 mm diamond-mesh to a 40mm square-mesh (SM40) codend. The results suggest that, immediately after implementation, the yield-per-recruit (Y/R) would be reduced by up to 20% for the three fish species but that, within five years, the Y/R of European hake would increase by > 50 %, provided fishing effort did not change markedly. For poor cod and greater forkbeard, the comparable increases would be more moderate, whereas for Norway lobster, the gains would only be small. Overall, marked long-term benefits might be obtained by changing to SM40 codends.

31. Bahamon N., Francesc Sardà, Petri Suuronen - Improvement of trawl selectivity in the NW Mediterranean demersal fishery by using a 40mm square mesh codend. 2007, GFCM-ATSELMED workshop, Barcelona 2 – 4 April, 2007. Commercial fishing trials with 40mm diamond (DM40) and square (SM40) mesh codends made of 5mm diameter knotted PE-netting were conducted in July 2005 on the continental shelf (~100 m) and upper slope (~400 m) of the Catalan Sea (NW Mediterranean) to assess the size selectivity of European hake (*Merluccius merluccius*), Norway lobster (*Nephrops norvegicus*), poor cod (*Trisopterus minutus capelanus*) and greater forkbeard (*Phycis blennoides*) in the demersal multi-species trawl fishery. In total, 28 tows were done using the standard covered codend method. For all four species, the SM40 showed a significantly higher mean selection length (L50) than the DM40. For hake the L50 was 16.0 cm in SM40 and 10.1 cm in DM40; the corresponding figures were 13.0 cm versus 9.2 cm for poor cod and 14.9 cm versus 9.8 cm for greater forkbeard. For Norway lobster, DM40 did not show any size-selectivity whereas SM40 produced a L50 of 22 mm. The selection range (SR) between DM40 and SM40 was not significantly ( $p > 0.05$ ) different for any of the three fish species. Our trials indicate that substantial improvement in size-selectivity for these commercially important species is achieved by switching from the conventional 40mm diamond mesh codend to a 40mm square mesh codend. Our analysis also suggests that by using a 40mm square mesh codend the short-term economic losses of commercial species, compared to the losses of 40mm diamond mesh codend, will be low in the slope fishery (less than ~5% of the total catch value), whereas in the continental shelf losses could be up to ~30% of the total catch value.

32. Baro J., I. Muñoz, E. Massuti, B. Guijarro, M. Garcia, A. Fernandez., 2005. "Selectivity of diamond and square mesh cod-end cod-ends in the coastal trawl mixed fisheries off the Spanish Mediterranean". GFCM -ATSELMED workshop Sète 9, 10 & 11 February 2005. This study was undertaken on the coastal mixed trawl fisheries in three different areas, Málaga, Alicante and Majorca Island, between 50 and 500 m, in autumn and in spring, with the aim of studying the selectivity of square and diamond mesh cod-ends on the main coastal species. These experiments were conducted onboard trawlers representative of the Spanish Mediterranean fleet which exploits the fishing zones between 50 and 800 m; two types of trawls were tested, among the gears the most in use, the "cuadrado" with a larger opening, and the "tangonero" mostly used for deep sea fishing. These experiments were based on the cover cod-end method. The duration of trawling is the same as that of the fishing vessels in each zone, i.e. between 90 and 240 mn ,on the usual zones of fishing. Three strata depths were concerned : 50-100 m; 100-200 m; 200 m. Since haul duration depends on several factors, including the layer sampled and of the relative abundance of the species, the data of capture were standardized in g/h so that the various yields be compared. The differences between the total captures obtained with each type of mesh were analyzed using ANOVA software for the main species. The yields obtained with each type of cod-end were compared by test T of

Student. Moreover, the possible differences between the frequencies of distributions obtained with each cod-end were tested with the test of Kolmogorov-Smirnov. Finally the L50 of the principal species were obtained by adjustment with the logistic function. 315 hauls were thus examined; if there is no significant difference between the yields of both types of cod-ends, as regards most of the species, on the other hand in the square mesh configuration the L50 of these species are higher than those obtained with diamond mesh, for an identical 40 mm mesh size, and they are in particular equal to or larger than the legal minimal size for *Mullus* spp., *S. smaris* and *M. Poutassou*. Furthermore, the discards are lower than with a diamond mesh cod-end. Although further experimentation are necessary, investigating other periods of the year and zones and different strata along with survival estimates of the individuals that have escaped, these first results give to think that the use of square mesh configuration can only improve in the short term, middle or long term the way many target species are exploited.

33. Baro J., Munoz de los Reyes I. 2006. Bottom trawl fishing yield and selectivity comparisons between square-and diamond meshes. *Inf. Tec. Inst. Esp. Oceanogr.* 16 pp.(Abstract missing).

34. Coll M., Nixon Bahamon, Francesc Sardà, Isabel Palomera, Sergi Tudela, Petri Suuronen, 2007 - Ecosystem effects of improved trawl selectivity in the South Catalan Sea. *GFCM-ATSELMED 2*, Barcelona, 2 – 4 April, 2007. Potential ecosystem effects of improved selectivity in the South Catalan Sea demersal trawl fishery with a 40 mm square mesh codend and a 20 mm bar spaced sorting grid was explored with a food web model representing current conditions of the ecosystem and selectivity data from recent fishing experiments. Direct and indirect impacts of fishing were evaluated and allowed insights on the sustainability of various management options for the trawl fishery. This fishery has the biggest fleet in the area, it is highly multispecies and catches are largely composed by juveniles of target species and non-target species often discarded in large quantities. Temporal dynamic simulations indicated that improvement of trawl selectivity would have noticeable and complex direct and indirect effects on target and non-target demersal species. The biomass and catch of various commercial species (e.g. anglerfish, adult hake) would increase, while that of invertebrates (e.g. suprabenthos, Norway lobster), juveniles and small-sized fish species (e.g. juvenile hake, blue whiting) would decrease due to higher predation mortalities and trophic cascades in the food web. A slight increase of the mean trophic level of the community and of the catch is predicted. Trawling would experience moderate catch decrease while long lining and bait trolling would gain. Including the mortality caused by the escape is shown to be important when assessing the ecosystem effects of improved trawl selectivity. Improving selectivity will not be sufficient to recovery of highly exploited or overexploited demersal species. Greater reduction of fishing effort would be necessary.

35. Coll M.; Bahamon, Nixon; Sarda, Francesc; Palomera, Isabel; Tudela, Sergi; Suuronen, Petri, 2008. Improved trawl selectivity: effects on the ecosystem in the South Catalan Sea (NW Mediterranean). *Marine Ecology Progress Series [Mar. Ecol. Prog. Ser.]*. Vol. 355, pp. 131-147. 2008. We explored the potential ecosystem effects of improved selectivity in the South Catalan Sea demersal trawl fishery. A calibrated food web model representing current conditions of the ecosystem and selectivity data from recent fishing experiments were used to perform temporal dynamic simulations. This enabled the evaluation of direct and indirect impacts of fishing and provided insights into the sustainability of various management options for the trawl fishery. This fishery has the biggest fleet in the area, it is highly multispecies, and catches are largely composed of juveniles of target species and non-target species, which are often discarded in large quantities. Simulations indicate that improvement of trawl selectivity would have noticeable and complex direct and indirect effects on target and non-target demersal species. The biomass and catch of various commercial species (e.g. anglerfish, adult hake) would increase, while that of invertebrates (e.g. suprabenthos, Norway lobster) and juvenile and small-sized fish species (e.g. juvenile hake, blue whiting) would decrease due to higher predation mortalities and trophic cascades in the food web. Impacts on the pelagic compartment would also be noticeable. A slight increase in the mean trophic level of the community and of the catch is predicted, as well as of ecosystem biomass diversity. Generally, however, a greater reduction of fishing effort would be necessary for the recovery of highly exploited or overexploited demersal species. Trawling would experience moderate decreases in catches, while long-lining and bait-trolling would benefit. This work highlights the importance of including the mortality incurred during or post-escape from trawl nets when assessing the ecosystem effects of improved trawl selectivity.

36. Guijarro B. Massuti E., 2006. Selectivity of diamond- and square-mesh codends in the deepwater crustacean trawl fishery off the Balearic Islands (western Mediterranean). *ICES Journal of Marine Science [ICES J. Mar. Sci.]*. Vol. 63, no. 1, pp. 52-67. Jan 2006. An analysis of 38 bottom trawl hauls at depths of 251-737m off the Balearic Islands (western Mediterranean) during autumn 2002 and spring 2003 was used to compare the species and size selectivity of 40-mm diamond- and square-mesh codends under commercial conditions. There was no difference in the catch composition or the yield that could be attributable to mesh shape, although the percentage of total and commercial species discarded with a diamond mesh was higher than with a square mesh. At least in the short term, the escapement ratio and the economic loss with the diamond mesh were lower than with square mesh, but economic efficiency was no different between them. For all the main species compared, except one flatfish, size selectivity parameters were lower for the diamond- than for the square-mesh codend. Selectivity values for the one flatfish species were similar. From the results it is concluded that, within the context of precautionary management, introduction of a 40-mm square mesh in the codend could be an appropriate and plausible measure to improve the

state of the resources exploited by the deepwater crustacean trawl fishery of the upper slope off the Balearic Islands, and to reduce the impact of the fishery on the ecosystem

37. Guillen J., 2007 Bio-Economic Analysis of Selectivity Changes in the Shared Hake Fishery in the Gulf of Lions Using MEFISTO-3 Model. GFCM-ATSELMED 2 workshop, Barcelona, 2 – 4 April, 2007. In this presentation are shown the results obtained in the BEMMFISH project by the research teams of ICM-CSIC, IFREMER and GEM-UB for the changes of a mesh size of 40 mm diamond into a 50 mm and 60 mm diamond mesh and a 40 mm square mesh, applying the MEFISTO-3 model. These analyses have shown that there is an initial period of losses due to the decrease in the catch, but it is followed by an increase in the catch and profits. Normally a better selectivity implies that stocks get better, and so, long term socio-economic performance. However, results can be different depending on the operational unit. The results obtained illustrate that the model can be suitable to simulate the effects of changes in the selectivity due to gear changes. However there could be the need of minor changes in the model that allow introducing the survival rates effect in order to reproduce more precisely the effects in the fishery.

38. Massutti E., Beatriz Guijarro, Jorge Baro, & Isabel Muñoz., 2005. Selectivity of diamond and square mesh cod-ends in the deep water crustaceans trawl fisheries off Balearic Islands (Western Mediterranean). GFCM -ATSELMED workshop Sète 9, 10 & 11 February 2005. The present contribution describes the effects of square mesh cod-end selectivity in deep trawl fisheries which exploit the Norway lobster (*Nephrops norvegicus*) and the red shrimp (*Aristeus antennatus*) in the west of the Mediterranean sea. A total of 38 tests was carried out in autumn 2002 and in spring 2003, onboard a professional trawler working on the continental slope of the South of the Balearic Islands, between 251 and 737 m depth. A conventional trawl of type "huelvano" was used with alternatively a diamond mesh cod-end and a square mesh cod-end, both of a 40 mm nominal mesh size. A 20 mm cover cod-end was added for selectivity measurement purposes. All the grids were measured with gauge ICES calibrated at 4 kgf. To take into account the effect of the various strategies of fishing, the standardized specific composition of the captures (kg/hour) was analyzed by hierarchical classification. The rates of escapement and discards as well as the loss and economic effectiveness (value ratio of the capture retained compared to the total capture) were considered and analyzed by variance analysis for each season, each depth and each shape of mesh. The saturation effect for both the mesh shapes was also tested from the comparison of the escapement rates for the capture selected. The selectivity by size was modeled by means of the generalized logistic curve. For all the species, the first capture sizes significantly increase when adopting square mesh to the detriment of diamond mesh. Furthermore, there is neither difference in the composition of the captures of the two types of cod-ends nor in that of the commercial yields of the main species. In conclusion, if the fact of mesh shape changing involves small but significant increase in the rate of

escapement (between 5 and 15%) and between 1.4 and 2.4 % of economic loss, then the outputs of the main species, in terms of biomass and economic effectiveness would be probably remain.

39. Massutí E., Francesc Ordines and Beatriz Guijarro., 2007. ATSELMED – GFCM, Barcelona, 2 – 4 April, 2007. Diamond vs. square mesh codend in the multi-species trawl shelf fishery of the Balearic Islands (Western Mediterranean): effects on catch composition, yield, size selectivity and discards. Using data from 24 hauls carried out under commercial conditions on the continental shelf off the Balearic Islands, the selectivity of the traditional 40 mm diamond mesh codend was compared with an experimental 40 mm square mesh codend. To deal with the multi-species characteristic of this fishery, multi-variant statistical tools were applied. Bathymetric differences in catch composition confirmed the existence of two different fishing strategies: one on the shallow shelf (SS, 50-80 m depth) and another on the deep shelf (DS, 150-200 m depth). In terms of biomass, the catch composition was significantly different between mesh shapes only on the SS, due to a reduction of the yields of *Spicara smaris* when the square mesh was used. No other differences attributable to mesh shape were found in commercial yields for any other target species. A clear increase of L50 was detected for most species when using square mesh, allowing many more individuals under their minimum landing size to escape. Escapement ratio and economic loss were always significantly higher with square as opposed to diamond mesh, although economic loss was almost negligible for both meshes on the DS. Significant discard reductions were detected with square mesh due to algae and fish on the SS and DS, respectively. The reduction in the discards increased the economic efficiency of square mesh, which was higher than diamond mesh on the SS, whereas no differences were detected on the DS. These results confirm that square mesh codends would help to reduce the fishing pressure on small specimens and reduce the impact of trawling on the ecosystem. The benefits would not lead to a reduction of the yields for commercial categories, except for *S. smaris*. A species very appreciated in the study area, where it is one of the main target species for the coastal trawl fishery.

40. Massutí E, Ordines F, Guijarro B, 2007. Efficiency of mesh cod-end geometry and sorting grids to improve selectivity of bottom trawl in the western Mediterranean. Working Document to the ICES/FAO Working Group on Fishing Technology and Fish Behaviour. Dublin, 23-27 April 2007, 20 pp. (abstract missing)

41. Massuti E; Ordines, F; Guijarro, B., 2009 Efficiency of flexible sorting grids to improve size selectivity of the bottom trawl in the Balearic Islands (western Mediterranean), with comparison to a change in mesh cod-end geometry. *Journal of Applied Ichthyology [J. Appl. Ichthyol.]*. Vol. 25, no. 2, pp. 153-161. Apr 2009. In recent years several studies have been developed to improve the selectivity of the Mediterranean bottom trawl fisheries, which exert high fishing pressure on young individuals. The focus has been mainly on increasing the mesh size in the cod-end or changing its



mesh geometry; few studies have assessed the efficiency of the sorting grid systems. Analysis of 21 trawl hauls carried out at depths of 117-697m off the Balearic Islands (western Mediterranean) in October-November 2005, studied size selectivity of the trawl using flexible sorting grids with 15 (SG15) and 20 (SG20) mm bar spacing. A divided polyamide bottom trawl designed for commercial purposes demonstrated high efficiency for the simultaneous use of both sorting grid sizes at different depth intervals (DS: deep shelf; US: upper slope; MS: middle slope). The results were also compared with those from the authors' previous studies in the area where 40mm diamond (DM) and square (SM) mesh cod-ends were used. A saturation effect was detected on the DS for both sorting grids, due to the large amount of biomass captured at this depth interval. Size selectivity of 11 species was modeled, which showed an increase in length at first capture (L50) from SG15 to SG20. Values of L50 estimated for the main target species were: 10.9cm total length (TL) with SG15, and 18.9cm TL with SG20 for *Merluccius merluccius*; 21.1mm carapace length (CL) with SG15, and 23.8mm CL with SG20 for *Nephrops norvegicus*; and 15.9mm CL with SG15, and 19.6mm CL with SG20 for *Aristeus antennatus*. Comparison of size selectivity parameters between the sorting grids and cod-ends of different geometry showed clear differences. For most species, the highest value of L50 was obtained with SM (e.g. 26.6mm CL for *N. norvegicus* and 22.1mm CL for *A. antennatus*). Exceptions were the round-fish *M. merluccius*, the flatfish *Lepidorhombus boscii*, and the crustacean *Parapenaeus longirostris*, with values of SG20 (18.9cm TL, 3.1cm TL, and 25.7mm CL, respectively) higher than with SM (15.2cm TL, 10.2cm TL, and 20.2mm CL, respectively). Sorting grid selection ranges were broader than those estimated for DM and SM. Experience shows that the exchange of the DM for the SM and/or the introduction of SG20 can improve selectivity in the Mediterranean trawl, SM being more efficient than SG20 in the Balearic Islands.

42. Maynou, F; Sarda, F; Tudela, S; Demestre, M., 2006. Management strategies for red shrimp (*Aristeus antennatus*) fisheries in the Catalan sea (NW Mediterranean) based on bioeconomic simulation analysis. *Aquatic living resources/Ressources vivantes aquatiques [Aquat. Living Resour./Ressour. Vivantes Aquat.]*. Vol. 19, no. 2, pp. 161-171. 2006. We present a simulation bioeconomic model based on an age-structured population biological sub-model and an economic sub-model with vessel-specific dynamics, applied to two red shrimp (*Aristeus antennatus*) stocks in the NW Mediterranean. The model is dynamic, the economic sub-model is disaggregated at the level of vessel and the two sub-models are linked by means of a fishing mortality vector. We analyzed the projection of selected indicators (catches, overall profits, fishing mortality and spawning stock biomass) for the target species of the deep-water trawl fishery in the NW Mediterranean, red shrimp. We built three alternative management scenarios based on input control and we examined the performance of these management strategies against the current management policies. The three alternative management strategies were: i) increase the cost of

effort by eliminating the fuel tax exemption currently in place, ii) limit the nominal effort level (days at sea) to current levels, in order to offset the increasing trend observed in the last decade, and iii) change the selectivity patterns of the trawl by increasing mesh size. Our results show that for the two stocks analyzed, any of the three management measures (input controls) would be beneficial both to the stock and the fleets (over the medium and long terms) when compared with the projections over time of the status quo. Improving the selectivity of the fishing gear is more beneficial than limiting nominal effort or increasing the cost of effort. Comparing the performance of the management strategies on two stocks, one heavily fished and the other moderately so, we show that none of these management measures is able to substantially redress the situation of a heavily fished stock, implying that for the full recovery of heavily fished red shrimp stocks, we need to contemplate even stricter measures of management.

43. Ordines, F; Massuti, E; Guijarro, B; Mas, 2006. R Diamond vs. square mesh codend in a multi-species trawl fishery of the western Mediterranean: effects on catch composition, yield, size selectivity and discards. *Aquatic living resources/Ressources vivantes aquatiques [Aquat. Living Resour./Ressour. Vivantes Aquat.]*. Vol. 19, no. 4, pp. 329-338. 2006. Selectivity studies usually describe the effects on target species, whereas information on by-catch and discards is scarce. Nevertheless, large quantities of undersized individuals and invertebrates are discarded in the Mediterranean multi-species bottom trawl fishery. The present work analyses the data from two surveys carried out on the shallow and deep continental shelf (50-78 m, and 147-189 m, respectively) off the Balearic Islands (western Mediterranean). In these surveys, the traditionally used 40 mm diamond mesh codend and an experimental square mesh codend were used under commercial conditions. Catch composition, yields, size selectivity of both target and by-catch species, and discards were compared between the two mesh types. The mean selection length (L50) clearly increased for most species when using square mesh, escaping many more individuals under their minimum landing size. Yield of *Spicara smaris* was significantly lower by using the square mesh, changing the composition of the retained catch. Escapement ratio and economic loss were significantly higher with square mesh, although economic loss was almost negligible for both meshes on the deep continental shelf. The use of square mesh significantly reduced the discards of algae in the shallow waters and fish on the deep continental shelf. The results confirmed that square mesh codend reduces the fishing pressure on small specimens as well as the impact of trawling on the ecosystem. These benefits would not lead to a reduction of the yields neither of the main target species, the fishes *Merluccius merluccius*, *Mullus surmuletus* *Zeus faber*, and the cephalopods *Loligo vulgaris* and *Octopus vulgaris*, nor of the rest of commercial categories, except for *Spicara smaris*.

44. Sardà, F., Molí, B., Palomera, I., 2004. Preservation of juvenile hake (*Merluccius merluccius*, L.) in the western Mediterranean demersal trawl fishery by using sorting grids. *Scientia Marina*, 68, 435–444. (abstract missing).

45. Sardà F., Nixon Bahamón and Petri Suuronen. 2005. “First experiences with grids in the Spanish Mediterranean sea ; success and failures in multi-species trawl fishery”. GFCM - ATSELMED workshop Sète 9, 10 & 11 February 2005. Two campaigns were completed in the Spanish Mediterranean to test selective grids on bottom trawls and to determine the most satisfactory bar spacing to allow the maximum escapement of the juveniles of *M. merluccius* and *M. barbatus* in the Mediterranean multi-specific fisheries. Thirty eight hauls were achieved onboard a professional vessel, ten with square mesh cod-ends, sixteen with grids offering a 20 mm spacing between bars, and eight with grids offering a 15 mm bar spacing. A device was built which consists of a lengthening piece fitted with a grid leading to three cod-ends allowing the separation in three categories, i.e. the large individuals, the smaller ones, and the refuse. A comparison of the captures achieved with the three types of devices on the fishing zones of the delta of Ebre showed significant differences in the selectivity parameters of the various commercial species captured and loss rates per escapement. Furthermore, it showed that regarding multispecific fisheries the choice of a selective single device did not turn out to be an optimal solution for all the species. A compromise must be found between the type of device, the L50 and the capture loss. In addition, when compared with the advantages of the square mesh cod-ends, the selective grids are more effective and allow a better survival after escapement, but they are more expensive and can be easily blocked. The talk concludes by underlining the interest which the development of these systems represents for the improvement of the selectivity of the trawl fisheries for hake and red mullet in the Mediterranean.

46. Sarda, F; Bahamon, N; Sarda-Palomera, F; Moli, B., 2005. Commercial testing of a sorting grid to reduce catches of juvenile hake (*Merluccius merluccius*) in the western Mediterranean demersal trawl fishery. *Aquatic living resources/Ressources vivantes aquatiques [Aquat. Living Resour./Ressour. Vivantes Aquat.]*. Vol. 18, no. 1, pp. 87-91. 2005. Mediterranean demersal fisheries have experienced an ongoing decline in catches over the past 20 years as a result of excessive increases in effort caused both by growth in trawler engine power and by rapid technological advances in fish finding and fishing technology. This has led to an overexploitation of these resources. An increasing share of the catches consists of immature individuals. This study was undertaken to test a sorting grid with a bar spacing of 20 mm as a means of excluding juveniles in the commercial hake (*Merluccius merluccius*) fishery in the Catalan Sea, western Mediterranean. The grid was placed in the extension section of the gear 5 m in front of a cod-end. Divided cod-end design was used to collect the escapees and target species. The mean selection length (L50) of the ten hauls was 14.2 plus or minus 0.7 cm SE, with a selection range of 7.3 cm plus or minus 0.4 SE. The biomass of hake under L50 that escaped through the grid represented 50.1% plus or minus 6.7

SE of the total hake biomass. These results are promising and indicate that a sorting grid can be used in excluding young hake. This was a first step toward implementation of sorting grids in commercial trawl gears as means of avoiding unwanted catches of small individuals in the hake fisheries in the Mediterranean Sea. Further trials are required to improve the sorting efficiency of the grid.

47. Sarda F. and J.B Company, 2007. Science versus fisherman decisions: a real experience. A document for reflexion. GFCM –ATSELMED workshop Barcelona 2 – April 2007. In relation to the new EC rules on implementation of 40 mm square mesh in the trawl cod-ends in the Mediterranean, a series of selectivity experiments in the Catalan multi-species fishery were conducted by members of ICM (CSIC). Experiments were performed applying strict scientific and statistical criteria. The results were disseminated in specialized journals, at scientific workshops, to fishermen's associations and directly to the sector. Reacting on this and the new regulation, the fishing industry arranged on their own, a one day experiment with three vessels testing a 40mm diamond-, a 50mm diamond- and a 40mm square mesh codend. It was the impression that this non scientific experiment had implication for the decision processes related to the implementation of the new EU regulations in the country and the presentation described the frustrations the fisheries management advice was facing on the issue.

48. Sarda, F; Bahamon, N; Sarda-Palomera, 2006. The use of a square mesh codend and sorting grids to reduce catches of young fish and improve sustainability in a multispecies bottom trawl fishery in the Mediterranean *Scientia Marina* (Barcelona) [Sci. Mar. (Barc.)]. Vol. 70, no. 3, pp. 347-353. Sep 2006. In order to improve the capacity of bottom trawl fishing gears to reduce catches of young fish and discards in a highly exploited demersal trawl fisheries in the Mediterranean, the size-selection performance of a 36-mm square-mesh codend and two sorting grids with 20 and 15 mm bar spacing was assessed. Alternate hauls were used to assess the selectivity of 36-mm square-mesh codend. Selectivity of sorting grids was assessed using a double codend in which fish that escaped through the grid were captured in the lower codend while other fish were guided into the upper codend. The mean selection length ( $L_{sub(50)}$ ) for European hake was 18.5 cm and that for the Atlantic horse mackerel was 14.0 cm with the 36-mm square-mesh codend. These values are close to their current minimum landing sizes (20 cm for hake and 3 cm for horse mackerel). The sorting grid with 20-mm bar spacing showed  $L_{sub(50)}$  value of 13.3 cm for hake, suggesting that a larger grid-spacing would be needed to obtain sufficient sorting performance. Similarly, for Atlantic mackerel the estimated  $L_{sub(50)}$  of 14.3 cm indicates that larger grid spacing is required to attain an  $L_{sub(50)}$  that would be close to the current MLS (18 cm). For Atlantic horse mackerel and red mullet, the  $L_{sub(50)}$  obtained with the sorting grid with 20-mm bar spacing was close to the MLS of these species (the MLS of red mullet is 11 cm). The selectivity of the sorting grid with 15-mm bar spacing was generally very poor. Size-selection performance of sorting grids was

assessed for the first time in the local fisheries. In order to effectively improve size-selection, seasonal and depth-dependent differences between target and by-catch species must be taken into account, which is a good indicator of the difficulty of implementing a single mesh size or grid spacing in the Mediterranean demersal trawl fishery.

### **Tunisia**

49. Marouene Bdioui and Rhida M'Rhabet., 2005. "Etude de l'influence de l'ouverture des mailles et de la forme des mailles de la poche sur la sélectivité des chaluts à crevettes tunisiens". GFCM -ATSELMED workshop Sète 9, 10 & 11 February 2005. In Tunisia, shrimp trawls and traditional Mediterranean trawls are used for deep-sea fishing.. These fisheries generate a great variety of by-catch and mainly small fish of great commercial value (red mullets). The study presented here aimed at determining and improving the selectivity of the professional trawls. The tests achieved onboard the R/V Hannibal enabled to obtain by the covered cod-end method the selectivity curves and parameters of three grids (48, 52, 60 mm) for the principal species (hake, red porgy, red mullet, bug). For both the Mediterranean trawl and the shrimp trawl, the values of L50 obtained for these species with a 40 mm mesh size are below their size of the first sexual maturity. They are higher only with a larger mesh size (52 mm for the red mullet) or square meshes (48 mm for the mullet). The development of a shrimp selective trawl combining both a grid and a guidance panel provided better results than the Canadian selective device Nordmore, by allowing the discard of a high proportion of immature fish and an increase of the hourly yields standard cod-end. There was no significant difference for annular sea bream. This can be explained by the body shape differences of the two species. The effects of different cod-end designs on the selectivity are discussed.

### **Turkey**

50. [Ates, C;](#) [Deval, MC;](#) [Boek, T;](#) [Tosunoglu, Z.](#), 2010 [Selectivity of diamond \(PA\) and square \(PE\) mesh codends for commercially important fish species in the Antalya Bay, eastern Mediterranean](#). Journal of Applied Ichthyology [J. Appl. Ichthyol.]. Vol. 26, no. 3, pp. 465-471. Jun 2010. Size selectivity of the 40 mm nominal polyethylene (PE) square mesh codend and the 44 mm nominal polyamide (PA) diamond mesh codend were determined under commercial conditions in the demersal trawl fishery. Data were collected using the covered codend technique and analyzed by logistic equation with a maximum likelihood method. Changing the mesh from a 44 mm PA diamond to a 40 mm PE square increased the mean retention lengths (L50s) of red mullet (*Mullus barbatus*), picarel (*Spicara maena*) and bogue (*Boops boops*) and decreased the selection ranges (SR) for common pandora (*Pagellus erythrinus*). For large-eye dentex (*Dentex macrophthalmus*) and axillary sea bream (*Pagellus acarne*) mean L50 and SR values were 9.6 and 11.8, and 2.4 and 2.4 cm, respectively, only in the DM44PA codend. For golden banded goatfish

(*Upeneus moluccensis*) values for SM40PE were only 15.0 and 2.7 cm, respectively. Results showed that the 40 mm PE square mesh codend provided higher selectivity for most of the Mediterranean fishes. The results also showed that regulating mesh size and requiring square mesh openings during trawling is essential for the release of immature individuals. This practice will result in a reduction in overfishing and permit recovery of overfished stocks.

51. Aydin, C; Oezaydin, O., 2008. Selectivity of a 50-mm diamond mesh knotless polyethylene codend for commercially important fish species in the Aegean Sea Journal of applied ichthyology/Zeitschrift fur angewandte Ichthyologie [J. Appl. Ichthyol./Z. Angew. Ichthyol.]. Vol. 24, no. 3, pp. 311-315. 2008. This research investigated effects of changing the diamond mesh size on codend selectivity in Mediterranean fisheries. The selectivity of a typical 50-mm diamond knotless polyethylene (PE) codend used in the Turkish fishery in the Aegean Sea was measured for commercially important species, in particular hake (*Merluccius merluccius*), horse mackerel (*Trachurus trachurus*), anglerfish (*Lophius piscatorius*) and John Dory (*Zeus faber*). Fishing trials were carried out on the commercial trawler 'Hapuloglu' between 9 and 3 December 2006 using a modified trawl net. Selectivity data were collected by the covered codend method and analysed by means of a logistic equation (Maximum Likelihood Method). The mean selectivity curve was estimated from individual hauls, taking betweenhaul variations into account. Mean mesh size of the codend was 49.4 mm as measured by digital calliper. Mean values for 50% retention length of hake and horse mackerel were estimated to be 11.4 and 15.6 cm total length; corresponding selection ranges were 4.1 and 5.5 cm respectively. The 50-mm diamond mesh codend showed adequate selectivity compared to the minimum landing size (MLS) for horse mackerel, while for hake it selected specimens in a size range far lower than the MLS. No selectivity values could be determined for anglerfish or John Dory. To design a more selective codend for the Turkish demersal trawl fishery, not only mesh size regulations but also other codend characteristics and netting material properties must be urgently considered.

52. Aydin, C; Tosunoglu, Z., 2010. Selectivity of diamond, square and hexagonal mesh codends for Atlantic horse mackerel *Trachurus trachurus*, European hake *Merluccius merluccius*, and greater forkbeard *Phycis blennoides* in the eastern Mediterranean. Journal of applied ichthyology/Zeitschrift fur angewandte Ichthyologie [J. Appl. Ichthyol./Z. Angew. Ichthyol.]. Vol. 26, no. 1, pp. 71-77. 2010. Knowledge on selectivity is considered essential for an adequate management of the trawl fishery. This paper compares the selectivity of conventionally used codends of 44 mm diamond mesh, 40 mm square, and hexagonal mesh for Atlantic horse mackerel, European hake and greater forkbeard in the eastern Mediterranean. Data were collected using the covered codend method and analyzed using the logistic equation with the maximum likelihood method. Mean selection curves were analyzed and compared using the between-haul variations model. The mean  $L_{sub(50)}$  values of diamond, square and hexagonal mesh codends are 14.7, 15.9

and 17.1 cm total length (TL) for horse mackerel, 10.4, 14.4 and 11.0 cm TL for hake and 3.2, 15.8 and 3.7 cm TL for greater forkbeard, respectively. For horse mackerel, the differences among the codends are statistically significant ( $P < 0.05$ ); however, the  $L_{sub(50)}$  values for all three meshes are higher than the minimum landing size (13 cm TL). For hake and greater forkbeard, the  $L_{sub(50)}$  value for the square mesh codend is significantly different from the values for diamond and hexagonal meshes ( $P < 0.01$ ), whereas there is no significant difference between diamond and hexagonal meshes ( $P > 0.05$ ). Regardless of the mesh shape,  $L_{sub(50)}$  values were substantially lower than the minimum landing size or size at first maturity for hake and greater forkbeard. To enable more effective solutions, research on species-selective trawls is required for the Mediterranean demersal trawl fishery.

53. Deval, MC; Boek, T; Ates, C; Ulutuerk, T; Tosunoglu, Z., 2009. Comparison of the size selectivity of diamond (PA) and square (PE) mesh codends for deepwater crustacean species in the Antalya Bay, eastern Mediterranean. *Journal of Applied Ichthyology [J. Appl. Ichthyol.]*. Vol. 25, no. 4, pp. 372-380. Aug 2009. The aim of this study was to compare selectivity results of currently used 44 mm nominal polyamide (PA) diamond mesh- and alternatively suggested 40 mm nominal polyethylene (PE) square mesh- codends in the deepwater crustacean trawl fishery in the Antalya Bay, eastern Mediterranean. Selectivity experiments were carried out during targeted trawling of four commonly harvested crustacean species: giant red shrimp *Aristeomorpha foliacea*, 'blue and red' shrimp *Aristeus antennatus*, rose shrimp *Parapenaeus longirostris*, and pandalid shrimp *Plesionika martia*. A conventional bottom trawl of 600 meshes around the fishing circle was operated onboard a commercial stern trawler between 6 and 18 June 2007. Depth of the fishing area varied between 441 and 630 m. Data were collected using the covered codend technique, and analyzed using a logistic equation with maximum likelihood for individual and pooled hauls. The commercially used trawl codend was unable to release immature crustaceans. Selectivity parameters of the three species of crustaceans were distinctly lower when collected with the polyamide diamond mesh than with the polyethylene square mesh, except in the case of giant red shrimp for which values were similar. However, the present and previous results show that in square mesh codends, mesh sizes must be more than 40 mm in order to keep catches clear of specimens below minimum landing sizes or 50% sexual maturity sizes of crustaceans in the Mediterranean. This study suggests that regulating mesh size by requiring square mesh openings during deep water crustacean trawling of the eastern Mediterranean is essential for the release of immature individuals.

54. Deval, MC; Boek, T; Tosunoglu, Z, 2009. Selectivity of diamond (PA) and square (PE) mesh codends for commercially important fish species in the Antalya Bay, eastern Mediterranean. *Journal of applied ichthyology/Zeitschrift fur angewandte Ichthyologie [J. Appl. Ichthyol./Z. Angew. Ichthyol.]*. Vol. 26, no. 3, pp. 465-471. 2009. Size selectivity of the 40 mm nominal polyethylene (PE) square mesh codend and the 44 mm nominal polyamide (PA) diamond mesh codend were

determined under commercial conditions in the demersal trawl fishery. Data were collected using the covered codend technique and analyzed by logistic equation with a maximum likelihood method. Changing the mesh from a 44 mm PA diamond to a 40 mm PE square increased the mean retention lengths ( $L_{50}$ s) of red mullet (*Mullus barbatus*), picarel (*Spicara maena*) and bogue (*Boops boops*) and decreased the selection ranges (SR) for common pandora (*Pagellus erythrinus*). For large-eye dentex (*Dentex macrophthalmus*) and axillary sea bream (*Pagellus acarne*) mean  $L_{50}$  and SR values were 9.6 and 11.8, and 2.4 and 2.4 cm, respectively, only in the DM44PA codend. For golden banded goatfish (*Upeneus moluccensis*) values for SM40PE were only 15.0 and 2.7 cm, respectively. Results showed that the 40 mm PE square mesh codend provided higher selectivity for most of the Mediterranean fishes. The results also showed that regulating mesh size and requiring square mesh openings during trawling is essential for the release of immature individuals. This practice will result in a reduction in overfishing and permit recovery of overfished stocks.

55. Kaykac, Hakan; Ozbilgin, Huseyin; Tokac, Adnan, 2009. Effects of Mesh Configuration on the Selectivity of Demersal Trawl Codends for *Nephrops norvegicus* (Linnaeus, 1758) (Decapoda, Nephropidae) Crustaceana [Crustaceana]. Vol. 82, no. 3, pp. 1569-1578. 2009. In the present study, we have compared the selectivity of a diamond mesh codend (40D), currently used by Turkish trawl fishermen, and a square mesh codend (40S), which is in the legislation for EU Mediterranean countries (EC 1967/2006). Trawling was carried out onboard the commercial trawler 'Niyazi Reis' in the international waters between Turkey and Greece, at depths ranging from 158 to 264 m, 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. *Nephrops norvegicus* escaped from the codends with retention ratios of 0.98 and 0.91 for 40D and 40S codends, respectively. The selection curves of the two codends are found to be significantly different ( $p < 0.01$ ). For combined sexes,  $L_{50}$  values of 16.03 (s.e. 0.41) and 19.38 mm (s.e. 0.51) were estimated in 40D and 40S codends, respectively. The results of this study clearly demonstrate that *N. norvegicus* took advantage of the increase in escape area provided by the change in mesh configuration from diamond to square.

56. Kaykac, Hakan; Tokac, Adnan Ozbilgin, Huseyin, 2009 Selectivity of commercial, larger mesh and square mesh trawl codends for deep water rose shrimp *Parapenaeus longirostris* (Lucas, 1846) in the Aegean Sea SCI. MAR., 73(3), September 2009, 597-604 We investigated the differences between size selectivity of a commercial codend (40 mm diamond mesh – 40D), a larger mesh codend (48 mm diamond mesh – 48D), and a square mesh codend (40 mm square mesh – 40S) for *Parapenaeus longirostris* in international waters of the Aegean Sea. Selectivity data were collected by using a covered codend method and analysed taking between-haul variation into account. The results indicate significant increases in  $L_{50}$  values in relation to an increase in mesh



size and when the square mesh is used in the commercial trawl codend. The results demonstrate that the commercially used codend (40D) is not selective enough for *P. longirostris* in terms of length at first maturity. Changing from a 40D to a 48D codend significantly improves selection, with an increase of about 15% in the L50 values (carapace length 14.5 mm for 40D and 16.6 mm for 48D). Similarly, 40 mm square mesh, which has recently been legislated for EU Mediterranean waters, showed a 3.4% higher mean L50 value (16.3 mm) than 40 mm diamond mesh for this species. However, despite these improvements, the 48D and 40S codends still need further improvements to obtain higher selectivity closer to the length at first maturity (20 mm carapace length).

57. Lök, A. Tokaç, Z. Tosunoglu, C. Metin and R. S. T. Ferro; 1997. The effects of different cod-end design on bottom trawl selectivity in Turkish fisheries of the Aegean Sea Fisheries Research Volume 32, Issue 2, 1 November 1997, Pages 149-156 The effect of different cod-end designs on bottom trawl selectivity was studied using the hooped cod-end cover method. The selectivities of three different cod-ends: standard, 15% shortened last-ridge rope and narrowed circumference (to 30 mesh from 150 mesh), were measured for red mullet (*Mullus barbatus* L., 1758) and annular sea bream (*Diplodus annularis* L., 1758) in Turkish territorial waters of the Aegean Sea in June and September 1994. Selection curves and selection parameters were calculated using a logistic model. 50% retention lengths and selection factors for red mullet were higher for the shortened lastridge rope case and narrow cod-end than the 1.

58. Lök A., Metin Cengiz, Tokaç Adnan, Özbilgin Hüseyin, Kaykaç Hakan, Ulas Ali, Metin Gülnur, Aydın İlker and Benal Gül. 2007. Size selectivity of diamond and square mesh codends for four commercial fish species in the eastern Aegean Sea. GFCM-ATSELMED, Barcelona, 2-4 April, 2007. Data on the comparison of the selectivity of diamond and square mesh codends is not sufficient when the geographical area and species varieties are concerned in the Mediterranean. Here we present the selectivity of diamond (DM) and square mesh codends (SM) for four marketable fish species in Izmir Bay, Eastern Aegean Sea. Trials were carried out aboard R/V Egesüf (27 m LOA, 463HP) between 18th and 29th July 2005 by using covered codend method. Both the codends were made of 44 mm nominal mesh size PE material. Selection parameters were obtained by fitting logistic equation using maximum likelihood method after stacking the data for each codend. Fifty percent retention lengths (L50) of diamond and square mesh codends, were found as 3.37 (se. 0.21) and 14.19 (se. 0.09) cm for red mullet (*Mullus barbatus*), 9.29 (se. 0.07) and 8.71 (se. 0.14) cm for annular sea bream (*Diplodus annularis*), 14.71 (se. 0.16) and 15.36 (se. 0.18) cm for picarel (*Spicara smaris*) and, 3.39 (se. 0.23) and 3.53 (se. 0.10) cm for common pandora (*Pagellus erythrinus*), respectively. It can be concluded that effect of using square mesh codends instead of diamond mesh may have positive, insignificant or negative influences on selection depending on the physical and behavioural characteristics of species. Therefore, before square mesh codends applied as a legislation, which may be the case in Turkish waters in very near future, a

special attention needs to be paid on the species composition of the fishing ground, and escape behaviour of common species in catch composition needs to be better understood.

59. Ozan Düzbastılar F., Altan Lök, Cengiz Metin, Hüseyin Özbilgin, Gülnur Metin, Ali Ulaş, Aytaç Özgül, Benal Gül, İlker Aydın, Adnan Tokaç. 2007. Survival rates of six fish species after escape from a trawl codend in the Aegean Sea in winter. GFCM-ATSELMED, Barcelona, 2-4 April, 2007. Survival rates of red mullet (*Mullus barbatus*), annular seabream (*Diplodus annularis*), common two banded seabream (*Diplodus vulgaris*), brown comber (*Serranus hepatus*), red bandfish (*Cepola macrophthalma*) and black goby (*Gobius niger*) were investigated after escaping from a commercial bottom-trawl codend in the Bay of Izmir, east coast of the Aegean Sea. The experiments were conducted between 29th January and 5th February 2007. A traditional bottom trawl with a 40 mm codend was used. A cover was attached over the codend to catch the escaping fish. At the end of each tow, the cover was detached from the codend and deployed at the observation site (17-26 m) by divers. Two controls and three experimental hauls were carried out. First control tow was terminated in 5 min, the other control and three test tows were carried out for 15 min. The cod-line was left untied in the case of the controls. Divers observed the cages three times per day over a 7-day period to remove dead fish and feed the survivors. Survival rates in 5 min tow control cage were higher than 15 min tow control cage for four species. There were not any *Gobius niger* and *Diplodus vulgaris* in 5 min tow control cage. Survival percentages in 5 min tow control cage, 15 min tow control cage, and average of three test cages were, respectively, 89.5, 44.6, and 49.2 for *Mullus barbatus*, 100, 96.6, and 98.9 for *Diplodus annularis*, not applicable, 100, and 100 for *Diplodus vulgaris*, 98.9, 98.3, and 98.5 for *Serranus hepatus*, 100, 90.4, and 97.4 for *Cepola macrophthalma* and finally, not applicable, 57.7, and 81.6 for *Gobus niger*. For the same gear and fishing ground, available data for *M. barbatus* in September 2001 indicates a significant decrease in survival rates from summer to winter with approximately 10 degree C decrease in water temperature. The study will be continued to investigate the seasonal differences in survival rates.

60. Ozbilgin Huseyin, ICES WGFTFB REPORT 2010 |103 Investigations to Improve Species and Size Selectivity in Mersin Bay (Northeast Mediterranean) Trawl Fisheries Mersin Bay is one of the most heavily trawled fishing grounds in the Northeast Mediterranean. According to 2006 data of Institute of State Statistics, number of the trawlers registered to ports of Mersin province (115) represents 15.9% of total number of trawl vessels registered in all Turkish ports (725). In recent years, reduction in catch per unit of effort and mean sizes of the landed products are among the most important problems experienced by fishers in the region. Poor selectivity and low engineering performance of the conventional trawl gears used in this fishery are some of the main reasons of the above mentioned problems. Significant amounts of benthos, rays, sharks, sea turtles, crab, juveniles of commercially important species such as red mullet, sole, and hake as well as litter are caught in trawling conducted in Mersin Bay. Exclusion of these components of the catch during

fishing operation will reduce the damage to marketable catch, sorting time of the crew on deck, and increase the performance of the gear. A nationally funded three year project starting in June 2010 will be conducted in four work packages: Determination of species and size groups which need to be excluded from the gear. This information will be obtained from the results of investigation of seasonal variation in catch and discard composition of the commercial trawl fleet. Observation of whether this species and size groups show different behavioural responses than target catch during trawling operation. Developing designs to improve selectivity (by using sorting grids and/or square mesh combinations), and adaptation of the most selective designs to trawl gear. Selective designs will be formed by evaluating the data from the first two work packages of the project, literature information, and opinion and criticisms by experienced fishers. Introduction of the selective design to the fleet. During the three year period 201 days of work at sea, and 40 days of seminars and workshops are planned. Development of a selective gear design and its acceptance by commercial fleet are the most important goals of the project. In the case of achievement of positive results in these targets, the project has a potential to be the first example for not only Turkish but for all Mediterranean trawl fisheries

61. Tokaç Adnan, Özbilgin Hüseyin, Hakan Kaykaç, 2007. - Selectivity of commercial and square mesh codends in the deep water trawl fishery in the Aegean Sea. GFCM-ATSELMED, Barcelona, 2-4 April, 2007. A switch from diamond to square mesh codends is considered as a potential measure to reduce the capture of immature fish in the Mediterranean demersal trawling. However, data on the comparison of the selectivity of diamond and square mesh codends is rather limited when the variety of the grounds and multi-species nature of the fisheries are concerned. This study presents the results of a selectivity study where commercially used diamond (DM) and square mesh codends (SM) tested for seven marketable species in the deep waters of the Aegean Sea under an EU funded project (NECESSITY). Both the codends were made of 40 mm nominal mesh size PE material. Experiments were conducted aboard commercial trawler Niyazi Reis (26.2 m LOA, 294KW) between 1st and 15th August 2005 by using covered codend method. Selection parameters were obtained by fitting logistic equation using maximum likelihood method after stacking the data for each codend. Fifty percent retention lengths (L50) of diamond and square mesh codends, respectively, were found as 16.03 (se. 0.41) and 19.38 (se. 0.51) mm for Norway lobster (*Nephrops norvegicus*), 14.46 (se. 0.14) and 16.24 (se. 0.14) mm for rose shrimp (*Parapenaeus longirostris*), 11.14 (se. 0.13) and 13.78 (se. 0.40) cm for hake (*Merluccius merluccius*), 17.11 (se. 0.27) and 19.79 (se. 1.00) cm for blue whiting (*Micromesistius poutosou*), 13.13 (se. 0.3) and 15.3 (se. 0.33) cm for greater forkbeard (*Phycis blennoides*), 8.45 (se. 0.18) and 9.66 (se. 0.35) cm for blackbelly rosefish (*Helicolenus dactylopterus dactylopterus*) and, 10.23 (se. 0.08) and 8.89 (se. 0.09) cm for fourspotted megrim (*Lepidorhombus boscii*). Results can be summarized as the presently used commercial codend is rather unselective. Square mesh codend improve the selectivity for two

crustacean and four fusiform fish species, however the L50 is significantly reduced for four spotted megrim, the only flatfish species. Therefore, before square mesh codends applied as a legislation, special attention needs to be paid on the species composition of the fishing ground.

62. Özbilgin H., Tosunoglu Z., Ayidin C., Kaikac H., Tokaç A. 2005. Selectivity of Standard, Narrow and Square Mesh Panel Trawl Codends for Hake (*Merluccius merluccius*) and Poor Cod (*Trisopterus minutus capellanus*). *Turk J Vet Anim Sci* 29: 967-973. (abstract missing).

63. Tokac Adnan, Z.Tosunoglu, C.Ayidin, H. Kaykaç, H.Özbiligin, 2008. A summary of size selectivity of diamond and square mesh codends for eight commercially important species in the Aegean Sea (GFCM-ATSELMED 3, Sète 2 – 4 July, 2008). Recent studies have shown that the selectivity of the 40 or 44 mm diamond mesh codends used commercially by Turkish bottom trawlers is rather poor. The study comprised two demersal trawl fisheries; one more shallow water fishery for fish and another deep water fishery where the dominant income was from deepwater shrimp. Four different codends were tested: 40 mm-, 44 mm- and 50 mm diamond mesh codends and 40 mm square mesh codend. The main findings were backed by state of the art statistical methodology and demonstrated a better selectivity for the majority of species in the 40 mm square mesh codend than in a 40 mm diamond mesh codend except for the four spotted megrim (a flatfish). The 50 mm diamond mesh codend gave the best selectivity for most species except for hake where the highest selectivity was found in the 40mm full square mesh codend. This might indicate a special issue for the Mediterranean and could be explained by the fact that the fish is so small that it does not have power to escape through a partly closed diamond mesh. The study also compared the new, modern and more efficient trawl design derived from the Atlantic demersal trawls with the standard Mediterranean trawl. Unfortunately, the new trawl design did not show a better selectivity with the same codends as tested for the old design. The shift to more modern and efficient trawls has been expected for many years and will most likely soon spread to the whole region.

64. Tokaç A., Özbilgin H., Tosunoğlu Z., 2004. Effect of PA and PE material on codend selectivity in Turkish bottom trawl. *Fisheries Research* 67: 317-327. This study investigates the differences in the selective properties of a 40mm nominal PE, 36 and 44mm nominal PA codends. The experiments were carried out in Izmir Bay in the Eastern Aegean Sea between 4 February 2002 and 22 March 2002. A conventional bottom trawl was operated onboard R/V Egesüf. Selectivity data were collected for red mullet (*Mullus barbatus*), annular sea bream (*Diplodus annularis*), picarel (*Spicara smaris*) and common pandora (*Pagellus erythrinus*) by using hooped covered codend method. Selectivity parameters were obtained by using logistic equation with the maximum likelihood method and by taking into account between-haul variation. Three codends were tested in a total of 25 hauls of which 18 were accepted valid for picarel and 23 valid for the other three species. In general, the PA material codends produced much higher L50 values than the PE codend.

However, the SRs of the three tested codends were very close to each other. L<sub>50</sub>'s of 40mm PE, 36mm PA and 44mm PA codends, respectively, were found as 8.8, 8.4 and 10.3 cm for annular sea bream; 10.8, 3.4 and 13.8 cm for common pandora. There were not enough red mullet and picarel retained in the 44mm PA codend to estimate the selectivity parameters. Due to insufficient amount of retained fish selection parameters of 44mm PA codend could not be obtained for red mullet and picarel. L<sub>50</sub>'s of PE 40mm and PA 36mm codends, respectively, were 10.7 and 3.8 cm for red mullet and 3.4 and 13.3 cm for picarel. It is thought that 40mm PE netting, which is commercially used, has rather poor selectivity. On the other hand, 44mm PA codend causes the loss of marketable fish. Amongst the three tested codends 36mm PA provides the most appropriate selection

65. Tokac, A; Ozbilgin, H; Kaykac, H., 2009. Selectivity of conventional and alternative codend design for five fish species in the Aegean Sea Journal of applied ichthyology/Zeitschrift für angewandte Ichthyologie [J. Appl. Ichthyol./Z. Angew. Ichthyol.]. Vol. 26, no. 3, pp. 403-409. 2009. Currently, traditional Mediterranean trawls are generally made with non-selective netting and the fishing boats are involved in multi-species fisheries. As a result, most near-shore stocks are over-exploited. Weather permitting, the demersal trawl fleet tends to fish in relatively deeper, international waters of the Aegean Sea, where the catch is usually higher. Therefore, the need for evaluation of the codends used in this fishery and the potential improvements to their selectivity are of prime importance. In the present study, selectivity data were collected for hake (*Merluccius merluccius*), blue whiting (*Micromesistius poutassou*), greater forkbeard (*Phycis blennoides*), blackbelly rosefish (*Helicolenus dactylopterus dactylopterus*) and four spotted megrim (*Lepidorhombus boschii*) in commercial (300 MC) and square mesh top panel (SMTPC) codends. Trawling was carried out at depths of 274-426 m onboard a commercial vessel chartered for a 15-day sea trial in August 2004. Selection parameters were obtained by fitting a logistic equation using a maximum likelihood method. Results of the selectivity analysis indicated that the commercially used 40 mm nominal mesh size PE codend was rather unselective for the species investigated in this study. In general, the square mesh top panel codend has relatively higher L<sub>sub(50)</sub> values than the commercial codend. However, except for blue whiting, even this codend is rather unselective when 50 % maturity lengths (L<sub>sub(M50)</sub>) are considered.

66. Tokaç A., Celalettin Aydın, Uğur Erdoğan 2010 Hexagonal and turned mesh (t90) codends selectivity for bottom-trawl nets in the Aegean Sea ,In this study, red mullet (*Mullus barbatus*), annular sea bream (*Diplodus annularis*), common pandora (*Pagellus erythrinus*), axillary sea bream (*Pagellus acarne*) and blotched picarels (*Spicara maena*) selectivity parameters were investigated with knot-less 44 mm hexagonal mesh codend (HMC), 40 mm 90° rotated knotless polyamide codend (PA T90) and 44 mm 90° rotated knotless polyethylene codend (PE T90). Experiments were carried out by RV "EGESÜF" between 05-3-2008 and 27-08-2009 with 900 meshes modified trawl net in around of Gülbahçe Bay and Hekim Island. A hooped covered codend

technique was used for estimating selectivity parameters. Individual and pooled data selectivity parameters were determined with CC2000, mean selectivity parameters were calculated with EC Modeller programmer. 3 with HMC, 10 with PA T90, 3 with PE T90 valid trials were carried out. For red mullet L50 values were estimated  $15.2 \pm 0.0$  cm,  $14.2 \pm 0.0$  cm and  $13.6 \pm 0.2$  cm in HMC, PA T90 and PE T90, respectively. For annular sea bream L50 values were determined as  $10.6 \pm 0.0$  cm,  $9.8 \pm 0.0$  cm and  $9.5 \pm 0.6$  cm in HMC, PA T90 and PE T90, respectively. For common pandora L50 values were calculated  $13.6 \pm 0.2$  cm,  $13.0 \pm 0.1$  cm and  $10.9 \pm 0.6$  cm in HMC, PA T90 and PE T90, respectively. For auxiliary sea bream L50 values were estimated at  $14.3 \pm 0.3$  cm,  $14.0 \pm 0.1$  cm and  $13.3 \pm 0.2$  cm in AGT. PA T90 and PE T90, respectively. For blotched picarel L50 values are determined as  $17.0 \pm 0.6$  cm,  $16.4 \pm 0.6$  cm and  $14.3 \pm 0.1$  cm in HMC, PA T90 and PE T90, respectively. As a result, a lot of fish which have different morphological characters can be caught in Eastern Mediterranean demersal trawl fishery. A mesh size and type appropriate for one species will ICES WGFTFB REPORT 2010 | 33 be unsuitable for many others. Therefore, in addition to size selectivity, species selectivity and fish behaviour studies need to be investigated.

67. Tokac, A; Oezbilgin, H; Kaykac, H., 2010. Selectivity of conventional and alternative codend design for five fish species in the Aegean Sea Journal of Applied Ichthyology [J. Appl. Ichthyol.]. Vol. 26, no. 3, pp. 403-409. Jun 2010. Currently, traditional Mediterranean trawls are generally made with non-selective netting and the fishing boats are involved in multi-species fisheries. As a result, most near-shore stocks are over-exploited. Weather permitting, the demersal trawl fleet tends to fish in relatively deeper, international waters of the Aegean Sea, where the catch is usually higher. Therefore, the need for evaluation of the codends used in this fishery and the potential improvements to their selectivity are of prime importance. In the present study, selectivity data were collected for hake (*Merluccius merluccius*), blue whiting (*Micromesistius poutassou*), greater forkbeard (*Phycis blennoides*), blackbelly rosefish (*Helicolenus dactylopterus dactylopterus*) and four spotted megrim (*Lepidorhombus boscii*) in commercial (300 MC) and square mesh top panel (SMTPC) codends. Trawling was carried out at depths of 274-426 m onboard a commercial vessel chartered for a 15-day sea trial in August 2004. Selection parameters were obtained by fitting a logistic equation using a maximum likelihood method. Results of the selectivity analysis indicated that the commercially used 40 mm nominal mesh size PE codend was rather unselective for the species investigated in this study. In general, the square mesh top panel codend has relatively higher L50 values than the commercial codend. However, except for blue whiting, even this codend is rather unselective when 50% maturity lengths (LM50) are considered.

68. Tosunoglu Zafer & Aydin Celalettin, 2007. - Trawl codend mesh selectivity of 50 mm braided PE material for commercially important species in the Aegean Sea. GFCM-ATSELMED, Barcelona, 2-4 April, 2007. The aim of this study is to estimate the selectivity of 50 mm diamond mesh (braided PE) codend for commercially important species, deep-water rose shrimp

(*Parapenaeus longirostris*), hake (*Merluccius merluccius*), horse mackerel (*Trachurus trachurus*), anglerfish (*Lophius piscatorius*) and John Dory (*Zeus faber*) in the Aegean Sea. Fishing trials were carried out on commercial trawler 'Hapuloğlu' between 9 and 3 November 2006. Data were collected by a knotless PE (Raschel) codend of the 300 mesh trawl net which is used commercially by the fishermen. The mean mesh size of the codend meshes (nominal 46 mm) was measured near to 50 mm by a digital calliper. Selectivity data were collected by the covered codend method and analysed by means of a logistic equation with the Maximum Likelihood Method. The mean selectivity curves were estimated from the individual hauls was fitted taking into account the between haul variation. The 50% retention length and selection range of rose shrimp were estimated as 19.6 and 6.2 mm carapace length, respectively. These values were also estimated 11.4 cm and 4.1 cm for hake and 15.6 and 5.5 cm for horse mackerel. The alternative (of European Community) 50 mm diamond mesh size of braided PE for Mediterranean showed relatively better selectivity considered to the MLS of the horse mackerel and the first maturity size of the rose shrimp, whereas it shows substantially low selectivity for hake regarding MLS and no selectivity for anglerfish and John Dory. These results showed that dimension of the body shape and behaviour of the fish species play an important role in size selectivity and it is difficult to manage multi-species fisheries based simply on mesh size regulation. For this reason, codend designs (made of this material) such as narrow codend and square mesh ensure better mesh opening in relation to fish body shape during trawling must be investigated immediately.

69. Tosunoglu, Z; Aydin, C; Oezaydin, O., 2008. Selectivity of a 50-mm diamond mesh knotless polyethylene codend for commercially important fish species in the Aegean Sea Journal of Applied Ichthyology [J. Appl. Ichthyol.]. Vol. 24, no. 3, pp. 311-315. Jun 2008. This research investigated effects of changing the diamond mesh size on codend selectivity in Mediterranean fisheries. The selectivity of a typical 50-mm diamond knotless polyethylene (PE) codend used in the Turkish fishery in the Aegean Sea was measured for commercially important species, in particular hake (*Merluccius merluccius*), horse mackerel (*Trachurus trachurus*), anglerfish (*Lophius piscatorius*) and John Dory (*Zeus faber*). Fishing trials were carried out on the commercial trawler 'Hapuloğlu' between 9 and 3 December 2006 using a modified trawl net. Selectivity data were collected by the covered codend method and analysed by means of a logistic equation (Maximum Likelihood Method). The mean selectivity curve was estimated from individual hauls, taking between-haul variations into account. Mean mesh size of the codend was 49.4mm as measured by digital calliper. Mean values for 50% retention length of hake and horse mackerel were estimated to be 11.4 and 15.6cm total length; corresponding selection ranges were 4.1 and 5.5cm respectively. The 50-mm diamond mesh codend showed adequate selectivity compared to the minimum landing size (MLS) for horse mackerel, while for hake it selected specimens in a size range far lower than the MLS. No selectivity values could be determined for anglerfish or John Dory. To design a more selective

codend for the Turkish demersal trawl fishery, not only mesh size regulations but also other codend characteristics and netting material properties must be urgently considered.

70. Tosunoglu, Z; Aydin, C; Salman, A; Fonseca, P., 2009. Selectivity of diamond, hexagonal and square mesh codends for three commercial cephalopods in the Mediterranean Fisheries Research (Amsterdam) [Fish. Res.]. Vol. 97, no. 1-2, pp. 95-102. Apr 2009. Undersized and immature commercially important cephalopods are often inadvertently caught by trawlers in the eastern Mediterranean. To evaluate the effectiveness of different mesh codends (diamond, hexagonal and square) to reduce bycatch of juvenile commercially important Mediterranean cephalopods (European squid *Loligo vulgaris*, broadtail shortfin squid *Illex coindetii* and pink cuttlefish *Sepia orbignyana*), a series of selectivity experiments was undertaken with a modified bottom trawl. The covered codend technique was used to capture escapees. For the broadtail shortfin squid and the pink cuttlefish, the square-shaped mesh displayed the highest 50% retention lengths ( $L_{50}$ ) compared to diamond and hexagonal mesh. For the European squid, selectivity could only be measured by pooling the data from all hauls for each mesh shape. For all three species, the  $L_{50}$  values of square and hexagonal mesh codends were significantly different ( $p < 0.01$ ). Beyond the mesh variability, species catch was found to have a significant impact in the selection range of the broadtail shortfin squid. Furthermore, for the cuttlefish, total catch and haul duration likely account for variability of  $L_{50}$  attributed to mesh configuration. For all species, regardless of the mesh shape,  $L_{50}$  values were substantially lower than the minimum landing size or length at first maturity. Therefore, the current legal minimum mesh size and codend configurations for demersal trawling are not suitable for the management of these species. As such, sustainability in Mediterranean cephalopod fisheries would profit from more selective gears. This could be achieved both by an increase in codend mesh size and change in codend shape; however, being part of a mixed fishery, when these changes are being practiced, the impact on the fish catches of target species will have to be taken into consideration.

71. Zengin, M., Z. Tosunoğlu, 2006. Selectivity of diamond and square mesh beam trawl cod ends for *Parapenaeus longirostris* (Lucas, 1846) (Decapoda, Penaeidae) in the Sea of Marmara. *Crustaceana*, 79, 9, 1049-1057. In this study, the effects of an increase in diamond mesh size from 24 to 28 and 32 mm, and changing mesh shape from diamond to square mesh on size selectivity for the deep-water rose shrimp, *P. longirostris* were investigated. Fishing trials were carried out on commercial beam trawlers in the various fishing areas of the Sea of Marmara in two periods, between 28 August and 8 September 2001, and 29 April and 9 May 2002. Data were collected by twin trawl and analysed by means of a logistic equation with the Maximum Likelihood Method of the SELECT model. The 50% retention length ( $L_{50}$ ) of *P. longirostris* increased consistently with diamond mesh sizes from 24 to 28 and 32 mm, and 28 mm square mesh gave a higher  $L_{50}$  value than diamond at the same mesh size. The 32 mm diamond mesh size showed relatively better



selectivity ( $L_{50} = 104.1$  mm) than the other cod ends, agreeing better with the Length at First Maturity (LFM) of 97 mm total length. The use of cod ends of 24 and 28 mm mesh size should be avoided in order to avoid a catch consisting mainly of small individuals. Such an increase in mesh size on beam trawl nets would contribute to reducing the amount of undersized *P. longirostris* in this fishery.

## Statistical method

### SUMMARY OF STATISTICAL METHODS FOR TOWED GEAR SELECTIVITY ANALYSIS

by Rene Holst

#### BACKGROUND

The experimental discipline of gear selectivity research has a long tradition that can be traced back hundreds of years.

This note aims at giving a short review of central aspects of size selectivity analysis of data from experiments with towed fishing gears. It is thus not intended as a technical introduction to the analysis. More detailed descriptions can be found elsewhere in the literature.

#### SINGLE HAUL ANALYSES

Experiments with towed can be conducted by different methods. The most commonly used are covered cod-end and paired gear techniques. These are characterized by collecting fish in two compartments one of which is assumed virtually non-selective. The purpose of the non-selective compartment is to collect information about the local abundance of fish that entered the combined gear. With the appearance of more complicated gear with multiple selective devices (e.g. grids or panels) the experimental gears have also developed into more complex designs.

The most important advancement in the analysis of single hauls was done by Millar in 1992, when he developed the SELECT method. The method is very general and covers not only all types of size selectivity experiments with towed gears but also experiments with passive gears, i.e. hooks, set-nets etc.

A fundamental proposition in size selectivity work was formulated by Baranov (1948) and has become known as the "principle of geometrical similarity". It states that the selectivity/retention of fish depends only on the geometry of the fish relative to the geometry of the mesh. This clearly relates to the morphology and circumference of the fish. In practice it is however much more easy to measure length rather than circumference and this is justified by well established strong correlation between the two measures. In effect size selectivity is therefore equivalent with length selectivity.

For illustration we will briefly describe the estimation of selectivity parameters from data obtained in a covered cod-end haul:

Let  $y_l$  denote the number of length  $l$  fish retained in the cod-end. The total number of length  $l$  fish retained in the cod-end or in the cover is denoted  $n_l$ . The probability that a length  $l$  fish is retained by the cod-end can be denoted  $\pi_l$  and each length-class constitutes a binomial experiment:

$$y_l \sim bi(n_l; \pi_l)$$

The selectivity can thus described by the parameters  $\pi_{l1}, \pi_{l2}, \dots, \pi_{lL}$ . It is however more convenient to look for a parametric function  $r(l; \theta)$  that can summarize the selectivities over all length classes. There are several (sigmoid shaped) candidates to choose among. The most commonly used is the inverse logistic curve:

$$r(l; \alpha, \beta) = \frac{\exp(\alpha + \beta \cdot l)}{1 + \exp(\alpha + \beta \cdot l)}$$

The objective is now "reduced" to estimate two parameters  $\alpha$  and  $\beta$ . This is achieved by maximizing the log-likelihood function (except for a constant):

A similar expression can be derived for the log-likelihood function for data obtained from paired gear experiments.

When the catches are big it may be impossible or impractical to measure all fish from the catches. In such cases the estimation of selectivity parameters may be based on a sub-sample of the catch. The analysis can account for the sub-sampling either by *raising* the data or by treating the sub-sampling ratios as effort parameters. Technical details can be found in Millar (1994). Here we will restrain the issue to say that raising the data causes over-dispersion and thus underestimation of the variance. It should therefore be avoided.

### **MULTIPLE HAUL ANALYSIS/AGGREGATION OF HAULS**

Experiments with fishing gear typically consists of a number of hauls. Fryer (1991) demonstrated that the practice of pooling data from several hauls could lead to erroneous inference, due to underestimation of the variance. He furthermore devised a model that accommodated the variability between hauls and a method for estimating it.

The core principle of the model is presented here:

Following standard maximum likelihood theory the estimates obtained from haul  $h$  can be assumed to be asymptotically normally distributed, provided certain mild conditions are met:

$$\hat{v}_h \sim N_2(v_h; R_h)$$

If we assume that the (unobserved) parameters vary around a common mean according to a normal distribution with mean  $v$  and variance  $D$ :

$$v_h \sim N_2(v; D)$$

these two results combines to

$$\hat{v}_h \sim N_2(v; R_h + D)$$

In other words: the estimates obtained from the  $h$ 'th haul is regarded as an observation from a bivariate normal distribution, where part of the variance  $R_h$  relates to the within-haul variance (i.e. the number of fish caught within the haul) and another part of the variance  $D$ , stems from the between haul variance.

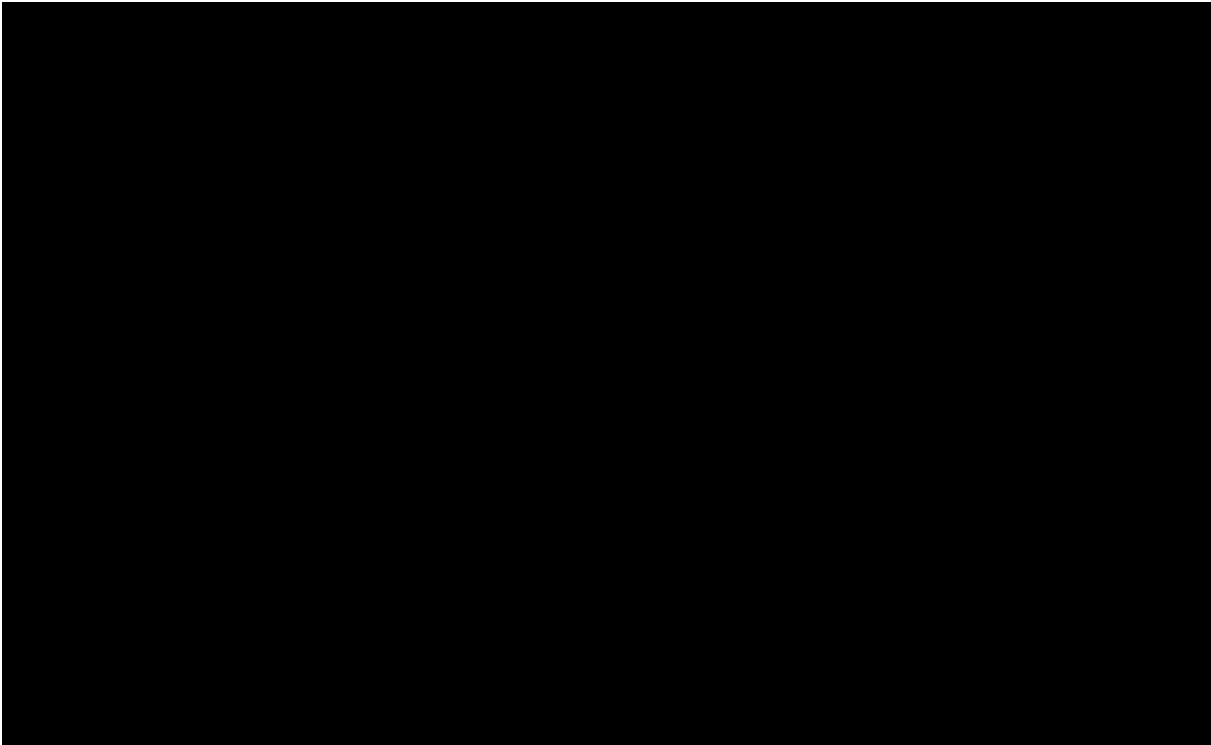
Fryer gives a detailed description of how the estimation can be implemented.

### **CONCLUSIONS**

This note has presented models for estimating selectivity at the level of individual hauls as well as at experiment level. The presentation aimed at presenting important landmarks and is not intended to describe technical details. These can be found in numerous articles and in particular key papers are listed below. The models have their strengths by being rigorous statistical models that aim to reflect the underlying mechanisms by which the data have been collected and by making use of classical statistical theory, that allows for proper inference. Furthermore they are very flexible and general and their use extends far beyond the applications described here. These works will therefore naturally serve as an offset for the development of statistical models for gear selectivity analysis in the Mediterranean context, with appropriate adaptations.

(from R. Holst –GFCM-ATSELMED 1 workshop, Sète 9 – 11 February, 2005)

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