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PROTOCOLS FOR A MEDITERRANEAN PILOT SELECTIVITY TRAWL SURVEY

Experimental application for the implementation of
the 40 mm square mesh size GFCM Resolution to the
trawl fleet in the Mediterranean Sea

J. Baro & J. Sacchi



**CopeMed II – ArtFiMed Technical Documents N°9
(GCP/INT/028/SPA – GCP/INT/006/EC)**

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**Protocols for a Mediterranean Pilot Selectivity Trawl Survey
(Experimental application for the implementation of the 40 mm
square mesh size GFCM Resolution)**

Jorge Baro & Jacques Sacchi

June 2009

The conclusions and recommendations given in this document and in other documents in the *Co-ordination to Support Fisheries Management in the Western and Central Mediterranean CopeMed II* Project series are those considered appropriate at the time of preparation. They may be modified in the light of further knowledge gained in subsequent stages of the Project. The designation employed and the presentation of material in this publication do not imply the expression of any opinion on the part of FAO, the Government of Spain or the Commission of the EU concerning the legal status of any country, territory, city or area, or concerning the determination of its frontiers or boundaries. This document has been financed by the European Union and Spain. The views expressed herein can in no way be taken to reflect the official opinion of the European Union or Spain.

Preface

The CopeMed II Project on *Co-ordination to Support Fisheries Management in the Western and Central Mediterranean* is executed by the Food and Agriculture Organization of the United Nations (FAO) and funded by The Kingdom of Spain, represented by the Secretaría del Mar, and the European Community, represented by the Commission of the European Communities (EC).

The objective of the project is to maintain the sustainability of the marine fisheries in the central and western Mediterranean Sea and its ecosystem, taking into consideration environmental, biological, economic, social and institutional issues. In addition, the project will continue to reinforce the collaboration between the participating countries of the sub-region by supporting their participation in the activities of the Scientific Advisory Committees (SAC) of the General Fisheries Commission for the Mediterranean (GFCM).

Regions covered by CopeMed II are the western and central sub-regions of the Mediterranean. Countries involved are Algeria, France, Italy, Libya, Malta, Morocco, Tunisia and Spain. The main beneficiaries are the fishery policy-makers, managers and fishery administrations in the western and central Mediterranean countries. The project is also contributing to strengthening regional collaboration by supporting the participation of the countries in relevant regional scientific organizations, such as the FAO General Fisheries Commission for the Mediterranean (GFCM) and the International Commission for the Conservation of Atlantic Tunas (ICCAT). Secondary beneficiaries include the national research institutes, fishers and fishers' associations, and industrial organizations.

Proyecto CopeMed II (FAO-FIRF)
Subdelegación del Gobierno en Málaga
Paseo de Sancha 64, Oficinas 305-307
29071 Málaga
España

Tel: (+34) 952 989299

Fax: (+34) 952 989252

e-mail: artfimed@fao.org

URL: <http://www.faoartfimed.org>

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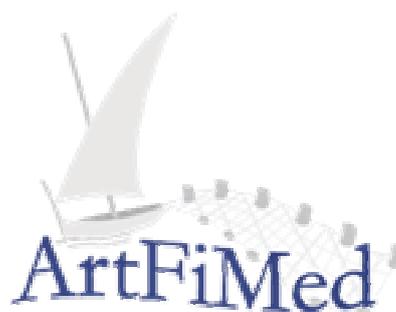
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Comments on this document would be welcomed and should be sent to the Project headquarters:

Proyecto CopeMed II
Subdelegación del Gobierno en Málaga
Paseo de Sancha 64, Oficinas 305-307
29071 Málaga (España)
copemed@fao.org

Proyecto ArtFiMed
Subdelegación del Gobierno en Málaga
Paseo de Sancha 64, Oficinas 305-307
29071 Málaga (España)
artfimed@fao.org



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Preparation of this document

This is the final version of the document “Protocols for a Mediterranean pilot selectivity trawl survey”. The first version was prepared by CopeMed II to be discussed during a workshop held in Malaga (Spain) during the 10 and 11 September 2009 an originally written by Jorge Baro and Jacques Sacchi two independent consultants who attended the project request and preparing two independent documents.

The document prepared by CopeMed II was discusses, improving the previous version by incorporating essentials information and ideas by the participants from Morocco, Algeria, Tunisia and Libya, the consultants and the CopeMed II staff during the workshop held in Malaga. After the meeting the CopeMed II staff finished and edited the document.

Acknowledgements

CopeMed II wish to thanks the experts Jacques Sacchi and Jorge Baro for their contribution to the final documents and also for their involvement in this CopeMed II activity, including the preparation of the workshop carried out in Malaga and their profitable discussions and thoughts during the meeting and later. We wish also thanks the Moroccan experts from the Mediterranean centres and from Casablanca HQ and specially to the INRH Director General at this time Mr. Abdelatif Berraho for their interest in preparing a proposal on the implementation of the 40 mm square mesh size in Morocco because the document presented by the INRH experts to the SAC Subcommittees was the origin of the GFCM request and the CopeMed II contribution.

CopeMed II wish also thanks all the experts involved in the Malaga workshop for their valuable contributions during and after the meeting because this final document is due to all of them.

J. Baro & J. Sacchi. 2009. Protocols for a Mediterranean pilot selectivity trawl survey. (Experimental application for the implementation of the 40 mm square mesh size GFCM Resolution). CopeMed II – ArtFiMed Technical Documents N° 9 (GCP/INT/028/SPA - GCP/INT/006/EC). Malaga, 2009. 12pp.

ABSTRACT

Considering the need to improve the trawl selectivity for a sustainable exploitation of Mediterranean fisheries and the results of selectivity studies carried out by some Mediterranean research teams 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. During the 33rd session the GFC adopted the Recommendation GFCM/33/2009/2 on a minimum 40-mm mesh size in the codend of demersal trawl nets by 31 January 2012. CopeMed II compromised with the GFCM to study the biological and socio-economic effects of such measure in the sub region and to organise a meeting of experts in Malaga (Spain) to analyse the implementation of such measure in a specific port, Nador (Morocco), and a particular fleet, the trawler, in order to elaborate methodologies that could be useful for the other Mediterranean countries. This document summarise the proposal of the experts corresponding to the objectives of such experimental selectivity trawl survey, the methodology and the on-board protocols, the data analysis, the milestone and responsible to implement each of the defined four phases of the pilot survey and a tentative budget that should be considered when the fisheries administrations and the research institutions must to decided this model of survey.

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1. 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 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, three 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, noting that studies were already planned in some countries such as Morocco and Tunisia”. The SCESS proposed to SAC for the next annual period “to develop directed studies on the socio-economic impacts of implementing the 40 mm square mesh size in trawl fisheries”.

To know the effects of the implementation of the GFCM Resolution, CopeMed II agreed during the 11th SAC session in supporting a pilot survey to evaluate the implementation of the 40 mm codend. According the discussion during the SAC and the Moroccan proposal the pilot study should be carried out in this country supported by CopeMed II and with the INRH participation (in terms of experts, material and fees) to carry out the compromise with the GFCM. That pilot survey should be considered an opportunity for the others CopeMed II countries lo learn on the pilot experience. CopeMed II should participate in this accomplishment as part of a subregional action to implement the GFCM Resolution and, by agreement of the Project’ Coordination Committee (Tangier, Morocco, 18-19 June 2009) considered and adopted support the participation of experts from the other countries.

During the 33rd session (Tunis, 23-27 March 2009) the GFCM adopted the Recommendation GFCM/33/2009/2 on a minimum 40-mm mesh size in the codend of demersal trawl nets to be implemented by 31 January 2012.

To have the necessary information for the pilot action new discussions were opened with international experts during the GFCM 33rd sessions resulting in the agreement for the preparation of a technical document to help the pilot survey implementation. Two documents financed by CopeMed II were prepared during the first 2009 quarter: i) by Mr. Jacques Sacchi (Ifremer, France) on *Experimental application of the 40 mm square mesh size to the Nador trawl fleet* and ii) by Mr. Jorge Baro (IEO, Spain) who prepared other document on *Protocols for a pilot selectivity trawl survey in Morocco*.

The present technical document is the result of a joint effort to combine the two aforementioned expert's documents with inputs from CopeMed II and from experts from Morocco, Tunisia, Libya and Algeria met in Malaga during a specific workshop. The objectives of this document are:

- a) To generate a joint agreed protocol on trawling gear selectivity survey for the Mediterranean CopeMed II countries.
- b) To standardize the methodologies to evaluate the biological and economical effects of the 40 mm mesh implementation, to be used in the different countries of the Mediterranean CopeMed II sub region.
- c) To prepare a practical tool to carry out standard methodologies and protocols for the analysis of the biological and socio economic effects in the CopeMed countries of the implementation of the GFCM/31/2007/3 Resolution.

The document includes all relevant phases from the project formulation, gear survey, trial protocol, indicative budget as well as technical support needs for different phases of the Project. The following aspects compose it:

- Theoretical background for the experimental survey implementation.
- Identification and technical characteristics of main trawl used. Definition of a standard commercial vessel for the experiment.
- Identification of the main objectives.
- Experts needs (expertises and observers; number of men/days).
- Economical analysis needs for the experiment results. Preliminary analysis.
- Budget for the proposed actions and material.
- Identification of the working area and depth strata.
- Equipment and necessary materials for the 40 mm experiment.
- Experimental design of the survey. Sampling by type of mesh (diamond, square) and strata.
- Definition of the work to be done. On board protocol.
- Analysis of the data and contents of the results report.

2. Bottom trawl Mediterranean fisheries. Preamble.

The Mediterranean is a semi-enclosed sea with narrow continental shelves. Its fisheries are a very important source of employment and income in many regions. The fisheries are very diverse, both in terms of the species caught and the fishing methods and gears used. Fishing is for the most part confined to coastal and shelf waters and, because the shelf is narrow, many fisheries take place in waters under the jurisdiction of coastal states (Anonymous, 2001).

The bottom trawl Mediterranean fisheries are characterized by the multi-specificity of their catches and by exercising a high fishing pressure on the younger age groups for most of the

species and, in many cases, on immature (Oliver, 1991). This strategy implies that a high percentage of catches of species has low or no commercial value and specimens of the target species captured below the legal minimum size, which causes totally inadequate mortality in natural populations. These fisheries, which no use of selective capture methods involves the removal from the sea of many non-target species returned to sea as unwanted, have very high discard rates (Carbonell, 1997, Abad and Baro, 2001).

The introduction of regulatory systems to avoid the capture of these non wanted species and / or undersized specimens, thus becomes a management tool more optimized to the reality of the fisheries and an effective measure to reduce the negative impacts of fishing in traditionally exploited populations as in the accompanying species. One of the technical measures of possible use to reduce the unwanted impact of the trawl gears is the introduction of 40 mm square mesh in the trawlers gear codend, which is not deformed due to the traction of art, to substitute the traditional rhombic grid mesh in the codend.

3. Objectives of a pilot study

The objectives of a pilot study on the “Experimental application of the 40 mm square mesh size t” are:

- To carry out a pilot survey to analyse the biological effects of selectivity and the implementation of a 40 mm square codend mesh size to a specific fleet of trawl vessels and on their catches.
- Establish the suitability of the mesh size by evaluating the yields of the main target species of bottom trawling on their traditional fishing grounds using a 40 mm codend with the traditional mesh (rhombic) and a codend of 40 mm with a square mesh (experimental).
- Obtain the parameters of selectivity (selection ranges and length at first capture) for the target species and those types of mesh.
- To determine the fraction of discarded catch using each mesh type, with particular emphasis on commercial species discards.
- Conduct an economic assessment of the effects of changing mesh size and type.
- To compare these experimental results with the obtained by the most common trawl gear used by the selected fleet, in terms of by-catch of unwanted species and juveniles and discards.
- To train experts from CopeMed II countries in appropriate methodologies.
- Draw lessons for application in other the GFCM countries

4. Methodology

The implementation of the 40 mm square mesh size to the Western and Central Mediterranean basic trawls cannot be studied without taking into account of the very traditional aspect of the majority of these national trawls gears and especially of the in general codend mesh size lower than 40 mm. The generalization of this recommendation to the whole Mediterranean fleet requiring of important modifications of the nets design with important effects on the economy of

the fisheries concerned. Consequently we proposed a more simple and a pragmatic approach based on 4 phases:

1. Characterization the main trawl fishery in the area.
2. Evaluation of the selectivity of a 40 mm square mesh codend (*sensu-stricto*) applied to a traditional trawl.
3. Comparison between the efficiencies of traditional trawl and 40mm square experimental trawl.
4. Data Analysis.

4.1 Biological and Economical Analysis Characterizing the main trawl fishery

It will be important to focus this study on the national trawl fishery that has the biggest socio-economical and biological impact in terms of:

- number of vessels,
- value of landings,
- amount and values of by-catch and discards, etc.

The fleet should be identified during this phase.

This main trawl fishery identified, information on technical characteristics must be collected (if doesn't exist) to provide on one hand a detailed and typical description of gear (standardized drawings) and the metier and a seasonal pattern of their landing in terms of weight and value.

This phase will required:

- The consultation of existing literature and available information on the selected fisheries.
- Surveys in the main landing ports and interview of several skipper and netmakers (this information normally should be in the fishery research institute of the area).

4.2 Selectivity study of a 40 mm square mesh codend applied to a traditional trawl

The objective of this phase will be to evaluate the selectivity of a bottom trawl codend (*sensu-stricto*) of the 40 mm square mesh size applied to a national traditional trawl, by supposing that there is no effect of the meshes of the former parts on this selectivity, due to their small size. This first stage will require the use of the technique of the *covered codend method* (Pope et al., 1983).

4.3 Efficiency of a 40 mm square experimental trawl

The objective of this phase will be to evaluate the bio – economical advantages or losses of the use of a trawl of 40 mm square mesh size codend.

This second stage will consist in comparing by the *alternated hauls method*, the catches of a traditional national trawl with those of an experimental trawl of the same geometry with at least

40 mm of opening diamond mesh size for any part of the trawl and 40 mm square mesh size codend.

Each trawl should be set in the same fishing conditions of haul time (i.e. 3 hours) and towed speed (i.e. three knots) used by the national commercial vessels for the metier selected. For each pair of hauls, the catches between the two trawls will be compared into terms of species, weight, length and economical values. Taking account the need to proceed by pair of hauls (one for the traditional trawl, the other for the experimental trawl), a minimum of two hauls (one pair) should be achieved for each day trip and four hauls (two pairs) within an optimal pattern reducing a little the hauls duration.

4.4 Data Analysis

4.4.1 Selectivity analysis

The collected data will be analysed by comparison of number of individuals for each size classes and for the main species between the covered codend and the whole catches. Exploratory analysis, L_{50} , selectivity intervals (L_{25} to L_{75}) will be done for each haul and for the main species, using the SELECT method.

To obtain the parameters, the corresponding data will be combined to the different sets for each type of mesh in the cod end (Cf Appendix).

For each set, it will be developed the frequency distribution of target species sizes, which means those with greatest commercial importance in trawl fisheries fishing where it has been operated.

Other results to be obtained will be relative to:

- Overall index of abundance and type of codend (weight and number) for the target species.
- Frequency lengths distribution of the population of the target species in the codend and covered-codend fractions.

4.4.2 Efficiency Analysis

The collected data (weight and size) will be compared for each pair of hauls and between each size classes for the main species.

The analysis will be done by the mean of classical exploratory statistical tools for observed differences between species composition and size composition for each main species and for each configuration (stratum and season).

The difference between weight for each species and each size classes will be evaluated.

4.4.3 Biology analysis

The catch comparison between traditional trawl and square mesh trawl should help to provide the benefit in terms of biomass for the main species at mean and long terms. This benefit should be estimated by the means of statistical models standardized and currently used in GFCM working group.

4.4.4 Economy analysis

It is recommended the application of the framework defined by the Atselmed group (SAC SCMEE) including the socio-economic aspects. The socio-economical sustainability of the selected trawl fishery needing to minimize the transitional cost in term of employment and input, the different costs of the gear shift should be evaluated:

- direct losses in sales,
- direct effects on prices,
- direct effects on variable costs (fuel and others),
- direct effects on gear costs,
- direct effects on benefits and turnover,

This analysis could be done using:

- the collection of data for a sample of trawlers (employment, capital, economical situation)

If the mean term effects are required, this analysis should be completed by a bio-economical analysis with the aim to simulate the behaviour of the fishers and the resource that obviously will need:

- the knowledge of the biomass situation for the species concerned by the implementation of the 40 mm square mesh codend (MSY level, recovering time, etc.),
- the development of a standardised methodology analysis taking account of different biological and economical indicators.

5. Report of results

Economic Analysis (effects on sales, costs and benefits).

The results report of the pilot survey should have the following structure:

1. Introduction.
2. General Considerations.
3. Methodology.
4. Data collected: Vessel data; Trawl data; codend data; cover codend data.
5. Haul data: Sampling catches; catch data.
6. Analysis of the data and selectivity parameter obtained.
7. Conclusions and recommendations.
8. References.

6. Reports and documents

An **Interim report** will be prepared after each phase as follow:

- **Phase 1, Description of the National trawl fisheries:** the report will provide a general presentation of the national Mediterranean trawl fisheries justifying the choice of the selected metier to be studied from the survey in the different fishing harbour and interviews of fishermen and netmakers. Technical description of this metier as well as information on landings and economical importance should be provided in particular.
- **Phase 2, Description of the selectivity experimentation:** the report will provide the description of the different gears to compare and general information on the technological characteristics of the hired vessel. Each experimental haul will be described providing haul duration, depth, and gear and rigging used; raw data will be provided in annex, including biological and technical ones.
- **Phase 3, Data Analysis:** each analysis will be described with their results giving in annex the statistics data.
- **Phase 4, The final report:** the final report will summarize the main results and will give the conclusion of the study in terms of benefit and possible improvement of the implementation of the square mesh codend and/or general selectivity.

7. Budget for the proposed actions and material

To facilitate the comprehension and the approximate budget needed for the implementation of a pilot survey on the implementation of the 40 mm square mesh size in each country, the budget prepared by CopeMed II for the meeting of experts is included here for information.

CopeMed II, implémentation 40 mm au Maroc. Budget Tentative en Euros

Phase 1: Elaboration de documents, réunion préparatoire et préparation de la campagne			
Activité	Actions	Partial (€)	Total (€)
Rédaction des Documents	<i>Consultants (contrat+voyage+DSA)</i>	2.401,7	
Réunion Málaga (10-11 Sep 2009)	<i>Voyage Participants (1 Maroc, 1 Tunisie, 1 Algérie)</i>	1.356,86	
	<i>DSA participants</i>	1.929,24	
Préparation du campagne à la mer et Formation (2 jours)	<i>Voyages internationaux à Nador (2 consultants et 1 expert Algérien)</i>	1.400	
	<i>DSA consultants et expert Algérien</i>	641,7	
	<i>Voyages nationaux Tanger- Nador (2 experts)</i>	1.065,64	
	<i>DSA 2 Marocains</i>	427,8	
	<i>Autre coûts</i>	500	
Total Phase 1			9.722,94

Phase 2: Campagne expérimentale de sélectivité à Nador		
Campagne Personnelle	<i>Consultants 2 x 5 jours</i>	2.400
	<i>DSA (consultants) 5 jours x 2 x</i>	1.069,5
	<i>DSA (international expert) 1 x 24 jours</i>	2.566,8
	<i>DSA (expert national) 2 x 24 jours</i>	2.053,44
Louage de bateau*	<i>22 jours</i>	29.117,75
Provisions**	<i>22 jours</i>	4.411,5
chaluts***	<i>2 chaluts + 2 chaluts couverts</i>	8.842,5
Filets et articles de pêche	<i>Conception de la maille carrée (1 scientifique 1 journée)</i>	250
	<i>Fabrication de la maille carrée</i>	500
GPS et software de navigation		950
Matériel divers	<i>filets, chaluts, etc</i>	2.800
Transport	<i>Matériel</i>	500
	<i>Equipements</i>	500
Total Phase 2		55.961,49

Phase 3: Analyse de données		
Personnel	<i>Analyse (INRH) 2 x 10 jours</i>	4.000
	<i>Analyse (consultants) 2 x 10 jours</i>	4.800
	<i>DSA Consultants 2 x 5 jours</i>	1.069,5
Voyages	<i>Voyages des Consultants de Sète et Malaga-Nador</i>	1.100
Total Phase 3		10.969,5

Phase 4: Rapport final et Conclusions		
Personnel	<i>Rapport et réunion (INRH) 3 experts x 4 jours</i>	2.400
	<i>Rapport et réunion (consultants) JB+JS, 2 x 4 jours</i>	1.920
Voyage	<i>Dernière réunion (INRH): 2 experts Tanger-Nador</i>	1.065,64
	<i>Dernière réunion (consultants) Sète, Malaga et Alger -Nador</i>	1.400
Total Phase 4		6.785,64

Total Fases 1 + 2 + 3 + 4	83.439,57
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* En accord avec la proposition de l'INRH: 15000DH/j x 22 jours

** En accord avec la proposition de l'INRH: 50000DH pour 28 jours (1 bateau)

*** En accord avec la proposition de l'INRH: 100000DH 2 sacs de chalut + 2 nappes de couverture

The total cost of the study in Morocco was calculated in 83.440 € including the four phases:

1.Documents preparation, workshop and survey organisation and preparation (9.722,94 €)

2.Experimental survey on selectivity in Nador (55.961,49 €); 3. Analysis of data (10.969,5 €) and

4.Final report and Conclusions (6.785,64 €).

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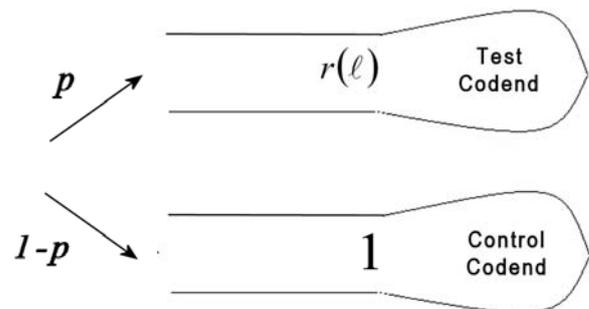
Appendix 1: Summary of Statistical Methods for Towed Gear Selectivity Analysis from Rene Holst, Atselmed 1 (Sète, 2005)

This note presents different models for estimating selectivity at the level of individual hauls as well as at experiment level.

Experiments with towed gear can be conducted by different methods. The most commonly used are **covered cod-end and paired gear techniques (as alternated hauls, trouser codend or twin trawls)**. 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.



Cover-codend technique



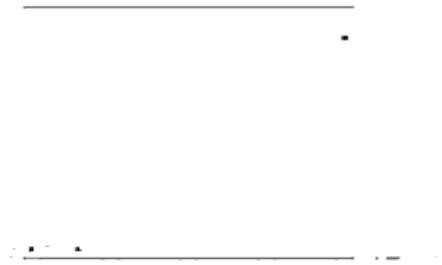
Pair gear technique (i.e alternated haul or trouser codend)

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.

Estimation of selectivity parameters from data obtained in a covered cod-end haul:

Considering that for one fish class l the probability to be retained by the codend is π_l and to escape through the codend and end up in the cover is $(1 - \pi_l)$, the proportion (y_l) of number of length l fish retained in the cod-end related to the total number (n_l) of this length-class retained in the cod-end and in the cover constitutes a binomial experiment as:

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



The selectivity can thus be described by the parameters $\pi/l_1, \pi/l_2, \dots, \pi/l_L$. It is however more convenient to look for a parametric function $r(l; \theta)$ that can summarize the selectivity over all length classes. There are several (sigmoid shaped) candidates to choose among. The most commonly used is the inverse logistic curve:

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

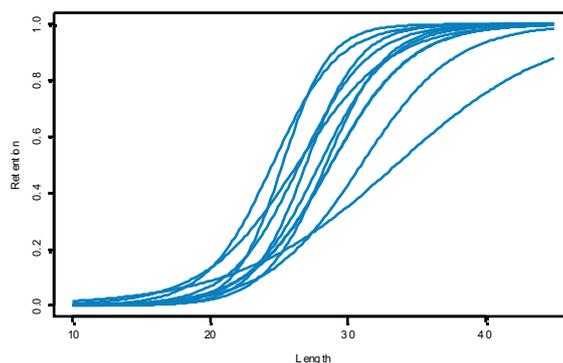
To “reduce” the estimation of the two parameters α and β this is achieved by maximizing the log-likelihood function.

- Big catch issue:

When the catches are too big 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). However raising the data causes over-dispersion and thus underestimation of the variance. It should therefore be avoided as far as possible.

- Small catch issue and catch data pooling (Fryer model of between hauls variation)

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.



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:

$$\hat{\nu}_h \sim N_2(\nu_h; R_h)$$

Assuming that the (unobserved) parameters vary around a common mean according to a normal distribution with mean ν and variance D :

$$\nu_h \sim N_2(\nu; D)$$

These two results combine to:

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

As 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.

These can be found in numerous articles and in particular key papers are listed below.

Main Relevant References

- Baranov, F.I.** 1948. Theory and assessment of fishing gear. Ch. 7: Theory of fishing with gill nets. Pishchepromizdat, Moscow. 45 p. (Translation from Russian by Ontario Department of Lands and Forests, Maple, Ont.).
- Fryer, R. J.** 1991. A model of the between-haul variation in selectivity. ICES J. Mar. Sci. 48: 281- 290.
- Millar, R.B.** 1992. Estimating the size selectivity of fishing gear by conditioning on the total catch. JASA 87, 962-968.
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- Wileman, D.A., Ferro, R.S.T., Fonteyne, R., Millar, R.B. (editors).** 1996. Manual of methods of measuring the selectivity of towed fishing gears. ICES Cooperative Research Report. No. 215.



Coordination pour soutenir la gestion des pêcheries
en Méditerranée occidentale et centrale
copemed@fao.org
www.faocopemed.org
www.fao.org



Développement durable de la pêche artisanale
méditerranéenne au Maroc et en Tunisie
artfimed@fao.org
www.faoartfimed.org
www.fao.org



Siège des Projets
Subdelegación del Gobierno en Málaga
Paseo de Sancha 64, Oficinas 305-307
29071 Málaga (España)
Tél: (+34) 952989299 Télécopie: (+34) 952989252