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# Scientific, Technical and Economic Committee for Fisheries (STECF)

## Standardization procedures for data preparation, stock assessment methods and estimate of MSY reference points for Mediterranean stocks (STECF-15-11)

Edited by Doug Beare & Giacomo Chato Osio

This report was reviewed by the STECF during its 49<sup>th</sup> plenary meeting  
held from 6 to 10 July 2015 in Varese, Italy

Institute for the Protection and Security of the Citizen (IPSC)

#### Contact information

STECF secretariat

Address: Maritime Affairs Unit, Via Enrico Fermi 2749, 21027 Ispra VA, Italy

E-mail: [stecf-secretariat@jrc.ec.europa.eu](mailto:stecf-secretariat@jrc.ec.europa.eu)

Tel.: 0039 0332 789343

Fax: 0039 0332 789658

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#### Abstract

The STECF EWG-15-06 took place to set up best practice standardized procedures to reconstruct times series of historical discard and landings data to be used in future stock assessment of Mediterranean stocks, to check and revise R codes, to carry out a sensitivity analysis, and to set up a best practice standardized procedures for estimating ranges of  $F_{MSY}$  and biomass reference points. The STECF reviewed the report during its 49th plenary meeting held from 6 to 10 July 2015 in Varese, Italy.

## TABLE OF CONTENTS

Standardization procedures for data preparation, stock assessment methods and estimate of MSY reference points for Mediterranean stocks (STECF-15-11).....	5
Background.....	5
Request to the STECF.....	6
Observations of the STECF .....	6
Conclusions of the STECF.....	8
<b>EXPERT WORKING GROUP EWG-15-06 REPORT .....</b>	<b>9</b>
1 Executive summary .....	10
2 Introduction.....	12
2.1 Terms of Reference for EWG-15-06 .....	12
3 The Working Group.....	13
3.1 ToR 1 - Set up a best practice standardized procedures to reconstruct times series of historical discard and landings data to be used in future stock assessment of Mediterranean stocks .....	13
3.1.1 Introduction.....	13
3.1.2 Review of available data.....	13
3.1.3 Size/age structure of the catches.....	21
3.1.4 Discards .....	22
3.1.5 Fleet capacity and fishing effort .....	23
3.1.6 Scientific trawl surveys.....	25
3.1.7 Auxiliary information .....	27
3.1.8 Policy changes in Mediterranean fisheries .....	29
3.1.9 CASE STUDY: Comparing Italian ISTAT and DCR/DCF landings.....	29
3.1.10 Conclusions on ToR1 .....	34
3.1.11 EWG suggestions and guidelines .....	34
3.1.12 References (ToR 1).....	34
3.2 ToR 2 Revision R scripts for survey index stratification and age slicing .....	39
3.2.1 Introduction.....	39
3.2.2 Extracting stratified numbers and length from the MEDITS data.....	39
3.2.3 Results (extraction).....	43
3.2.4 Converting numbers-at-length to numbers-at-age (age slicing) .....	50

3.2.5	Conclusions (ToR 2).....	52
3.2.6	Recommendations (ToR 2).....	52
3.2.7	References (ToR 2).....	52
3.3	ToR 3 - Carry out a sensitivity analysis of the impact of different assumptions on selectivity (i.e. dome shaped, logistic, etc) on the estimation of SSB and F for multi-gear fisheries of hake and red mullet in GSA 5, 6, 7, 9, 10, 16, 17, 18, 22, 25.....	54
3.3.1	Introduction.....	54
3.3.2	The Approach .....	55
3.3.3	Modeling tools .....	58
3.3.4	Selectivity analyses.....	59
3.3.5	Selectivity in the SS3 assessment of red mullet from GSA 17.....	68
3.3.6	Exploration of selectivity models and parameters via simulation and projections.....	79
3.3.7	VIT projections (red mullet in GSA 17).....	83
3.3.8	Conclusions.....	90
3.3.9	References (ToR 3).....	90
3.4	ToR 4 - Set up a best practice standardized procedures for estimating ranges of FMSY and biomass reference points for Mediterranean stocks. ....	92
3.4.1	Introduction.....	92
3.4.2	Hake in GSA 6.....	92
3.4.3	Red mullet in GSA 17.....	93
3.4.4	Deep water rose shrimp in GSA 6 .....	94
3.4.5	Sardine in GSA 22 .....	96
4.	CONTACT DETAILS OF STECF MEMBERS AND EWG-15-06 List of Participants .....	99
5.	List of Background Documents .....	104

**SCIENTIFIC, TECHNICAL AND ECONOMIC COMMITTEE FOR FISHERIES  
(STECF)**

**Standardization procedures for data preparation, stock assessment methods and estimate of  
MSY reference points for Mediterranean stocks (STECF-15-11)**

**THIS REPORT WAS REVIEWED DURING THE PLENARY MEETING HELD IN  
Varese, Italy, 7-8 July 2015**

**Background**

Under the premises of STECF, EWG MED carries out around 30 stock assessments every year in the Mediterranean Sea. The methods used for preparing data for populating the stock assessment models, however, often vary substantially. The reconstruction of historical landings and discards data, for example, is not currently done according to any coherent set of procedures/guidelines and it is suspected that this may lead to 'assessment bias'. Historical landings data are particularly important for deriving estimates of time-trend in both Biomass and BMSY, and are thus crucial for any accurate quantification of Mediterranean fisheries resources. In the absence of reliable stock assessments, sensible management decisions will clearly be difficult to make.

Similarly, stock assessments done by SGMED rely on the 'slicing' of length-frequency data into age categories. The different methodologies that are currently used may result in varying levels of accuracy and reproducibility, depending on species, data quality and availability.

Furthermore, recent published literature has shown that any choice of selectivity curve is fundamental for estimating SSB and F. This is especially true for fisheries prosecuted using gears with very different selectivity features such as gillnets and trawls: commonly the case for most demersal fisheries in the Mediterranean. New assessment models, however, that are now available to the Med EWG can exploit expert knowledge to specify the shape of the selectivity function. Since assumptions on selectivity can affect SSB estimation, sometimes by orders of magnitude, clear guidelines and a standard approach should be defined within the STECF EWG to avoid disseminating drastically different assessment results for consideration by management.

Finally, methods and guidelines for estimating ranges of FMSY and Biomass reference points have been recently developed for the North East Atlantic but, either have not or have rarely been applied to Mediterranean stocks.

## **Request to the STECF**

STECF is requested to review the report of the STECF Expert Working Group meeting, evaluate the findings and make any appropriate comments and recommendations.

## **Terms of reference of the WG:**

The EWG was asked to produce clear guidelines for: (i) reconstructing historical landings and discard data; (ii) data processing and length-frequency 'slicing' procedures; (iii) specifying selectivity functions; and (iv) identifying the ranges of  $F_{MSY}$  and Biomass reference points all in the context of Mediterranean fish stock assessments.

Specifically the EWG was asked to:

1. Set up a best practice standardized procedures to reconstruct times series of historical discard and landings data to be used in future stock assessment of Mediterranean stock.
2. To check and revise the R code developed by Osio, Rouyer, Bartolino and Scott (<https://github.com/drfinlayscott/R4Med>) to extract MEDITS numbers at length and produce stratified numbers. Set up a best practice standardized procedures for slicing methodology to be used in reconstructing times series of number at age data derived from catches and surveys for future stock assessment of Mediterranean stocks.
3. Carry out a sensitivity analysis of the impact of different assumptions on selectivity (i.e. dome shaped, logistic, etc) on the estimation of SSB and F for multi-gear fisheries of hake and red mullet in GSA 5, 6, 7, 9, 10, 16, 17, 18, 22, 25.
4. Set up a best practice standardized procedures for estimating ranges of  $F_{MSY}$  and biomass reference points for Mediterranean stocks.

## **Observations of the STECF**

STECF acknowledges the work of the EWG 15-06 in progressing methods for the assessment of Mediterranean stocks.

STECF notes the effort and significant contribution made towards defining efficient standard procedures for stock assessment in the MED. In relation to each of the Terms of Reference (ToRs), STECF notes the following:

Reconstructing long time-series of total catch per species is a key step for building appropriate scientific advice. In particular, it provides the potential basis for a longer term perspective on the exploitation history and trends in stock biomass.

EWG 15-06 gives an overview of available data, including landings, discards, size/age catch composition, survey data, or fishing effort. STECF notes that EWG-15-06 provides useful guidelines for the reconstruction of time series usable in stock assessment, but was not in position to define a unique standard procedure for such an operational reconstruction. This should probably be done in the frame of a mid-term research program, in close cooperation

with scientists involved in stocks assessment. STECF notes that the EMODnet project (European Marine Observation and Data network), supported by the Commission, aims to provide long term time series of catch for Mediterranean fisheries. However, STECF notes that EMODnet will not provide that catch-at-age, effort and survey data necessary for stock assessments.

STECF notes that EWG 15-06 revised and improved the R code used to extract numbers at length from the standardized MEDITS surveys. In particular, this improved version allows the estimation of stratified length frequency distributions by sex. EWG 15-06 discussed three methods of conversion of catch at length into catch at age: the knife-edge slicing, the use of fixed age/length keys called proportional slicing, and the fitting of a mixture of distributions to the length-frequency data (Hasselblad 1966). EWG 15-06 proposes using the proportional slicing as the default method and notes that the fitting of a mixture of distributions is not straightforward and the outcomes very sensitive to model settings. Nevertheless, STECF notes that using constant age/length keys might lead to an underestimate of the year to year variability in the abundance of each age classes (MacDonald et Pitcher 1979, Kimura and Chikuni 1987).

EWG 15-06 investigated the impact of assumptions on selectivity on the estimation of SSB and F for hake and red mullet (GSA 17). Simulations performed by EWG 15-06 confirmed that different assumptions on the functional form and on the parameters of selectivity have a large impact on the model estimates (SSB, F and Recruitment), when using assessment tools explicitly modelling age or length compositions, such as SS3. EWG 15-06 advised to use reliable prior information on the spatial and temporal distribution of the different life stages of the stocks compared to those of the survey and fleets in order to guide the choice of functional form of selectivity. In the case that such prior information is not available, assessment methods that do not model selectivity (e.g. a4a, SAM) should be preferred.

STECF notes that EWG 15-06 undertook an analysis of multi-fleet management options based on fleets' partial F across different approaches (aggregated vs. multi-fleet) but that no firm conclusions were achieved. STECF considers that if possible, this area should be further investigated at the next Mediterranean Assessment EWG, as multi-fleet forecasts constitute one of the major products of scientific advice.

EWG 15-06 used the empirical relationship fitted on 19 northern European stocks, in order to estimate the range of  $F_{MSY}$ . Simulations performed by the EWG, applying MSE to four stocks considered as case studies, suggested that setting F to  $F_{upper}$  lead to a very low probability of the stock falling below  $B_{lim}$  if defined as the lowest observed biomass ( $B_{loss}$ ). STECF notes, that in the absence of  $F_{MSY}$  ranges derived for the stocks in question, this necessitated the development of the pragmatic approach by means of an empirical function based on the ranges Northern European stocks. STECF considers that such an approach is appropriate for the purposes of the work undertaken by the EWG.

STECF further notes that due to the use of  $F_{0.1}$  as a proxy for  $F_{MSY}$ , the upper limit of the  $F_{MSY}$  range will be lower than those based on stock-recruitment relationships, which in practice results in smaller biological risks. On the other hand, ranges based on  $F_{0.1}$  will not represent the area of the yield curve that provides 95% of MSY, if the exploitation pattern is kept constant.

STECF notes, the use of  $F_{0.1}$  for Mediterranean stocks will lead to a more precautionary outcome in practice. Furthermore, STECF notes that for the simulated case studies, the EWG 15-06 assumed constant recruitment in the MSE simulations. Given the low starting biomasses, and assuming that biomass does not decline further, this implies that the future recruitment is likely to be underestimated and therefore future SSB and catches are underestimated in the MSE. STECF notes that reaching  $F_{MSY}$  or even  $F_{upper}$  implies a substantial decrease in fishing mortality on the stocks examined, which is currently between 5 and >10 times the  $F_{MSY}$  estimates. Such large reductions in  $F$  give estimates for future SSB that have never been previously observed in the available time series. Consequently, at such high stock sizes the stock dynamics are unknown, thereby rendering the outcomes of the forecasts uncertain in an absolute sense. However, STECF notes that the general trends can be considered indicative of likely trends in SSB and catch.

STECF considers that the main priority for the management of Mediterranean stocks should be the rapid introduction of efficient measures designed to reduce fishing mortality from the current very high levels.

### **Conclusions of the STECF**

STECF concludes that results of the analyses undertaken by the EWG 15-06 constitute a significant step forward to improve and standardize assessment methods used for Mediterranean stock assessments. STECF endorses the guidelines provided by the EWG in relation to ToRs 1 to 3 and that the guidelines should be carefully considered by EWG's dealing with Mediterranean stocks.



**EXPERT WORKING GROUP EWG-15-06 REPORT**

## **REPORT TO THE STECF**

### **EXPERT WORKING GROUP ON STANDARDISATION PROCEDURES FOR DATA PREPARATION, STOCK ASSESSMENT METHODS AND ESTIMATE OF MSY REFERENCE POINTS FOR MEDITERRANEAN STOCKS (EWG-15-06)**

**Ispra, Italy, 8-12 June 2015**

This report does not necessarily reflect the view of the STECF and the European Commission and in no way anticipates the Commission's future policy in this area

## 1 EXECUTIVE SUMMARY

EWG15-06 met at EC JRC in Ispra between 8 and 12 June 2015 to address the 4 Terms of Reference (ToRs) outlined in detail below. At the start of the meeting the main group was divided into four sub-groups allowing each to address/focus on a particular ToR although there was cross-over between the groups and some individuals worked on more than one ToR. Results were discussed at regular plenaries throughout the week.

ToR 1 was concerned with developing procedures to standardize the use and maximise the utility (for stock assessment) of the historical, national and international datasets that are available. For ToR 1 EWG15-06 found that:

- i. FAO data (from 1950) and GFCM (from 1970) should be identical but are not;
- ii. Levels of catches of small pelagics reported by the Italian authorities (ISTAT), the FAO, and GFCM had for some years different absolute levels but similar time-trends.
- iii. FAO statistical areas are not the same as GSAs except in a few cases; but by changing the spatial scales of the stock-assessments it might be possible to utilise FAO data.
- iv. Species level and biological (age, length, sex, maturity) data are unavailable in coherent, systematic formats.
- v. Time-series of fishing capacity and effort are not available from either FAO or GFCM.
- vi. Environmental indices (eg. North Atlantic Oscillation Index) and cycles can be used to inform and fill-in data gaps.
- vii. Data for discarding are scarce, although EWG15-06 found that discarding rates were negligible in the past.
- viii. Historical data should be used in stock assessment models for Mediterranean stocks both quantitatively and qualitatively, ie. to document the history of the fisheries and understand the long-term dynamics.
- ix. An official request for historical time-series data to Mediterranean member states should be considered.
- x. More work should be done to compare catch trends in recent DCF data with historical data.
- xi. Historical CPUE indices should be standardised for 'technological creep' and used as indices of abundance for some stocks.

ToR 2 examined methodological issues relating to two main problems. How to extract stratified numbers and length data from the MEDITS surveys and how then to convert those lengths to ages (age-slicing)? The ToR 2 group developed, and substantially improved, the R-code that already existed. The output of the extraction routine, for example, now feeds directly into the age-slicing procedure. They found that:

- i. The default method for age-slicing should be 'deterministic' and not 'statistical', preferably the FAO proportional method.
- ii. The three age-slicing methodologies have different user-interfaces and that these should be modified so that both MEDITS and DCF data can be processed with the same procedures.

- iii. The age-slicing procedures within the 'a4a' modelling framework should be investigated in more detail.
- iv. Efforts should be made by everyone to use the same, most up-to-date versions of the code.
- v. The code should be packaged into an R-library which should be hosted on JRC's official GitHub repository site.

ToR 3 was concerned with the problem of 'selectivity' in stock assessment models as different assumptions can have profound impact on the output (SSB, R, etc.). This a particularly difficult, contentious problem, and only partial progress was made during the meeting. More work on understanding these issues needs to be done. EWG15-06 found that:

- i. Even the definition of 'selectivity' was unclear but it was agreed that, 'selectivity is the combination of mechanical selection and availability.
- ii. The impact of different functional forms for selectivity is difficult/impossible to predict *a priori*.
- iii. The aggregation level for fleet input data generates different results.
- iv. Understanding the spatio-temporal distribution of fish stocks and its age-dependence is crucial for guiding the choice of selectivity function.
- v. Specific models should be used for cases where there is no a-priori information on selectivity, and where fleet data exist at different levels of aggregation.
- vi. An exploration of multi-fleet management options based on fleet partial F produced no firm conclusions and requires more work.
- vii. Length and sex-based differentiated models (eg. Norway lobster, hake) have promise in this context but there was insufficient time available during EWG15-06 to explore them properly.
- viii. The CAPAM group are producing guidelines on the choice of selectivity which will be useful for Mediterranean stocks.

ToR 4 was concerned with best-practices for estimating FMSY ranges and biomass reference points for Mediterranean stocks. The group decided to base its estimates of FMSY ranges on a meta-analysis on northern European stocks assessed by ICES which provided candidate Fupper numbers for Mediterranean stocks. To determine whether the Fupper ranges estimated were plausible, ie. could the stock be 'crashed' at this level, a Management Strategy Evaluation was set up using FLR and tested on four stocks (hake in GSA6, red mullet in GSA17, deepwater shrimp in GSA 6 and sardine in GSA 22). The analysis showed that, if Fupper was selected in the manner described, then the relevant stock could be fished sustainably into the future. This was true for all four stocks examined. The 'meta-analysis' is basically a linear model where FMSY is fitted to Fupper (and lower) for a range of north European stocks assessed by ICES. There is not necessarily any reason why these simple relationships can sensibly be transferred south to completely different stocks/species, but it worked to the satisfaction of EWG15-06.

In summary ToRs 1, 2, and 4 were straightforward and were adequately addressed by EWG15-06. ToR 3, on the other hand, remains problematic. Substantial progress was made on the issue of selectivity but many issues remain unresolved.

## 2 INTRODUCTION

Under the premises of STECF, EWG MED carries out around 30 stock assessments every year in the Mediterranean Sea. The methods used for preparing data for populating the stock assessment models, however, often vary substantially. The reconstruction of historical landings and discards data, for example, is not currently done according to any coherent set of procedures/guidelines and it is suspected that this may lead to 'assessment bias'. Historical landings data are particularly important for deriving estimates of time-trend in both Biomass and BMSY, and are thus crucial for any accurate quantification of Mediterranean fisheries resources. In the absence of reliable stock assessments, sensible management decisions will clearly be difficult to make.

Similarly, stock assessments done by SGMED rely on the 'slicing' of length-frequency data into age categories. The different methodologies that are currently used may result in varying levels of accuracy and reproducibility, depending on species, data quality and availability.

Furthermore, recent published literature has shown that any choice of selectivity curve is fundamental for estimating SSB and F. This is especially true for fisheries prosecuted using gears with very different selectivity features such as gillnets and trawls: commonly the case for most demersal fisheries in the Mediterranean. New assessment models, however, that are now available to the Med EWG can exploit expert knowledge to specify the shape of the selectivity function. Since assumptions on selectivity can affect SSB estimation, sometimes by orders of magnitude, clear guidelines and a standard approach should be defined within the STECF EWG to avoid disseminating drastically different assessment results for consideration by management.

Finally, methods and guidelines for estimating ranges of  $F_{MSY}$  and Biomass reference points have been recently developed for the North East Atlantic but, either have not or have rarely been applied to Mediterranean stocks.

### 2.1 Terms of Reference for EWG-15-06

1. Set up a best practice standardized procedures to reconstruct times series of historical discard and landings data to be used in future stock assessment of Mediterranean stock.
2. To check and revise the R code developed by Osio, Rouyer, Bartolino and Scott (<https://github.com/drfinlayscott/R4Med>) to extract MEDITS numbers at length and produce stratified numbers. Set up a best practice standardized procedures for slicing methodology to be used in reconstructing times series of number at age data derived from catches and surveys for future stock assessment of Mediterranean stocks.

3. Carry out a sensitivity analysis of the impact of different assumptions on selectivity (i.e. dome shaped, logistic, etc) on the estimation of SSB and F for multi-gear fisheries of hake and red mullet in GSA 5, 6, 7, 9, 10, 16, 17, 18, 22, 25.
4. Set up a best practice standardized procedures for estimating ranges of  $F_{MSY}$  and biomass reference points for Mediterranean stocks.

### 3 THE WORKING GROUP

#### 3.1 ToR 1 - Set up a best practice standardized procedures to reconstruct times series of historical discard and landings data to be used in future stock assessment of Mediterranean stocks

##### 3.1.1 *Introduction*

Ecosystems are dynamic and change over time due to both anthropogenic and natural factors. Fisheries management, therefore, should and cannot be successful if based only on studies of recent populations. Extensive fisheries time-series data are available for northern European seas but data for the Mediterranean, in the right format for stock assessment models, usually cover the last few decades only, and current management advice is perforce based on data starting in the early 1990s at best. Therefore, any availability of long-term series of fisheries data should be regarded as an opportunity to place fish and shellfish populations in a more realistic perspective, avoiding the problems caused by 'shifting baselines' likely experienced by each new cohort of fisheries managers.

##### 3.1.2 *Review of available data*

###### 3.1.2.1 FAO and GFCM landings databases

Sources of historical annual landings data for Mediterranean stocks are: FAO, GFCM, and the data collected by countries through their statistical data collection systems, see Fig. 3.1.1. FAO data since 1950 can be retrieved from the FAO Global Catch Production database (<http://www.fao.org/fishery/statistics/global-capture-production/en>). It uses information on capture production collected annually from relevant national offices concerned with fishery statistics. A questionnaire (FISHSTAT NS 1) is dispatched to countries on an annual basis, requesting information on nominal catch data for all commercial, industrial, subsistence, and recreational fishery operations in all inland and marine fishing areas. Information on how FAO deals with the validation of data submitted by countries can be found at: (<http://www.fao.org/fishery/statistics/global-capture-production/4/en>). The FAO derived catch trends for the Mediterranean are showed in Fig. 3.1.2.

The EWG1506 suggested that caution is needed when using the FAO Global Catch Production database because many species have negligible reported catch levels at the beginning of the time-series. FAO catch production data are also reported in some cases as part of large taxonomic aggregates (e.g. Clupeoids, Scorpionfishes, Penaeus shrimps, Raja rays, Gadiformes etc) instead of single species. Also in the case of very small stocks, FAO catch data are well known to be unreliable (Costello et al 2012, Hilborn & Ovando 2014). In addition, within the FAO time series of catch for a fishery, individual years may have missing data. For fisheries missing less than 10% of their landings data, the EWG1506 suggested that the missing data points could be filled in by simple linear interpolation (Costello et al 2012).

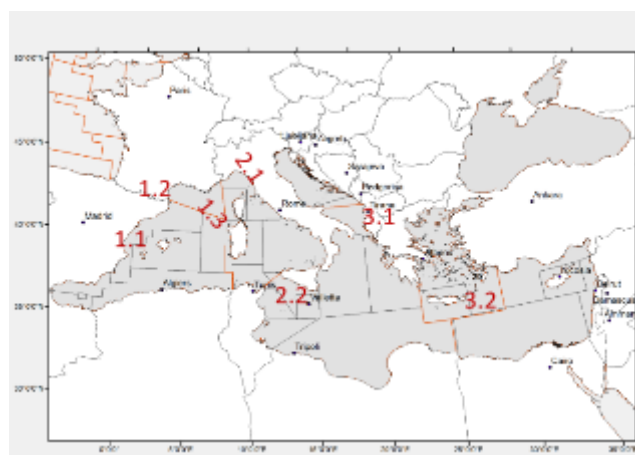
The GFCM (General Fisheries Commission for the Mediterranean) Capture Production Database (<http://www.gfcmonline.org/data/productionstatistics/>) starts from 1970. It is populated with catch statistics for the Mediterranean and Black Sea area as reported by the national authorities of countries to GFCM through the STATLANT 37A questionnaire. The national catch figures are processed and compared with the data collected by FAO at “major fishing area” level (through the FISHSTAT NS1 questionnaire), without the breakdown of catches by species and statistical subdivisions. At the end of this process, the original figures may be revised, and missing values estimated in order to ensure coherence with the FAO Global Capture Production database, at least at the level of groups of species established by the “*International Standard Statistical Classification of Aquatic Animals and Plants*”. Neither the FAO nor GFCM include data disaggregated by the main fleet segments (Table 3.1.1).

**Table 3.1.1. Main characteristics of FAO/GFCM catch databases.**

Database	Time-coverage	Spatial resolution	Fleet disaggregation	Species resolution
GFCM	1970-2013	FAO statistical divisions/Countries	NO	ISSCCCP
FAO	1950-2013	FAO statistical divisions	NO	ISSCCCP
Italy (ISTAT)	1960-2000	Italian regions	NO	52 groups including aggregated taxa
Greece (HELSTAT, ASG)	1950-2010	16-22 fishing areas, prefectures	YES	58 fish, 5 cephalopods, 6 crustaceans

The GFCM database contains annual statistics (1970 onwards) for capture production expressed as, 'live weight equivalent of landings' in the Mediterranean and Black Sea region split by species and countries or areas. Information on capture production is collected annually from the relevant national offices concerned with fishery statistics. The lowest spatial scales available in the GFCM Capture Production data set are FAO Fishing Areas and countries. These two can, in some situations, be combined to obtain data at finer resolutions, e.g. Country = Italy + Area = Ionian will return approximate combined landings for GSAs16,

18 and 19. Neither GFCM nor FAO data can be sensibly split by GSA. Only a few exceptions exist. Fishing Area (FAO Sub-division) 1.2, for example, coincides with GSA 7 (Gulf of Lions), while Fishing Area 2.1 coincides with GSA 17 (northern Adriatic Sea). In all the other cases, disaggregation of GFCM data is needed to break data down to GSA level.



**Fig. 3.1.1. Mediterranean GSAs and FAO statistical subdivisions (red lines): 1.1 Balearic, 1.2 Gulf of Lions, 1.3 Sardinia, 2.1 Adriatic, 2.2 Ionian, 3.1 Aegean, 3.2 Levant**

The datasets potentially available for Mediterranean stock assessment (e.g. FAO, GFCM, and national reported landings) might have some gaps, some mis-reporting bias and other collection problems. Furthermore, the data are not always available at species level; a particular issue for elasmobranchs, horse mackerels and anglerfishes. To date, however, these are the only form of information on catches pre-2000 and are too valuable to not be used in stock assessment. A detailed table with all FAO/GFCM species common names and categories along with comments on potential misreporting between species is given as supplementary information (Table S3.1.1).

### 3.1.2.2 National landings statistics and data

#### Italy

Official catch statistics can be obtained from the statistical offices of EU Mediterranean countries. These basically provide similar temporal trend to the ones available in the FAO and GFCM catch data but with better spatial resolution.

The Italian National Institute for Statistics (ISTAT) has, for example, been collecting landings and effort statistics since before (at least) the Second World War) for the main fleet segments, species (Table 3.1.2) and Italian regions.

**Table 3.1.2. Species/groups of species used in ISTAT database (Italian names)**

Alici	Sarde	Sgombri	Tonni
Aguglie	Boghe	Caponi	Cefali
Leccie	Mendole	Merluzzi	Pagelli

Palamite	Potassoli	Pesci.spada	Rane.pescatrici
Razze	Sogliole	Sugarelli	Triglie
Altre.specie.pesci	Calamari	Polpi	Seppie
Totani	Altri.molluschi	Pannocchie	Scampi
Altre.specie.crosta cei	Moscardini	Cernie	Elasmobranchi
Anguille	Bisi	Ombrine	Dentici
Ghiozzi	Latterini	Saraghi	Orate
Palombi	Rombi	Gamberi.bianchi	Spigole
Mitili	Aragoste.ed.astici	Gamberi.rossi	
Vongole	Gamberi	Mazzancolle	

## Spain

The Spanish Ministry of Agriculture, Food and Environment (“MAGRAMA”) is the official organization in charge of the collection of data on marine fisheries production. The ultimate data sources are the individual sales slips provided by fish traders through the compulsory auction system. This information is channeled to the Ministry through the Fisheries Directorate of Individual Autonomous Communities (for the Mediterranean: Catalonia, Balearic Islands, Valencia, Murcia and the eastern half of Andalusia). The original sales slips data are extremely detailed and usually recorded at the level of individual species and fishing boat. Due, however, to subsequent processing of the data at the level of Fisheries Directorates or Ministry, as well as certain confidentiality policies, the data eventually available to researchers are unfortunately aggregated over substantial geographic areas. The details of data collection and data treatment are available in the “Standardized Methodological Report” (<http://www.magrama.gob.es/es/estadistica/temas/estadisticas-pesqueras/pesca-maritima/estadistica-capturas-desembarcos/default.aspx#para1>).

The data are nevertheless easily accessible through the Ministry portal. They take the form of predefined query results for the period 2004 – 2013. This information is reported at a very coarse geographical level (FAO Fishing areas). Taxa (species and groups of species) are coded using FAO standards: ISCAAP code, taxonomic code and 3-alpha code, giving a total of 810 taxa. This information is available as an Excel workbook for the period 1992-2013. In the following table the first rows of the publicly available data are shown below (Table 3.1.3) as an example:

**Table 3.1.3. Format of the landings data publicly available for Spain.**

Year	Species	Zona	Live weight (kg)	Taxonomic groups
1992	SKA	21	1,473,000	Tiburones, rayas, quimeras
1992	SRX	37	397,483	Tiburones, rayas, quimeras
1992	SRX	99	1,707,917	Tiburones, rayas, quimeras



1992	SAA	37	1,643,343	Arenques, sardinas, anchoas
1992	SIX	27	520,000	Arenques, sardinas, anchoas
1992	SIX	99	757	Arenques, sardinas, anchoas

### **Autonomous Communities**

The administrative boundaries of “Autonomous Communities” do not match the geographical sub-areas exactly, resulting in an additional difficulty when trying to use landings data for fisheries stock assessments. Only one Autonomous Community corresponds to a GSA: The Balearic Islands is GSA 05. The other two Spanish Mediterranean GSAs are covered by the eastern half of Andalusia and Murcia (GSA01), and Valencia and Catalonia (GSA06). Fisheries capture data from the Fisheries Directorates of individual Autonomous Communities are sometimes more easily accessible or more useful for the Mediterranean assessment working groups because they provide public data on catches by species and fishing gear (e.g. for the Region of Murcia: [http://www.regmurcia.com/servlet/s.SI?sit=c,24,m,3113&r=ReP-23978-DETALLE\\_REPORTAJESPADRE](http://www.regmurcia.com/servlet/s.SI?sit=c,24,m,3113&r=ReP-23978-DETALLE_REPORTAJESPADRE)). However, not all five Autonomous Communities provide landings data in a homogenous format. Also, fisheries catch data are not usually readily available before 2000. Thus, while Catalonia provides public access to landings data for the main species in GSA06 since 2000 via the Government portal ([http://agricultura.gencat.cat/ca/ambits/pesca/dar\\_estadistiques\\_pesca\\_subhastada/dar\\_captures\\_especie/](http://agricultura.gencat.cat/ca/ambits/pesca/dar_estadistiques_pesca_subhastada/dar_captures_especie/)), Valencia only provides landings data by species since 2007.

### **Historical landings data**

Historical data for the period 1940 – 1984 exist in paper form as official annual statistics produced by the Secretaría General de Pesca Marítima (General Secretariat for Marine Fisheries, of the Spanish Ministry), under different names: Estadística de Pesca (1940-1971) and Anuario de Pesca Marítima (1973 – 1984). These data, at the level of individual species, port and fleet, may have been digitized by individual researchers and used in scientific publications, but access to such data in a usable form for assessment working groups would not be straightforward and it would require a considerable amount of work to make such data available.

## Greece

The Hellenic Statistical Authority (HELSTAT, <http://www.statistics.gr/portal/page/portal/ESYE>) has recorded landings by subarea since at least the mid-1960s although unfortunately this has often been erratic. Between 1964 and 1969 data were collected from all motorized fishing vessels, while since 1970 only data from large vessels (>19hp) were recorded. An additional data source for the species targeted by the small scale fishery are those logged by the 'Agricultural Statistics of Greece (ASG)' which recorded landings by prefecture for only small-scale vessels with engine power < 19 HP between 1974 and 2007 (for access contact D. Moutopoulos). The EWG1506 suggested that the data recorded by the ASG should be taken into consideration in any catch reconstruction of the species targeted by the small scale fishery, as small-scale vessels with engine power < 19 HP represent a non-negligible part of the respected fishery in Greece. A summary of the different sources of fisheries landings statistics available for Greece is given in Table 3.1.4

**Table 3.1.4. Summary of the fisheries landings statistics recorded by the different statistical organizations for Greek waters, 1950-2010 (from Moutopoulos et al., 2015). The records of the Hellenic Statistical Authority (HELSTAT) exclude landings data from the small-scale vessels with engine power < 19 HP and might refer to single species or group of species depending on the recorded period.**

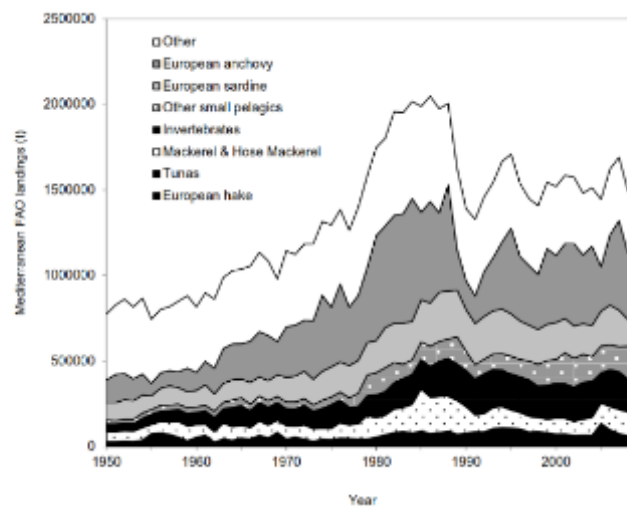
Period	Fishery type	Species resolution	Gear type	Spatial resolution	Source
1950-2007	Marine	58 fish, 5 cephalopods and 6 crustaceans	Per gear type (i.e. trawl, purse-seine, beach-seine and other small-scale) for all engine vessels	For 16 fishing subareas	Moutopoulos and Stergiou (2012)
1950-1963	All fisheries (i.e., marine*, freshwater and lagoons) combined	Total landings (i.e., all species combined)	All gear types combined for all fishing vessels	Total for Greek waters	Ananiadis (1968)
1975-2007	Marine	Total (i.e. for all fish, cephalopod, and crustacean) annual landings per vessel	Rowing recreational vessels	For 41 prefectures	ASG
1995-1996	Marine	26 fish and 1 cephalopod	Rowing recreational vessels	Total for Greek waters	Anagnopoulos <i>et al.</i> (1998)
2008-2010	Marine	<i>Auxis thazard</i> , <i>Euthynnus alletteratus</i> , <i>Thunnus</i> spp. and <i>Xiphias gladius</i>	All gear types combined excluding small vessels	Total for Greek waters	FAO
2008-2010	Marine	56 fish, 5 cephalopods and 5 crustaceans	Per gear type (i.e. trawl, purse-seine, beach-seine and other small-scale) excluding small vessels	For 16 fishing subareas	HELSTAT
1952-1963	Overseas fisheries	16 fish and 3 cephalopod species	Trawl type	Total for world seas	Ananiadis and Chondronikolas (1970)
1964-1981	Overseas fisheries	17 fish, 4 cephalopods and 1 crustacean	Trawl type	For 22 areas	HELSTAT
1982-2010	Overseas fisheries	56 fish, 5 cephalopods and 5 crustaceans	Trawl type	For 22 areas	HELSTAT

\*Bivalve and eel species were excluded from the reconstruction of the fisheries landings from both Greek and overseas landings.

Overall, Mediterranean catch statistics available, particularly before the implementation of EU Data Collection system, were not harmonized between countries. Various recent attempts have been made to “reconstruct” and validate historical data (i.e. Piroddi et al., 2014; Moutopoulos et al., 2015; Coll et al., 2015) for the Mediterranean but mainly for reasons other than fisheries stock assessment. It is clear to the members of EWG1506 that a real effort should be made to identify other potential sources of data that might help with stock assessment, e.g. data from fish markets (prices), local data collection systems, fishermen's tally books, and the literature (peer-reviewed papers, PhD theses etc). Such information

should be evaluated where possible and used as independent observations to either adjust or verify the official catch statistics where appropriate.

In a recent attempt to reconstruct the historical development of Mediterranean stocks and fisheries, Garcia (2012) found that FAO landings trends of the main groups of species do indeed reliably reflect the underlying fisheries dynamics and their interaction with the resources. This can indicate that the trends in official landings, despite all the alleged and real problems with their quality, can reflect the impact of the fishing fleets; particularly during the most substantial phase of development between 1960 and 1990 (Garcia, 2012).



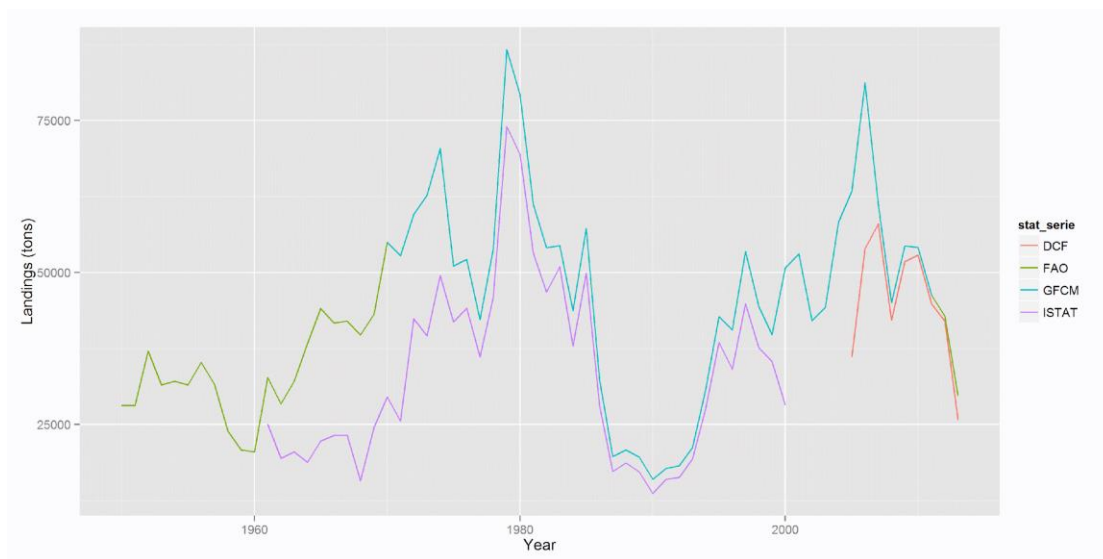
**Fig. 3.1.2. FAO catch trend of Mediterranean catches for the main group of species since 1950** (from Coll et al., 2015)

## France

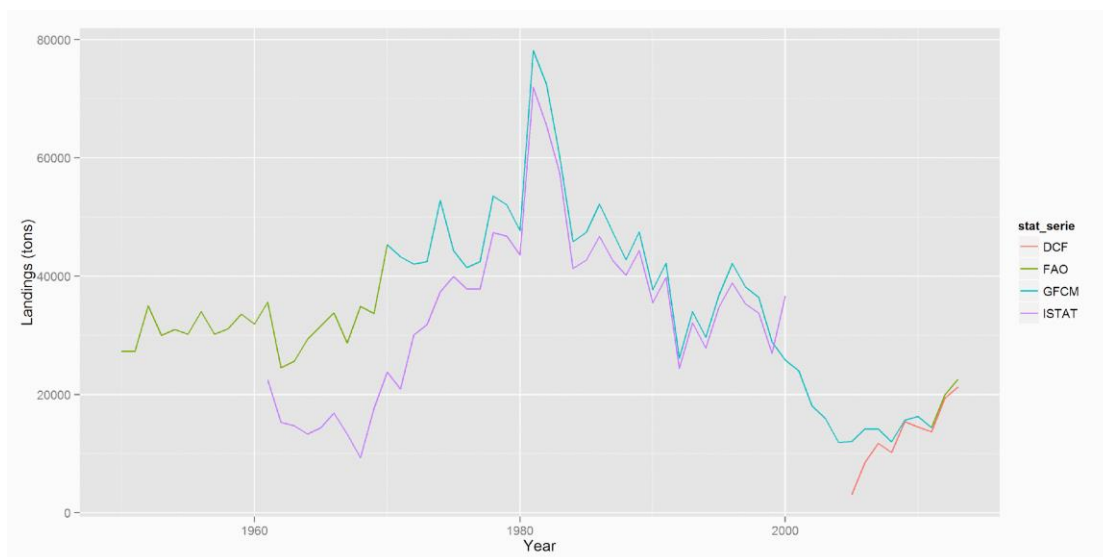
In France landings have been recorded for the period 1951-1980 in the bulletin: Statistiques des Pêches Maritimes published by the Secrétariat General de la Marine Marchande-Direction Generale des Pêches Maritimes. Older reports exist as well.

### 3.1.2.3 Comparing global landings datasets: FAO, GFCM, ISTAT and DCF

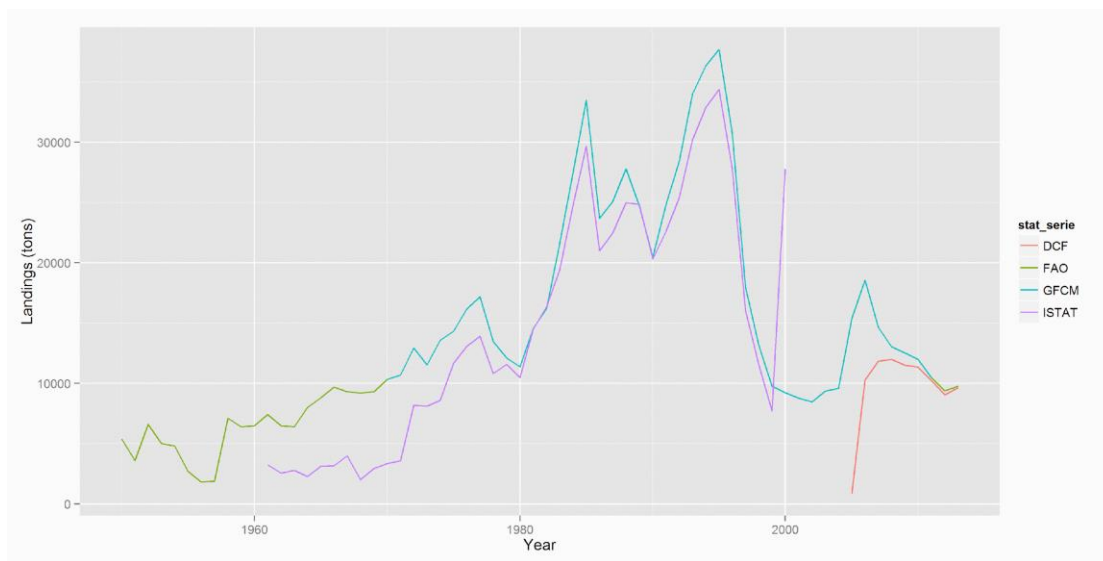
One way of validating historical landings is to compare trend patterns and absolute levels of landings available from the various sources, at comparable spatial scales. The EWG1506 presents below certain selected 'case studies' where we compared, at Italian national level, landings data from FAO Global capture database (1950-2012), reconstructed ISTAT (1962-2000), GFCM Mediterranean production (1972-2013) and DFC (2004-2013).



**Fig. 3.1.3. Landings statistics for anchovy reported by FAO Global Capture, GFCM, ISTAT and DCF/DCF.**



**Fig. 3.1.4. Landings statistics for sardines reported by FAO Global Capture, GFCM, ISTAT and DCF/DCF.**

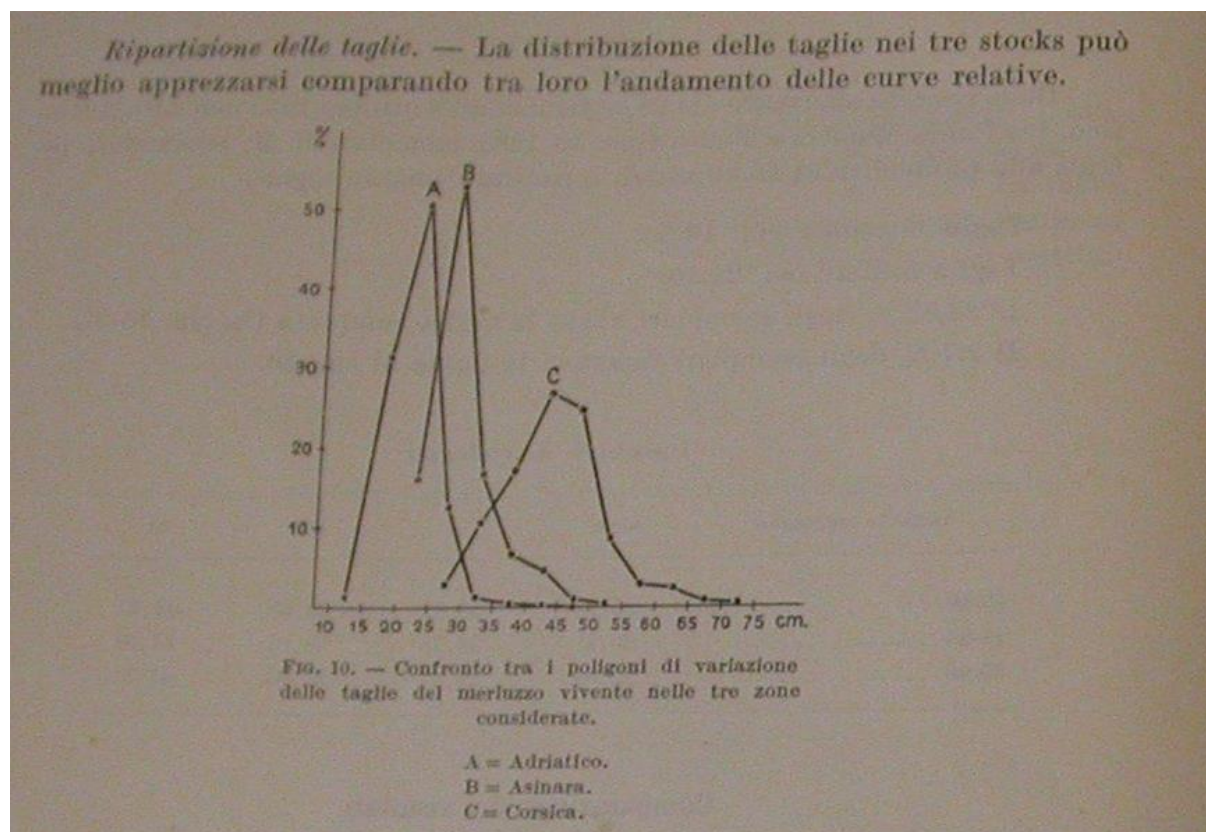


**Fig. 3.1.5 Landings statistics for Mediterranean hake reported by FAO Global Capture, GFCM, ISTAT and DCF/DCF.**

### 3.1.3 *Size/age structure of the catches*

Most stock assessment models available today, require that the catch data be divided into either size or age categories: the quality of 'fit' largely depending on the number of complete cohorts in the data. Unfortunately, however, such information was not collected routinely by Mediterranean states before the advent of the EU Data Collection program. Typically the historical data available are for total landings and lack any other useful biological information on, for example, the age or length structure. Therefore, assumptions allowing the reconstruction of age structure are a prerequisite.

As an example, frequency distributions of Mediterranean hake caught by means of trawl gear from different Mediterranean locations can be found in technical reports like Matta (1954), these data could be used to reconstruct the size structure of the catches in the 1950s, Fig. 3.1.6.



**Figure 3.1.6. Length frequency distribution for Mediterranean hake caught by otter trawl in areas in the North Adriatic, in Sardinia (Asinara) and Corsica from Matta 1954.**

#### 3.1.4 Discards

Time-trends in historical landings often provide the only information available for changes that have occurred in the past, as data for discards are scarce and scattered. Kelleher (2005) notes that studies on discards cover only a small proportion of the total fishing activity in the Mediterranean Sea. This issue has been acknowledged as an important constraint for performing reliable stock assessments (Caddy, 2009) depending on the fishery. Studies on discards were particularly scarce before 2000 but much progress has been made in recent years following, and the implementation of the EU Data Collection Regulation [Commission Regulation (EC) No 1639/2001; currently, Data Collection Framework, Council Regulation (EC) no 199/2008] (Tsagarakis et al., 2013). Despite the progress substantial gaps in our knowledge remain.

Nevertheless various expert reviews on the evolution of fisheries in the Mediterranean have highlighted the fact that discard rates of commercial species might have been significantly lower in the past than those observed in recent years (Farrugio et al., 1993; Damalas et al., 2015). Lower discard rates may have several root causes. First of all, the desperate economic situation in many countries in the first periods after the 2nd World War created exceptionally

high demand for cheap sources of food, such as those potentially provided by fisheries, with low discards of edible species a consequence. In addition, available evidence from the immediate post-war period shows that comparatively 'well-structured populations' existed, with older ages better represented than would be the case at present. The relatively higher prevalence of these older, larger, more marketable fish might also have led to lower discard rates in the past.

Anyway, the decreasing trend in individual lengths of fish caught should not have produced any increase in discard rates, at least until recent years. Both market demand, and the general lack of respect for rules and regulations by fishers (together with the lack of effective monitoring and control by both national governments and regional organizations) - behavior that has been manifest for a long time - may have determined the continuation of fisheries based on the landings of massive amounts of juveniles of many commercial species. In fact, available knowledge shows that significant fractions of undersized specimens of commercial species, such as European hake and red mullet, were marketed in several areas of the Mediterranean (Martin et al., 1999; Sardà et al., 2004, 2006). Low compliance, with constraints concerning minimum landing size has also been observed in various fisheries (Tsagarakis et al., 2013). A significant portion of undersized fish is landed by bottom trawls (Machias et al., 2004; Edelist et al., 2011; Damalas and Vassilopoulou, 2013), purse-seines (Tsagarakis et al., 2012), swordfish longlines (Tudela, 2004), and small-scale fisheries (Tzanatos et al., 2008). Viva and De Ranieri (1994) reported that the landings of undersized European hake represented up to 40-50% of the total landings of this species by trawl fleets in some ports along north-western Italian coasts.

In recent years, the implementation of DCF and the more effective enforcement of EU regulations have contributed to the ban on the landing of undersized fish, forcing a consequent increase in the discard rates of commercial species. Data coming from monitoring activities at the landing points carried out in some ports along north-western Italian coasts showed a sudden interruption of the landings of undersized European hake and red mullet in the period 2002-2003 (Ligas, unpublished data).

In the view of these considerations, we can safely assume that discarding was negligible in the past, and that historical landings represent historical catches; certainly up to the late 1990s and early 2000s and use them, along with the data on total catches, (landings + discards) for the more recent years (i.e. since the introduction of DCF) for stock assessment purposes. However, the EWG 15-06 recommend that thorough checks be done to see whether discard data actually exist before relying on such an assumption. When historical information on discards is available, the EWG 15-06 suggested that it must be taken into account, and data can be extrapolated from intermediate periods with available information (Coll et al., 2015).

### 3.1.5 *Fleet capacity and fishing effort*



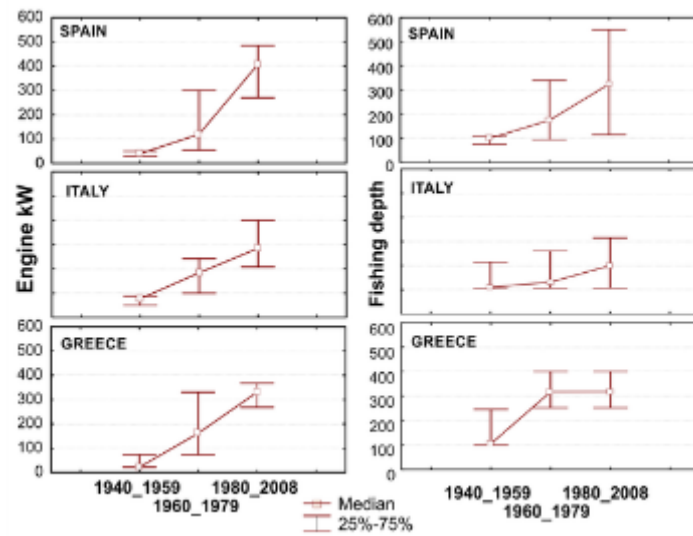
GFCM and FAO apparently do not have publicly available time-series data on Mediterranean fleets dynamics. However, trends in effort and capacity can potentially be reconstructed for each relevant management area and main fleet segment using data retrieved from national fleet registers/databases or maritime offices (see EVOMED project and see Fig 3.1.7). Attempts in this direction have been explored by EU-funded projects such as EVOMED and ECOKNOWS and explored by e.g. Machias et al., 2008; Damalas et al., 2015; Ligas et al., 2013. Historical catch/effort data collated by these projects were also used during STECF EWG 12-10 to apply surplus production models to some commercial stocks in Greek waters. Osio (2012) performed an extensive reconstruction of trawl fleet capacity and fishing power for Catalonia, Gulf of Lions and parts of Italy.

Fishing effort is traditionally estimated by combining available physical measurements of fishing capacity (fixed production inputs) and fishing activity (variable production inputs; Marchal et al., 2007). Fishing capacity is frequently approached by some physical attribute of the operating vessel (engine power, gross tonnage), but is also dependent on other factors, including gear technology and on-board equipment, which are often ignored. The introduction of new gear and technology includes both larger marked technological investments (e.g. acoustic fish-finding equipment, electronic navigation tools) and smaller stepwise improvements to the gear (e.g. netting characteristics, changes in the design of trawl panels), which in combination cause a noticeable increase in capacity over time (Marchal et al., 2007, Osio 2012). Fishing activity measurements should include all those factors that potentially may impact fishing pressure, including the number and the sizes of gear deployed, or the effective time used for fishing (e.g. days at sea). All aspects connected to the evolution of fishing capacity and activity of the relevant fleets across time should be taken into account to assess the increasing in efficiency of fishing vessels (technological creep).

The main problem with estimating fishing effort is that the types of information and data necessary were not commonly collected by the statistical systems of EU Mediterranean countries in the past. Such data may exist but require a sustained and expensive effort to be gathered from auxiliary sources, such as inquiries to vessel captains, fishing enterprises, etc. An attempt in this direction was made by the EVOMED project for fleets targeting demersal species in some areas of Spain, Italy and Greece.

Methods to evaluate time variations in fishing efficiency can be found in a number of studies (see Marchal et al., 2007 for a review on this topic) and are usually based on analysing CPUE with regression models (e.g. Generalised Linear Models) although more complex methods such as multi-output distance functions have also been tried. The advantages of adjusting fishing effort can be assessed by examining the relationship between fishing mortality and fishing effort, for the fleets and fish stocks under investigation. Usually growth in fishing power/efficiency is accounted for using correction factors that are not available for Mediterranean fleets, except trawl gear (Osio 2012). Alternative approaches to deal with the technological creep have been suggested by Cardinale et al. (2009) and Ligas et al. (2013).

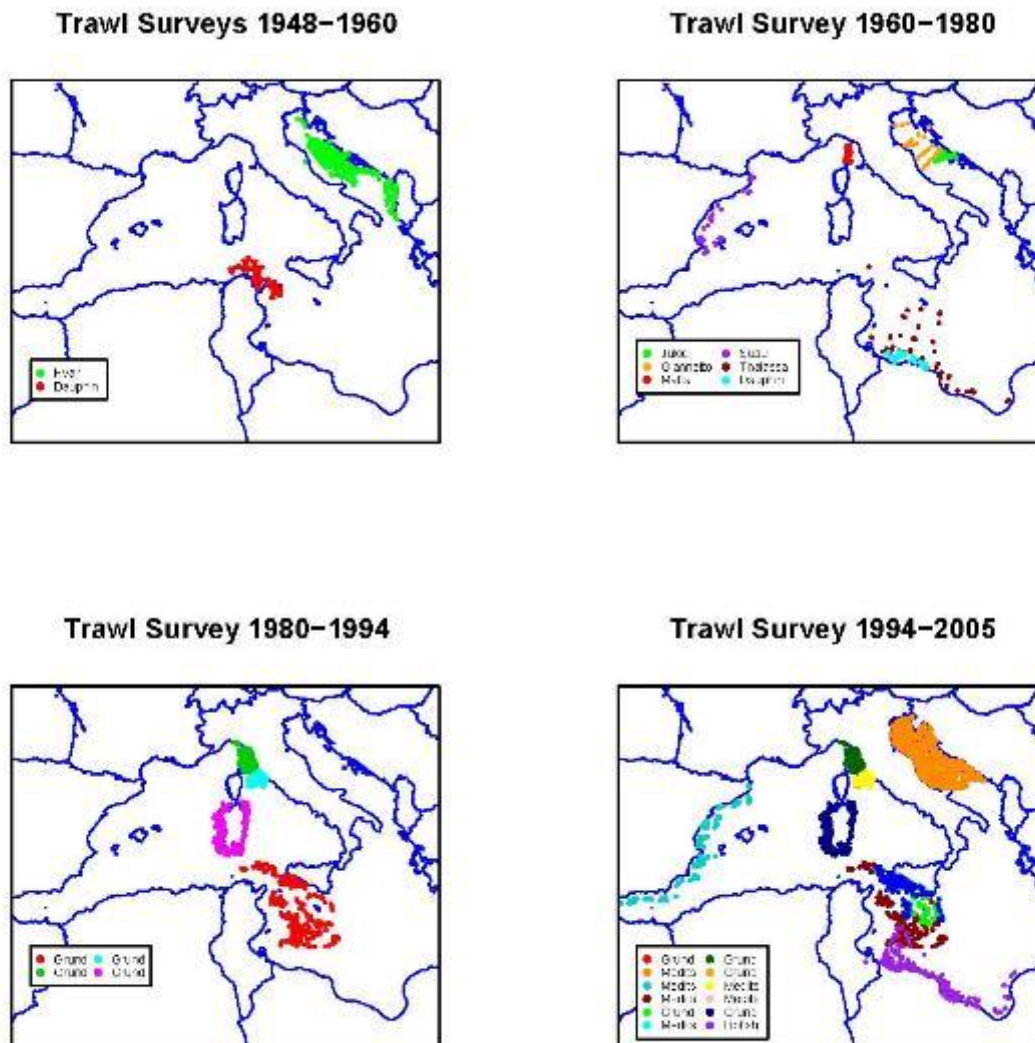




**Fig. 3.1.7 Trend in fishing effort and fishing depth in Spain, Italy and Greece in the period 1940-2008 (from Damalas et al., 2015).**

### 3.1.6 *Scientific trawl surveys*

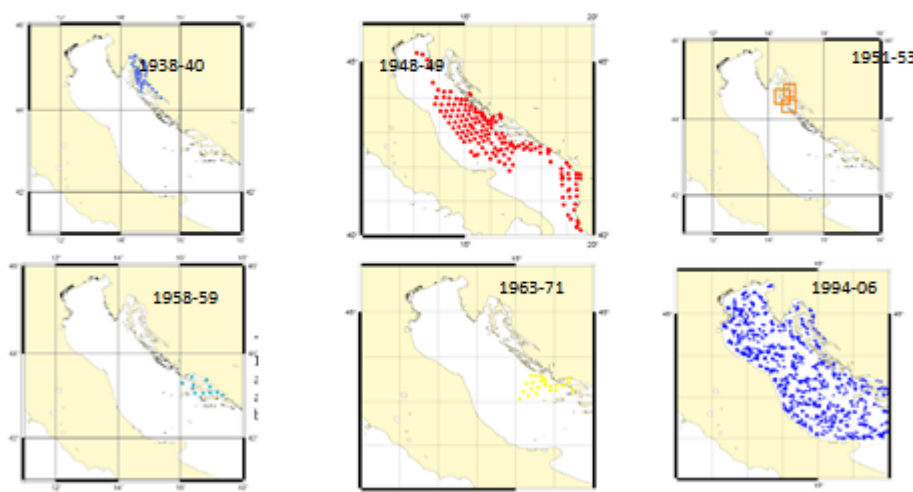
Bottom trawl surveys have been carried out in different areas of the Mediterranean since the 1920s. At the beginning these revolved mainly around gear testing or fishing ground exploration and the information collected was mostly reported by total catch. After the 1940s more systematic fishing ground exploration started with varying intensities across Mediterranean countries, and data started being reported at species level. In the 1980s more systematic surveys began but, until 1994, there was no standard sampling protocol until MEDITS was set up and started to make data available under the DCR/DCF. Figures 3.1.8 and 3.1.9 shows the location and time-frame of a selection of demersal surveys that have been done in the Mediterranean.



**Figure 3.1.8. Timeline of different bottom trawl surveys performed in the Western Mediterranean since 1948.**

The Adriatic Sea is also a comparatively ‘survey rich area’. Ferretti et al 2013 recovered most of the survey data and modelled trends in elasmobranch CPUE (Fig. 3.1.9). These data also contain information from the commercial fisheries that can be used, for example, for building tuning indices for stock assessment.

## Adriatic Trawl Surveys Identified



**Figure 3.1.9 Demersal trawl surveys performed in the Adriatic sea used in Ferretti et al. (2013)**

### 3.1.7 Auxiliary information

Environmental and meteorological 'oscillation' indices can potentially be used as auxiliary information for summarizing changes in recruitment or spawning in fish. A range of environmental indices are available that could be included as covariates in stock-recruitment relationships, or as indices of abundances along with various survey indices. A tentative list of such indices is given in Table 3.1.3.

**Table 3.1.3. List of tentative environmental and oscillation indices to be included in stock assessment models.**

Name of indicator	Abbreviation	Period available	Comments	Source
Atlantic Multidecadal	AMO	1856-present	Related to the patterns of SST variability in the North Atlantic	<a href="http://www.esrl.noaa.gov/psd/data/timeseries/AMO/">http://www.esrl.noaa.gov/psd/data/timeseries/AMO/</a>
Mediterranean Oscillation Index (Gibraltar/Israel)	MOI	1948-2013	Associated with Temperature and Precipitation Patterns	<a href="http://www.cru.uea.ac.uk/cru/data/moi/">http://www.cru.uea.ac.uk/cru/data/moi/</a>
Mediterranean Oscillation Index (Algiers/Cairo)	MOIAL	1948-2013	Associated with Temperature and Precipitation Patterns	<a href="http://www.cru.uea.ac.uk/cru/data/moi/">http://www.cru.uea.ac.uk/cru/data/moi/</a>

Western Mediterranean Oscillation Index	WEMOI	1821-2013	WeMOi has been correlated with sunshine variability and winter rainfall trends in the Western Mediterranean	<a href="http://www.ub.edu/gc/English/wemo.htm">http://www.ub.edu/gc/English/wemo.htm</a>
North Atlantic Oscillation	NAO	1950-present	Associated with Temperature and Precipitation Patterns	<a href="http://www.cpc.ncep.noaa.gov/data/teledoc/nao.shtml">http://www.cpc.ncep.noaa.gov/data/teledoc/nao.shtml</a>
satellite Chl-a concentration	CHL-A	1998 onward from MODIS A	Associated with primary production and can be adjusted to provide 'rates'.	<a href="http://www.oceancolor.gsfc.nasa.gov">http://www.oceancolor.gsfc.nasa.gov</a>
satellite Sea Surface Temperature	SST	1994 onward from AVHRR		<a href="http://www.eoweb.dlr.de:8080">http://www.eoweb.dlr.de:8080</a>

Different kinds of indices can be used for this purpose, taking into account species biology such as the relationship between spawning and/or recruitment with certain environmental variables like temperature or productivity. Such relationships are well documented for small pelagic fish but can also be helpful for other species. Environmental information is typically available at different temporal (e.g. monthly, quarterly, or annual) and spatial scales (e.g. latitude or longitude or 'region'). The choice of the appropriate temporal scale should be based on species biology (spawning period, recruitment period) and spatial distribution, e.g. mean productivity estimates within the bathymetric zone that coincides with the target species main distribution grounds.

Many of the indices record similar information. For example, the NAO index contains information that is included in the SST series. EWG15-06 notes that the inclusions of multiple sources of similar or correlated information will not improve the assessment model. It is therefore important to use only those indices that contain information *not* provided by other sources. A thorough investigation of all available environmental indices is required in order to identify the correlations amongst them and exclude the redundant ones.

Choosing meaningful and independent indices is probably the most challenging part of the work. Many methods are available to quantify the strength of associations between pairs of variables. The most familiar method for this purpose is correlation. Correlation, however, is only for quantifying the strength of a linear relationship and, in the real world, most relationships are non-linear and only approximately linear over a small range, meaning that correlation must be used with care. The EWG 15-06 suggested distance correlation (dcorr) (Székely et al., 2007) as more suitable than correlation to identify relationships between variables. However, it is possible that the distance correlation score between two independent data sets can be greater than zero, implying dependence, i.e. the chance of a Type I error (a false positive). An R script to apply distance correlation is available as supplementary information to this report.

An example of the a4a stock assessment approach (Jardim et al., 2014) used for anchovy and sardine stocks in GSA 22 is given below (Jardim et al. 2015). Indices were chosen based on the season corresponding to the period prior/beginning spawning for each species (See Table 3.1.4).

**Table 3.1.4. Environmental indices used in the a4a stock assessment model applied for anchovy and sardine stock in GSA 22 (Jardim et al. 2015)**

A4A assessment model	Auxilliary abundance Index	Covariate in SR relationship
Anchovy short time series	CHI-a 2nd trimester	SST 2nd trimester
Sardine short time series	CHI-a 4th trimester	SST 4th trimester
Anchovy long time series	CHI-a 2nd trimester	MOI 2nd trimester
Sardine long time series	SST 4th trimester	MOI 2nd trimester

### 3.1.8 *Policy changes in Mediterranean fisheries*

Over the last decades many changes have occurred in fishery policies related to technical measures, control and surveillance. These will have substantially affected both fishing activities at sea (e.g. closed seasons, gear regulations, etc.) and landings reporting. A clear summary of these policy changes should be drawn up in the form of a 'timeline' and this would be extremely helpful in the interpretation of the official trends in catch and effort.

### 3.1.9 *CASE STUDY: Comparing Italian ISTAT and DCR/DCF landings*

#### 3.1.9.1 Italy

The Italian government agency, ISTAT has done some important sampling work over the decades but unfortunately the spatial unit of sampling has changed. A number of important fish markets were, for example, covered between 1954 and 1955. Caution is, however, needed when trying to interpret these data, as ISTAT collected data at different spatial scales. Specifically, from 1960 to 1971 ISTAT collected data at Italian Province level, while from 1971 to 2000 sampling was carried out at Italian Maritime District level. Thus, to be able to compare these time series with DCR/DCF data at the GFCM statistical unit, it was necessary to reconcile Maritime District and Province at a GSA level. This was done according to the following structure, outlined for convenience in the R-code:

```
it.land$GSA <- ifelse(it.land$regione=="liguria" |
                     it.land$regione=="toscana" |
                     it.land$regione=="lazio" , "SA 9", it.land$GSAn)

it.land$GSA <- ifelse(it.land$regione=="campania" |
                     it.land$regione.amministrativa=="calabria tirrenica" |
                     it.land$regione.amministrativa=="sicilia nord" |
                     it.land$province=="palermo" |
```

```

        it.land$province=="cosenza" |
        it.land$province=="vibo valentia"|
        it.land$province=="torre del greco"
    |it.land$province=="gaeta" , "SA 10" , it.land$GSA )

it.land$GSA <- ifelse(it.land$regione=="sardegna" |
        it.land$regione.amministrativa=="sardegna" , "SA 11", it.land$GSA )

it.land$GSA <- ifelse( it.land$province=="trapani" |
        it.land$province=="porto empedocle" |
        it.land$province=="mazara del vallo"|
        it.land$province=="agrigento" |
        it.land$province=="ragusa" |
        it.land$province=="caltanissetta" |
        it.land$regione.amministrativa=="sicilia sud" , "SA 16", it.land$GSA )

it.land$GSA <- ifelse( it.land$regione=="veneto" |
        it.land$regione=="friuli-venezia giulia" |
        it.land$regione=="abruzzo"|
        it.land$regione=="marche"|
        it.land$province=="macerata" |
        it.land$province=="ascoli piceno" |
        it.land$regione=="emilia-romagna" , "SA 17", it.land$GSA )

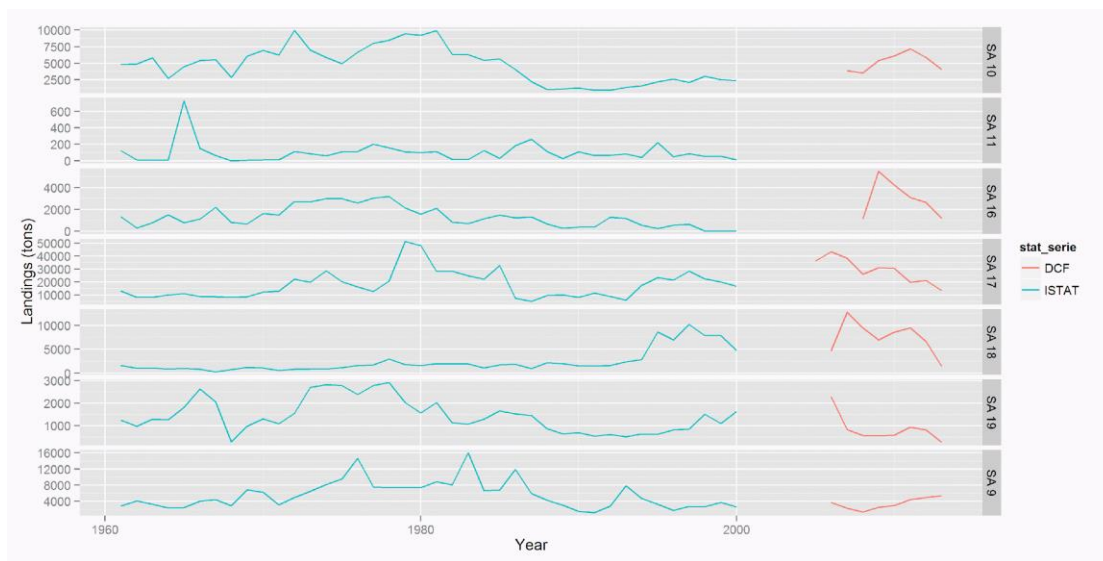
it.land$GSA <- ifelse( it.land$province=="manfredonia" |
        it.land$province=="molfetta" |
        it.land$province=="bari" |
        it.land$province=="brindisi" |
        it.land$regione=="basilicata" |
        it.land$province=="lecce" |
        it.land$province=="foggia" |
        it.land$regione.amministrativa=="puglia nord", "SA 18", it.land$GSA
)

it.land$GSA <- ifelse( it.land$province=="taranto" |
        it.land$province=="crotone" |
        it.land$province=="campobasso" |
        it.land$province=="catanzaro" |
        it.land$province=="reggio di calabria" |
        it.land$province=="siracusa"|
        it.land$province=="messina"|
        it.land$province=="catania"|
        it.land$province=="gallipoli"|
        it.land$province=="augusta"|
        it.land$regione.amministrativa=="calabria ionica"|
        it.land$regione.amministrativa=="sicilia est", "SA 19", it.land$GSA
)

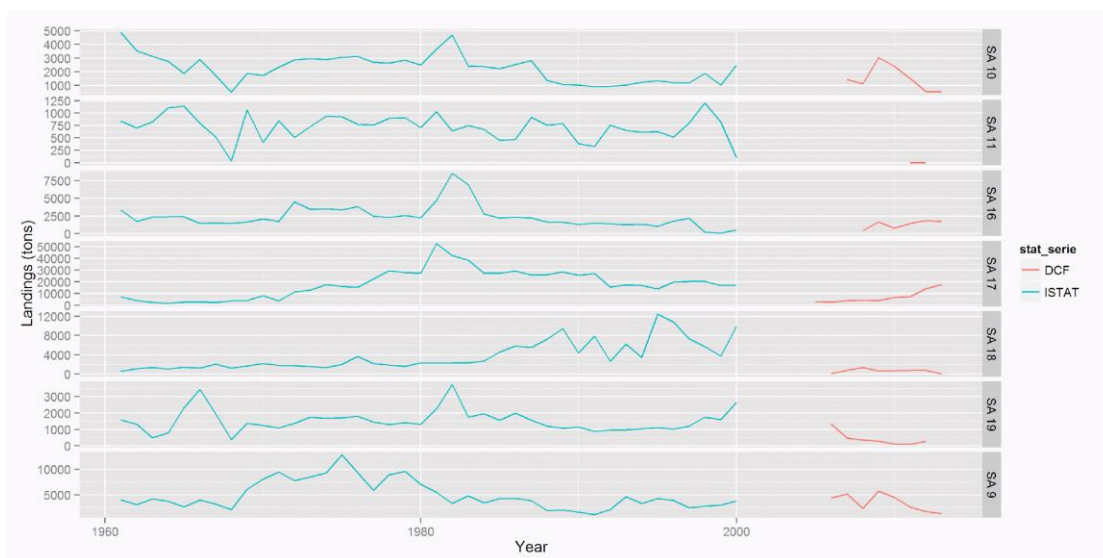
```

The 'spatially restructured' data were then compared at GSA level for some selected species where the reliability of species identification was most assured. The selected species are sardine (Fig. 3.1.10.), anchovy (Fig. 3.1.11), Mediterranean hake (Fig. 3.1.12.), Norway lobster (Fig. 3.1.13), giant red shrimp (Fig. 3.1.14) and deep-water rose shrimp (Fig 3.1.15). Landings data from DCF were extracted from the Catch at age table from the JRC data call from STECF EWG 14-09 and aggregated by species, GSA and year over métier, mesh size, fleet segment, and gear to make it comparable.

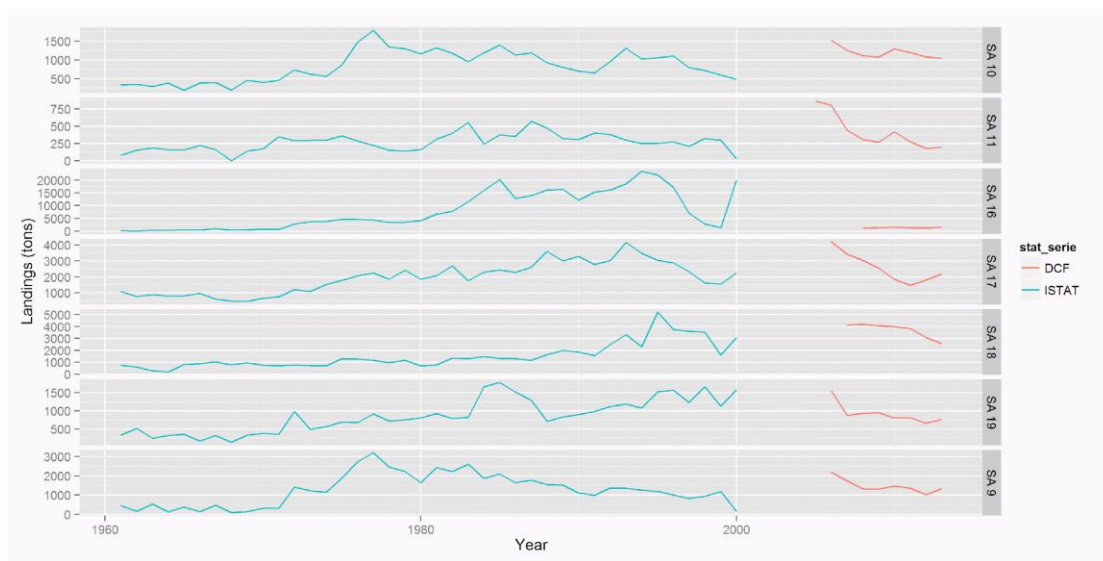
We explored the consistency of the trends and the alignment of the levels of the landings, despite a data gap between 2001 and 2005. This period was in between ISTAT and DCR data collection and it is not included in the past EC Mediterranean and Black Sea data calls.



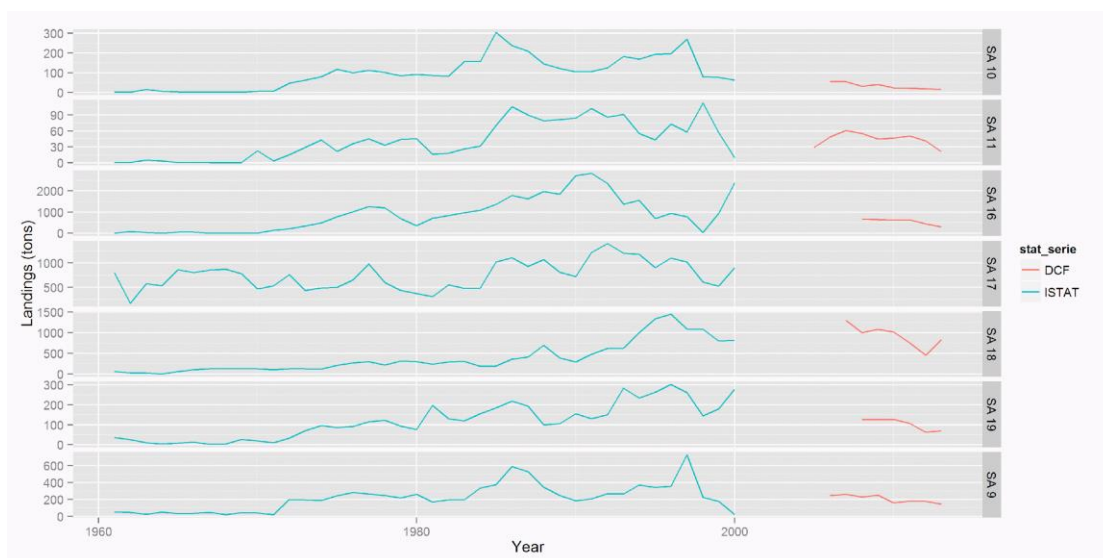
**Fig 3.1.10 Landings of Anchovy from ISTAT and DCF by GFCM GSA**



**Fig. 3.1.11 Landings of Sardine**

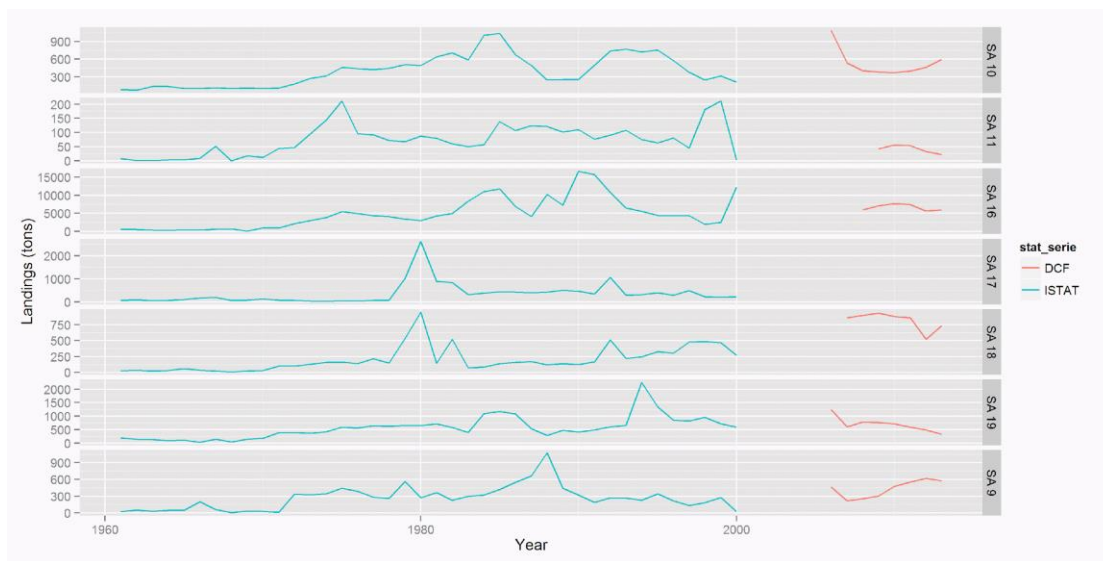


**Fig 3.1.12 Landings of Mediterranean hake from ISTAT and DCF**

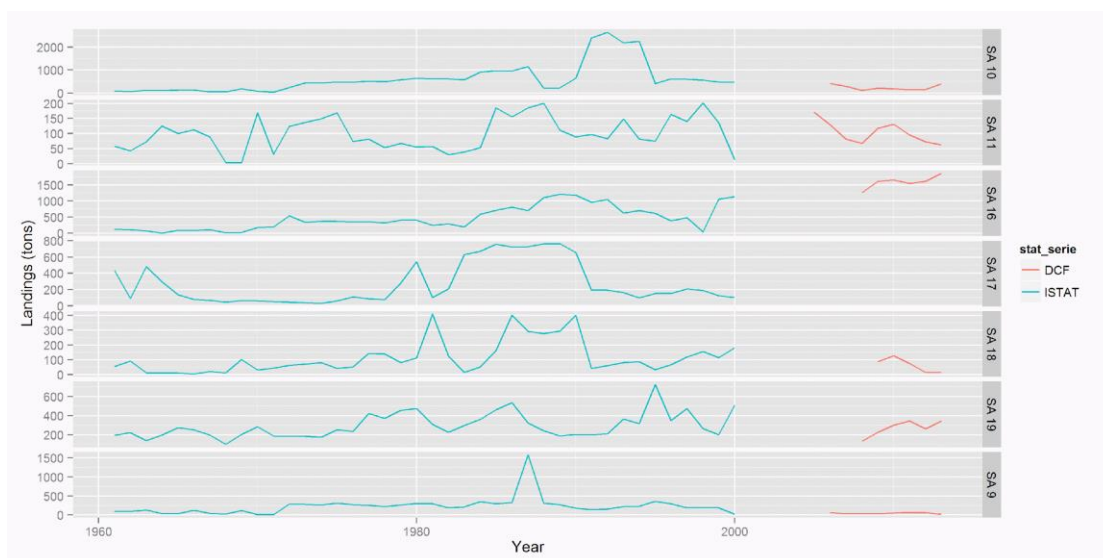


**Fig 3.1.13. Landings of Norway lobster from ISTAT and DCF**





**Fig 3.1.14. Landings of Deep Water rose shrimp**



**Fig. 3.1.15. Landings of Giant Red Shrimp from ISTAT and DCF.**

### 3.1.10 *Conclusions on ToR1*

See file Conclusions\_of\_the\_EWG15-06.docx

### 3.1.11 *EWG suggestions and guidelines*

See file Advice-and-recommendations-of-EWG15-06.docx

### 3.1.12 *References (ToR 1)*

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### 3.2 ToR 2 Revision R scripts for survey index stratification and age slicing

- To check and revise the R code developed by Osio, Rouyer, Bartolino and Scott (<https://github.com/drfinlayscott/R4Med>) to extract MEDITS numbers at length and produce stratified numbers. Set up a best practice standardized procedures for slicing methodology to be used in reconstructing times series of number at age data derived from catches and surveys for future stock assessment of Mediterranean stocks.

#### 3.2.1 Introduction

The work for ToR 2 covered the following two main issues:  
:

1. To check and revise the R scripts to extract MEDITS stratified numbers and length
2. The conversion ('age-slicing') of numbers-at-length data (MEDITS and catch data to numbers-at-age for use in stock assessment models.

The exploration of these issues was divided into the following two separate sections in the report: i) Extracting stratified numbers and length from the MEDITS data and ii) Converting numbers-at-length to numbers-at-age (age slicing).

#### 3.2.2 Extracting stratified numbers and length from the MEDITS data.

MEDITS sample design is a simple random sample stratified according to depth, with random allocation of the haul and the total numbers of hauls is proportional to the areas of each bathymetric layers

MEDITS protocol (MEDITS Handbook 2013) stated that the stratified numbers and length should be estimated according to the formulae of Souplet (1996) for a random stratified sampling design:

$$\bar{x}_i = \frac{\sum_{j=1}^{n_i} x_{i,j}}{\sum_{j=1}^{n_i} A_{i,j}}$$

(1)

Mean by stratum:

where:  $x_{i,j}$  is the weight of the individuals caught in the haul at each stratum and  $A_{i,j}$  is the

swept area of each haul in each stratum.

The abundance index by strata (shelf, slope and total area) is then calculated according to Pennington and Brown (1981):

$$I = \sum_{i=1}^N W_i \bar{x}_i$$

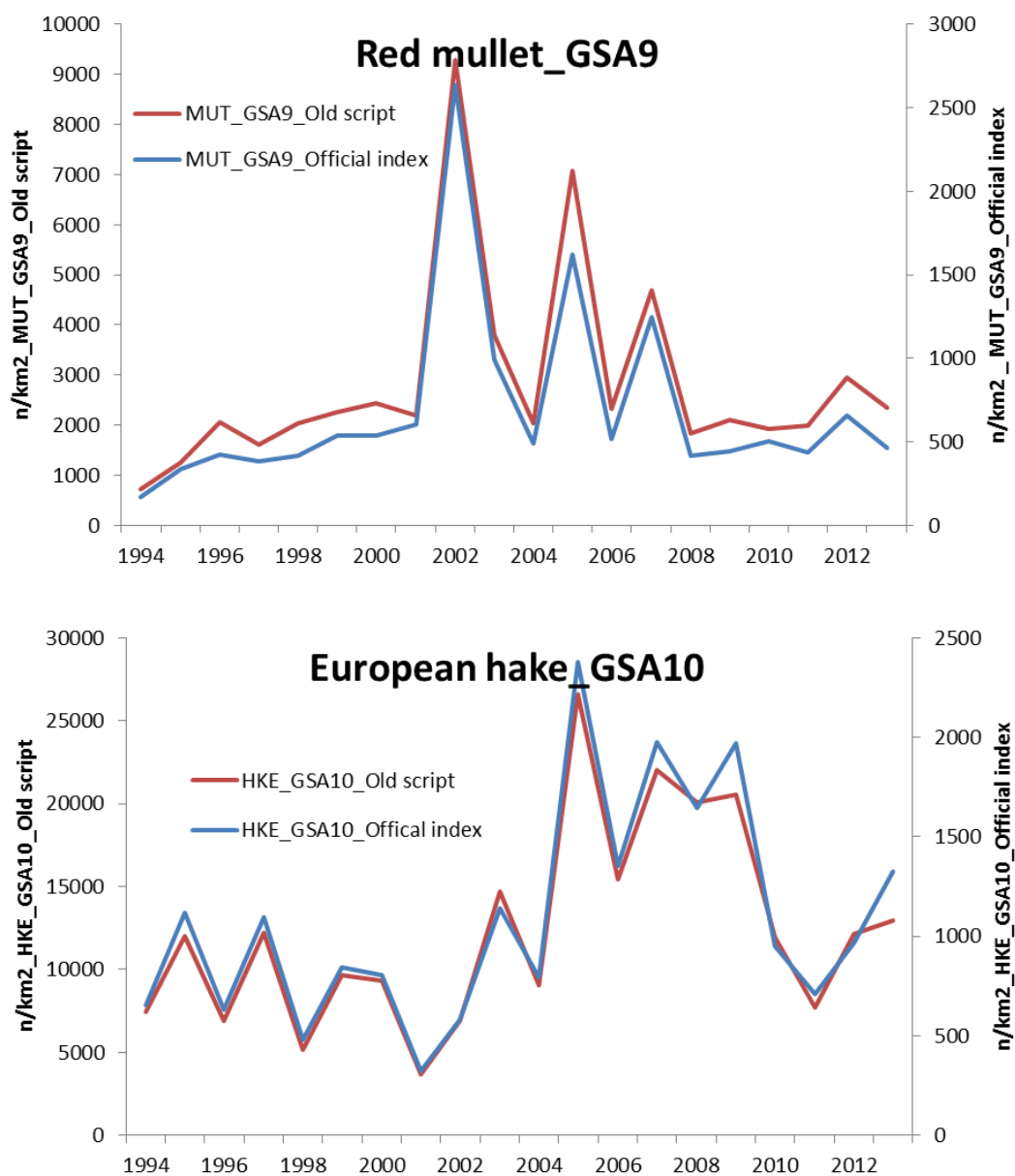
(2)

where  $W_i$  is the weight of each single stratum estimated as the ratio between the area of the stratum and the total area of the GSA.

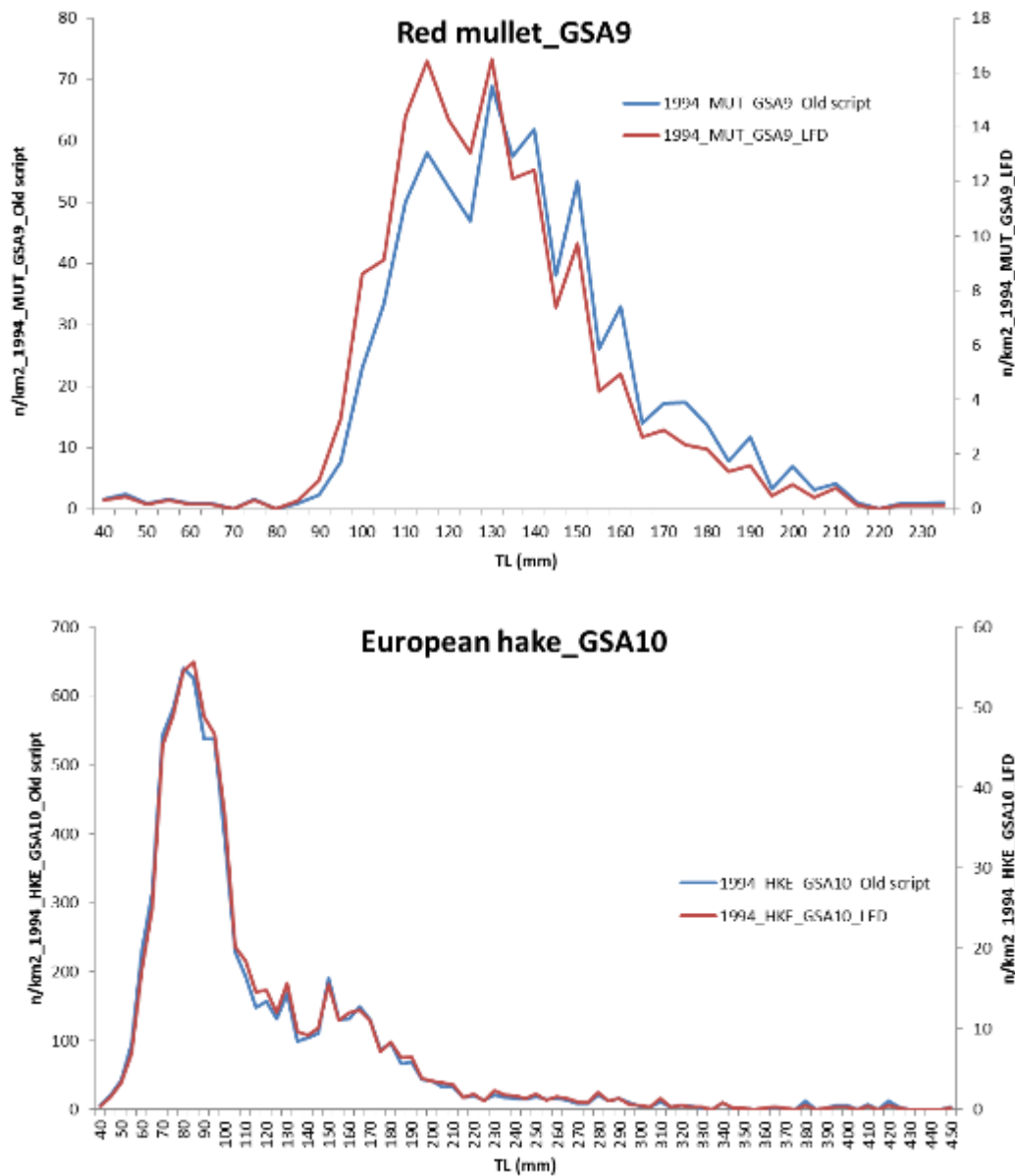
MEDITS abundance indices and standardized length-frequency distributions are available for the Italian GSAs from the “*Annuario sullo stato delle risorse e sulle strutture produttive dei mari italiani*” (Anonymous, 2015) and from the web-based platform (FISHTRAWL) used by the MEDITS project. EWG 15-06 used these freely available datasets to test the R code developed by Osio, Rouyer, Bartolino and Scott (<https://github.com/drfinlayscott/R4Med>). Two GSAs, GSA9 (Ligurian and Northern Tyrrhenian seas) and GSA10 (Southern Tyrrhenian Sea), and two species, *Merluccius merluccius* (European hake) and *Mullus barbatus* (Red mullet) were chosen for the comparisons.

The FISHTRAWL estimates were identical to the estimations reported in the *Annuario delle risorse*, while the comparison with the output from the routine used by EWG1506 also showed a very similar pattern, but highlights the differences in magnitude of the standardized density indices (Fig.3.2.2) and of the standardized length distributions (LFD) for both GSAs and species (Fig. 3.2.3).





**Fig.3.2.2. Time series of the MEDITS density indices estimated for red mullet (GSA9) and European hake (GSA10). The left axes show outputs from the ‘routine’ described in the text and on the right the “official” versions.**



**Fig.3.2.3. Standardized number per length class for red mullet (GSA9) and European hake (GSA10). Year 1994. The left axes are the output obtained by the routine and on the right axes the “official” ones.**

When we analyzed the computer codes for the ‘routines’ the values assigned as the weight of each stratum ( $W_i$  in formula 2) appeared to be wrong which caused the difference in magnitude among the indices. In the original R script (Osio, Rouver, Bartolino, and Scott) sex differences were not taken in to account. Most fish species show differential growth rates by sex it and if this were taken into account stock assessments could be improved.

The three R scripts available before the meeting: i) `std_indexMEDITS18_07_2014.R`, ii) `db_connection_16_07_2014FINAL.R` and iii) `stratifiedmeans16_07_2014.R`) did not easily allow changes in the calculation of the indices to be made. EWG1506, therefore, decided to rewrite part of the code.

The main goals for the new code were to: i) obtain correct estimations of the indices; ii) allow indices to be calculated by sex; iii) link this new routine with the slicing routine; and iv) to simplify the code which was hitherto un-necessarily complex.

### 3.2.3 *Results (extraction)*

The new routine (`LFD_4_EWG.R`) developed by EWG1506 allows the extraction of data by multiple GSAs and species, both from text-files (.csv, .txt) and databases MS Access (.mdb). To run it is necessary to first set the parameters needed to filter and extract the LFD, see extract below:

```

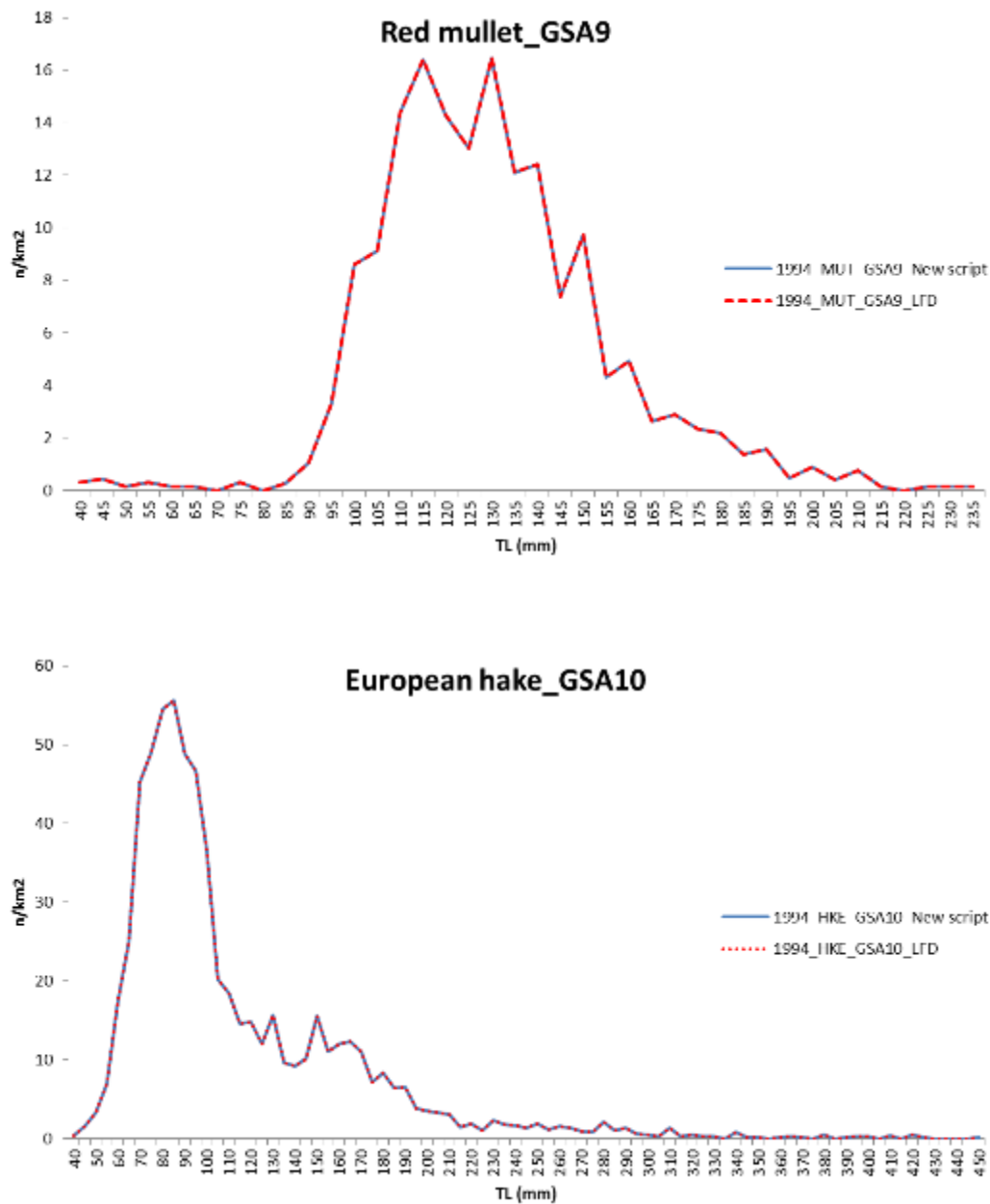
44 - # MODIFY this section to set the parameters needed and run the script below ####
45 # set an output code for the meeting
46 EWG <- "EWG1506_" # code for the current meeting
47
48 # do you like to split sex?
49 sex.by <- "n" # sex combined
50 # sex.by <- "y" # split by sex
51
52 # how many species and how many GSAs?
53 hm.sp <- 2 # two species
54 # hm.gsa <- 1 # one subarea
55 hm.gsa <- 2 # two subareas
56
57 # select area (GSA) and species according to MEDIST standard species coding
58 # which species?
59 spp <- c("MERL MER", "MULL BAR") # to select the ONE or MORE species
60 nspp <- c("Merluccius merluccius", "Mullus barbatus")
61 codspe <- c("HKE", "MUT")
62
63 # which GSAs?
64 gsa <- c("16", "9") # to select ONE or TWO GSAs
65
66 # which length unit? (ACTIVE ONLY ONE)
67 len.unit <- "cm" # choose between "mm"=millimeters and "cm"=centimeters
68 # len.unit <- "mm" # choose between "mm"=millimeters and "cm"=centimeters
69
70 # The source of raw data can be an access or a csv table.
71 # Since it is difficult to filter long csv tables (i.e. tc files), it is necessary
72 # to load the whole dataset. This takes the csv option much longer.
73 # MDB, instead, can be easily filtered by an sql query
74 #
75 # Here we set which type of dbtype we are going to use as source of raw data.
76 # Default is mdb (it should be faster!)
77 dbtype <- "mdb"
78 database <- "Surveys.mdb"
79 # dbtype <- "csv"

```

Having set the parameters the procedure starts and the function (LFD\_fun.R) calculates the LFD. The outputs include, both the \*.png plot, and the \*.csv table of stratified N at length (stratified\_N@len).

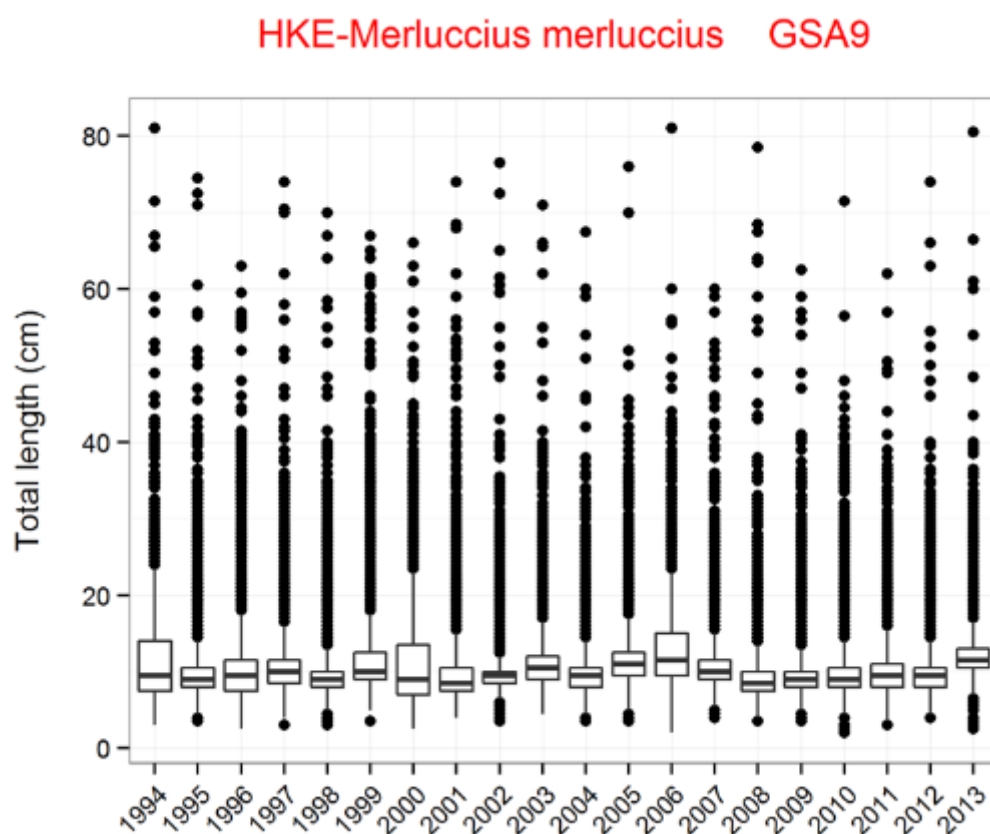
The routine was tested using a computer with the following specifications: Processor i7-4558U CPU @ 2.80 Ghz (RAM 8.00 GB, System Type 64-bit). We found that the time requested to extract the raw data (2 species for 2 GSAs) was much faster when accessing the mdb database directly. For this reason the dbtype parameter was set by default as “mdb” (ie. archive Surveys.mdb).

The standardized length-frequency distribution, obtained with the LFD4EWG.r routine completely overlap the GSAs estimation (3.2.4)



**Fig.3.2.4. Comparison of the standardized number per length class for red mullet (GSA9) and European hake (GSA10) obtained with the new routine (year 1994).**

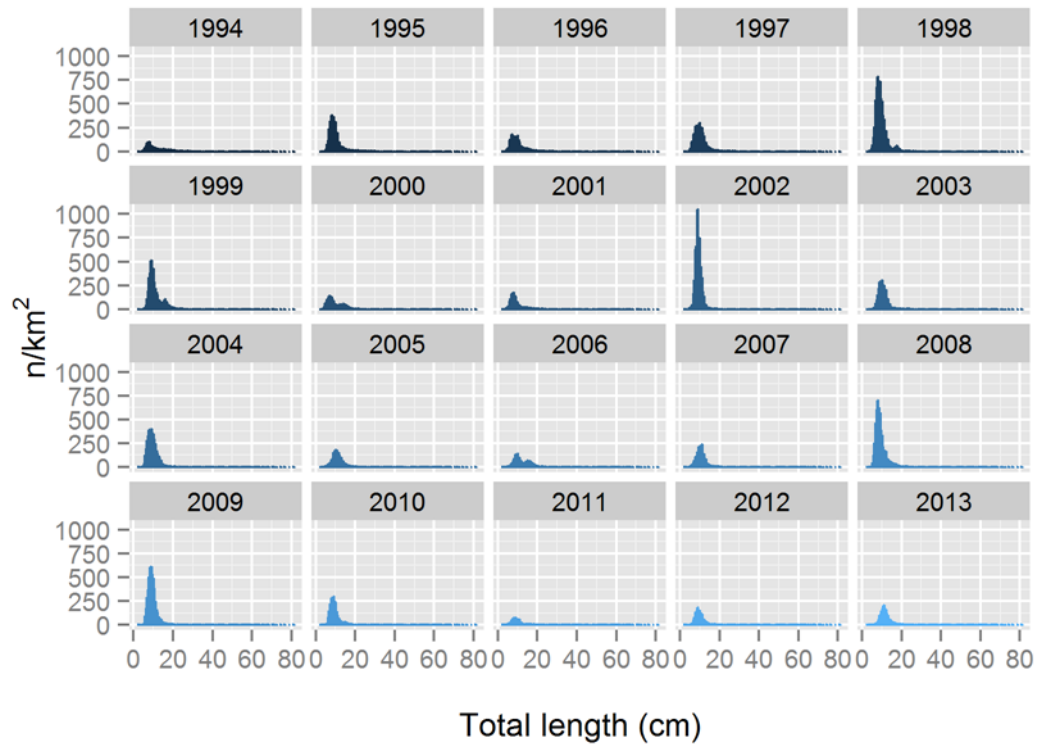
The stratified numbers at length distribution by year and sex obtained with the new routine are plotted in Fig. 3.2.5. The boxplot (Fig. 3.2.5) and the length distribution of stratified numbers by year and sex (Fig 3.2.6) are shown here as an example of the new routine's



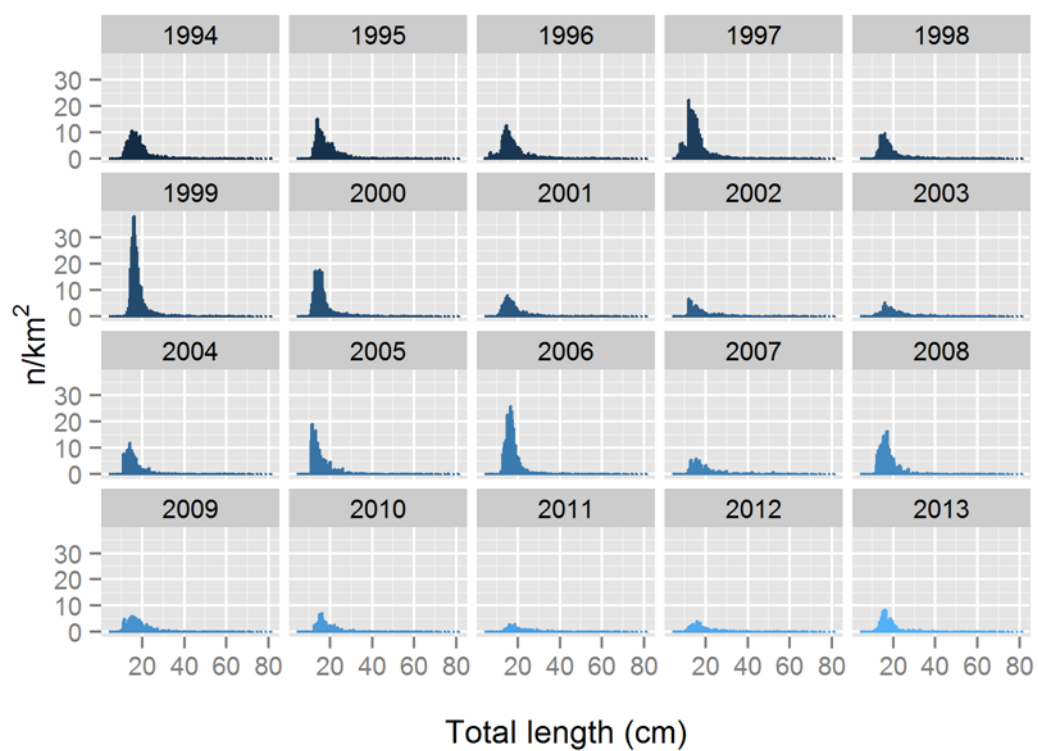
output.

**Figure 3.2.5. Boxplot of standardized lengths obtained with the LFD\_4\_EWG routine for European hake (GSA9, sexes pooled) from the MEDITS time-series.**

# HKE-Merluccius merluccius GSA9

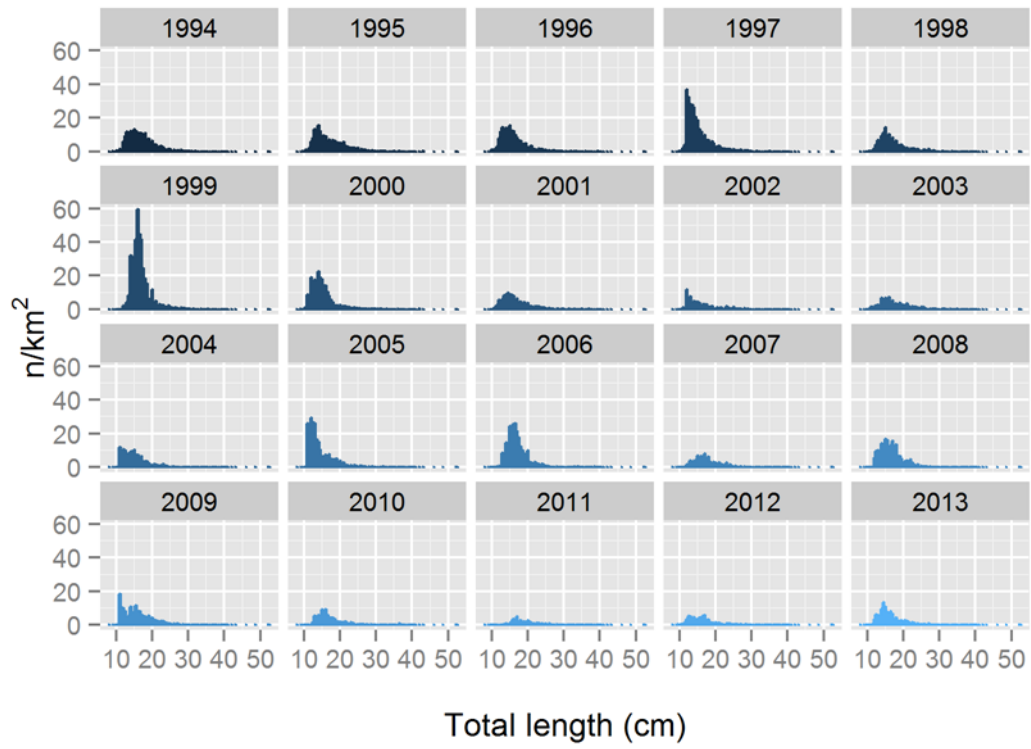


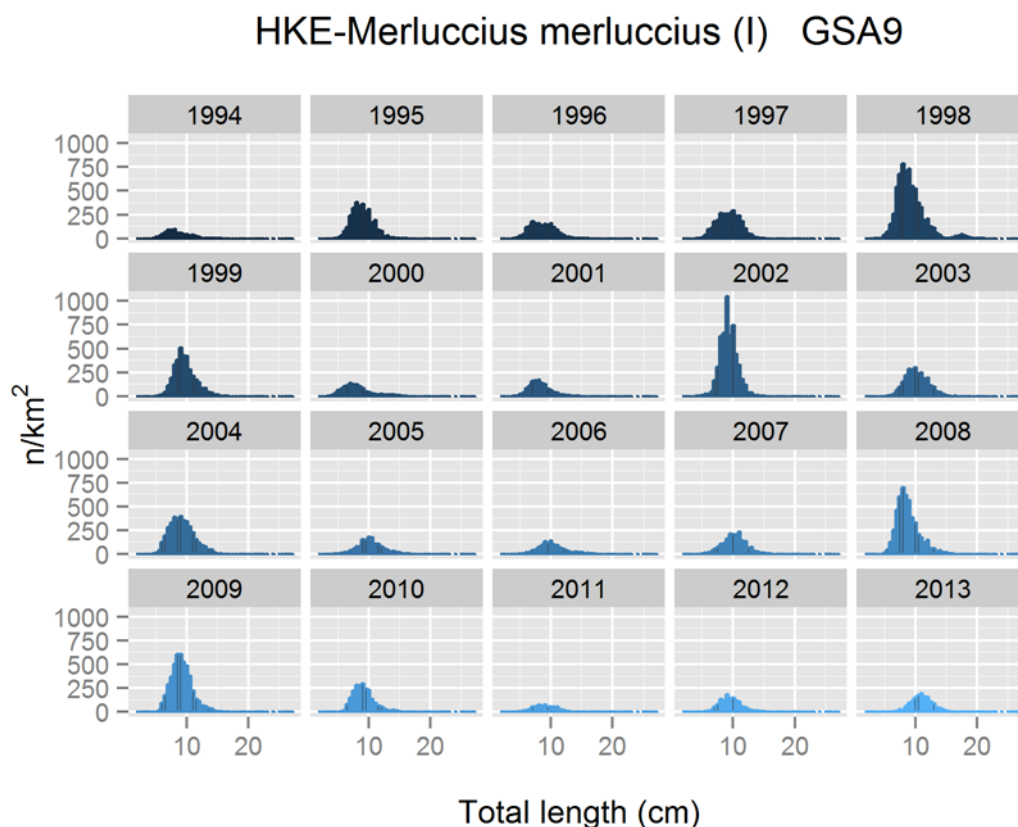
# HKE-Merluccius merluccius (F) GSA9





# HKE-Merluccius merluccius (M) GSA9





**Figure 3.2.6. Standardized length-frequencies by year obtained with the LFD\_4\_EWG routine for European hake (GSA9) pooled (top) and by sex (F=female, M=male, I=not determined) .**

Testing of the new code for extracting MEDITS stratified numbers and length was successful. The LFD\_4\_EWG.r script allows the user to obtain a ‘graphical standard format’ for the length-frequency distributions output together with an output file suitable for populating the ‘age-slicing’ routine.

### 3.2.4 *Converting numbers-at-length to numbers-at-age (age slicing)*

The following three methods are currently used by the SGMED group:

- Deterministic FAO proportional
- Deterministic knife-edge
- Statistical slicing (fitting distributions)

The deterministic FAO proportional method is based on the slicing technique described in

Sparre and Venema (1998). The method involves building the age-length key (ALK – the proportions of fish in a length class that are allocated to each age class) from ‘von Bertalanffy’ growth parameters. This is then applied across the numbers in each class for each year. For example, if the length class interval is 1 cm, and one-year old fish are 12.6 cm (according to the growth function), then of the fish in the 12-13cm interval, 0.6 of them are allocated to age group 0, and 0.4 of them are allocated to age group 1. This method is currently used by the SGMED group to convert the standardized numbers-at-length data extracted from the MEDITS data to numbers-at-age, to be used as tuning indices in a stock assessment. The method is simple to use and can be used with any numbers-at-length data. It can also be used automatically, i.e. without interaction with the user.

The deterministic knife-edge method is similar to the FAO proportional method in that it is based on applying a growth curve according to von Bertalanffy (SP) which is used to calculate the length in the middle of the length class to age. This age is then rounded down to the nearest integer, e.g. an age of 0.9 is rounded down to 0 (Kell and Kell, 2011; Scott *et al*, 2011). This method is currently used by the SGMED group to convert the catch data from the DCF database to numbers-at-age to be used in stock assessment. The method is straightforward to use and can be applied to any numbers-at-length data. It can also be used automatically, i.e. without any interaction with the user.

The statistical slicing method is different to the previous two methods in that it involves the fitting of distributions to the length-frequency data (Macdonald, 2011). The method is not straightforward to use and requires interaction from the user to decide what type of distribution to fit, which parameters to fix, and what the initial values should be. These decisions can have a strong impact on the result. It is therefore necessary for the user to perform multiple fits with different assumptions and compare the results. There are thus strong data requirements for the method to be successfully used (Scott *et al*, 2011). Moreover there must be clear modes in the length-frequency data or else the fitting will fail which means that it cannot be used to process individual haul data, unlike the deterministic methods described above.

It has been suggested that the deterministic knife-edge method estimates lower numbers-at-age in the low ages than the statistical slicing method (Kell and Kell 2011; Scott *et al*, 2011). However, the statistical slicing is not appropriate for all cases, given the level of required user input and data requirements.

A fourth method is also available in the 'a4a' approach (Jardim *et al*, 2014). This method is similar to the deterministic FAO proportional method. It offers, however, three potential advantages. It is not restricted to using the von Bertalanffy growth function and can use other growth models, if the parameters are available. It is possible to include stochasticity on the parameters of the growth model, for example by assuming a statistical ‘distribution’. This stochasticity represents process uncertainty (Francis and Shotton, 1997); a key concern in stock assessments. The uncertainty in the growth model parameters is then propagated through to the resulting numbers-at-age and can be used by the chosen stock assessment model. Finally, the 'a4a' approach has been implemented using the FLR framework making it easier to generate data ‘objects’ that can then be used by the stock assessment methods available in FLR. The code is available in the FLa4a package.

### 3.2.5 *Conclusions (ToR 2)*

See file Conclusions\_of\_the\_EWG15-06.docx

### 3.2.6 *Recommendations (ToR 2)*

See file Advice-and-recommendations-of-EWG15-06.docx

### 3.2.7 *References (ToR 2)*

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Sparre, P. and Venema, S. C., 1998, Introduction to Tropical Fish Stock Assessment, FAO Fisheries Technical Paper 306/1 Rev. 2, Food and Agriculture Organisation of the United Nations, Rome.

### **3.3 ToR 3 - Carry out a sensitivity analysis of the impact of different assumptions on selectivity (i.e. dome shaped, logistic, etc) on the estimation of SSB and F for multi-gear fisheries of hake and red mullet in GSA 5, 6, 7, 9, 10, 16, 17, 18, 22, 25.**

#### *3.3.1 Introduction*

FAO defines selectivity as the ‘Ability to target and capture fish by size and species during harvesting operations, allowing by-catch of juvenile fish and non-target species to escape unharmed. In stock assessment, it is conventionally expressed as a relationship between retention and size (or age) with no reference to survival after escapement’. From an assessment method perspective selectivity is the combination of mechanical selection (i.e., the probability of retention of a fish when it encounters a gear) and availability (i.e., the probability a fish is present in the area and at the time a fishery is conducted). Selectivity is influenced by a combination of confounding processes including fishing gear characteristics, fish behavior, and spatial heterogeneity in the distribution of different sizes/ages of fish and the spatial distribution of the fishery (or sampling).

Beside the progress in experiments with fishing gear, aimed at understanding the complex, and often confounded interactions between these processes, estimation of selectivity remains one of the major challenges for the class of stock assessment model that depends on such information; namely Stock Synthesis (SS3) which is used for some stocks in the Mediterranean.

ICES (2012), classified SS3 as, an ‘Integrated Assessment model with age-structured population dynamics’. This class of stock assessment method allows the estimation of selectivity curve parameters integrated with the estimation of a number of other parameters, which represents a more detailed reconstruction of the stock dynamics, accounting for interaction across several processes such as growth, natural mortality, and recruitment. The drawbacks of such a detailed approach are the data requirements and the increasing number of parameters to be estimated in order to disentangle the effect of competing processes. Generally only short time series of fisheries data are available in the Mediterranean for stock assessments.

In a recent workshop carried on by the Center for the Advancement of Population Assessment Methodology (CAPAM, 2013) the issue of selectivity for stock assessment has been thoroughly reviewed and a number of considerations made, based on a large number of case studies and considerable expertise participation. The functional form assumed for selectivity is recognized as having a large potential impact on the reconstruction of any fish population based on this class of stock assessment model. An important part of the issue is concerned with the choice of, either a dome shaped, or asymptotic selection curve (i.e. logistic). Ideally, scientific surveys should be able to sample the entire range of lengths/ages of a fish stock with an increasing asymptotic selectivity. Accordingly to Maunder et al (2015), if dome-shape selectivity is estimated for all gears, a ‘cryptic’ biomass phenomenon may arise, which may translate into population estimates for older fish that are not proportional to those observed through sampling efforts. Assuming dome-shaped selectivity for all fisheries and surveys is inherently confounded with assumptions surrounding natural mortality, and will typically increase the uncertainty of any abundance estimate.

Another problem concerns the effect of using a multi-fleet approach versus a single fleet approach. In the context of integrated assessment methods, Punt et al. (CAPAM report) recommend defining as many fisheries as practical, and then applying model selection techniques to determine which fisheries should have selectivity estimated, and those that should 'share' selectivities with related fisheries.

One of the needs in Mediterranean fisheries management is to have short term forecasts by fishing fleet. One of the appealing points of an integrated assessment is that it produces individual fleet based estimates which could be used to produce short term forecasts. However, using integrated assessments is not the only way of producing fleet based forecasts. Via portioning of the mortality at age with the catch at age matrix by fleet, the partial fishing mortalities can be derived and then used for fleet based forecasting. Examples and code are summarized in the JRC technical report by Jardim et al 2014 ([http://stecf.jrc.ec.europa.eu/c/document\\_library/get\\_file?uuid=8c3e3651-7bd9-42ff-8cf2-7db66025d3c6&groupId=43805](http://stecf.jrc.ec.europa.eu/c/document_library/get_file?uuid=8c3e3651-7bd9-42ff-8cf2-7db66025d3c6&groupId=43805))

### 3.3.2 *The Approach*

In light of the considerations presented above, the working group applied a number of different modelling tools to address TOR3, which was approached as follows:

- The effect on SSB and F estimation of using a single-fleet or multi-fleet model was explored with 'SS3' (see section below for description).
- The effect of different selectivity shapes, for both survey and fishing fleet, on the Spawning Stock Biomass and on F, was assessed using SS3. For comparison purposes, the SSB and F estimates from SS3 under the different selectivity assumptions were compared with those estimated by XSA (VPA) and a4a (statistical catch-at-age).
- Finally, the impact on SSB and F of different parameterization of the dome-shaped curve was explored using a simulation approach (i.e. ALADYM, transitional analysis in VIT).

To address TOR3, *Merluccius merluccius* (European hake) and *Mullus barbatus* (red mullet) in GSA17 were used as case studies. The models fitted were:

- Random walk selectivity for both surveys and fishing fleets (i.e. multifleets); [[not converged]]
- Logistic selectivity for the fishing fleets and random walk for the surveys (i.e. multifleets); [not converged]]
- Double normal selectivity for the fishing fleets and random walk for the surveys (i.e. multifleets); [not converged]
- Logistic selectivity for both surveys and fishing fleets (i.e. multifleets); [not converged]
- Double normal selectivity for both surveys and fishing fleets (i.e. multifleets); [not converged]

- Random walk selectivity for both surveys and for an aggregated “single” fishing fleet; (i.e. single pseudo-fleet)[converged]
- Random walk selectivity for both surveys and a logistic selectivity for the aggregated “single” fishing fleet; (i.e. single pseudo-fleet)[not converged]
- Random walk selectivity for both surveys and a double normal selectivity for the aggregated “single” fishing fleet; [converged]

### 3.3.2.1 Summary and results of all assessment runs

**Table 3.3.1. Summary of assessment runs on hake and red mullet in GSA 17 highlighting the impact of selectivity decisions.**

GSA	Species	Age class	Time series	Model	Assumption on selectivity	Fleet	% change SSB*	CV**	% change in F***
17	<i>M. barbatus</i>	0-6	1970-2013	SS3	Fleet and survey: Logistic	Single Fleet	-70.8	0.14	-2.4
17		0-6	1970-2013	SS3	Fleet and survey: Dome-Shaped	Single Fleet	225.4	0.16	-87.8
17		0-6	1970-2013	SS3	Fleet and survey: Random-Walk	Single Fleet	-47.0	0.23	4.9
17		0-6	1970-2013	SS3	Fleet: Dome-Shaped, Survey: Logistic	Single Fleet	-79.3	0.06	17.1
17		0-6	1970-2013	SS3	Fleet: Random-Walk; Survey: Logistic	Single Fleet	-50.3	0.05	-46.3
17		0-6	1970-2012	SS3	Fleet and survey: Logistic	Multi Fleet	-35.2	0.05	13.4
17		0-6	1970-2013	SS3	Fleet and survey: Dome-Shaped	Multi Fleet	47.7	0.14	-7.07
17		0-6	1970-2013	SS3	Fleet and survey: Random-Walk	Multi Fleet	reference run	0.14	
17		0-6	1970-2013	SS3	Fleet: Dome-Shaped, Survey:	Multi Fleet	-61.5	0.08	43.9



					Logistic				
17		0-6	1970-2013	SS3***	Fleet: Random-Walk; Survey: Logistic	Multi Fleet	Not converged	–	
17		0-6	2000-2013	a4a		Single Fleet	-31.4		59.8
17		0-6	2000-2013	XSA		Single Fleet	-24.9		85.4
17	<i>M. merluccius</i>	0-10	1983-2013	SS3***	Fleet: Logistic; Survey: Random Walk	Single Fleet	Not converged	–	
17		0-10	1983-2013	SS3***	Fleet: Double Normal; Survey: Random Walk	Single Fleet	Not converged	–	
17		0-10	1983-2013	SS3	Fleet and survey: Random-Walk	Single Fleet	20.7	0.19	2.8
17		0-10	1983-2013	SS3***	Fleet: Logistic; Survey: Random Walk	Multi Fleet	Not converged –	–	
17		0-10	1983-2013	SS3	Fleet: Double Normal; Survey: Random Walk	Multi Fleet	-36.8	0.05	200.1
17		0-10	1983-2013	SS3	Fleet and survey: Random-Walk	Multi Fleet	reference run	0.15	
17		0-10	1983-2013	SS3	Fleet and survey: Double normal	Multi Fleet	Not converged		
17		0-10	1983-2013	SS3	Fleet and survey: Logistic	Multi Fleet	Not converged		

\* % change in the average SSB over the last three years compared to the reference run

\*\* CV of the estimate of SSB in the last year

\*\*\* Red mullet GSA 17 F in 2011 compared to the reference run; Hake GSA 17, F in 2012 compared to the reference run

### 3.3.3 *Modeling tools*

#### 3.3.3.1 Stock Synthesis 3

Stock Synthesis 3 (SS3) provides a statistical framework for the calibration of a population dynamics model using fishery and survey data. It is designed to accommodate both population age and size structure data. Multiple stock sub-areas can also be analyzed. It projects the relevant population forward in time in the so-called “statistical catch-at-age” (hereafter SCAA) approach. SCAA estimates initial abundance at age, recruitments, fishing mortality and selectivity. In contrast to VPA-based approaches (e.g. by XSA) SCAA calculates future abundance and allows for errors in the catch-at-age matrices. Selectivity is generated as age-specific by fleet, with the ability to capture the major effect of age-specific survivorship. The overall model contains subcomponents which simulate the population dynamics of the stock and fisheries, derive the expected values for the various observed data, and quantify the magnitude of difference between observed and expected data. SS3 features include ageing error, growth estimation, spawner-recruitment relationships, and movement between areas; although in the present assessment such features are not summarized in the results. The ADMB C++ software, in which SS is written, searches for the set of parameter values that maximize the goodness-of-fit, then calculates the variance of these parameters using inverse Hessian methods.

#### 3.3.3.2 A4A

A4 is a stock assessment framework based on a statistical catch-at-age model developed under the JRC initiative, ‘a4a’ (<https://fishreg.jrc.ec.europa.eu/web/a4a>). The framework allows the user to set the structure of sub-models for fishing mortality, abundance indices, stock-recruitment relationships, population in the first year of the data, and variance components of catch-at-age and survey indices. All the sub-models are defined through the equation interface of R and can use most of the linear modelling tools, including GLMs and GAMs. The method assumes log-normal error in catch-at-age and abundance indices. The estimation is performed using automatic differentiation implemented by ADMB.

#### 3.3.3.3 XSA

Extended Survivors Analysis (XSA), (Shepherd, 1992), an extension of Survivors Analysis (Doubleday, 1981), is a VPA-like method that overcame some deficiencies of the classical VPA. In particular, it reduces the sensitivity to observation error in the final year. XSA is tuned by a weighted least-squares minimisation of discrepancies between survey and catch estimates of final year survivors. It also allows for ‘shrinkage towards the mean’. The detailed algorithm is presented in Darby and Flatman (1994). The model was run in R, using the FLXSA package contained in the FLR library.

#### 3.3.3.4 VIT

VIT (Leonart & Salat, 1992, 1997) is a software developed to analyze data poor fisheries, particularly in the Mediterranean context (no TACs). It is based on length or age ‘pseudo-cohort analysis’ of a single stock exploited by several fleets. VIT has a projection module allowing it to perform projections of the fishery under different conditions (changing selectivity, effort, etc.). This is the part of the software that was used in the current study.

### 3.3.3.5 ALADYM

ALADYM is a single species and multi-fleet model (Lembo et al. 2009) capable of assigning different selectivities to different fleets and to evaluate the impact of different selectivity hypotheses on the estimation of both SSB and catch. It describes the state of the resources, exploitation and management dynamics, and allows users to explore the consequences of different management measures, comparing, for example, respective impacts of changing factors such as fishing effort and/or technical measures on gears. ALADYM is a multi-fleet model that works on a monthly time scale. Here we used it to do a sensitivity analysis of the impact of different assumptions on selectivity on the estimation of SSB and F for the multi-fleet fisheries prosecuting red mullet in GSA 17.

### 3.3.4 *Selectivity analyses*

#### 3.3.4.1 Selectivity in the SS3 assessment of European hake from GSA 17

Hake in GSA 17 was assessed in 2014 by GFCM using the stock assessment software Stock Synthesis 3 (SS3, for more details see Angelini et al., 2015). The model allows the specification of different data sources, providing different uncertainty estimates for each data set. The SS3 analyses for hake in GSA 17 have been done here using total landings between 1983 and 2013, and catch-at-age data from the following three commercial fleets:

1. Italian bottom trawl
2. Croatian bottom trawl
3. Croatian longlines.

Moreover, aggregated indices of abundance and age composition from three scientific surveys were used as tuning:

1. MEDITS (Figures 3.3.1a,b)
2. Italian GRUND
3. Croatian GRUND

For further details on the input data and model settings, see (Angelini et al., 2015).

#### 3.3.4.2 SS3 model set-up (hake GSA 17)

The model settings used here were slightly modified compared to the model settings in Angelini et al. (2015). In particular, selectivity was always estimated by the model for all fleets. The input data and the model settings are available upon request to the JRC.

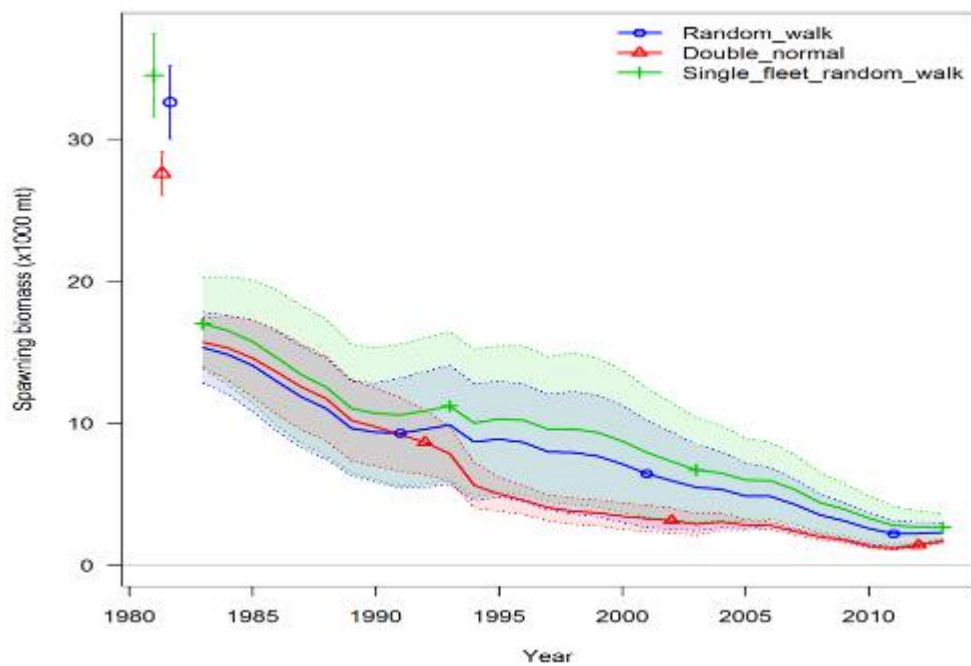
Keeping the same model settings of the “basic model” (Angelini et al., 2015; “multi-fleets based model” with selectivity modeled as random walk), we fitted two “multi-fleets based models” changing only the functional form of the selectivity of the commercial fleets (i.e. survey selectivity was kept as a random walk) and three models for which the catch-at-age data for the different commercial fleets were collapsed into a single catch at age matrix and thus a single combined selectivity was estimated (i.e. “single fleet based model”). In particular, for the “multi-fleets based models”, we set the selectivity of the commercial fleets

to be logistic and double normal, while for the “single fleet based model” we set the selectivity to be logistic, double normal and random walk. Two extra runs were also conducted, one with all fleets (both commercial fleets and surveys) selectivity assumed to be double normal or logistic.

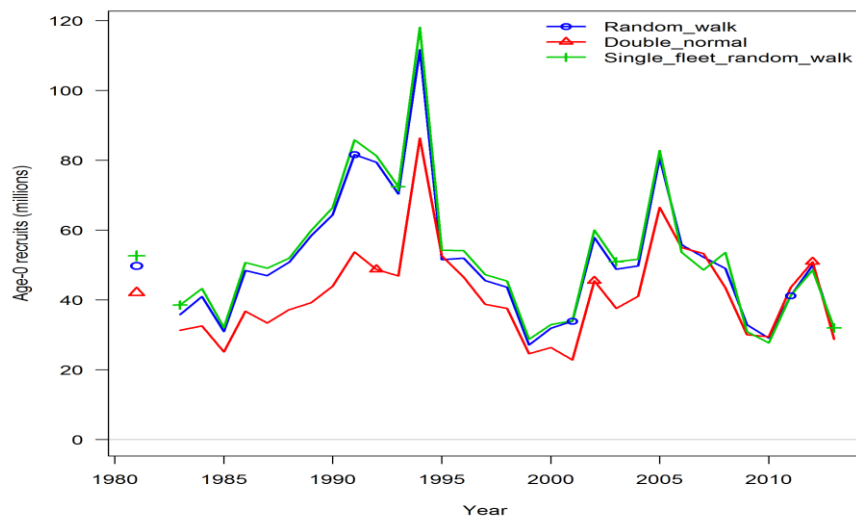
#### 3.3.4.3 SS3 results (hake GSA 17)

The models for which selectivity was set as ‘logistic’ did not converge for either the multi-fleets or the single fleet based models and thus these models could not be used for the successive analysis. The single fleet based model which used the ‘double normal’ selectivity did not converge either and could not be used in successive analyses. Similarly, the runs with selectivity of all fleets (both commercial fleets and surveys) assumed to be ‘double normal’ or ‘logistic’ did not converge and were not retained. Therefore, multi-fleets and the single fleet based models with ‘random walk’ selectivity and the multi-fleets based model with ‘double normal’ were retained and the SSB and recruitment compared.

The results show a rather similar trend for the three models for both SSB and recruitment, even if differences in the level of SSB were evident since the middle of the 1990s (Figures 3.3.2 and 3.3.3). The shape of the selectivity of the multi-fleets based model double normal and the random walk were rather similar, with the main difference found in the selectivity peak, which is located at older ages for the double normal. Selectivity of the single fleet based model with ‘random walk’ selectivity was basically the same as the selectivity estimated by the multi-fleets based model ‘random walk’ model for the Italian bottom trawl fleet, which is the main fleet fishing hake in GSA 17 (Figures 3.3.4, 3.3.5 and 3.3.6).



**Figure 3.3.2. Hake in GSA 17. Trend in SSB with the confidence intervals from the three converging runs.**

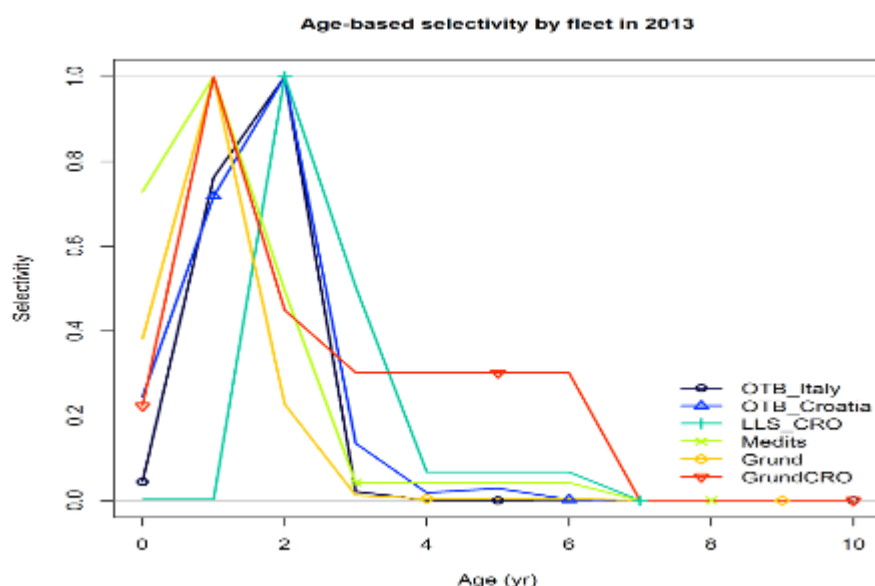


**Figure 3.3.3. Hake in GSA 17. Trend in recruitment from the three converging runs.**

Trend and absolute values of  $F$  (estimated as the arithmetic average between ages 0 and 4) were very similar between the different runs. However, the random walk models estimated a much smaller  $F$  for ages 3 to 10 when compared to the double normal (data not shown).

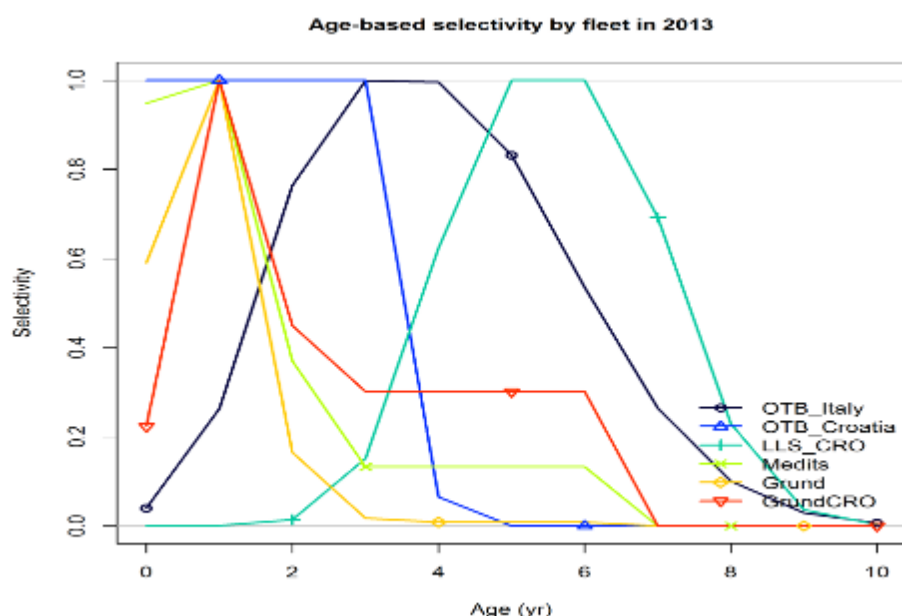
Contemporary age and length compositions for hake stocks in the Mediterranean for both the fleets and the surveys are usually right-truncated, with large fish generally being very rare or absent in the data (STECF 2014). This is a characteristic common to all hake stocks in the Mediterranean (e.g. hake in GSA 09). Past historical trawl surveys carried out in the Mediterranean do, however, show non-truncated size frequencies and indeed captured large hake. Truncated length distributions can have implications for the estimation of selectivity and also can lead to large differences in stock estimates if the selectivity is misspecified. Here, we tried to investigate how changes in the assumed functional form of selectivity influence the fitting of an SS3 assessment model for hake in GSA 17, and what were the consequences for the stock estimates in terms of SSB and R (recruitment).

Models for hake in GSA 17, for which selectivity was assumed to be logistic did not converge, suggesting that there is a conflict between the data, the logistic specification of selectivity, and with other model settings requiring further investigation. The lack of model convergence in many scenarios also indicates that there is a problem with the model settings requiring further investigation. This hampered a proper comparison across scenarios.



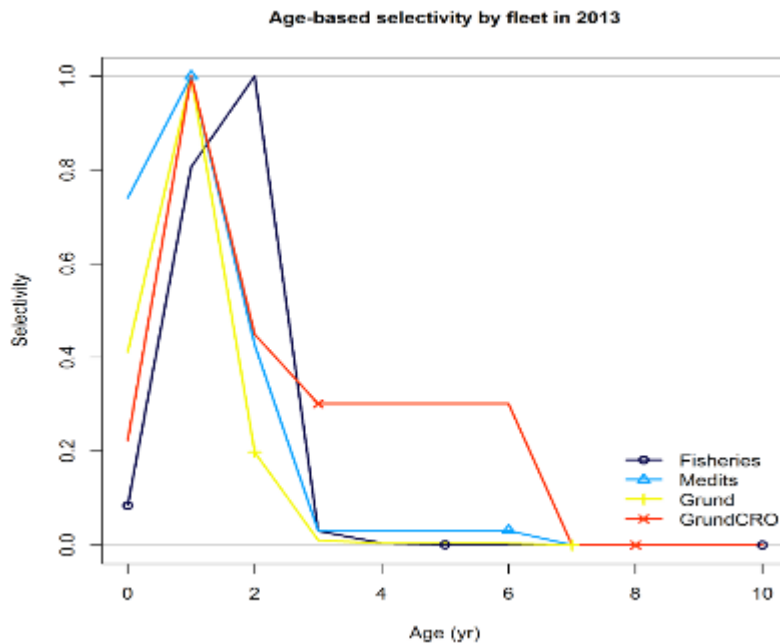
**Figure 3.3.4. Hake in GSA 17. Age based selectivity by fleet for the multi-fleet random walk run.**

The results for the other models were not too different in terms of either the SSB or R they estimated and they are in line with the expectations (i.e. larger SSB for the random walk compared to the double normal model). However, it is important to note that uncertainty around the SSB estimates is much smaller for the double normal than for the random walk model.



**Figure 3.3.5. Hake in GSA 17. Age based selectivity by fleet for the multi-fleet double normals run.**

In the case of Mediterranean hake, where there are indications that certain fleets; either do not fish where adults are distributed (Figure 3.3.6), that large hake can escape the trawls (Jorgensen et al., 2007), or be located in so called refuge areas (Caddy, 1990), selectivity in a SS3 type of model can be set by first exploring the distribution of the surveys and the commercial fleets in relation to the distribution of the different parts of the stock (i.e. juveniles and adults). The temporal dynamics of these data should, however, be used carefully since surveys only capture a short time period of the year (MEDITS), and the fleet dynamics pre-2006 are not well documented. If the different fleets do fish in particular areas where hake juveniles or adults are distributed, the model should preferably be set as a multi-fleet model to take into account the different selectivities by the fleets.



**Figure 3.3.6. Hake in GSA 17. Age based selectivity by fleet for the single fleet random walk run.**

Osio et al 2010 (Ocean Past III Conference, Dublin 18-20 November 2010) presented a reconstruction of length frequency distribution and estimates of total mortality ( $Z$ ) of Mediterranean hake caught in trawl surveys in the Gulf of Lions. The spatial distribution is comparable in the 4 periods (Figure 3.3.6a). Figure (3.3.6b) show clearly that, when hake was available to trawl gear (in 1957) large individuals (30-60 cm) were caught, potentially contradicting one of the assumptions that large hake are not caught even if they are available (Jorgensen et al., 2007). As the exploitation increased over time the larger individuals disappeared from the catches in trawls. If we were to look only at the length-frequency distributions for hake from MEDITS the confusion between availability and mechanical selection could favor, in an assessment, the selection of a dome shaped selectivity that would erroneously imply that large fish are there but not caught.



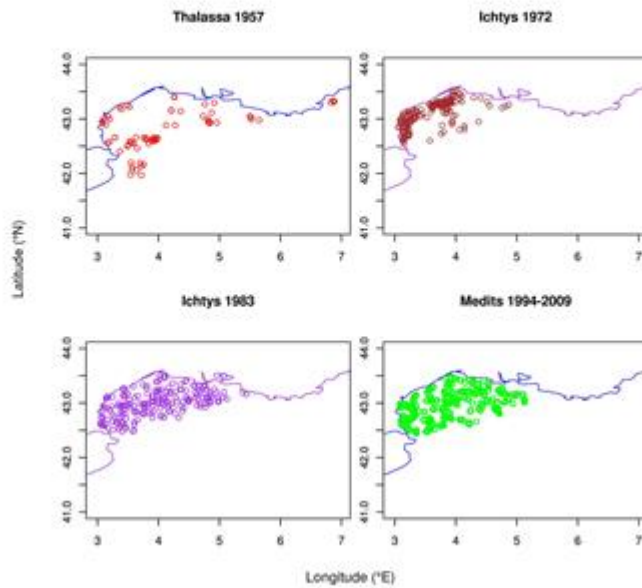


Figure 3.3.6a. Spatial distribution of survey hauls in the 4 different trawl surveys.

## Hake Gulf Lion

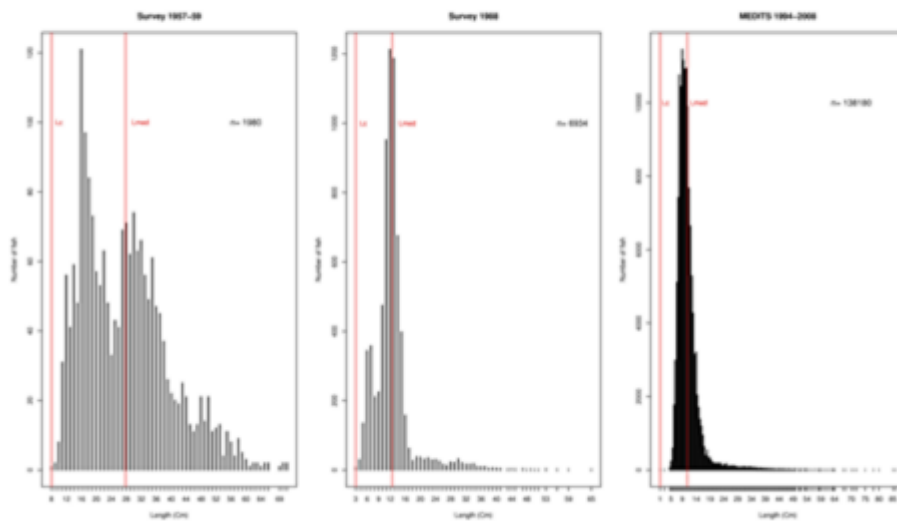
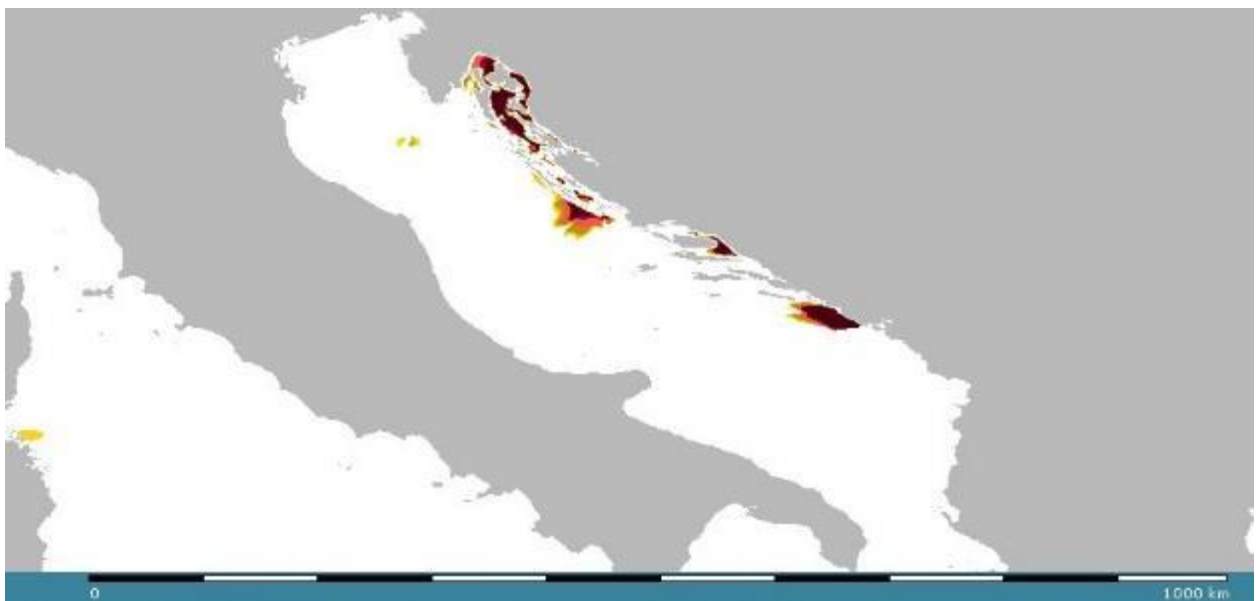
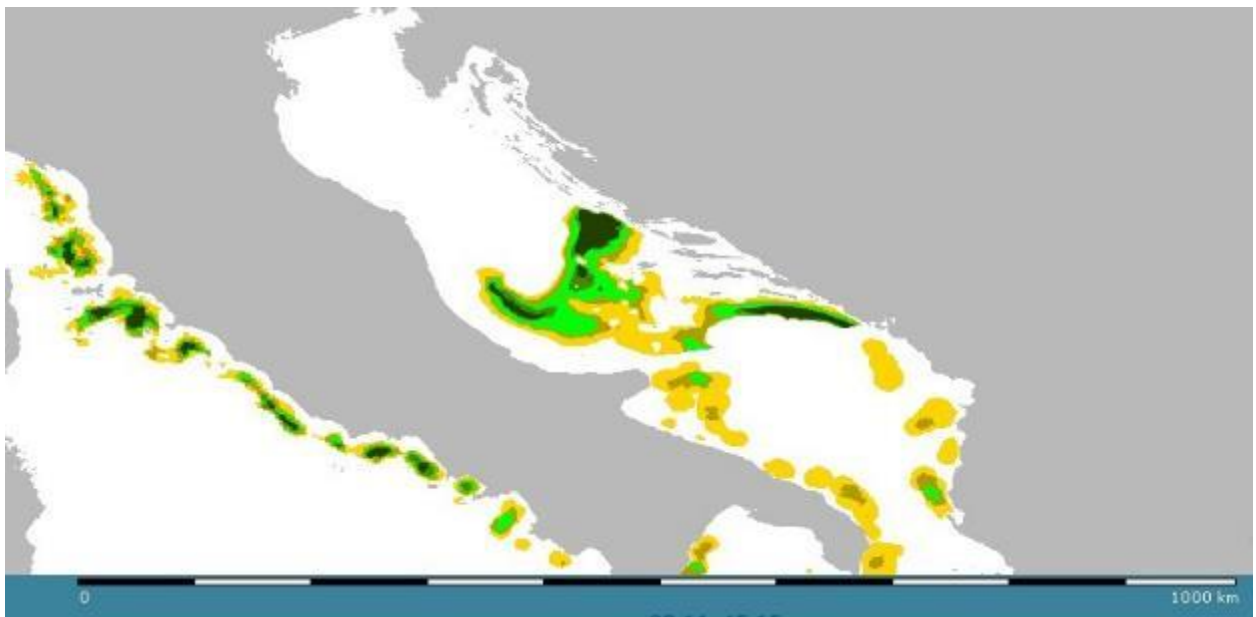
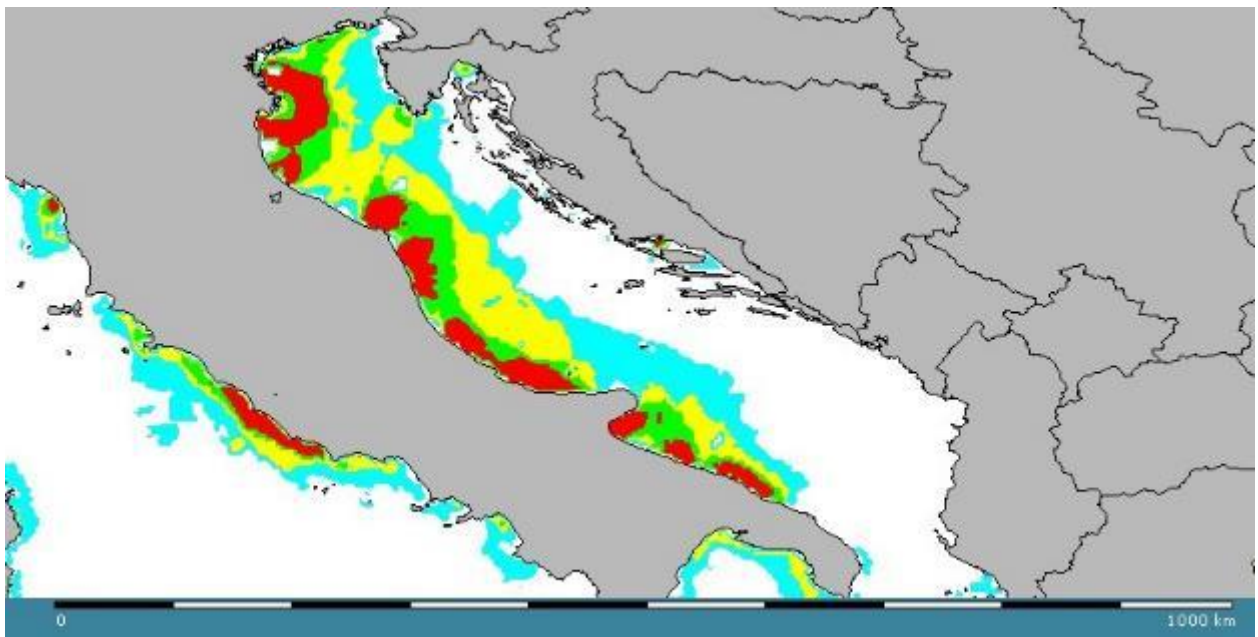


Figure 3.3.6b Length-frequency distribution of Mediterranean hake in different time periods and trawl surveys.

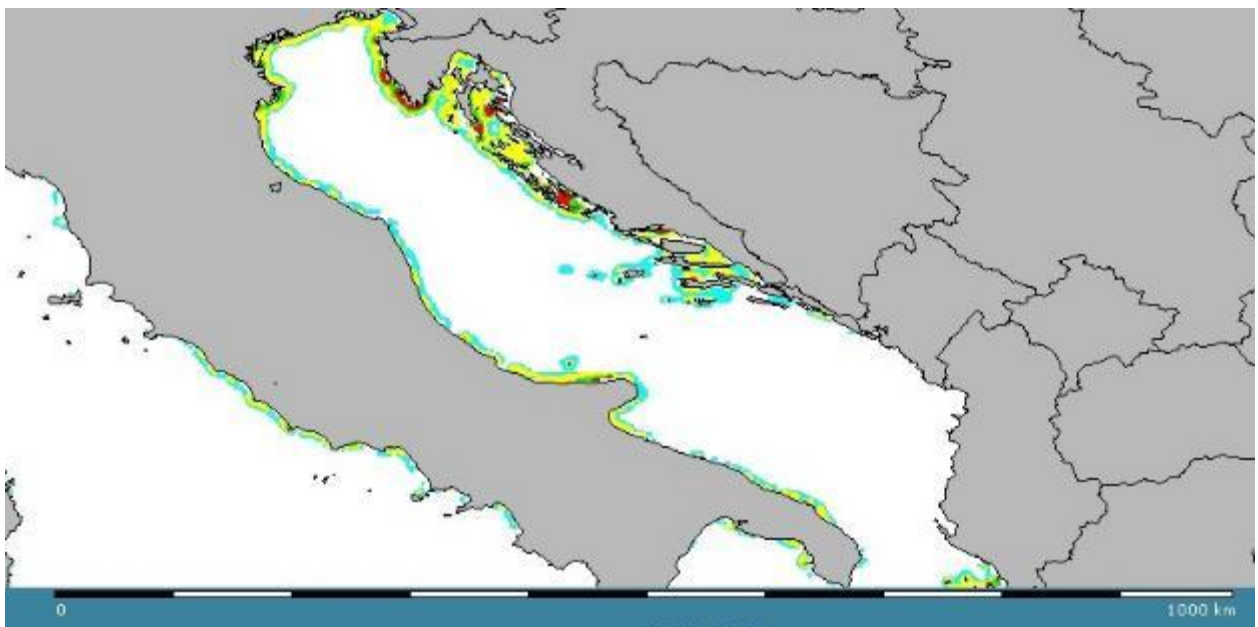


**Figure 3.3.7. Hake in GSA 7. Spatial distribution of juveniles (top) and adults (bottom).**

Alternatively, and especially when the different fleets cannot be disaggregated, models which use non-parametric functions to estimate selectivity should be preferred. When using VPA-type models such as XSA, care should be taken to include as many age classes as possible in the model and to estimate  $F$  at age for as many age classes as possible and avoid the assumption that  $F$  of the older age classes is the same as the  $F$  estimated for the younger ages



**Figure 3.3.8. Hake in GSA 17. Spatial distribution of trawls and small-scale fisheries (vessels between 12 and 24m).**



**Figure 3.3.9. Distribution of effort from small scale fisheries targeting hake in GSA 17**

### 3.3.5 *Selectivity in the SS3 assessment of red mullet from GSA 17*

Red mullet in GSA 17 was assessed in 2013 by STECF-EWG 13-19 using Stock Synthesis 3 (SS3) and in 2014 by GFCM using an XSA. The SS3 analyses for red mullet in GSA 17 were done with total landings between 1970 and 2012 and catch at age data from the following three commercial fleets (between 2000 and 2012):

1. Italian bottom trawl
2. Croatian bottom trawl
3. Slovenian bottom trawl.

Aggregated indices of abundance and age compositions from three scientific surveys were used as ‘tuning’:

1. MEDITS
2. Italian GRUND
3. Croatian GRUND

For comparison purposes SSB estimates were compared with results from XSA (VPA) and a4a (SCA) fitted to the years 2000 to 2012.

#### 3.3.5.1 Model set-up (red mullet GSA 17)

The following combinations of assumptions on selectivity for both surveys and commercial fleets were investigated with the SS3 model:

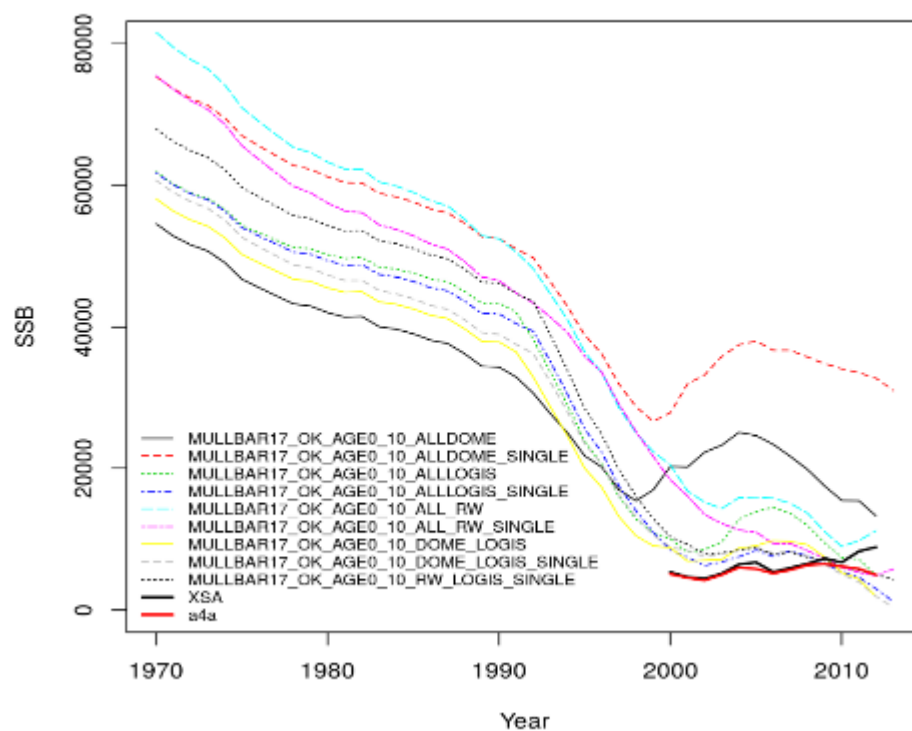
- Random walk selectivity for both survey and fishing fleet;
- Logistic selectivity curve for both survey and fishing fleet;
- Dome shaped selectivity curve for both survey and fishing fleet;
- Dome shaped selectivity for the fishing fleet and logistic for the survey.
- Random walk selectivity for the fishing fleet and logistic selectivity for the survey.

#### 3.3.5.2 Results (red mullet GSA 17)

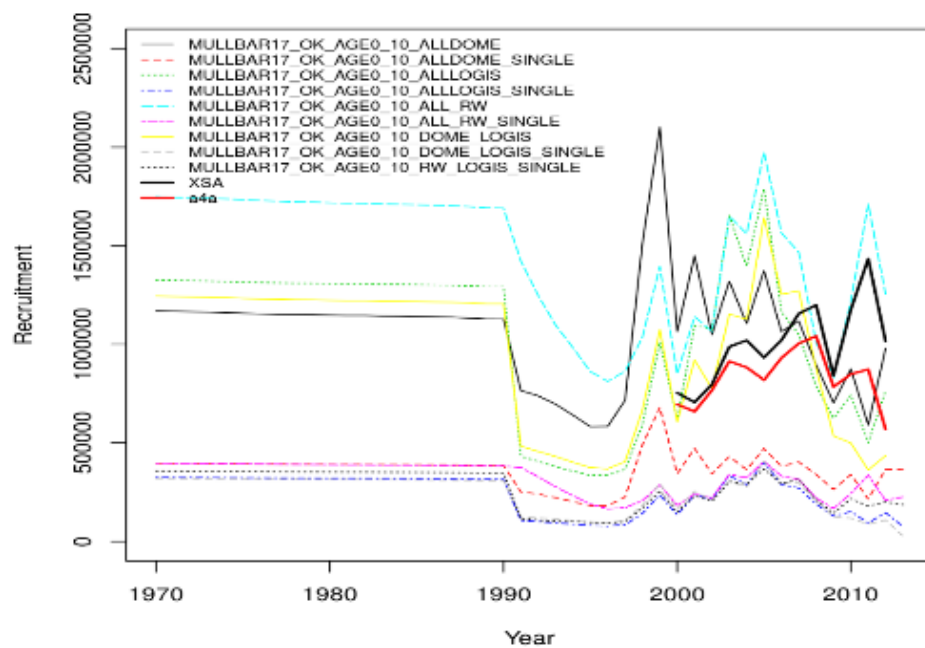
The random walk + logistic selectivity model did not converge for the multi fleet model and was thus excluded from the successive analysis. All the other options worked/converged and were, therefore, compared for Recruitment, Spawning Stock Biomass and F (Figures from 3.3.11 to 3.3.13). The shapes of the selectivity of the models considered were rather similar for the “logistic model” and the “dome shaped + logistic model”, being all logistic; it was dome-shaped when the “random-walk selectivity model” was applied; it was dome-shaped for the MEDITS survey and logistic for the fleet when the “dome-shaped” model was applied.

The results of the models were quite different for the three variables examined (Figures 3.3.11-3.3.13 and Table 3.3.1). In terms of effect, SSB and R increase significantly and F decreases when a dome-shaped model was applied, most likely because the survey has a

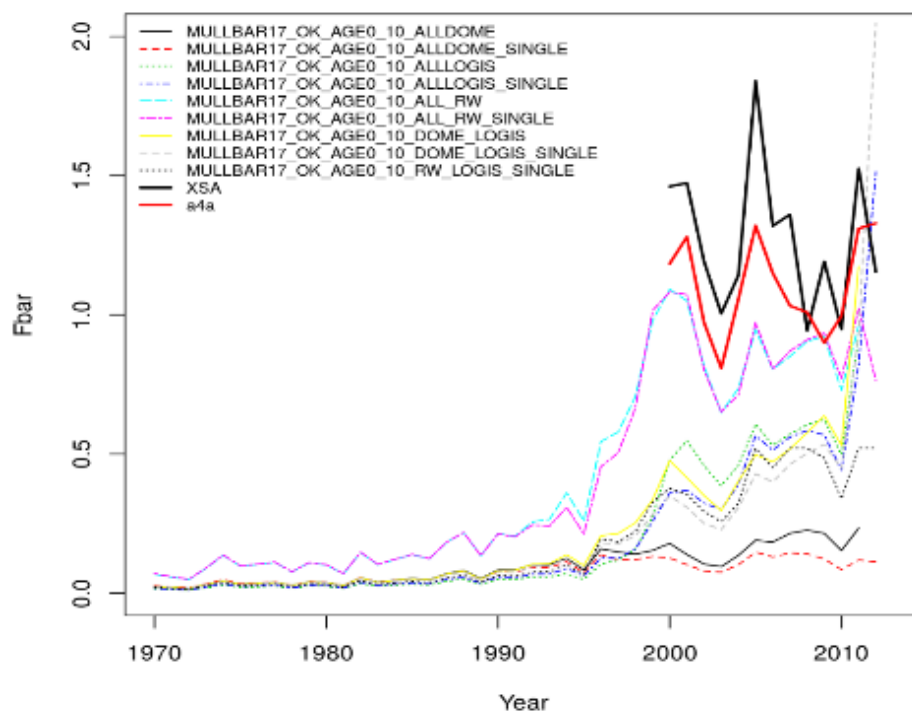
dome-shaped form, resulting in a “cryptic” biomass effect similar to what was suggested by Maunder *et al.* (2014).



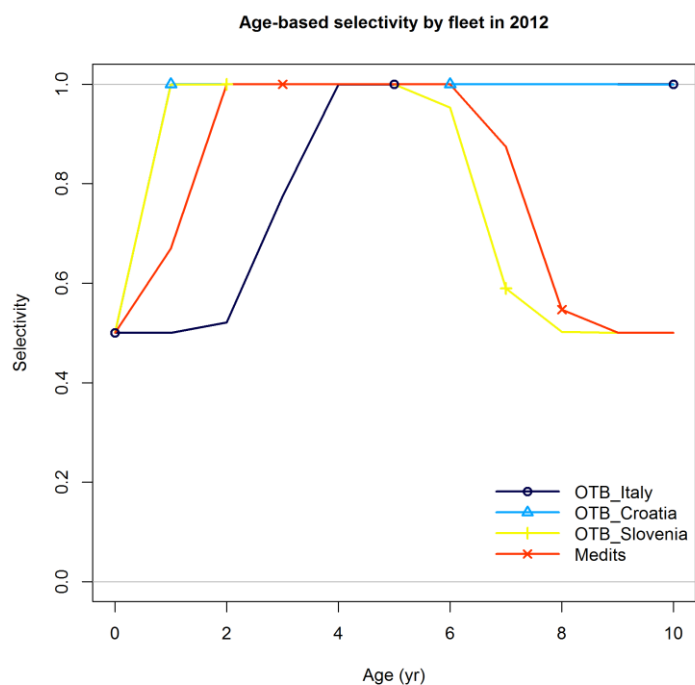
**Figure 3.3.10. Red mullet in GSA 17. Trends in SSB from the different runs summarized in Table 3.3.1.**



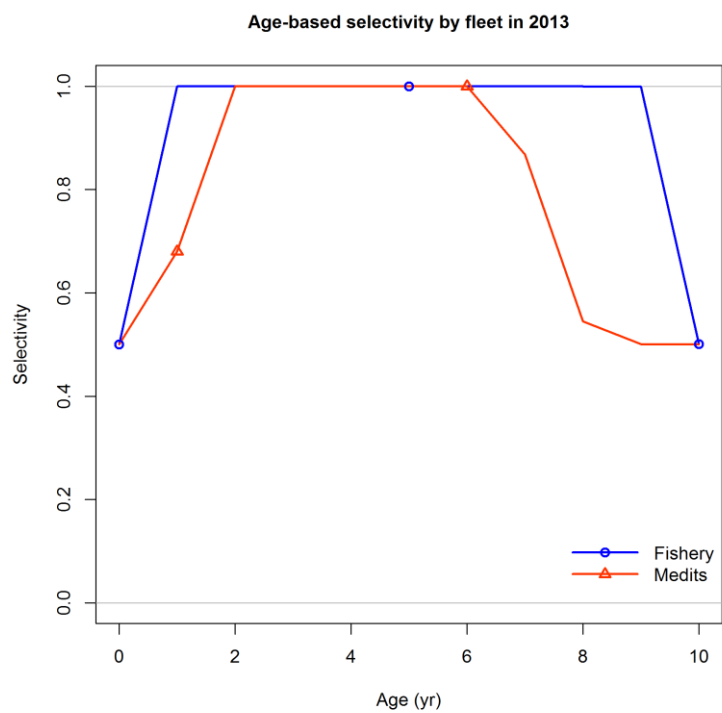
**Figure 3.3.11. Red mullet in GSA 17. Trends in recruitment from the different runs summarized in Table 3.3.1.**



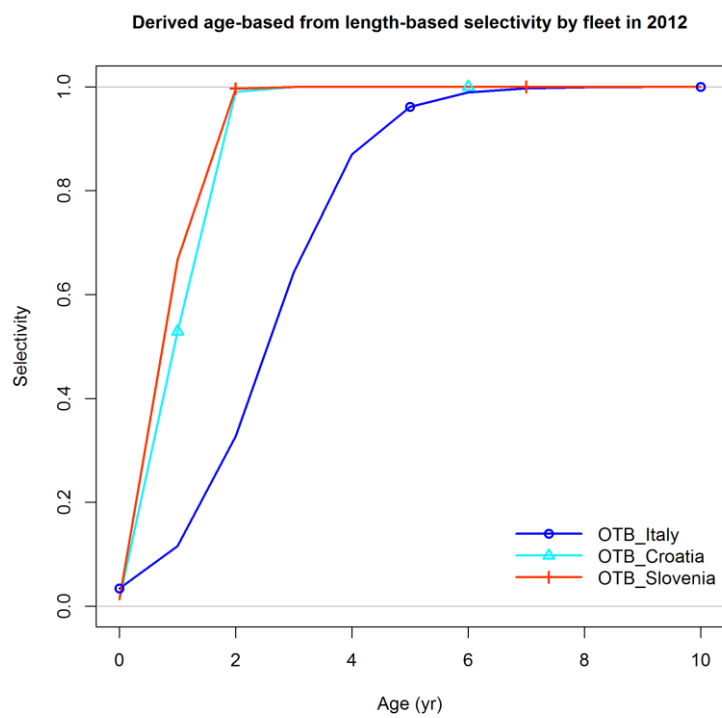
**Figure 3.3.12. Red mullet in GSA 17. Trends in Fbar from the different runs summarized in Table 3.3.1.**



**Figure 3.3.13. Red mullet in GSA 17. Age based selectivity by fleet for the multi-fleet and survey double normal run.**

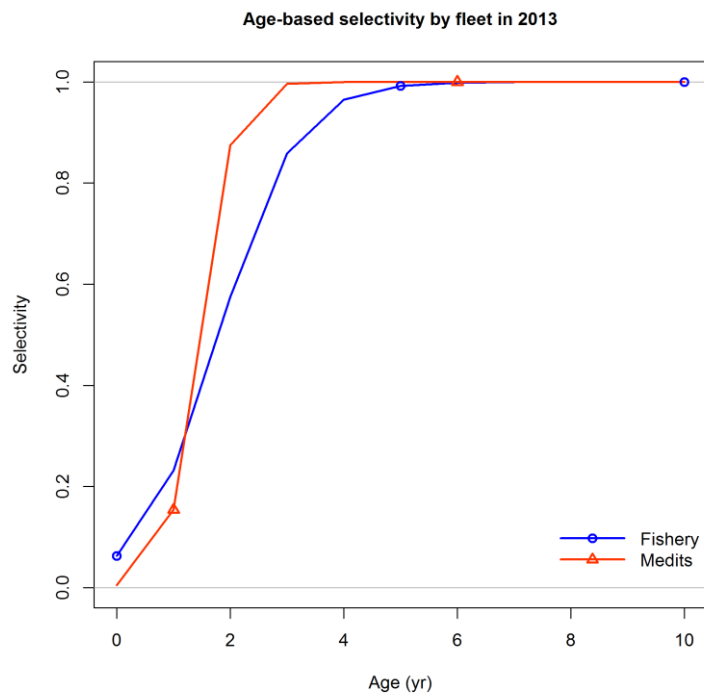


**Figure 3.3.14. Red mullet in GSA 17. Age based selectivity by fleet for the single fleet and survey double normal run.**

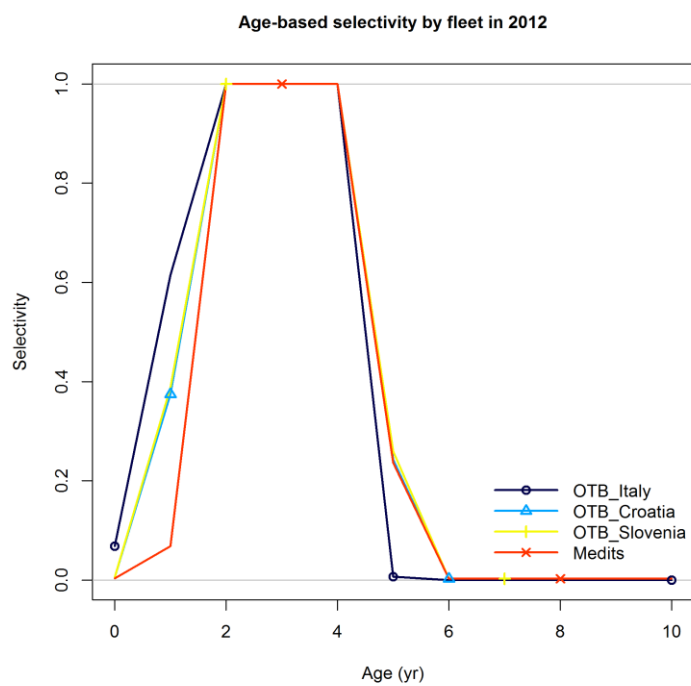




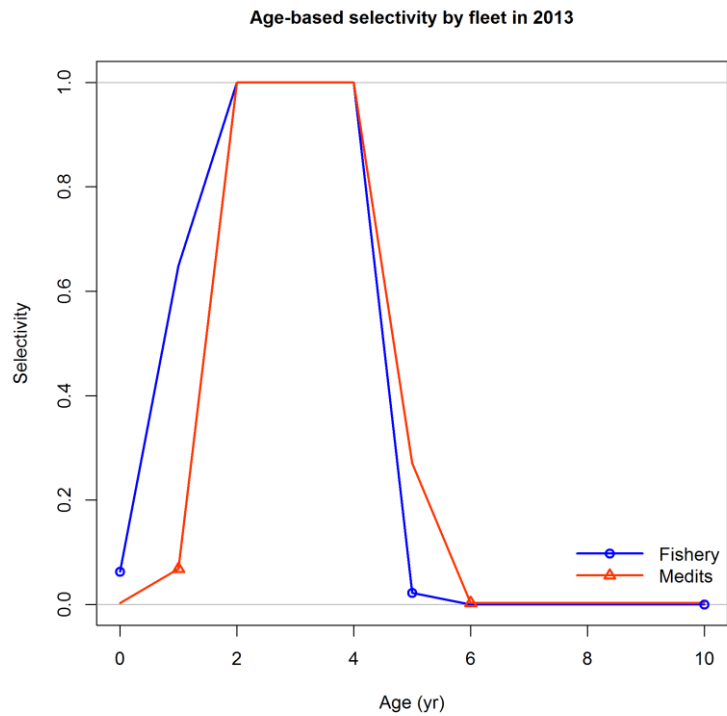
**Figure 3.3.15. Red mullet in GSA 17. Age based selectivity by fleet for the multi-fleet and survey logistic run.**



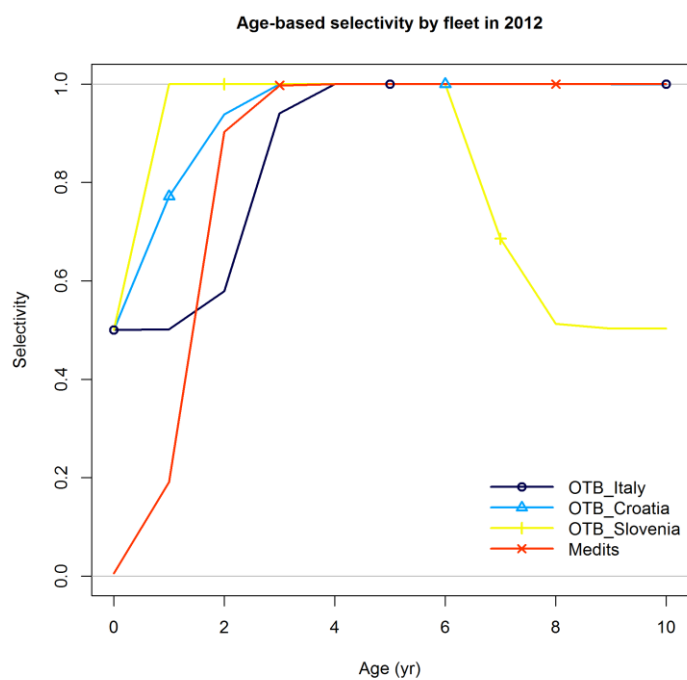
**Figure 3.3.16. Red mullet in GSA 17. Age based selectivity by fleet for the single fleet and survey logistic run.**



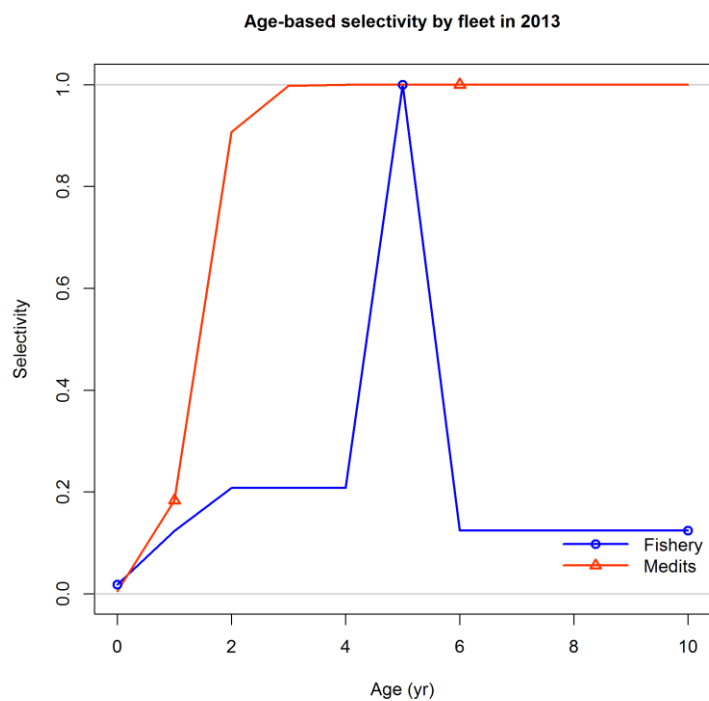
**Figure 3.3.17. Red mullet in GSA 17. Age based selectivity by fleet for the multi-fleet and survey random walk run.**



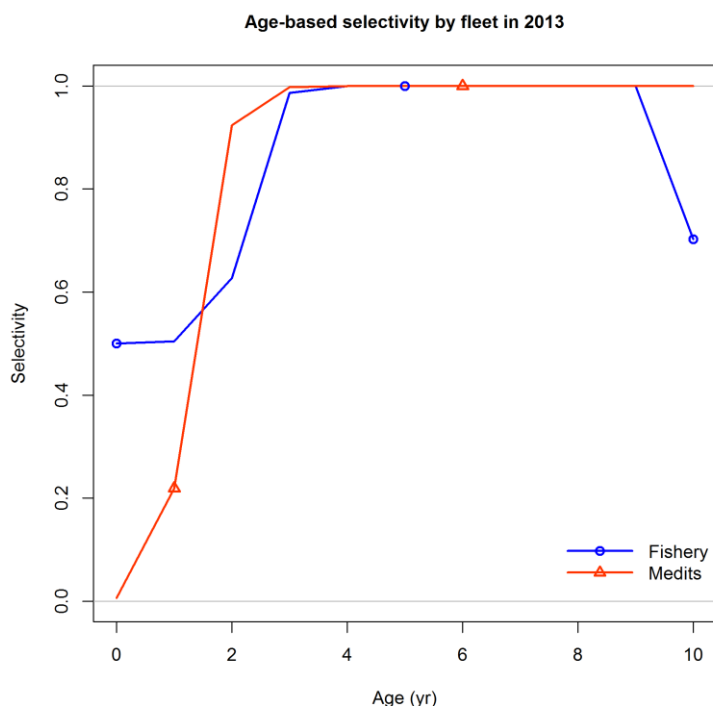
**Figure 3.3.18. Red mullet in GSA 17. Age based selectivity by fleet for the single fleet and survey random walk run.**



**Figure 3.3.19. Red mullet in GSA 17. Age based selectivity by fleet for the multi-fleet double normal and survey logistic run.**



**Figure 3.3.20. Red mullet in GSA 17. Age based selectivity by fleet for the single fleet random walk and survey logistic run.**



**Figure 3.3.21. Red mullet in GSA 17. Age based selectivity by fleet for the single fleet double normal and survey logistic run.**

The random walk selectivity curve depends greatly on the parameterization: in the run carried out, the shape turned out to be dome-shaped, likely due to the constraints on the ages necessary to make it converge. The results for the SSB and R in the multi-fleet and the single-fleet are rather different, both in terms of trends and in terms of absolute values (Table 3.3.1). The Fbar on the other hand did not show any significant difference. When a “logistic selectivity model” is assumed, the SSB and the Fbar estimates appear consistent between the multi-fleet and the single-fleet options. In general, for red mullet in GSA17, it seems that the differences in estimation of recruitment are driven mainly by the choice of multi-fleet over single-fleet, while for SSB and Fbar the differences are driven by the selectivity curve assumption.

The comparison between different models shows a good agreement between a4a and the SS3 run with logistic selectivity. Also XSA has a similar trend, with the exception of the last 2 years of data where the trend just departs towards a higher value (in general in VPA-like approaches the estimation of the last year can be unstable).

The Italian and Croatian fleets that target red mullet in the Adriatic Sea tend to exploit different parts of the population. The Croatians catch larger individuals while the Italian fleet catches smaller ones. Concerning the MEDITS survey, it is reasonable to assume full selection for larger individuals and, therefore, adequate representation of the whole population. This exploitation pattern can be corroborated by the distribution of the red mullet, both juveniles and adults, and by the distribution of the fleets targeting the stock, as reconstructed by the MEDISEH project. The temporal dynamics of these data should,

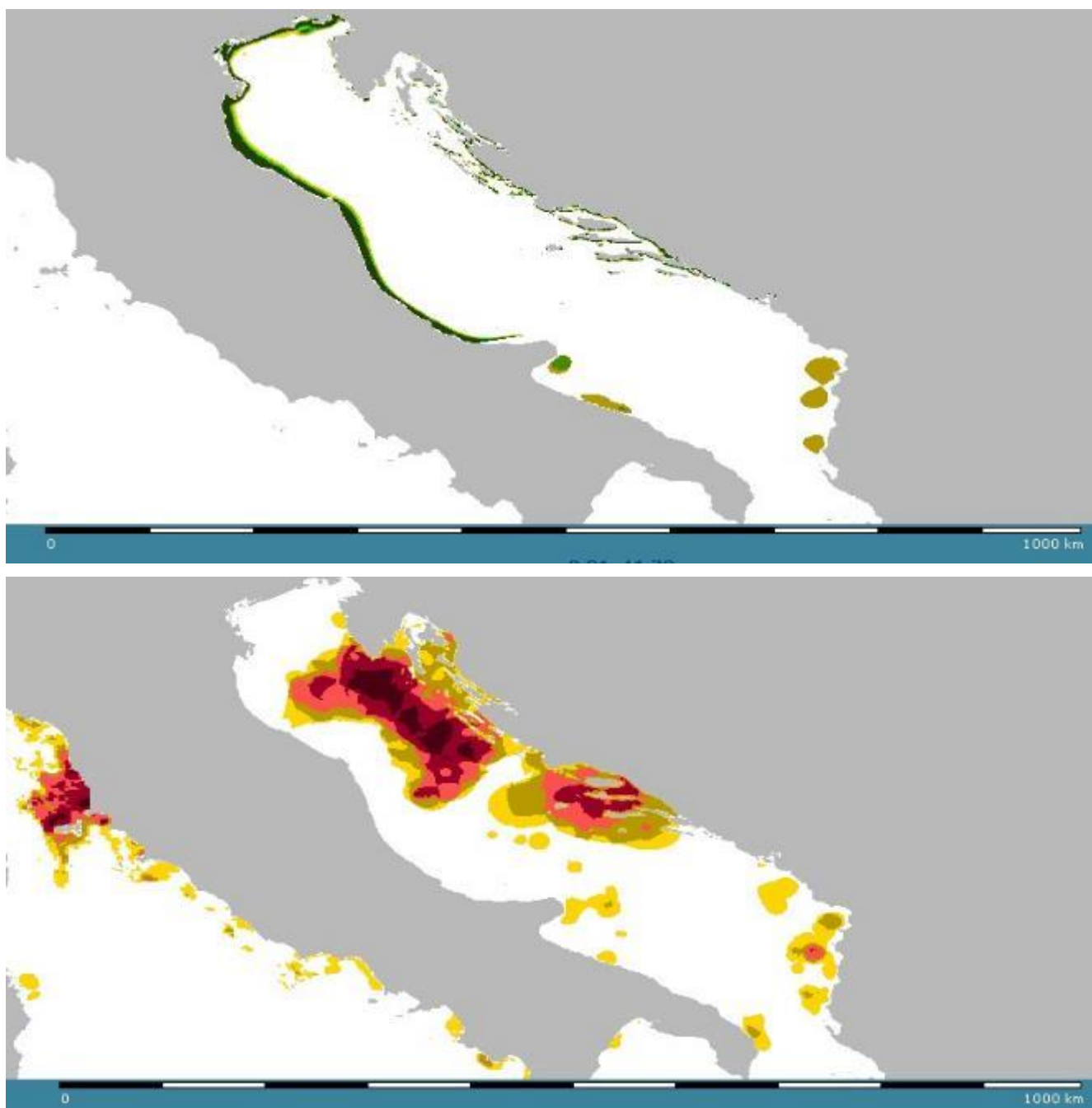
however, be used carefully since surveys only capture a short time period of the year (MEDITS) and the fleet dynamics pre-2006 are inadequately documented.

Here we tried to investigate how changes in the assumed functional form of selectivity influence the fitting of an SS3 assessment model for red mullet in GSA 17; and what are the consequences for the stock estimates in terms of SSB, F and R.

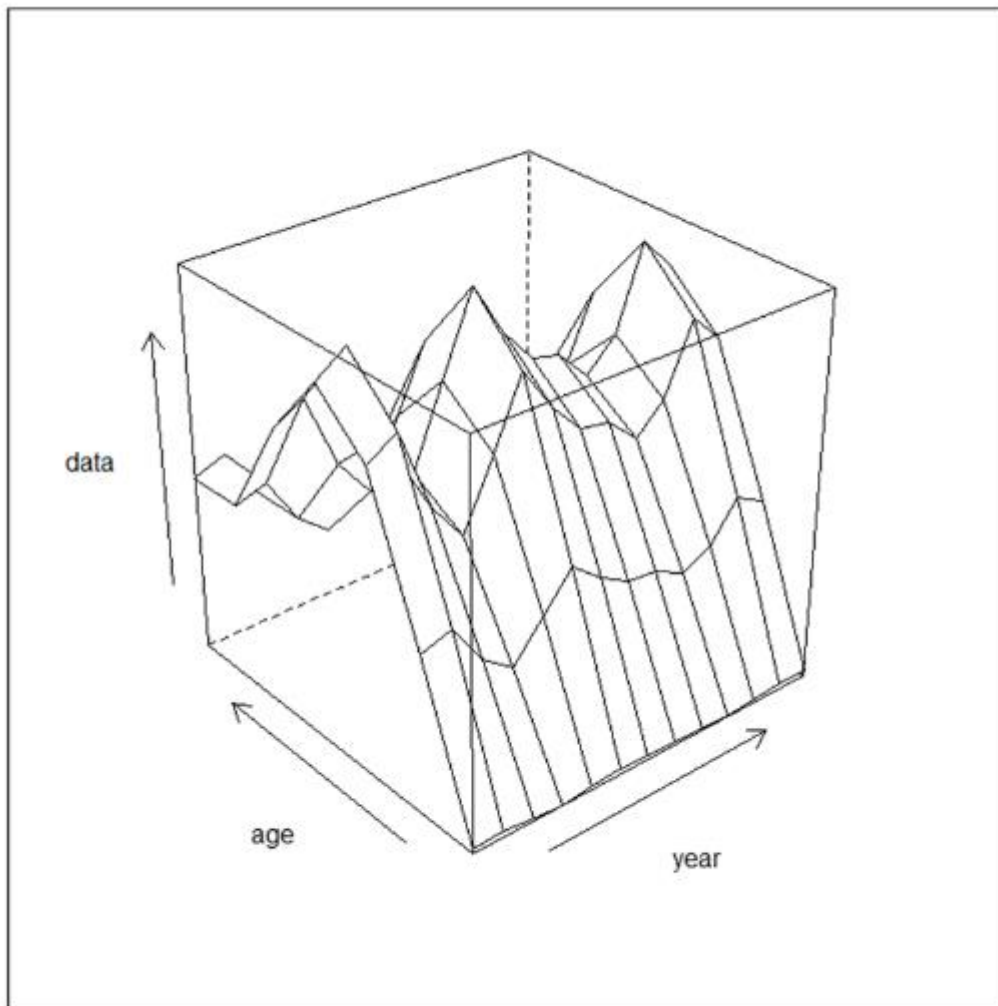
In general, the assumptions on selectivity, as well as the choice of using a multi-fleet as compared to a single-fleet model, greatly influenced the results. Different selectivity assumptions do not simply result in a larger biomass and R for the dome shaped pattern, and results show how different assumptions may result in complex, unexpected outcomes which may influence our perception of the stock.

For example, it was reasonably expected that the ‘random walk’ assumption would have led to a logistic shape, since the results were in general closer to the ones obtained with the logistic assumption (e.g. SSB) and the selectivity estimated using a dome shaped approach was logistic for the main fleet segments considered (i.e. Italian and Croatian); however, the results obtained using the random walk assumption leads to a dome shaped selectivity (Figure 3.3.18-3.3.19).

The SS3 model with a logistic curve gave very different results to the two assessments carried out with a4a (SSB = +31%, F=+60%) and XSA (SSB=25%, F=+85%) and also very different results when compared to the reference model with a random walks selectivity (Table 3.3.1). In the case of red mullet in GSA17, where there are indications that the Croatian fleet catches larger individuals than the Italian fleet, and that juveniles and adults have a different spatial distribution (Figure 3.3.22), selectivity in a SS3 type of model should be set as a random walk to account for the different distributions of juvenile and adults and of the fleets over the assessment area (see Figure 3.3.23).



**Figure 3.3.22. Red mullet in GSA 17. Spatial distribution of juveniles (top) and adults (bottom).**



**Figure 3.3.23. Red mullet in GSA 17. F at age estimated by the a4A model.**

### 3.3.6 *Exploration of selectivity models and parameters via simulation and projections*

#### 3.3.6.1 ALADYM simulations

The aim of this exercise was to evaluate the implication, for SSB and F estimations, of assuming different selectivity curves in a simulation setting. The simulations focused on the right part of the selectivity curve, which is generally the most uncertain for a variety of reasons, e.g. a lack of large individuals, unavailability to the fishery, etc... and the one on which the scientific expert has to make a number of assumptions.

The data used in this exercise are the MEDITS indices, by age, from 2000 to 2012 to obtain:

- an estimate of the total mortality ( $Z_{inp}$ ) affecting the population,

- an index of recruitment (age 0) to obtain an absolute recruitment through the calibration option and reconstruct the population at sea.

Moreover, the yield by fleet to associate a fishing mortality to each of the three fleets was used. All the biological parameters related to the life history traits of the species are the ones reported in STECF EWG 13-19. The estimated  $Z_{inp}$  was used to simulate the population at sea and the catches by fleet, according to the following formula:

$$F_f(a) = (Z_{inp} - \text{mean}(M)) \cdot \text{Sel}_f(a) \cdot f_{act,f} \cdot p_f$$

where:

$F_f(a)$  is the fishing mortality of fleet  $f$  acting on age  $a$  in each month;

$Z_{inp}$  is the total mortality in input;

$\text{Mean}(M)$  is the average natural mortality on all ages;

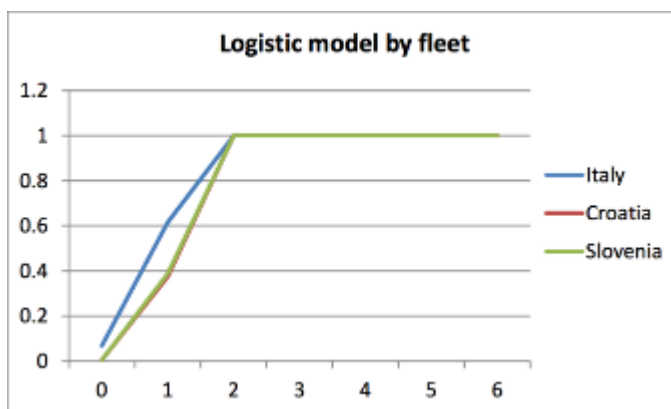
$\text{Sel}_f(a)$  is the selectivity of fleet  $f$  acting on age  $a$ ;

$f_{act,f}$  is the activity of fleet  $f$  in the month;

$p_f$  is the proportion of yield due to fleet  $f$ .

The selectivity models ( $\text{Sel}_f(a)$ ) by fleet explored are 6:

1. Logistic (see Figure 3.3.24);



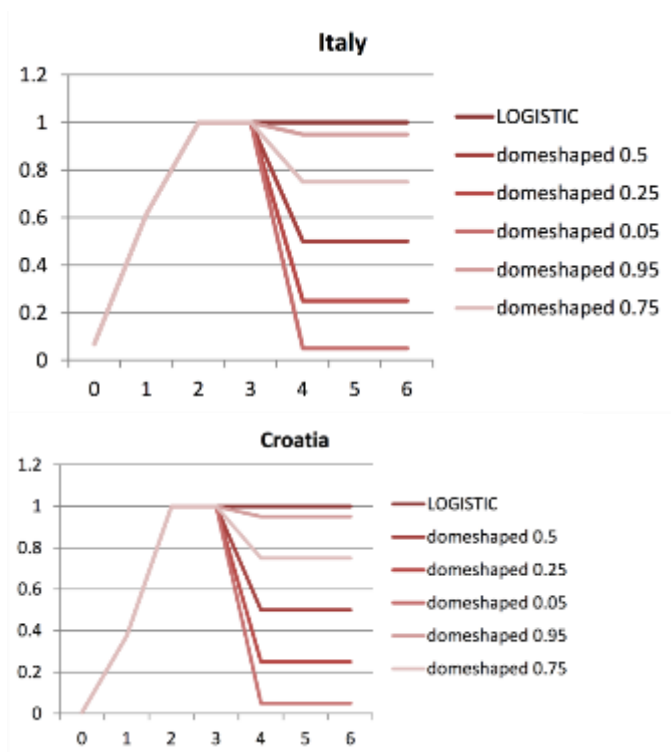
**Figure 3.3.24. The selectivity has been input as vector by age and by fleet (equal for all the years) for logistic selectivity hypothesis.**

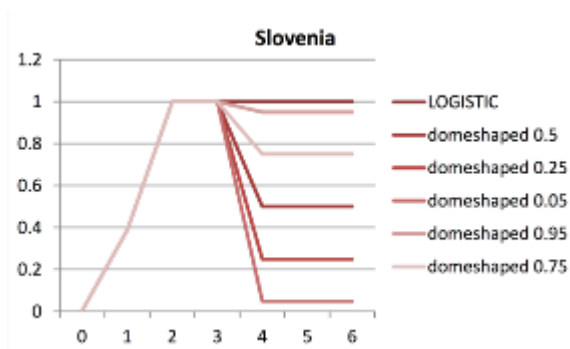
Dome-shaped assuming same left part as the logistic and different selection levels for the right side of the curve for fish of age 4+ (see Figure 3.3.25):

2. 5%,



3. 25%,
4. 50%,
5. 75%,
6. 95%.

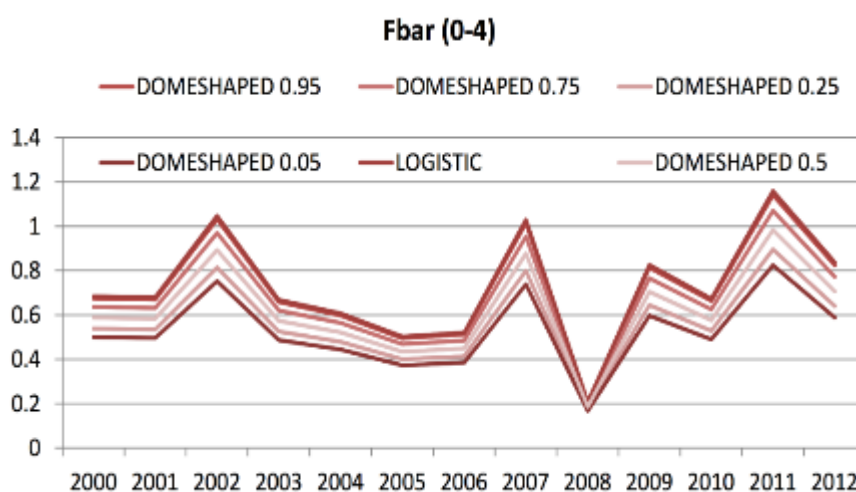




**Figure 3.3.25. Selection curves used in the simulations by age and by fleet (equal for all the years) for dome-shaped hypotheses (0.05, 0.25, 0.50, 0.75 and 0.95 runs).**

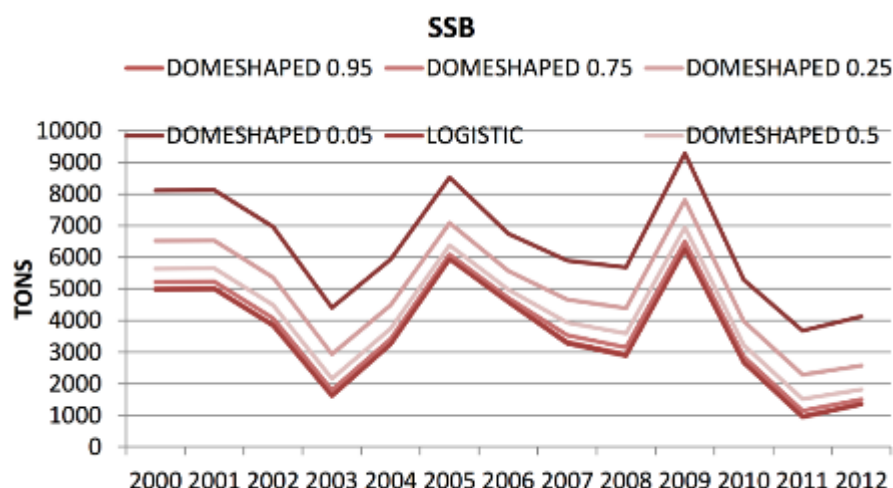
### 3.3.6.2 ALADYM results

The results of the simulations showed that assuming a logistic selectivity would result in lower SSB trajectories. As expected, a dome-shaped curve assumption on the fleet selectivity will result in progressively higher SSB as the level of selection on large fish decreases (Figure 3.3.26, 3.3.27). A dome-shaped curve with 95% of selectivity in ages 4+ results in only a difference of 1% in SSB and -1% on the overall Fbar compared to the logistic curve assumption. At the extreme end of the spectrum explored, a selection of only 5% on the last ages will result in an increase of SSB up to 78%.



**Figure 3.3.26. Fbar (0-4) according to the different selectivity runs**

As a consequence of progressively lower selection in the last ages and increasing SSB, the F associated decreases with respect to the logistic run (from the -7% of the run with 75% of retained to the 27% of the run with 5% of retained in the last ages, Figure 3.3.26).



**Figure 3.3.27. SSB according to the different selectivity runs**

In the table below are summarized the impact on overall F, F by fleet and on SSB according to the different selectivity hypotheses we tested.

% respect LOGISTIC	0.05	0.25	0.5	0.75	0.95
Fbar (0-4)	-27	-22	-14	-7	-1
Fbar Italy	-27	-21	-14	-7	-1
Fbar Croatia	-30	-24	-16	-8	-2
Fbar Slovenia	-30	-24	-16	-8	-2
SSB	78	38	16	6	1

### 3.3.7 VIT projections (red mullet in GSA 17)

#### 3.3.7.1 Introduction

The purpose of this chapter is to analyze the effects of changes in selectivity on the forecast SSB estimated for the red mullet in subarea 17, under different scenarios of selectivity and stock-recruitment relationship. In this subarea red mullet is caught by three different fleets (Italian, Croatian, Slovenian) each one with different F profile. The investigation on selectivity was done by projecting changes in the F at ages 0 and 1, while keeping the Fs at

the other ages unchanged. Ultimately these changes affect only the Italian fleet, since the Croatian and Slovenian fleets do not catch such young red mullet.

The F profiles per fleet and year were computed through XSA and show the very deep differences among fleets. The initial conditions of the simulations were: the cohort 2000-2006 and the software VIT (projections 1 and 2), and the last age composition of year 2012 (projection 3). The changes in selectivity involve percentages of F at ages 0 and 1 (projections 1 and 3a), and fitting new logistic selectivity curves increasing L50 by 1 cm (projections 2 and 3b). Constant stock-recruitment relationships were used in simulations 1 and 2a, and Beverton & Holt stock-recruitment relationships in 2b, 2c and 3. Each projection was run in a stochastic environment affecting recruitment according to a log-normal stochastic variable with 1000 iterations each.

XSA was used to obtain F by year (2000 to 2012) and age (0 to 6). The Fs were split according to the following order: Italian, Croatian and Slovenian. The Fs by fleet were obtained through the proportionality between Catch-in-numbers and F:  $(\text{Total Catch})/F(\text{Total}) = (\text{Italian Catch})/F(\text{Italian}) = (\text{Croatian Catch})/F(\text{Croatian}) = (\text{Slovenian Catch})/F(\text{Slovenian})$ .

It can be noted that: (i) The Slovenian F is irrelevant, (ii) The Italian fleet has a dome-shaped F at age for all years, and (iii) The Croatian fleet has an increasing F at age for all years. According to the experts the differences between Italian and Croatian F shape is due to the distributions of the different fractions of the population and to the fishing grounds, rather than the gear selectivity.

### 3.3.7.2 VIT projections

From the cohort of 2000-2006 several projections were done under different scenarios.

All the scenarios consisted of changing the F pattern on the Italian fleet for the first two age-classes. The parameter of interest in the projections is SSB.

1. Decreasing F of the two first age-classes (0 and 1) in the Italian fleet. Constant recruitment and deterministic resulted in the following at different settings of F0 and F1:

1a F0 and F1 at 90% of its original values. SSB increases 5%

1b F0 and F1 at 70% of its original values. SSB increases 17%

1c F0 and F1 at 50% of its original values. SSB increases 30%

2. Fitting a logistic curve to F of the first three ages of the Italian fleet (assuming the lengths, not ages follow the logistic, the parameters were estimated from length distribution), we obtain:  $SL_{50} = 9.465 \text{ cm} \approx 0.73 \text{ years}$ . The parameters obtained for the logistic ( $y = L / (1 + \exp(-k(x - x_0)))$ ) are:

$x_0 = 9.465$

$L = 1.205$

$K = 0.453$

In all simulations SL50 increased by 1 cm (i.e. from 9.5 cm to 10.5 cm). This means a change of the F for the F of the first three ages from:

age	original F	new F
0	0.101	0.044
1	0.806	0.697
2	1.205	1.111

2a with a constant recruitment and deterministic: the SSB increases 13%

2b Assuming a stock Recruitment relationship according to the Beverton & Holt equation. (parameters:  $\alpha = 0.90909$  and  $\beta = 0.86907$ ) and a stochastic error according to a log-normal function with variance= 0.01. Iterations= 1000. SSB increases 14%

2c Assuming a stock Recruitment relationship according to the Beverton & Holt equation (parameters:  $\alpha = 0.66667$  and  $\beta = 3.1869$  and stochastic error according to a log-normal function with variance= 0.01. Iterations= 1000. SSB increases 19%

3. Projections from the last year available, 2012, were also done. The initial conditions in this year are out of the steady state. In this particular case, the stock appears to be in a decreasing trend, so that if fishing mortality does not change, the stock will decrease by around 16%. Two scenarios are proposed. The simulations were done with constant recruitment with the application of stochastic error (log-normal, variance 0.1) with 1000 iterations. The simulations were done with the software MEFISTO.

3a) Decreasing the F of the three first ages for the Italian fleet to 70% would produce an increase in the SSB of 10% from its lowest level (in year 1)

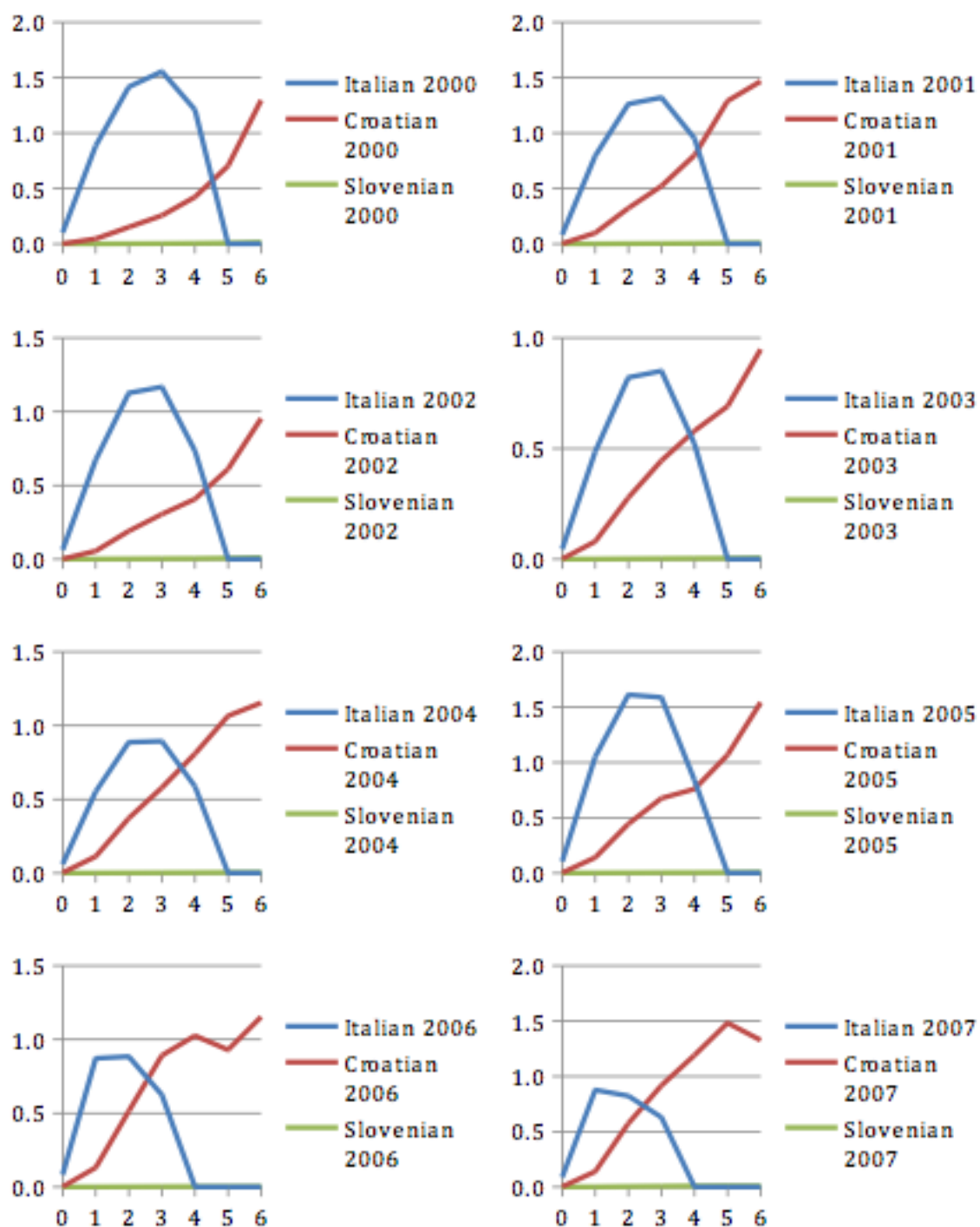
3b) Decreasing the F of the three first ages for the Italian fleet according to translation of the logistic L50 from 9.5 cm to 10.5 would mean multiplying F0, F1 and F2 by 0.44, 0.86, and 0.92. The SSB would recover 7% from its lowest level (in year 1)

### 3.3.7.3 Results (VIT projections)

The results of the VIT projections are summarized graphically in Figures 3.3.28-3.3.33. Selectivity 'improvement' leads to an increase of SSB. This increase ranged between 5% and 30% (both in simulations 1) according to the simulation settings. With a B&H stock-recruitment relationship the SSB increases are between the more realistic values of 7% and 19%. The confidence intervals are wide, and the probability of continuing an SSB decrease is significant.

Given the high catches of small fish, and considering that the age composition of the stock in 2012 was unbalanced, with the trend decreasing under a status quo policy, it seems that selectivity should be 'improved'.

Figure 3.3.28. Red mullet, GSA 17. F by year as calculated from XSA for the time period 2000-2012.



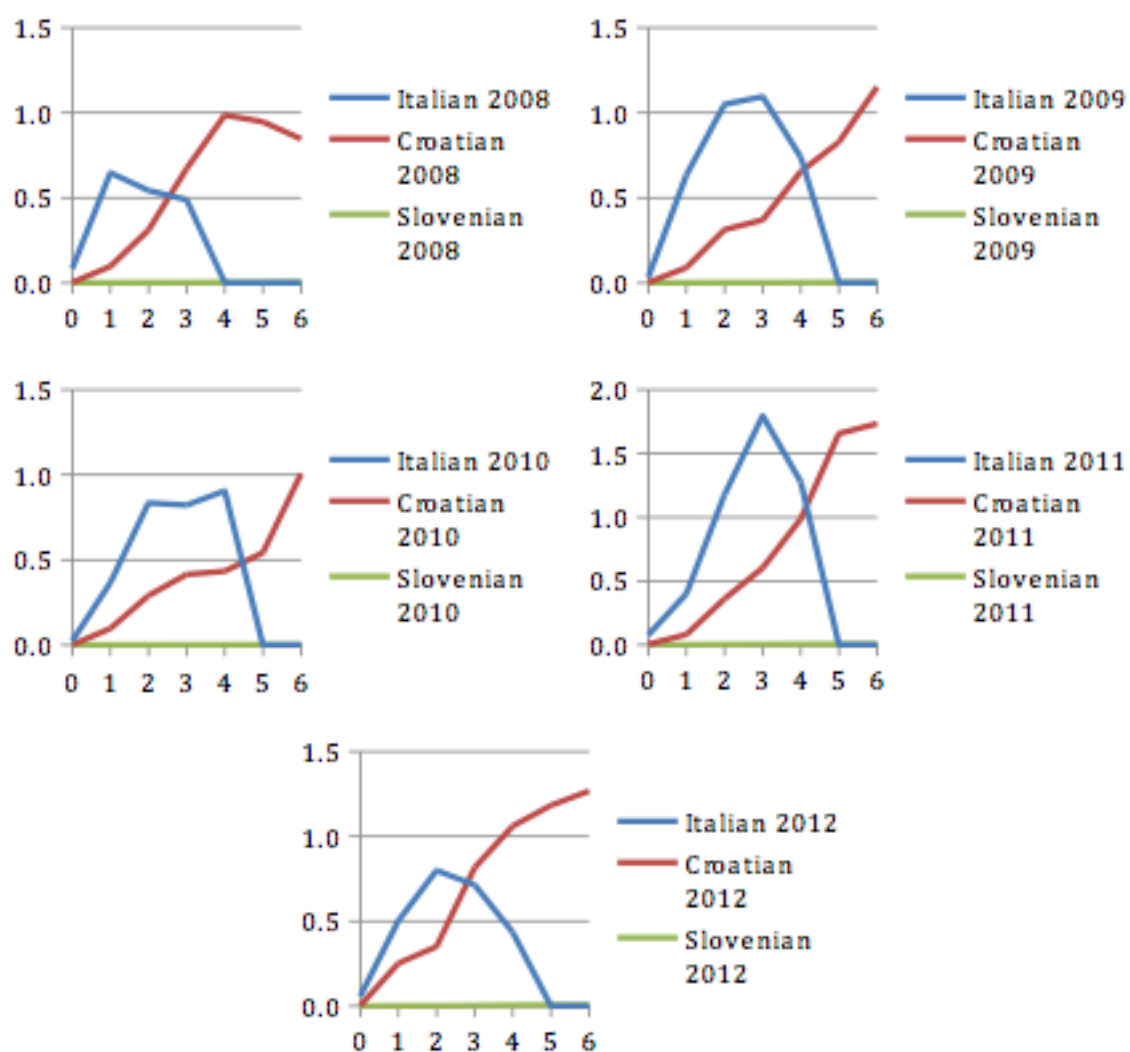
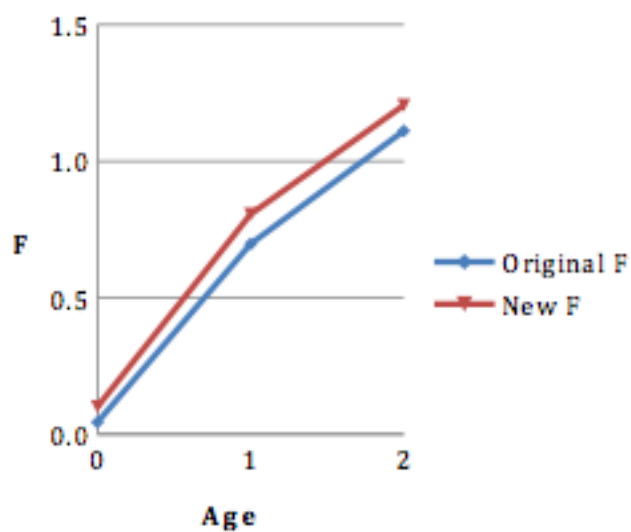


Figure 3.3.29. Red mullet, GSA 17. Change of F according to a new logistic selectivity with



1 cm increased L50

Figure 3.3.30. Red mullet, GSA 17. Projection of changes of selectivity. Scenario 2b

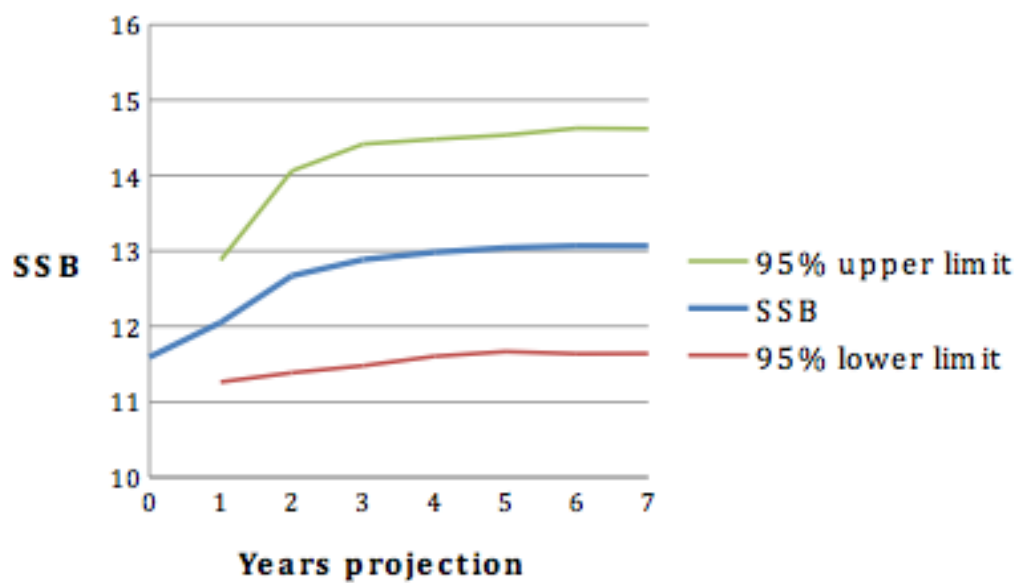




Figure 3.3.31. Red mullet, GSA 17. Projection of changes of selectivity. Scenario 2c

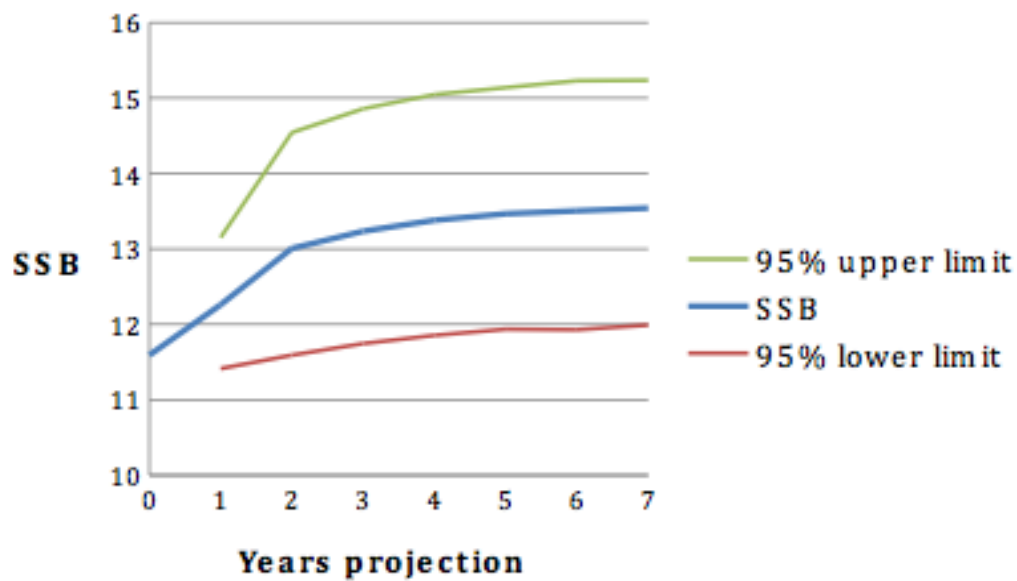
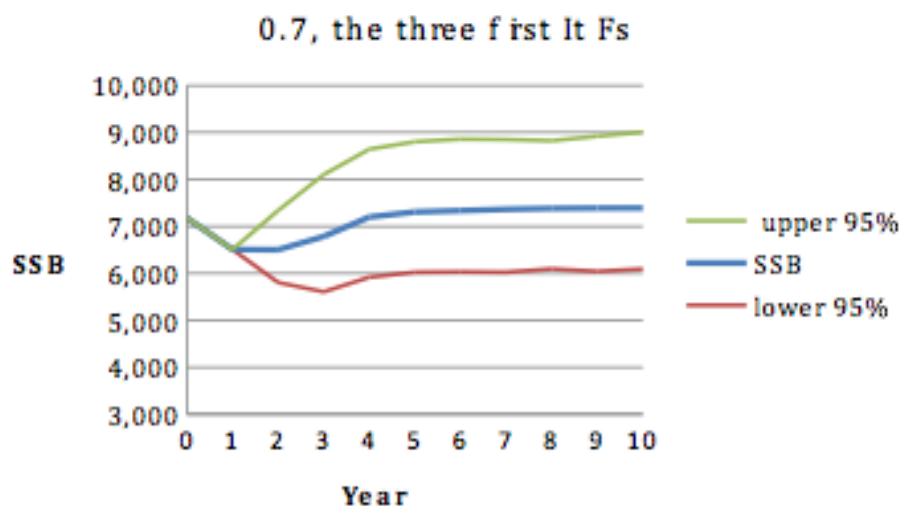
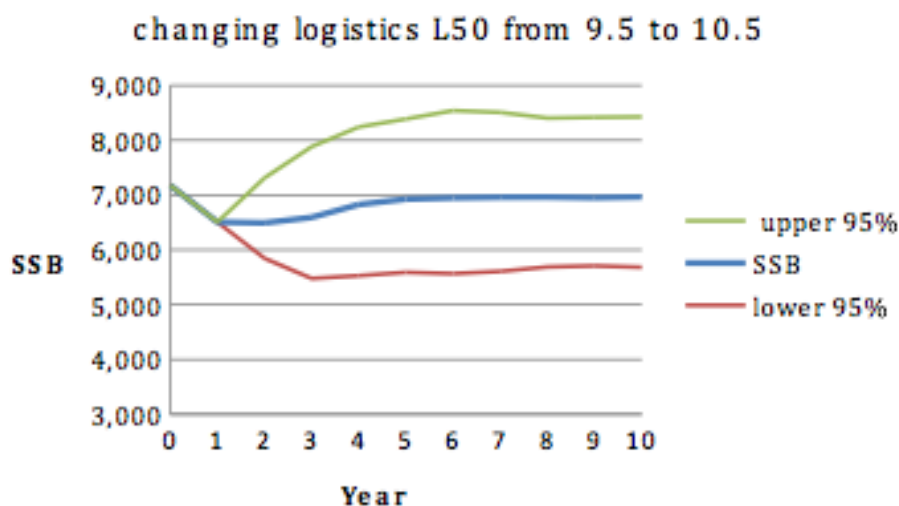


Figure 3.3.32. Red mullet, GSA 17. Projection of changes of selectivity. Scenario 3a



**Figure 3.3.33. Red mullet, GSA 17. Projection of changes of selectivity. Scenario 3b**



### 3.3.8 Conclusions

See file Conclusions\_of\_the\_EWG15-06.docx

### 3.3.9 References (ToR 3)

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### **3.4 ToR 4 - Set up a best practice standardized procedures for estimating ranges of FMSY and biomass reference points for Mediterranean stocks.**

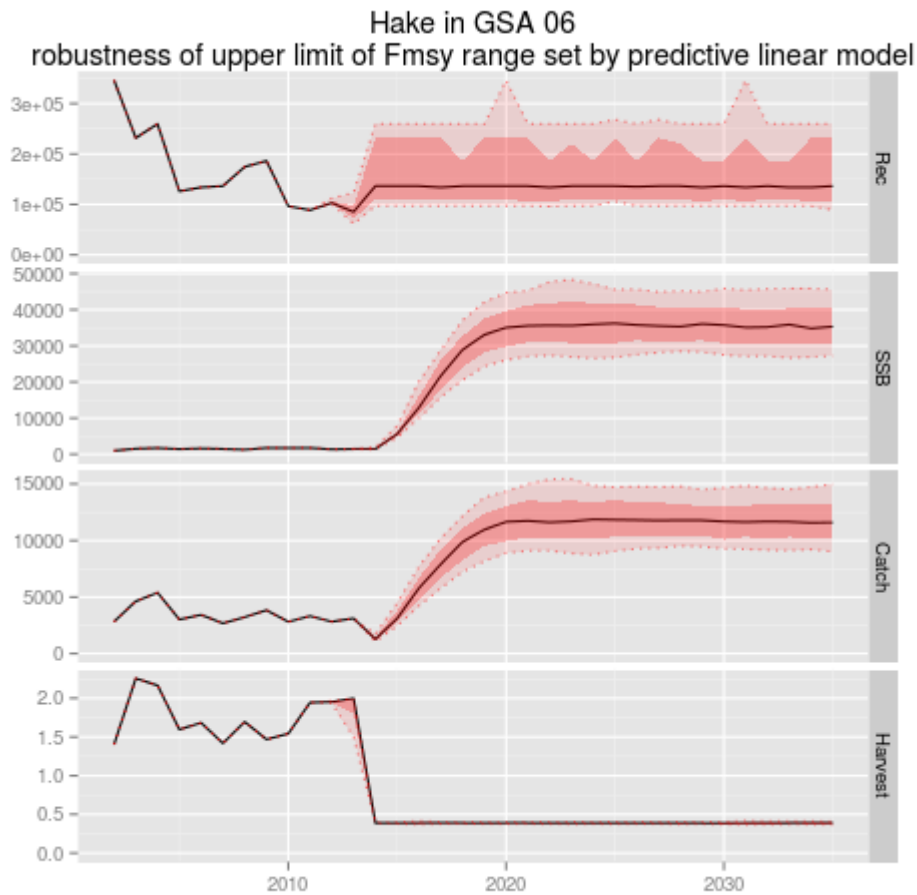
#### *3.4.1 Introduction*

F ranges have been modelled as a function of Fmsy for ~20 fish stocks from northern Europe by Ernesto Jardim according to the following formula:  $F_{upper} = 0.007801555 + 1.349401721 \cdot F_{msy}$ . EWG15-06 decided to use the parameters calculated from these models to estimate candidate ranges for Mediterranean stocks. Once these ranges were calculated they were tested in a MSE framework, described below, to see whether the stock would collapse at Fupper. Candidate stocks which EWG15-06 agreed would be tested were: hake in GSA 6 (Ernesto), red mullet in GSA 17 (Piera), deep water shrimp in GSA 6 (Francesco) and possibly – depending on time available – one of the small pelagics such as anchovy (Marianna).

To test if exploiting a stock at the upper limit of the provisional Fmsy ranges obtained through the linear models, a MSE was developed. The management procedure uses a full feedback model, with an a4a stock assessment, and the traditional 2 year forecast carried out by assessment working groups to provide catch options under different scenarios. The operating model is based on the official assessment, or an a4a assessment that mimics the official assessment as closely as possible. Stock-recruitment is based on a segmented regression model, although other models could be used, and error in recruitment is derived from the residuals of the stock-recruitment model fit. The observation error model included error on survey catchability by age, derived from model estimates. Implementation error is not considered. The process is forecast for 24 years and 250 iterations are used to describe uncertainty.

#### *3.4.2 Hake in GSA 6*

In the case of hake in GSA06, the stock exploitation is very high and the reduction in fishing mortality, towards the target F0.1, drives the fishery and the stock to levels outside the historical range. The stock dynamics in the forecast become very uncertain, although it is not expected that the levels of recruitment will remain the same when the SSB becomes +20 times higher. Nevertheless, the risk of collapse is zero in the simulations. The values of Bpa and Blim were computed using Bloss (=Blim) and multiplying by 1.4 to get Bpa (Figure 3.4.1).



**Figure 3.4.1. Hake in GSA 6. Robustness of upper limit of Fmsy range set by predictive linear models.**

### 3.4.3 Red mullet in GSA 17

Red mullet (*M. barbatus*) in GSA17 was chosen as one of the three case studies to be explored in ToR4. The stock was assessed in STECF EWG 14-08 using SS3 and was also used as a case study for addressing ToR3. The assessment model we used to address ToR 4 is the same a4a assessment as used for ToR3. The data used span from 2000 to 2012. Both SSB and recruitment show a slight decrease in the last few years, with F increasing accordingly. The fishing mortality estimated for the stock (based on Fbar over ages 1 to 3) for 2012 is  $F=1.329$ .

Due to the absence of an SR relationship, a “geomean” function was used: this resulted in a unreliable value for FMSY, therefore ‘spr.30’ (spr.30 = 0.25) was used instead as reference point. As mentioned, Fupper was computed from the heuristic relationship provided to the group in a working document by Ernesto Jardim, which basically estimates Fupper from a range of Fmsy and Fupper of northern stocks, following the linear relationship:

$$F_{upper} = 0.007801555 + 1.349401721 * F_{msy}$$

In this exercise,  $F_{upper}$  was estimated, through the simulation process, as being equal to 0.344. Note that the biomass reference points used in this exercise was based on  $B_{loss}$  (lowest SSB observed in the historical 2001 – 2012 series):

$$B_{lim} = B_{loss} = 4179 \text{ t}$$

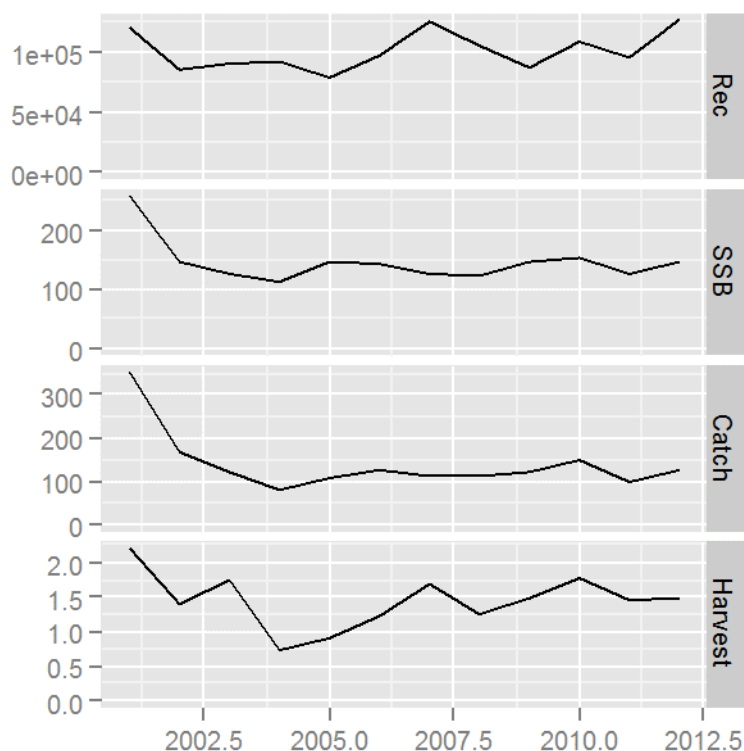
$$B_{pa} = 1.4 * B_{lim} = 5851 \text{ t}$$

A Management Strategy Evaluation (MSE) simulator based on FLR was coded to assess the risk that future SSB falls below  $B_{lim}$  after applying  $F_{upper}$  to the fishery. The simulations were run from 2013 to 2030 with 250 iterations and the probability of falling below  $B_{lim}$  in the projected years is shown below:

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	
p	0	0	0.008	0	0	0	0	0	0	0	
Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	
p	0	0	0	0.696	0	0	0	0	0.016	0.008	
Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
p	0	0.008	0.020	0.020	0.016	0.036	0.032	0.036	0.012	0.016	0.024

#### 3.4.4 *Deep water rose shrimp in GSA 6*

This stock was assessed in STECF EWG13-09 using XSA on a data set spanning the period 2001 – 2012. The stock showed relatively stable recruitment, fluctuating around a mean level, and a progressive decrease of landings and SSB during the twelve years of data, possibly linked to excessive fishing mortality. The basic assessment quantities are shown in the following graph (Figure 3.4.2).



**Figure 3.4.2. Deep water rose shrimp in GSA 06. Stock summary 2001 to 2012.**

The fishing mortalities estimated for that stock (based on  $F_{bar}$  over ages 2 to 4) were:

$$F_{current} = 1.402$$

$$F_{max} = 1.021$$

$$F_{01} = 0.269$$

Due to the “flat top” nature of the Y/R curve,  $F_{01}$  was used as proxy for  $F_{MSY}$  in this exercise and not  $F_{max}$ .  $F_{upper}$  was computed from the heuristic relationship provided to group EWG15-09 in a working document by Ernesto Jardim, which basically estimates  $F_{upper}$  from a range of  $F_{msy}$  and  $F_{upper}$  of other stocks, following the linear relationship:

$$F_{upper} = 0.007801555 + 1.349401721 * F_{msy}$$

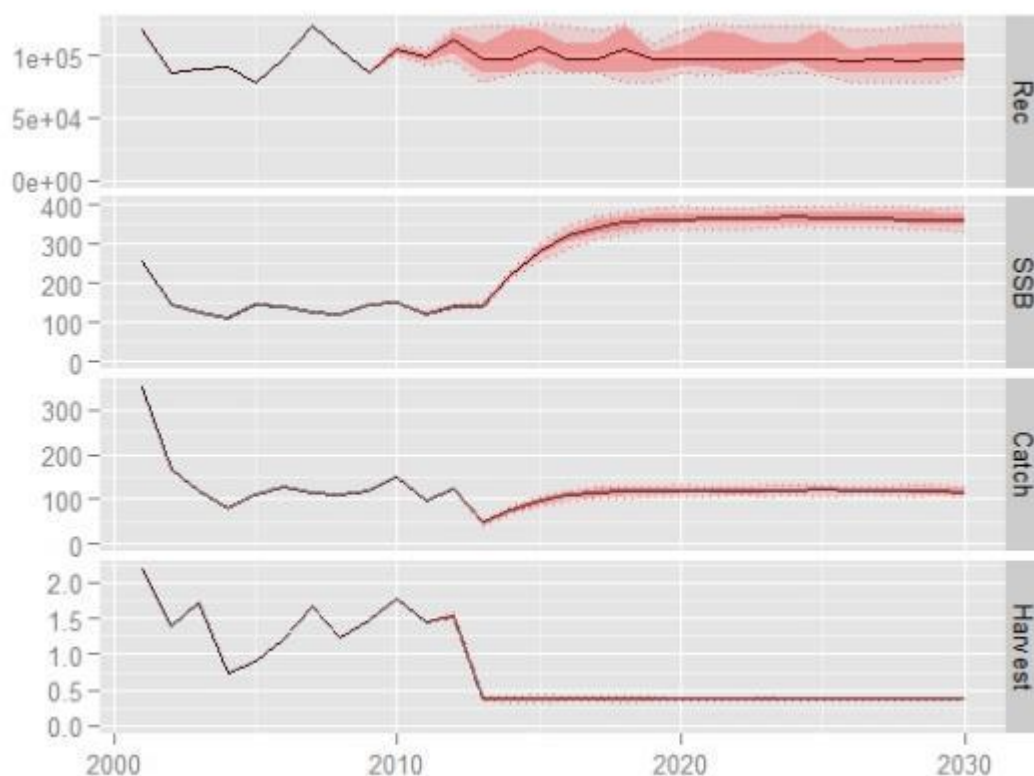
In this exercise,  $F_{upper} = 0.371$

The biomass reference points used in this exercise were based on  $B_{loss}$  (lowest SSB observed in the historical 2001 – 2012 series):

$$B_{lim} = B_{loss} = 113.4 \text{ t}$$

$$B_{pa} = 1.4 * B_{lim} = 158.8 \text{ t}$$

A Management Strategy Evaluation (MSE) simulator based on FLR was coded to assess the risk that future SSB falls below Blim after applying Fupper to the fishery (Figure 3.4.3). The simulations were run from 2013 to 2030 with 250 iterations. The basic results of this simulation are shown in the following graphs:



**Figure 3.4.3. Deep water rose shrimp in GSA 6. Robustness of upper limit of Fmsy range set by predictive linear models**

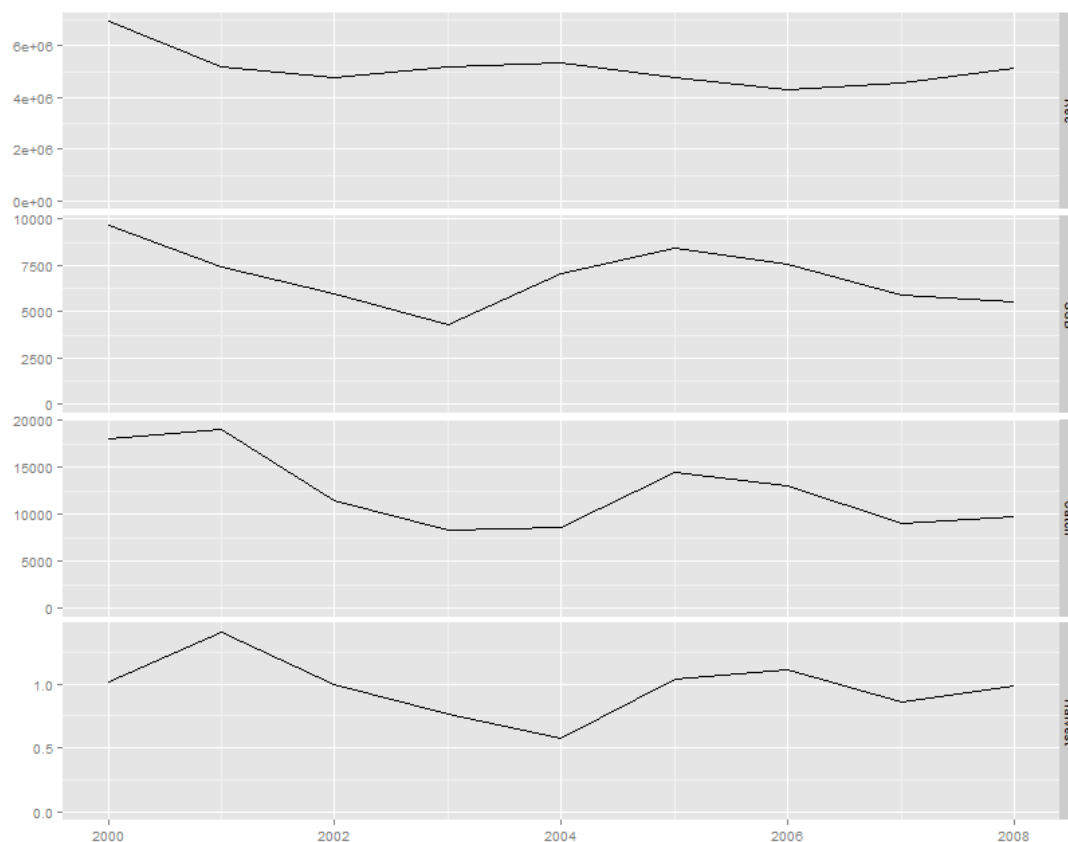
Fishing at Fupper would ensure a level of catches compatible with the average of recent years, around 100 t, and would allow rebuilding the biomass by a factor of ca. 2.5x and reduce the risk of SSB falling below Blim to 0.

#### 3.4.5 *Sardine in GSA 22*

Sardine was assessed in STECF-EWG 11-20 using XSA on a data set spanning the period 2000 – 2008. The stock relatively stable recruitment, fluctuating around a mean level, and a progressive decrease of landings and SSB during the twelve years of data, possibly linked to



excessive fishing mortality (Figure 3.4.4). The basic assessment quantities are shown in the following graphs:



**Figure 3.4.4. Sardine in GSA 22. Stock summary 2000 to 2008.**

The fishing mortalities estimated for that stock (based on  $F_{\text{bar}}$  over ages 1 to 3) were:

$F_{\text{current}(2008)}$	=
0.979	
$F_{\text{msy}}$	= 0.8895
$F_{\text{max}}$	= 7.471
$F_{01}$	= 0.9634
$F_{\text{spr}30}$	= 0.5705

Due to the “flat top” nature of the Y/R curve,  $F_{\text{spr}30}$  (30% of SSB) precautionary was used as proxy for  $F_{\text{MSY}}$  in this exercise and not  $F_{\text{max}}$  or  $F_{01}$ .

$F_{upper}$  was computed from the heuristic relationship provided to group EWG15-09 in a working document by Ernesto Jardim, which basically estimates  $F_{upper}$  from a range of  $F_{msy}$  and  $F_{upper}$  of other stocks, following the linear relationship:

$$F_{upper} = 0.007801555 + 1.349401721 * F_{msy}$$

In this exercise,  $F_{upper} = 0.777$

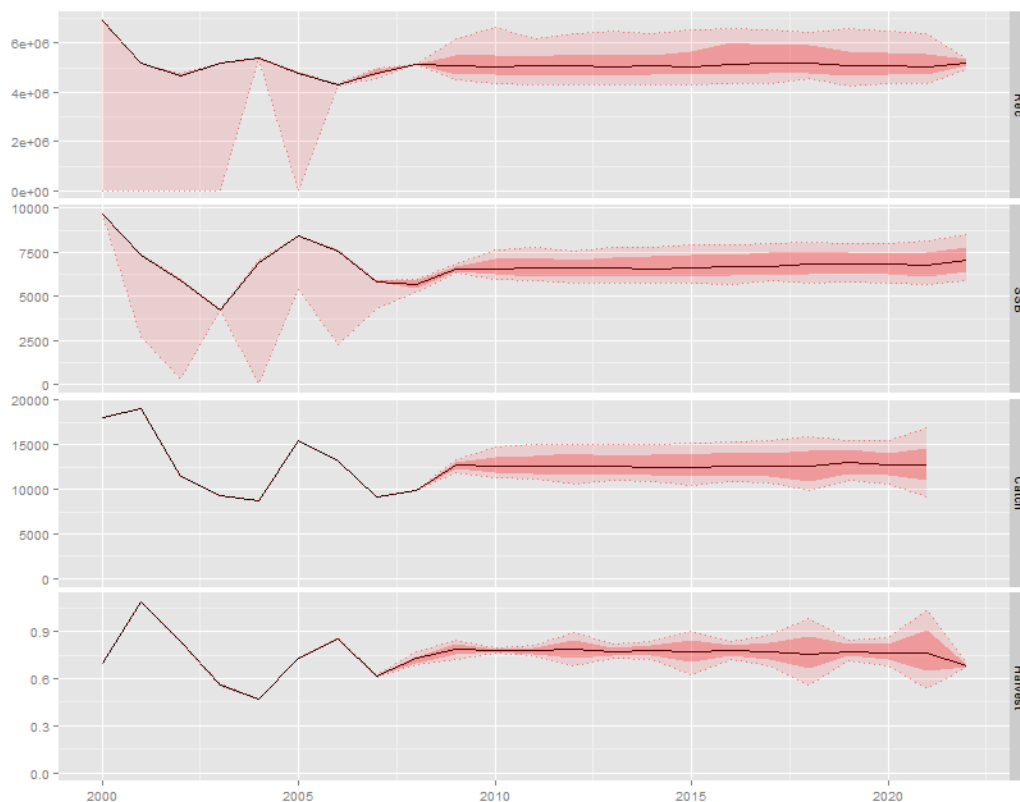
The biomass reference points used in this exercise were based on  $B_{loss}$  (lowest SSB observed in the historical 2000 – 2008 series):

$$B_{lim} = B_{loss} = 4303.22 \text{ t}$$

$$B_{pa} = 1.4 * B_{lim} = 6024.51 \text{ t}$$

A Management Strategy Evaluation (MSE) simulator based on FLR was coded to assess the risk that future SSB falls below  $B_{lim}$  after applying  $F_{upper}$  to the fishery (Fig. 3.4.5). The simulations were run from 2009 to 2020 with 250 iterations fitting a Ricker model for the stock recruitment relationship.

The basic results of this simulation are shown in the following graphs:



**Figure 3.4.5. Sardine in GSA 22. Stock summary 2000 to 2008**

Fishing at  $F_{upper}$  would ensure an average level of catches around 12000 t and reduce the risk of SSB falling below  $B_{lim}$  to 0 (see Table below).

2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
0	0	0	0	0	0	0	0	0	0	0	0

#### 4. CONTACT DETAILS OF STECF MEMBERS AND EWG-15-06 LIST OF PARTICIPANTS

1 - Information on STECF members and invited experts' affiliations is displayed for information only. In some instances the details given below for STECF members may differ from that provided in Commission COMMISSION DECISION of 27 October 2010 on the appointment of members of the STECF (2010/C 292/04) as some members' employment details may have changed or have been subject to organisational changes in their main place of employment. In any case, as outlined in Article 13 of the Commission Decision (2005/629/EU and 2010/74/EU) on STECF, Members of the STECF, invited experts, and JRC experts shall act independently of Member States or stakeholders. In the context of the STECF work, the committee members and other experts do not represent the institutions/bodies they are affiliated to in their daily jobs. STECF members and invited experts make declarations of commitment (yearly for STECF members) to act independently in the public interest of the European Union. STECF members and experts also declare at each meeting of the STECF and of its Expert Working Groups any specific interest which might be considered prejudicial to their independence in relation to specific items on the agenda. These declarations are displayed on the public meeting's website if experts explicitly authorized the JRC to do so in accordance with EU legislation on the protection of personnel data. For more information: <http://stecf.jrc.ec.europa.eu/adm-declarations>

STECF members:

Name	Address <sup>1</sup>	Tel.	Email
<b>STECF members</b>			
Abella, J. Alvaro (vice-chair)	ARPAT – AREA MARE Agenzia Regionale per la Protezione Ambientale della Toscana Articolazione Funzionale RIBM Risorse Ittiche e Biodiversità Marina Via Marradi 114, 57126 Livorno – Italia	Tel. 0039-0555- 3206956	<a href="mailto:alvarojuan.abella@arpat.toscana.it">alvarojuan.abella@arpat.toscana.it</a>

Name	Address <sup>1</sup>	Tel.	Email
<b>STECF members</b>			
Andersen, Jesper Levring (vice-chair)	Department of Food and Resource Economics (IFRO) Section for Environment and Natural Resources University of Copenhagen Rolighedsvej 25 1958 Frederiksberg Denmark	Tel.dir.: +45 35 28 68 92	<a href="mailto:jla@ifro.ku.dk">jla@ifro.ku.dk</a>
Bailey, Nicholas	Fisheries Research Services Marine Laboratory, P.O Box 101 375 Victoria Road, Torry Aberdeen AB11 9DB UK	Tel: +44 (0)1224 876544 Direct: +44 (0)1224 295398 Fax: +44 (0)1224 295511	<a href="mailto:baileyn@marlab.ac.uk">baileyn@marlab.ac.uk</a> <a href="mailto:n.bailey@marlab.ac.uk">n.bailey@marlab.ac.uk</a>
Bertignac, Michel	Laboratoire de Biologie Halieutique IFREMER Centre de Brest BP 70 - 29280 Plouzane, France	tel : +33 (0)2 98 22 45 25 - fax : +33 (0)2 98 22 46 53	<a href="mailto:michel.bertignac@ifremer.fr">michel.bertignac@ifremer.fr</a>
Cardinale, Massimiliano	Föreningsgatan 45, 330 Lysekil, Sweden	Tel: +46 523 18750	<a href="mailto:massimiliano.cardinale@slu.se">massimiliano.cardinale@slu.se</a>
Curtis, Hazel	Sea Fish Industry Authority 18 Logie Mill Logie Green Road Edinburgh EH7 4HS	Tel: +44 (0)131 558 3331 Fax: +44 (0)131 558 1442	<a href="mailto:H_Curtis@seafish.co.uk">H_Curtis@seafish.co.uk</a>
Delaney, Alyne	Innovative Fisheries Management, -an Aalborg University Research Centre, Postboks 104, 9850 Hirtshals, Denmark	Tel.: +45 9940 3694	<a href="mailto:ad@ifm.aau.dk">ad@ifm.aau.dk</a>
Daskalov, Georgi	Laboratory of Marine Ecology, Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences	Tel.: +359 52 646892	<a href="mailto:gmdaskalov@yahoo.co.uk">gmdaskalov@yahoo.co.uk</a>
Döring, Ralf	Thünen Bundesforschungsinstitut, für Ländliche Räume, Wald und Fischerei, Institut für Seefischerei - AG Fischereiökonomie, Palmaille 9, D-22767 Hamburg, Germany	Tel.: 040 38905-185 Fax.: 040 38905-263	<a href="mailto:ralf.doering@ti.bund.de">ralf.doering@ti.bund.de</a>
Gascuel, Didier	AGROCAMPUS OUEST 65 Route de Saint Brieuc, bat.4 CS 84215, F-35042 RENNES Cedex France	Tel:+33(0)2.23.48.55.34 Fax: +33(0)2.23.48.55.35	<a href="mailto:Didier.Gascuel@agrocampus-ouest.fr">Didier.Gascuel@agrocampus-ouest.fr</a>
Graham, Norman (chair)	Marine Institute, Fisheries Science Services (FSS), Rinville, Oranmore, Co. Galway, Ireland	Tel: + 353(0) 91 87200	<a href="mailto:norman.graham@marine.ie">norman.graham@marine.ie</a>

Name	Address <sup>1</sup>	Tel.	Email
<b>STECF members</b>			
Garcia Rodriguez, Mariano	Instituto Español de Oceanografía, Servicios Centrales, Corazón de María 8, 28002, Madrid, Spain		<a href="mailto:Mariano.Garcia@md.ieo.es">Mariano.Garcia@md.ieo.es</a>
Gustavsson, Tore Karl-Erik	Independent Consultant, Göteborg, Sweden		<a href="mailto:tore.gustavsson@hotmail.com">tore.gustavsson@hotmail.com</a>
Jennings, Simon	CEFAS Lowestoft Laboratory, Pakefield Road, Lowestoft Suffolk, UK NR33 0HT	Tel.: +44 1502562244 Fax: +44 1502513865	<a href="mailto:simon.jennings@cefas.co.uk">simon.jennings@cefas.co.uk</a>
Kenny, Andrew	CEFAS Lowestoft Laboratory, Pakefield Road, Lowestoft Suffolk, UK NR33 0HT	Tel.: +44 1502562244 Fax: +44 1502513865	<a href="mailto:andrew.kenny@cefas.co.uk">andrew.kenny@cefas.co.uk</a>
Kraak, Sarah	Thünen-Institut für Ostseefischerei, Alter Hafen Süd 2, 18069 Rostock Germany	Tel. +49 3818116113	<a href="mailto:sarah.kraak@ti.bund.de">sarah.kraak@ti.bund.de</a>
Kuikka, Sakari	University of Helsinki, Department of Environmental Sciences, P.O. Box 65 (Viikinkaari 1), FI-00014 University of Helsinki, FINLAND	Tel.: +358 50 3309233 Fax. +358-9-191 58754	<a href="mailto:skuikka@mappi.helsinki.fi">skuikka@mappi.helsinki.fi</a>
Martin, Paloma	CSIC Instituto de Ciencias del Mar Passeig Marítim, 37-49 08003 Barcelona Spain	Tel: 34.93.2309500 direct line : 34.93.2309552 Fax: 34.93.2309555	<a href="mailto:paloma@icm.csic.es">paloma@icm.csic.es</a>
Malvarosa, Loretta	NISEA S.c.a.r.l.		<a href="mailto:malvarosa@nisea.eu">malvarosa@nisea.eu</a>
Murua, Hilario	AZTI - Tecnalia / Unidad de Investigación Marina, Herrera kaia portualdea z/g 20110 Pasaia (Gipuzkoa), Spain	Tel: 0034 667174433 Fax: 94 6572555	<a href="mailto:hmurua@azti.es">hmurua@azti.es</a>
Nord, Jenny	The Swedish Agency of Marine and Water Management (SwAM)	Tel. 0046 76 140 140 3	<a href="mailto:Jenny.nord@havochvatten.se">Jenny.nord@havochvatten.se</a>
Nowakowski, Piotr	Maritime University of Szczecin. – Faculty of Food Science and Fisheries, Department of Fishing Technique, Szczecin		<a href="mailto:npfgd@poczta.onet.pl">npfgd@poczta.onet.pl</a>
Prelezzo, Raul	AZTI - Tecnalia / Unidad de Investigación Marina Txatxarramendi Ugarteia z/g 48395 Sukarrieta (Bizkaia), Spain	Tel: 94 6029400 Ext: 406- Fax: 94 6870006	<a href="mailto:rprelezzo@suk.azti.es">rprelezzo@suk.azti.es</a>
Sala, Antonello	Fishing Technology Unit National Research Council (CNR) Institute of Marine Sciences (ISMAR) - Fisheries Section Largo Fiera della Pesca, 1 60125 Ancona - Italy	Tel: +39 071 2078841 Fax: +39 071 55313	<a href="mailto:a.sala@ismar.cnr.it">a.sala@ismar.cnr.it</a>

Name	Address <sup>1</sup>	Tel.	Email
<b>STECF members</b>			
Scarcella, Giuseppe	Environmental Management Unit National Research Council (CNR) Institute of Marine Sciences (ISMAR) - Fisheries Section Largo Fiera della Pesca, 1 60125 Ancona - Italy	Tel: +39 071 2078846 Fax: +39 071 55313	<a href="mailto:g.scarcella@ismar.cnr.it">g.scarcella@ismar.cnr.it</a>
Somarakis, Stylianos	Department of Biology University of Crete Vassilika Vouton P.O. Box 2208 71409 Heraklion Crete Greece	Tel.: +30 2610 394065, +30 6936566764	<a href="mailto:somarak@biology.uoc.gr">somarak@biology.uoc.gr</a>
Stransky, Christoph	Thünen Institute [TI-SF] Federal Research Institute for Rural Areas, Forestry and Fisheries, Institute of Sea Fisheries, Palmaille 9, D- 22767 Hamburg, Germany	Tel. +49 40 38905-228 Fax: +49 40 38905-263	<a href="mailto:christoph.stransky@ti.bund.de">christoph.stransky@ti.bund.de</a>
Theret, Francois	Scapêche 17 Bd Abbé Le Cam 56100 Lorient France		<a href="mailto:ftheret@comata.com">ftheret@comata.com</a>
Ulrich, Clara	DTU Aqua, National Institute of Aquatic Resources, Technical University of Denmark, Charlottenlund Slot, Jægersborg Allé 1, 2920 Charlottenlund, Denmark		<a href="mailto:cu@aqua.dtu.dk">cu@aqua.dtu.dk</a>
Vanhee, Willy	ILVO - Institute for Agricultural and Fisheries Research Unit Animal Sciences - Fisheries Ankerstraat 1, B-8400 Oostende, Belgium	Tel 00-32-59-34-22-55 Fax 00-32-59-33-06-29	<a href="mailto:willy.vanhee@ilvo.vlaanderen.be">willy.vanhee@ilvo.vlaanderen.be</a>
van Oostenbrugge, Hans	Landbouweconomisch Instituut- LEI, Fisheries Section, Burg. Patijnlaan 19 P.O.Box 29703 2502 LS The Hague The Netherlands	Tel: +31 (0)70 3358239 Fax: +31 (0)70 3615624	<a href="mailto:Hans.vanOostenbrugge@wur.nl">Hans.vanOostenbrugge@wur.nl</a>

## EWG-15-06 participants

<b>STECF members</b>			
Name	Address <sup>1</sup>	Telephone no.	Email
Cardinale, Massimiliano	Föreningsgatan 45, 330 Lysekil, Sweden	Tel: +46 523 18750	<a href="mailto:massimiliano.cardinale@slu.se">massimiliano.cardinale@slu.se</a>

Scarcella, Giuseppe	Environmental Management Unit National Research Council (CNR) Institute of Marine Sciences (ISMAR) - Fisheries Section Largo Fiera della Pesca, 1 60125 Ancona - Italy	Tel: +39 071 2078846 Fax: +39 071 55313	<a href="mailto:g.scarcella@ismar.cnr.it">g.scarcella@ismar.cnr.it</a>
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Invited experts			
Name	Address	Telephone no.	Email
Valerio BARTOLINO	Department of Aquatic Resources- Swedish University of Agricultural Sciences Turistgatan 5 45330 LYSEKIL Sweden	Tel: +46 523 18750	<a href="mailto:valerio.bartolino@slu.se">valerio.bartolino@slu.se</a>
Douglas BEARE	Globefish Consultancy Services 8 West Street PO209AA SELSEY United Kingdom	Tel: +44(0)1243 602834	<a href="mailto:doug.beare@gmail.com">doug.beare@gmail.com</a>
Isabella BITETTO	COISPA Tecnologia & Ricerca. via dei trulli 18 70126 BARI	Tel: +39 080 5433596	<a href="mailto:bitetto@coispa.it">bitetto@coispa.it</a>
Piera CARPI	CNR-ISMA Largo Fiera della Pesca- 260122 ANCONA Italy	Tel: + 34932309500	<a href="mailto:piera.carpi@an.ismar.cnr.it">piera.carpi@an.ismar.cnr.it</a>
Francesco COLLOCA	CONSIGLIO NAZIONALE DELLE RICERCHE - ISTITUTO AMBIENTE MARINO COSTIERO VIA L. VACCARA 61 91026 MAZARA DEL VALLO (TP) Italy	Tel: +39 0923948966	<a href="mailto:francesco.colloca@iamc.cnr.it">francesco.colloca@iamc.cnr.it</a>
Marianna GIANNOULAKI	HCMR Ext American Base Gournes- PO BOX 2214 GR71103 GOURNES Greece	Tel: 00302810337831	<a href="mailto:marianna@hcmr.gr">marianna@hcmr.gr</a>
Alessandro LIGAS	Centro Interuniversitario di Biologia Marina ed Ecologia Applicata Viale N. Sauro 57128 LIVORNO Italy	Tel: +39 0586 260723	<a href="mailto:ligas@cibm.it">ligas@cibm.it</a>
Jordi LLEONART	Institut de Ciències del Mar CSIC Psg Marítim de la Barceloneta 37-49, 8003, Barcelona Spain	Tel: 00 34 93 230 95 00	<a href="mailto:lleonart@icm.csic.es">lleonart@icm.csic.es</a>
Alessandro MANNINI	University of Genoa- DISTAV Department, V.le Benedetto XV- 3, 16132, GENOVA	Tel: +39 0103538036	<a href="mailto:Alessandro.Mannini@unige.it">Alessandro.Mannini@unige.it</a>
Francesc MAYNOU	Institut de Ciències del Mar CSIC Psg Marítim de la Barceloneta 37-49, 8003, Barcelona Spain	Tel: + 34932309500	<a href="mailto:maynouf@icm.csic.es">maynouf@icm.csic.es</a>
MATTEO MURENU	Universita di Cagliari – DBAE, Viale Poetto-1, 9126 CAGLIARI, Italy	Tel: +39 070 6758017	<a href="mailto:mmurenu@unica.it">mmurenu@unica.it</a>
George TSERPES	Hellenic Centre for Marine Research (HCMR) Greece	Tel: +30 2810337851	<a href="mailto:gtserpes@hcmr.gr">gtserpes@hcmr.gr</a>

JRC experts			
Name	Address	Telephone no.	Email
Ernesto JARDIM	Joint Research Centre (IPSC) Maritime Affairs Unit Via E. Fermi, 2749 21027 Ispra (Varese), Italy	+390332785311	<a href="mailto:ernesto.jardim@jrc.ec.europa.eu">ernesto.jardim@jrc.ec.europa.eu</a>

Giacomo OSIO	Chato	Joint Research Centre (IPSC) Maritime Affairs Unit Via E. Fermi, 2749 21027 Ispra (Varese), Italy	+390332785948	<a href="mailto:giacomo-chato.osio@jrc.ec.europa.eu">giacomo- chato.osio@j rc.ec.europa.e u</a>
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## 5. LIST OF BACKGROUND DOCUMENTS

Background documents are published on the meeting's web site on:

<http://stecf.jrc.ec.europa.eu/ewg1506>

List of background documents:

- EWG-15-06 – Doc 1 - Declarations of invited and JRC experts (see also section 5 of this report – List of participants)



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#### European Commission

EUR 27408 EN – Joint Research Centre – Institute for the Protection and Security of the Citizen

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#### Authors:

##### STECF members:

Abella, J. A., Andersen, J., Bailey, N., Bertignac, M., Cardinale, M., Curtis, H., Daskalov, G., Delaney, A., Döring, R., Garcia Rodriguez, M., Gascuel, D., Graham, N., Gustavsson, T., Jennings, S., Kenny, A., Kraak, S., Kuikka, S., Malvarosa, L., Martin, P., Murua, H., Nord, J., Nowakowski, P., Prellezo, R., Sala, A., Scarcella, G., Somarakis, S., Stransky, C., Theret, F., Ulrich, C., Vanhee, W. & Van Oostenbrugge, H.

##### STECF EWG 15-06 members:

Bartolino, V., Beare, D., Bitetto, I. Cardinale, M., Carpi, P., Colloca, F., Giannoulaki, M., Ligas, A., Lleonart, J., Mannini, A., Maynou, F., Murenu, M., Osio, G.C., Scarcella, G., Tserpes, G..

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