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Methodology for the Stock Assessments in the Mediterranean Sea

(STECF-17-07)

Edited by Simmonds, J., Mannini, A. and Osio G. C.

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Joint Research Centre

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Abstract

Commission Decision of 25 February 2016 setting up a Scientific, Technical and Economic Committee for Fisheries, C(2016) 1084, OJ C 74, 26.2.2016, p. 4–10. The Commission may consult the group on any matter relating to marine and fisheries biology, fishing gear technology, fisheries economics, fisheries governance, ecosystem effects of fisheries, aquaculture or similar disciplines. This report deals with methods for stock assessments in the Mediterranean Sea was reviewed by the STECF during its 55th plenary meeting held from 10 to 14 July 2017 in Brussels, Belgium.

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EWG-17-02 report:

Simmonds, E. J., A., Abella, J.A., Bitetto, I., Colloca, F., Isajlovic, I., Jardim, E., Kokkalis, A., Mannini, A., Martin, P., Molla Gazi, K., Murenu, M., Ligas, A., Osio, G. C., Pengal, P., Ramirez, J., Scott, F., Ticina, V., Vrgoc, N.

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Background provided by the Commission

i) Background for ToR 1 of EWG-17-02

The use of deterministic length slicing can have an influence on our understanding of the stock dynamics, as it can result in different population values or reference points. As a consequence, significantly different reference points and other parameters are available for the different stocks of the same species. For example, STECF 16-22 concluded: "that length indicators are very sensitive to length infinity (L_{inf}) in the growth model, and marked inconsistencies were observed in some of the stocks analysed, with the reported L_{inf} from DCF data call lower than largest observed size of individuals and sometimes below mean lengths. Depending on which Linf will be used, indicators can be calculated to be greater or less than 1 and thus, the exploitation rate for a stock can be above or below F_{MSY}." STECF 16-21 further highlighted the necessity to provide an explicit guidance for the methodological approaches and parameter choices used in length based assessment and reference point analyses. Further work is required to better understand these issues by exploring other options and defining shared guidelines.

ii) Background for ToRs 2, 3 and 4 of EWG-17-02

Multiannual plans (MAPs) as described in Articles 9 and 10 of the Regulation (EU) No 1380/2013 on the Common Fisheries Policy are a fundamental fisheries management tool to deliver maximum sustainable yield (MSY) exploitation rates with a view to restore and maintain fish stocks above biomass levels capable of producing MSY. They are also the most adequate management vehicle to implement the landing obligation for the species subject to the minimum conservation reference size in the Mediterranean Sea. In addition to the quantifiable targets, conservation reference points and safeguards measures, a MAP may also contain conservation measures to avoid and reduce unwanted catches. The development of MAPs for the Mediterranean areas may require analyses with limited data. In many cases due to short time series or missing information analytical assessments are difficult to obtain and data limited methods are required. While a range of data limited approaches have been reviewed previously, this review has been in a general context, and without reference to specific data availability. There is a need to focus more directly on the specific data availability and use the experience of applying methods (such as length based indicators) where both assessments and data limited approaches have been tried, to obtain a better idea of the utility of the available methods.

SCIENTIFIC, TECHNICAL AND ECONOMIC COMMITTEE FOR FISHERIES (STECF) - Methodology for the Stock Assessments in the Mediterranean Sea (STECF-17-02)

The EWG-17-02 report was reviewed during the plenary meeting held in Brussels, 10-14 July 2017.

Request to the STECF

STECF is requested to review the EWG 17-02 report, to evaluate its findings and make appropriate comments including, where possible, explicit endorsement with respect to the methods and advices provided therein.

In particular, on the basis of the EWG results and STECF is requested:

As regards the Length based Analyses

To provide solutions including shared guidelines, where feasible, on how to overcome the shortcoming identified

As regards the Data Limited Stocks

to provide a reasoned list of Mediterranean data limited stocks that can be regularly assessed with the identified methods over the next 3-5 years

As regards the target stocks and main by-catch associated species for possible future multiannual plans

-To advise on the stocks that should be considered, either as driving the fisheries or as relevant by-catches

-To provide pros and cons of the geographical scope of each possible plan taking into account the content requirements of the multiannual plans, the distribution of the stocks, the dynamics and technical interactions between fleets as well as the scientific knowledge currently available to the scientific community.

STECF response

STECF observations

The working group was held in Arona, Italy, from 5th to 9th June 2017. The meeting was attended by 18 experts in total, including 3 STECF members and 4 JRC experts.

The objective of the Mediterranean Methodology EWG 17-02 was to develop a number of scientific areas to assist in future assessments. The ToRs were partially based on ideas developed from STECF-16-17 (Demersal stock assessments in the Mediterranean Sea). In addition, two review ToRs were added.

TERMS OF REFERENCE GIVEN TO THE EWG:

The STECF-EWG 17-02 was requested:

(1) To collate and review all relevant information of length based analyses (including length slicing to age and choice of biological parameters) used so far in STECF-EWG for Mediterranean stock assessment (STECF 16-22; 16-21; 16-17 and other relevant sources). Consider both the influence on the results of stock assessment and also the influence on MSY reference points. In the light of this review, provide solutions on how to overcome the shortcomings and develop shared guidelines so that further improvements in the estimates of parameters, reference points, stock status and exploitation rates are delivered. The following species are, inter alia, to be considered,: hake (*Merluccius merluccius*), red mullet (*Mullus barbatus*[#]) and deepwater rose shrimp (*Parapenaeus longirostris*).

(2)

i) To apply and compare potential data poor methods to provide MSY advice by taking into account timespan and types of data series available under the DCF. The following stocks are, inter alia, to be considered: blue whiting in GSAs 6 and 9 (STECF 14-17) and hake in GSAs 6, 7 and 9,

ii) for the same stocks, to compare the data poor methods to the existing analytical assessments in order to indicate differences in the quality of the results obtained by the different approaches;

iii) to apply the best available data poor method that resulted from point 2i and 2ii above to the following data poor stocks: blue whiting in GSAs 17, striped red mullet in GSA 11 (tbc).

(3) To carry out a critical review of the stock boundaries for the species and areas listed below. This review shall take into account the latest bioecological and fishery-related information available including, inter alia, recent analyses on the topic supported by DG MARE (see Annexes [X]1). In the light of this review, propose scientifically sound stock units for:

a) anchovy (*Engraulis encrasicolus*) and sardine (*Sardina pilchardus*) in the western Mediterranean Sea (GSAs 5, 6, 7, 8, 9, 10 and 11);

b) common Pandora (*Pagellus erythrinus*), Norway lobster (*Nephrops norvegicus*) and common cuttlefish (*Sepia officinalis*) in the Adriatic Sea (GSAs 17 and 18); and

c) European hake (*Merluccius merluccius*) and red mullet (*Mullus barbatus*[#]) in the Ionian Sea (GSAs 19 and 20).

(4) To advise on the stocks that should be considered, either as driving the fisheries or as relevant by-catches, for possible multiannual plans addressing the small pelagic fisheries of the Western Mediterranean Sea (GSAs 5, 6, 7, 8, 9, 10, 11), the demersal fisheries of the Adriatic and Ionian Seas (GSAs 17, 18, 19, 20) and the demersal fisheries of the Eastern Mediterranean Sea (GSAs 22, 23, 25). For this purpose, the annexes [1], [2] and [3] provide an overview of the main elements that could be considered so far.

The advice shall provide also pros and cons of the geographical scope of each plan taking into account the content requirements of the multiannual plans, the distribution of the stocks, the dynamics and technical interactions between fleets as well as the scientific knowledge currently available to the scientific community. Synoptic overview of the information used in support of the advice shall be reported.

*1 Work to be done through ad-hoc contracts during the first semester of 2017.

red mullet (Mullus barbatus) was originally noted incorrectly in the as *Mullus surmuletus* this is corrected here

STECF comments

In relation to each of the Terms of Reference (ToRs), STECF notes the following:

ToR 1 - STECF acknowledges the EWG's exploration of the impact of length slicing to age and choice of biological parameters to the assessment of stock status. STECF notes that in the past there has been considerable variation in the parameter values used for length slicing and for natural mortality for the three important demersal species investigated. STECF analysed the impact of changes in von Bertalanffy Growth Parameters (hereafter VBGP) and M values on the assessment outcomes. While minor changes to the parameters may not have a significant impact, STECF notes that in the cases the assessment outcome is close to the MSY reference point, a change of 0.05 in k (corresponding to a approx. 10% uncertainty around the estimate) could lead to a different diagnosis of the stock from overexploited to underexploited. In the case of deep water rose shrimp, European hake and red mullet, major differences have been observed in VBGP parameters historically estimated, and these can have a considerable influence on stock assessment.

STECF agrees with the EWG that there is a need for greater consistency in VBGP parameters across stocks of the same species and that EWGs should attempt to base VBGP values on the underlying data where possible (and not on values published in the literature). The EWG suggests calling for the underlying data, the age length keys (ALK) for the stocks for which these are planned in the DCF National Plans. STECF supports the request to include the information in future data calls, and reiterates the need to have data by quarter. In addition, the EWG suggests that the DCF Catch Table should be amended to include a field documenting the method and parameters used for the length to age determination and the range of years used for the VBGP estimation in case of use of a deterministic slicing.

STECF notes that in the case that direct ageing can be carried out (e.g. otolith reading) and the ageing process has been validated and is well documented, an approach based on estimated ages is preferable to slicing. In the case direct ageing is not possible and the species shows rapid and variable growth during the first 1-2 years (e.g. deep water rose shrimp), the use of length based models, ideally based on quarterly data, should be explored.

ToR 2 - STECF acknowledges the EWG's evaluation of stock exploitation indicators (proxies for stock status) suitable for data limited stocks. STECF supports the conclusions that individual indicators are often unbiased but can be noisy indicators of stock status, and therefore supports the view for further development work on use of multiple indicators. STECF supports the request for an ad-hoc contract to develop this work further to explore the basis for the provision of advice using data limited indicators, STECF provide draft background and ToR for the ad hoc contract (annex).

ToR 3 - STECF notes that the proposed ad-hoc contracts to evaluate appropriate species areas considered in ToR 3 were not placed. Given the limited information available (STOCKMED report and a few additional published papers collected during the meeting), STECF agrees with the EWG conclusion that the basis for many stock divisions is weak. STECF is not aware of currently ongoing projects dealing with stock identity, and acknowledges that unless more data become available, population boundaries will remain uncertain. STECF recalls that the STOCKMED project (which finished in 2014) that aimed at the definition of stocks units in the Mediterranean was not conclusive due to a generalized lack of evidence on some aspects useful for stock discrimination such as larval dispersal, connectivity, genetics, and also in detailed fisheries activities as spatial distribution of the fleets (STECF PLEN 17-01). STECF considers that the proposed stock boundaries (Section 2.1.3 of the EWG report) should be used for current assessments and management until better options become available.

ToR 4 - In addressing ToR 4 (the identification of main species and main gears either as driving the fisheries or as relevant by-catches) the EWG built on work performed previously as part of the work on multiannual plans (MAP) (Mediterranean Methods July 2016 (STECF 16-14)) and Landing obligation part 6 from October 2015 (STECF 15-19)). STECF endorses the EWG proposals for inclusion of extra gears (beam trawl, hydraulic dredge, shore and boat seine) in geographical scope in ToRs Annex 1 (GSAs 17, 18, 19 and 20). Regarding the list of species, STECF endorses the conclusions for species list in the three areas' MAPs detailed in the ToR, but notes that some commercially important shellfish species have been previously omitted and should be added to the MAPs: Primarily the addition of one major species (striped venus clam *Chamelea gallina*) in GSAs in ToRs Annex 1; but also the minor changes to 'additional species' lists for areas in Annex 1 and Annex 3 (GSAs 22, 23 and 25) (see Section 2.1.4 of EWG report). STECF notes that these species have been proposed based on the current catches and the EWG did not differentiate whether the plans should be implemented at national or multi-national level.

As regards the request to STECF to provide solutions including shared guidelines, where feasible, on how to overcome the shortcoming identified in the length-based analyses, STECF notes that the EWG proposed recommendations for future work. These recommendations refer to the need of *i)* coherence of all growth parameters used in the assessments; *ii)* improvement in documenting and defining the growth models and age slicing; *iii)* test where possible age slicing by sex; *iv)* t_0 should be truncated to values between 0 and -0.2; *v)* review the raw age length data, where necessary refitting growth models (section 2.2 in the EWG report).

STECF was also requested to provide a list of Mediterranean data limited stocks (DLS) that can be regularly assessed with the identified methods over the next 3-5 years. This request had not been included in the EWG 17-02 ToRs, and STECF was unable to derive such a list during the Plenary meeting. An initial analysis was carried out by STECF EWG 16-05 in June 2016. However, the evaluation by EWG 16-05 could only investigate the presence/absence of data, not the quality of the information. In order to develop the required list STECF proposes a further work, under an ad hoc contract to assess the availability and suitability of survey data and/or catches. Following this a selection of the most promising DLS can be made. This preliminary list would later be assessed by the EWG and STECF. Draft terms of reference of the ad-hoc contract are proposed in the annex. STECF notes that in addition to this analysis, it is necessary to explore the use of multiple indicators for giving advice for data limited stocks, which should also be done through an ad hoc contract - see above.

STECF conclusions

STECF acknowledges that the EWG has addressed all its terms of reference, which could also be performed thanks to better and more timely coordination on the work need between STECF, JRC and DGMARE.

STECF commends the EWG on its exploration of the impact of length-based factors in assessments and stock status. STECF notes that in the past there has been considerable variation in the parameter values used for length slicing and for natural mortality, so the analyses performed by the EWG were strongly needed to improve the quality of stock assessment.

STECF commends the EWG for its evaluation of stock exploitation indicators (proxies for stock status) suitable for data limited stocks. STECF supports the conclusions that individual indicators are often unbiased but can be noisy indicators of stock status, and therefore supports the view for further development work on use of multiple indicators.

Regarding the request to provide pros and cons of the geographical scope of each possible MAP, STECF notes that the main issue, the stocks configuration, remains uncertain. There is hardly any new information on stock boundaries existing in addition to that collected during the STOCKMED project. In order to advance knowledge on stock boundaries, it is necessary to initiate new data collection (such as tagging, genetic etc.) that can generate new information on stock identity and distribution.

STECF proposes two ad hoc contracts, one to evaluate the quality of the DCF data, which will allow the elaboration of a list of data limited stocks that can be assessed, and the second one to explore the use of multiple indicators for giving advice for data limited stocks.

Annex

AD-HOC contract to evaluate quality of DCF data for data limited information.

The purpose of this is to obtain summary information to be used to identify stocks with promising or unpromising data for future work. The objective would be to check for consistency of data in terms of availability and sampling and the potential for significant changes in time, that might provide useful signals. The proposal is to concentrate on demersal data for stocks of general interest. Two types of DCF data should be evaluated, survey data and catch data.

1) **Survey evaluation** -MEDITS survey by species by GSA presented on no more than one page per species/ GSA this should be based on annually tabulated summary data in a simple data frame (in R) and then output in plots on a single page, combined with some overall statistics for the data set for a species in a GSA.

Annual summary stats for each species for each year calculate and tabulate and plot.

DCF calls for TA file (hauls), TB (catch by species and haul), TC (length, sex and maturity by target species). Analysis on biomass and density indexes should be possible for all the species caught during the survey (based on the TB file in the DataCall) while the length analysis can be carried out only for target species (TC file in the DataCall). For example in TB file GSA9 for year (2015) reported data for 270 species and for 63 in TC file and obviously not for all these species we have enough information to do anything. The following should be stored in a data frame and plotted

- Total number of trawl stations by year
- Proportion of positive stations by year
- Mean and CV of (standardised) catch abundance (including zero values) by year
- Mean and CV of (standardised) catch weight (including zero values) by year
- Min. max and mean day in year of survey data by year (or 5,50,95%)

For species with length data (TC data file):

- 5, 50 and 95% on fish length caught by year.
- Mean and CV of (standardised) mature catch abundance (including zero values) by year
- Mean and CV of (standardised) mature catch weight (including zero values) by year

Age based evaluation based on deterministic length slicing using VBGF from the Data Call biological file. In addition in for a limited number of species and limited years age data has been collected since 2012 for some target species (Hake, Red mullet, Striped red mullet) and stored in TE MEDITS file. This should be used if available:-

- Matrix plot of n at age at age in year y with n at age a+1 in year y+1

Series Summary statistics across all years

- Autocorrelation coefficient on mean abundance (1st order)
- Autocorrelation coefficient on mean catch weight (1st order)
- Autocorrelation coefficient on mean time (1st order)
- Fraction of years with the mean abundance outside median of mean values +-2CV
- Fraction of years with the mean biomass outside median of mean values +-2CV

For Multiple GSAs

In addition to single GSA the following combinations should also be presented:

1,5,6, 7,8,9, 10,11, 15,16 17-18, 20,22,23.

Notes :

MEDITS is a standardized survey based on random sampling stratification with hauls number by strata allocated based on the surface of the strata (see MEDITS handbook) http://www.sibm.it/MEDITS%202011/principaledownload.htm.

The TA file contain hauls information including distance covered and horizontal net open so we can estimate swept area by haul. For all the GSA JRC has the stratification scheme by strata and stratum so we can compute the abundance and biomass index by square kilometre.

Having the stratification surface we can combine across GSAs.

The issue that will arise dealing with some GSAs in which MEDITS time series is different (e.g. GSA17 ITALY, CROATIA and SLOVENIA) for which some extra assumptions may be needed (maybe assuming some kind of proportion for missing year based on the years in which we have data).

Additionally, in some areas (16 and maybe 18), the random stratified design has been violated with the addition of a new area of sampling after 10 years of survey. So in these cases a statistical standardization with GLMs would likely be more appropriate.

2) **2 Catch evaluation -** by species by GSA presented on no more than one page per GSA Quality of fleet segment sampling by year using whatever fleet segmentation has been delivered by MS. It is known that for some areas the metier (as combination of gear, fishery and mesh size) is not clearly reported in the data, so the data should be analysed in the best way

- No of different fleet segments or metiers reporting catch by year
- Fraction of catch with samples (sum of catch with samples/total)

For species with length data and if applicable growth data:

- 5, 50 and 95% on fish length caught by year.
- Matrix plot of n at age at age in year y with n at age a+1 in year y+1 from commercial catch

AD HOC contract for developing advice for stocks without survey time series and only a short time series of commercial catch at length data.

Background

There is a need to improve understanding of the utility of simple annual indicators based on catch at length data. The EWG 17-02 has examined LB-SPR, VIT and Lmean/LFeM for existing assessment data in order to obtain year by year estimates of indicators exploitation, proxies for F/F_{MSY}. Some of these approaches require ancillary information such as VBGPs, L-W, Terminal F, M, Maturity ogive, to run. It seems that Lmean/LFeM is unbiased but very noisy indicator of stock status but it is not directly suited for management advice on its own. It's possible that by adding other indicators the noise might be reduced and the advice may be more reliable. The limited exploration of VIT and LB-SPR carried out by EWG 17-02 suggests that these methods may also give useful indicators of exploitation rate. An AD HOC contract is needed to take this the next step onwards. The JRC has a database of assessment results and assessment stock objects, this should be used to calculate stock exploitation indicators to be compared with assessed annual values of F/F0.1. This has already been done for the length indicator Lmean/LFeM. Some of the other approaches require ancillary information such as VBGPs, L-W, Terminal F, M, Maturity ogive, for this study these are available from the assessment files, and could mostly be obtained for data poor stocks, if the methodology appears useful. The purpose of this exercise is to complete the analysis for other indicators, to build a better understanding of the use of multiple indicators.

ToR

For a maximum of 10 years per stock (using whichever years are available for 2004 to 2013) for the listed assessed stocks from 2016 in the table below carry out the following.

1) Using existing JRC archived stock objects carry out further analyses to derive the annual indicators of F/F_{MSY} from VIT
2) Using existing JRC archived stock objects carry out further analyses to derive the annual indicators of exploitation rate from LB-SPR by stock and by year.
3) Tabulate these with existing Lmean/LFeM values and existing assessment estimates of F/F0.1 for all the stocks and assessed years .

4) Other methods could be added here if applicable to single year LF commercial catch data

Species	GSA	Linf
MUR	9	32.0
NEP	6	74.1
NEP	9	74.1
NEP	11	74.1
DPS	1	45.0
DPS	9	38.3
DPS	10	43.0
ANE	6	19.0
ANE	9	17.0
ANE	17_18	19.4
PIL	6	25.0
PIL	17_18	19.8

Provide:

1) The R scripts to carry out the analyses and
2) a data frame with, input data used and collated results of all methods and assessment results
3) Explore the relationships between single / multiple indicators and the assessed values, and evaluate and propose the best weighting of these indicators to most closely indicate stock exploitation status.
4) Provide a report of the analyses carried out and results obtained.

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[1] - Information on STECF members' affiliations is displayed for information only. In any case, Members of the STECF shall act independently. In the context of the STECF work, the committee members do not represent the institutions/bodies they are affiliated to in their daily jobs. STECF members 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

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REPORT TO THE STECF

EXPERT WORKING GROUP ON

Methodology for the Stock Assessments in the Mediterranean Sea

(STECF 17-02)

Arona, Italy, 5-9 June 2017

1 INTRODUCTION

1.1 Approach to the work

The working group was held in Arona, Italy, from 5th to 9th June 2017. The meeting was attended by 18 experts in total, including 3 STECF members and 4 JRC experts.

The objective of the Mediterranean Methodology EWG 17-02 was to develop a number of scientific areas to assist in future assessments. The ToRs were partially based on ideas developed from STECF-16-17 (Demersal stock assessments in the Mediterranean Sea). In addition, two review ToRs were added by DGMARE. An initial plenary session commenced at 09:00 on the first day. The ToRs were discussed and examined in detail.

The group was informed that there was a misspecification on ToRs 1 and 3c about red mullet. The species was *Mullus barbatus* and not *Mullus surmuletus*. The ToR given below has been modified accordingly

The EWG was informed that no ad hoc contracts were issued for work associated with ToR3 and so no additional information were available during the EWG.

ToRs different tasks were allocated to four subgroups based on the expertise of the invited researchers.

An ftp repository was created ad-hoc to share documents, data and scripts and prepare the report.

Plenary sessions were held each day to monitor progress and share results. The overall conclusions of each ToR were discussed and finalized in plenary on the last day.

1.2 Structure of the report

Sections 1 and 2 of the report dealt with EWG introduction, ToRs and main results. The following four sections were organised by ToRs. Section 3 addresses the evaluation of length approaches in assessments (ToR 1), Section 4 was about ToR 2 (namely data poor method approaches), Section 5 dealt with the review of the stock units, finally Section 6 reviewed species and gear basis for three specific MAPs (ToR4). The last sections report references, annex, contact details and background documents.

1.3 Terms of Reference for EWG-17-02

DG MARE focal persons: Franco Biagi

Chair: E.J. Simmonds

Background

i) Background for ToR 1.

The use of deterministic length slicing can have an influence on our understanding of the stock dynamics, as it can result in different population values or reference points. As a consequence, significantly different reference points and other parameters are available for the different stocks of the same species. For example, STECF 16-22 concluded: "that length indicators are very sensitive to length infinity (Linf) in the growth model, and marked inconsistencies were observed in some of the stocks analysed, with the reported Linf from DCF data call lower than largest observed size of individuals and sometimes below mean lengths. Depending on which Linf will be used, indicators can be calculated to be greater or less than 1 and thus, the exploitation rate for a stock can be above or below F_{MSY}." STECF 16-21 further highlighted the necessity to provide an explicit guidance for the methodological approaches and parameter choices used in length based assessment and reference point analyses. Further work is required to better understand these issues by exploring other options and defining shared guidelines.

ii) Background for ToRs 2, 3 and 4.

Multiannual plans (MAPs) as described in Articles 9 and 10 of the Regulation (EU) No 1380/2013 on the Common Fisheries Policy are a fundamental fisheries management tool to deliver maximum sustainable yield (MSY) exploitation rates with a view to restore and maintain fish stocks above biomass levels capable of producing MSY. They are also the most adequate management vehicle to implement the landing obligation for the species subject to the minimum conservation reference size in the Mediterranean Sea. In addition to the quantifiable targets, conservation reference points and safeguards measures, a MAP may also contain conservation measures to avoid and reduce unwanted catches.

The development of MAPs for the Mediterranean areas may require analyses with limited data. In many cases due to short time series or missing information analytical assessments are difficult to obtain and data limited methods are required. While a range of data limited approaches have been reviewed previously, this review has been in a general context, and without reference to specific data availability. There is a need to focus more directly on the specific data availability and use the experience of applying methods (such as length based indicators) where both assessments and data limited approaches have been tried, to obtain a better idea of the utility of the available methods.

Terms of Reference: The STECF-EWG 17-02 is requested:

(1)

To collate and review all relevant information of length based analyses (including length slicing to age and choice of biological parameters) used so far in STECF-EWG for Mediterranean stock assessment (STECF 16-22; 16-21; 16-17 and other relevant sources). Consider both the influence on the results of stock assessment and also the influence on MSY reference points. In the light of this review, provide solutions on how to overcome the shortcomings and develop shared guidelines so that further improvements in the estimates of parameters, reference points, stock status and exploitation rates are delivered. The following species are, inter alia, to be considered: hake (*Merluccius merluccius*), red mullet (*Mullus barbatus*[#]) and deep-water rose shrimp (*Parapenaeus longirostris*).

(2)

i) To apply and compare potential data poor methods to provide MSY advice by taking into account timespan and types of data series available under the DCF. The following stocks are, inter alia, to be considered: blue whiting in GSAs 6 and 9 (STECF 14-17) and hake in GSAs 6, 7 and 9,

ii) for the same stocks, to compare the data poor methods to the existing analytical assessments in order to indicate differences in the quality of the results obtained by the different approaches;

iii) to apply the best available data poor method that resulted from point 2i and 2ii above to the following data poor stocks: blue whiting in GSAs 17, striped red mullet in GSA 11 (tbc).

(3)

To carry out a critical review of the stock boundaries for the species and areas listed below. This review shall take into account the latest bioecological and fishery-related information available including, inter alia, recent analyses on the topic supported by DG MARE (see Annexes [X]1). In the light of this review, propose scientifically sound stock units for:

a) anchovy (*Engraulis encrasicolus*) and sardine (*Sardina pilchardus*) in the western Mediterranean Sea (GSAs 5, 6, 7, 8, 9, 10 and 11);

b) common Pandora (*Pagellus erythrinus*), Norway lobster (*Nephrops norvegicus*) and common cuttlefish (*Sepia officinalis*) in the Adriatic Sea (GSAs 17 and 18); and

c) European hake (*Merluccius merluccius*) and red mullet (*Mullus barbatus*#) in the Ionian Sea (GSAs 19 and 20).

(4)

To advise on the stocks that should be considered, either as driving the fisheries or as relevant by-catches, for possible multiannual plans addressing the small pelagic fisheries of the Western Mediterranean Sea (GSAs 5, 6, 7, 8, 9, 10, 11), the demersal fisheries of the Adriatic and Ionian Seas (GSAs 17, 18, 19, 20) and the demersal fisheries of the Eastern Mediterranean Sea (GSAs 22, 23, 25). For this purpose, the annexes [1], [2] and [3] provide an overview of the main elements that could be considered so far.

The advice shall provide also pros and cons of the geographical scope of each plan taking into account the content requirements of the multiannual plans, the distribution of the stocks, the dynamics and technical interactions between fleets as well as the scientific knowledge currently available to the scientific community. Synoptic overview of the information used in support of the advice shall be reported.

*1 Work to be done through ad-hoc contracts during the first semester of 2017.

red mullet (*Mullus barbatus*) was originally noted incorrectly in the as *Mullus surmuletus* this is corrected here

ToR ANNEX 1

Possible MAP for demersal fisheries in the Adriatic and Ionian Seas

1) **Geographical scope**:
- GSAs 17, 18, 19 and 20.

2) **Fishing gears**:
- Bottom trawl nets, longlines, bottom-set nets (including trammel nets and gillnets) and traps.

3) **Target stocks defining the fishery**: **Area**	**Common name**	**Scientific name**
GSA 17-18	European hake	*Merluccius merluccius*

GSA 19	European hake	*Merluccius merluccius*
GSA 20	European hake	*Merluccius merluccius*
GSA 17-18	Red mullet	*Mullus barbatus*
GSA 19	Red mullet	*Mullus barbatus*
GSA 20	Red mullet	*Mullus barbatus*
GSA 17-18	Norway lobster	*Nephrops norvegicus*
GSA 17-18-19	Deep-water rose shrimp	*Parapenaeus longirostris*
GSA 17	Sole	*Solea vulgaris*
GSA 17-18	Spot-tail mantis shrimp	*Squilla mantis*

4) **Relevant by-catch species**
- Gilt-head sea bream (Sparus aurata)
- Sea bass (Dicentrarchus labrax)
- Common pandora (Pagellus erythrinus)
- Squids (Loligo spp.)
- Common cuttlefish (Sepia officinalis)

ToR ANNEX 2

Possible MAP for small pelagic fisheries in the western Mediterranean Sea

1) **Geographical scope**:
- GSAs 5, 6, 7, 8, 9, 10 and 11.

2) **Fishing gears**:
- Purse seiners and pelagic trawlers.

3) **Target stocks defining the fishery**: **Area**	**Common name**	**Scientific name**
GSA 5-6-7	European anchovy	*Engraulis encrasicolus*
GSA 5-6-7	Sardine	*Sardina pilchardus*
GSA 8-9-10-11	European anchovy	*Engraulis encrasicolus*
GSA 8-9-10-11	Sardine	*Sardina pilchardus*

4) **Relevant by-catch species**
- Atlantic mackerel (Scomber scombrus)
- Chub mackerel (Scomber japonicus)
- Atlantic horse mackerel (Trachurus trachurus)
- Mediterranean horse mackerel (Trachurus mediterraneus)

ToR ANNEX 3

Possible MAP for demersal fisheries in the Eastern Mediterranean Sea

1) **Geographical scope**:
- GSAs 22, 23, 25.

2) **Fishing gears**:
- Bottom trawl nets, longlines, bottom-set nets (including trammel nets and gillnets) and traps.

3) **Target stocks defining the fishery**: **Area**	**Common name**	**Scientific name**
GSA 22	European hake	*Merluccius merluccius*
GSA 22	Red mullet	*Mullus barbatus*
GSA 22	Striped Red Mullet	*Mullus surmuletus*
GSA 22	Norway lobster	*Nephrops norvegicus*
GSA 22	Deep-water rose shrimp	*Parapenaeus longirostris*
GSA 23	Hake	*Merluccius merluccius*
GSA 23	Red mullet	*Mullus barbatus*
GSA 23	Deep-water rose shrimp	*Parapenaeus longirostris*
GSA 23	Striped Red Mullet	*Mullus surmuletus*
GSA 25	Striped Red Mullet	*Mullus surmuletus*
GSA 25	Red mullet	*Mullus barbatus*
GSA 25	Bogue	*Boops boops*

4) **Relevant by-catch species**
- Gilt-head sea bream (*Sparus aurata*)
- Sea bass (*Dicentrarchus labrax*)
- Common pandora (*Pagellus erythrinus*)
- Squids (*Loligo* spp.)
- Common cuttlefish (*Sepia officinalis*)
- Picarels (*Spicara* spp)

2 THE RESULTS OF THE EWG.

2.1 Specific outcomes by ToR.

2.1.1 Specific outcomes ToR 1

Sensitivity of assessments to choice of growth parameters in length slicing is an important aspect of most Mediterranean assessments.

A review of values used for hake, red mullet and deep-water rose shrimp, shows that a wide range of growth (L_{inf}, k, and t_0) and natural mortality (M) values have been used in practice, and in some cases these have not been internally consistent. As a result the estimates of stock size from assessments, and F_{MSY}, usually derived from yield per recruit models, showed a large variability across areas and sometimes years.

Evaluations of sensitivity to choices of M and k have been carried out particularly for deep-water rose shrimp in GSAs 17-18 and 9 and red mullet in GSA 18. The main metrics used to assess the sensitivity has been F, SSB and $F/F_{0.1}$.

As expected changing k or t_0 changes the numbers at age in the assessment, slower growth results in a wider spread of ages; a more negative t_0 results in increasing proportions at age 0.

From the small number of evaluations, it has been possible to carry out we see that F and SSB and selection by age are sensitive to the choice of k, but that $F/F_{0.1}$ is far less sensitive. The differences expected to result from uncertainty at the level of sampling or fitting models is essentially negligible. However, substantially mis-specifying k is likely to affect the value of $F/F_{0.1}$ and this might under some circumstances result in misclassification of under/overfishing.

Comparison of assessment results for different length slicing methods was carried out on red mullet in GSA 18. Three main options were tested: deterministic age slicing using DCF von Bertalanffy parameters (Datacall 2016); age slicing according to the proportions of ages by length observed in the age length key; and deterministic age slicing using revised von Bertalanffy parameters (GFCM 2016).The GFCM assessment using SS3 was used. The different slicing methods can result in considerable shift of commercial catch and survey catch numbers between ages, the effect is particularly large between ages 0 and 1. The selection function at age is sensitive to this. However, comparing SSB, F and $F_{0.1}$ show that the effect is rather slight for this stock, and the assessment is generally not sensitive to these choices.

During EWG an exercise to compare stock status perception using the most common EWG stock assessment method was carried out: XSA. The same SS3 data input were used in the XSA assessment but MEDITS data (at length in the SS3 assessment) were sliced in age in XSA assessment). To keep the approach coherent with the common EWG approach the length data were sliced based on the deterministic slicing approach. Some difficulty was encountered in setting up XSA, particularly for MEDITS survey data, as the SS3 model uses multiple selectivity parameters changing over time. The XSA final run output were in general agreement with those obtained using SS3 both in term of fishing mortality and SSB.

Some specific guidance on handling length to age conversion based on the work here is given in Section 2.2.

2.1.2 Specific outcomes ToR 2

A series of different data poor indicators were reviewed:

MSY length indicator: A study of length indicators as an indicator of fishing pressure relative to F_{MSY} has been carried out. The results indicate that the length indicator appears to be an unbiased estimator. On average the transition from above to below exploitation at F_{MSY} is the same. However, the uncertainty in exploitation status derived from the length indicator is high. There are no diagnostics that might help to determine if the fit is good or not. Consequentially there is a high risk to give an incorrect classification, unless the stock is very heavily or very lightly exploited. As the uncertainty is high, management using length indicators is expected to perform badly, as indicated by particularly poor results when a linear mixed effects model is used to fit the results, showing that individual stocks can have consistent relationships that depart from the average. Simulation work also suggests that some harvest control rules using length indicators have not been successful for management (Jardim et al., 2015). Currently it is considered that the best option under these circumstances is to collect additional information to inform management, and to use multiple indicators of stock status.

LB-SBR and VIT Assessment: The data-poor approach VIT and LB-SPR were used to evaluate and compare the trend and current population status for hake in GSA 6. This analysis produced results consistent with those given by VPA performed with XSA. LB-SPR was able to identify changes in F-at-age as a temporal variation in selectivity and F/M. The SPR calculated by LB-SPR was lower than that derived from the VIT analysis (only the VIT analysis gives an estimate of an SSB reference point, the XSA does not provide SSB reference points directly). However, overexploitation and temporal changes in SPR were well shown in all cases .The agreement between F/F_{MSY} for VIT and XSA was very good, confirming published study (Raetz et al 2010) and supporting the use of VIT for situations where only a few years of data are available.

LB-SPR was then tested on available data for blue whiting GSA 17 stock status. The commercial catch data was considered to be poorly reported, the species is landed as a species mix and not representative of the removals from the population. Medits data was considered to be correctly identified to species, and thus did not suffer from the same issue as the landings data. The LB-SPR method was not able to fit the model derived from MEDITS trawl surveys for the blue whiting stock in GSA 17. This was because of this species exhibits a short spawning period, a relatively fast individual growth and some ages can be spatially segregated, so MEDITS data does not reflect overall yearly population size distribution. Although the LB-SPR outputs could suggest the population status of blue whiting as overexploited condition, but in this case the quantitative temporal changes of SPR can be considered as not reliable.

Future use of LB-SPR was considered in the Mediterranean context. The LB-SPR method could be a suitable tool in cases where only reliable length-frequency data coming from catches for few or many years is available. However, the specific level of SPR is strongly dependent of L_{inf} and M/k that usually are poorly known in data-limited stocks. Therefore, the implementation of the LB-SPR method should be accompanied by uncertainty analysis. Meta-analysis or other sources might be used to obtain the necessary range of biological parameters. This could be used to test the robustness of conclusions to the uncertainty in the biological information. Even if the status is uncertain it may be possible to infer the trends in status over time if length data from the fishery is a variable over a number of years. The potential use of this approach for survey data can be considered limited, especially in the case only one survey is conducted each year as in the Mediterranean (MEDITS surveys).

Advice based on survey only information: Where survey data indices are available, simulations of management using the ICES rule Cat 3 indicate that that these indices can provide guidance for management (catch advice or change in exploitation rate) provided that the overall the stock status can be inferred as not over exploited. ICES is currently developing proxies for exploitation rates for survey only assessments, this work is linked to the work in length indicators and LB-SPR described above. As this work matures exploitation rate proxies will be developed.

If a survey is considered to be adequate for trends, it is proposed to continue to use the ICES cat 3 relative change rule if no assessment is available.

Advice for Blue Whiting in GSA 17

The data for this species is limited, catches are considered to be poorly reported and landings are a mix coming from at least three species (Micromesistius poutassou, Trisopterus capelanus and Merlangus merlangus).

The MEDITS survey catches blue whiting erratically and no survey index can be specified. Evaluations of LB-SPR which gave plausible results for hake in GSAs 6, gave unstable results for blue whiting.

Overall no advice is available for this stock.

Advice for Striped Red Mullet in GSA 11

The data for striped red mullet in GSA 11 had a preliminary evaluation in EWG 16-17 and no conclusions on stock status were obtained. Both catch and survey data were further explored in this WG.

Catch data was found to be poorly sampled and fleet data reported inconsistently. By combining average length distributions over several years by fleet it was possible to obtain a single VIT analysis, this was compared with length analysis from EWG-16-17, these were not inconsistent. However, the results were inconclusive, because only one VIT analysis could be carried out and the catch sampling underlying the length analysis was very variable.

Examination of survey data suggested that the survey captured striped red mullet inconsistently from year to year, sometimes including large recruit (age 0) catches, and with variability in catches of older fish. The recruits are usually found when the surveys start/continue later and the earlier surveys show greater abundance of adults. It was concluded that the variable timing of the survey was contributing to this variation of the abundance. MEDITS is in general not considered a good tool for evaluating this species in this area or indeed in any area. It is thought that CPUE from commercial fisheries are the most likely source of information. If advice for this species in this area (GSA 11) is required the sampling of the small scale fishing needs to be improved.

Overall no advice could be provided for this stock.

2.1.3 Specific outcomes ToR 3

The three areas/species combinations defined in the ToRs were evaluated. Despite identifying some potential participants to carry out the three proposed ad-hoc contracts, these were not placed and so the WG had limited resources to answer the questions. Given the limited information available, STOCKMED report and a few additional papers found during the meeting, the EWG considers the basis for the advised units is weak. As little new information is available the management areas should generally follow the STOCKMED report, (with some boundaries aligned with GSAs boundaries for practical reasons). The detailed discussion is provided in Section 5 and section 6 by area and by stock, the conclusions are presented below.

Because basis for these proposed stock allocations is based predominantly on the STOCKMED report, it is weak, and it is expected that the configuration below will need to be reviewed if further information become available.

a) Western Mediterranean (GSAs 5, 6, 7, 8, 9, 10 and 11)

a1) **Anchovy** – STOCKMED describes a quite complex situation; 3 different stock units are identified in the western Mediterranean, one stock unit is distributed in GSAs 5,6,7 and 9; 2nd stock unit is mainly present in GSAs 8 & 11, with possible presence in GSA9 also; 3rd stock unit is present in GSA10, but extending its distribution to central and eastern Mediterranean (i.e. GSAs 15,16,18,19,20,22,23,24 and 25) also;

The proposal is for 3 units: 1st stock unit is distributed in GSAs 5,6,7 and 9; 2nd stock unit is considered within GSAs 8 and 11; 3rd stock unit is in GSA10.

a2) **Sardine** – 2 stock units seem to be present in western Mediterranean; one of them is distributed along coastline of Spain and in Gulf of Lyon, and another is distributed along western coast of Italy and around Corsica, Sardinia and Sicily.

The proposal is for 2 units i) GSAs 5,6,7 and 9, ii) GSA 8,10,11

b) Adriatic Sea (GSA 17 and 18)

b1) **Common pandora** – there are indictions that 2 stock units may be present in the Adriatic Sea; one of them is present in the northern part of GSA17, while fish from GSA18 belong to different stock unit, distributed along western coast of Italy and around Corsica, Sardinia and Sicily also; it is likely that mixing of these 2 stock units occur in the southern part of GSA17.

The proposal is for 2 units i) GSAs 17, ii) GSA 18 , however, the stock in GSA 17 is mixed to some extent with those in GSA 18 it may be better in the short term to give a combined assessment and in the longer term organise data collection so that stock estimation and management may be better optimally split along stock lines within GSA 17.

b2) **Norway lobster** – there are indications in STOCKMED that only one single stock unit is present in the entire Adriatic Sea, extending its distribution in the Ionian Sea also; however, according to recent work, it seems that more that one population may exist in GSA17, there is evidence of difference size and possibly growth in different parts of the Adriatic. Practically it has so far been not possible to provide multiple assessments for Norway Lobster in GSA17-18 and thus estimation and management may need to be at a single unit scale until more detailed information becomes available.

The proposal is for one unit GSAs 17-18.

b3) **Common cuttlefish** – one single stock for the Adriatic Sea is proposed; however, due to discontinuity in abundance and biomas indices in southeastern part of GSA18 (non-EU waters), additional research efforts are to be suggested to this area of the Adriatic Sea. Preliminary examination suggests survey data from MEDITS does not look promissing as a stock status index, but may be useful as a source of recruit index. This species currently classified as G2 for sampling, if management is needed better fishery data is required. Currently the DCF reports very limited biological parameters, only L_{inf} and maturity for GS17 from Slovenia and maturity in GSA 18 from Italy. This species is not currently part of DCF for some countries, so if management is required, then obligations to deliver data should be changed.

The proposal is for one unit: GSAs 17-18.

c) Ionian Sea (GSA 19 and 20)

c1) **European <u>hake</u>** – STOCKMED indicates 2 different stock are present, eastern (GSA20) and western (GSA19) Ionian Sea; The report indicates hake from eastern Ionian Sea (GSA20) belongs to stock unit from the Adriatic Sea, while hake from western Ionian Sea (GSA19) belongs to stock unit distributed in GSAs 7,8,9,10,11,15&16.

The proposal is for 2 units: GSA 17,18 and 20 should form a single stock unit. GSA 19 should be considered separately from the other three GSAs.

c2) **<u>Red mullet</u>** - STOCKMED indicates 2 different stocks are present, eastern (GSA20) and western (GSA19) Ionian Sea; fish from eastern Ionian Sea (GSA20) belong to the same stock unit distributed in the Adriatic and Aegean Sea, while fish from western Ionian Sea belong to another stock unit distributed in the central and western Mediterranean Sea (GSAs 1,5,6,7,8,9,10,11,15&16).

The proposal is for 2 units: GSA 17,18 and 20 should form a single stock unit. GSA 19 should be considered separately from the other three GSAs.

2.1.4 Specific outcomes ToR 4

Area 1 Demersal

There are three additional fishing gears that need to be considered: Beam trawl, hydraulic dredge, shore and boat seine.

Some shellfish species have been omitted from previous evaluations but based on value of landing one additional species should be added to the MAP: striped venus (vongole - clam)

Two additional species should be monitored as these are considered significant species though are not primary species: Eledone spp. and Octopus spp.

Area 2 Pelagic

The plan is considered to cover all the relevant small pelagic species and fishing gears.

Area 3 Demersal

The plan is considered to cover all the relevant primary species and fishing gears; however, additional species should be monitored as this is considered a significant species though not a primary species: Octopus spp.

2.2 Further recommendations for future work.

For ToR 1 the EWG made the following recommendations for future assessment work:

- All the growth related parameters used in the assessment should be coherent (e.g. M-at age derived using PRODBIOM from the same growth parameterised for age slicing). Any changes through periods should be justified. Minor changes should be treated as noise and average values used.
- Improvements are needed in documenting and defining the growth models and age slicing, better documentation is needed to be included with data delivered under the DCF.
- Were possible age slicing by sex should be tested, it is expected to give better results.
- Setting of t_0 can change proportions at age 1 significantly, large negative values have no meaning, and should be truncated to values between 0 and -0.2.
- It is advisable for assessment WGs to obtain and review the raw age length data, where necessary refitting growth models, in order to obtain the most representative values for growth and natural mortality for the assessment.

For ToR 2 the EWG made the following recommendations for future advice:

- If no assessment is available and a survey is considered to be adequate for trends, it is proposed to continue to use the ICES cat 3 relative change rule to advise on changes in exploitation rate.
- It is clear that individual indicators may give unbiased but uncertain estimates of exploitation status but one indicator alone is unlikely to be useful for management.
- Further work sourcing additional indicators to support management is necessary, and could be facilitated by extending the work on JRCs database through an ad-hoc contract.
- Methods should be checked perhaps in a similar way to the length indicators. Once testing of these indicates they are stable and unbiased potentially useful for management, testing probably through MSE is needed.

- The EWG recommends an ad-hoc contract to take this forward, this should:-
    - Evaluate which of potential indicators can be parameterised
    - Carry out indicator evaluations for stocks for which assessment data are available and evaluate relationships between stock status indicators.
    - Based on any identified relationships evaluate the combinations for management.
- Choice of indicators should be linked to and coordinated with those required for MSFD.

3 EVALUATION OF LENGTH APPROACHES IN ASSESSMENTS

ToR: *To collate and review all relevant information of length based analyses (including length slicing to age and choice of biological parameters) used so far in STECF-EWG for Mediterranean stock assessment (STECF 16-22; 16-21; 16-17 and other relevant sources). Consider both the influence on the results of stock assessment and also the influence on MSY reference points. In the light of this review, provide solutions on how to overcome the shortcomings and develop shared guidelines so that further improvements in the estimates of parameters, reference points, stock status and exploitation rates are delivered. The following species are, inter alia, to be considered: hake (Merluccius merluccius), red mullet (Mullus surmuletus) and deep-water rose shrimp (Parapenaeus longirostris)*

3.1 Approach / general comments

The issues were examined in a number of ways, firstly the range of historic values of L_{inf} k and t_0 from the growth equations and M at age used in historic assessments were tabulated for the stocks in the ToR. These were used to inform the range of values to be considered, and the sensitivity of two deep-water rose shrimp stock assessments in terms of F, SSB and $F/F_{0.1}$ to these parameters were examined.

For another assessment (red mullet in GSA 18) length equations, and age length keys were available, the assessment was rerun with two different deterministic non overlapping length slicing approaches, and age length key based length slicing, and the results compared.

Based on these analyses general conclusions were drawn, on the sensitivity of the approaches. This was then used to inform guidance for future work.

Sources of age at length data were examined to determine for other stocks what was the potential for future assessments using age at length data directly.

3.2 Range of Historic values used

Issues related to parameters standardization for Mediterranean fish and shellfish stocks were previously discussed during the STECF/SG-ECA/RST/MED 09-01 Instituto Español de Oceanografia in San Pedro del Pinatar, Murcia (Spain) from 2-6th March 2009. In particular, the group discussed how to "*derive and agree on appropriate values for M and growth parameters for stocks of demersal and small pelagic species*".

Regarding the natural mortality (M) for the assessment of exploited resources and the advisory process to fisheries management, the STECF WG 09-01 recommended basing M assumptions on the longevity of the species concerned, if no quantitative information about M is available. Furthermore, M should account for the different ontogenetic stages (particularly from juveniles to adults) and for changes in fish condition (health) if observed.

The parameters used by STECF and GFCM working groups for the assessment of deep-water rose shrimp (DPS), European hake (HKE) and red mullet (MUT) stocks since 2012 were tabulated during STECF EWG 17-02.

Deep-water rose shrimp, *Parapenaeus longirostris* (DPS)

A total of 15 assessments carried out in GSAs 1, 5, 6, 9, 10, 17-18, 19, and combining data for GSAs 9, 10, 11 and from 12 to 16 were considered (Table 3.2.1). A major difference appeared in the parameter k of the von Bertalanffy growth curve with a substantially lower value (k = 0.39) in GSAs 1 and 6 compared with the other areas where k was between 0.57 and 0.74 (Table 3.2.1). The L_{inf} values were in a narrow range of variability between 43.5 and 46 mm carapace length (CL). The resulting growth curves indicated a very similar growth pattern across central and western Mediterranean except in GSAs 1 and 6, where growth appears substantially lower (Figure 3.2.1). Growth parameters in GSAs 1 and 6 for deep-water rose shrimp appeared therefore as outliers that would need to be carefully re-considered applying standard methods of modal progression analysis.

Most of the assessments, with the exception of GSAs 9 and 10, were carried out combining sex and converting lengths in ages using a combined von Bertalanffy growth curve. In this regard, STECF EWG 17-02 pointed out the need to slice lengths separately by sex when substantial differences in growth and longevity occur between males and females, such as in the case of deep-water rose shrimp.

All the assessments were carried out using natural mortality vectors (M-at-age) calculated using the Prodbiom method (Abella et al., 1997). These M vectors did not appear always consistent with the growth parameters used across GSAs and time, in particular for the last two age classes. For instance, in GSA 1 a consistent change in M-vector appears in assessments carried out in different years (2012 and 2015), despite using the same growth parameters. Several versions of the PRODBIOM excel spreadsheet have circulated since 1997. The more recently revised version is from 2009 which shows changes in some details of the computations. However, the results derived from these different versions should only produce slight changes in the M vector. The observed differences using the same set of parameters are due to a misuse of the software. The model contemporarily estimates two parameters and multiple combinations of these two parameters may fit with the requested balance between biomass losses due to natural mortality and gains in production. In the paper that describes the method, authors warns users on this. They suggest some actions aimed at avoiding such multiple solutions, by the introduction into the computations of some reasonable constraints. For instance, if reliable estimates of the natural mortality rate for adults are available, it is possible to take this into account and constrain the choice of the A and B parameters by MS-Excel SOLVER, so that the mortality trajectory passes through or close to these values. Users should take care to ensure results are within the expected range.

The range of $F_{0.1}$ (as proxy of F_{MSY}) spreads from 0.26-0.27 (GSAs 1 and 6) to 0.89-0.93 (GSA 19, GSAs 9, 10, 11 combined and GSA 10) with most of the F_{MSY} values in the range between 0.6 and 0.84.

Red mullet, *Mullus barbatus* (MUT)

A total of 36 assessments (18 from STECF, 19 from GFCM) carried out in GSAs 5, 6, 7, 9, 10, 11, 17, 18, 19, 25, 1, 15-16 and 17-18 were considered for red mullet (Table 3.2.2).

The parameter k of the von Bertalanffy growth curve varied between 0.25 (in GSA 7) and 0.7 in GSA 19. As concerns L_{inf}, the highest value (34.5 cm TL) is used in GSAs 1 and 6, while the lowest value was used in GSAs 15-16 (23.6 cm TL). All the assessments were performed by sex combined, however, for some GSAs and years (15-16 in 2011, 19 in 2012 and 9 in 2013) different sets of growth parameters were used for males and females to convert length structures by sex into age. The separated age structures were then combined to perform the assessment. For some assessments the VBGF parameters were borrowed from other GSAs due to the lack of that information in the GSA analyzed.

As concerns the values of natural mortality M, when reported, they were always derived from Prodbiom and generally as vectors.

All the assessments were carried out using the XSA methods and showed a big variation of fishing mortality (F_{cur} ranged from 0.3 to 1.69). Also $F_{0.1}$ estimates were variable (from $_{0.1}$ to 0.6). The status of the stock was generally overexploited: the ratio $F/F_{0.1}$ varied from 0.8 (GSA 10, 2012) up to 9.7 (GSA 11, 2011).

European hake, *Merluccius merluccius* (HKE)

A total of 32 assessments carried out in GSAs 1, 5, 6, 9, 10, 17, 18, 19, and 12-16 were considered for European hake (Table 3.2..3). Two additional assessments were performed combining GSAs from 1 to 7, and from 9 to 11; however, those assessments used the same parameters as those used in the single GSA assessments, therefore, were not added to the table. The parameter k of the von Bertalanffy growth curve varied between 0.1 (in GSAs 17-18) and 0.248 in GSA 11. As concerns L_{inf}, the highest value (110 cm TL) was used in GSAs 1, 5 and 6, while the lowest value was used in GSA 19 (85 cm TL). All the assessments were performed by sex combined, however, different sets of growth parameters are used for males and females in GSA 7 (Gulf of Lions) and in GSA 10 (in 2012 only). Deterministic slicing is generally used to convert length structures by sex into age structures that are then combined and used to perform the assessment by sex combined.

As concerns assessment methods, XSA was used in most of the assessments of European hake in the Mediterranean GSAs. Statistical catch-at-age (a4a) was used in the GSA 7 in 2014 (Reference year 2013), while Integrated Analysis (SS3) were used to assess hake stocks in GSAs 17-18 and GSA 9 (Reference year 2015). Regarding the assessment outputs, none of the stocks analyzed shows a situation of sustainable exploitation. Fishing mortality F ranged from 0.48 in GSAs 17-18 to 2.6 in GSA 11, but, in general, is around 1.0 in most of the stock assessments performed (average F is 1.2). The reference point $F_{0.1}$ also shows a wide range, varying from 0.11 in GSA 7 to 0.28 in GSA 17, with an average of 0.18. As a result, the estimated ratio between F current and the reference point $F_{0.1}$ show a very wide range, from 2.3 in GSAs 17-18 to 16.6 in GSA 7, with an average of 7.5.

Table3.2.1. Growth parameters and natural mortality at age adopted for the assessment of deep-water rose shrimp (DPS) stocks in Mediterranean GSAs since 2012. F current and F_{MSY} estimates (F_{01}) are also shown.

Sex	GSA	Ref. Year	Linf	k	to	Natural mortality						Slicing method	F cur	Age range	FMSY	Assessment method	WG
						Method	M-at-age 0	1	2	3	4						
combined	1	2012	45	0.39	0.1	Prodbiom	1.25	0.82	0.39	0.28	0.22	L2AGE	0.43	1-3	0.26	XSA	
combined	6	2012	45	0.39	0.1	Prodbiom	1.25	0.82	0.39	0.28	0.22		1.48		0.27	XSA	
combined	10	2012	46	0.575	-0.2	Prodbiom	1.41	0.81	0.7	0.7			1.24		0.93	XSA	
combined	19	2012	46	0.575	-0.2	Prodbiom	1.41	0.81	0.7	0.7		LFDA	1.31		0.67	XSA	
combined	5	2012	44	0.67	-0.21	Prodbiom	1.22	0.55	0.44	0.39		L2AGE	0.77		0.62	XSA	
combined	12-16	2014	44.6	0.6	-0.12	Prodbiom*	1.41	1	1	1		Deterministic	0.96	0-2	0.84	XSA	
combined	9	2014	43.5	0.74	-0.11	Prodbiom	1.66	0.68	0.48	0.48		Deterministic	0.71	0-2	0.69	XSA	
combined	18	2014	45	0.6	-0.2	Prodbiom	1.41	0.81	0.7	0.65		LFDA	1.64	0-2	0.74	XSA	
combined	18	2014	45	0.6	-0.2	Prodbiom	1.41	0.81	0.7	0.65		LFDA	1.56	0-2	0.72	XSA	
combined	19	2014	46	0.6	-0.2	Prodbiom	1.41	0.81	0.7	0.65		LFDA	1.46	0-2	0.89	XSA	
combined	1	2015	45	0.39	0.1	Prodbiom	1.72	0.97	0.82	0.76			0.78	1-3	0.8	XSA	
separated**	9	2015	43.5	0.74	-0.13	Prodbiom	1.45	0.6	0.43	0.35		Deterministic	0.71	0-2	0.71	XSA	
combined	9,10,11	2015	46	0.68	-0.25	Prodbiom	1.41	0.81	0.7	0.7		Deterministic	0.8	0-2	0.91	XSA	
separated**	10	2015	46	0.575	-0.2	Prodbiom	1.41	0.81	0.7	0.7		LFDA	1.81	0-2	0.93	XSA	
combined	17,18,19	2014	45	0.6	-0.2	Prodbiom	1.41	0.81	0.7	0.65		Deterministic	1.53	0-2	0.69	XSA	

* M was assumed constant after the second year

**females

Table 3.2.2. Growth parameters and natural mortality at age adopted for the assessment of red mullet (MUT) stocks in Mediterranean GSAs since 2012. F current and F_{MSY} estimates (F_{01}) are also shown.

Sex	**GSA**	**Ref. Year**	**Linf**	**k**	**to**	**Natural mortality**								**Slicing method**	**F cur**	**Age range**	**FMSY**	**Assessment method**	**WG**
						Method	**M-at-age**												
							0	**1**	**2**	**3**	**4**	**5**	**6**						
combined	7	2011	29	0.6	-0.1	Prodbiom	1.3	0.79	0.62	0.54	0.54	0.54		Deterministic	1.26		0.51	XSA	STECF
separated**	15_16	2011	F: 23.6; M: 20.2	F: 0.45; M:0.57	-0.8	Prodbiom	1	0.6	0.42	0.36	0.33	0.31		Statistical	1.3	1-5	0.45	XSA	STECF
combined	17	2011	25	0.42	0.37	Prodbiom	1.6	0.84	0.37	0.29	0.26	0.25		Deterministic	0.71	1-3	0.36	XSA	STECF
combined	18	2011	30	0.4	-0.3	Prodbiom	1.03	0.71	0.65	0.62					1.5		0.5	XSA	STECF
combined	9	2011	29	0.6	-0.1	Prodbiom	1.3	0.79	0.62	0.54					0.68		0.61	XSA, ADAPT	STECF
combined	11	2011	29.1	0.41	-0.39	Prodbiom	1.3	0.45	0.27	0.24				Statistical	0.97	1-3	0.29	XSA	STECF
combined	17	2011	26.9	0.3	-1.1	Prodbiom	1.6	0.84	0.37	0.29	0.26				0.82	1-3	0.36	XSA	STECF
combined	19	2011	30	0.4	-0.3	Prodbiom	1	0.61	0.54	0.47				Deterministic	none	0-2	0.3	XSA	STECF
combined	5	2012	26	0.41	-0.4	Prodbiom	0.8	0.38	0.29	0.26	0.24	0.23			0.93	1-3	0.14	XSA	STECF
combined	6	2012	29	0.6	-0.1	Prodbiom	0.99	0.46	0.3	0.24	0.21			Deterministic	1.69	0-2	0.45	XSA	STECF
combined	11	2012	29.1	0.41	-0.39	Prodbiom	1.3	0.45	0.27	0.24				Deterministic	1.07	1-3	0.11	XSA	STECF
combined	17	2012	26.9	0.3	-1.1	Prodbiom	1.6	0.84	0.37	0.29	0.26	0.25	0.2		0.55	0-5	0.21	SS3	STECF
combined	6	2013	29	0.6	-0.1	Prodbiom	0.99	0.46	0.3	0.24	0.21				1.47	0-2	0.45	XSA	STECF
combined	7	2013	29	0.25	-0.13	Prodbiom	0.83	0.35	0.26	0.18	0.15				0.45	0-4	0.14	XSA	STECF
separated**	9	2013	F: 29; M:20	F: 0.6; M: 0.59	-0.1	Prodbiom									0.7	1-2	0.6	XSA	STECF
combined	25	2013	26	0.26	-0.4	Prodbiom	0.58	0.39	0.32	0.28	0.26	0.25			NA		0.3	XSA	STECF
combined	17-18	2014	30	0.4	-0.3	Prodbiom	1.03	0.71	0.65	0.62				Deterministic	0.54	0-2	0.41	XSA	STECF
combined	19	2014	30	0.4	-0.3	Prodbiom	1.03	0.71	0.65	0.62				Deterministic	1	0-2	0.45	XSA	STECF
	7	2011													NA		NA		GFCM

combined	15_16	2011	23.6	0.45	-0.8	?	1	0.6	0.42	0.36	0.33	0.31			1.3		0.45	XSA	GFCM
combined	17	2011													0.5		0.253	XSA	GFCM
combined	5	2012	26	0.41	-0.4	missing									0.93		0.15	XSA	GFCM
combined	6	2012	34.5	0.34	-0.143	Prodbiom	0.99	0.46	0.3	0.24					0.9	1-2	0.51	XSA	GFCM
combined	7	2012	29	0.25	-0.128	Prodbiom	0.83	0.35	0.26	0.18	0.15	0.14			0.56		0.14	XSA	GFCM
combined	10	2012	30	0.38	-0.35	missing									0.44		0.55	XSA	GFCM
combined	17	2012	26.86	0.295	-1.1	Prodbiom	1.6	0.84	0.37	0.29	0.26	0.25	0.22		1.06		0.2	XSA	GFCM
separated**	19	2012	F: 27; M: 20.6	F: 0.697; M: 0.696	F: -0.39; M: -0.6	Prodbiom	0.92	0.4	0.3	0.26	0.23				1.17		0.38	XSA	GFCM
-	6	2013													0.69		0.51	XSA	GFCM
combined	7	2013	29	0.25	-0.128	missing									0.45		0.14	XSA	GFCM
combined	10	2013	30	0.38	-0.35	Prodbiom	1.03	0.71	0.65	0.62					0.5		0.5	XSA	GFCM
-	25	2013													0.34		0.23	XSA	GFCM
combined	7	2014	29	0.25	-0.128	Prodbiom	0.83	0.35	0.26	0.18	0.15				0.34		0.14	XSA	GFCM
combined	18	2014	30	0.4	-0.3	Prodbiom	1.03	0.71	0.65	0.62					0.48		0.42	XSA	GFCM
combined	25	2014	26.02	0.308	-0.86	Prodbiom	0.47	0.23	0.18	0.16	0.15	0.14			0.54		0.22	XSA	GFCM
-	5	2014													0.48		0.17	XSA	GFCM
combined	1,3,4	2014	34.5	0.34	-0.143	Prodbiom (scalar)	0.25	0.25	0.25	0.25	0.25	0.25	0.25		0.43		0.26	XSA	GFCM
-	17	2014													1.3		0.52	XSA	GFCM

Table3.2.3. Growth parameters and natural mortality at age adopted for the assessment of European hake (HKE) stocks in Mediterranean GSAs since 2012. F current and F_{MSY} estimates (F_{01}) are also shown.

Sex	GSA	Ref. Year	Linf	k	to	Natural mortality								Slicing method	F cur	Age range	FMSY	Assessment method	WG
						Method	M-at-age												
							0	1	2	3	4	5	6						
separated**	7	2011	F: 100.7; M: 72.8	F: 0.236; M: 0.233	0	Prodbiom	0.88	0.43	0.33	0.25	0.22	0.2	0.19	Deterministic	1.43	0-3	0.24	XSA	
combined	11	2011	100.7	0.248	-0.01	Prodbiom	1.1	0.61	0.39	0.33	0.31			Statistical	2.6	0-4	0.19	XSA	
combined	17	2011	104	0.2	-0.01	Prodbiom	1.16	0.58	0.46	0.41	0.39	0.35		Statistical	2.02	0-4	0.2	XSA	
combined	19	2011	85	0.172	-0.177	Prodbiom	0.87	0.38	0.29	0.25	0.23	0.21		Deterministic	1.09	0-4	0.12	XSA	
combined	18	2011	104	0.2	-0.01	Prodbiom	1.16	0.53	0.4	0.35	0.32			Statistical	0.92	0-2	0.21	VIT	
separated**	10	2012	F: 97.9; M: 50.8	F: 0.135; M: 0.25	-0.4	Prodbiom	1.16	0.53	0.4	0.35	0.32	0.3	0.3	Deterministic	1	1-4	0.14	XSA	
separated**	7	2012	F: 100.7; M: 72.8	F: 0.236; M: 0.233	0	Prodbiom	0.88	0.43	0.33	0.25	0.22	0.2	0.19	Deterministic	1.83	0-3	0.11	XSA	
combined	1	2012	110	0.178	0	Prodbiom	1.24	0.58	0.45	0.4	0.37	0.35		Deterministic	1.61	0-2	0.22	XSA	
combined	11	2012	100.7	0.248	-0.01	Prodbiom	1.1	0.61	0.39	0.33	0.31			Statistical	NA	0-4	NA	XSA	
combined	19	2012	104	0.2	-0.01	Prodbiom	1.08	0.5	0.38	0.33	0.3	0.29		Deterministic	1.21	0-4	0.22	XSA	
combined	18	2012	104	0.2	-0.01	Prodbiom	1.16	0.53	0.4	0.35	0.32			Statistical	1	0-4	0.19	XSA	
combined	6	2013	106	0.2	-0.0028	Prodbiom	1.12	0.55	0.44	0.39	0.36	0.35		Deterministic	1.48	0-3	0.15	XSA	
separated**	7	2013	F: 100.7; M: 72.8	F: 0.236; M: 0.233	0	Prodbiom	0.88	0.43	0.33	0.25	0.22	0.2	0.19	Deterministic	1.67	0-3	0.17	a4a	
combined	9	2013	103.9	0.212	0.031	Prodbiom	1.3	0.6	0.46	0.41	0.3	0.2		Deterministic	1.3	0-2	0.22	XSA	
combined	17	2013	104	0.2	-0.01	Prodbiom	1.16	0.58	0.46	0.41	0.39	0.35		Statistical	1.01	0-4	0.28	XSA	
combined	1	2014	110	0.178	0	Prodbiom	1.24	0.58	0.45	0.4	0.37	0.35		Deterministic	1.2	0-2	0.21	XSA	
combined	5	2014	110	0.178	0	Prodbiom	1.24	0.58	0.45	0.4	0.37	0.35		Deterministic	1.06	0-3	0.16	XSA	

combined	6	2014	110	0.178	0	Prodbiom	1.24	0.58	0.45	0.4	0.37	0.35		Deterministic	1.39	1-3	0.26	XSA	
separated**	7	2014	F: 100.7; M: 72.8	F: 0.236; M: 0.233	0	Prodbiom	0.88	0.43	0.33	0.25	0.22	0.2	0.19	Deterministic	1.64	0-2	0.11	XSA	
combined	9	2014	103.9	0.212	0.031	Prodbiom	1.3	0.6	0.46	0.41	0.3	0.2		Deterministic	0.95	0-2	0.23	XSA	
combined	10	2014	104	0.2	-0.01	Prodbiom	1.16	0.53	0.4	0.35	0.32	0.3	0.3	Deterministic	0.906	1-4	0.198	XSA	
combined	11	2014	100.7	0.248	-0.01	Prodbiom	1.15	0.57	0.46	0.41	0.38	0.27		Deterministic	1.49	0-3	0.166	XSA	
combined	17-18	2014	104	0.2	-0.01	Prodbiom	1.16	0.53	0.4	0.35	0.32	0.32		Deterministic	1.1	0-4	0.16	XSA	
combined	19	2014	104	0.2	-0.01	Prodbiom	1.16	0.53	0.4	0.35	0.32			Deterministic	0.95	0-3	0.18	XSA	
combined	5	2015	110	0.178	0	Prodbiom	1.24	0.58	0.45	0.4	0.37	0.35		Deterministic	1.3	0-3	0.17	XSA	
combined	6	2015	110	0.178	0	Prodbiom	1.24	0.58	0.45	0.4	0.37	0.35		Deterministic	1.6	0-3	0.2	XSA	
separated**	7	2015	F: 100.7; M: 72.8	F: 0.236; M: 0.233	0	Prodbiom	1.03	0.51	0.33	0.26	0.22	0.2		Deterministic	1.92	0-2	0.12	XSA	
combined	17-18	2015	106.8	0.1	-0.994	Prodbiom	0.69	0.29	0.21	0.18	0.16	0.14	0.13	Statistical	0.48	1-6	0.21	SS3	
combined	12-16	2015	100	0.116	-0.6	Prodbiom	1.38	0.56	0.27	0.22	0.19	0.18	0.17	Deterministic	0.83	1-5	0.12	XSA	
combined	9	2015	90	0.17	-0.19	Prodbiom	1.3	0.6	0.46	0.41	0.35	0.3	0.28	Statistical	1.08	0-2	0.24	SS3	

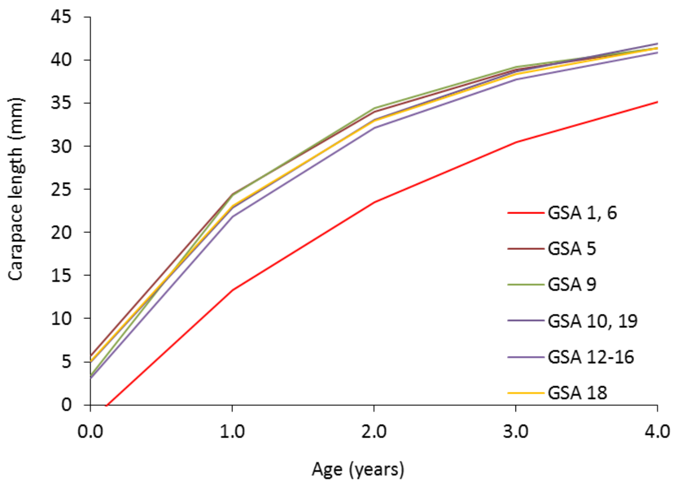


Figure 3.2.1. Von Bertalanffy growth curves of deep-water rose shrimp in different GSAs (data from Table 3.2.1)

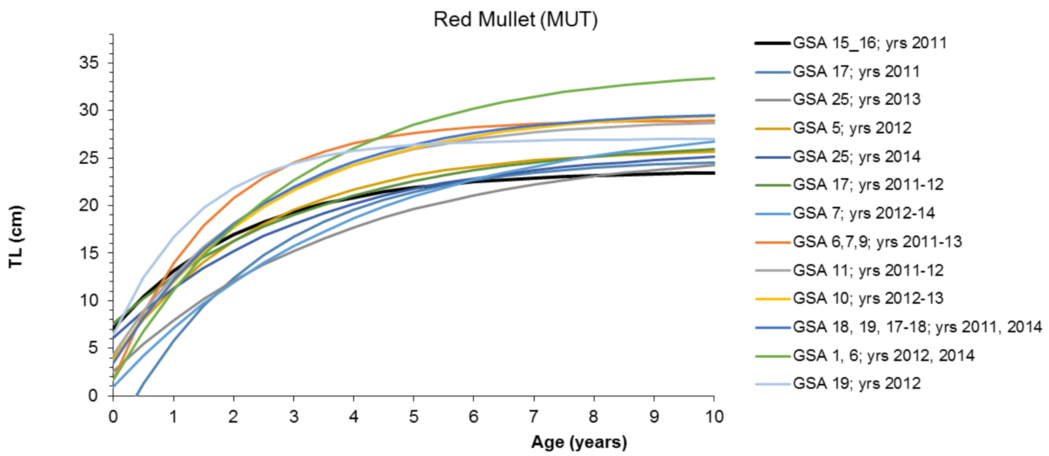


Figure 3.2.2. Von Bertalanffy growth curves of red mullet in different GSAs (data from Table 3.2.2)

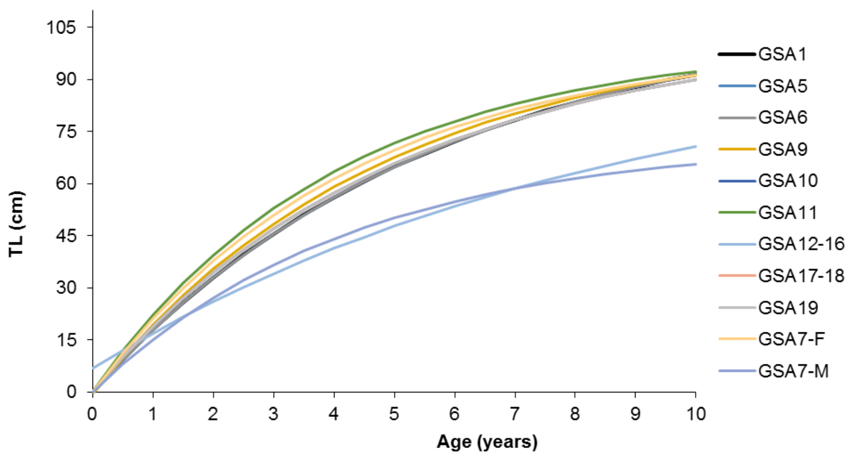


Figure 3.2.3. Von Bertalanffy growth curves of red mullet in different GSAs (data from Table 3.2.3)

3.3 Exploration of VB parameters (k, L_{inf} and t_0) from DCF GP database

Growth parameters from the Mediterranean and Black Sea Data call were explored to identify potential regional discrepancies and large outliers. L_{inf}, k and t_0 were plotted by species and area and for either sex combined (C) or males (M) and females (F). Across all figures for Striped red mullet, red mullet, hake, Norway lobster, deep water pink shrimp, anchovy and sardines, it is clear that in many cases t_0 values ranging from -4 to 0 are reported. The L_{inf} of several stocks are unrealistically low and differ from the literature, for example an L_{inf} = 30.6 cm for Mediterranean hake males (Figure 3.3.3).

For

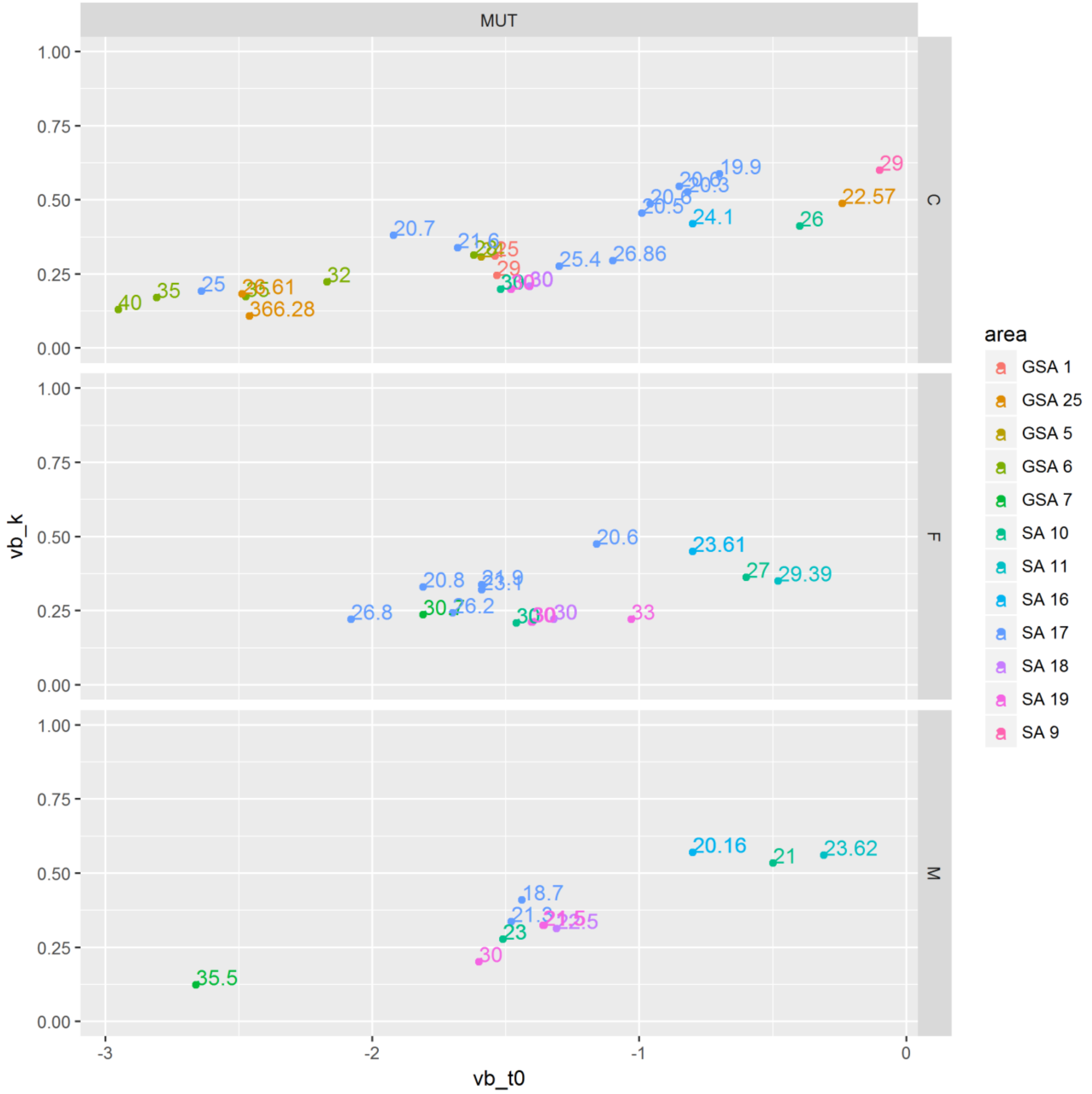


Figure 3.3.1 L_{inf} (printed value in plot), k (vb_k) and t_0 (vb_t0) for Striped red mullet and area and for either sex combined (C) or males (M) and females (F).

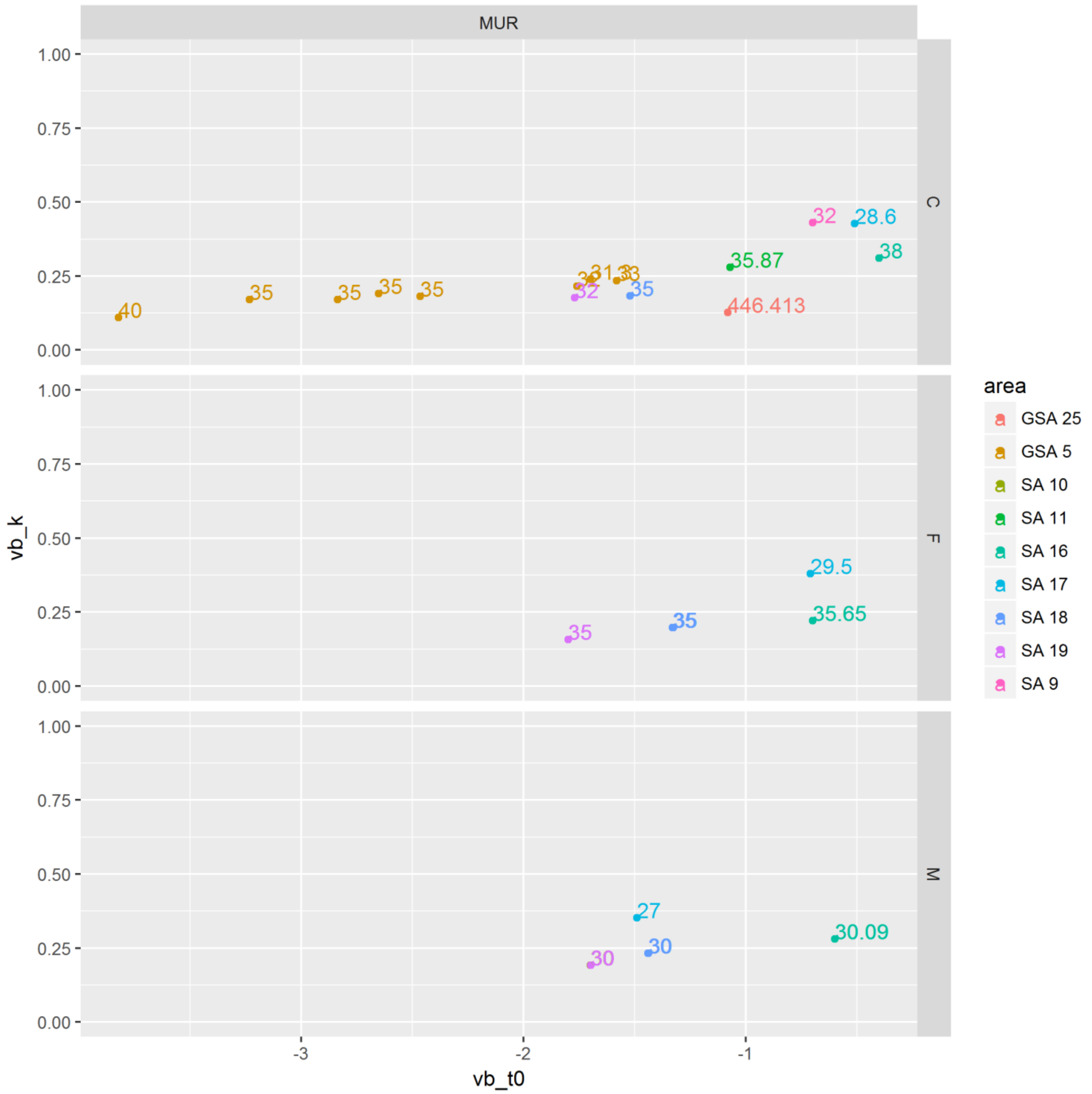


Figure 3.3.2 Linf (printed value in plot), k (vb_k) and t_0 (vb_t0) for Striped red mullet and area by sex combined (C) or males (M) and females (F).

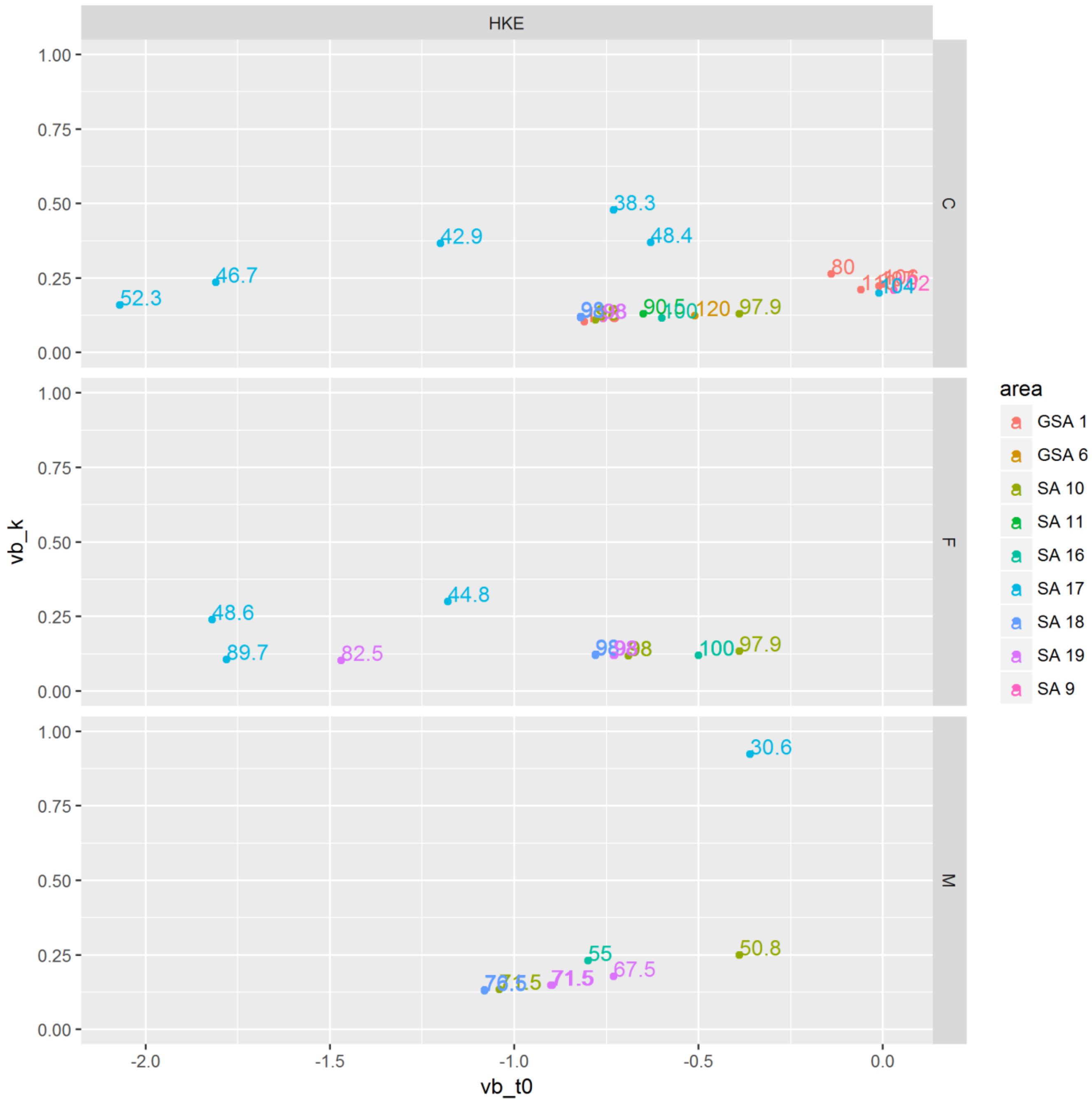


Figure 3.3.3 L_{inf} (printed value in plot), k (vb_k) and t_0 (vb_t_0) for Mediterranean hake and area by sex combined (C) or males (M) and females (F).

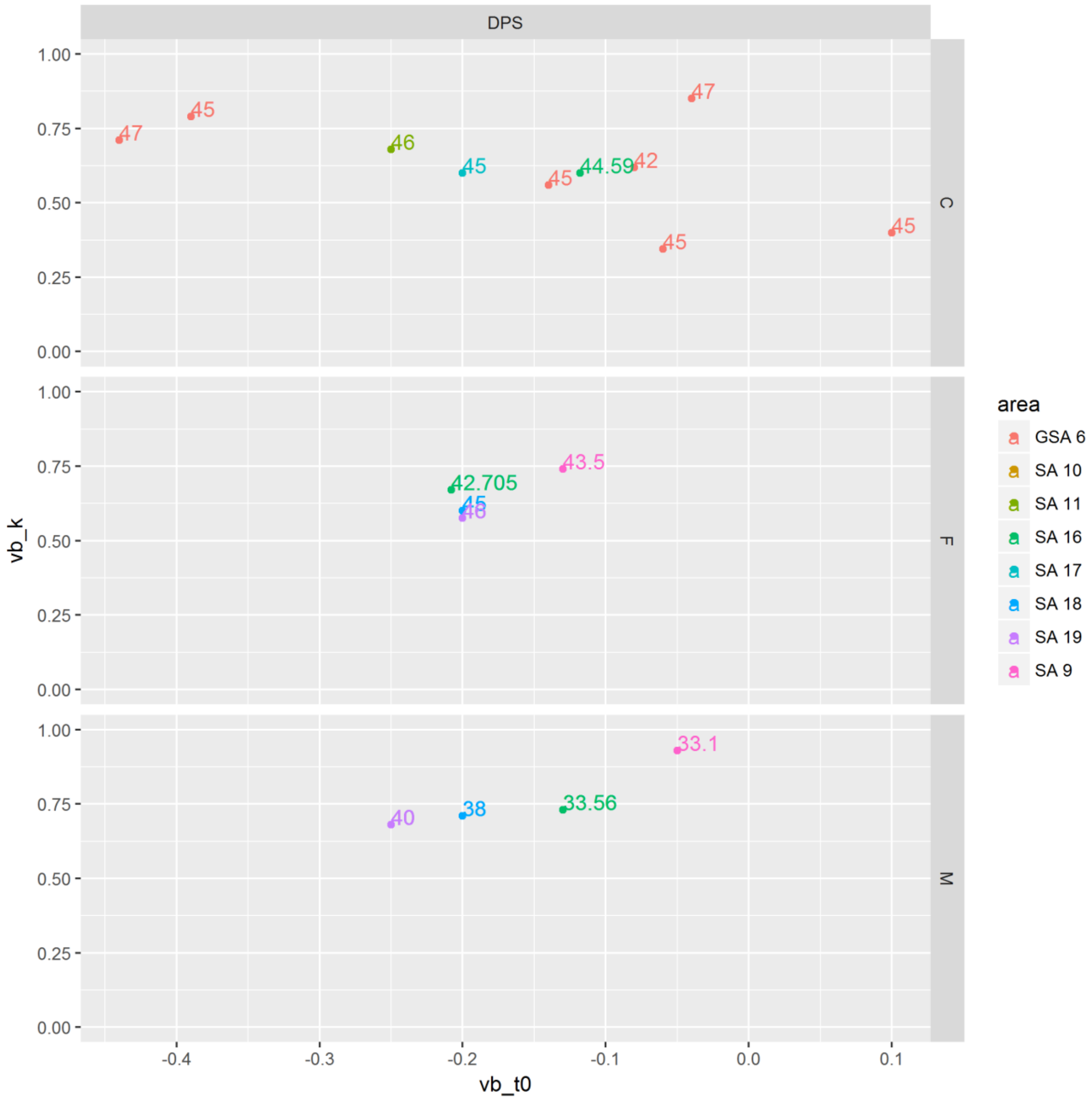


Figure 3.3.4 L_{inf} (printed value in plot), k (vb_k) and t_0 (vb_ t_0) for deep-water rose shrimp and area by sex combined (C) or males (M) and females (F).

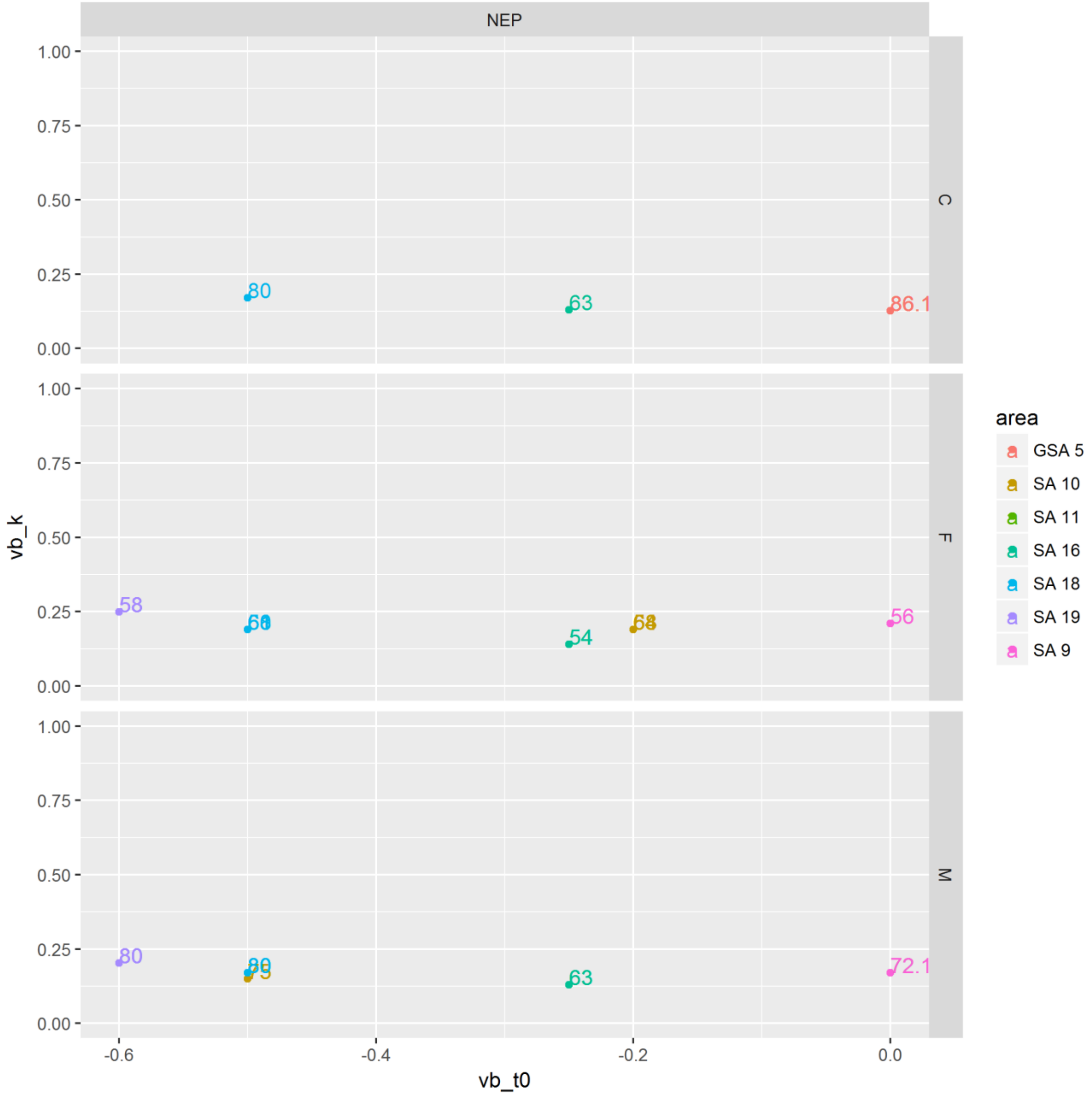


Figure 3.3.5 L_{inf} (printed value in plot), k (vb_k) and t_0 (vb_ t_0) for Norway lobster and area by sex combined (C) or males (M) and females (F).

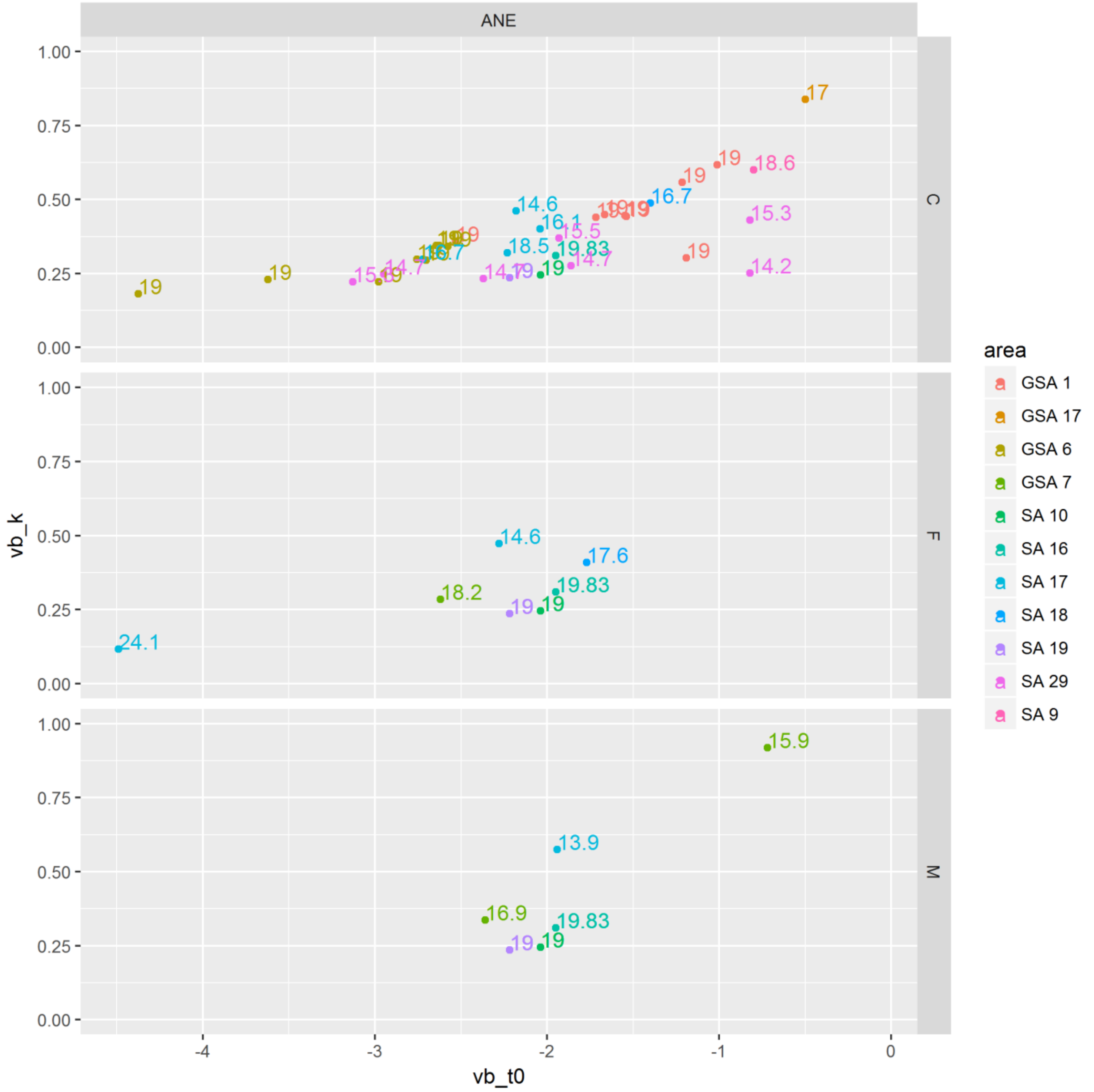


Figure 3.3.6 L_{inf} (printed value in plot), k (vb_k) and t_0 (vb_ t_0) for anchovy and area by sex combined (C) or males (M) and females (F).

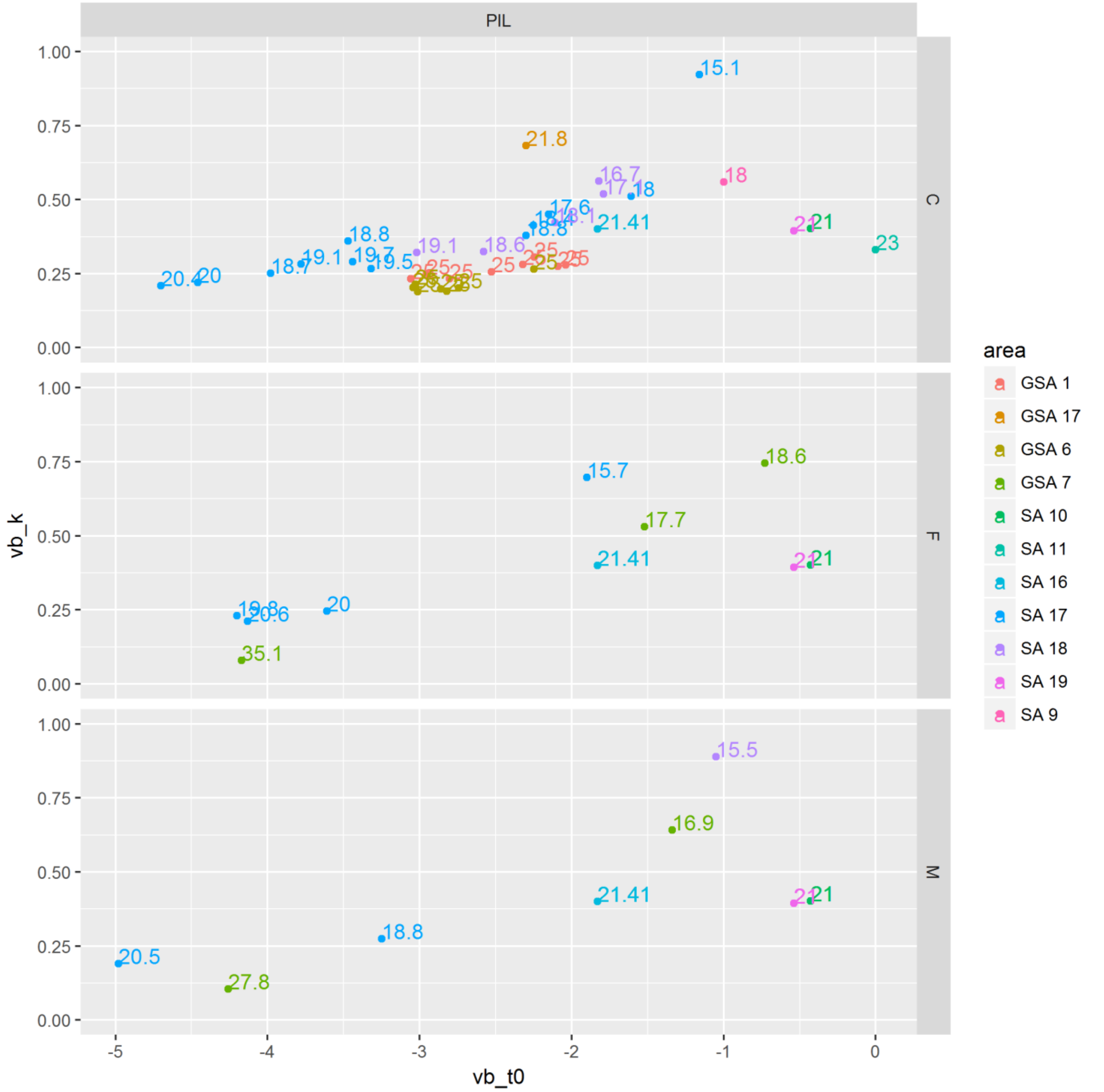


Figure 3.3.7 L_{inf} (printed value in plot), k (vb_k) and t_0 (vb_ t_0) for sardine and area by sex combined (C) or males (M) and females (F).

CONCLUSIONS on DCF reported VGB parameters

- There are very large differences within species in VB t_0 at similar L_{inf} and k.
- Some L_{inf} reported in the data call are from small samples or emerging from the catches, in either case are very far from literature L_{inf} .

To overcome the problem of large negative t_0 and problematic VBGFs, the EWG suggests using VBGFs that have t_0s forced through the origin or close to 0 to overcome underestimation of age at length. Since the EWG has no means to verify DCF VGB estimates, the EWG suggest calling for the underlying data, the age length keys (ALK) for the stocks for which these are planned in the DCF National Plans to be able to:

- refit VGB through the origin,
- to use yearly VGBs for age slicing if appropriate,
- to use yearly ALK for direct lenght to age conversion if available.

General comments and recommendations

1) Growth parameters

Large differences in growth parameters used are reported for the assessed stocks of the three species, particularly in red mullet where the k value ranges from 0.25 to 0.70. Some large difference occurs also across years for the same stock (e.g. MUT in GSA 7 and 6), or between adjacent areas (e.g. MUT in GSA 9 and 10). The biological basis for such a geographic variability is unclear and seems more related to differences in aging and/or interpretation of the ring pattern on otoliths among laboratories than to spatial differences in factors affecting growth rate (e.g. genetics, temperature, etc.).

In particular, there is a clear need to reduce differences in L_{inf} and k parameters in order to standardize the estimation of natural mortality M, and make the outputs of the assessments comparable.

During STECF EWG 09-03, a range of plausible L_{inf} and k values for red mullet and deep-water rose shrimp were discussed. In the case of L_{inf} for red mullet, a range between 27 and 31 cm TL was assumed as realistic and recommended to be adopted for the estimation of natural mortality, whereas no indication was provided for the range of k. For European hake, a L_{inf} ranging between 90 and 100 cm TL was assumed as realistic. In the case of deep-water rose shrimp, it was recommended to adopt L_{inf} values between 43 and 45 mm CL, and a k between 0.45 and 0.60.

2) Age slicing

In the Mediterranean growth parameters are widely used to convert length-frequency distributions (LFDs) into age-frequency distributions, while the use of age-length keys (ALKs) to convert size distribution into age structure is uncommon. In most of the cases, the method used is a deterministic slicing (knife-edge) generally based on a single set of VBGP (von Bertalanffy growth parameters) combined for the two sexes and applied across the whole time series. In some stocks, the slicing is also done separately for the two sexes using VBGP by sex.

Lack of accounting for sexual differences in growth is likely to introduce a bias in the reconstructed catch at age matrices. In addition, the growth is assumed constant through time although changes in growth rate from year to year cannot be excluded for fast growth species such as deep-water rose shrimp. Using different sets of parameters, as estimated within the DCF, for different groups of years should be considered in future assessments.

In addition, the internal consistency (e.g. cohort consistency, scatterplots between subsequent age classes) of the numbers-at-age matrix obtained with the slicing is generally not documented in the assessment reports.

The statistical slicing or other approaches based on separating cohort within LFDs, such as the Bhatthacharya method, are rarely applied. These methods have the potential to incorporate variability in growth rate across years without directly relying upon growth parameters. The methods, however, work best with LFDS in which modes are clearly separable. For many stocks where commercial catch data is aggregated to year, this separation is not found. In the case of survey data which is also split to age by length less overlap between cohorts would be expected.

The usefulness of the statistical slicing was discussed during STECF EWG 11-14 held in Larnaka (Cyprus) in 2011. STECF EWG 11-14 suggested that given the flexibility of the method and the associated uncertainty in the fitting over the data, several fits with different options should be carried out to decide which one is the most appropriate. In contrast, the deterministic knife-edge method is simple and can work with any amount of data. Due to the simplicity in using, the STECF EWG 11-14 suggested to always use the knife-edge method in combination to the statistical method, and to compare the results between the two methods. A comparison of two XSA assessments run with the different deterministic slicing methods revealed only minor differences in the results, particularly in the estimate of SSB (see below)

3) Natural mortality

All the assessments considered applied an M-at-age vector calculated using the ProdBiom method (Abella et al., 1997). These M vectors did not appear always consistent with the growth parameters used across GSAs and time, in particular for the oldest age classes. For instance, M-vector for deep-water rose shrimp in GSA 1 changes in the assessments carried out in different years (2012 and 2015), despite the growth parameters being the same. A check of the relationship between the average M values derived from the M vectors and the k values of the von Bertalanffy growth curve clearly show a high variability of the average M for similar k values (Figure 3.3.8). The average M values appear proportional to k when all the three species are considered together. Looking at the single species, such relationships are basically missing thus likely indicating that there are inconsistencies among M and k used in the assessments (Figure 3.3.9).

Variability in M appears therefore to derive to some "structural" issues related to the application of the ProdBiom method. Users have obtained in different times fairly different M vectors even using as input the same set of growth parameters, length/weight relationship parameters and assumptions on longevity needed for running the model. This is probably mostly due to a misuse of the model. It is clear that without some adjustments the program can produce multiple solutions regarding combinations of the two parameters A and B (Asymptotic M and curvature parameter). As stated in the description of the approach (Abella et al., 1997), in order to avoid multiple solutions, some reasonable constraints must be introduced into the computations. For instance, having reliable estimates of the natural mortality rate for adults, it is possible to constrain the choice of the A and B parameters by SOLVER so that the mortality trajectory passes through or close to those values.

4) F_{MSY}

F_{MSY} values varied largely for the three species according to the growth and M values used in the assessments. However, inconsistencies arise when F_{MSY} values are compared with those of k (Figure 3.3.10). Although an increasing of F_{MSY} with k should be expected, no clear relationship between these two parameters can be found for deep-water rose shrimp and European hake. In the case of red mullet, a weak relationship between M and k appears, although with a high variability (e.g. for k values around 0.4 F_{MSY} ranges between 0.10 and 0.55).

Changes in F_{MSY} are often in the same direction as the assessment estimates. Testing for sensitivity of stock status to differences in growth parameters is recommended.

Consistency between life history parameters should always be maintained; historically this has not always been the case. It is recommended to try to always calculate these as set for any assessment.

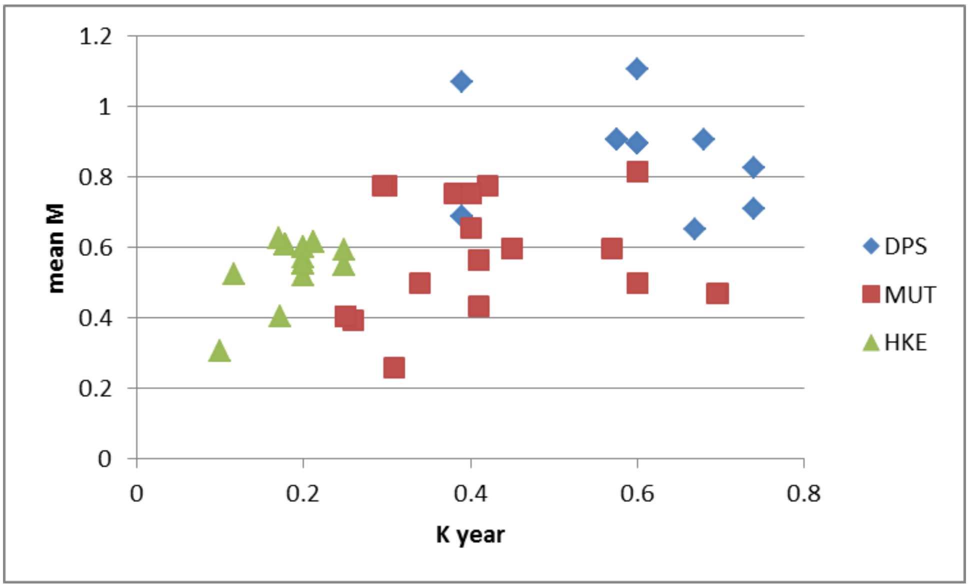


Figure 3.3.8. Scatterplot showing relationship between k and mean natural mortality M in the three species.

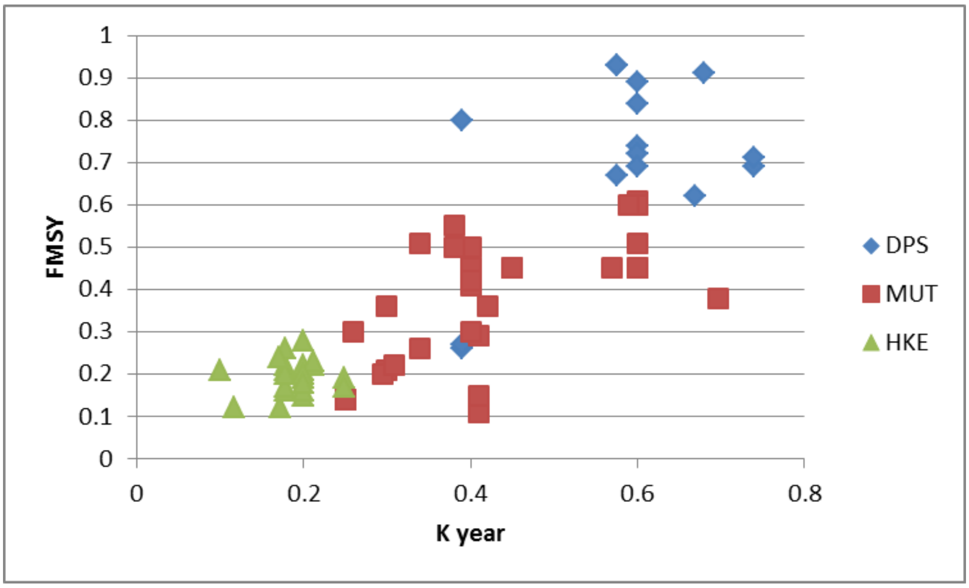


Figure 3.3.9. Scatterplot showing relationship between k and F_{MSY} in the three species.

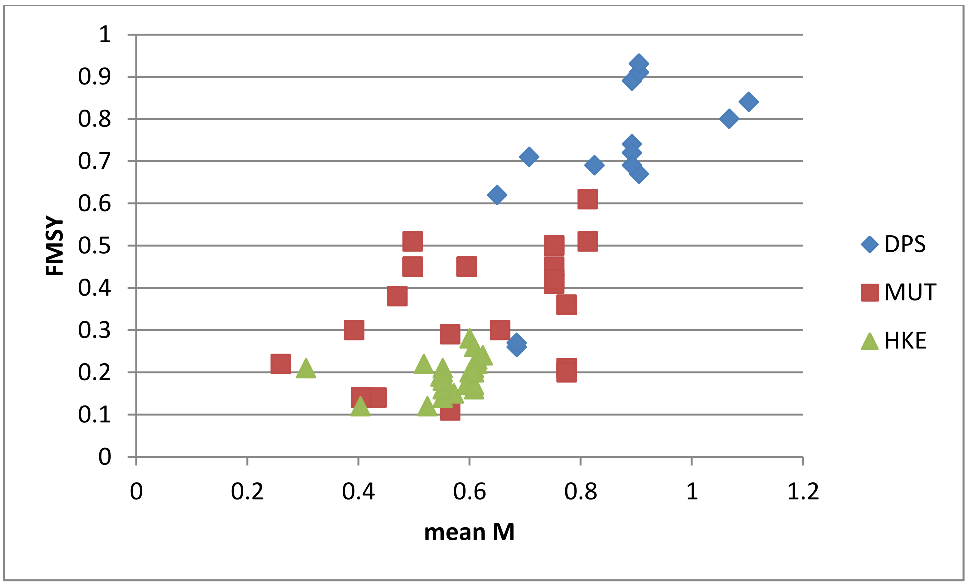


Figure 3.3.10. Scatterplot showing relationship between mean natural mortality M and F_{MSY} in the three species.

3.4 Sensitivity of DPS assessments to growth parameters

3.4.1 Deep-water rose shrimp in GSA17-18-19: a case study with a4a

3.4.1.1 Data and Methods

To run the analysis the stock of deep-water rose shrimp in GSAs 17-19 was used as a case study. The input data was extracted from the STECF EWG 15-16.

The analysis consisted in running a set of assessments to the same stock, changing the value of k used to slice the length frequencies into age groups. The process required a single model stock assessment to be fit to all pseudo-stocks, which resulted in finding a compromise across pseudo-stocks, but this way avoiding introducing an extra source of variability in the analysis.

In detail the algorithm of the analysis was:

1. read and process data
2. set biological parameters
3. set a4a growth model
4. set a4a M model (to be consistent with growth)
5. create FLR length based objects
6. slice to create FLR age based objects
7. fit statistical catch at age model
8. summarise results

The von Bertalanffy parameters were set based on the DPS parameters collected for the North Mediterranean stocks.

L_{inf} = 45.0 mm

k = {0.4, 0.45, 0.5, 0.55, 0.6, 0.65, 0.7, 0.75} $year^{-1}$

t_0 = -0.2 year

The a4a stock assessment model was set to fit reasonably well to all the pseudo-stocks generated with the different k. The abundance indices, based on MEDITS, were modelled with a constant catchability over time, fitting a coefficient for each age group, except for GSA 19 for which a two level model for ages 0 and >=1 was used. Fishing mortality was modelled as a separable function, with a thin plate spline for both effects, age and year, with basis of size 3 and 8, respectively.

3.4.1.2 Results

The von Bertalanffy models obtained from changing k are shown in the Figure 3.4.1.2.1 The natural mortality set for each level of k is an adaptation of Gislason's, which reduces the slope to become more similar to Prodbiom, which is used for this stock (Figure 3.4.1.2.2).

Figures 3.4.1.2.3 and 3.4.1.2.4 shows the effect of increasing k in catch at age and fishing mortality estimates, respectively. The value of f increase in the central ages and the selection pattern becomes steeper. This result is expectable, since the increase in k concentrates the number of individuals caught in less and younger ages.

In Figure 3.4.1.2.5 all assessments are plotted together. The scaling effect of changing k is clear, in particular in F and SSB. In some cases it's also visible some changes in the time series, which most likely are a result of the stock assessment fit. The fits are fairly comparable but not totally neutral in the comparison.

Yield-per-recruit curves are shown in Figure 3.4.1.2.6. Figure 3.4.1.2.7 shows $F_{0.1}$ reference points, namely f, biomass per recruit and yield per recruit. The reference points increase with k, although the increase is not as much as the estimates of fishing mortality, which ends up showing a small constant deterioration of the stock status with the increase in used k (Figure 3.4.1.2.9).

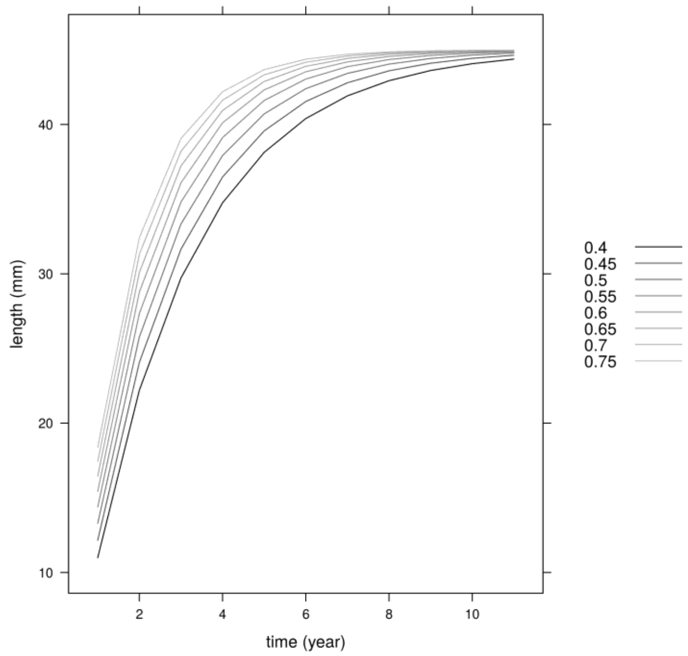


Figure 3.4.1.2.1 – DPS GSA17_18_19: The von Bertalanffy models obtained from changing k

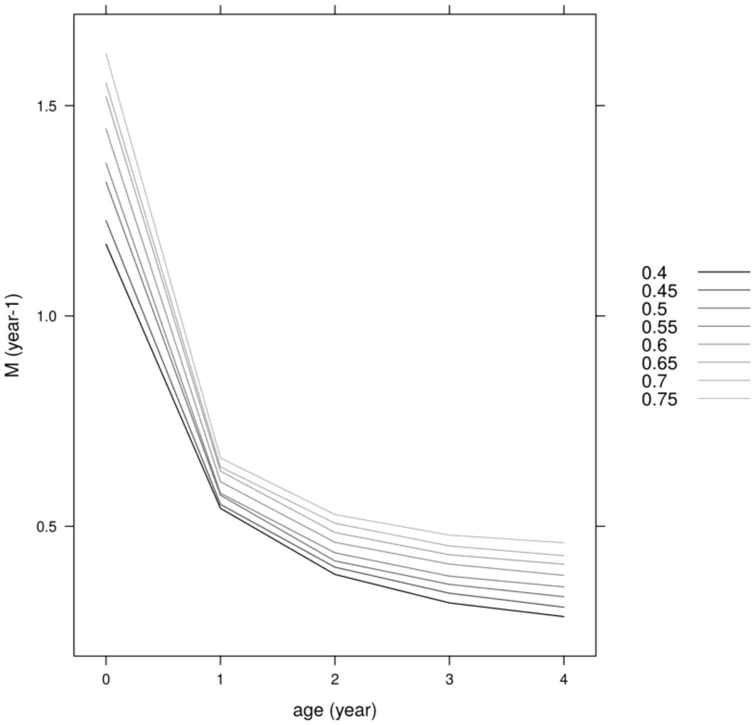


Figure 3.4.1.2.2 – DPS GSA17_18_19: The natural mortality set for each level of k is an adaptation of Gislason

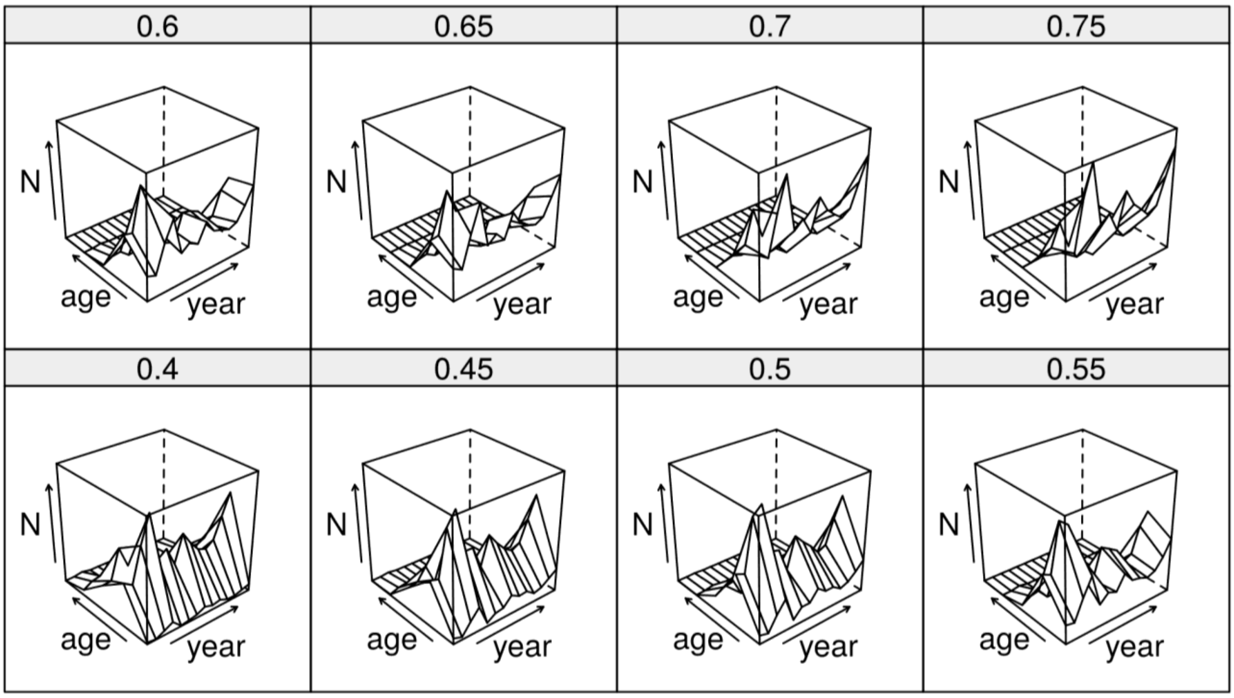


Figure 3.4.1.2.3 – DPS GSA17_18_19: effect of increasing 'k' in catch at age

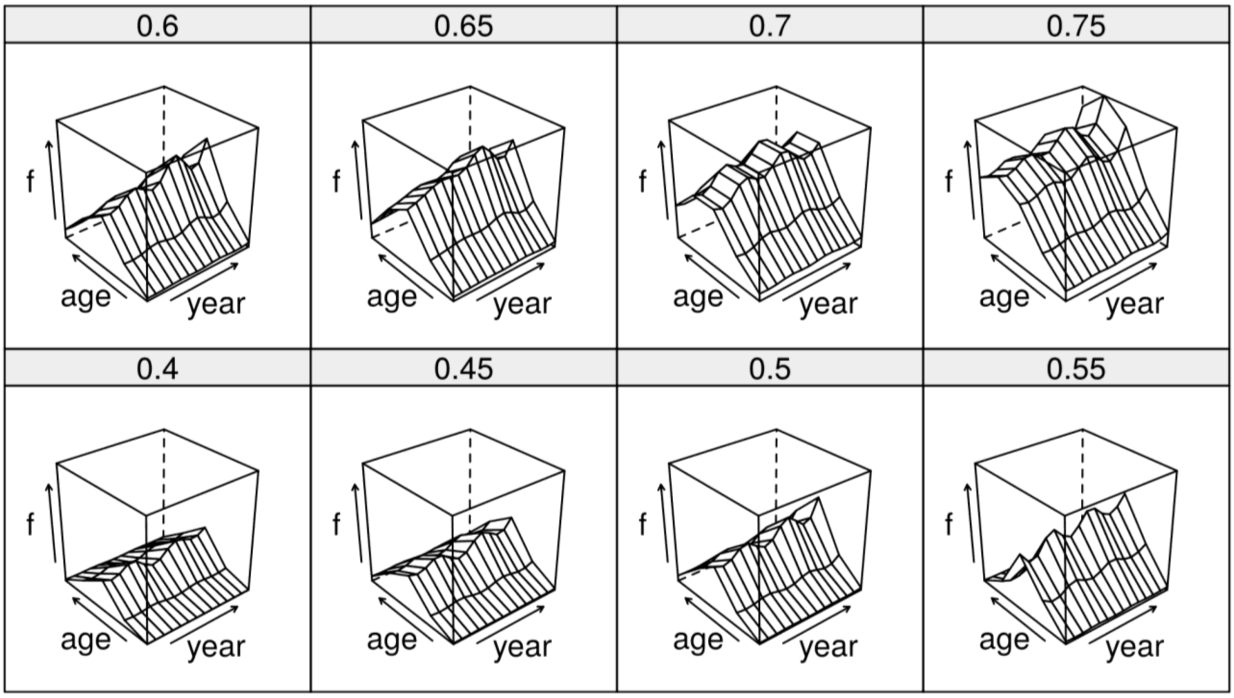


Figure 3.4.1.2.4 – DPS GSA17_18_19: effect of increasing k on fishing mortality estimates at age

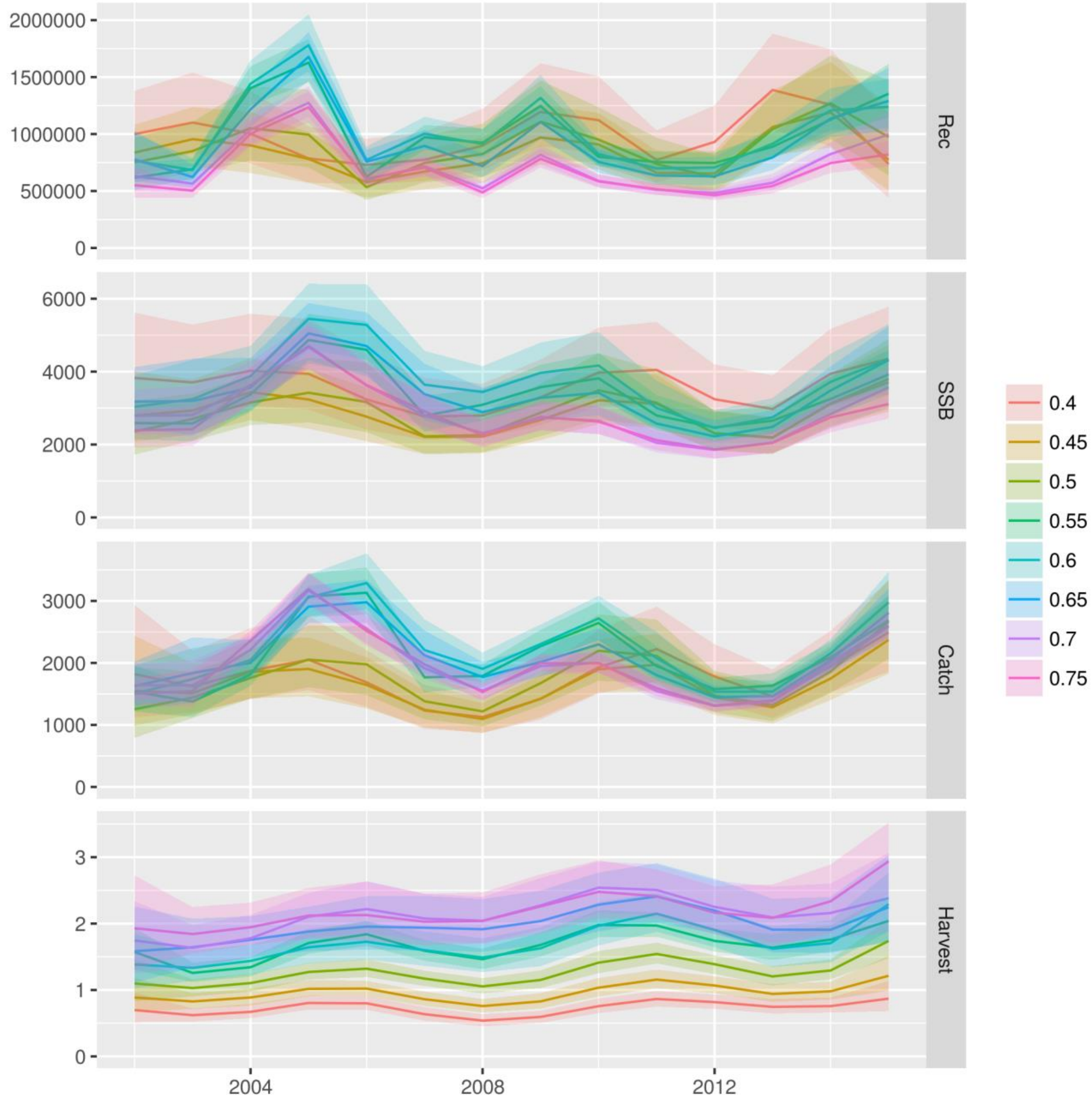


Figure 3.4.1.2.5 – DPS GSA17_18_19: assessments results increasing k.

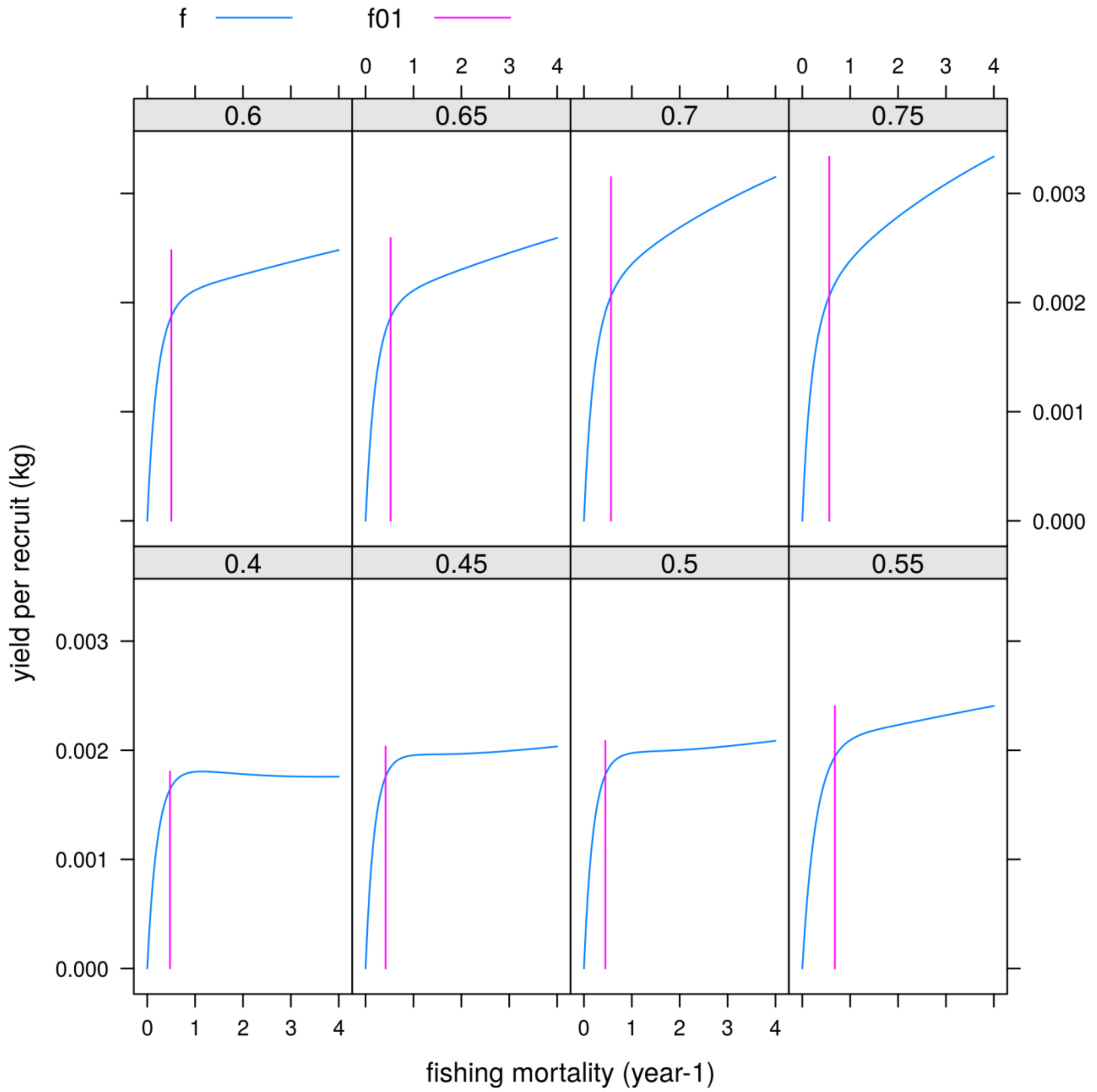


Figure 3.4.1.2.6 – DPS GSA17_18_19: Yield per Recruit curve increasing 'k'.

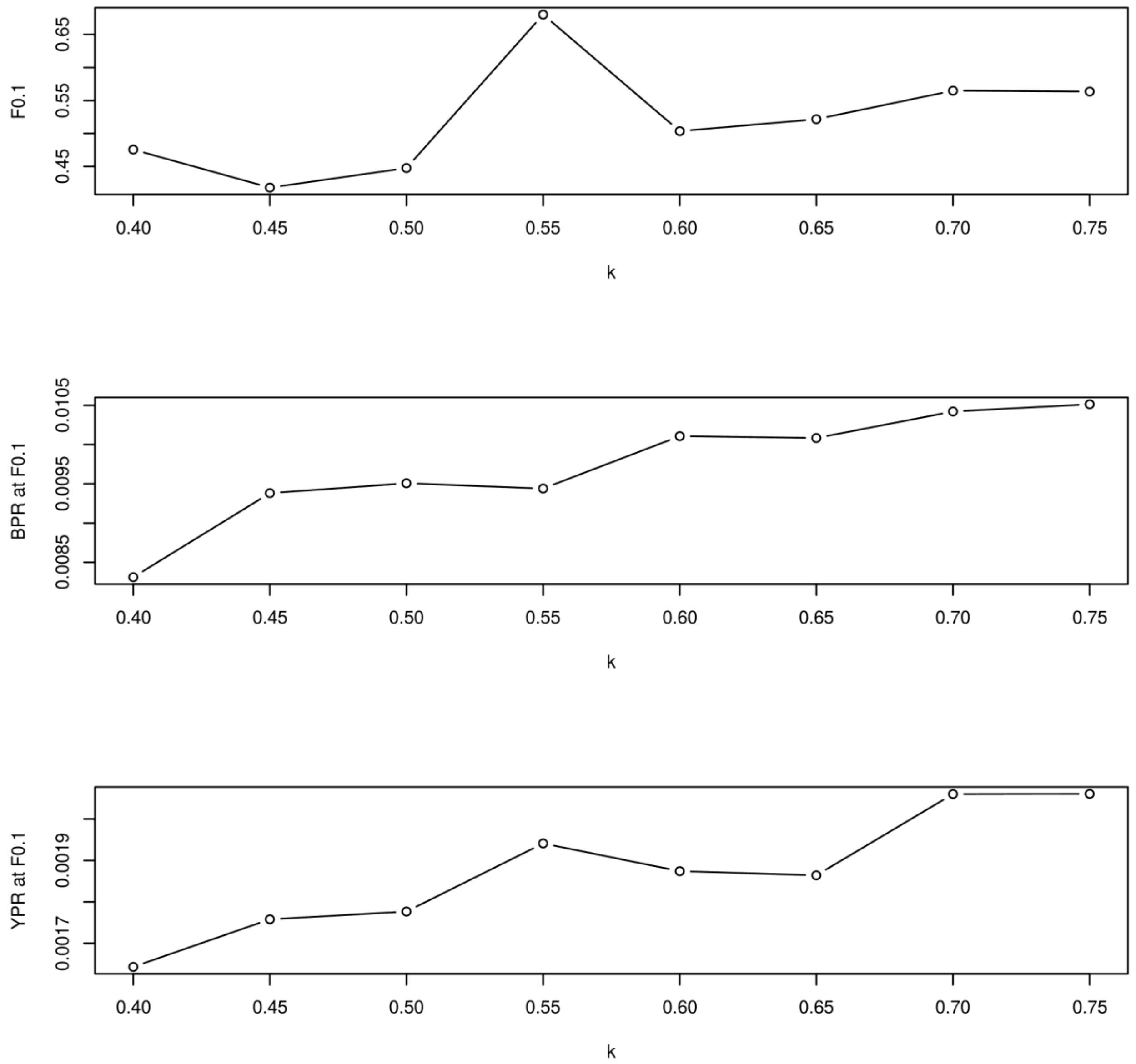


Figure 3.4.1.2.7 – DPS GSA17_18_19: $F_{0.1}$ reference points, namely f, biomass per recruit and yield per recruit.

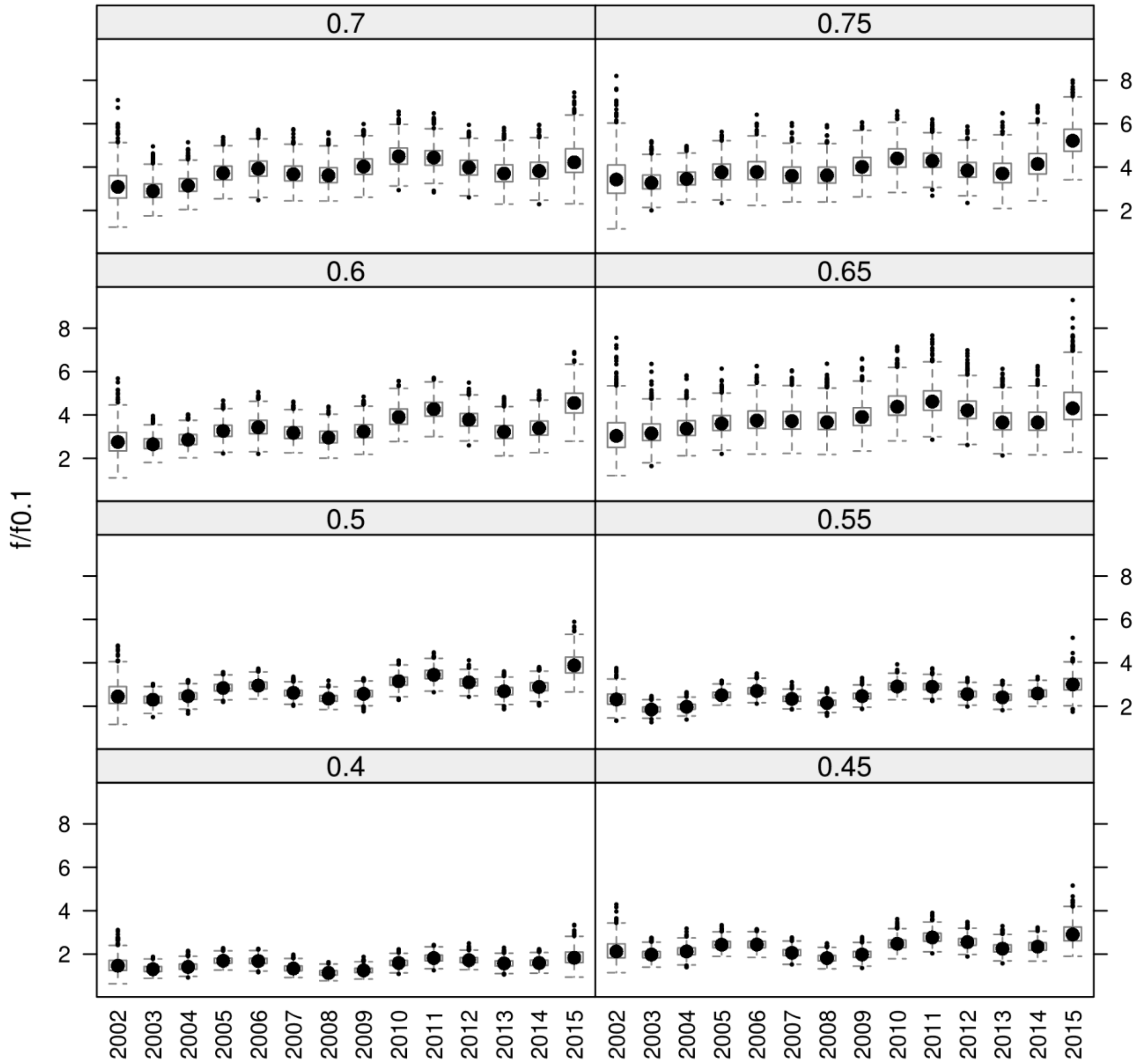


Figure 3.4.1.2.9 – DPS GSA17_18_19: ratio $F/F_{0.1}$ increasing k.

3.4.1.3 Final Comments for a4a evaluation

In practice in an EWG framework the stock assessment models would be subject to a better scrutiny to get a better fit, which in this situation when dealing with several stocks simultaneously is not possible. On the other hand having a single model, as we have done here, rules out the model effect across stocks, making the results more comparable.

The effect of larger k values is to concentrate the individuals in a shorter, younger, range of age groups, which ends up creating an increase in F at younger ages. This increase in F in some ages changes the shape of the selection pattern, which affects the shape of the yield per recruit curve, impacting the reference points. The change in M which changes with k is also influencing the reference points. Although our analysis show that small differences in k don't seem to have a major impact in the final perception of the stock status, the range of that difference will most likely depend on the specific stock.

The EWG did not investigate including uncertainty in growth parameters in a single assessment, just evaluating the effect on point advice. However it's an important subject to take into account when considering the output of an assessment to use for management. Methods to deal with this uncertainty exist and can be further developed to be used in a stock assessment context.

Considering the results obtained, the EWG suggests the effect of growth parameters to be investigated for each stock, in order to evaluate the impact in the results, but the evidence so far suggests that small changes have on limited effect. However, the major differences seen in the historic tables can have a considerable influence.

The EWG identified some stocks with inconsistent growth parameters across the same species. The EWG suggests a study/WK/whatever could be developed/organized to estimate growth parameters for each species so that a reference set of parameters, including plausible ranges and uncertainty, can be estimated. Such set of parameters will provide important guidance for the analysts to deal with the assessment of stocks with limited data.

3.4.2 Deep-water rose shrimp in GSA9: simulation exercise using different values of k with XSA

The stock assessment of deep-water rose shrimp (DPS) in GSA9 is performed using catch-at-age data that are derived from length distributions separated by sex. To this end, different sets of growth parameters for males and females are used to perform the age slicing. Once numbers-at-age are derived by sex, they are combined to obtain a single catch-at-age matrix that is used in the assessment.

Table 3.4.2.1 – DPS in GSA9: growth parameters for males and females used to perform age slicing under the accepted assessment.

	Growth parameters			Length-weight relationship	
Sex	L_{inf}	k	t_0	a	b
Male	33.1	0.93	-0.05	0.0044	2.359
Female	43.5	0.74	-0.13	0.0045	2.377

Under STECF EWG 17-02, a simulation exercise (based on the script provided in Annex III) was performed to test the effects of different values of k (from the VBGF) to the outputs of the assessment. To this end, a set of growth parameters was used. L_{inf} was kept constant at 40 mm CL and t_0 at -0.20. The parameter k was varying in the range 0.40-0.85 (step 0.05) in order to test the whole range of k values used in the assessment of this species in different areas of the Mediterranean (see Table 3.4.2.1). Furthermore, the value of 0.85 was considered an adequate approximation of the average of the k values of males and females as used in the accepted assessment for this stock (0.74 for females, 0.93 for males). Also, the value of 40 mm CL for L_{inf} was selected as an adequate approximation of the average of the L_{inf} values of males and females (43.5 for females, 33.1 for males) used in the validated assessment.

Only the females length-weight relationship parameters were used to estimate mean weight-at-length and then mean weight-at-age (a = 0.0045, b = 2.377). Length at first maturity (L_{50}) for this stock (females) is 19.9 mm CL (MR ± 8.4).

Figure 3.4.2.1 shows the catch numbers-at-age distributions by year obtained by means of the deterministic age slicing using different values of k, ranging from 0.40 to 0.85 (0.05 step). It is possible to observe how the age structure is changing along the k value, with the age class 0 becoming predominant with increasing k value.

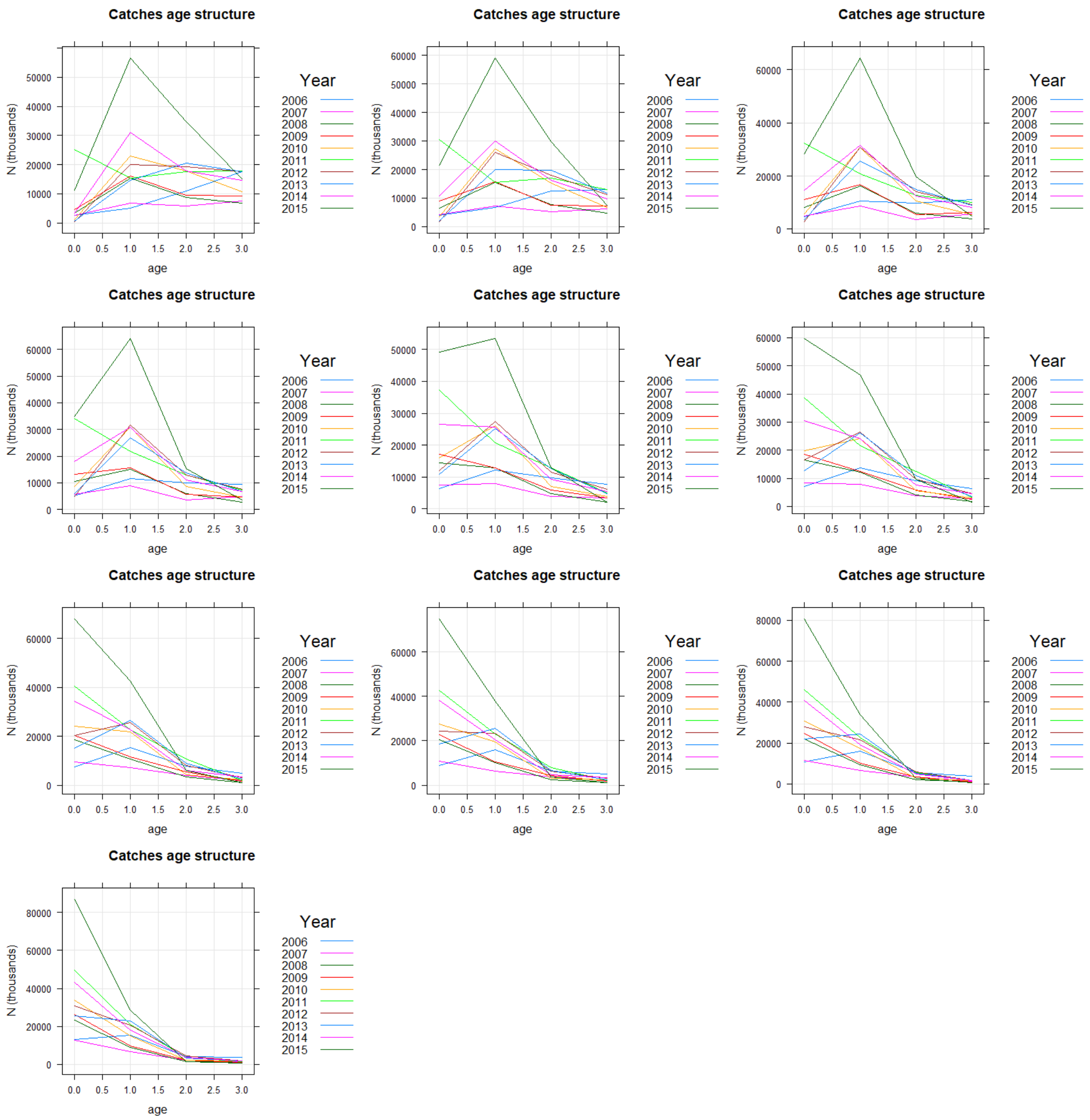


Figure 3.4.2.1 – DPS in GSA9: Catch-at-age distributions by year with the different k values, from 0.40 (top-left) to 0.85 (bottom-left).

Natural mortality (M) vectors were calculated by means of the Gislason formula using the different values of k (Figure 3.4.2.2). The M vector (obtained using ProdBiom, Abella et al., 1997) used in the accepted assessment is also shown in Figure 3.4.2.2. The largest differences in terms of M are present at age 0, while the changes in M values for the rest of age classes are rather small.

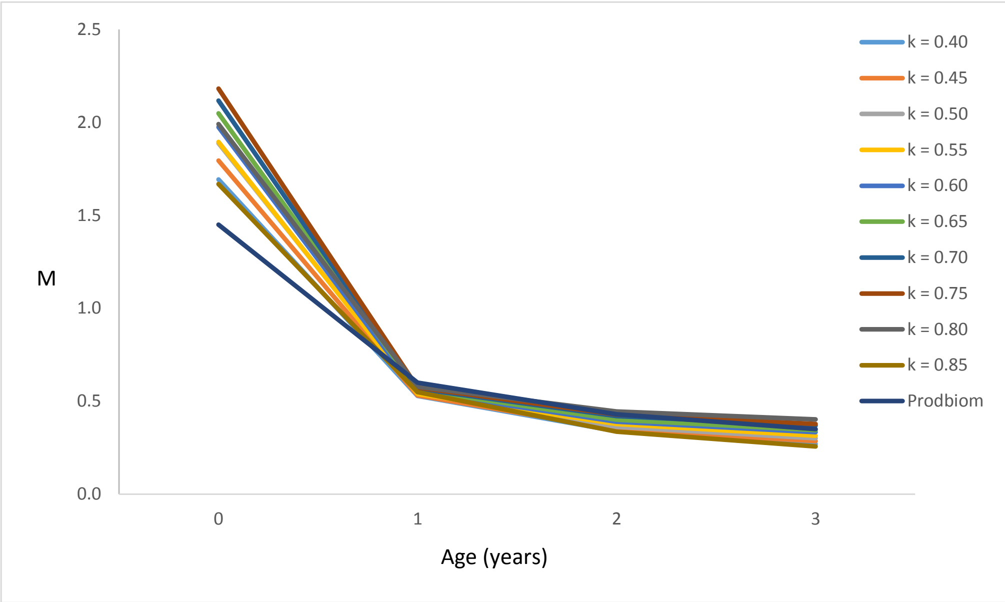


Figure 3.4.2.2 – DPS in GSA9: Natural mortality (M) vectors obtained for each value of k. The M vector (obtained using ProdBiom, Abella et al., 1997) used in the accepted assessment is also shown.

Ten XSA runs were performed based on the survey (MEDITS in GSA9) and commercial catch-at-age matrices obtained from age slicing with k values ranging from 0.40 to 0.85 (0.05 step). The XSA settings were the same as those used in the validated assessment performed at STECF EWG 16-17 (Table 3.3.12).

Table 3.4.2.2 – DPS in GSA9: settings of the XSA assessment.

fse	rage	qage	shk.n	shk.f	shk.yrs	shk.ages
2.0	0.0	2.0	TRUE	TRUE	5.0	2.0

Figures 3.4.2.3 and 3.4.2.4 show, respectively, the plots of the residuals for the MEDITS surveys and the retrospective analysis for each of the 10 XSA run. The diagnostics of all the 10 runs shows acceptable results both in terms of residuals and retrospective analysis.

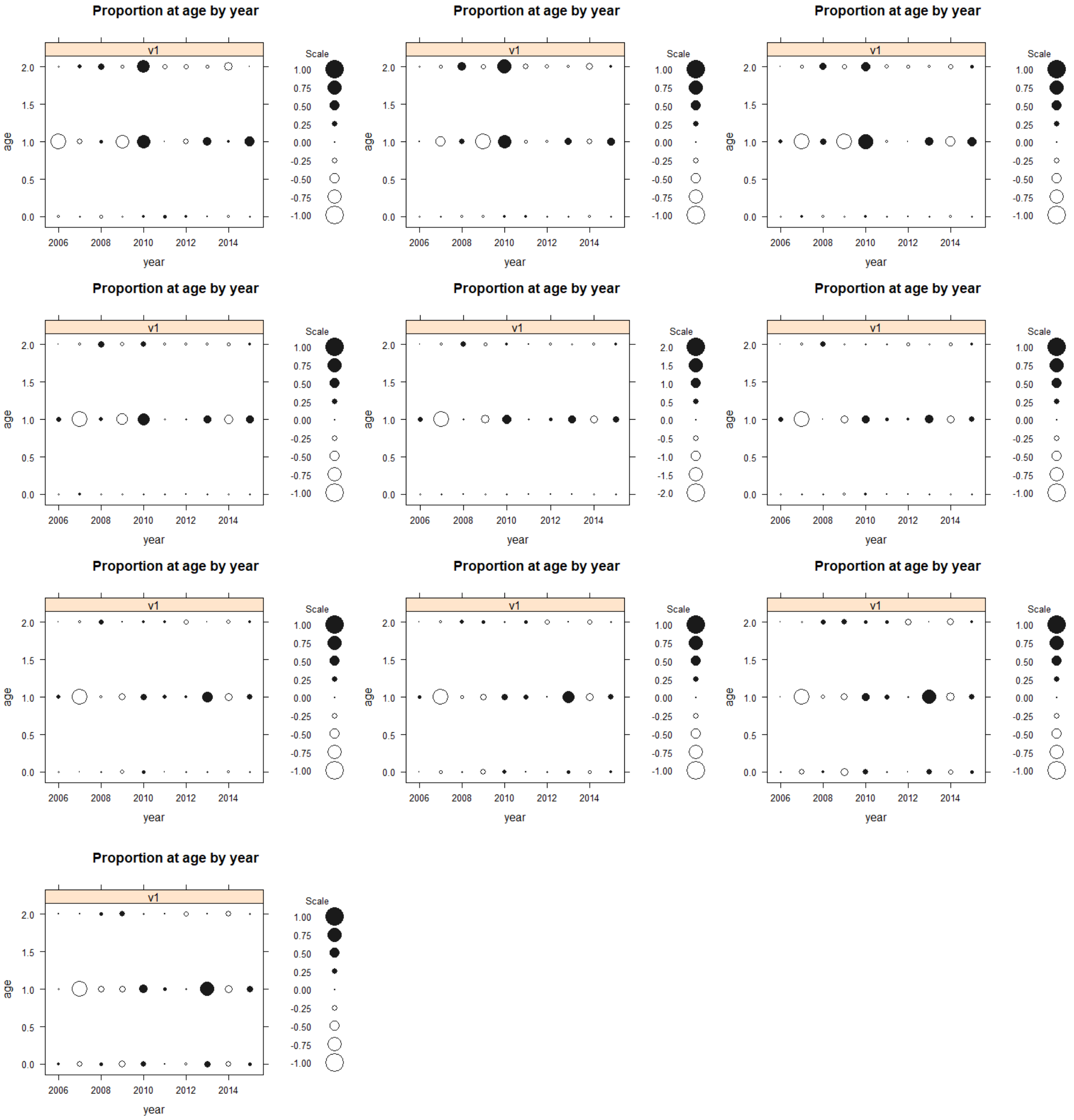


Figure 3.4.2.3 – DPS in GSA9: Bubble plots of residuals (MEDITS survey) with the different k values, from 0.40 (top-left) to 0.85 (bottom-left).

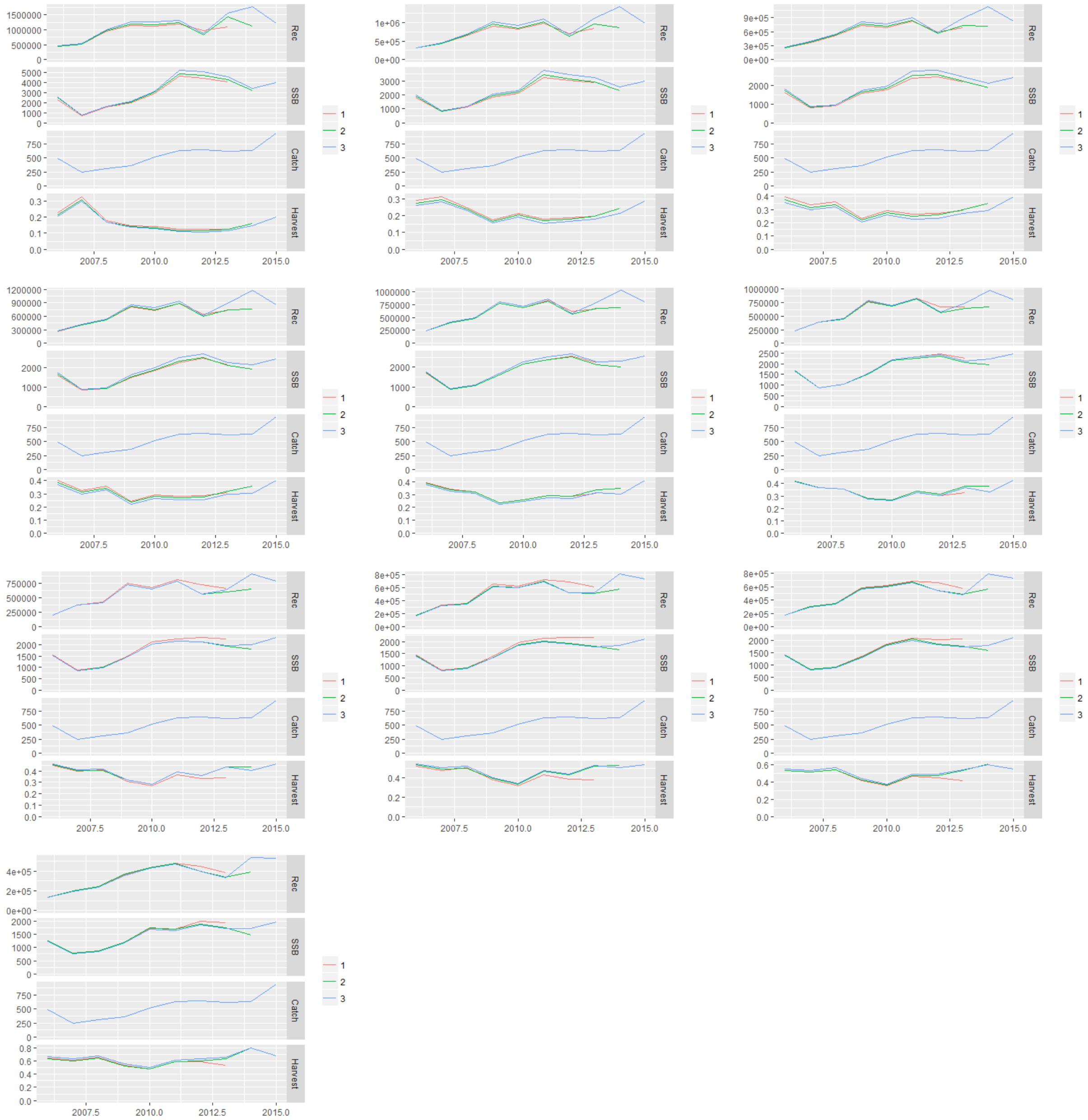


Figure 3.4.2.4 – DPS in GSA9: retrospective analysis for the assessments with the different k values, from 0.40 (top-left) to 0.85 (bottom-left).

Figure 3.4.2.5 shows the outputs of the 10 XSA runs. Fishing mortality (F, Harvest) increases along with k. An opposite pattern is shown by the spawning stock biomass (SSB) and recruitment. Fishing mortalities deriving from the assessments run with catch-at-age data obtained from age slicing using low values of k show very low values that are considered unreliable for this stock. As concerns recruitment and SSB, only the assessments based on k values of 0.40 and 0.45 show very different and high results compared to the rest of the runs, which are rather similar.

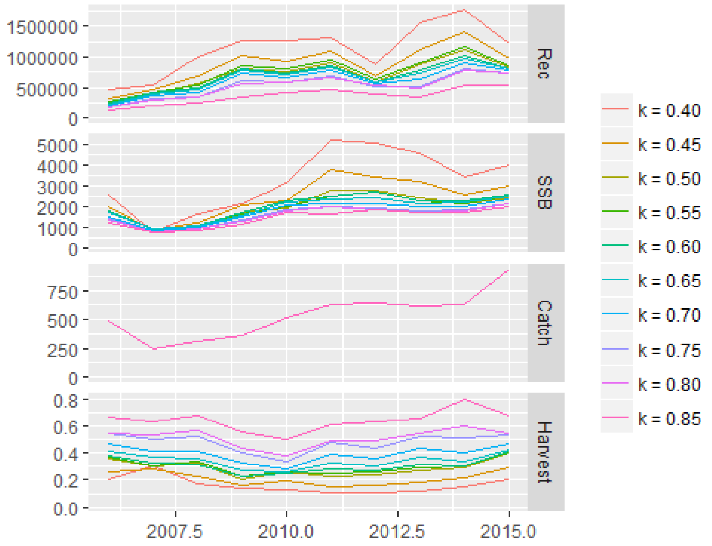


Figure 3.4.2.5 – DPS in GSA9: summary of the results of the 10 assessment runs with different k values.

Table 3.4.2.3 shows the reference points ($F_{0.1}$ as proxy for F_{MSY}) obtained for each of the ten XSA assessments using the FLBRP package. The current fishing mortality (F_{curr}) as well as the ratio between F_{curr} and $F_{0.1}$ are also shown. All the assessments show a stock status in a slight level of overfishing ($F_{curr}/F_{0.1} > 1$), with the only exception of the assessment based on k equal to 0.85 (Figure 3.4.2.6). This assessment is also the one that is providing a value of $F_{0.1}$ that is in line to those obtained for the majority of the stocks of this species in the Mediterranean Sea.

Table 3.4.2.3 – DPS in GSA9: summary of reference points ($F_{0.1}$ as proxy for F_{MSY}), F current (F_{curr}), and the ratio between F_{curr} and $F_{0.1}$.

k	**$F_{0.1}$**	**F_{curr}**	**$F_{curr}/F_{0.1}$**
0.40	0.15	0.16	1.04
0.45	0.16	0.23	1.42
0.50	0.20	0.32	1.61
0.55	0.23	0.33	1.45
0.60	0.25	0.34	1.38
0.65	0.29	0.38	1.30
0.70	0.31	0.43	1.40
0.75	0.40	0.52	1.30
0.80	0.45	0.56	1.24
0.85	0.85	0.71	0.83

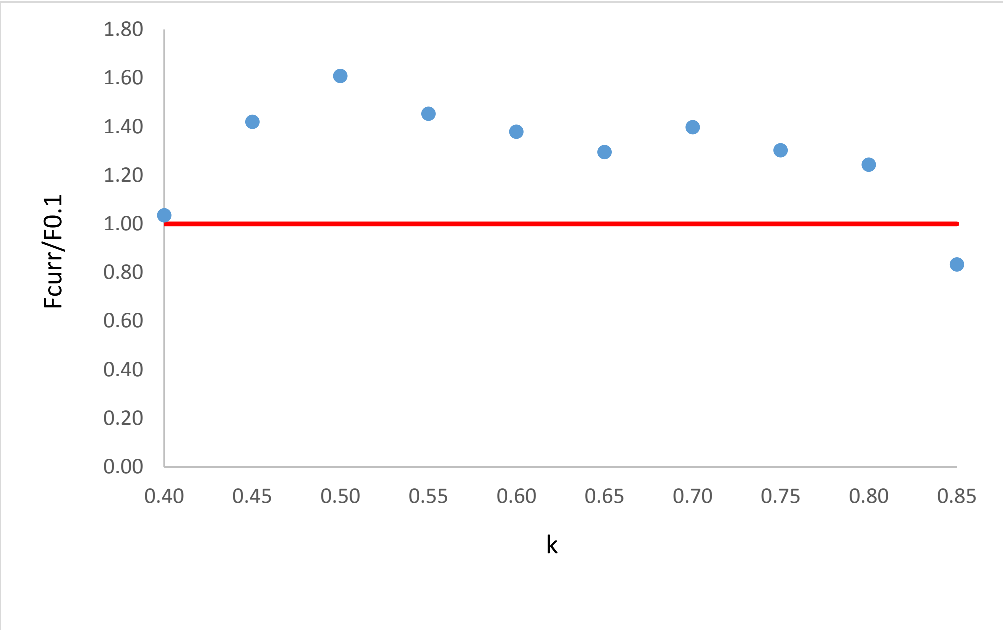


Figure 3.4.2.6 – DPS in GSA9: ratio between F_{curr} and $F_{0.1}$ for each of the ten assessments performed using k values ranging from 0.40 to 0.85. Red line shows the ratio equal to 1.

Conclusions

- The results of this exercise illustrate how important is the selection and use of appropriate growth parameters to calculate catch-at-age distributions by means of age slicing procedures, and to estimate natural mortality vectors;
- The use of inappropriate growth parameters can lead to assessment outputs that are providing different stock status figures, though the variation in stock status ($F/F_{0.1}$) is much less than F and SSB;
- The use of growth parameters that are in line to those used in the validated assessment (k = 0.85, as the average of k values of males and females in the validated assessment) are those providing the results that are the closest to those of the validated assessment.

3.5 Comparison of different models for red mullet in GSA 18.

The aim of this exercise was to investigate the impact of different slicing methods on the assessment results with Stock Synthesis 3 (SS3, Methot and Wetzel, 2013), to answer to the request of ToR 1 to consider their influence both on the results of stock assessment and also on MSY reference points.

3.5.1 SS3 model with different length slicing: red mullet in GSA 18.

The case study analysed is based on the official stock assessment of red mullet (*M. barbatus*) in GSA 18 (Southern Adriatic Sea) presented during the GFCM Working Group on Stock Assessment of Demersal species (WGSAD) held in November 2016 in Rome (Bitetto et al., 2016, in press). During the same working group a new set of von Bertalanffy parameters for sexed combined was presented, following the exceptional finding of 4 cm-sized metamorphosed specimens during a MEDITS survey.

The Stock Synthesis assessment program provides a statistical framework for calibration of a population dynamics model using a multi-fleet approach. It is designed to include different information from fishery and survey data, as well as to consider different subareas within the same stock. The model allows to work by length or by age and to assume different selectivity patterns for the different fleet exploiting the stock. In the model the selectivity is a combination of availability and vulnerability.

SS3 is based on ADMB C++ software, allowing to easily work with large databases, as well as to simultaneously estimate a number of parameters. A wide number of options are available for modelling the selectivity patterns of the different fishing gears. Moreover, time varying selectivity can be defined in order to take into account annual changes in vulnerability and availability of the stock.

The model built in SS3 for this stock for the GFCM WGSAD 2016 had the following features:

- Commercial and survey data from 2003-2015;
- Age based fitted to Length-based data;
- Discard included in catch data;
- sex combined;
- 1 area;
- annual time step;
- 4 commercial fleets (Italian trawlers, Italian gill and trammel netters, Albanian trawlers, Montenegrin trawlers and gill and trammel netters)
- 1 survey fleets (MEDITS whole GSA 18 (ITA, ALB, MON))
- time-varying selectivity for all the commercial fleets and for the survey;
- logistic selectivity for the survey and all commercial fleet except the Italian gill and trammel netters (double-normal function);
- Albanian trawlers with the same selectivity of Italian trawlers;
- no stock-recruitment relationship (annual scalar recruitment).

In this exercise the commercial catch at age matrices for Italian trawlers and Italian nets have been substituted to the LFD used in the official assessments; for eastern fleets and for MEDITS indices the LFDs have been left in the model as in the original model, not being available the corresponding age length key during the meeting. However, the Italian fleets represent the 89% of the total production of red mullet in GSA 18. This was the only modification applied to the original model; indeed, all the other settings remained the same (natural mortality, hypothesis on selectivity, maturity, etc.).

The slicing methods considered are:

- deterministic age slicing with DCF von Bertalanffy parameters (Table 3.4.1);
- deterministic age slicing with von Bertalanffy parameters revised during the GFCM WGSAD 2016 (Table 3.4.1);
- Age-Length Keys (ALKs).

The age readings data used to estimate the revised von Bertalanffy parameters are the same used to obtain the ALK.

Table 3.5.1.1. von Bertalanffy parameters used to slice the LFDs through the deterministic age slicing.

Source	**Sex**	**L_{inf}**	**k**	**t_0**
DCF 2016	F	30	0.207	-1.41
DCF 2016	M	22.5	0.313	-1.31
GFCM WGSAD revision	C	27	0.34	-0.4

The age slicing method is crucially based on the assumption that there is no overlap in lengths among cohorts. In Figure 3.5.1.1 an example of assignment of the length classes to the age classes through deterministic age slicing and by ALK is shown. The assumption of no overlap is never met and this is shown for example by the variability in lengths within each cohort in the corresponding ALK. The presence of the overlap between age 0 and age 1 in ALK results in the change in the shape of catch at age structure in input data and the stock assessment results when the approach is changed between direct use of ALK and application of age slicing. The difference between the two methods influences the shape of catch at age distribution (Figure 3.5.1.2): for trawlers, with age slicing we have that the bulk of the catch is represented by age 0 individuals, while in ALK is age 1.

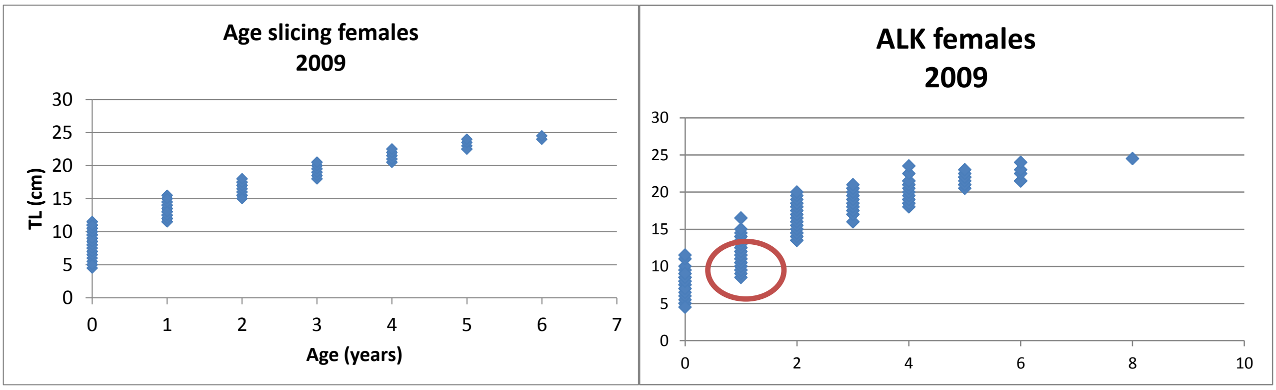
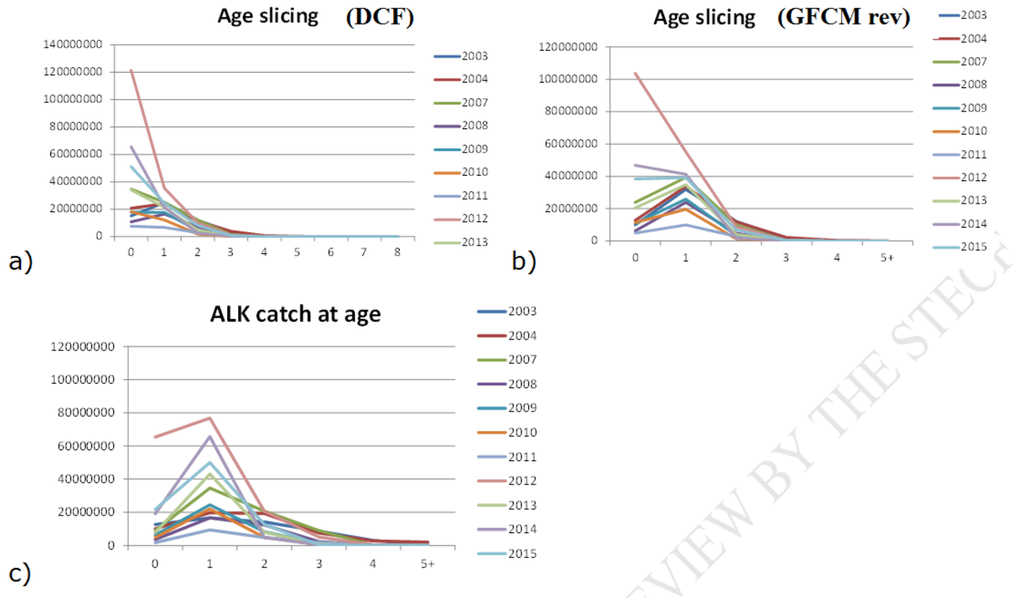


Figure 3.5.1.1 Example of assignment of the length class to the age class through deterministic age slicing and by Age-Length Key.



F

Figure 3.5.1.2 Catch at age matrices obtained according to a) deterministic age slicing with DCF von Bertalanffy parameters, b) deterministic age slicing with von Bertalanffy parameters revised during the GFCM WGSAD 2016 and c) proportions observed in Age-Length Key.

The results of the 3 runs carried out during the STECF EWG 17-02 are consistent with the ones of the official GFCM assessment by length.

The impact was evaluated in terms of:

- Recruitment;
- Selectivity;
- F;
- SSB;
- Population;
- Reference points.

The results of the different runs showed that age slicing (for both sets of von Bertalanffy parameters) returns a smaller recruitment variability and slightly smaller values. Indeed, the CV on recruitment of Age-Length Key was 59%, on age slicing with DCF parameters was 44% and on age slicing with revised parameters was 42% (Figure 3.4.3, panel a)). This results is in agreement with Mohn (1994), Restrepo (1995) and Ailloud et al. (2015).

The average SL50% in the age slicing is smaller than in ALK run, because of the catch age structure derived by the two methods (Figure 3.4.4 panel a)); as consequence, the F of the age slicing run is generally higher (Figure 3.4.3 panel b)). This was expected because when age slicing is applied, the fishery in then considered to exploit more the younger individuals. Consistently, the ALK run returns a higher SSB (Figure 3.5.1.3 panel c)). Overall the reconstructed population seems consistently stable for age 0, while but is more different for age 1, which contributes more to the catch and to the SSB (Figure 3.5.1.4 panel b)).

The $F_{0.1}$ estimated according to three methods is quite stable around 0.4 (Figure 3.5.1.3, panel b)).

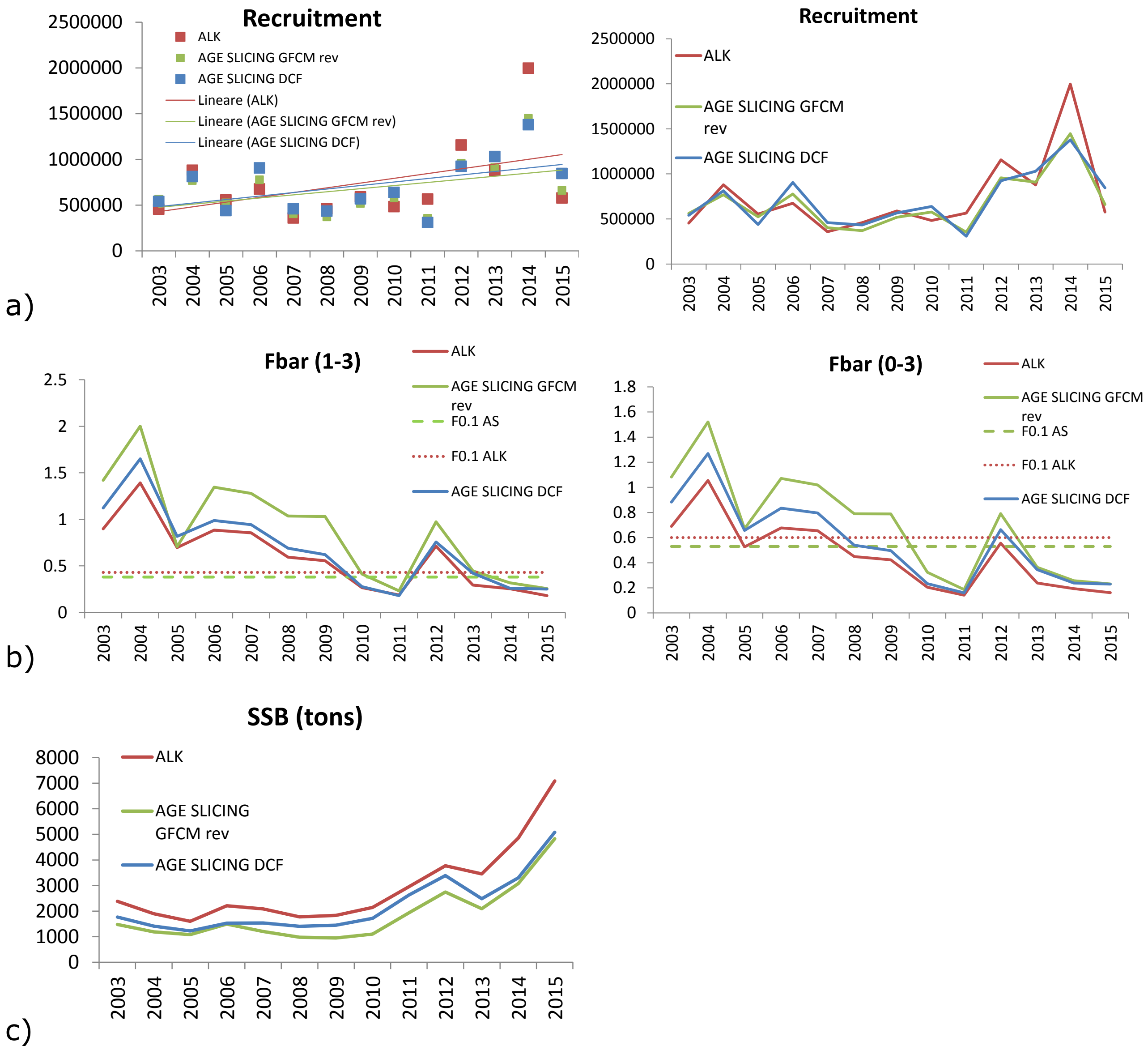


Figure 3.5.1.3 Impact of the different slicing methods on the stock assessment results: a) fishing mortality on ages 1-3 and on ages 0-3; b) recruitment trend and variability and recruitment times series; SSB.

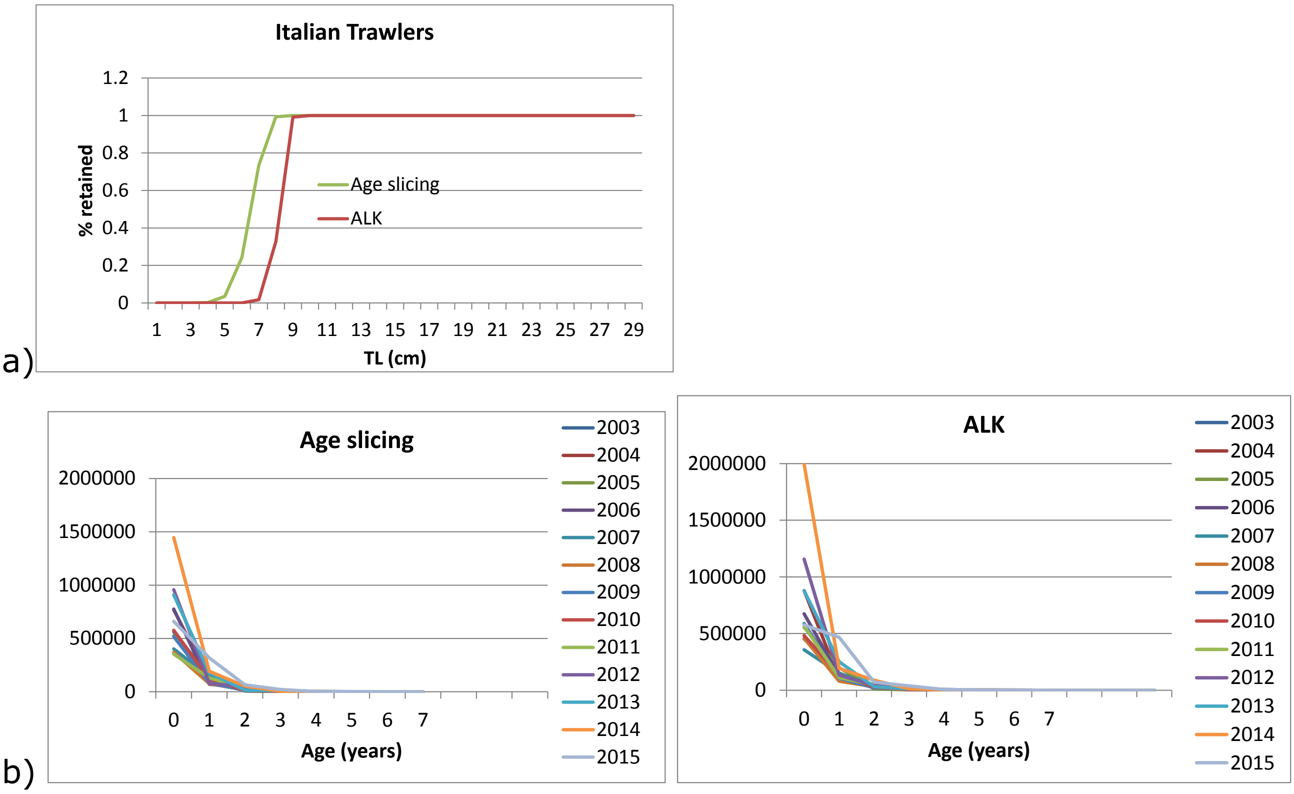


Figure 3.5.1.4 Impact of the different slicing methods on the stock assessment results: selectivity and population. The results between the two age slicing runs (with DCF parameters and GFCM revised ones) are very similar both in panel a) and in panel b); for this reason, only the results of the GFCM revised run have been reported.

3.5.2. Using the s6model size based method

A recent size-based assessment method (s6model) is tested that uses the size information from the catch directly instead of transforming length to age. The s6model is a single-species, size-based data-limited equilibrium assessment method. The method requires only weight distributions from the commercial catch and life history parameter information and gives the stock status quantified as the fishing mortality over F_{msy}. The method is based on the theoretical framework by Andersen and Beyer (2015) that describes demography and recruitment of an exploited population characterized by a set of life-history invariants (most importantly M/K) and the asymptotic weight (W_∞). The framework is formulated in two levels:

(i) **individual level**: available energy depends on body size and is allocated to activity, growth and after maturation to reproduction. The mortality is modelled as a size-dependent natural and fishing mortality resulting from asymptotic selectivity.

(ii) **population level**: Scaling up to the population level is achieved using the McKendrick–von Foerster conservation of mass equation.

In steady state, an analytical solution of the partial differential equation leads to the theoretical size-spectrum of the population. The model is parameterized using Beverton–Holt life-history invariants, reducing the number of model parameters and making the results insensitive to the input values for most of them; the results are mostly influenced by the value of physiological mortality, which corresponds to the M/k Beverton–Holt invariant. For more information on the theoretical framework see Andersen and Beyer (2015) and for a simulation analysis investigating the sensitivity of the method to parameter input see Kokkalis et al. (2015). The method was validated using data-rich stocks by comparing its outputs to the official age-based assessments (Kokkalis et al., 2017). The method is implemented as an R package available here: https://github.org/alko989/s6model.

Weight frequencies per year

Available length frequency distributions from the commercial catch for years 2003–2015 (data not available for 2006) are transformed to weight using the following weight-length relationship from Bitetto et al., (2016, in press)::

$$w = 0.006 * l^{3.085}$$

Two options were tested: (i) the size distribution of each year separately (Figure 3.5.2.1) and (ii) a 3-year aggregated moving window (Figure 3.5.2.2).

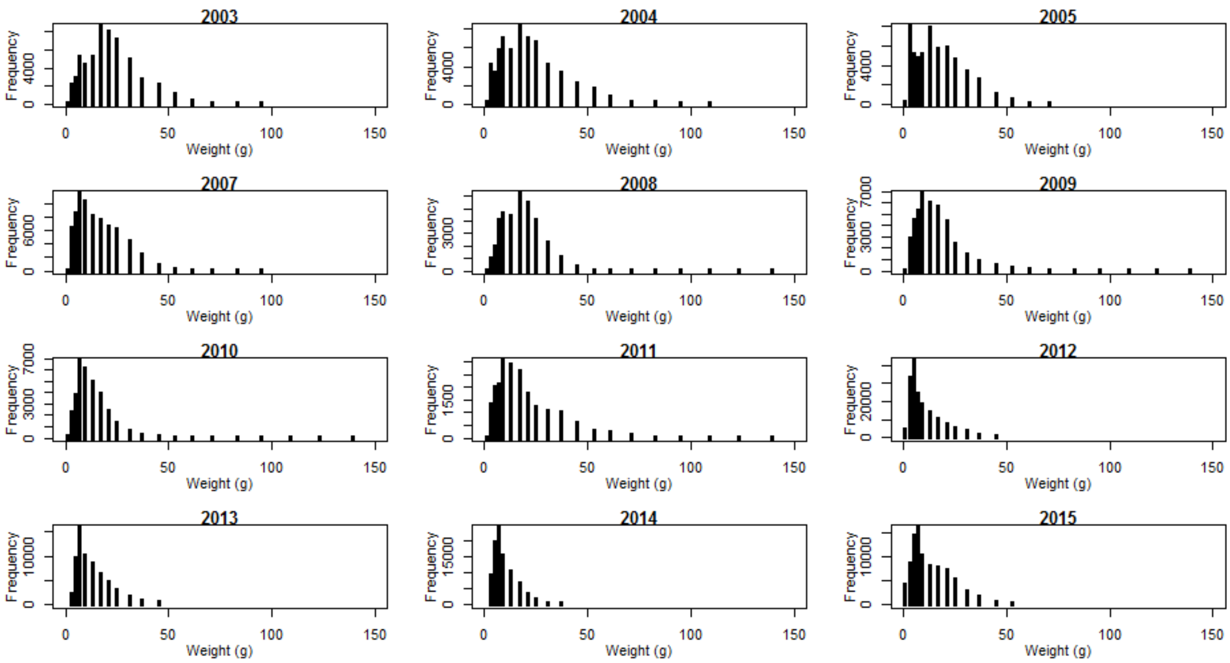


Figure 3.5.2.1 Weight frequency distributions of red mullet in GSA 18.

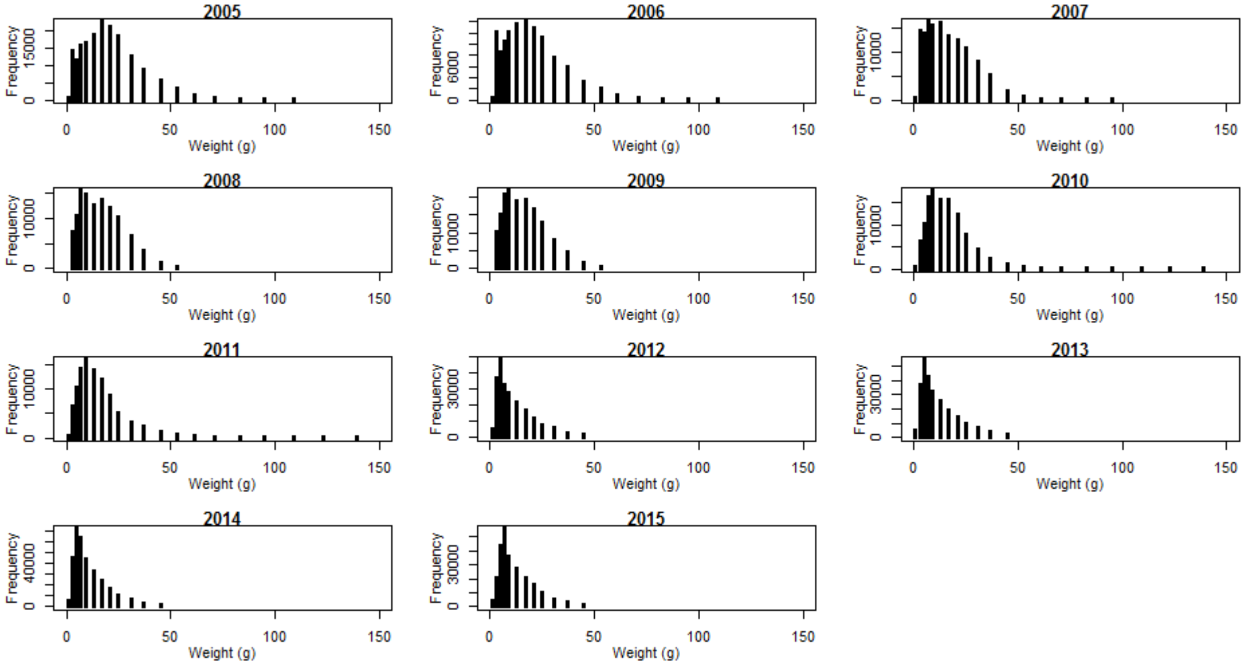


Figure 3.5.2.2 Aggregated three year moving window weight frequency distributions of red mullet in GSA 18.

Parametrisation

The method requires some input life history parameters; the values used for the assessment are summarized in Table 3.5.2.1.

Table 3.5.2.1. Parameter values used in the s6model assessment of red mullet in GSA 18.

Parameter	Value	Notes
Weight-length relationship, a	0.006	$W = aL^b$
Weight-length relationship, b	3.085	
M/K	2.41	
A	3.91	$A \propto KL_\infty$
Relative maturation size:	0.045	$(L_{mat}/L_\infty)^b$
Natural mortality	size dependent	Figure 3.5.2.3

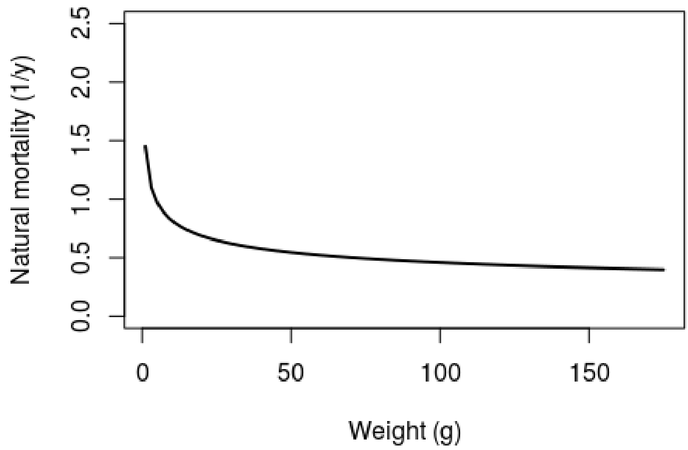


Figure 3.5.2.3 Natural mortality used in the s6model assessment of *M. barbatus* in GSA 18.

Results

The results are shown that the stock is overexploited for the whole period. The run with separate years is as expected more variable (Figure 3.5.2.4), whereas the aggregated data run is smoother (Figure 3.5.2.6). The fit of the model to the data is shown in Figure 3.5.2.5 and Figure 3.5.2.7 for the two runs. For some years the fit seems to be problematic and the results for these years should be treated carefully, e.g. the data for 2005 show two peaks, something that the model cannot accommodate (i.e. the stock does not seem in steady state).

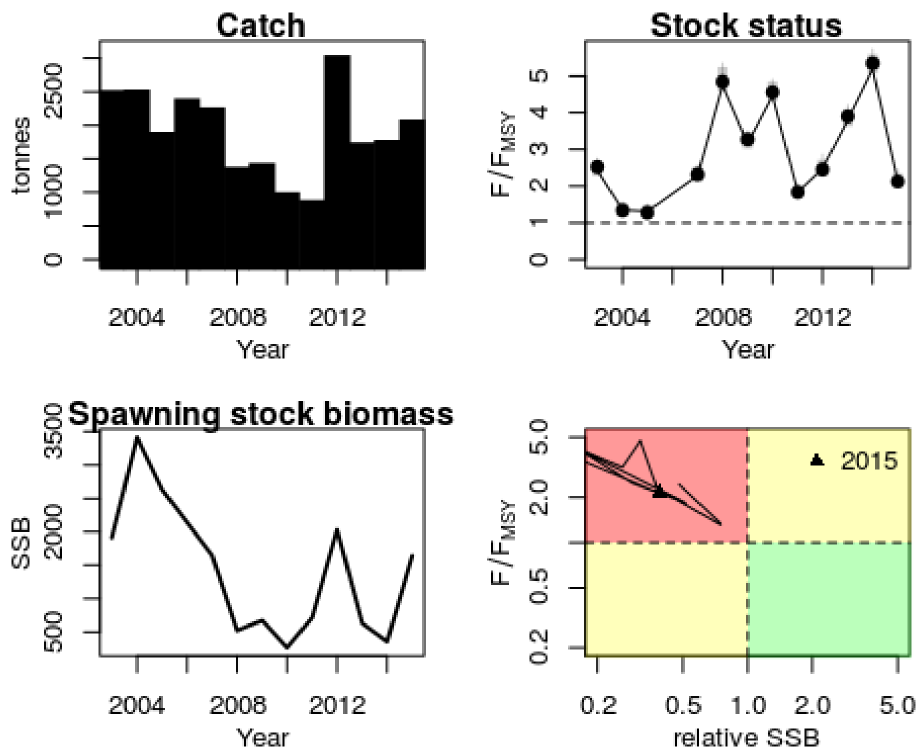


Figure 3.5.2.4 Main output of the red mullet assessment in GSA 18 using s6model with separate years.

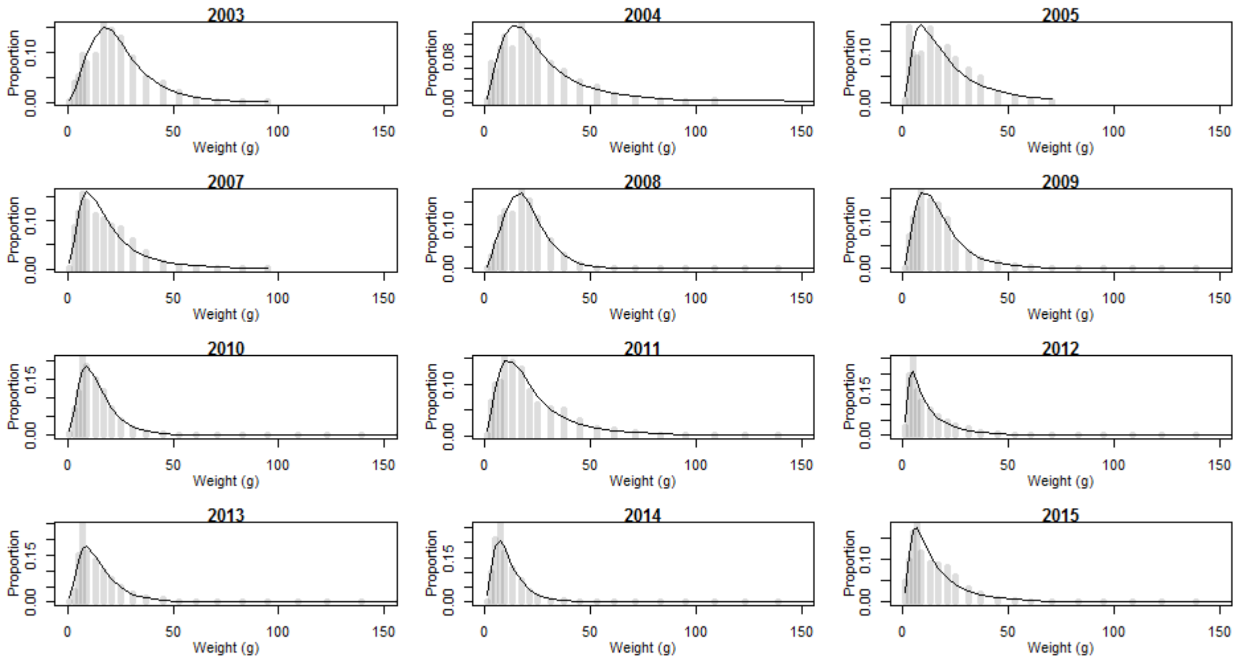


Figure 3.5.2.5 Weight frequency distributions (bars) and model fit (line) for the s6model assessment.

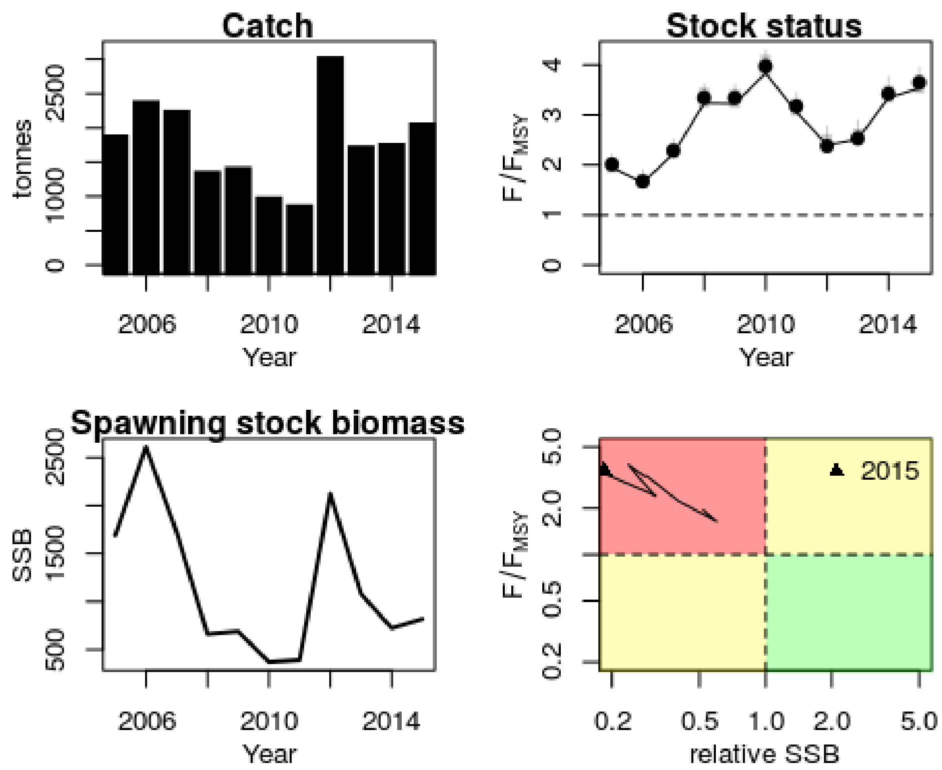


Figure 3.5.2.6 Main output of the red mullet assessment in GSA 18 using s6model with 3 year moving window aggregated data.

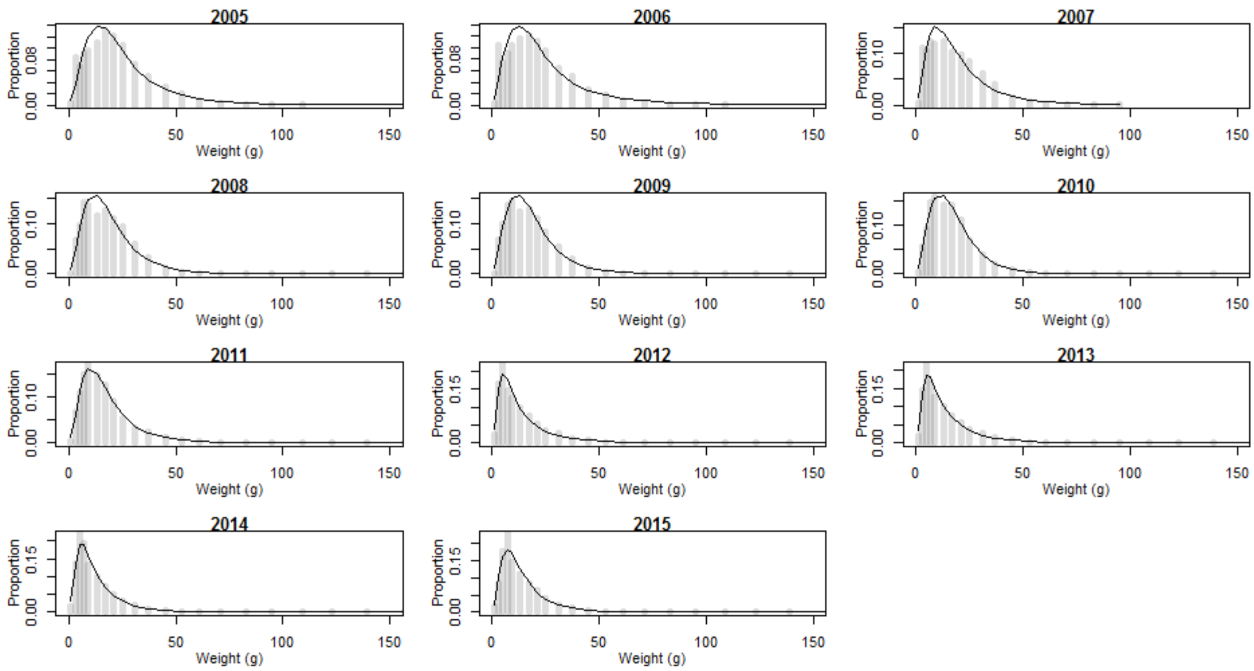


Figure 3.5.2.7 Weight frequency distributions (bars) and model fit (line) for the s6model assessment.

Comparison with SS3 runs

Comparing the results of the aggregated data s6model run with the official GFCM assessment and the three SS3 runs presented in this chapter shows different trends (Figure 3.5.2.8) especially for the fishing mortality. An interesting observation is that the pattern of the estimated fishing mortality is very similar to the nominal effort of trawlers in the area (Figure 3.5.2.9); it should be noted that the effort is not used by the model.

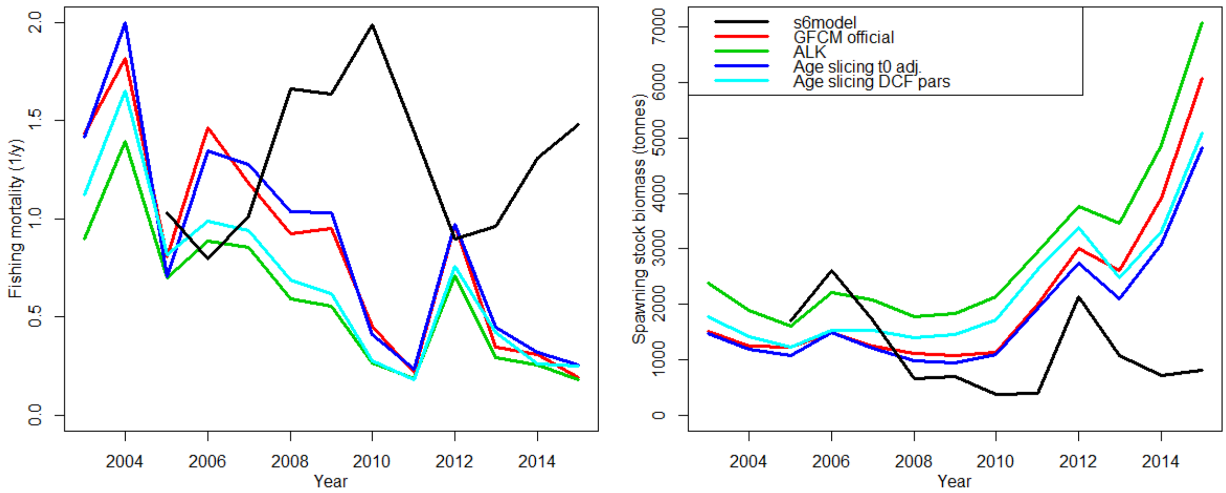


Figure 3.5.2.8 Comparison of fishing mortality estimates (left) and spawning stock biomass (right) for s6model (black line), the official assessment of GFCM (red line) and the three SS3 runs presented in this chapter.

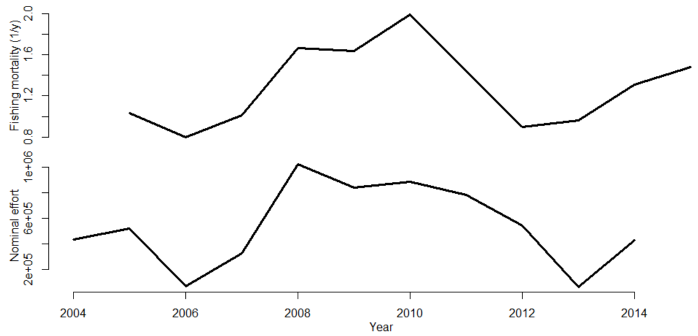


Figure 3.5.2.9 The fishing mortality estimates of red mullet in GSA 18 from s6model (top) and the nominal effort of trawlers from the same area (bottom).

3.5.3 Comparison between SS3 and XSA

XSA is the most common stock assessment method used during the recent Mediterranean Stock Assessment EWGs. EWG 17-02 tried to carried out an evaluation on the stock status of MUT in GSA18 using this method.

Input data were the same used for SS3.

Two different approaches were followed:

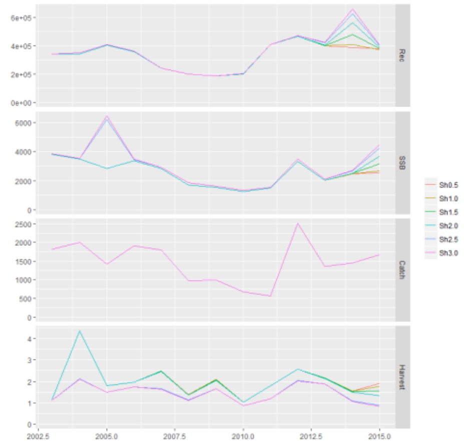
- Run the assessment used the same SS3 age structured (6 age classes and 5+ as plus group);
- Run the assessment aggregating age data in 4 age classes (with 3+ as plus group). This latter approach was the same used during the GFCM WGSAD (2015)

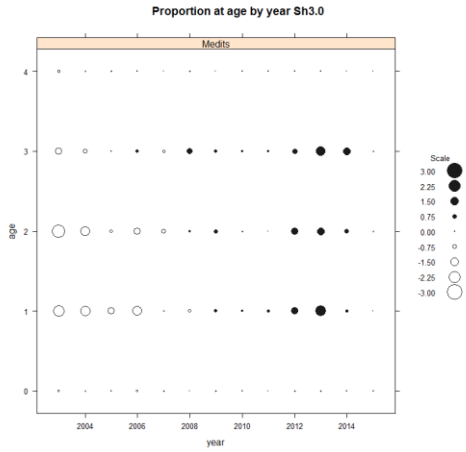
In Figure 3.5.3.1 and 3.5.3.2 shows the main outputs obtained in some of the best runs.

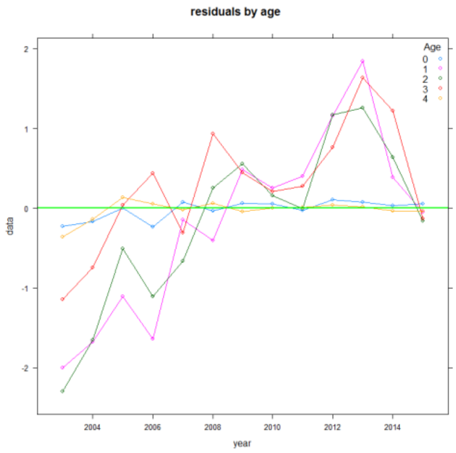
The maximum absolute values in the residuals were never larger than 2, although in all the runs a clear pattern in the residuals was detected (increasing value in time). This pattern was also observed in SS3 diagnostics. This was due to the fact that the surveys in the last three years were carried out later in the year than on previous occasions and so important recruitment signals were detected in the survey catches, but did not reflect real changes in recruitment. Moreover, retrospective analysis showed some inconsistency in the results when removing 2 or 3 years of data.

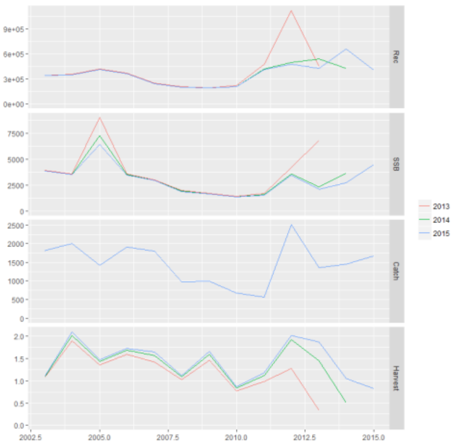
Stock status perception following the first approach was quite different compared to SS3 results (Figure 3.5.3.1). Fishing mortality was higher and never below the reference point, and SSB was comparable with SS3 estimation.

A completely different perception was instead obtained with the second approach. Fishing mortality levels in the earlier year were lower though in the last year comparable to those obtained with SS3 and SSB was estimated about 50% higher (Figure 3.5.3.2).


Rec
SSB
Catch
Harvest
Sh0.5
Sh1.0
Sh1.5
Sh2.0
Sh2.5
Sh3.0


Proportion at age by year Sh3.0
Medits
age
year
Scale


residuals by age
Age
data
year


Rec
SSB
Catch
Harvest
2013
2014
2015

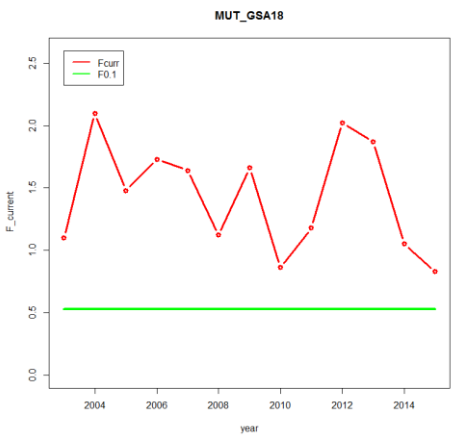

MUT_GSA18
Fcurr
F0.1
F_current
year

Figure 3.5.3.1 – XSA RUN1: fse=3.0, rage=0, qage=2.0, shk.yrs=2.0, shk.ages=2.0 – Fbar1-3 - Plus group5+

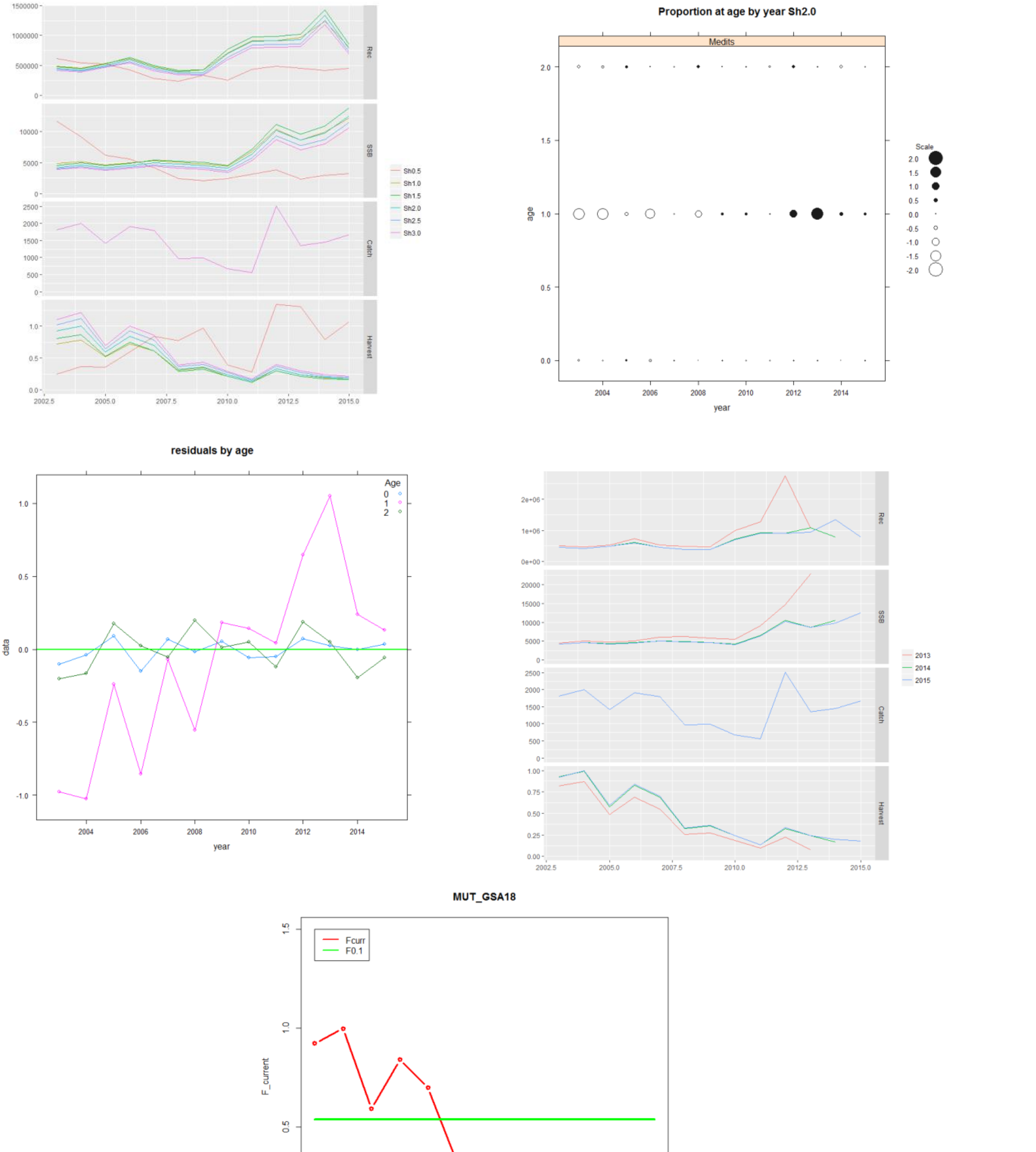


Figure 3.5.3.2 – XSA RUN2: fse=2.0, rage=0, qage=2.0, shk.yrs=2.0, shk.ages=2.0 – Fbar1-2 - Plus group3+

3.6 Comparison of age slicing and DCF age data

To address TOR1, the EWG had carried out some sensitivity tests of the effects of deterministic age slicing vs use of age length keys on the stock status estimation. The intention was to substitute the catch at age matrix from the currently performed STECF assessments, which is mostly from deterministic age slicing, with the catch at age matrix from the DCF catch table which should contain number of fish at age obtained from Age Length Keys (ALK) conversion. Here we provide and exploration of effective age sampling in numbers at age and in growth parameters from DCF data. The EWG explored the DCF catch matrix in relation to levels of age sampling and methods, but while the levels of age sampling are reported, the actual method for converting age to length is not reported, so numbers at age in the catch could derive from a number of different approaches and the attempt of rerunning the stock assessments was hence dropped. The lack of a methodology for length to age conversion is a likely driver of why EWG experts normally don't use the catch at age matrix bust start from the numbers at lengths from the Landings table.

The levels of age sampling were explored anyway both in the catch at age and in the biological parameters GP file where Von Bertalanffy growth parameters (VBP) are reported.

From the DCF catch table the records with positive numbers of age measurements in landings were filtered and summed by stock (species + GSA area). By retaining the sum of age measurements in landings, 80 stocks have age measurements, as reported in Table 3.6.1.

Table 3.6.1

	species	area	country	age_meas_lands	age_meas_catch
1	ANE	GSA 1	ESP	7043	7043

2	ANE	GSA 17	SVN	2968	-188
6	ANE	GSA 6	ESP	3077	3077
8	ANE	SA 10	ITA	3925	3531
12	ANE	SA 16	ITA	3280	-107
14	ANE	SA 17	ITA	5978	16059
15	ANE	SA 18	ITA	314	2387
16	ANE	SA 19	ITA	3681	3681
24	ANE	SA 7	FRA	7315	2080
25	ANE	SA 9	ITA	47156	-40
29	ANK	GSA 6	ESP	1557	1557
38	ANK	SA 19	ITA	555	848
87	BOG	SA 10	ITA	528	613
94	BOG	SA 18	ITA	351	644
97	BOG	SA 25	CYP	3353	2700
99	BOG	SA 9	ITA	1462	-57
238	DOL	SA 15	MLT	1102	1110
319	GFB	SA 9	ITA	201	-41
369	GUU	SA 9	ITA	712	-39
370	HKE	GSA 1	ESP	3281	3281
373	HKE	GSA 5	ESP	720	720
374	HKE	GSA 6	ESP	6281	5547
376	HKE	SA 10	ITA	11357	9199
383	HKE	SA 16	ITA	20580	-275
385	HKE	SA 17	ITA	376	4731
387	HKE	SA 18	ITA	11801	13048
389	HKE	SA 19	ITA	15908	8688
398	HKE	SA 9	ITA	6577	-47
411	HMM	SA 18	ITA	273	440
417	HMM	SA 9	ITA	1762	-57
418	HOM	GSA 1	ESP	3156	3156
426	HOM	SA 16	ITA	2305	-215
429	HOM	SA 18	ITA	213	550
434	HOM	SA 9	ITA	826	-55
500	MAZ	GSA 6	ESP	2263	2263
568	MUR	GSA 5	ESP	8967	8013
571	MUR	SA 10	ITA	635	635
576	MUR	SA 16	ITA	10645	-249
577	MUR	SA 17	ITA	220	260
578	MUR	SA 18	ITA	2814	2824
579	MUR	SA 19	ITA	3416	2468
585	MUR	SA 25	CYP	1291	667
587	MUR	SA 7	FRA	209	-23
588	MUR	SA 9	ITA	2041	-43
589	MUT	GSA 1	ESP	2855	2855
593	MUT	GSA 5	ESP	1017	1017
594	MUT	GSA 6	ESP	2017	2017
596	MUT	SA 10	ITA	8666	9347
602	MUT	SA 16	ITA	6132	-206
604	MUT	SA 17	ITA	654	4283

606	MUT	SA 18	ITA	7634	8492
607	MUT	SA 19	ITA	14347	7686
612	MUT	SA 25	CYP	2023	1075
615	MUT	SA 7	FRA	4721	4752
616	MUT	SA 9	ITA	6532	-47
638	OCC	GSA 5	ESP	930	-116
671	PAC	SA 10	ITA	826	1067
676	PAC	SA 16	ITA	5544	-266
683	PAC	SA 25	CYP	1898	1209
685	PAC	SA 9	ITA	1372	-46
686	PIL	GSA 1	ESP	9553	9553
687	PIL	GSA 17	SVN	3710	-244
690	PIL	GSA 6	ESP	8810	8806
692	PIL	SA 10	ITA	2020	2007
697	PIL	SA 16	ITA	2821	-118
699	PIL	SA 17	ITA	3818	10481
700	PIL	SA 18	ITA	186	1086
701	PIL	SA 19	ITA	2136	2180
707	PIL	SA 7	FRA	8824	5815
708	PIL	SA 9	ITA	15276	-37
724	POD	SA 9	ITA	543	-36
820	SBG	SA 7	FRA	532	440
859	SOL	SA 17	HRV	405	-6
868	SOL	SA 9	ITA	478	-45
879	SPC	SA 17	HRV	603	332
888	SPC	SA 25	CYP	2341	2077
890	SPC	SA 9	ITA	157	-24
1003	TUR	GSA 29	ROM	261	179
1015	WHB	GSA 6	ESP	3643	3643
1027	WHB	SA 9	ITA	459	-46

For the DCF VBG parameters are requested on a tri-annual basis, but can also be provided by year. Plot (Fig 3.6.1) shows the frequency of reporting of VBG parameters derived only from otolith/elicium reading. Some GSAs report one set of VBG parameters over the entire year range (like GSA9), while the majority report on a tri-annual basis (Fig 3.6.1), higher frequency depends on reporting by sex and length of years (Fig 1.1).

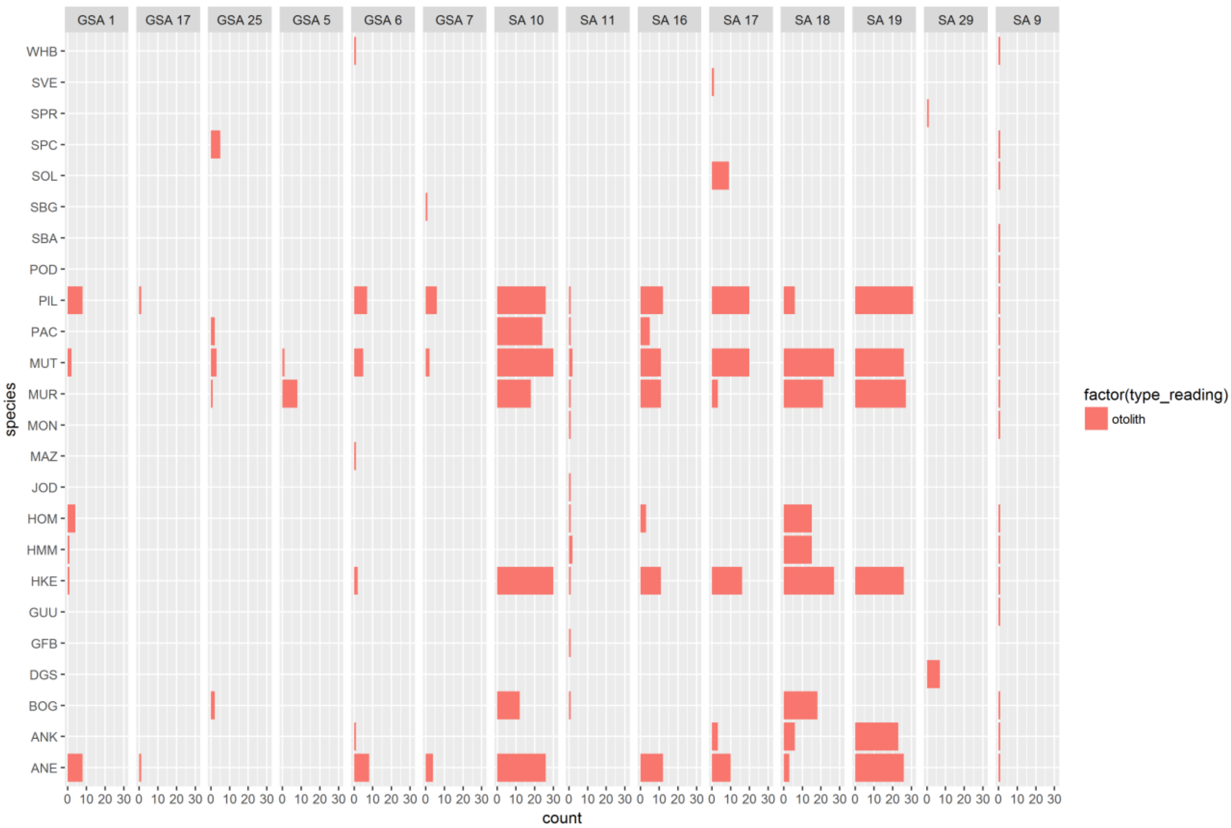


Figure 3.6.2 Frequency of reporting of VBG parameters from otolith readings by species and GSA.

The number of species for which age sampling is reported and the extent of age sampling can be compared by species and between GSAs. For example areas like GSA 9 perform age sampling on more species than other areas, and areas like GSA 10, 18 and 19 carry out more extensive age samplings of hard structures than other areas, covering a reasonable number of species.

The levels of age sampling underlying the age to length conversion (based on otolith or ilicium reading) is summarized by species and area based on the DCF Growth Parameter table and Catch data table (Fig 3.6.2 and 3.6.3).

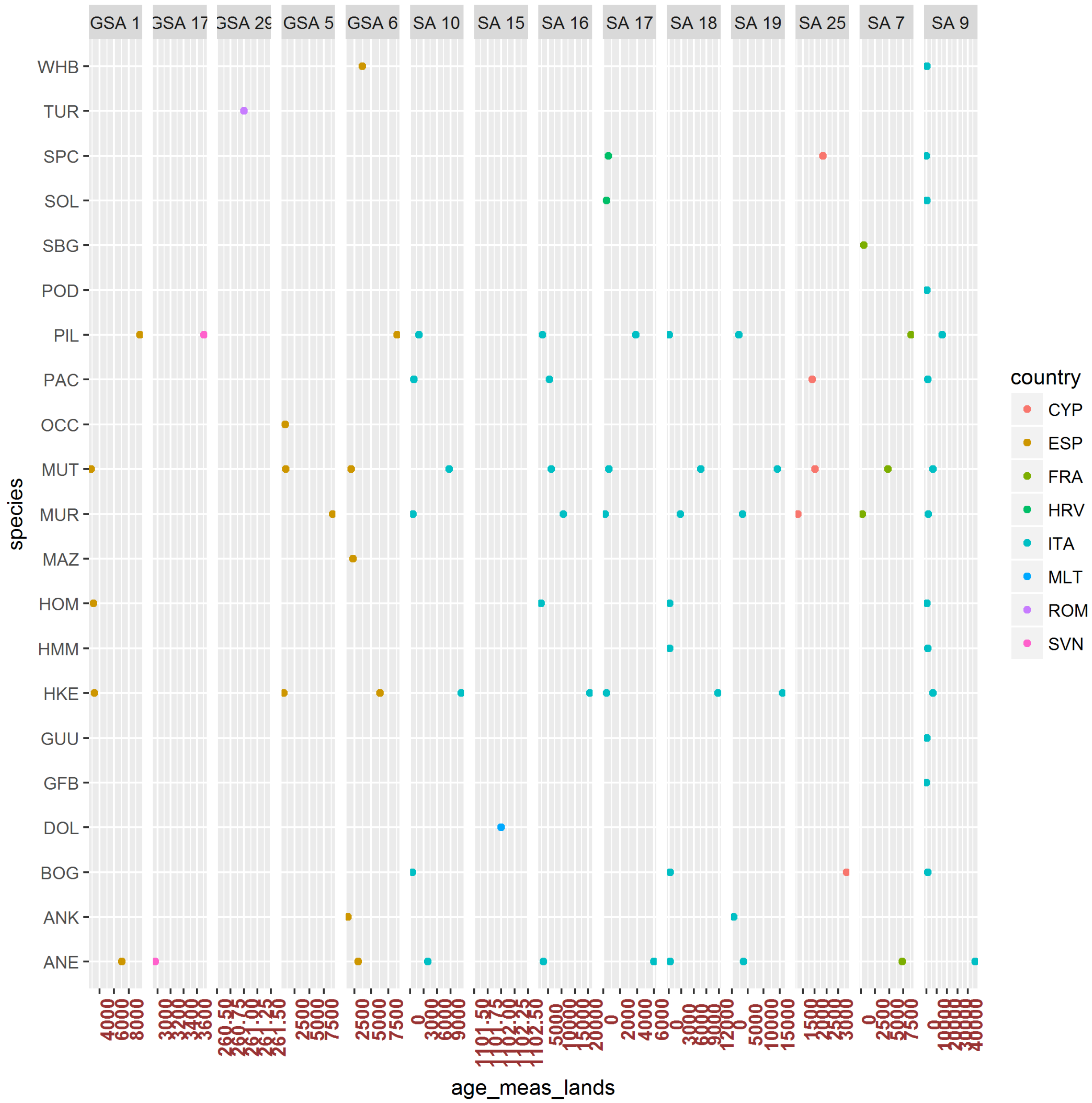


Figure 3.6.3 Cumulative number of age measurements by species in the DCF Catch table, pooled over years and sexes.

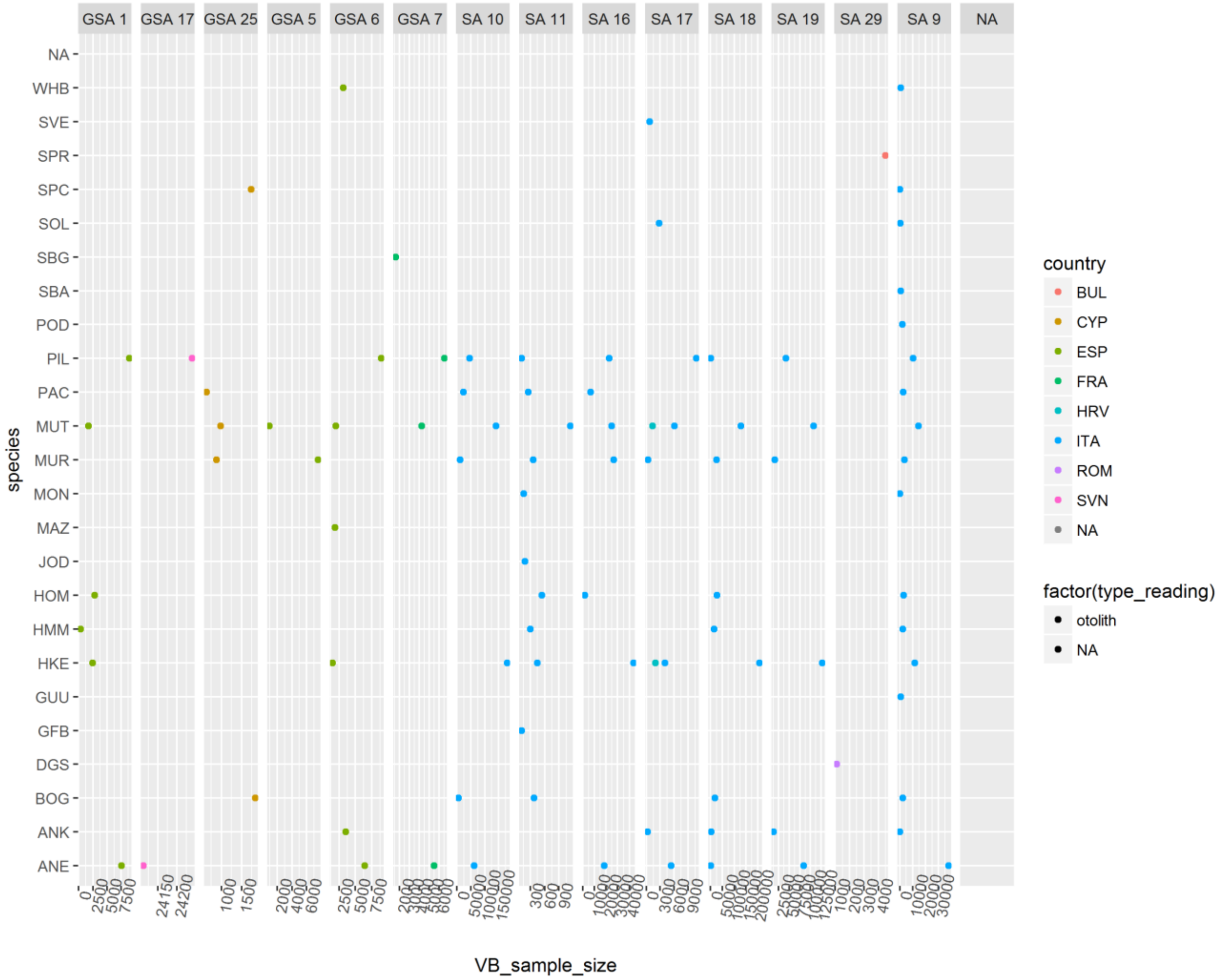


Figure 3.6.4 Cumulative number of age measurements by species in the DCF growth parameter (GP) table, pooled over years and sexes.

Age samples reported for VBG parameters show disparity between number of species sampled by GSA, which might be in line with National DCF Sampling plans.

Number of age samples underlying VBG parameter estimation have a wide range with some GSA with low age sampling numbers (as an example in GSA 11).

CONCLUSIONS

- In the DCF Catch table it is not possible to uniquely identify the method used for length to age conversion. Likely what is reported in estimation of VGB in GP table is a strong indication, but the two tables might not be aligned.
- The majority of STECF stock assessments are based on catch@age matrices constructed during the EWG starting from numbers@lenght deterministically age sliced using VGB parameters either from the DCF GP

or from the literature. Very rarely the catch@age matrix is used. There are a number of reasons for this:

- The basis of the age determiniation is not clear
- L to a conversion is performed on sex combined while often assessors considers more apporpriate sex separated.

The EWG suggests amending the DCF Catch Table to include a field documenting/defining the method used for the length to age determination and the range of year used for the VBP estimation in case of use of a deterministic slicing.

4 DATA POOR METHODS

TOR:

i) To apply and compare potential data poor methods to provide MSY advice by taking into account timespan and types of data series available under the DCF. The following stocks are, inter alia, to be considered: blue whiting in GSAs 6 and 9 (STECF 14-17) and hake in GSAs 6, 7 and 9,

ii) for the same stocks, to compare the data poor methods to the existing analytical assessments in order to indicate differences in the quality of the results obtained by the different approaches;

iii) to apply the best available data poor method that resulted from point 2i and 2ii above to the following data poor stocks: blue whiting in GSAs 17, striped red mullet in GSA 11 (tbc).

4.1 Introduction / approach

The development of MAPs for the Mediterranean areas may require analyses with limited data. In many cases due to short time series or missing information the use of analytical assessments is precluded and the utilization of alternative methods is required. While a range of data limited approaches have been reviewed previously, those reviews have been done in a general context, and without reference to specific data availability, specific local exploitation patterns. There is a need to focus more directly on the specific data availability and use the experience of applying methods (such as length based indicators) especially where both analytical assessments and data limited approaches have been tried, to obtain a better idea of the utility of the available methods.

Here the EWG considered specifically three main methods for applying non-analytical assessments of stock status and stock advice. The WG reviewed the ICES approach to survey index based methods where such indices can be obtained. In addition where commercial catch data only is available three methods: MSY length indicator, LB-SPR and VIT assessment analysis were examined for utility in estimating exploitation status for stocks. This was done through comparison of the indicators and assessed values derived from more formal approaches for a number of stocks.

4.2 ICES survey based index methods

ICES has developed a framework for advice which includes consideration of stocks without analytical assessments and with only abundance indices available. The approach increases or decreases advised catch in line with the available abundance index. This changes are limited to ±20%. This approach has been extensively simulation tested at workshops WKLife III and IV, and found to be precautionary.

The following description of the basis of ICES advice is taken from the *ICES Advice 2016, Book 1.*

"A substantial part of the stocks for which ICES provides advice do not have population estimates from which catch options can be derived using the MSY framework. ICES has therefore developed a precautionary framework for quantitative advice regarding such stocks. "

"The overall aim of the approach for these stocks is to ensure that the advised catch is sustainable. The underlying principles of the approach are that (a) the available information should be used, (b) the advice should, where possible, be based on the same principles as applied for stocks with analytical assessments and catch forecasts, and (c) a precautionary approach should be followed. The latter implies that as information becomes increasingly limited, more conservative reference points should be used and a further margin of precaution should be adopted when there is limited knowledge of the stock status. The margin of risk tolerance is a management prerogative, but in the absence of any proposal by managers ICES applies the values given below. "

"In order to apply a precautionary approach for categories 3–6 the framework for these stocks includes the following considerations regarding uncertainty and precaution which have been applied in sequence:

- As the methodologies used to estimate stock status, trends, and forecasts, due to the limited data or knowledge about their biology, are expected to be more susceptible to noise than methods used to produce forecasts for data-rich stocks, a change limit of ±20% (uncertainty cap) has been applied in the advice. This change limit is relative to the reference on which it is based and may be, e.g. recent average catches or a projection of a trend.

• A principle of an increasing precautionary margin with decreasing knowledge about the stock status has been applied:

- The reference points for exploitation used have, when proxies could be identified, been selected on the lower margins of F_{MSY} – either at the lower range of an interval, as $F_{0.1}$, or similar.

- A precautionary margin of −20% (precautionary buffer) has been applied for those cases when it is likely that $F>F_{MSY}$ or when the stock status relative to candidate reference points for stock size or exploitation is unknown. Exceptions to this latter rule have been made in cases where expert judgement determines that the stock is not reproductively impaired, and where there is evidence that the stock size is increasing significantly or exploitation has reduced – for instance, based on survey indices or a reduction in fishing effort in the main fishery if the stock is taken as a bycatch species."

"The advice is applicable to a time-frame which is compatible with a measurable response in the metrics used as the basis for the advice. Where the least amount of information is available, including cases where the 20% precautionary margin has been applied, ICES therefore considers that the advice is not expected to be changed for a fixed and determined period such as, for example, three years, unless important new knowledge emerges regarding a stock which may justify a revision of the advice. "

"The advice rule used to provide quantitative advice on fishing possibilities depends on the available information, and ICES has developed separate advice rules for each of the stock categories listed in Section 1.2.5.1. "

"Category 3. Stocks for which survey-based assessments indicate trends. The advice is based on the recent advice; catch or landings data are adjusted to change in the abundance index for the two most recent values relative to the three preceding values. Other reference years may be used, based on the knowledge of the biology of the stock (e.g. species with a relatively large longevity) or the quality of the data."

ICES experience with this approach to provision of advice is illustrated by the number of stocks for which this advice basis (Cat 3) has been used over the recent years. ICES provides advice on about 100 stocks annually, and 36 of these currently use the abundance index method, this has increased from 27 in 2014. Some of the stocks in earlier years have moved to cat 1 or 2 analytical assessments, and a number of new previously catch based stocks in 2014 have moved to the survey based method in 2017. Experience with this approach has been generally good and results relatively consistent. Nevertheless, it has been noted that where stocks might already be over exploited it is unclear if the method which includes a 20% additional reduction (a precautionary buffer) will ensure recovery in all cases. ICES is currently bringing in stock status proxies to further enhance the approach. It is accepted that this will be an improvement once the methodology is mature.

An example of the ICES approach can be found for dab in the Baltic Sea. The example is repeated here to show the method used. The stock size indicator from surveys has increased by a factor of three since the early 2000s and has been stable since 2010.

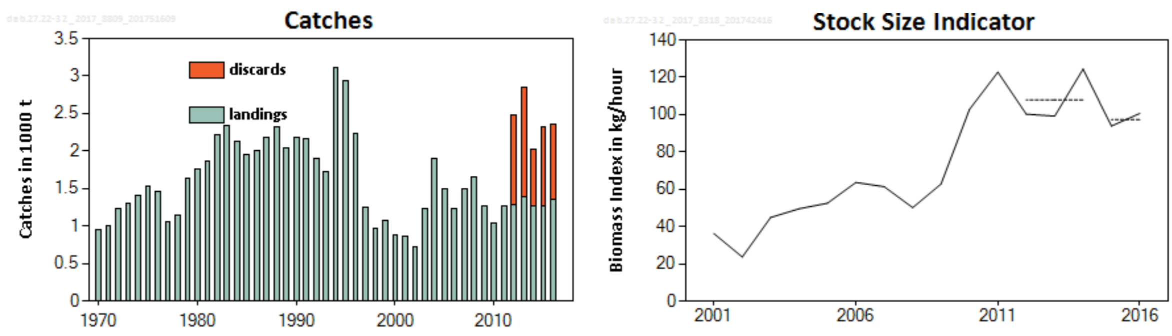


Figure 4.2.1 - Dab in subdivisions 22–32. Left: ICES landings and ICES estimates of discards (in thousand tonnes). Discard data have only been included since 2012. Right: Combined biomass index (kg h−1) of dab larger than 15 cm, from the Baltic International Trawl Survey (BITS – Q1 and Q4) in subdivisions 22, 23, and 24. Dashed lines indicate the average biomass index of the respective year range.

The ICES framework for category 3 stocks was applied (ICES, 2012). The geometric mean of the biomass per hour of dab larger than or equal to 15 cm from the Baltic International Trawl Survey in quarters 1 and 4 (BITS–Q1 and Q4) was used as the index of stock development. The advice is based on a comparison of the two latest index values (index A) with the three preceding values (index B), multiplied by the recent advised catch.

The index is estimated to have decreased by less than 20% and thus the uncertainty cap was not applied in estimating the catch advice. Fishing mortality is considered to be below proxies of the MSY reference points (as indicated by a length-based analysis). The stock size relative to reference points is unknown. The stock size indicator has been stable since 2010 after a threefold increase since the early 2000s. Therefore, no additional precautionary buffer was applied. Discarding is known to take place; the discard ratio is variable and has been estimated based on a three-year average.

Table 4.2.1. - Example of the ICES advice:- Dab in subdivisions 22–32. The basis for the catch option.

Index A (2015, 2016)	97 kg/hour
Index B (2012, 2013, 2014)	108 kg/hour
Index ratio (A/B)	0.90
Uncertainty cap	Not applied
Advised catch for 2017	3069 tonnes
Discard rate (2014, 2015, 2016)	0.42
Precautionary buffer	Not applied
Catch advice for 2018 (and 2019)	2762 tonnes
Landings corresponding to the catch***	1607 tonnes

(Catch= A/B [limited by uncertainty cap] *previous advised catch)*Precautionary buffer.

Conclusion to ICES survey index method

The EWG considers that where survey data indices are available, simulations of management using the ICES rule Cat 3 indicate that these can provide guidance for management provided overall stock status (not over exploited) an be inferred. It is proposed that, if no assessment is available and survey is considered to be adequate, the STECF EWG will to continue to use this method to give advice. In addition the EWG should continue the development of stock status proxies for such situations in order ensure the advice is consistent with the precautionary approach.

4.3 Length based methods compared to assessment

The EWG explored the use of the length based indicator L_{mean} relative to L_{FeM} (L_{mean} / L_{FeM}) to assess stock status (see Annex I). The indicator was proposed by ICES (2015, see also ANNEX II). L_{mean} / L_{FeM} can be used as an indicator of F_{MSY} and is recommended to be >= 1, i.e. a value < 1 suggests overfishing. Lc is the length at first catch, L_{mean} is the mean length of individuals larger than Lc and L_{FeM} is calculated as 0.75 L_c + 0.25 L_{inf}. The indicator is very dependent on the value of L_c. The original calculation of L_c used by ICES was based on the lowest mode of the catch distribution. This was found to be extremely sensitive to the detail of the length distribution, leading to unstable results (STECF 2016a), visual examination of the method indicated that the instability was being driven by very minor aspects of the estimated length distribution, and did not reflect real changes in L_c. An alternative approach was used in the previous expert working group (STECF 2016b) where the 0.25 quantile of the catch distribution was used as the estimate of L_c. A normal cumulative probability distribution was fitted to the catch-at-length distribution of each year. The estimated mean and standard deviation of the distribution was then used to calculate L_c as the 0.25 quantile of the estimated distribution. It was found that this gave a more stable value for L_c than the original method that used the first mode in the data, giving greater confidence in the calculated value of the length indicator. Here L_c is calculated using this method. In this annex, the indicator L_{mean} / L_{FeM} is calculated for the stocks from STECF-16-22 and STECF-17-06 that have accepted analytical assessments. The estimated F_{bar} is compared to L_{mean} / L_{FeM} across all of the stocks and for individual stocks using a linear mixed effects model.

When all the stocks were analysed together there is a general inverse relationship between the estimated exploitation and the indicator. However, only 66% of points were correctly categorized as being either under or over exploited. More worryingly, 25% of points were incorrectly identified as being under exploited when the assessment suggested that they were over exploited. So the length indicator appears as a noisy but unbiased estimator of stock status.

Considering the stocks on an individual basis, a linear mixed effect model with stock as a random effect found that only half of the stocks had the desired inverse relationship between estimated exploitation and the indicator. Thus for an individual stock when considering the utility of the length indicator as a tool for managing a stock it is found that the length based indicator is not an effective guide to the Fbar, and may not change in the way needed as F changes annually. This is expected as length indicators can generally be expected to take some years to settle following changes. This reduces confidence in the use of the indicator on its own for managing stocks, agreeing with simulation studies (Jardim et al. 2015).

It should be noted that the results are conditional on the 12 selected stocks which are considered here, and the uncertainty in F is not dealt with independently of the uncertainty in L_{mean} / L_{FeM}. These stocks are not necessarily a good representation across 'stock space'. For example, only 5 species are included and only a limited range of GSAs are explored. However, the current results are not encouraging. A more thorough study with a greater number of species and GSAs will present an opportunity for more insight, for example by including species and GSA as random effects.

4.4 Use of length based assessment of spawning potential ratio

4.4.1 European Hake in GSA6

4.4.1.1 Introduction

Tests were carried out using the Length Based Spawning Potential Ratio R Package (http://adrianhordyk.com/LBSPR/) this was tested as a possible method to provide information of the population status of data-poor stocks in the

Mediterranean Sea. This method has been recently proposed by Hordyk *et al.* (2015) to obtain information on biomass depletion. For this purpose, *LB-SPR* takes advantage the fact that the distribution of length frequency of a population and the spawning potential ratio are strongly related to *F/M*, *M/k* and the ratio between length at maturity and asymptotic length (*Lm/L∞*) (Prince *et al.* 2015). From these life history parameters, the *LB-SPR* method estimates the selectivity-at-length parameters *SL50* and *SL95* and the rate *F/M*, which are finally used to estimate the spawning potential ratio.

The estimation of the spawning potential ratio from the life-history parameters and length frequencies from the observed population (mainly from catches) relies in several strong assumptions. First, asymptotic gear selectivity, meaning that if length data proceeds from a fishery characterized by a dome-shaped selectivity the *SPR* will be underestimated. In data-poor stocks the *SPR* underestimation could not totally be problematic since the outputted *SPR* will be considered as a precautionary estimation. Second, a single curve describes growth of both sexes. If this is not the case for the assessed stock, the underlying assumption will imply that only life-history parameters and length data from females can be used. Third, length-at-age frequencies are normally distributed. Fourth, it is assumed that rates of natural mortality do not change across adult age classes. Fifth, the cohort of a stock exhibits constant growth rates (Hordyk *et al.* 2015a).

In order to test the methods performance on the Mediterranean Sea context, the *LB-SPR* was applied to a species for which available information allowed in the past an analytical assessment, the European hake in the GSA6. Once the *LB-SPR* was tested, results of the two assessments were compared. Successively it was applied to the data-limited stock blue whiting GSA17.

4.4.1.2 Method

The status of hake GSA6 has been evaluated with XSA. This approach produces as main output the F current and F_{MSY} or a proxy as $F_{0.1}$ is used as a referent point. An explicit state of *SSB* related to its pristine level is not delivered. Conversely, the *LB-SPR* main output is an estimation of the spawning potential ratio that is compared with SPR40% as conservative proxy for MSY (Myers *et al.* 1994) and SPR20% as the level that produces an impaired recruitment (Rosenberg 1993).

The performance of this data-poor method was not possible to test through a direct comparison of the results of both approaches. In order to overcome such issue, with the same data used for running XSA, the VIT (Lleonart and Salat 1997; Rätz *et al.* 2010) method was run, as one of the VIT outputs ($SSB/SSB_{0.1}$) provides a SPR survival level necessary for being compared with that derived from the *LB-SPR* method. XSA and VIT stock assessments that resulted were consistent. Secondly, the estimation of the *F-at-age* (for the most fished ages, 0-2) by XSA was used for comparing the *LB-SPR* outputs *SL50* and *SL95* as well as F/M.

The hake in GSA6 has been assessed using a single growth curve (STECF 2015), although each sex exhibits a different growth curve (Mellon *et al.* 2010). In order to keep as much as possible the same model parameterization, *LB-SPR* considered the same input data that the XSA and VIT used. However, such length-based method precludes the use an *M-at-age vector* as in VPA. Therefore, from the *M at age* used in XSA for ages from 0 to 5 was derived an average single *M* value for being introduced in the *LB-SPR* assessment. Finally, sensitivity analysis for parameter values of *L∞* and *M/k* were performed.

4.4.1.3 Input data

The *LB-SPR* method was performed using the catch length-frequency data from 2002 to 2015 (Table 4.4.1.3.1) and the life-history parameters used in the stock assessment (Table 4.4.1.3.2). The stock assessment performed with VIT used the same landing data of the official stock assessment (STECF 2015). For comparison purposes, the VIT was only performed from 2010 to 2014.

Table 4.4.1.3.1. Length frequency data (catches + discards) of hake landings in GSA6

Length	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
5	25.725	41.379	19.312	0	0	0	0	0	0	0	0	4.253	0	0
6	338.556	898.734	289.634	0	154.117	7.221	136.8	0	3.77	0	0	0	0	0
7	1350.596	3420.817	1203.866	76.415	477.919	94.145	217.996	0	45.276	0	3.443	0	5.706	0
8	4470.043	9615.367	2959.866	421.298	1329.885	318.458	1033.024	512.884	122.404	0	14.497	0	27.102	0
9	7489.326	11992.535	4694.922	830.075	3051.619	803.917	2395.452	1839.607	310.524	1.43	44.074	0.541	30.196	3.791
10	8537.563	15052.084	5103.237	1455.937	3613.789	1861.865	4733.873	2288.442	1566.493	5.626	143.066	18.133	26.093	124.921
11	7941.362	24398.32	5817.634	2965.584	4050.913	3587.012	6987.823	2992.686	1467.119	166.548	365.014	54.534	263.007	266.678
12	6147.855	26255.085	7023.241	4960.033	6950.273	4781.854	5948.756	5605.374	938.044	280.541	455.46	176.141	677.254	319.74
13	5035.854	24713.112	7072.36	5021.807	7532.616	5050.472	7042.434	6908.457	1351.5	707.235	563.65	423.383	1096.919	445.996
14	4076.603	20321.623	7179.71	4826.61	7513.374	5561.92	6034.866	11105.64	1322.367	968.853	788.472	572.461	943.477	598.099
15	3373.51	20418.09	7038.101	3665.205	6972.849	5256.322	5919.052	10671.147	1205.375	1215.099	1378.568	833.668	1003.723	509.625
16	1944.121	15430.922	8369.596	3715.746	5816.147	4472.684	5107.789	10534.711	1034.786	1052.423	1290.843	967.154	886.683	571.149
17	901.199	11698.466	7070.686	2974.052	4467.723	2997.475	4109.304	7088.584	933.322	1184.435	1049.383	1153.48	612.562	665.852
18	548.207	8876.776	4671.048	2918.179	3073.747	2202.789	3292.764	6889.763	1128.48	1202.302	1736.97	1425.433	545.395	638.631
19	418.896	9095.036	1998.231	1859.644	2426.275	1235.332	2553.612	4675.56	1305.154	1514.394	2275.056	1522.434	624.731	616.476
20	241.46	9172.41	1569.09	1695.761	2130.551	1010.98	2075.859	2378.74	1275.591	1639.322	2383.464	1381.137	789.411	793.383
21	285.22	11482.972	1611.137	1459.106	1745.765	906.043	1526.95	1858.336	1803.183	1928.668	2219.887	1907.382	927.114	822.605
22	316.372	10730.617	1501.969	1140.523	1461.419	702.224	1411.928	1430.927	1551.382	1989.325	1605.337	1457.722	816.07	713.927
23	238.048	7914.976	1318.029	1086.294	1231.495	625.498	1053.735	1397.33	1355.245	1947.068	1317.581	1548.251	812.402	747.847
24	220.674	6642.791	1111.451	968.886	1094.43	569.267	1055.83	1102.307	1231.55	1530.958	1321.697	1658.301	804.026	776.464
25	232.857	5109.065	996.204	787.546	888.646	552.897	797.485	731.781	1216.877	1273.019	993.688	1124.201	806.306	633.859
26	180.559	4457.162	764.666	795.985	888.355	452.614	673.03	671.98	908.619	991.732	780.427	1512.991	819.406	494.213
27	206.687	3394.098	711.587	641.706	822.875	303.089	554.944	605.997	785.303	962.362	632.878	1130.496	776.795	523.939
28	140.173	2448.52	691.859	782.959	758.991	344.951	558.507	652.016	621.296	611.541	511.338	866.298	595.641	412.915
29	151.101	1922.498	673.608	647.418	682.423	357.595	540.267	453.496	665.251	522.303	420.033	562.063	607.485	320.839
30	134.54	1861.387	626.768	575.197	485.529	293.534	442.574	375.279	581.903	415.187	344.84	397.549	457.885	314.863
31	127.945	1194.235	586.025	349.953	500.83	250.353	345.35	262.923	517.138	527.791	355.642	401.669	430.401	300.482
32	119.469	1241.417	433.355	336.886	356.507	292.222	378.517	229.696	419.301	396.951	271.619	359.207	360.803	252.07
33	76.967	544.319	339.094	367.42	406.378	279.462	298.469	173.516	347.722	465.81	301.241	257.778	310.524	243.607
34	72.248	1002.875	261.301	404.993	342.143	230.253	235.719	179.903	382.725	402.443	228.268	350.243	315.616	196.15
35	66.66	688.897	182.594	265.572	293.322	210.504	190.973	148.951	300.657	406.793	255.865	267.746	303.821	179.384
36	58.027	747.831	170.072	184.81	265.463	200.027	144.61	130.617	353.3	312.155	192.582	218.236	277.772	169.826
37	49.29	292.895	105.902	158.986	214.991	210.976	138.07	194.072	328.597	236.71	180.791	159.01	231.317	128.126
38	55.161	408.475	90.435	135.559	187.315	181.828	127.699	110.849	222.495	234.845	154.987	179.549	225.552	119.196
39	46.371	342.814	75.89	76.816	135.146	143.376	49.962	323.382	234.695	210.511	96.714	149.051	171.799	98.317
40	43.951	265.055	61.331	99.138	105.663	96.132	44.917	50.369	177.394	147.796	114.383	100.002	155.856	83.155
41	50.424	390.501	60.781	46.955	76.244	112.328	35.788	247.918	168.904	136.321	100.711	98.375	119.202	60.842
42	36.785	114.298	49.211	90.821	110.121	78.129	54.301	171.617	88.862	148.981	80.007	50.904	87.917	53.477
43	27.468	282.071	51.928	43.794	79.095	83.628	40.033	147.297	108.858	87.582	64.635	51.411	81.131	50.437
44	43.522	158.499	48.659	49.154	69.781	42.489	29.852	64.255	69.23	98.541	44.039	46.483	60.086	50.312
45	11.724	144.679	33.515	48.749	58.905	46.52	17.914	13.672	104.329	65.912	53.861	51.287	46.994	28.926
46	5.038	42.696	34.332	41.986	47.88	32.24	16.143	71.392	64.07	58.035	32.964	40.282	43.375	25.56
47	14.674	31.221	27.77	49.492	47.738	36.035	19.281	19.445	40.591	42.816	30.091	24.078	30.978	20.394
48	9.451	96.277	24.689	53.152	42.188	40.024	11.803	71.07	29.341	44.137	34.113	46.948	20.514	17.07
49	8.168	51.772	30.142	30.565	60.561	18.945	10.561	10.97	23.431	39.27	18.172	20.651	26.901	26.934
50	6.189	61.116	19.03	25.876	39.223	54.78	12.973	25.347	28.752	22.004	22.216	26.703	14.181	10.81
51	4.972	27.898	15.681	32.165	29.388	20.846	11.206	23.727	27.371	31.047	5.161	37.736	13.363	10.76
52	8.893	36.042	2.585	19.064	27.942	15.801	3.155	50.521	12.314	19.956	9.544	8.702	6.131	8.169
53	10.307	40.525	2.655	31.455	18.605	19.178	8.399	17.074	11.423	17.535	12.997	5.671	14.172	5.545
54	2.919	19.528	10.058	6.699	11.415	17.338	6.644	13.88	16.752	11.629	3.925	8.496	12.039	3.097
55	1.482	20.22	2.865	4.161	3.754	16.2	12.96	25.63	14.811	9.71	5.934	16.163	7.066	3.02
56	5.324	13.157	5.504	4.11	3.73	12.891	6.564	21.416	8.968	10.407	4.484	4.373	4.144	7.806
57	2.907	61.454	2.532	5.489	7.131	11.133	10.114	29.752	10.34	7.914	4.446	3.744	5.837	1.696
58	1.344	27.252	1.61	3.075	1.455	8.891	6.947	32.88	3.531	9.041	1.847	3.723	3.501	1.038
59	1.903	7.08	0.717	6.475	4.945	5.717	5.566	14.16	12.771	7.427	2.498	8.559	2.072	3.577
60	0.235	16.67	0.709	1.157	1.913	3.518	3.725	6.992	6.08	6.049	11.22	0.867	0.959	4.947
61	0.881	5.855	0.113	3.491	4.07	2.268	2.234	1.733	17.41	4.099	1.04	1.428	1.212	1.108
62	0.032	6.268	4.147	4.964	1.108	7.725	20.04	2.444	4.69	2.45	2.065	0.457	2.951	0.646
63	0	29.173	0.19	0	0.541	3.02	0.887	2.244	9.825	6.251	1.991	0.314	0.84	0.192
64	0.032	2.817	0.323	3.365	0	3.266	0	1.372	2.596	2.376	1.761	2.726	0.391	0.167
65	0	2.927	0.698	0.988	0.037	0	0	3.469	2.773	4.622	0.075	2.58	0.43	0.449
66	0.16	0	0	0	0.48	4.284	0.129	0.628	2.156	1.797	0.191	1.607	0.068	0.278
67	0	0.788	0.19	1.512	2.419	0.417	0.841	1.771	1.236	0.049	0.225	0	0.174	0.178
68	0	0	0.659	0	0	0.586	0	3.576	1.959	0.065	0	0	0.081	0.118
69	0	0	2.971	0	0.037	0	0	0.842	0.501	0.422	0.294	0	0.739	0.271
70	0	11.909	0	0	0	2.996	0.015	0.02	0.301	3.403	0.983	0.046	1.468	0
71	0	1.351	1.884	0	0	0.213	1.191	0.1	0.227	0.159	0.055	0	0	0
72	0	0	0	0	0	0	0	0.172	0.227	0	0	0.007	0	0
73	0	0	0.48	0	0	0	0	0.195	0	0	0.027	0	0.139	0.029
74	0	0	0.733	0	0.087	0	0	0	0	0.192	0	0	0	0
75	0	0	1.965	0	0	0	0.003	0	0	0	0.027	0	0	0
76	0	0	0.343	0	0	0	0	0.22	0.227	0	0	0	0	0
77	0	0	0	0	0	0	0	0	0	0.056	0	0	0	0
78	0	1.173	0	0	0	0	0	0	0.318	0	0	0	0	0
79	0	0	0	0	0	1.294	0	0	0	0	0	0	0	0
80	0	0	0	0	0	1.439	0	0	0	0	0	0	0	0
81	0	0	0	0	0	0	0	0	0	0	0	0	0	0
82	0	0	0	0	0	0	0	0	0	0	0	0	0	0
83	0	0	0	0	0	0	0	0	0	0.182	0	0	0	0
84	0	0	0	0	0	0	0	0	0	0	0	0	0	0
85	0	0	0	0	0	0	0	0	0	0	0	0	0	0
86	0	0	0	0	0	1.439	0	0	0	0	0	0	0	0
87	0	0	0	0	0	0	0	0	0	0	0	0	0	0
88	0	0	0	0	0	0	0	0	0	0	0	0.225	0	0
89	0	0	0	0	0	0	0	1.367	0	0	0	0	0	0
90	0	0	0	0	4.559	0	0	0	0	0	0	0	0	0

Table 4.4.1.3.2. Life history parameters growth and M used for performing stock assessment of hake through three different methods in GSA6

	XSA	VIT	*LB-SPR*
L∞ (cm)	110	110	110
k (yr^{-1})	0.178	0.178	0.178
M			
Average	n/a	n/a	0.57
Age-0	1.24	1.24	n/a
Age-1	0.58	0.58	n/a
Age-2	0.45	0.45	n/a
Age-3	0.4	0.4	n/a
Age-4	0.37	0.37	n/a
Age-5	0.35	0.35	n/a
L50	n/a	n/a	30
L95	n/a	n/a	40

4.4.1.4 ***LB-SPR* sensitivity analysis**

Additionally to perform the *LB-SPR* analysis emulating the life-history parameters of the official stock assessment of hake, the sensitivity for *M* and von Bertalanffy growth parameters on estimation of SPR was tested. L∞=110 cm, 100 cm and 88 cm according to combined sex (Mellon-Duval et al., 2010), females (Aldebert and Recasens 1996) and sex combined (Aldebert and Recasens 1996), were used respectively. *M*=0.56 yr^{-1} for average of *M-at-age* derived from Prodbiom, *M*=0.4 yr^{-1} and *M*=0.2 yr^{-1} were also tested.

4.4.1.5 **Results**

The VIT outputs kept both similar absolute levels for the stock and recruits and trends when were compared with XSA (Figure 4.4.1.5.1), meaning that along the compared years (2010-2014) VIT was able to provide very close estimates of relative fishing mortality and *SSB* (Figure 4.4.1.5.2). The $SSB/SSB_{0.1}$ for the assessed period ranged from 3.8% to 6.5%, suggesting a highly overexploited population of hake.

Under the same (emulated) parameterization for XSA and VIT (Table 4.4.1.3.2), the *LB-SPR* method led to a *SPR* from 2% to 3% (2010-2014) (Figure 4.4.1.5.3). Differences between methods, however, could be influenced by a distinct effect of *M at age* in *XSA* and VIT than *M* in *LB-SPR*. Consequently, the average *M* calculated from the *M* at age for the ages involved in the stock assessment by XSA could be promoting underestimation of the SPR.

The fishing mortality during the same period estimated by VIT and XSA were both from about 4 to 5 times higher than $F_{0.1}$ (Table 4.4.1.5.1, Figure 4.4.1.5.2), while the proportion of fishing mortality/natural mortality ratio was estimated by *LB-SPR* from 2.8 to 3.26 (Figure 4.4.1.5.3). This means that despite *LB-SPR* estimated lower values of SPR, fishing mortality was perceived as lower than that derived from VIT and XSA (Figure 4.4.1.5.4).

Finally, the XSA indicated that since 2010 the fishing mortality in the youngest individuals (age 0) has been reduced, whereas an increased number of the two-year individuals are observed (Figure 4.4.1.5.5). This result was also well caught by the *LB-SPR* showing selectivity rising since 2010 (Figure 4.4.1.5.3). Although the fishing mortality has increased in age two, catches mostly concentrated on immature fish (Figure 4.4.1.5.5), keeping an overexploitation pattern as indicated by the *LB-SPR* method (Figure 4.4.1.5.6).

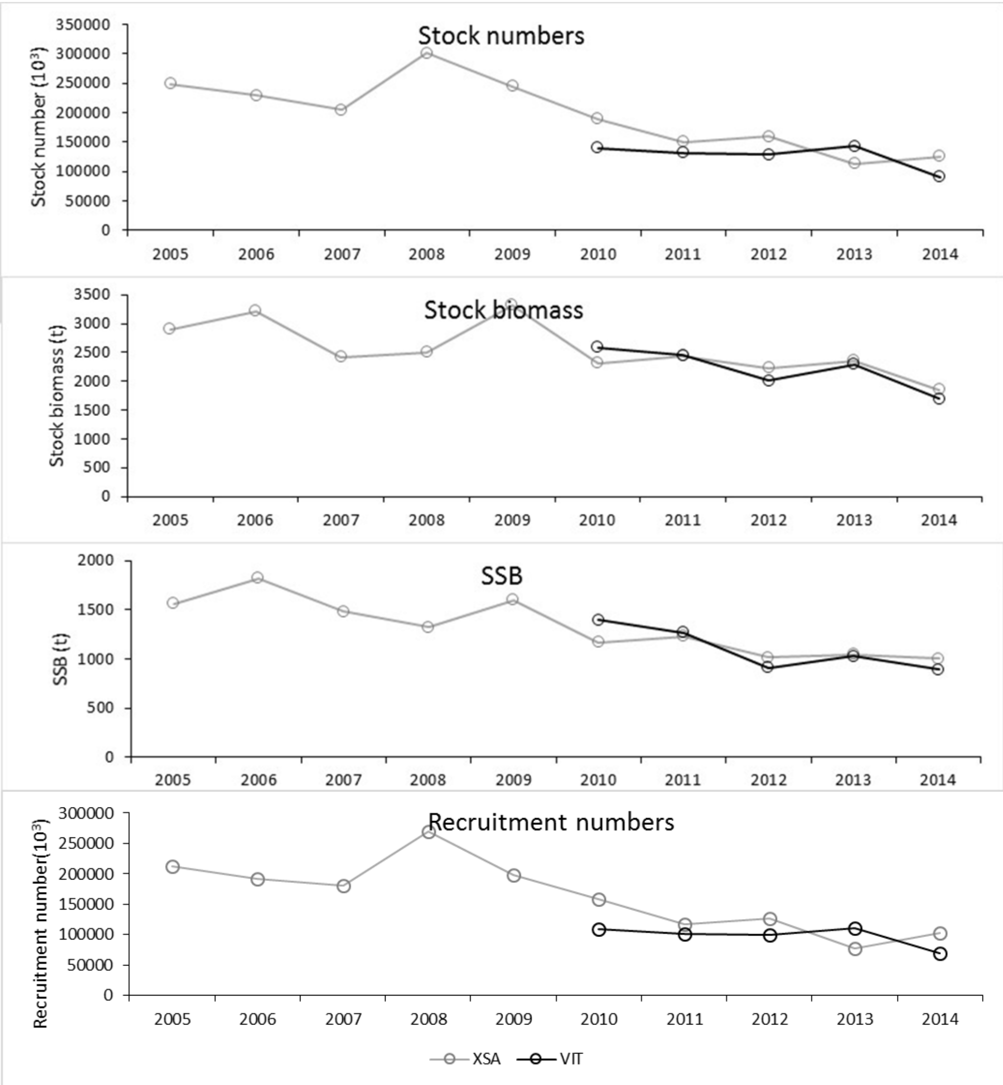


Figure 4.4.1.5.1. Population size of hake in GSA6 estimated by XSA and VIT.

Table 4.4.1.5.1. Comparison of fishing mortality of hake by VIT and XSA

	XSA (F0-2)				
Age	2010	2011	2012	2013	2014
0	0.473	0.142	0.147	0.177	0.119
1	1.522	1.815	1.775	1.79	1.227
2	1.732	2.219	1.868	2.223	1.605
Fbar	1.242	1.392	1.263	1.397	0.984
F0.1	0.260	0.260	0.260	0.260	0.260
F0.1/Fbar	4.778	5.354	4.859	5.372	3.783
	VIT (F0-2)				
Age	2010	2011	2012	2013	2014
0	0.185	0.095	0.114	0.079	0.149
1	1.398	1.484	1.829	1.76	1.297
2	1.792	1.672	1.687	2.067	2.114
Fbar	1.125	1.084	1.210	1.302	1.187
F0.1	0.260	0.260	0.260	0.260	0.260
F0.1/Fbar	4.327	4.168	4.654	5.008	4.564

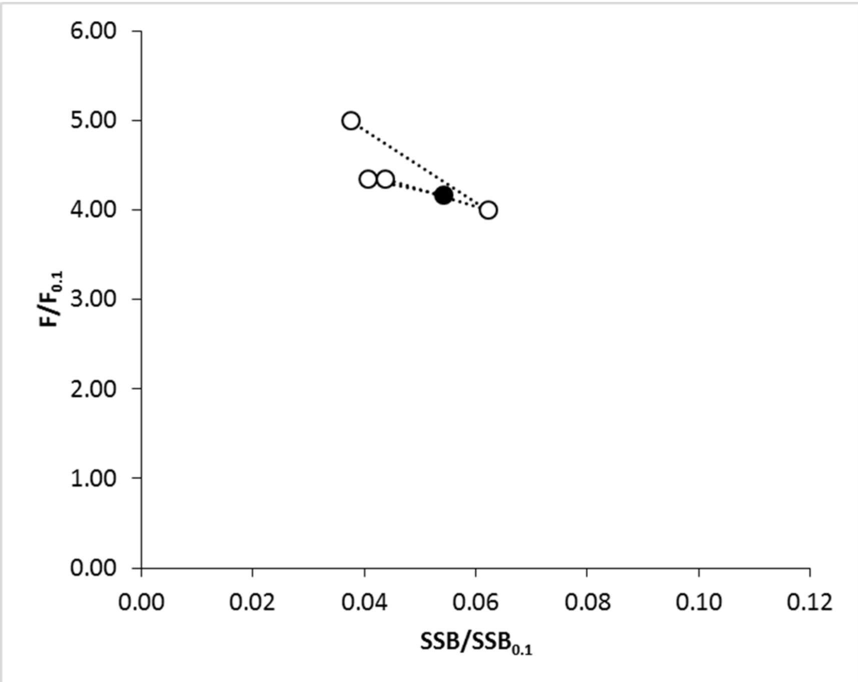


Figure 4.4.1.5.2. Fishing mortality and spawning stock biomass relative to reference points of $F_{0.1}$ and $SSB_{0.1}$ for hake in GSA6 estimated by VIT.

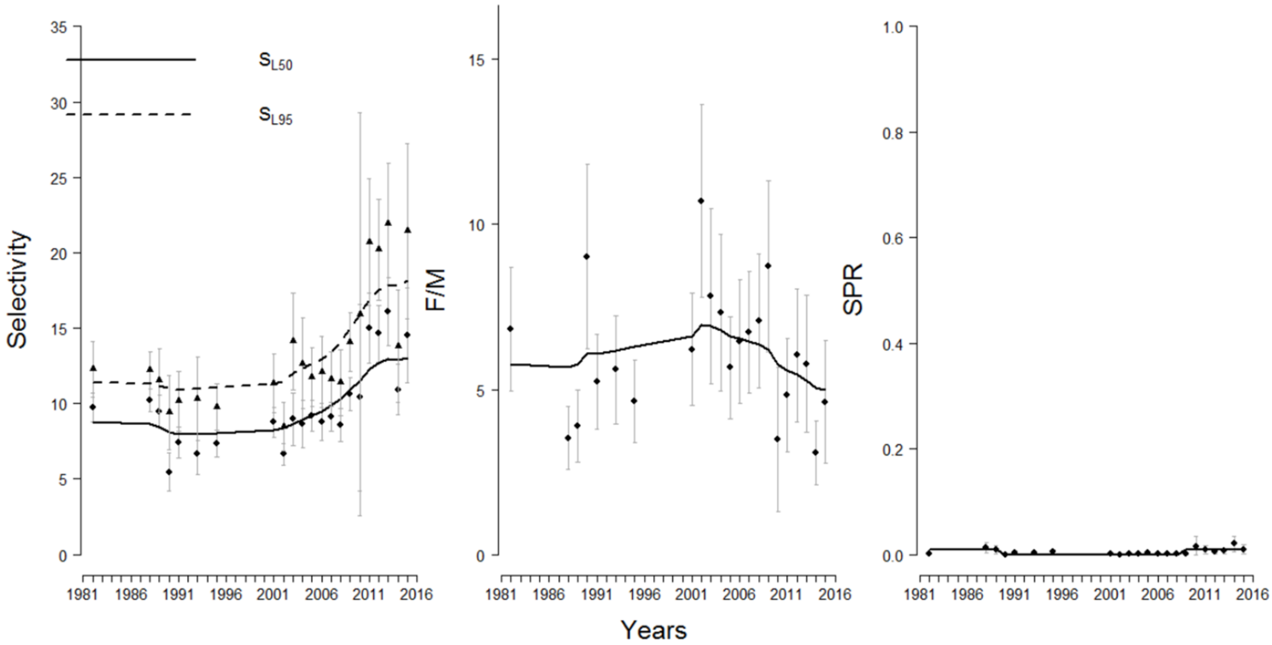


Figure 4.4.1.5.3. LB-PR outputs of selectivity, F/M and SPR for the emulated parameterization of inputs in the XSA stock assessment.

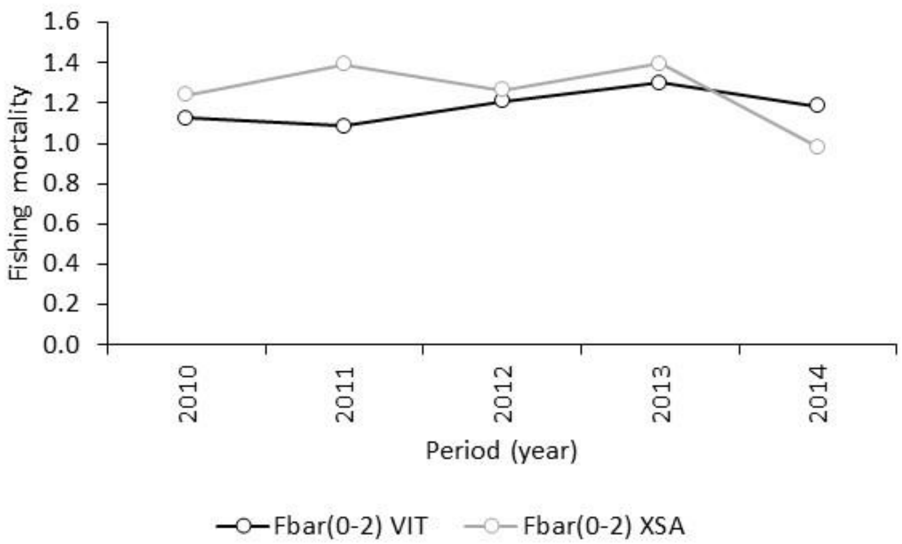


Figure 4.4.1.5.4. Comparison of Fbar by VIT and XSA for hake GSA 6

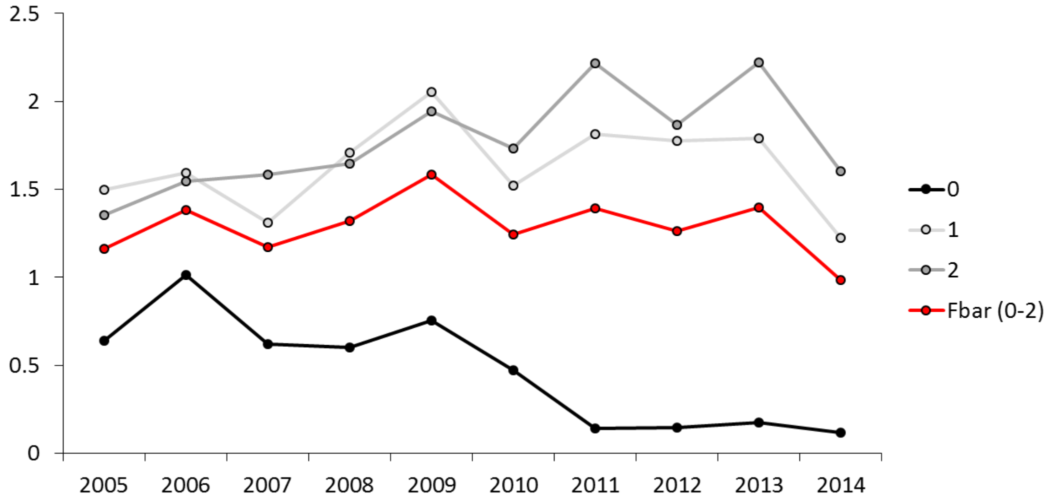
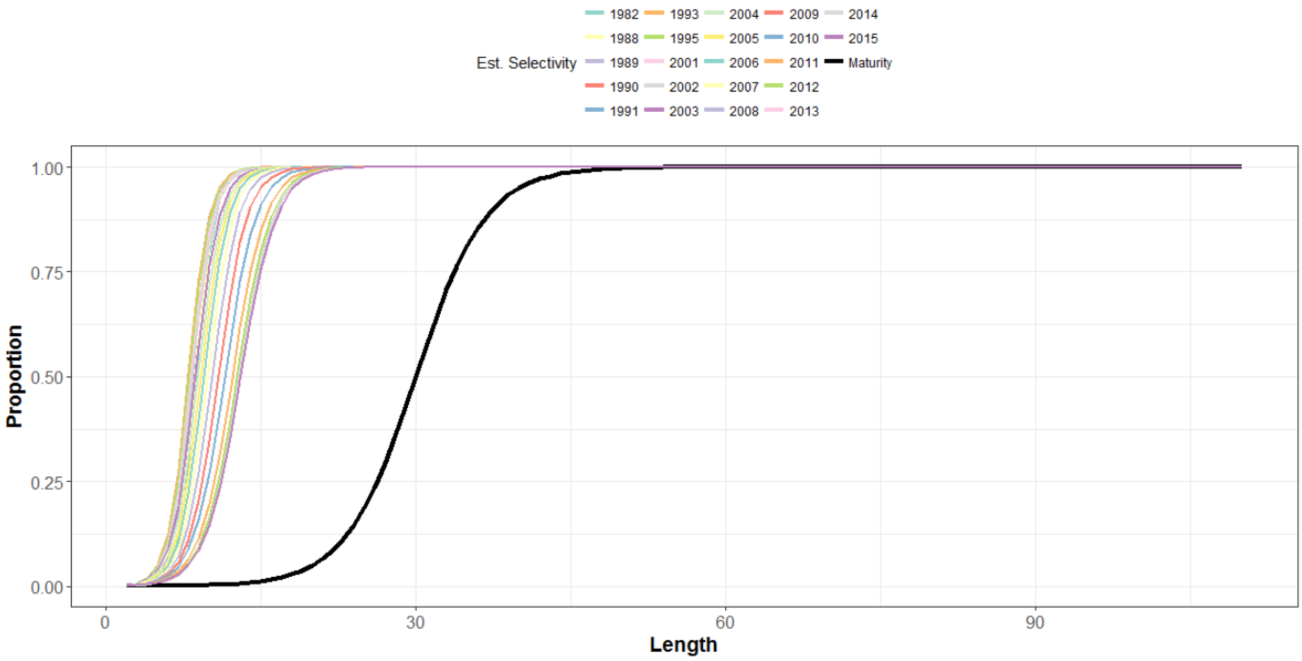


Figure 4.4.1.5.5. Fishing mortality by age for the most fished ages of hake in GSA6



4.4.1.5.6. Size of selectivity and maturity at size of hake in GSA6 outputted by *LB-SPR* method

The sensitivity analysis derived important changes in *F/M* and SPR (Table 4.4.1.5.1). The spawning potential ratio was increased more than double when *L*∞ was reduced from 110 to 88 cm (tests 1, 4 and 5). This is explained by the fact that all sizes not recorded are assumed by the *LB-SPR* model as fished. Thus, a smaller *L*∞ produces a more optimistic view of the population overexploitation status. When *M/k* varied (tests 1, 2 and 3) the *SPR* was importantly modified. As lower was the *M/k*, the *SPR* dropped to lower values. Even, when M=0.2 yr^{-1} as used by Aldebert and Recasens (1996) and k=0.178 yr^{-1} (Mellon *et al.* 2010) were considered, the *SPR* dropped to zero. This result is not reasonable given that a stock with such a low *SPR* would probably have collapsed many years ago. On the other hand, *M/k*=3.15 would seem too high for hake but this value produced still lower values of *SPR* than the showcased by the *VPA*. Finally, the *SPR* method can graphically show how the model is fitted to length frequency data. In the case of hake, only when values of *L*∞=88 cm and *M/k*=3.15 were given to the model, were the length-frequency data well fitted in all years. When *L*∞ took a value of 110 cm as the official stock assessment does, 2002 and 2009 were did not fit given that these length frequencies produced too high F/M (higher than 5) (Figure 4.4.1.5.3).

Table 4.4.1.5.1. Sensitivity test of life-history parameters for hake in GSA6

Test	1		2		3		4		5	
L∞	110		110		110		100		88	
k	0.178		0.178		0.178		0.178		0.178	
M	0.56		0.4		0.2		0.56		0.56	
M/k	3.15		2.25		1.12		3.15		3.15	
Year	F/M	SPR	F/M	SPR	F/M	SPR	F/M	SPR	F/M	SPR
2002	4.42	0.01	6.56	0.00	14.17	0.00	3.83	0.01	3.12	0.02
2003	4.21	0.01	6.27	0.00	13.59	0.00	3.64	0.01	2.96	0.02
2004	4.08	0.01	6.08	0.00	13.22	0.00	3.52	0.01	2.85	0.02
2005	3.93	0.01	5.87	0.00	12.8	0.00	3.38	0.01	2.73	0.02
2006	3.85	0.01	5.76	0.00	12.57	0.00	3.31	0.02	2.66	0.03
2007	3.77	0.01	5.65	0.01	12.36	0.00	3.24	0.02	2.60	0.03
2008	3.68	0.02	5.53	0.01	12.11	0.00	3.16	0.02	2.52	0.04
2009	3.56	0.02	5.35	0.01	11.75	0.00	3.04	0.03	2.42	0.05
2010	3.26	0.02	4.94	0.01	10.92	0.00	2.77	0.04	2.18	0.06
2011	3.14	0.03	4.77	0.01	10.58	0.00	2.65	0.04	2.07	0.06
2012	3.06	0.03	4.67	0.01	10.37	0.00	2.58	0.04	2.01	0.06
2013	2.95	0.03	4.5	0.01	10.05	0.00	2.48	0.04	1.91	0.07
2014	2.8	0.03	4.3	0.01	9.64	0.00	2.34	0.05	1.80	0.08
2015	2.77	0.03	4.26	0.01	9.57	0.00	2.32	0.05	1.78	0.08

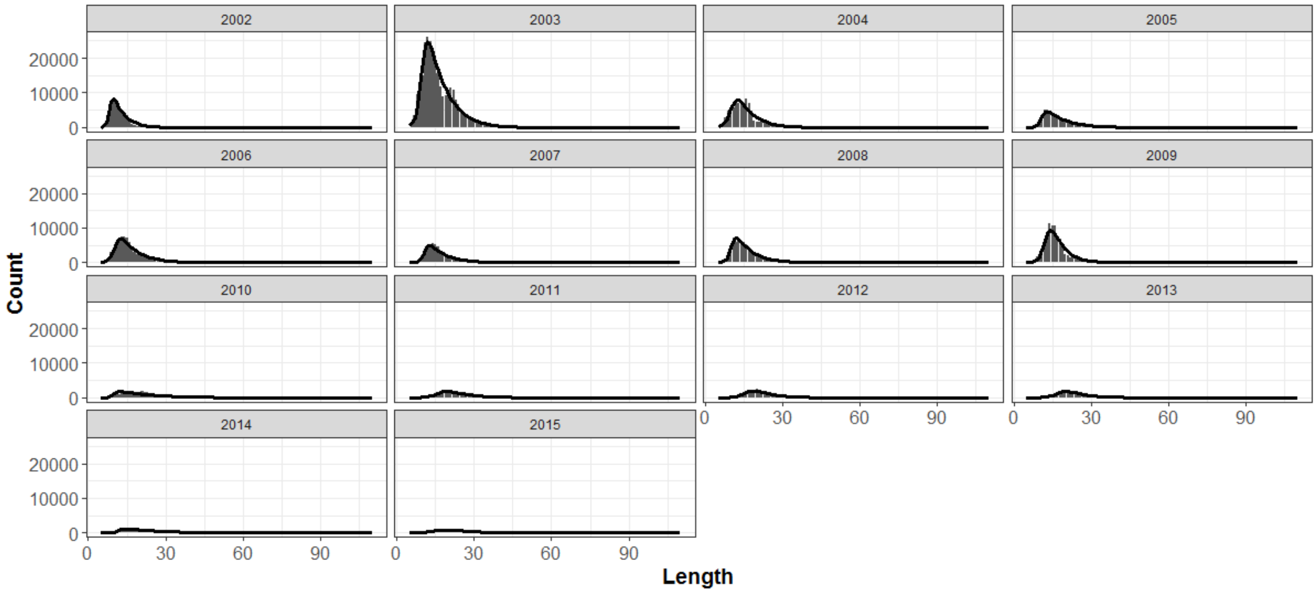


Figure 4.4.1.5.6. Data fitted by the *LB-SPR* method when *L*∞=88 cm and *M/k*=3.15

According with the findings for hake in GSA 6, the *LB-SPR* method could represent acceptably well the trend on fishery harvest (F/M), while this method indicated similar relative values of spawning stock biomass than VPA did. Therefore, the *LB-SPR* could be a suitable method to evaluate the population status of data-limited stocks that accomplish with the model assumptions (Prince *et al.* 2015). Nevertheless, uncertainty on life-history parameters should be explored in detail when little information is available for the species.

In fitting the length data in LF-SPR it was noted that the quality of the fit could vary, and this required careful inspection to insure that the results were not modified by a poor fit.

4.4.2 Blue whiting in GSA 17

4.4.2.1 Introduction

The official data of blue whiting (*Micromesistius poutassou*) in GSA 17 used for assessing the population status of the stock probably include combined catches and length frequencies of three species. This prevents the use of those catches and size distribution for assessing the fishery effects on the stock. Therefore, *LB-SPR* was examined as a potential tool for exploring the population status of this species using surveys length frequency data.

4.4.2.2 Method

The *LB-SPR* method used the reconstructed length frequencies structure coming from MEDITS for each individual year from 2002 to 2015. Length frequency data was extracted from the MEDITS Data call by the r code required to read and grouping data per GSA and country (Mannini, 2014).

4.4.2.3 **Input data**

The length frequencies of blue whiting were derived from the MEDITS data for GSA 17, including data from the Italian and Croatian waters (Figure 4.4.2.3.1). The length frequency standardised data included the number of females, males and undetermined individuals per km^2. As the MEDITS surveys are not overlapped but the Italian and Croatian surveys entirely cover the GSA 17, the individuals from both surveys were summed. The table 4.5.3.1 shows the data used in the *LB-SPR* analysis.

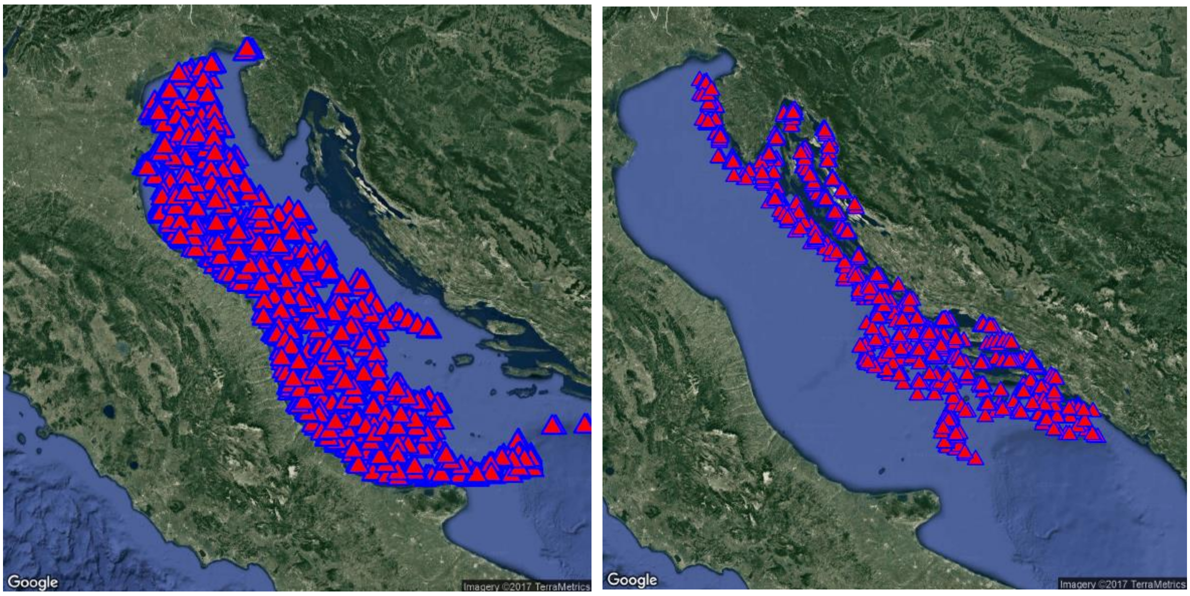


Figure 4.4.2.3.1. Map of tows distribution of MEDITS surveys in GSA 17 in Italy (left panel) and Croatia (right panel)

Surveys were mainly performed from June to August in Italy and Croatia but variations between countries, months and years were observed (4.4.2.3.2).

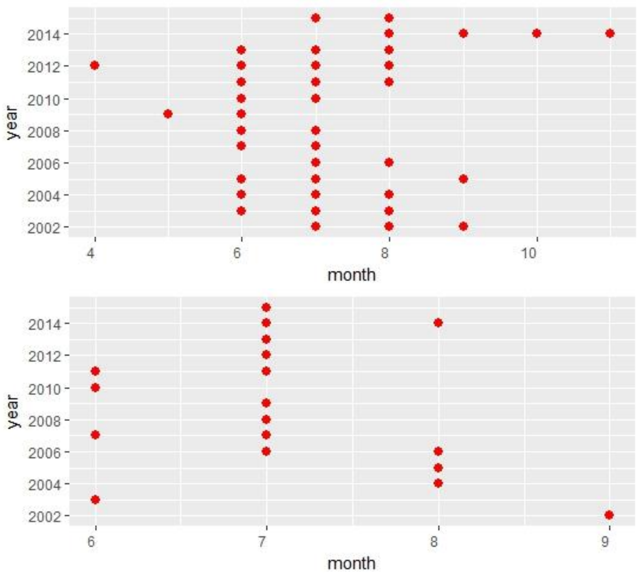


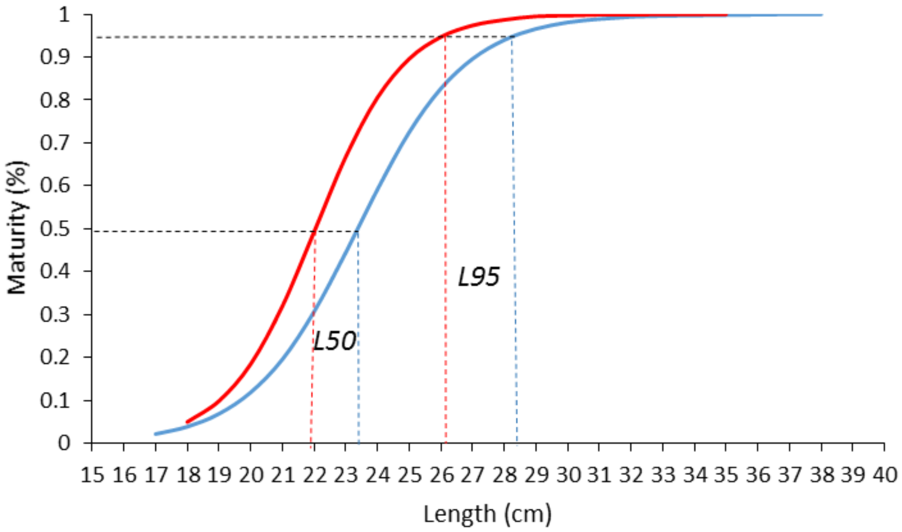
Figure 4.4.2.3.2. Month used for carrying out the MEDITS surveys in Italy (top panel) and Croatia (bottom panel) from 2002 to 2015.

The von Bertalanffy growth parameters of blue whiting in GSA 17 were derived from GSA 9, where $L\infty$= 45.3 cm, k=0.35 yr^{-1} and t_0 =0 yr. The sensitivity of natural mortality was tested using values from 0.2 yr to 0.4 yr (0.2, 0.25, 0.30, 0.35 and 0.40).

Table 4.4.2.3.1. Standardized length frequencies by km^2 of blue whiting coming from MEDITS in GSA 17

Length	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
4.5	0	0	0	0	0.49	0	0	0	0	0	0	0	0	0
5.5	0	0	0	0	0	0	0	0.23	0	0	0	0	0	0
6.5	0	0.77	0	0	0	0	0	0	0	0	0	0	0	0
7.5	0	0.22	0	0	0	0	0	0.23	0	0	10.49	0	0	0
8.5	0	0.43	0	0.32	0.26	0	0	2.99	0	0.21	0.23	0	0	0.18
9.5	0	7.05	0.48	0.67	0	1.44	0	28.53	2.21	4.25	1.66	0	0	3.8
10.5	0.18	47.81	1.27	6.59	1.36	4.49	3.02	88.98	11.19	14.61	121.38	1.77	2.74	17.19
11.5	2.4	126.05	7	23.44	5.79	14.18	24.13	95.59	57.89	32.62	661.03	3.53	10.32	56.23
12.5	21.27	172.88	16.63	64.24	25.15	18.34	72.53	30.01	164.92	47.73	979.03	55.46	15.86	125.63
13.5	121.63	84.5	34.7	103.72	58.29	10.07	149.09	8.46	234.52	38.79	1300.51	109.2	19.08	90.76
14.5	345.12	21.37	40.39	76.07	73.67	2.61	287.06	10.77	134.51	17.59	1269.3	103.15	14.61	47.97
15.5	493.44	5	42.16	32.43	66.44	0.59	230.01	2.66	40.17	2.63	635.12	79.11	19.63	20.5
16.5	167.95	0.81	28.4	7.72	15.13	0.08	88.8	1.7	6.33	0.44	101.16	20	10.86	1.88
17.5	19.01	0	7.52	2.17	2.79	0.3	10.05	1.52	0.65	0.56	11.53	34	3.78	1
18.5	5.44	1.24	0.6	0.09	0.14	1.34	0	9.05	0.91	2.33	0	341.7	26.55	2.35
19.5	0	3.39	0	0	0	6.17	0	37.31	8.46	18.34	0.53	752.99	117.76	9.63
20.5	0	26.51	2.23	0.13	0.3	14.68	0	51.07	38.29	39.11	4.95	612.05	325.99	28.97
21.5	0	52.34	5.2	1.54	3.83	13.72	0.88	43.07	54.56	33.8	19.19	166.89	342.3	177.53
22.5	0.39	26.77	12.11	6.78	13.31	12.33	8.69	23.9	51.39	30.25	24.15	30.04	164.02	136.37
23.5	0.37	10.56	16.64	12.5	23.41	10.98	5.3	7.35	35.73	35.55	35.43	22.27	61.1	136.34
24.5	0.23	2.25	13.15	10.46	12.28	15.89	4.77	1.2	13.93	25.22	24.73	37.45	42.43	40.42
25.5	0	0.56	11.97	9.21	12.44	14.38	8.2	5.21	11.54	16.35	15.71	39.95	39.76	69.14
26.5	0.72	0.43	6.47	11.41	9.28	10.57	5.48	4.56	5.05	6.59	12.87	35.36	30.08	52.01
27.5	0.96	0	2.84	4.73	1.99	6.03	9.09	2.09	3.69	4.82	20.42	22.05	19.5	2.4
28.5	0.57	1.07	0	6.32	5.66	3.27	8.16	3.58	2.1	1.75	1.76	9.92	11.35	17.15
29.5	0.96	0.27	0.41	1.49	1.14	1.44	4.67	2.71	5.99	2.44	0.12	9.74	10.17	0.85
30.5	0.23	1.06	0	1.34	0.58	1.27	4.42	1.13	2.18	2.15	0.12	2.38	7.62	15.8
31.5	0	0	0	0.09	0.09	0.59	3.57	2.36	2.08	1.85	0.12	0.33	1.57	0.41
32.5	0	0	0	0	0.09	0.68	2.71	0.51	0.63	0.25	0.12	1.44	0.12	15.41
33.5	0	0	0.11	0	0	0.17	1.03	0.51	0.4	0.43	0	0.2	0	0
34.5	0	0	0	0	0	0.34	0.96	0.17	0.2	0.21	0.1	0	0	0
35.5	0	0	0	0	0	0.08	0	0	0.39	0	0	0	0	0.3
36.5	0	0	0	0	0	0	0.88	0	0	0	0	0	0	0
37.5	0	0	0	0	0	0	1.76	0	0	0	0	0	0	0
38.5	0	0	0	0	0	0	0.88	0.7	0	0.75	0	0	0	0
39.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40.5	0	0	0	0	0.09	0	0	0	0	0	0	0	0	0
41.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
42.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
43.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
44.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
45.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0

The *LB-SPR* analysis requires size of maturity *L50* and *L95.* These values were derived from maturity at length calculated for blue whiting in GSA9. Using the precautionary approach, the analysis considered *L50*=23.5 cm and *L95*= 28.5 cm derived from females.



4.4.2.3.3. Maturity at size of blue whiting in GSA 9 for males (red line) and female (blue line).

4.4.2.4 ***LB-SPR* sensitivity analysis**

In addition to the sensitivity analysis performed on natural mortality, two different length-frequency patterns were explored. This was required since for most of years the survey data provided a bimodal length frequency distribution (Figure 4.4.2.1), indicating that the *LB-SPR* dome-shaped assumption had not been fulfilled. While the first pattern included all length frequencies collected by MEDITS surveys, a second length frequency pattern was extracted where all length frequencies smaller than 18 cm (juveniles) were eliminated in order to accomplish the above-mentioned assumption. (Figure 4.4.2.4.1). Those years where most of length frequencies were found for individuals smaller than 18 cm were excluded of the analysis.

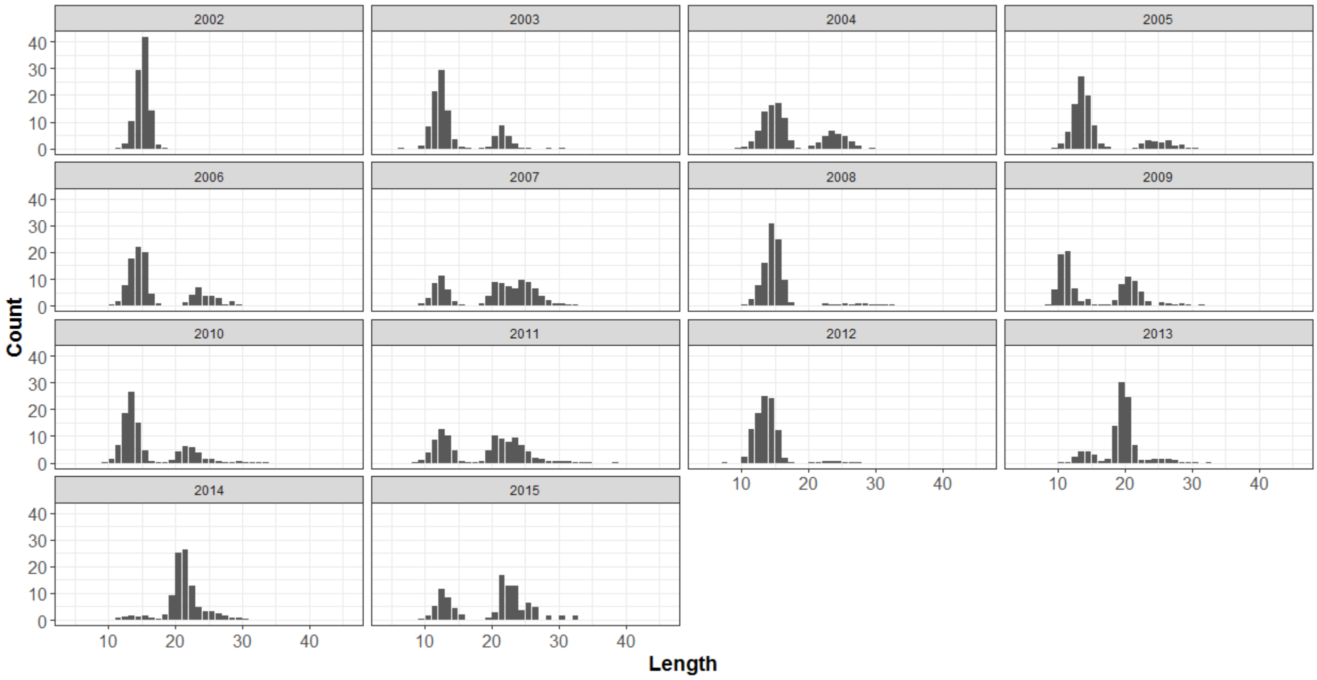


Figure 4.4.2.4.1. Distribution of length frequencies (percentage) derived from MEDITS surveys of blue whiting in GSA 17.

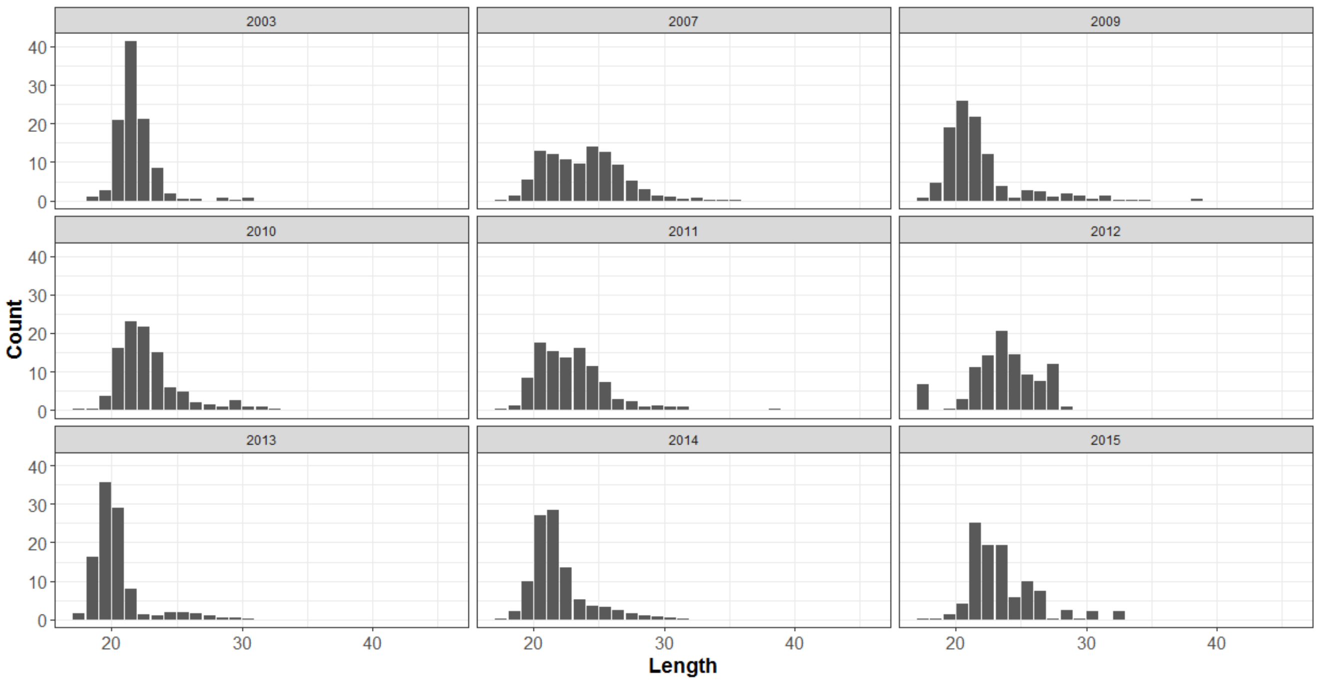


Figure 4.4.2.4.2. Distribution of length frequencies (percentage) larger than 18 cm derived from MEDITS surveys of blue whiting in GSA 17.

4.4.2.5 Results

The *LB-SPR* model was not able to adequately fit the length-frequency data. This occurred because the bimodal distribution shown in many years (i.e. 2003, 2004, 2007 and 2015) did not conform to the required dome-shaped assumption. In some years, for instance 2006 and 2007, the *LB-*

SPR was able to fit the data and a warning message was not advised (Figure 4.4.2.5.1). However, the visual inspection clearly shows that the model is not able to adequately represent the length frequency distribution. On the other hand, several years are warned as "Estimated *F/M* appears be unrealistically high" (incomplete message is outputted in the Figure 4.4.2.5.1). These high F/M are related to length-frequency distributions exhibiting a peak on small sizes while larger individuals were not recorded (Figure 4.4.2.5.1).

The *SPR* of blue whiting with default natural mortality (0.4) were placed below 0.2 but it mostly drooped below 0.05 (Figure 4.5.5.2). The sensitivity test of natural mortality (0.2 – 0.4) varied the *SPR* of blue whiting from 0.01 to 0.05, including all study years. This means that increasing *M* by a factor of two did not largely affect the stock status based on SPR, keeping it on very low levels (Table 4.4.2.5.1). Although the population recorded by the MEDITS surveys corresponded to immature individuals (Figure 4.4.2.5.3), it is not possible to define what is the level of spawning potential ratio remaining for blue whiting in GSA 17 by *LB-SPR* method.

Treating the data as if individuals smaller than 18 cm were not caught in the surveys (only using length frequencies higher than this size), *F/M* was placed around 10 and SPR kept a value of 0.03 (Figure 4.5.5). However, all years were warned as exhibiting a too high ratio for fishing and natural mortality. Despite that, in this case, the dome-shaped distribution assumption was accomplished; the data fitting performed by the model determined that data were not suitable for being used.

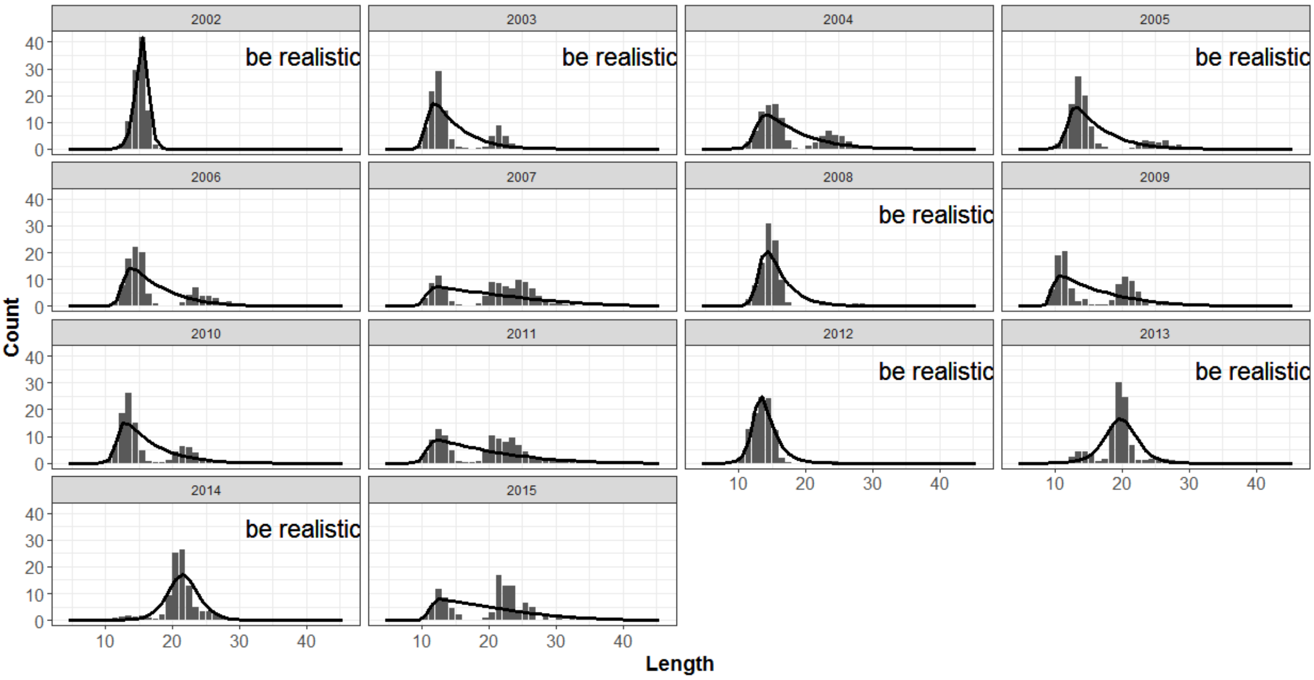


Figure 4.4.2.5.1 - Graphical output of the model-fitted length frequencies for blue whiting GSA 17. Some panels are warned with the message "Estimated F/M appears be unrealistically high".

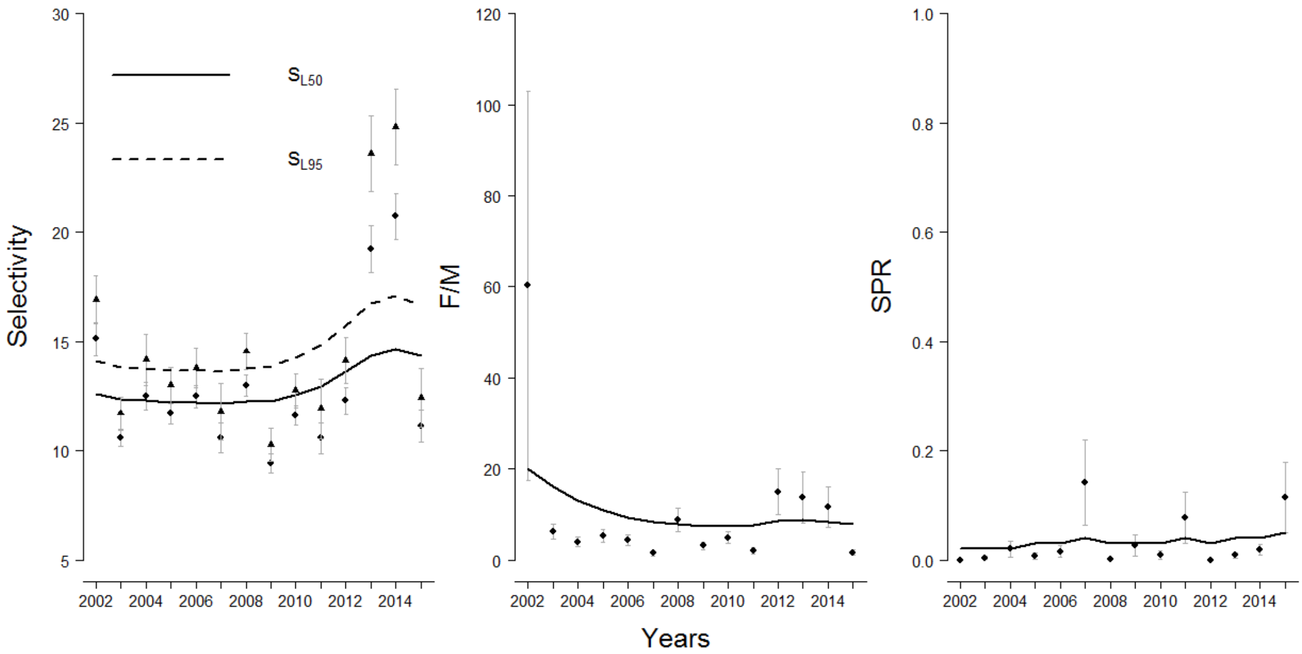


Figure 4.4.2.5.2 - *LB-SPR* outputs of selectivity, F/M and SPR for blue whiting in GSA 17.

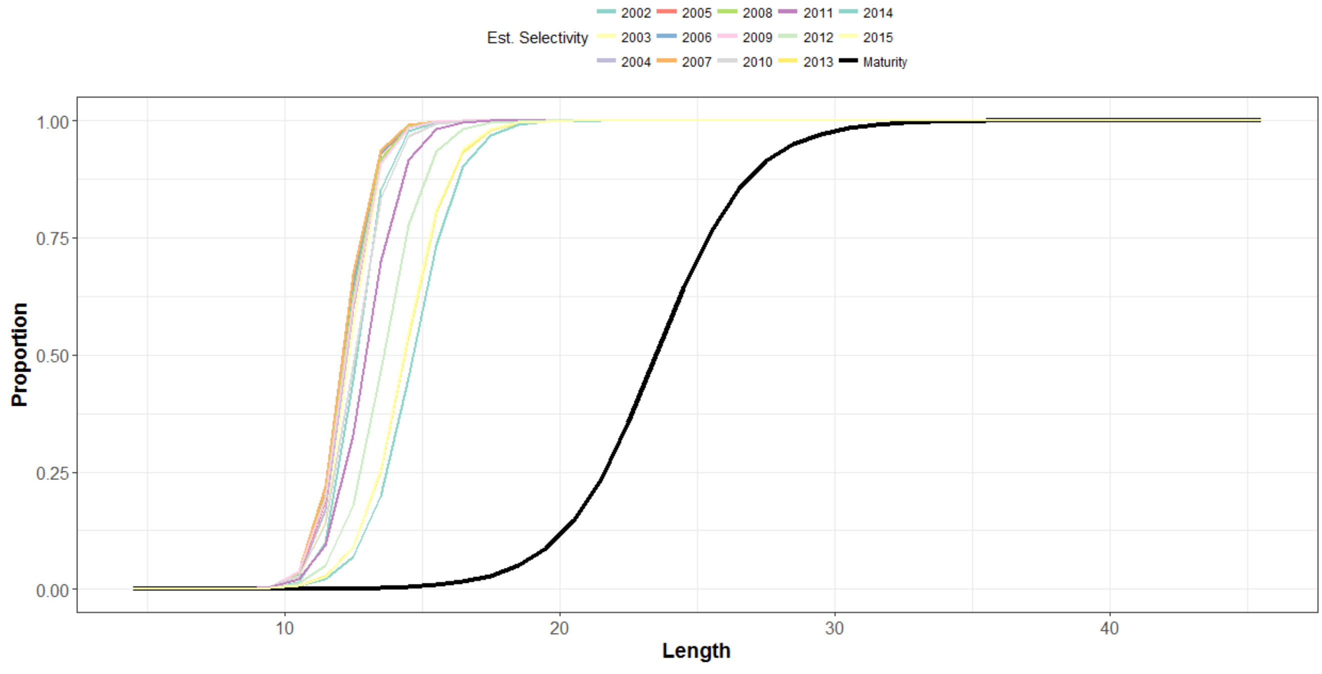


Figure 4.4.2.5.3 - Size of selectivity and maturity at size of blue whiting in GSA 17 for the population portion recorded by the MEDITS surveys.

Table 4.4.2.5.1- Sensitivity test of the effect of natural mortality on F/M and SPR for blue whiting in GSA 17

Test	1		2		3		4		5	
L∞	45.3									
k	0.35									
M	0.2		0.25		0.3		0.35		0.4	
M/k	0.57		0.71		0.86		1.00		1.14	
Year	F/M	SPR	F/M	SPR	F/M	SPR	F/M	SPR	F/M	SPR
2002	41.12	0.01	42.08	0.01	26.91	0.01	13.77	0.01	20.06	0.02
2003	33.12	0.01	33.06	0.01	21.61	0.01	11.7	0.02	16.06	0.02
2004	27.08	0.01	26.28	0.01	17.61	0.01	10.09	0.02	13.05	0.02
2005	22.86	0.01	21.44	0.01	14.82	0.02	9.01	0.02	10.94	0.03
2006	19.75	0.01	17.97	0.02	12.76	0.02	8.21	0.02	9.39	0.03
2007	17.63	0.01	15.62	0.02	11.36	0.02	7.71	0.03	8.33	0.04
2008	16.9	0.01	14.54	0.02	10.87	0.02	7.8	0.03	7.96	0.03
2009	16	0.01	13.45	0.02	10.28	0.02	7.67	0.03	7.52	0.03
2010	15.99	0.01	13.14	0.02	10.27	0.02	7.93	0.03	7.51	0.03
2011	16.49	0.01	13.42	0.02	10.6	0.02	8.4	0.03	7.76	0.04
2012	18.13	0.01	14.65	0.02	11.69	0.02	9.48	0.03	8.58	0.03
2013	18.51	0.01	14.9	0.02	11.94	0.02	9.78	0.03	8.77	0.04
2014	17.89	0.01	14.36	0.02	11.53	0.03	9.49	0.03	8.46	0.04
2015	16.66	0.02	13.36	0.02	10.71	0.03	8.81	0.04	7.84	0.05

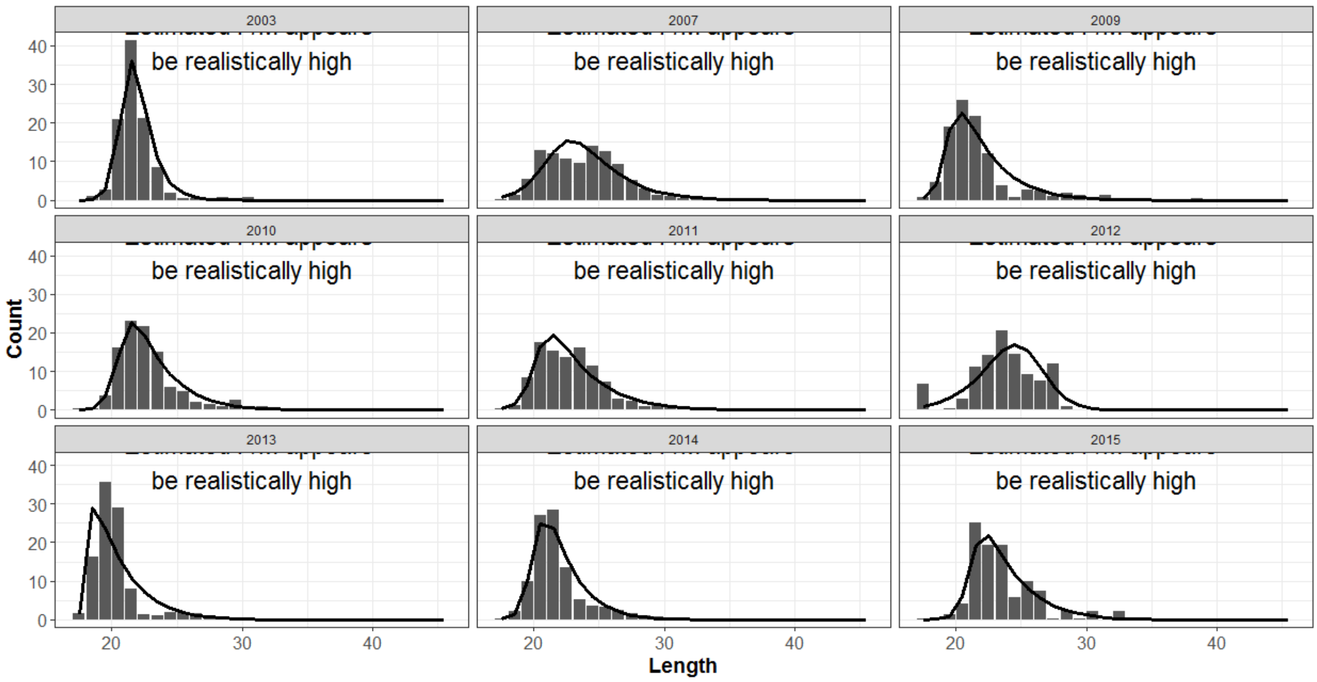


Figure 4.4.2.5.4 - Graphical output of the model-fitted length frequencies larger than 18 cm for blue whiting GSA 17. Some panels are warned with the message "Estimated F/M appears be unrealistically high".

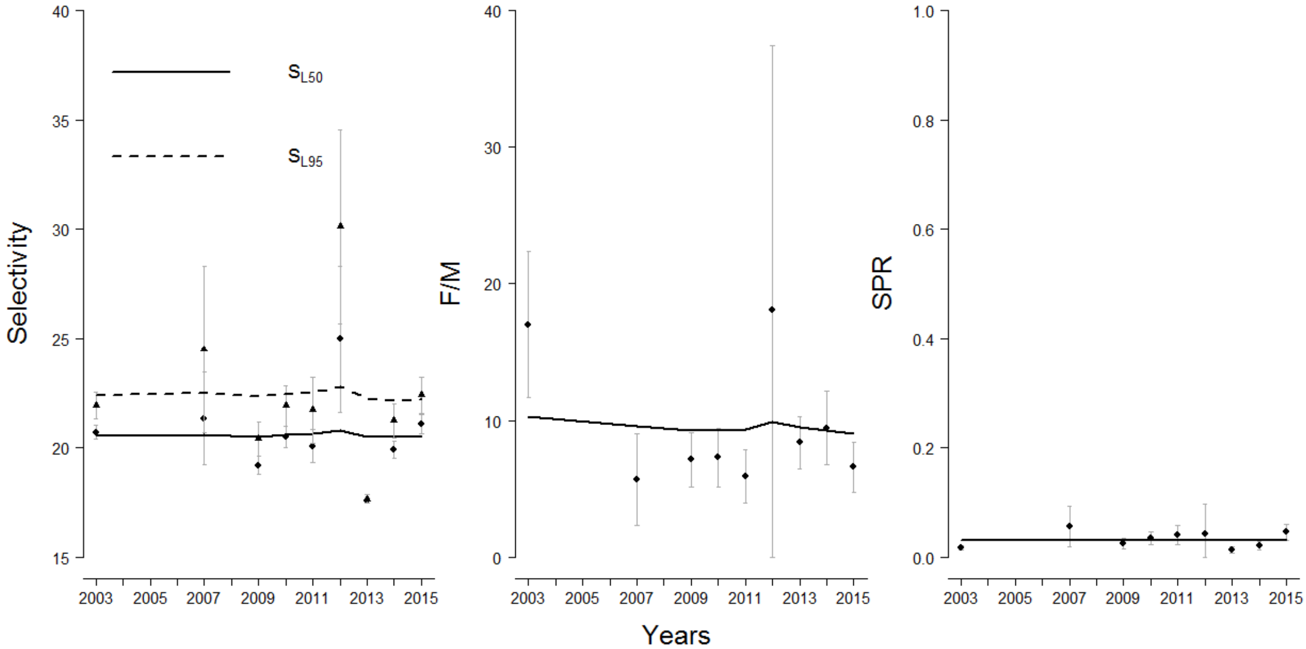


Figure 4.4.2.5.5. *LB-SPR* outputs of selectivity, F/M and SPR when only length frequencies larger than 18 cm were used for blue whiting in GSA 17.

The approach used appears to be useful in the case of hake when compared results with the estimated surviving fraction of spawners obtained with an equilibrium cohort analysis performed with VIT, that showed results considered consistent with those obtained using XSA. The results for blue whiting resulted were not meaningful as the model is not able to interpret in a proper way the size structures of the caught individuals in the surveys in different years. This is not surprising as the authors of the model warns on the need to avoid using the model when multimodal distributions are observed (Hordyk *et al.* 2015b). Such multimodal shape is in this case due to the presence in the catch of different cohorts that are very clearly separated. This distribution is not unexpected as the species grows quite quickly and the survey is carried out only once per year and hence we are observing a static instantaneous snapshot of the size structure at sea. In such circumstances, the *LB-SPR* model is not able to fit the data well, and estimates of F/M, selectivity and SPR obtained with these data will likely to be unrealistic (Hordyk *et al.* 2015b). In conclusion, when only one or two surveys are available per year as is the case for blue whiting the LF-SBR method is not suitable. There are further considerations that may discourage the use of the method for this species. The species shows a very contagious concentration pattern and a complicate model of vertical distribution based on temperature and food availability (Martin *et al.* 2016). Such sensitivity to environmental conditions may drastically condition recruitment success (cycles of abundance have been hypothesised) and availability/vulnerability of the gear in use. In consequence, high fluctuating yearly abundance indexes for the whole stock or by age can be expected.

The *LB-SPR* method is more suitable for being used for analysing commercial catch data while for a proper use of surveys data with such method, it would be necessary to have each year a certain number of representative and comparable size distributions that allows the reconstruction of the size structure for the whole year. Collecting data at such higher temporal resolution (e.g. monthly for short-lived species) followed by a successive aggregation over a year may provide a length composition more representative of the size composition.

4.5 Stripped Red Mullet in GSA 11

The status of striped red mullet stock in GSA 11 has never been successfully evaluated because of data limitations, thus data availability was explored.

Landings

Mullus surmuletus is one of the main fishing targets of the small-scale fishing in this area, in particular of trammel net (GTR). It is also fished with bottom trawl (OTB) and gillnet (GNT).

Examination of landings data from the DCF biological data base ("Fisheries data") showed inconsistencies: i) in the most recent year, 2015, striped red mullet landings were reported only for OTB; and ii) the relative importance of GNT and GTR in the 2013 and 2014 was very different. Because of these inconsistencies, the landings data series was compared with that in the "Economic transversal data". The landings values from the economic database were higher than those from the biological database, and coincidental in 2013. The last year that information is available on landings by fishing gear in the economic database is 2014 and, hence, information on 2015 landings by fishing gear is not available (Table 4.5.1).

Table 4.5.1. Striped red mullet (*Mullus surmuletus*) landings (t) in GSA 11.

Landings economic transversal data

year	GNS	GTR	OTB	Total
2008	28.2	216.2	132.4	376.8
2009	68.4	295.4	113.8	477.9
2010	30.5	257.7	145.3	436.8
2011	22.7	257.5	136.0	416.2
2012	18.6	128.1	128.9	275.6
2013	2.4	156.6	149.6	308.6
2014	37.9	67.5	68.0	173.5
2015				
Fisheries Data				
2015			135.7	

Fishing effort

Data on fishing effort, expressed in fishing days, showed the GNT and GTR activity in 2015. The discrepancy between the reported striped red mullet landing in 2015, only for OTB, and the small–scale activity should be checked (Table 4.5.2).

Table 4.5.2. Fishing effort, expressed in fishing days, in GSA11.

	GNS	GTR	OTB
2002		102826	14539
2003		126272	18957
2004	163570	179002	45627
2005	165457	165457	49328
2006	160163	169677	41868
2007	169591	169591	81584
2008	117656	117656	70117
2009	155955	155955	150783
2010	184226	152624	174752
2011	139932	165645	161502
2012	156576	151445	147746
2013	39507	141864	74028
2014	172130	142403	99029
2015	129003	136339	64296

Length frequencies distributions by fishing gear

From the length frequencies distributions by fishing gear in the most recent years in which this information is available, 2013 and 2014, it can be concluded that the number of measured individuals was low and therefore it should be increased so as to provide reliable information on the size structure of the landings. Since the information in field "quarter" is "-1", it should be clarified whether the length frequencies distributions are presented on an annual basis.

The available information on the striped red mullet length frequencies distributions by gear and year (2006 – 2014) was merged so as to know the exploited sizes by each fishing gear. The resulting length frequencies distributions showed a clear overlapping between GNS and GTR (Figure 4.5.1).

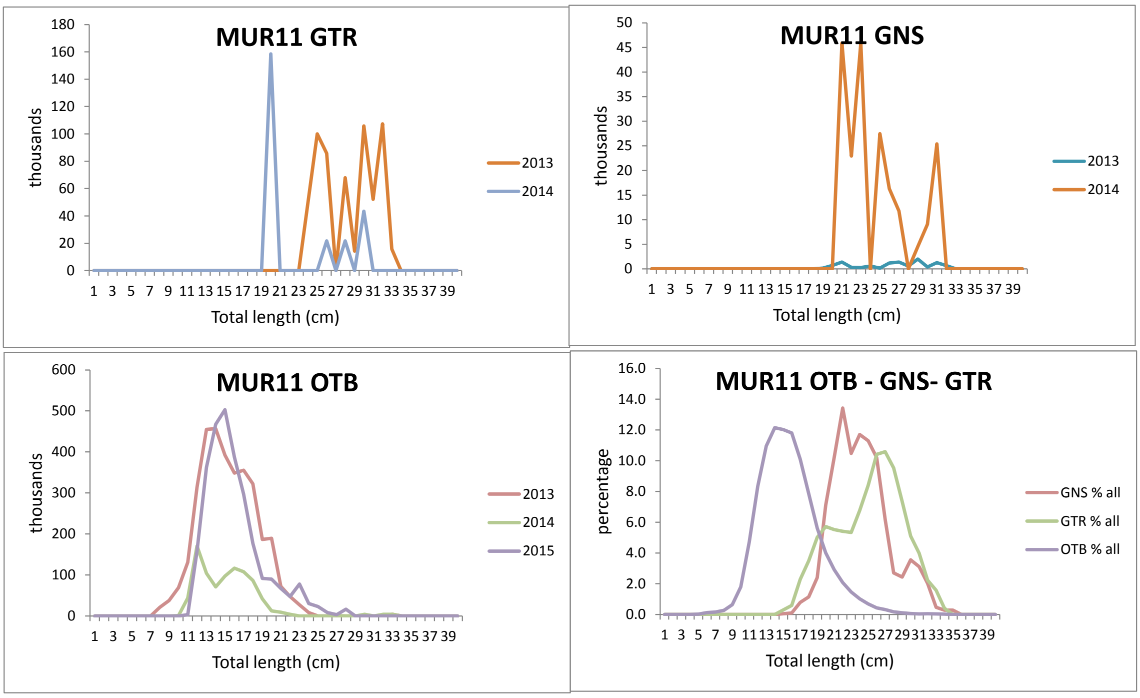


Figure 4.5.1 - Striped red mullet (*Mullus surmuletus*) length frequencies distributions by gear in the most recent years 2012 – 2015. The lower right panel shows the "mean" length frequencies distribution by gear, expressed in percentage.

<u>MEDITS</u>

The bottom trawl survey data, MEDITS, were explored. It is worth noting that that because of the relationship between the striped red mullet recruitment period and the survey, changes in the timing of the survey may lead to important changes in the information collected regarding overall abundance and abundance of recruits (≤ 10 cm TL) and also larger sized individuals (> 10 cm TL). Figure 4.5.2. shows the very different MEDITS length frequencies distributions in 2013 – 2015 and the timing of MEDITS surveys in GSA 11. In 2014 the survey was extended until August and recruits were caught.

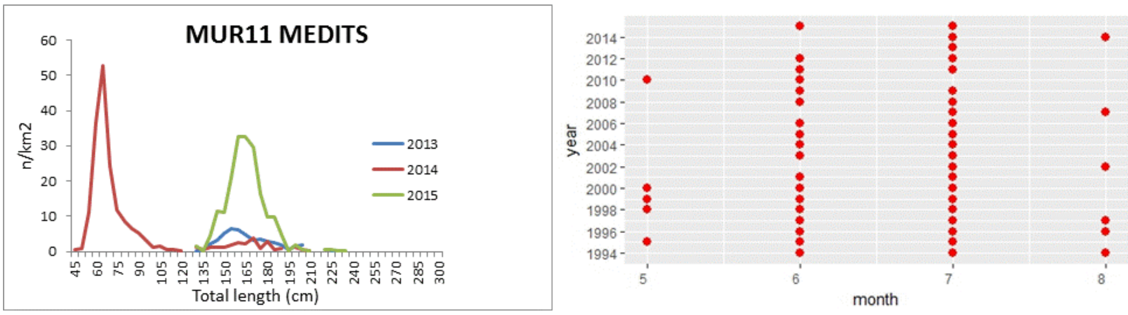


Figure 4.5.2. Striped red mullet (*Mullus surmuletus*) length frequencies distributions from MEDITS surveys in 2013 – 2015. The highest abundance in 2014 is explained by the presence of recruits.

The result of different survey timing for the period 1994 – 2015 is shown in Fig. 4.6.3. The highest abundances are linked to the presence of recruits. However, the timing influences not only estimates of recruits, when the survey starts early in May, the observed abundances of non-recruits individuals is higher than when the survey starts later. This is explained by the fact that the surveyed individuals in May have not yet been exposed to the intense fishing the following summer months (Figure 4.5.3).

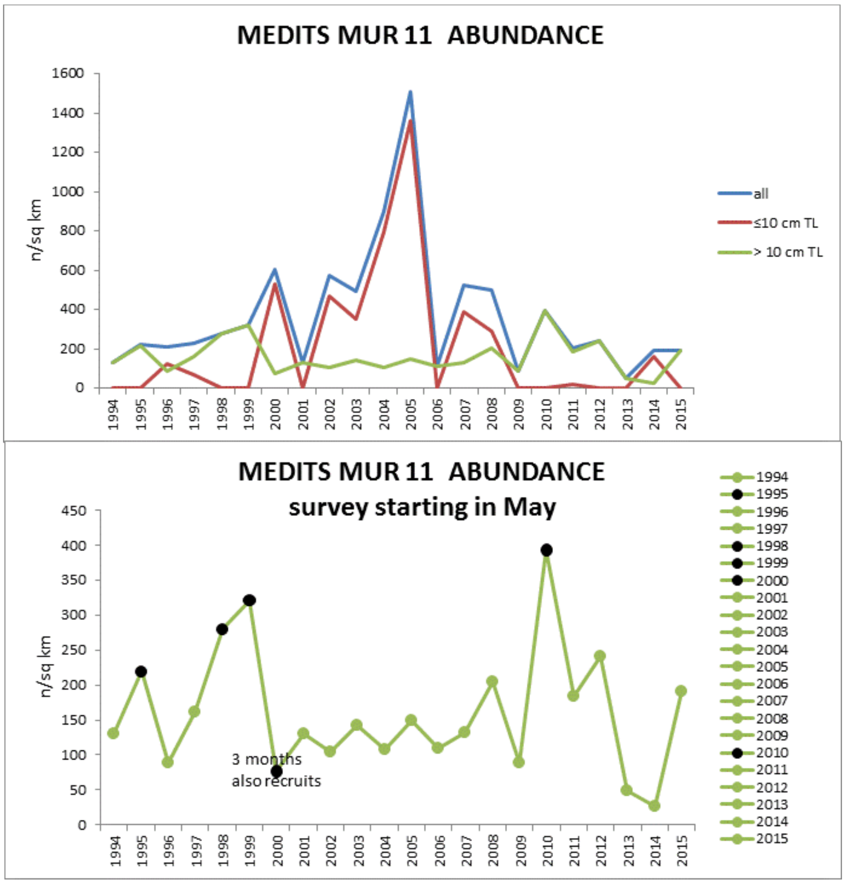


Figure 4.5.3. Striped red mullet (*Mullus surmuletus*) density in GSA 11 as resulting from MEDITS survey. Data are shown for the total, ≤ 10 cm TL and > 10 cm TL individuals (upper panel). The abundance of > 10 cm TL individuals was higher in the years when the survey started in May (black dots, lower panel). In 2000 the survey extended throughout three months.

Methods explored to assess the striped red mullet stock in GSA 11

- Length indicators (see section 4.3)
- Length cohort analysis
- Catch curve

Length cohort analysis (VIT software)

Length cohort analyses were run for 2013 and 2014, the most recent years with available complete information on landings by gear (GNS, GTR, and OTB).

Input data:

Growth parameters: L_{inf} = 35.87, k = 0.28, to = -1.07 (taken from DCF GSA 11).

Length-weight relationship: a = 0.0063, b = 3.2217 (taken from DCF GSA 11).

Maturity ogive (taken from DCF GSA 10, both sexes combined)

Total length (cm)	10	11	12	13	14	15	16
% mature	0.001	0.01	0.169	0.757	0.979	0.999	1

Natural mortality vector as estimated with the method proposed by Gislason.

ages	0	1	2	3	4	5	6	7+
M	1.43	0.8	0.57	0.46	0.4	0.36	0.34	0.3

Length frequencies distributions by gear, as shown in Figure 4.5.1, lower right panel.

Results

Main results are shown in Table 4.5.3 and Figure 4.5.4. According to these results, striped red mullet would have been being exploited sustainably in 2013 and 2014. These results are consistent with those obtained with length indicators. Nevertheless, these results should be taken with caution considering the assumption of equilibrium assumed by VIT and the above explained data limitations, in particular those regarding the size structure by fishing gear and year.

Table 4.5.3. Striped red mullet (*Mullus surmuletus*) in GSA 11. Length cohort analyses main results.

	GNT+GTR+OTB	GNT+GTR+OTB
	2013	2014
Landings (t)	308.643	173.452
R(thousands)	32657.117	18481.041
Bmean(t)	1315.073	771.558
SSB (t)	1117.660	658.946
F	0.308	0.303
F(0.1) factor	1.01	1.03

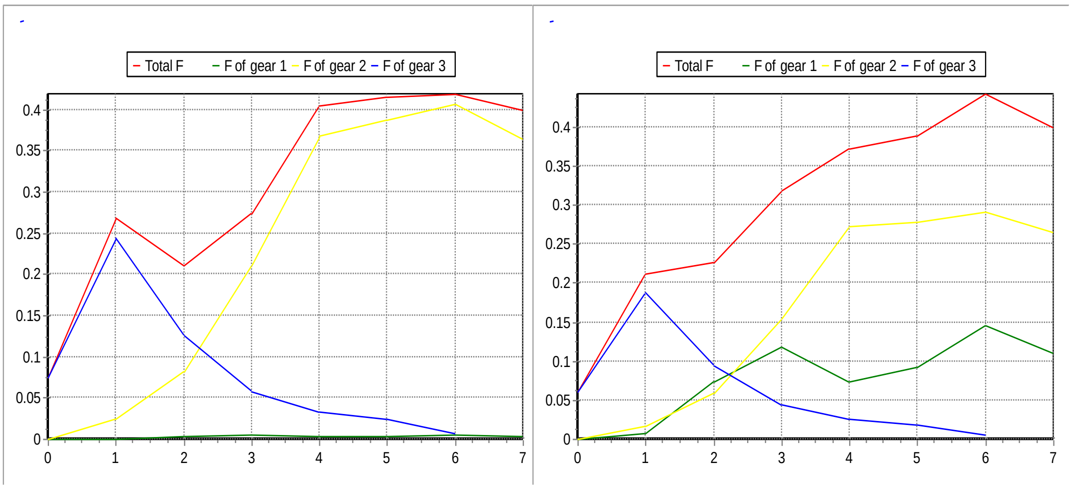


Figure 4.5.4. Striped red mullet (*Mullus barbatus*) in GSA 11. Fishing mortality, total and by gear in 2013 (left) and 2014 (right; gear 1 = GNS, gear 2 = GTR, gear 3 = OTB).

Catch curve for Z estimation

MEDITS data were explored with a view on their suitability for the estimation of Z. To this aim, the MEDITS 2008 – 2015 length frequencies distributions were transformed into ages using LFDA software. Later, Z was calculated for the different cohorts using the survival equation. In several cases, negative Z values were observed between consecutive ages within a cohort, as shown in Table 4.6.4, with different colors, between age (t) and age (t+1). It was therefore concluded that the MEDITS data were not suitable for the application of catch curve methods.

Table 4.5.4. Striped red mullet (*Mullus surmuletus*) in GSA 11: MEDITS age structure (upper panel) and in different color the trend of Z of three cohorts selected as example; in bold, negative values for Z.

ages	2008	2009	2010	2011	2012	2013	2014	2015
0	293.311	0	0	18.235	0.941	0	146.478	0
1	20.946	7.455	127.225	21.631	49.609	5.901	22.894	17.732
2	162.087	73.503	245.989	134.397	179.132	37.387	16.977	168.507
3	16.17	7.795	17.354	27.959	10.628	5.073	2.419	4.013
4	5.09	0.579	2.038	0.49	0.805	0.097	0.73	0.508
5	0.182	0.246	0.32	0	0	0	0.258	0
6	0.204	0	0	0	0	0.257	0	0
7	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0
9	0	0	0	0	0.098	0	0	0
10	0	0	0	0	0.012	0	0	0
Z	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
0								
1		1.595			-0.435	-0.797		0.917
2		**-0.545**	**-1.518**	**-0.024**	-0.918	0.123	-0.459	-0.867
3		1.318	0.627	0.944	**1.102**	1.548	1.189	0.626
4		1.446	0.583	1.549	1.541	**2.040**	0.842	0.678
5		1.316	0.258				**-0.425**	
6								
7								
8								
9								
10								

In conclusion none of the methods, survey analysis, of catch analysis with VIT, catch curves or length indicators give a consistent reliable picture of the state of this stock. The survey is difficult to use as it is particularly sensitive to timing and species behaviour. The catch data is very variable both in terms of fleets and quantities sampled. Without a concerted effort to improve that data it is unlikely that this situation will improve in the near future.

4.6 Using SPiCT to assess the anchovy in GSA 6

4.6.1 Introduction

This chapter investigates the applicability of a state-of-the-art surplus production model, the Surplus Production model in Continuous Time (SPiCT, Pedersen and Berg, 2017) for Mediterranean stocks that have time series of catch and biomass index. SPiCT is based on the surplus production model by Pella and Tomlinson (1969) formulated in continuous time as a state-space model, i.e. having a representation of the unobserved states: exploited biomass and fishing mortality, the observation function: catch and biomass index, and quantifying the uncertainty of both observed (observation error) and unobserved (process error) states. SPiCT is implemented as an R package (available at: https://github.com/mawp/spict) that utilises the Template Model Builder (TMB, Kristensen et al. 2016) that allows estimating parameters of state-space models using the Laplace approximation and provides one-step-ahead residual estimation (Thygesen, 2017) and diagnostics.

4.6.2 Anchovy in GSA-6

The anchovy in GSA 6 is used as an example to illustrate the use of the SPiCT assessment method. The stock has previously been assessed using the ASPIC surplus production model (STECF, 2016), but there were some considerations about the quality of the assessment; that report stated that alternatives, like SPiCT should be considered.

4.6.2.1 Available data

The data comprise of a reconstructed landings time-series for 1945 - 2015 and a biomass index from MEDITS for 2003 - 2015 (Figure 4.61).

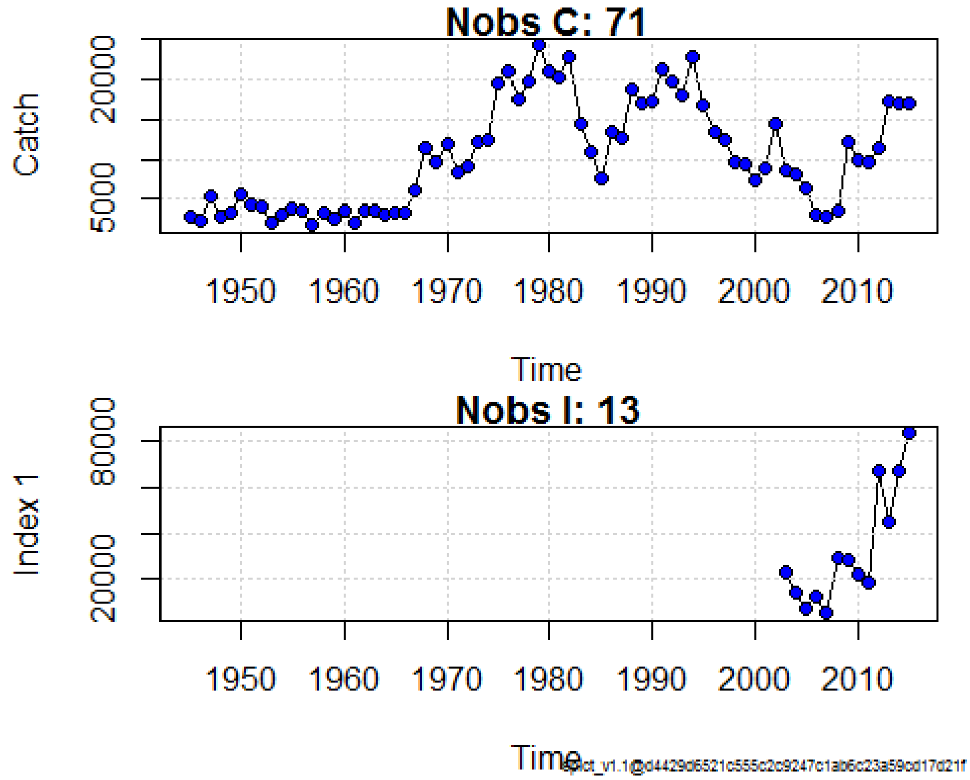


Figure 4.6.1 Input data for anchovy in GSA 6, total landings (top) and biomass index from MEDITS (bottom).

4.6.2.2 Assessment results

The stock status is quantified as two ratios, F/F_{MSY} and B/B_{MSY}. The estimates at the end of 2015 (95% confidence intervals in parentheses) are: F/F_{MSY} is 1.48 (0.48, 4.55) and B/B_{MSY} is 0.67 (0.22, 2.01). All the results are shown in Figure 4.6.2 and in the following summary.

```
Convergence: 0  MSG: relative convergence (4)
Objective function at optimum: 48.3348298
Euler time step (years):  1/16 or 0.0625
Nobs C: 71,  Nobs I1: 13

Priors
     logn  ~  dnorm[log(2), 2^2]
 logalpha  ~  dnorm[log(1), 2^2]
  logbeta  ~  dnorm[log(1), 2^2]

Model parameter estimates w 95% CI
            estimate        cilow        ciupp    log.est
 alpha  5.953437e+00 6.027767e-01 5.880023e+01  1.7839686
 beta   6.739530e-01 3.709698e-01 1.224392e+00 -0.3945949
 r      5.838759e-01 1.307754e-01 2.606844e+00 -0.5380668
 rc     1.019929e+00 5.202095e-01 1.999684e+00  0.0197326
 rold   4.028541e+00 6.496000e-03 2.498339e+03  1.3934043
 m      1.635013e+04 1.407232e+04 1.899663e+04  9.7019911
 K      8.157335e+04 3.252902e+04 2.045623e+05 11.3092579
 q      2.680398e+00 1.200601e+00 5.984113e+00  0.9859654
```

```
 n      1.144935e+00 4.262626e-01 3.075277e+00  0.1353477
 sdb    7.270290e-02 7.374600e-03 7.167494e-01 -2.6213742
 sdf    2.879310e-01 2.006362e-01 4.132069e-01 -1.2450344
 sdi    4.328320e-01 2.856649e-01 6.558159e-01 -0.8374056
 sdc    1.940520e-01 1.384353e-01 2.720127e-01 -1.6396292

Deterministic reference points (Drp)
          estimate        cilow        ciupp    log.est
 Bmsyd 3.206132e+04 1.787128e+04 5.751844e+04 10.3754056
 Fmsyd 5.099643e-01 2.601047e-01 9.998418e-01 -0.6734145
 MSYd  1.635013e+04 1.407232e+04 1.899663e+04  9.7019911
Stochastic reference points (Srp)
          estimate        cilow        ciupp    log.est  rel.diff.Drp
 Bmsys 3.194428e+04 17892.733587 5.703080e+04 10.3717484 -0.0036639589
 Fmsys 5.097952e-01     0.260226 9.987132e-01 -0.6737462 -0.0003317246
 MSYs  1.628502e+04 13929.805229 1.903845e+04  9.6980010 -0.0039980707

States w 95% CI (inp$msytype: s)
                   estimate        cilow        ciupp    log.est
 B_2015.00      2.229148e+04 9576.0807984 51890.774099 10.0119600
 F_2015.00      7.272844e-01    0.3030335     1.745492 -0.3184377
 B_2015.00/Bmsy 6.978240e-01    0.2868442     1.697640 -0.3597884
 F_2015.00/Fmsy 1.426621e+00    0.5348476     3.805282  0.3553084

Predictions w 95% CI (inp$msytype: s)
                 prediction        cilow        ciupp    log.est
 B_2016.00      2.133983e+04 7.587624e+03 60017.278324  9.9683308
 F_2016.00      7.529931e-01 2.727893e-01     2.078522 -0.2836992
 B_2016.00/Bmsy 6.680331e-01 2.196647e-01     2.031588 -0.4034176
 F_2016.00/Fmsy 1.477050e+00 4.757591e-01     4.585676  0.3900470
 Catch_2016.00  1.578242e+04 1.014951e+04 24541.547281  9.6666518
 E(B_inf)      1.943177e+04           NA           NA  9.8746645
```

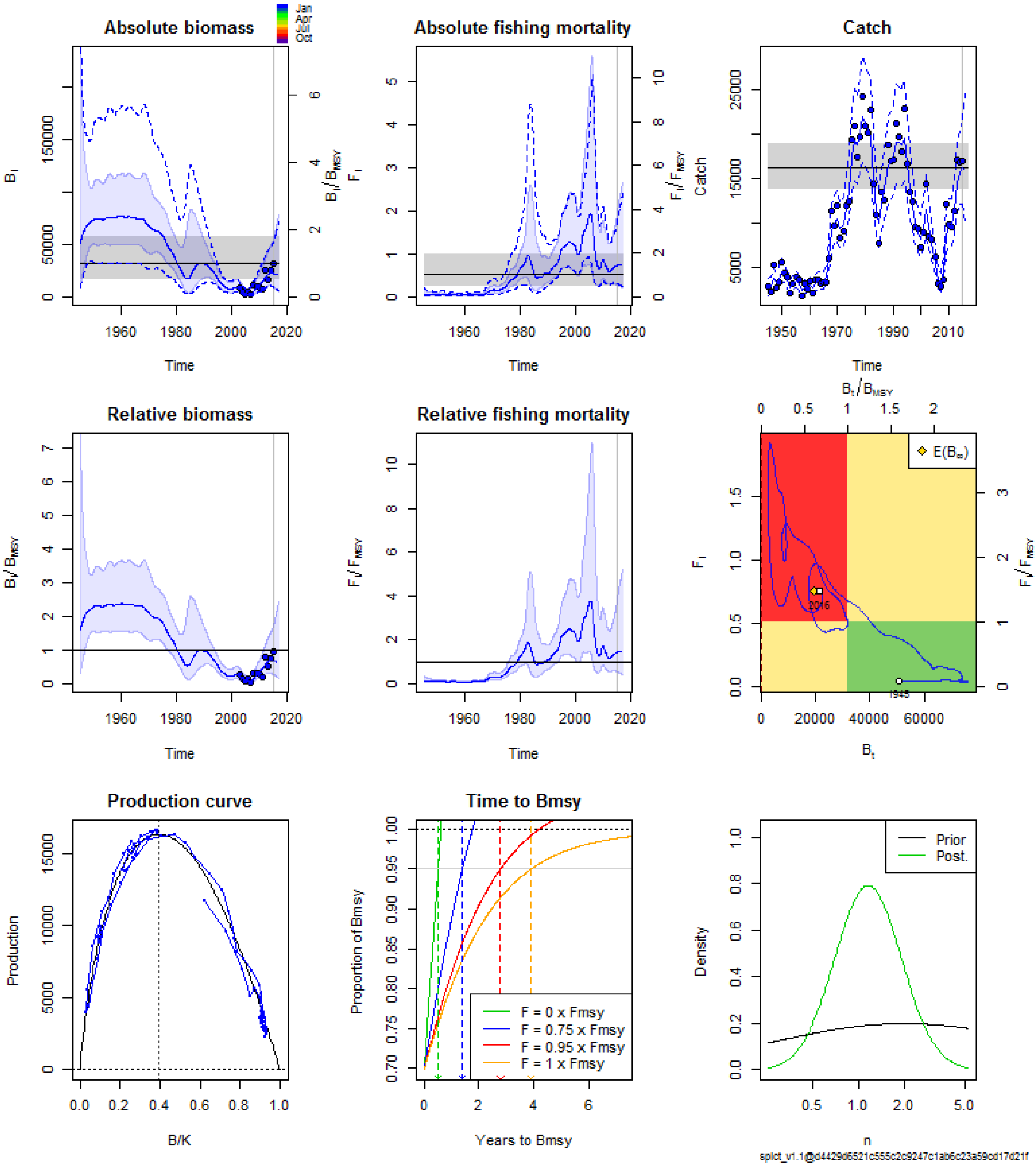


Figure 4.6.2 Standard SPiCT output for the assessment of anchovy in GSA 6.

The production curve (Figure 4.5.2) shows that the data have enough contrast (there are periods where the stock is under- and over-exploited) and the data can inform the data to estimate the exponent (n) of the surplus production model.

The fit of the data to the model is validated using the one-step-ahead (OSA) residuals and a retrospective analysis. The OSA residuals are not biased, not auto-correlated and normally distributed (Figure 4.5.3). Additionally, the retrospective analysis (Figure 4.5.4) shows no problematic patterns. Therefore, the assessment and the estimates are considered valid.

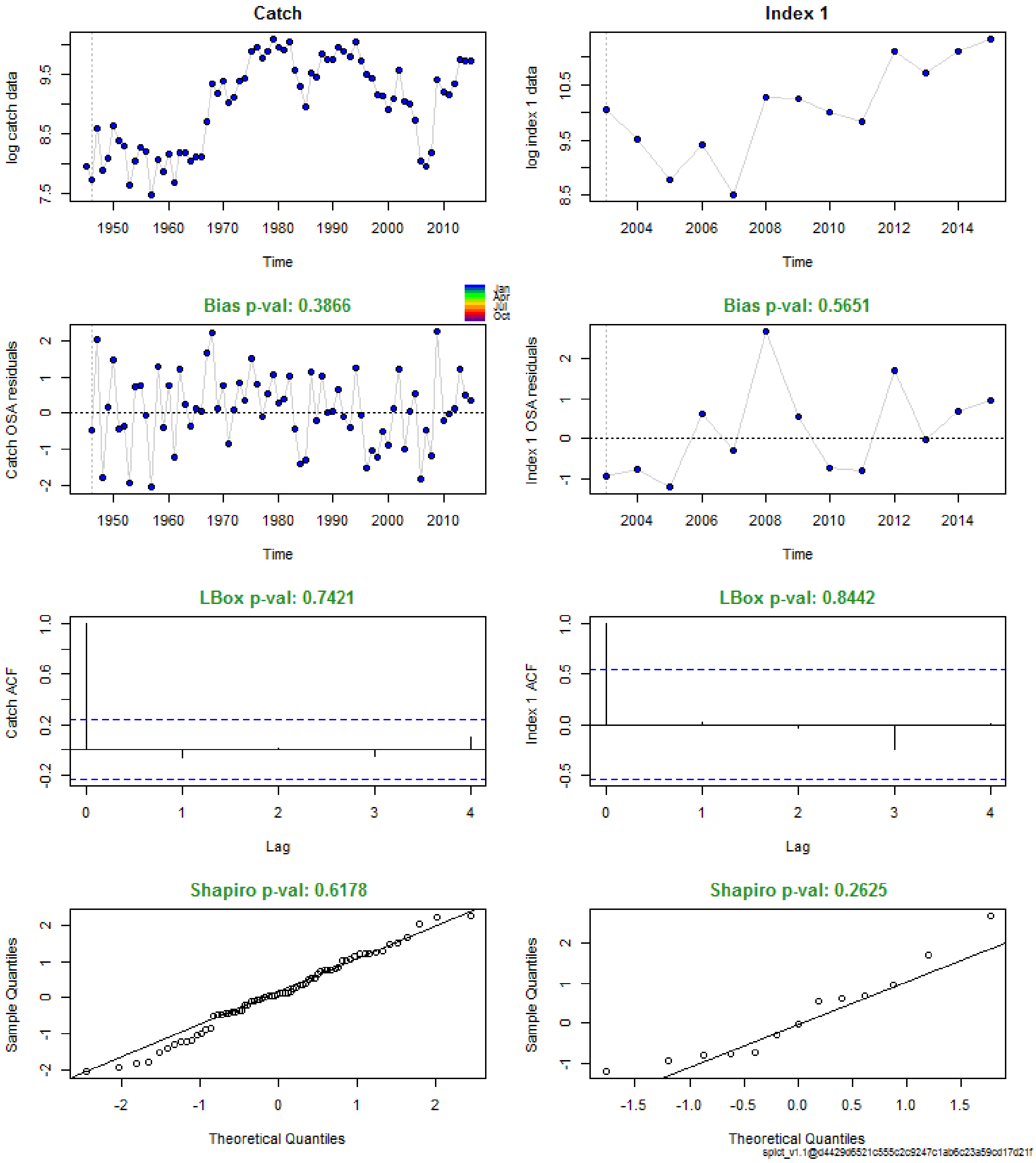


Figure 4.6.3 One-step-ahead-residual analysis of the anchovy in GSA 6 assessment.

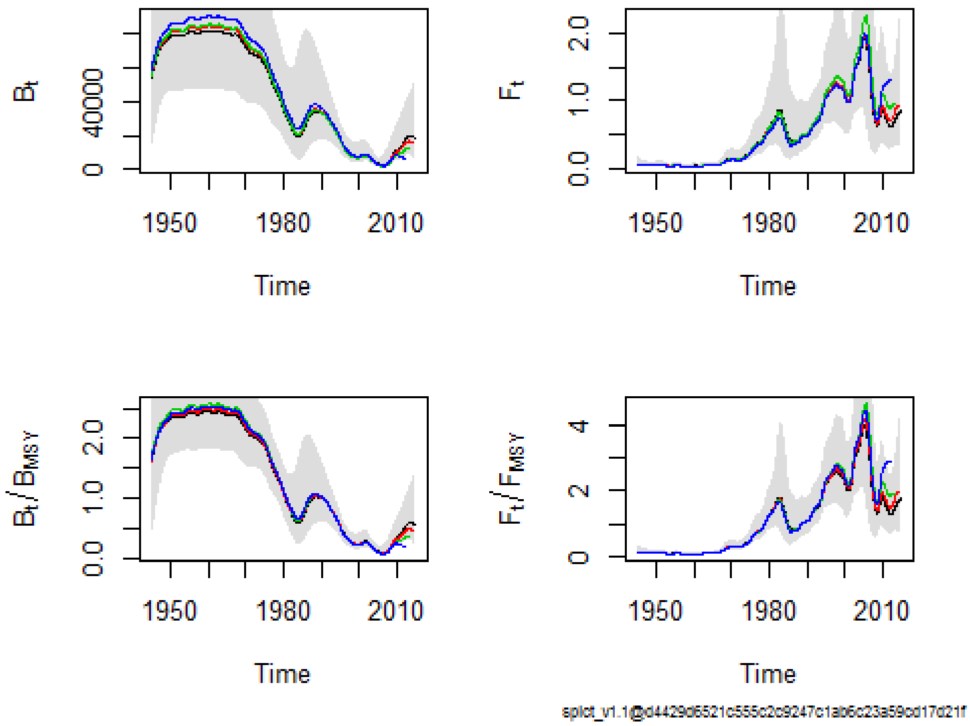


Figure 4.6.4 Retrospective analysis of the anchovy in GSA 6 SPiCT assessment.

SPiCT provides a stochastic forecast and a management table with the stock projection (in terms of, catch, biomass and status) under different management options in the following output.

```
## Observed interval, index:  2003.00 - 2015.00
## Observed interval, catch:  1945.00 - 2016.00
##
## Fishing mortality (F) prediction: 2017.00
## Biomass (B) prediction:          2017.00
## Catch (C) prediction interval:    2016.00 - 2017.00
##
## Predictions
##                         C        B      F    B/Bmsy  F/Fmsy perc.dB perc.dF
## 1. Keep current catch 16345.9  20351.4 0.787  0.637    1.543   -4.6     4.5
## 2. Keep current F     15782.4  20597.0 0.753  0.645    1.477   -3.5     0.0
## 3. Fish at Fmsy       11814.0  25034.7 0.510  0.784    1.000   17.3   -32.3
## 4. No fishing            21.7  37560.4 0.001  1.176    0.001   76.0   -99.9
## 5. Reduce F 25%       12790.4  23956.7 0.565  0.750    1.108   12.3   -25.0
## 6. Increase F 25%     18290.9  17699.8 0.941  0.554    1.846  -17.1    25.0
```

4.6.2.3 Comparison with the current ASPIC assessment

The latest assessment of the stock is presented in STECF (2016) and was done with ASPIC. Figure 4.6.5 shows that the stock status estimates are comparable for the two surplus production models, with the ASPEC results lying within the intervals on the SPiCT model. The SPiCT model provides a slightly more pessimistic view of current stock status (higher F and lower SSB, which comes from a wider dynamic range over the stock history. In addition the SPiCT model provides indication of model precision. ASPIC was not able to do this for this particular model fit.

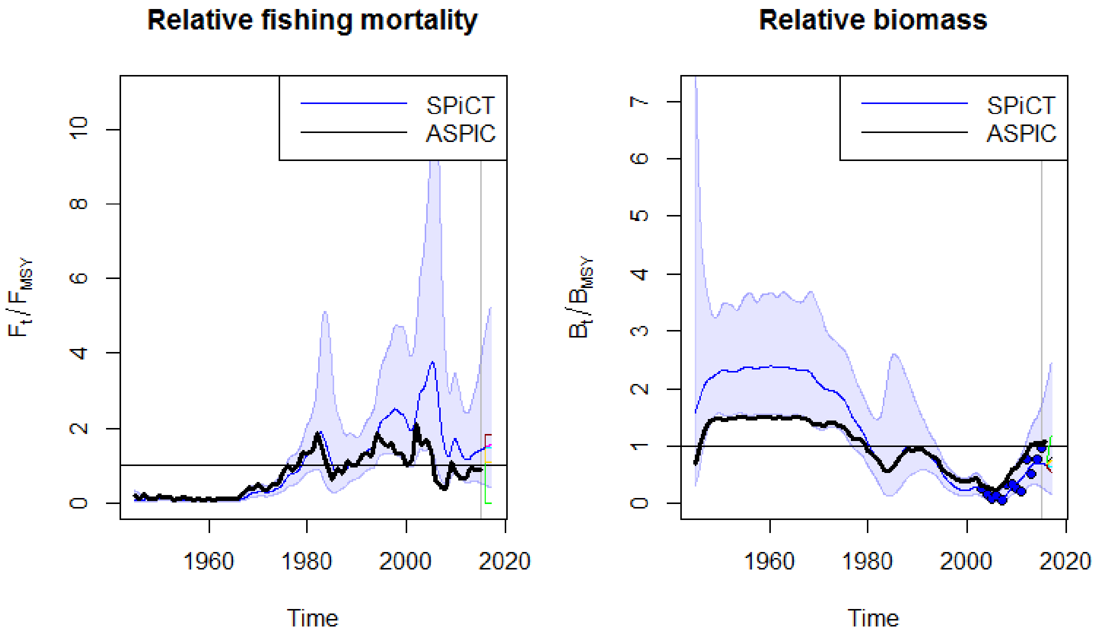


Figure 4.6.5 Comparison of SPiCT (solid blue line, shaded area is 95% confidence interval) and ASPIC (solid black line).

4.6.3 Conclusion

The assessment of anchovy in GSA 6 that is presented here is a good example of a stock where SPiCT can be used to make the assessment. The contrast in the data allows for good assessment of the stock status.

If SPiCT is to be used in the future to assess Mediterranean stocks, especially when the time series are short (10 years or less), the results have to be used only when the diagnostics (one-step-ahead residual analysis, retrospective analysis) indicate a good fit and no deviation from the assumptions.

It is important to state that some steps have to be taken to ensure that the biomass index is the correct one before it is used in a surplus production model. It has to be standardised and it has to be assured that is an index only of the exploitable part of the population.

If the biomass index comes from a scientific survey, only the part that is available to the commercial gear should be included in the biomass index. In other words, the calculation has to exclude smaller individuals that are captured by the survey gear but not by the commercial gear. A commercial CPUE reflects the exploitable biomass and no correction is needed.

5 ORGANISATION OF SPECIES BY GSA FOR THREE SPECIFIC AREAS

ToR: To carry out a critical review of the stock boundaries for the species and areas listed below. This review shall take into account the latest bioecological and fishery-related information available including, inter alia, recent analyses on the topic supported by DG MARE (see Annexes [X] 1). In the light of this review, propose scientifically sound stock units for:

a) anchovy (Engraulis encrasicolus) and sardine (Sardina pilchardus) in the western Mediterranean Sea (GSAs 5, 6, 7, 8, 9, 10 and 11);

b) common Pandora (Pagellus erythrinus), Norway lobster (Nephrops norvegicus) and common cuttlefish (Sepia officinalis) in the Adriatic Sea (GSAs 17 and 18); and

c) European hake (Merluccius merluccius) and red mullet (Mullus surmuletus) in the Ionian Sea (GSAs 19 and 20).

5.1 General approach

EWG17-02 was requested to carry out a critical review of the stock boundaries for the species and areas listed below:

a) Anchovy (*Engraulis encrasicolus*) and sardine (*Sardina pilchardus*) in the western Mediterranean Sea (GSAs 5, 6, 7, 8, 9, 10 and 11) - Figure5.1.1: blue area;

b) Common Pandora (*Pagellus erythrinus*), Norway lobster (*Nephrops norvegicus*) and common cuttlefish (*Sepia officinalis*) in the Adriatic Sea (GSAs 17 and 18) – Figure 5.1.1: red area;

c) European hake (*Merluccius merluccius*) and red mullet (*Mullus surmuletus*) in the Ionian Sea (GSAs 19 and 20) – Figure 5.1.1: yellow area.

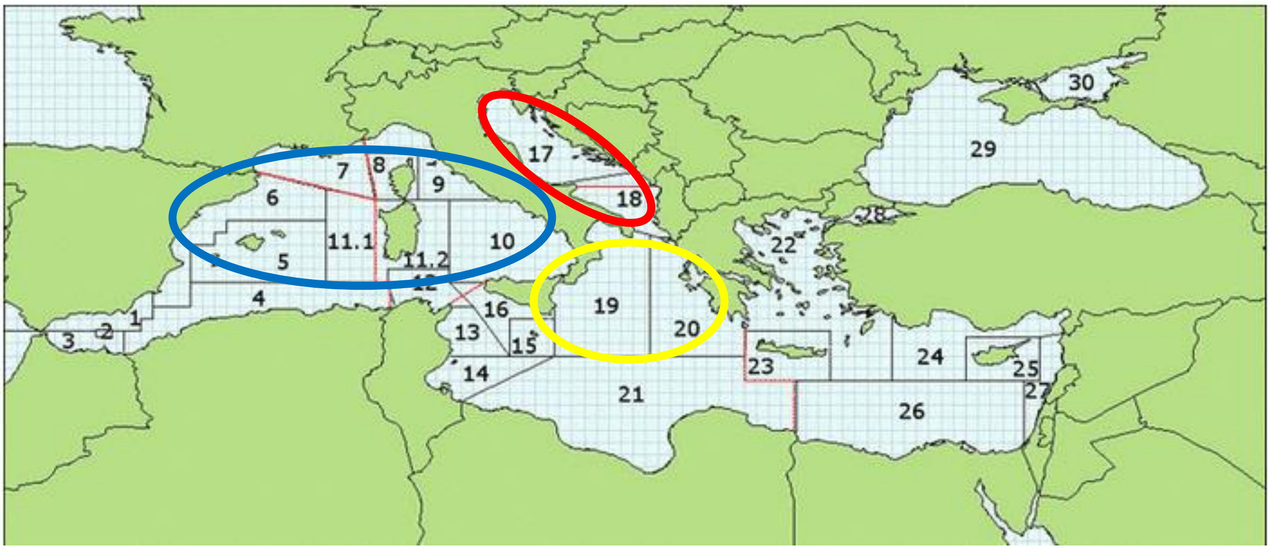


Figure 5.1.1-Map of GSAs in the Mediterranean Sea; red, blue and yellow areas are related to ToR 3.

It was expected that review of EWG17-02 would be based on the work previously done i.e. analyses of outcomes of STOCKMED project, supported by DG MARE and on the basis of *ad-hoc* contracts, carried during the first semester of 2017. However, no *ad-hoc* contracts are placed during the first semester of 2017, and results of analyses of outcomes of STOCKMED project were not available to the EWG 17-02. Therefore, EWG17-02 used STOCKMED Project final report directly as it is written, as main source of information on results of different kind of analyses preformed within the Project framework.

The STOCKMED project was aimed at identifying stock units and related boundaries for a group of demersal and small pelagic species which are considered important fishery resources in the Mediterranean Sea. Within the Project, various studies were performed, such as analyses of trends of abundance indices from scientific surveys (MEDITS), and information on local studies of biological information on otoliths, biometry, spawning and recruitment patterns, growth performances, and limited studies ion parasites, tagging, migration patterns and larval drifts. A synthesis of the spatial pattern of these biological data in the case study areas was made. Furthermore, available Genetic Stock Structure Analysis (GSSA) data assessing spatial population connectivity, as well as analyses of the geo-morphological, oceanographic and fishery spatial patterns have been reviewed. Finally, identification of the most probable stock units and stock boundaries has been made by multi-criteria approach and different outcomes were presented on the maps.

For most of species listed in ToR 3, EWG 17-02 used available information from STOCKMED Project Report. In addition, fishery related information collected through DCF (i.e. catch, discard, landings), as well as available surveys information (MEDITS) have been used as basis to provide a more complete response to Tor 3.

MEDITS surveys geo-referenced scientific data, which are useful for spatial analyses, have been used within STOCKMED Project framework. The Group noticed lack of coverage in some areas (i.e. GSA 7,8 and 9) on the map shown in the STOCKMED Project final report (Figure 5.1.2), but also realised that these data exist and were used in the analyses.

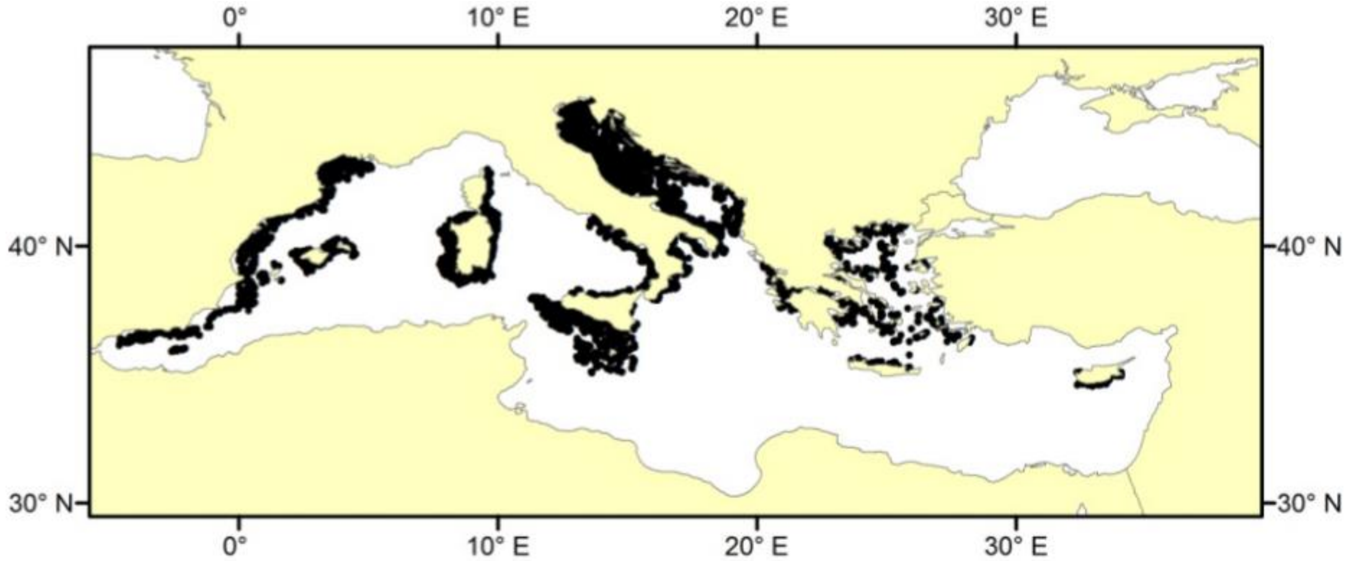


Figure 5.1.2 - Spatial coverage of MEDITS trawls across the Mediterranean Sea (from: STOCKMED Final Report)

MEDIAS surveys (Figure 5.1.3), although produce high quality scientific data, are focused on small pelagic species only (i.e. target species: anchovy and sardine). Despite the fact that spatial information of fish abundance are collected during surveys, according to current data calls MEDIAS provide information on GSA level only. Also, the EWG 17-02 noted that no acoustic surveys are carried out in the western part of Ionian Sea (GSA19), nor in the Balearic island area (GSA5), Corsica (GSA8) and Sardinia (GSA11).

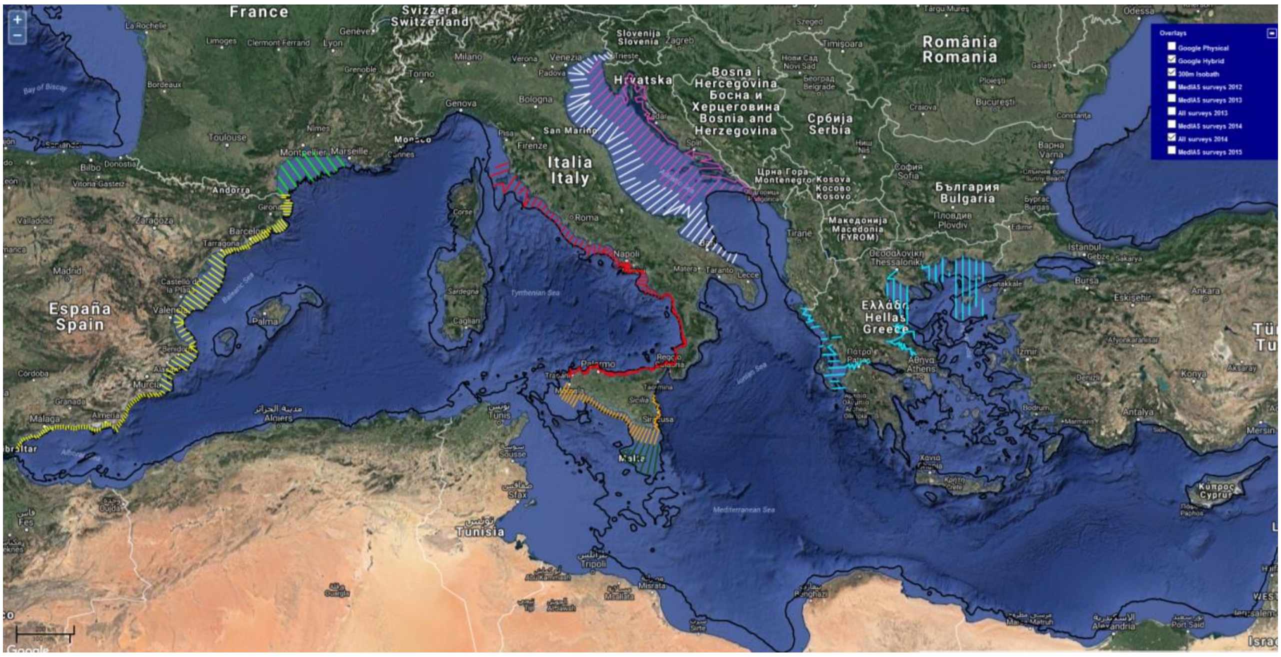


Figure 5.1.3 - Map of DFC-MEDIAS (http://www.medias-project.eu/)

In this section the EWG provides a summary of the situation and a conclusion by species for each of the 3 areas specified in the ToRs. These overall conclusions by stock are collected together and reported in Section 2 above. It should be noted that in some situations species/stock differences are not aligned directly with GSA boundaries. In order to allow existing reported data, particularly catch data, to be used for stock assessment, the EWG has proposed stock boundaries that make best use of the available stock differences observed combined with data availability at GSA level, giving a practical solution.

5.2 Anchovy (*Engraulis encrasicolus*) and sardine (*Sardina pilchardus*) in the western Mediterranean Sea (GSAs 5, 6, 7, 8, 9, 10 and 11)

Based on information available, EWG 17-02 noted that situation with stock units of anchovy (*Engraulis encrasicolus*) in the western part of the Mediterranean is quite complex. According to STOCKMED Project, three different stock units can be found in this area (Figure 5.2.1). During extensive discussion made and taking into consideration recent scientific paper on anchovy genetics (Zarraonaindia et al., 2012; Viñas et al, 2014), the EWG noted that possible mixing of different stock units may occur in GSAs 9 and 10, due to the fact that GSAs boundaries do not correspond to stock units boundaries.

In EWG's final conclusion is to propose two stock units, 1st stock unit is distributed in GSAs 5,6,7 and 9; 2nd stock unit is considered witin GSAs 8 and 11; 3rd stock unit is present in GSA10.

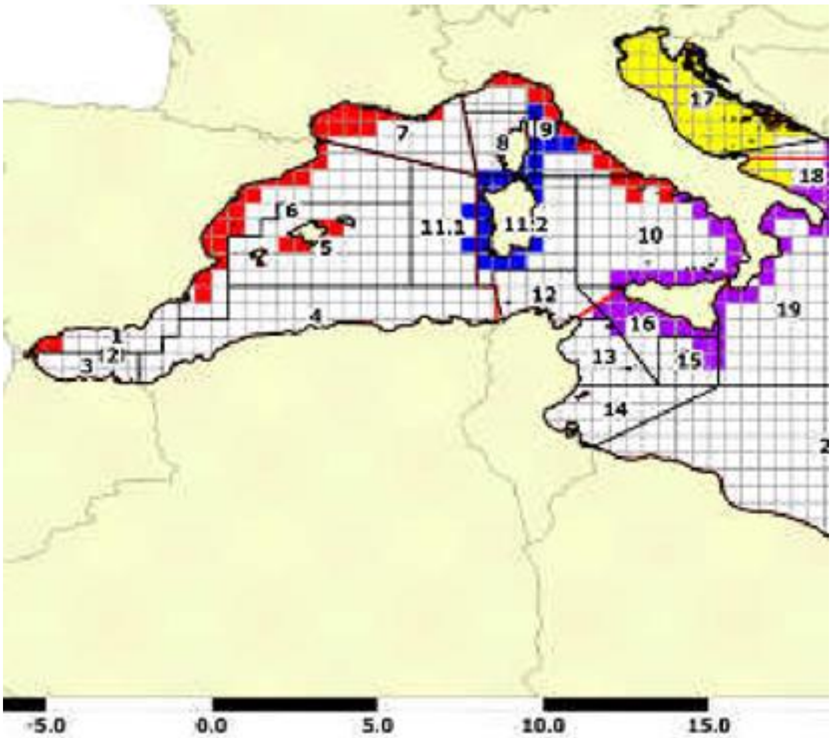


Figure 5.2.1 - Three different stock units (red, blue & violet) of anchovy in the western Mediterranean Sea (Source: STOCKMED Project)

In the case of sardine, two stock units were proposed according to outcomes of STOCKMED Project (Figure 5.2.2). One of them is present in the western part of this area (GSAs 5, 6 and 7), while another stock unit is present mostly in the central and eastern part of this area (i.e. GSAs 8, 9, 10 and 11). EWG noted that in GSA7 mixing of these two stock units of sardine may occur. After discussion made, emphasising that Gulf of Lyon is the most important part of GSA7 in relation to sardine abundance (i.e. the only part of this GSA covered by acoustic survey), EWG concluded that two stocks should be proposed: 1) GSA7 should be combined with GSAs 5 and 6 as containing one common stock unit of the sardine. The second stock unit of sardine is considered to be combined within GSAs 8, 9, 10 and 11.

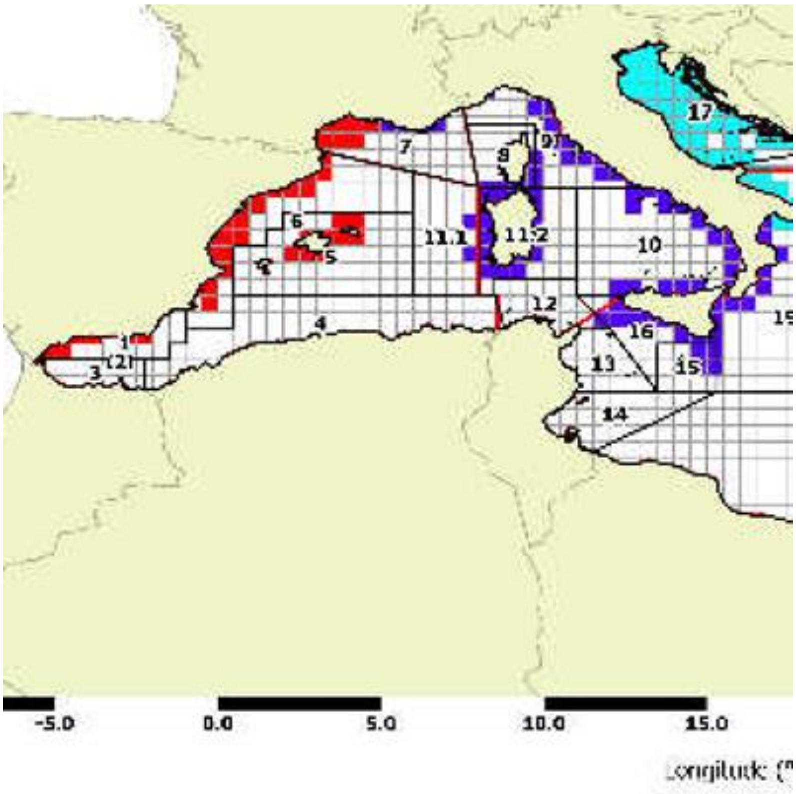


Figure 5.2.2 - Two different stock units (red & blue) of sardine in the western Mediterranean Sea (Source: STOCKMED Project)

5.3 Common Pandora (*Pagellus erythrinus*), Norway lobster (*Nephrops norvegicus*) and common cuttlefish (*Sepia officinalis*) in the Adriatic Sea (GSAs 17 and 18)

In the case of common pandora (*Pagellus erythrinus*) in the Adriatic Sea (GSAs 17 and 18), outcomes of STOCKMED Project suggest the existence of two different stock units in this area (Figure 5.3.1). EWG discussed available evidence, pointing out the fact that as a demersal species, common pandora is not distributed deeper than 300 m, and usually inhabits depth layers from 20 to 100 m (www.fishbase.org). Therefore, depths greater than 200-300 m may represent a barrier (i.e. Pomo pit in GSA17), limiting spatial distribution of this species to shallow parts of the Adriatic Sea. Thus, EWG agreed that in the Adriatic Sea two stock units of common pandora probably exist, and despite of their possible mixing in southern part of GSA17, EWG suggests that given data availability for now <u>stock units from GSAs 17 and 18 should be considered as separate stocks</u>. However, possibility to combine these two GSAs in the Adriatic Sea in the future, in light of future research studies, is not excluded.

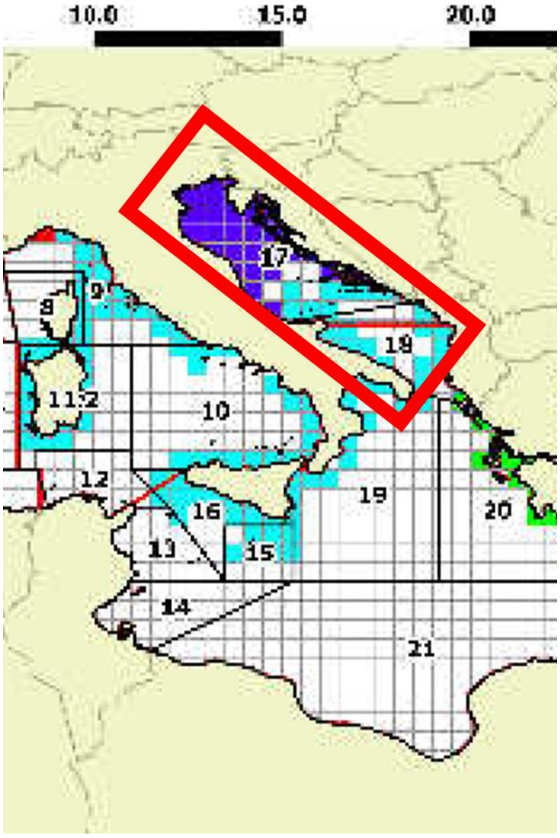


Figure 5.3.1 - Two different stock units (dark blue & light blue) of common pandora (*Pagellus erythrinus*) in the Adriatic Sea. (Source: STOCKMED Project)

In the case of Norway lobster (*Nephrops norvegicus*) in the Adriatic Sea (GSAs 17 and 18), outcomes of STOCKMED Project suggest existence of only one single stock unit in this two GSA areas (Figure 5.3.2). In the discussion made within EWG, different opinions were expressed, pointing out the possibility that in some smaller isolated parts of GSA17, separated stocks may exist According to recent work, it seems that more that one population may exist in GSA17, there is strong evidence of difference size and possibly growth in different parts of the Adriatic, though this currently cannot be assigned to separate stocks it is an indication of differetial development across the area. Practically it has so far been not possible to provide multiple assessments for Norway Lobster in GSA17-18 and thus estimation and management may need to be at a single unit scale until more detailed information becomes available. For the time being, based on the evidence currently available, the EWG concluded that Norway lobster within entire Adriatic Sea should be considered as one single stock unit. However, possibility to separate these two GSAs in the Adriatic Sea in the future, in light of new research studies in the future, is not excluded.

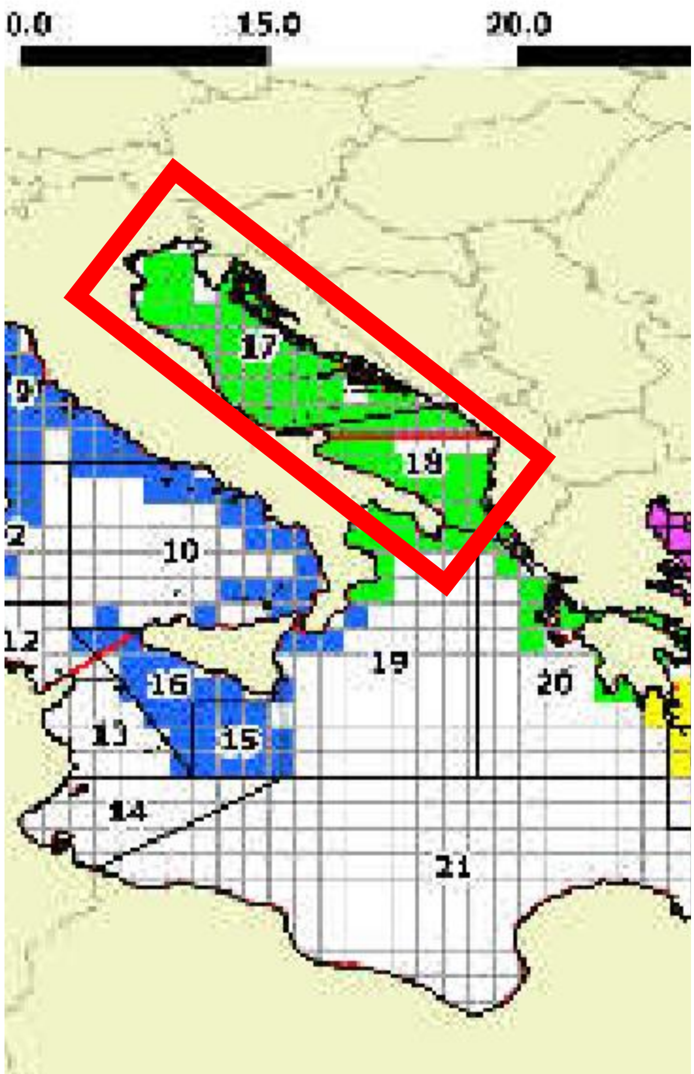


Figure 5.3.2 - One single stock unit (green) of Norway lobster (*Nephrops norvegicus*) in the Adriatic Sea. (Source: STOCKMED Project)

Common cuttlefish (*Sepia officinalis*) in the Adriatic Sea (GSAs 17 and 18) has not been analysed within STOCKMED Project framework. Therefore, EWG has studied other sources of information available. Beside of some publications available, MEDITS geo-referenced data from GSAs 17 and 18 were considered as the best suitable to deal with spatial related issues.

Using these data, the EWG analysed the spatial distribution of abundance and biomass indexes within GSAs 17 and 18 (Figure 5.3.3 and 5.3.4). The EWG noted continuous distribution of abundance along the coast (except to the eastern part of GSA18), EWG concluded that at the moment there is no evidence from the survey data that suggest existence of more than one stock unit of common cuttlefish in the Adriatic Sea.

Biomass and abundance indices show variation with no clear trend. The highest values of indices were recorded in shallower depth strata (less than 50 m). Population density is significantly higher in the northern part of Adriatic (GSA 17) than in GSA 18. (Figure 5.3.5 and 5.3.6). In GSA 18 MEDITS surveys in 1994 and 1995 were conducted only in Italian waters, Albania joined from 1996 and Montenegro from 2008 (except in 2009). Occurrence of *Sepia officinalis* during MEDITS surveys shows low values with higher occurrence in GSA 17 than in GSA 18, especially in Slovenian territorial waters. In GSA 18 trend of occurrence shows dispersed values between years (Figure 5.3.7). Average body length of common cuttlefish from sampled population in GSA 17 during summer period shows less variation among years in comparison to the GSA 18 (Figure 5.3.8).

Analysing the fisheries related data, the lack of information is evident. The length frequency distribution data of *Sepia officinalis* caught and landed by main fishing gears (OTB, setnets and FPO) are available only from Italian side for some years. No data about catches of this species from Albania and Montenegro are currently available. Discard data were recorded in some years in Slovenian territorial waters with very low values (Table 1). There is also lack of information regarding growth parameters. Only data for Length-weight relationship were recorded properly by countries (Italy and Slovenia) (Table 2). Length frequency data from the landed catches of the main commercial fishing gears were recorded for some years only by Italy (Figure 14, 15 and 16).

In conclusion common cuttlefish should be considered as a single in GSA 17 and 18. However it is noted that there does not currently appear to be sufficient data being reported to inform management for this area i.e. there is not sufficient information to obtain estimate stock status in terms of exploitation rates or biomass.

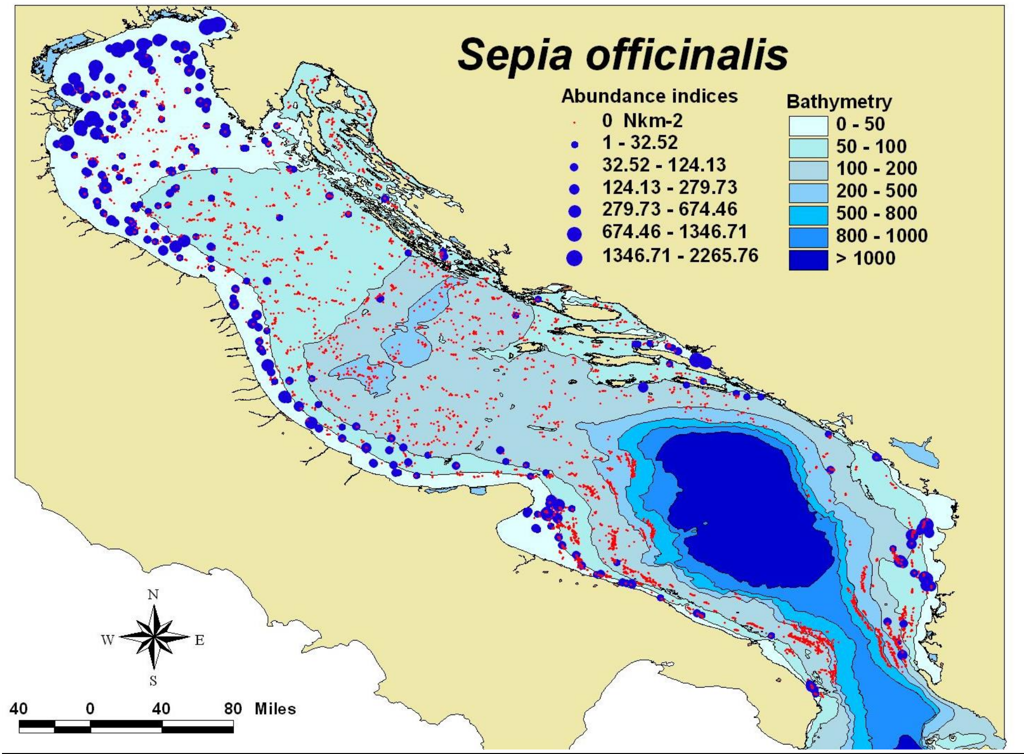


Figure 5.3.3 - Abundance indices in the Adriatic Sea of common cuttlefish (*Sepia officinalis*) according to MEDITS data analysed.

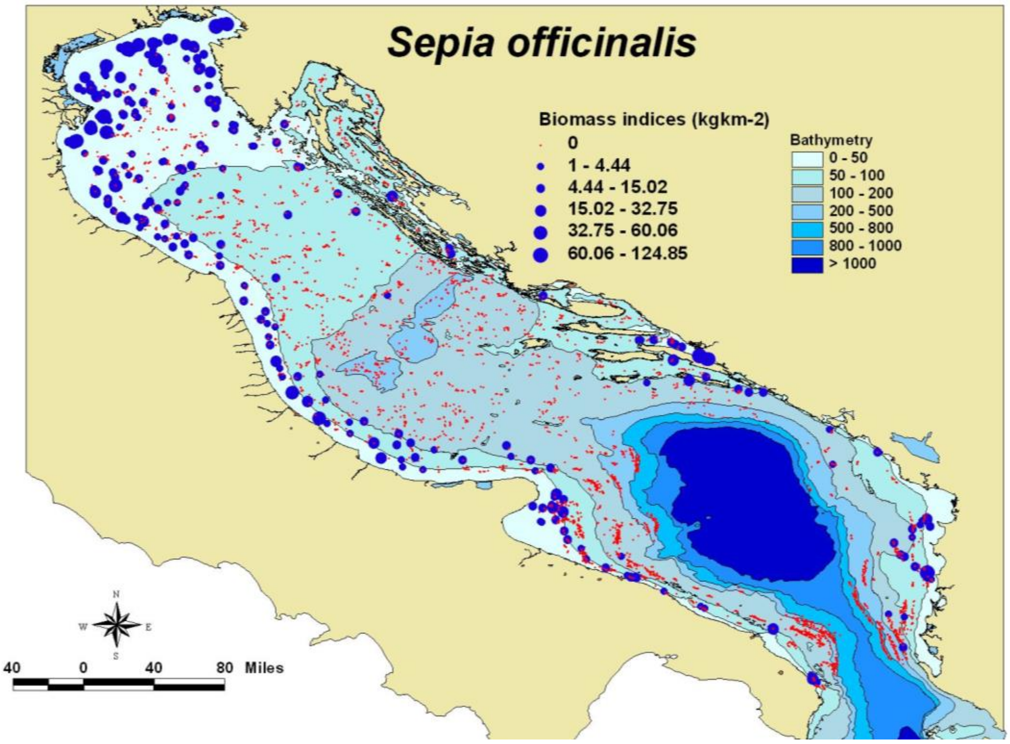


Figure 5.3.4 - Biomass indices in the Adriatic Sea of common cuttlefish (*Sepia officinalis*) according to MEDITS data analysed.

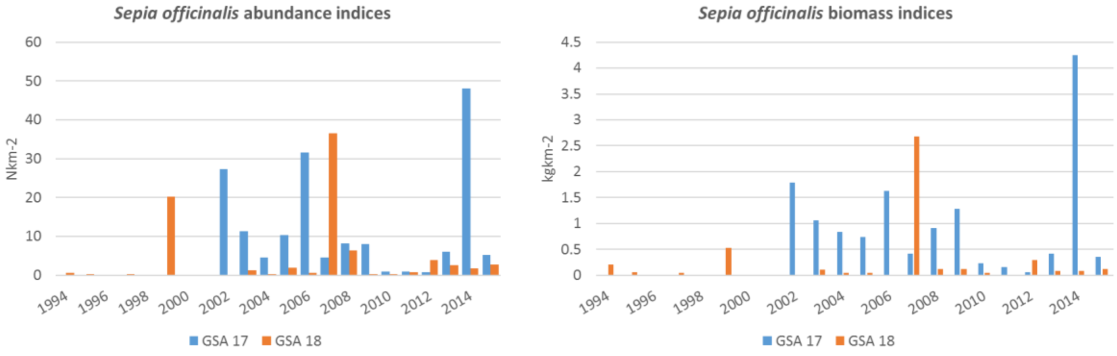


Figure 5.3.5 - *Sepia officinalis* trends of abundance (a) and biomass (b) indices in GSA 17 and 18 from the MEDITS survey

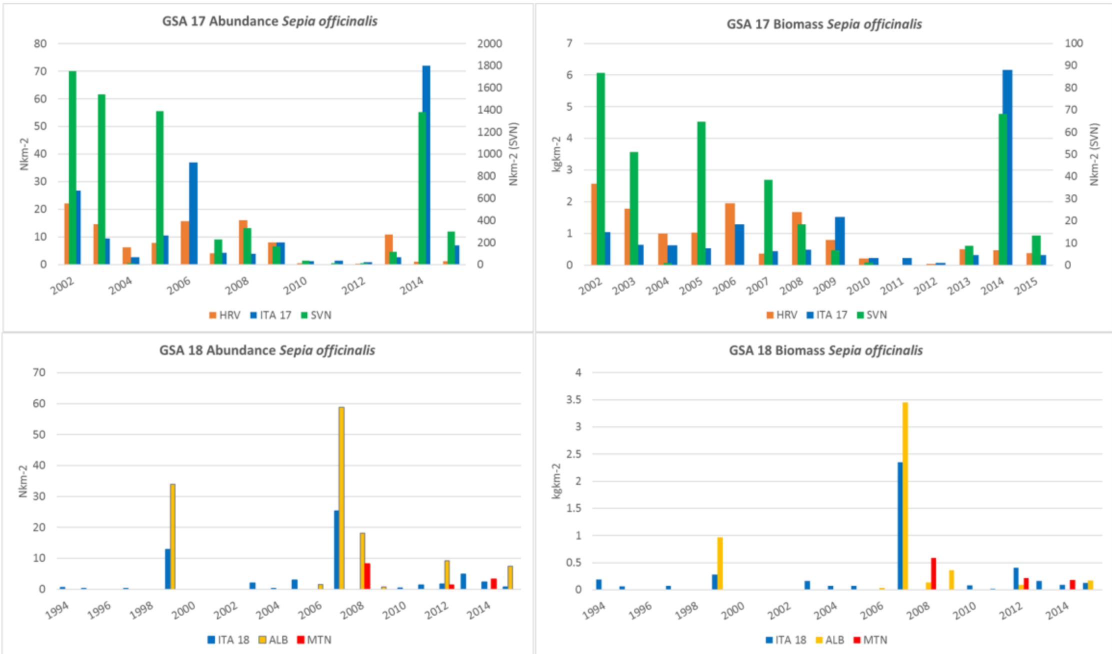


Figure 5.3.6 - Trends of abundance (a) and biomass (b) indices in GSA 17 and 18 from the MEDITS survey by country

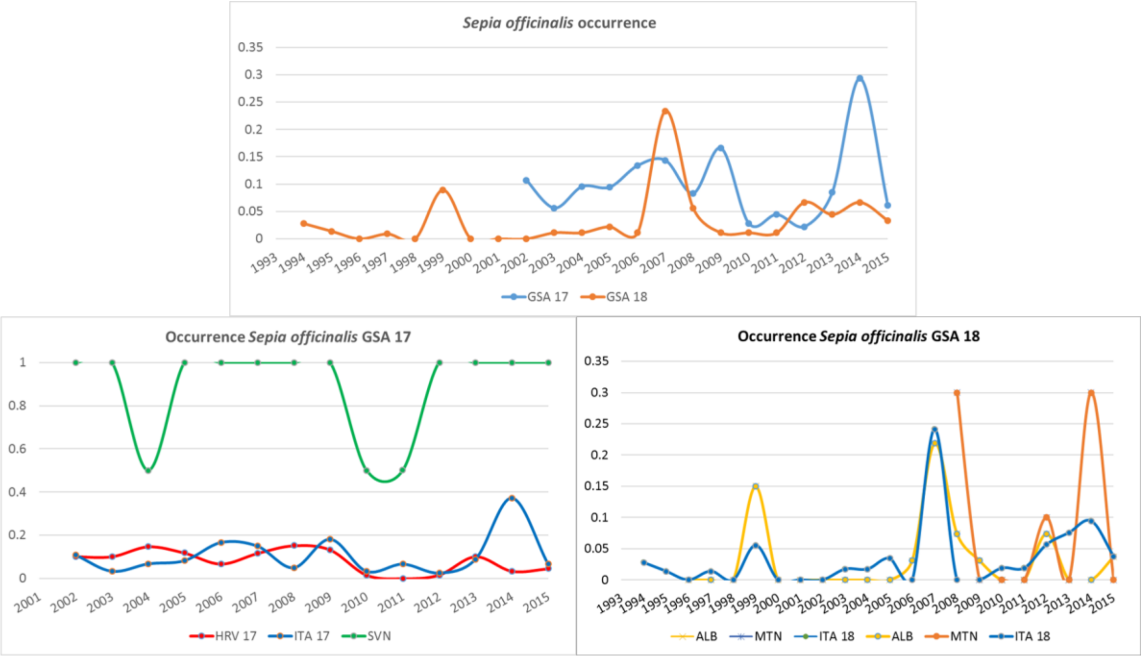


Figure 5.3.7 - Occurrence (Fraction of hauls with one or more individuals) of *Sepia officinalis* through MEDITS surveys in GSA 17 and 18 (a) and by countries (b; c)

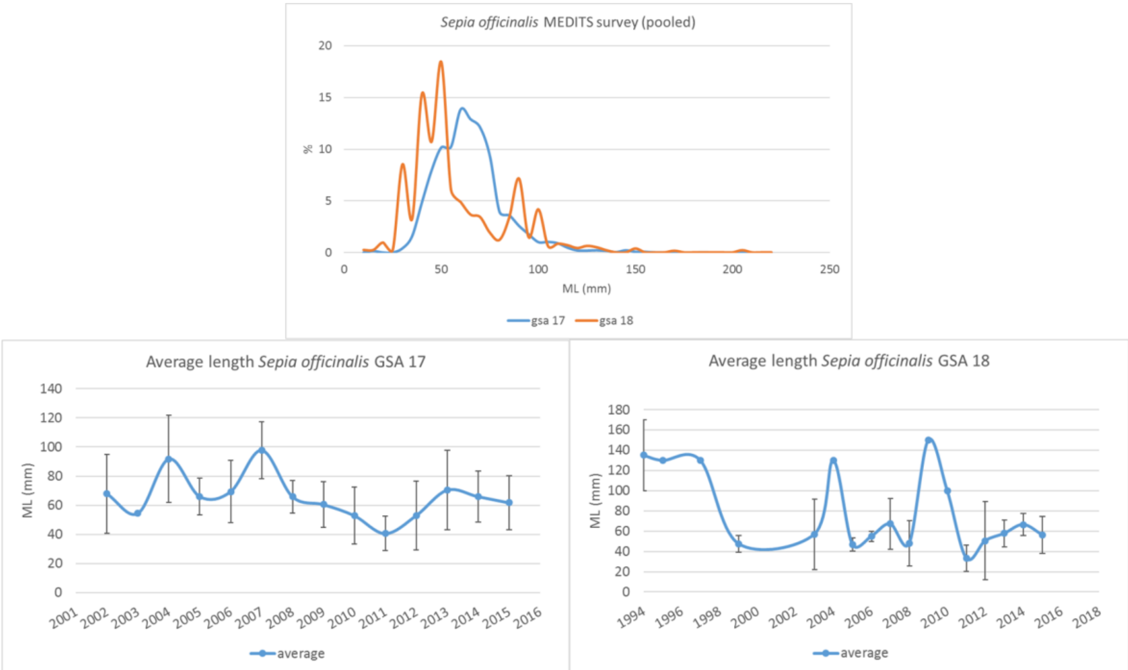


Figure 5.3.8 - Length frequencies distribution of *Sepia officinalis* through MEDITS surveys in GSA 17 and 18 (a) and average body length (b,c)

Table 5.3.1 - Availability of fisheries related data of *S. officinalis* by countries in GSA 17 and 18

	SVN	OTB ITA17	ITA18	HRV		SVN	SETNETS ITA 17	ITA 18	HRV		SVN	ITA 17	FPO ITA 18	HRV
2005	18.941					1.382					0.007			
2006	21.925	1921	1007.485			1.919		443.9672			0.024			
2007	36.79	2339	686.0026			3.324		409.2237			0.043	2518		
2008	12.122	2183	642.3298	3.7102		2.498		317.2352	15.7801		0.005	2250		0.6121
2009	10.06	1782	795.3156	27.8972		3.455		447.44	15.09134		0.011			0.6459
2010	4.558	1200	593.2526	28.02882		2.144		546.9514	21.3421		0.055			0.5353
2011	6.661	822	505.1715	44.48265		1.481	239	360.3767	35.56915		0.031	697		0.4199
2012	9.233	1043	473.7444	107.9536		0.728	244	189.6985	34.37776		0.019	692		0.282
2013	1.839	1259	458.38	96.6763		0.985		527.6133	48.53078		0.031	767		0.3564
2014	3.153	1389	468.3309	99.3742		1.684	101	225.8426	48.86314		0.008	641	32.43067	0.32531
2015	1.943	1285	548.7065	70.7		1.973	102	225.9706	53.5		0.022	725	0.4149	0.8
	No LFD													

No LFD

Table 5.3.2 - Availability of growth parameters data of *S. officinalis* by countries in GSA 17 and 18

id	country	area	start_y	end_ye	species	sex	vb_linf	vb_k	vb_t0	vb_sam	vb_size	vb_unit	vb_met	a	b	l_w_sa	l_w_siz	l_w_un
6	SVN	GSA 17	2002	2015	CTC	C	16.4			587	2.9-15.5 cr	cm	Linf estim	0.2182	2.757	1036	1.9-15.5 cr	cm
980	ITA	SA 17	2013	2013	CTC	C					"	"	"	0.1893	2.841	546	2-23 cm	cm/g
981	ITA	SA 17	2013	2013	CTC	M					"	"	"	0.2409	2.735	252	3-17 cm	cm/g
982	ITA	SA 17	2013	2013	CTC	F					"	"	"	0.1947	2.838	280	3-23 cm	cm/g
983	ITA	SA 17	2012	2012	CTC	C					"	"	"	0.2356	2.786	493	3-19 cm	cm/g
984	ITA	SA 17	2012	2012	CTC	M					"	"	"	0.2924	2.676	191	4-18 cm	cm/g
985	ITA	SA 17	2012	2012	CTC	F					"	"	"	0.2418	2.784	203	4-19 cm	cm/g
986	ITA	SA 17	2011	2011	CTC	C					"	"	"	0.3123	2.65	798	3-22 cm	cm/g
987	ITA	SA 17	2011	2011	CTC	M					"	"	"	0.399	2.536	311	3-22 cm	cm/g
988	ITA	SA 17	2011	2011	CTC	F					"	"	"	0.3084	2.668	391	3-20 cm	cm/g
989	ITA	SA 17	2010	2010	CTC	C					"	"	"	0.368	2.59	2050	3-19 cm	cm/g
990	ITA	SA 17	2010	2010	CTC	M					"	"	"	0.475	2.468	960	3-19 cm	cm/g
991	ITA	SA 17	2010	2010	CTC	F					"	"	"	0.353	2.613	1074	3-18 cm	cm/g

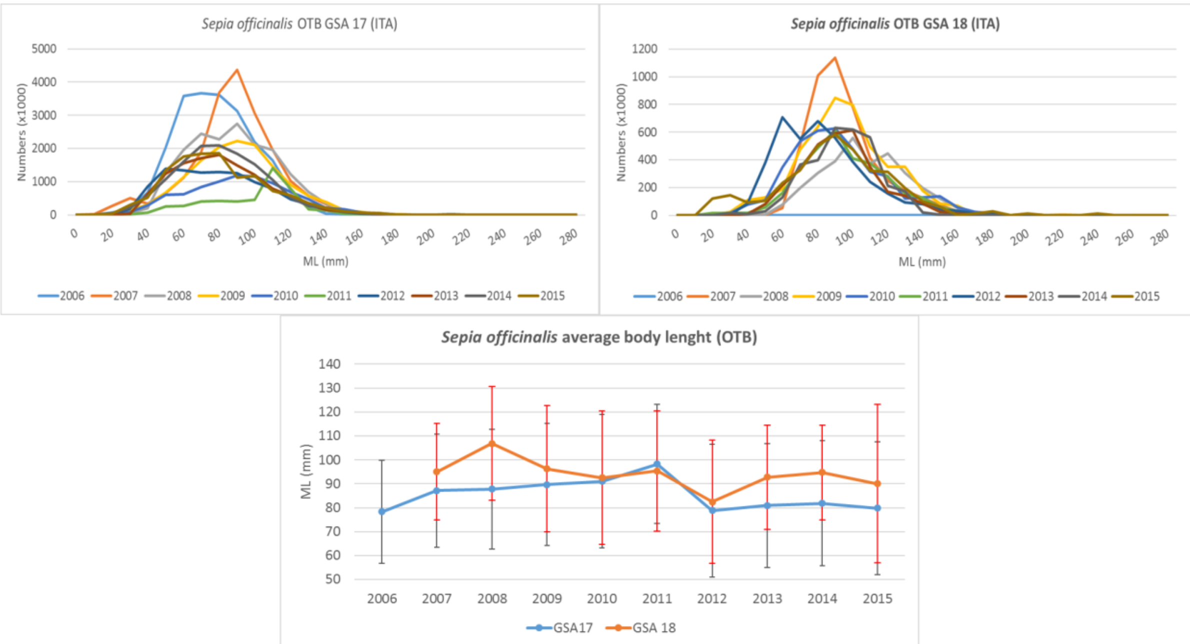


Figure 5.3.9 - Length frequency distribution of *Sepia officinalis* landed from OTB catches in GSA 17 (a) and 18 (b) and average body length (c)

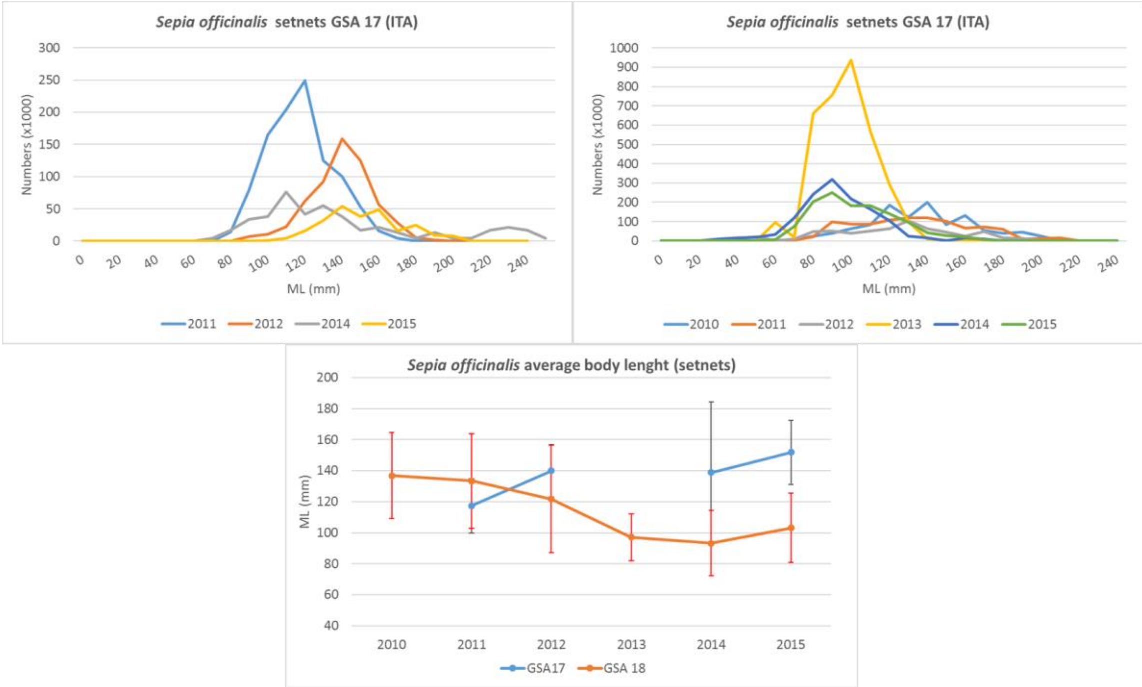


Figure 5.3.10 - Length frequency distribution of *Sepia officinalis* landed from setnets catches in GSA 17 (a) and 18 (b) and average body length (c)

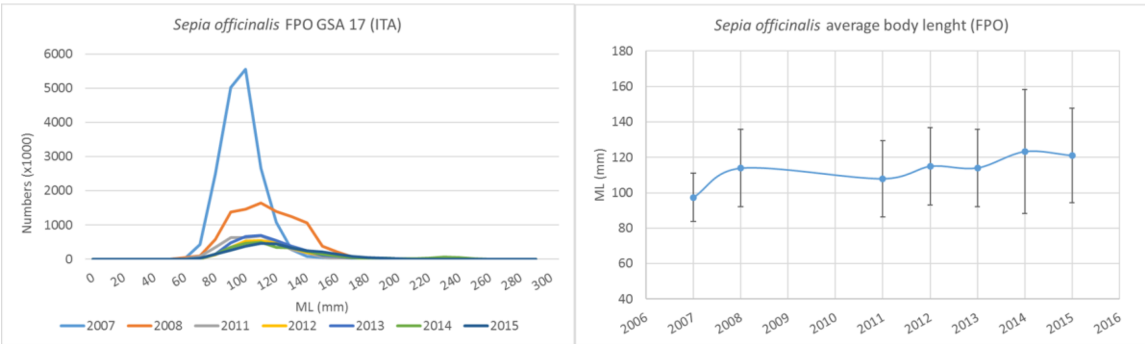


Figure 5.3.11 - Length frequency distribution of *Sepia officinalis* landed from FPO catches in GSA 17 (a) and 18 (b) and average body length (c)

5.4 European hake (*Merluccius merluccius*) and red mullet (*Mullus barbatus*) in the Ionian Sea (GSAs 19 and 20)

Hake – The STOCKMED report suggests 2 different stock units are in eastern (GSA20) and western (GSA19) Ionian Sea (Figure 5.4.1); hake from eastern Ionian Sea (GSA20) belongs to stock unit from the Adriatic Sea, while hake from western Ionian Sea (GSA19) belongs to stock unit distributed in GSAs 7,8,9,10,11,15&16. Combining GSA 17,18 and 20 would appear to be a practical solution with data available to do this. The larger area to the west is more complex and good data from some GSAs are not available, thus proposing a single management unit extending from GSA 7 to 19 does not appear practical.

The proposal is for 2 units: GSA 17,18 and 20 should form a single stock unit. GSA 19 should be considered separately from the other three GSAs.

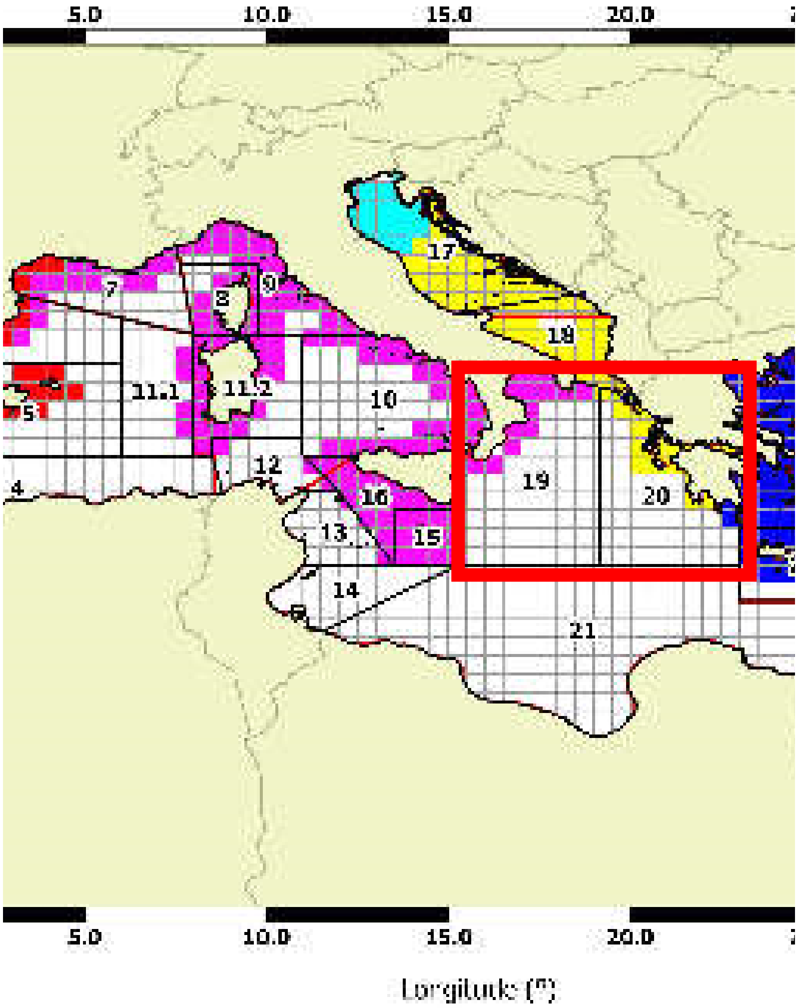


Figure 5.4.1 - Two stock units (violet and yellow) of the European hake (*Merlucius merluccius*) in the Ionian Sea. (Source: STOCKMED Project)

Red mullet - The STOCKMED report gives 2 different stock units in eastern (GSA20) and western (GSA19) Ionian Sea (Figure 5.4.2); red mullet from eastern Ionian Sea (GSA20) belong to the same stock unit distributed in the Adriatic and Eagean Sea, while those from western Ionian Sea belong to another stock unit distributed in the central and western Mediterranean Sea (GSAs 1,5,6,7,8,9,10,11,15&16). The situation is similar to hake, combining GSA 17,18 and 20 would appear to be a practical solution with data available to do this. The larger area to the west is more complex and good data from some GSAs are not available, thus proposing a single management unit extending from GSA 1 to 19 does not appear practical.

The proposal is for 2 units: GSA 17,18 and 20 should form a single stock unit. GSA 19 should be considered separately from the other three GSAs.

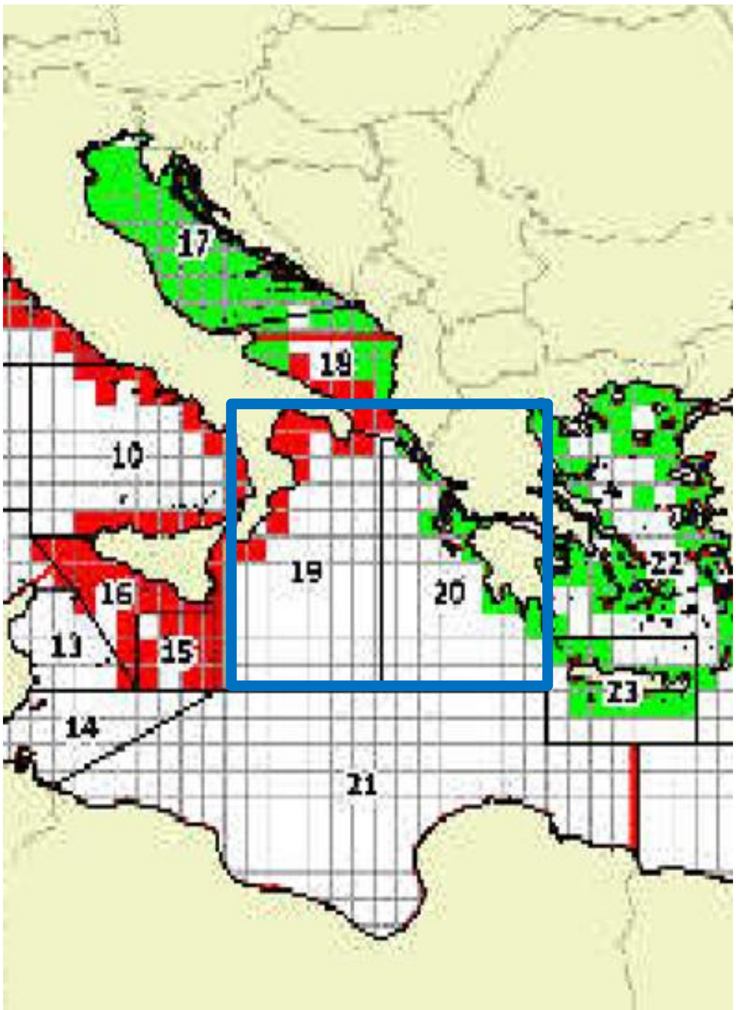


Figure 5.4.2 - Two stock units (red and green) of the red mullet (*Mullus barbatus*) in the Ionian Sea. (Source: STOCKMED Project)

6 REVIEW OF SPECIES AND GEAR BASIS FOR THREE SPECIFIC MAPS

ToR: *To advise on the stocks that should be considered, either as driving the fisheries or as relevant by-catches, for possible multiannual plans addressing the small pelagic fisheries of the Western Mediterranean Sea (GSAs 5, 6, 7, 8, 9, 10, 11), the demersal fisheries of the Adriatic and Ionian Seas (GSAs 17, 18, 19, 20) and the demersal fisheries of the Eastern Mediterranean Sea (GSAs 22, 23, 25). For this purpose, the annexes [1], [2] and [3] provide an overview of the main elements that could be considered so far.*

The advice shall provide also pros and cons of the geographical scope of each plan taking into account the content requirements of the multiannual plans, the distribution of the stocks, the dynamics and technical interactions between fleets as well as the scientific knowledge currently available to the scientific community. Synoptic overview of the information used in support of the advice shall be reported.

The three areas have been considered separately, for each area, a number of elements were checked: the STECF report on species selection from EWG 16-05 (STECF16-14) was consulted to determine if any species with high value landings has been omitted; the STECF report of landing obligation pt. 6 from EWG 15-14, (STECF 15-19) was checked to determine if any relevant fisheries or gears had been omitted; the value of catches of shellfish not included in EWG 16-05 were evaluated to see if any important species had been excluded because these had been omitted from that analysis due to the difficulties in providing vulnerability criteria for the PSA analysis used. The sub sections 6.1-6.3 below give proposals for a limited number of additions in both gears and species that the EWG considers should be monitored. The overall conclusions are summarised in Section 2

6.1 Possible MAP for demersal fisheries in the Adriatic and Ionian Seas

6.1.1 Hake (*Merluccius merluccius*)

Hake ranked first in the PSA/Landing value analysis in all GSAs of the Adriatic and Ionian Seas and was also among the most important target species exploited by the main fishing fleets operating in the area both in terms of landing volume and value. Additionally, hake was found among the most important target species driving the main Mediterranean demersal fisheries, since it was identified as such in all - set gillnet, trammel net, set longline and bottom otter trawl fisheries. (STECF-16-14)

According to the StockMed project report there are 6 different stock units of hake population in the Mediterranean (Figure 6.1.1.5). A few zones in this configuration e.g. the Gulf of Lakonikos along the Peloponnesus and the area West to Adalia (Turkey) present a slight mixture of elements belonging to two different contiguous clusters from neighbouring GSAs, possibly as a result of the influence of some thematic descriptors. On the other hand, it seems that the selected configuration for the Northern Adriatic Sea is driven more by the combination of the indicators used in the constrained clustering, since the cluster identified in the North is very likely the northernmost propagation of the stock unit identified in the rest of the Adriatic based on the current knowledge of the species distribution.

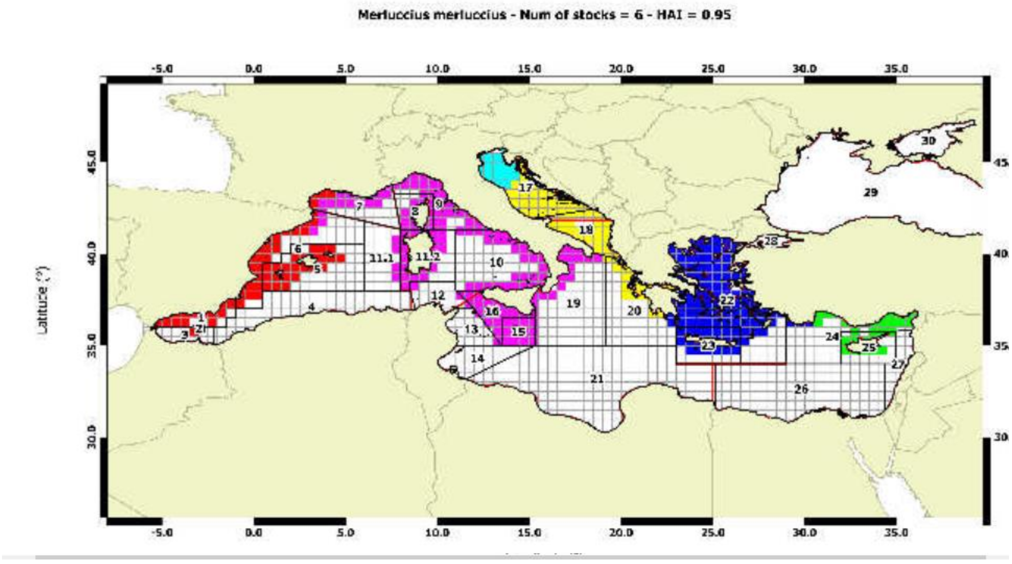


Figure 6.1.1.5: Hake stock units in Mediterranean (StockMed project)

Therefore, it seems that there is one stock unit of hake in GSAs 17, 18 and 20 and it is different from the stock unit distributed in GSA 19 which belongs to the Central and Western Mediterranean stock unit (See also section 5.4).

Stock assessment of hake has been previously performed jointly for GSAs17 and 18 and separately for GSAs 19 and 20.

6.1.1.1 GSA 17-18-20

Hake ranked first in the priority demersal species list prepared during the STECF 16-14 for all the three GSAs (17, 18 and 19; STECF-16-14). According to EWG 15-19 hake is one of the most important target species in terms of landing volume and value in the majority of the fisheries operating in the Adriatic Sea – Croatian and Italian bottom otter trawl fleets in GSA 17 as well as Italian bottom otter trawl and set longlines fleets in GSA 18. In addition, this species is exploited by 3 out of 4 Greek demersal species fisheries operating in the area, being among the most important target species in terms of landing value and volume for set gillnets, set longlines and bottom otter trawl fisheries. Additionally, hake is also among the most important species in terms of landing volume for the Greek trammel nets fishery of GSA 20. (STECF-15-19)

6.1.1.2 GSA19

Hake ranked first in the priority demersal species list in GSA 19 during the STECF 16-14, since both vulnerability and value indices were high for this species (STECF-16-14).

Hake is exploited by all Italian fisheries of the GSA 19 and ranks among the most important target species both in terms of landing values and landing volumes in set longlines, set gillnets and trammel nets fisheries. In addition, it is caught as a by-catch species in the three bottom otter trawl fisheries operating in the area. (STECF-15-19)

6.1.2 Red mullet (Mullus barbatus) and Striped red mullet (Mullus surmuletus)

Red mullet scored relatively low in the PSA/Landing value analysis performed in STECF 16-14, but it is heavily exploited in most of the Adriatic and Ionian Seas. Thus far, the two similar species coexisting in the Mediterranean Sea are often reported as Mullus spp., so the information provided in the reports and here as well, pertain to both the species and not specifically to the red mullet (*Mullus barbatus*). Hence, the Mullus spp. ranks among the most important target species in terms of value and volume of landings of the main fleets of all the GSAs suggested for inclusion in the MAP for demersal fisheries in the Adriatic and Ionian Seas. It is also one of the target species driving the main Mediterranean demersal fisheries. appearing as such in the analysis of set gillnet, trammel net, pole line and bottom otter trawl fisheries. (STECF-16-14)

According to the StockMed project report three stock units of red mullet exist in the Mediterranean Sea (Figure 6.1.2.1). This configuration suggests some border zones, i.e. the southernmost side of the Adriatic Sea (GFCM GSA18) and to a lesser extend a very small area on the border between the GSAs 22 and 24. Some elements of this cluster expand from the neighbouring GSA, possibly as a local effect of the combination of the indicators used in the constrained clustering and the thematic descriptors related to genetics and growth. Considering the distribution of the fishing effort in GSA18 (trawling 12-24 and small scale) and in GSA 22 the joining of such elements to the main neighbour areas is suggested. Thus, GSA 18 is globally aggregated with the cluster of GSAs 17, 20, 22 and 23, while 2 rectangles of GSA 22 are aggregated to GSA 24.

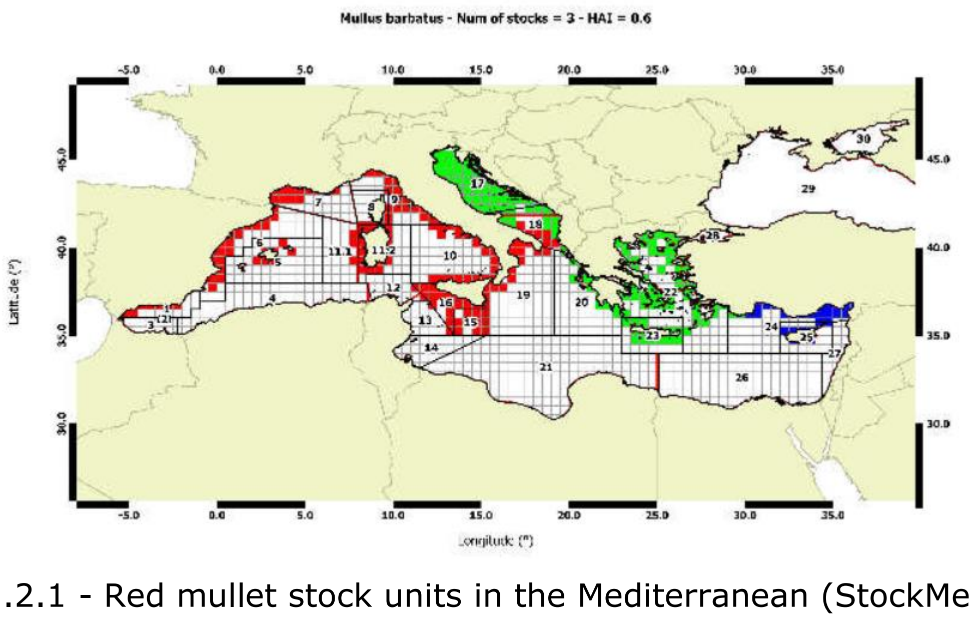


Figure 6.1.2.1 - Red mullet stock units in the Mediterranean (StockMed project)

In conclusion, the red mullet of GSAs 17, 18 and 20 belong to a different stock unit than the red mullet in GSA 19 which belongs to the Central and Western Mediterranean stock unit.

For striped red mullet the StockMed project found 6 stock units in the Mediterranean (Figure 6.1.2.2). According to this configuration there are some border zones like a small area in the Peloponnesus between GSA 20 and GSA22 and another very small area between GSAs 22 and 24, where very few rectangles from the clusters of the neighbouring GSAs are present. Another area which seems differentiated inside GSA 22 is the Gulf of Thessaloniki. These situations are probably spurious signs in the constrained clustering process where only 3 biological indicators could be considered. In addition, the thematic layers were not bringing such kind of signs. Thus, the two units identified in GSA 22 of the Aegean Sea were joined and finally 5 stock units were identified in the Mediterranean.

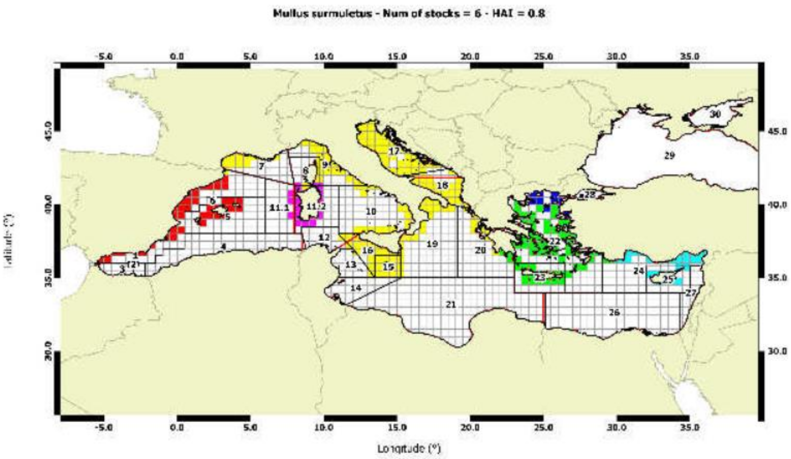


Figure 6.1.2.2 - Striped red mullet stock units in the Mediterranean (StockMed project)

Hence, there is one stock unit of striped red mullet in the Adriatic and Ionian area (GSA 17, 18, 19 and 20) according to the StockMed results.

6.1.2.1 GSA 17-18-20

Red mullet ranked 13th, 17th and 5th among the priority demersal species list prepared by STECF 16-14 for GSA 17, 18 and 20 respectively (STECF-16-14). This species is among the most important target species in terms of landing values and volume of the Croatian and Italian bottom trawl fleets operating in GSA 17 as well as the three Italian demersal species fisheries operating in GSA 18 – set gillnets, trammel nets and bottom otter trawls (STECF-15-19). Moreover, both species in the genus Mullus spp. rank among the most important target species of the three largest Greek fleets operating in GSA 20 – set gillnets, trammel nets and bottom otter trawls (STECF-15-19).

6.1.2.2 GSA 19

Red mullet was not ranked among the demersal species priority list in GSA 19 (STECF-16-14). However, both species in the genus Mullus spp. are among the most important species in terms of landing value and volume for the main Italian fisheries of GSA 19 – set gillnets, trammel nets and bottom otter trawls (STECF-15-19).

6.1.3 Norway lobster (*Nephrops norvegicus*) GSA 17-18

As regards Norway lobster, 7 stock units option was selected as the best in the StockMed project (Figure 6.1.3.1). In order to compare this configuration with the current GSA setting few rectangles in the GSA 19 belonging to the cluster of GSA 15 were aggregated with the GSA 17-20 cluster. Likewise, 2 rectangles in GSA 23 belonging to the cluster of GSA 24 were associated with the cluster of GSA 23. Some rectangles of the cluster of GSA 23 expanding into GSA 22 were considered part of GSA 22.

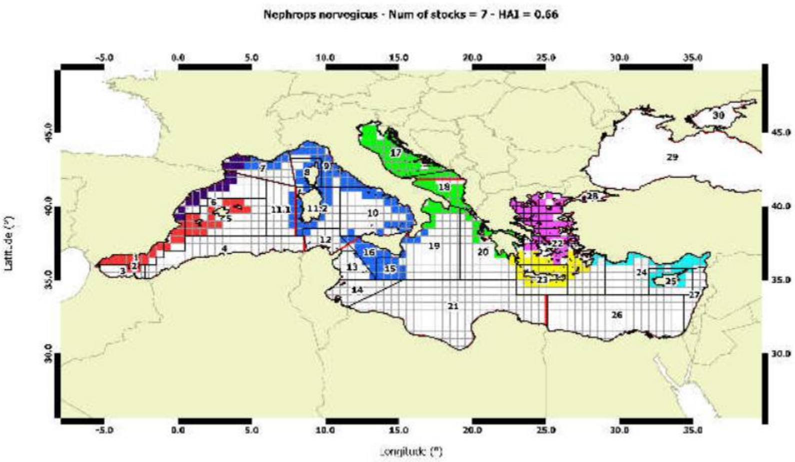


Figure 6.1.3.1 - Norway Lobster stock units in the Mediterranean (StockMed project)

Therefore, according to the StockMed project there is only one stock unit in the Adriatic-Ionian area that encompasses GSAs 17-20. However, recent work done in the SAC GFCM indicates that at least two stock units of Norway lobster are distributed in GSA 17 – one in the deepest part of the Adriatic Sea (Pomo Pit) and another in the shallowest part of GSA 17.

Norway lobster ranked 3rd and 4th in the demersal species priority list in GSA 18 and 17 respectively (STECF-16-14). It is also among the most important target species in terms of landing values and volumes of the Croatian and Italian bottom trawl fleets operating in GSA 17. Furthermore, Norway lobster is among the most important target species of the Italian bottom otter trawl demersal and deep-water species fisheries operating in GSA 18 and was also found to be one of the species driving the main Mediterranean fisheries, specifically set gillnet and bottom otter trawl fisheries (STECF-16-14). Therefore, it is reasonable to include this species in the possible MAP for demersal fisheries in the Adriatic and Ionian Seas.

6.1.4 Deep-water rose shrimp (*Parapenaeus longirostris*) GSA 17-18-19

For the deep-water rose shrimp, the configuration with 5 stock units was considered the best in the StockMed project (Figure 6.1.4.1). However, few rectangles belonging to the cluster of GSA 17 and expanding in GSA 18 on the Western side should instead be associated with GSA 18, vice versa for the rectangles belonging to the cluster of GSA 18 and expanding in GSA17 on the Eastern side of the Adriatic should be combined with GSA 17 stock unit. Similar considerations hold in GSA 24, where few rectangles belonging to the cluster of GSA 22 should instead be associated with GSA 24.

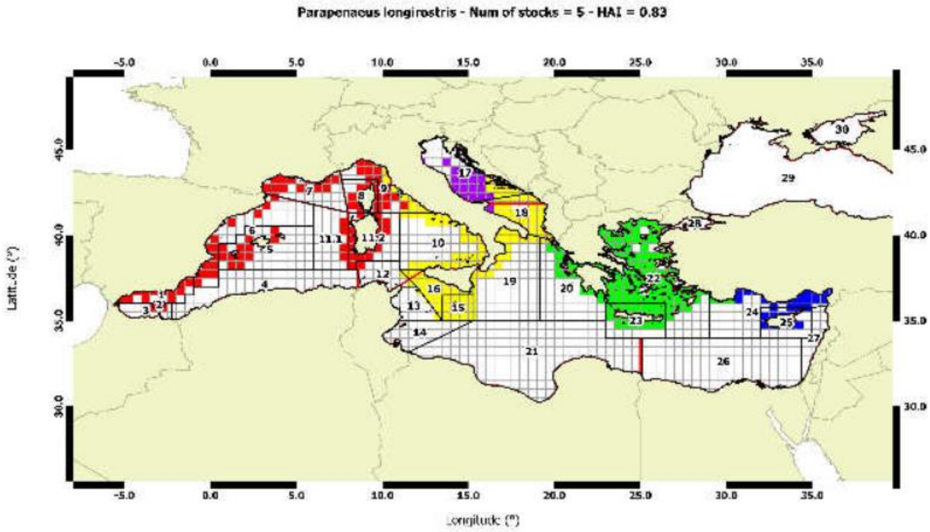


Figure 6.1.4.1 - Deep-water rose shrimp units in the Mediterranean (StockMed project)

According to the StockMed results there are three stock units of the deep-water rose shrimp in the Adriatic-Ionian area: GSA 17 forms one stock unit, GSAs 18 and 19 belong to another stock unit, and the Eastern Ionian Sea of GSA 20 belongs to the third stock unit.

Strong scientific evidence supports the inclusion of the deep-water rose shrimp in the MAP for demersal fisheries in the Adriatic and Ionian Seas. While it did not make it on the list of the demersal species priority list for GSA 17, it ranked 12th in GSA 18 and 6th in GSA19 (STECF-16-14). In addition, this species is among the most important target species in terms of landing value and volume of the Croatian bottom trawl fleet operating in GSA 17 as well as Italian bottom otter trawl fisheries operating in GSAs 18 and 19. Deep-water rose shrimp is also one of the target species driving the main Mediterranean demersal fisheries, namely the bottom otter trawl fishery. (STECF-15-19)

6.1.5 Common sole (Solea solea) GSA 17

A 5-stock units configuration has been defined by the StockMed project in the Mediterranean for common sole (Figure 6.1.5.1). According to this configuration there are some rectangles that expand to GSA 23 from the cluster of GSA 20. However, these differences very likely derive from the low number of indicators in the MEDITS survey available for the constrained clustering analysis. Hence, those rectangles were aggregated to the cluster of GSA 23. In addition, few rectangles belonging to the cluster of GSA 23 were present and consequently assumed as belonging to GSA 24, on the basis of the results from genetics studies. Finally, it is worth mentioning that, given the results from genetics studies, the East side of GSA 18 should be considered as a separate stock from the rest of the GSA 18.

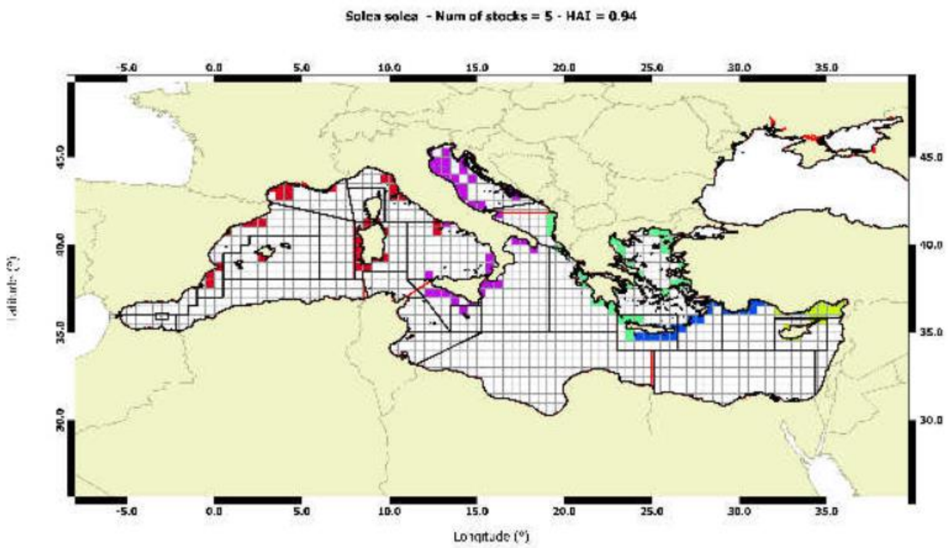


Figure 6.1.5.1 - Common sole units in the Mediterranean (StockMed project).

Therefore, two different stocks of common sole have been identified in the Adriatic and Ionian Seas: one encompassing GSA 17, Western part of GSA 18 and whole GSA 19 and another one distributed in the Eastern part of GSA 18 and in GSA 20.

Common sole ranked second in the demersal species priority list for GSA 17, but did not make the list in any of the other GSAs (STECF-16-14). It is also among the most important target species of the small scale fisheries (set gillnets and trammel nets) operating in the coastal areas of GSA 17 both in terms of landing in values and volumes. Moreover, common sole is also exploited by the Greek trammel net fleet operating in GSA 20, ranking among the most important target species both in terms of landing value and volume. This species is also among the most important target species defining the main Mediterranean demersal fisheries, occurring as such in set gillnet and trammel net fisheries. (STECF-15-19)

6.1.6 Spot-tail mantis shrimp (*Squilla mantis*) GSA 17-18

The spot-tail mantis shrimp is widespread in the Eastern Atlantic, from the Iberian peninsula to Angola, including the Mediterranean Sea, but is absent from the Black Sea (Figure 6.1.6.1). It occupies the continental shelf to the maximum recorded depth of 247 m (Manning, 1997), but it usually digs burrows on soft bottoms to a depth of 100 m. The highest densities of mantis shrimp in the Adriatic Sea are usually found on bottoms characterized by fine sand or sandy mud at depths of less than 50 m (Froglia et al., 1996). The species is more frequent in the Western side of the basin while it is quite rare in the Eastern side where the sediment features are not as suitable for their borrowing behaviour.

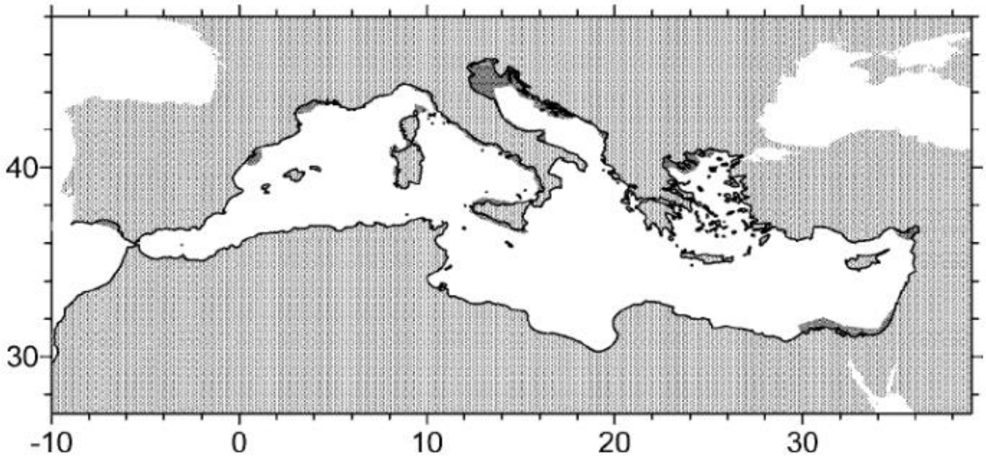


Figure 6.1.6.1 - Distribution of spot-tail mantis shrimp in the Mediterranean (Mayanou et al., 2005)

Unfortunately, genetic studies to support the identification of different stocks in the Mediterranean are missing. However, considering its territorial behaviour, it is reasonable to assume that the population inhabiting the Adriatic Sea is divided in 2 sub-populations characterized by a low rate of mixing and the sub-populations distributions loosely align with the two Adriatic GSAs (GFCM-WGSADS, 2012).

This species is exploited by bottom otter trawl, gillnet and rapido trawl fisheries in the Western Adriatic Sea. In addition, it is exploited all year round mainly by the Italian trawlers in GSAs 17 and 18 and ranks first among the crustacean landings in the Adriatic ports. Along the Eastern coast catch is very small. As concerns artisanal fisheries, mantis shrimp is an alternate target of set gillnet fishery targeting common sole, especially during spring summer seasons in the coastal area. The species is not present in the list of shared stocks of GFCM since it is present and commercially fished mainly in the Italian Territorial Waters of GSAs 17 and 18.

Spot-tail mantis shrimp ranked 5^{th} and 14^{th} in the demersal species priority list for GSA 17 and 18 respectively (STECF-16-14). Additionally, it is among the most important target species of the set gillnet and bottom trawl fleets operating in the coastal areas of GSA 17 both in terms of landing in values and volumes. It is also an important target species in terms of landing volume for the Italian bottom otter trawl fisheries targeting demersal and deep-water species in GSA 18. Moreover, the spot-tail mantis shrimp constitutes an important by-catch species in the pot and trap fishery of Slovenia as well as set gillnet and trammel net Italian and Greek fisheries in GSA 18 and 19 respectively. Finally, spot-tail mantis shrimp is one of the main target species defining the pot and trap Mediterranean fishery as well as one of the most important other species of the Mediterranean set gillnet and bottom otter trawl fisheries. (STECF-15-19).

6.1.7 Other relevant species

6.1.7.1 Gilt-head sea bream (Sparus aurata)

There is some indication that gilt-head sea bream should be included in the MAP for demersal fisheries in the Adriatic and Ionian Seas, especially due to its high vulnerability. It ranked 19^{th} in GSA 17 and 3^{rd} in GSA 20, but did not make it among the demersal species priority list according to the PSA/Landing value analysis in the other 2 GSAs (STECF-16-14).

On the level of species defining the main Mediterranean demersal fisheries, gilt-head sea bream is among the most important target species in terms of landing value and volume of the set gillnet and trammel net fleets operating in GSA 17 in Slovenia as well as the Greek trammel net, set longline and bottom otter trawl fisheries in GSA 20 (STECF-15-19).

6.1.7.2 Sea bass (Dicentrarchus labrax)

The highest vulnerability indices of all analysed species were determined for sea bass in all GSAs of the Adriatic and Ionian Seas (GSAs 17 to 20). Therefore, this species ranked high in all the demersal species priority lists, specifically it ranked 7^{th}, 4^{th}, 5^{th} and 6^{th} in GSAs 17-20 respectively (STECF 16-14).

Sea bass is among the most important target species of the set gillnet fleet operating in GSA 17 in Slovenia, but does not appear to be an important target species in any of the other commercial fisheries in the area (STECF 15-19). On the level of species defining the Mediterranean demersal fisheries, sea bass only appears among the most important target species of Slovenian set gillnet fishery in GSA 17.

6.1.7.3 Common Pandora (Pagellus erythrinus)

Common pandora is generally more vulnerable than gilt-head sea bream which resulted in higher vulnerability indices and consequently the higher ranking of this species in the PSA/Landing value analysis performed in STECF 16-14. Common Pandora ranked 14th and 9th in GSAs 17 and 18 respectively and 10th in both GSAs 19 and 20 (STECF-16-14). However, the majority of data available on common Pandora actually relates to the genus Pagellus spp. rather than individual species, thus any status assessment of this species would require additional data collection.

Pagellus spp. are among the most important target taxa of the set gillnet fleet operating in GSA 17 in Slovenia. This group of species is also an important target taxa of the trammel net fisheries of Italy in GSA 19 and Greece in GSA 20 as well as the Greek bottom otter trawl fishery in GSA 20. On the level of species defining the Mediterranean demersal fisheries, genus Pagellus is among the most important target taxa of Italian trammel net and bottom otter trawl fisheries of GSA 19, Slovenian fyke net and set gillnet fisheries in GSA 17. (STECF 15 - 19).

6.1.7.4 Squids (Loligo spp.)

There is a general issue with species identification and reporting for squids, so the data is not available by species. Squids ranked 18^{th} and 16^{th} in the demersal species priority lists for the GSAs 17 and 18, but did not appear among the most important species in the PSA/Landing value analysis of GSAs 19 and 20 (STECF-16-14).

Loligo spp. are among the most important target taxa of the bottom trawl fleets operating in GSA 17 in Slovenia and GSA 20 in Greece both in terms of landing value and volume. On the level of species defining the main Mediterranean demersal fisheries, squids are important in Slovenian fyke net, pole line and bottom otter trawl fisheries in GSA 17 and Italian bottom otter trawl fishery of GSA 18. (STECF 15 - 19).

6.1.7.5 Common cuttlefish (Sepia officianalis)

Common cuttlefish ranked 3rd and 6th on the list of priority demersal species in GSAs 17 and 18 respectively, 7th on the list of GSA 19 and 19th in GSA 20 (STECF-16-14).

Common cuttlefish is the most important target species in terms of landing value and volume of the Italian pots and traps and bottom otter trawl fleets operating in GSA 17, the Italian set gillnet and trammel net fisheries in GSA 18, the Italian trammel net fishery in GSA 19 and trammel nets Greek fishery in GSA 20. Common cuttlefish is also an important target species of the Greek bottom otter trawl fishery in GSA 20, but only in terms of landing volume.

On the level of species defining the Mediterranean demersal fisheries common octopus appears among the important species of Italian bottom otter trawls in GSAs 17 and 18 in terms of landing value. In terms of both landing value and volume, this species is recorded as important in Italian set net and trammel net fishery of GSAs 18 and 19, Italian fyke net fishery in GSA 19, Italian and Slovenian pots and traps fisheries in GSA 17 as well as Italian pots and traps fishery in GSA 19. (STECF 15 - 19).

6.1.8 Additional relevant species

In addition to those proposed another 3 taxonomic groups appeared as important target species in the analysis either due to their high vulnerability and susceptibility or landing value and volume.

6.1.8.1 Venus clam (Chamelea gallina)

After sardine and anchovy, the venus clam is the most landed species in the Adriatic Sea, since it is the most important target species of the Italian dredge fleet operating in the coastal areas of GSA 17. It is a target of the Italian national management plan for dredges and it is also among the most important species defining the Mediterranean demersal fisheries. (STECF-15-19) It was not included in the PSA/Landing value analysis at the STECF 16-14.

Boat dredge for molluscs (MOL_DRB) that exclusively target venus clams are present in GSAs 1, 6, 10, 17 and 18. The selectivity of dredges is usually the sum of two selective processes: the selectivity of the main gear (the dredge or cage) and the selectivity of the sieve. Many factors are known to affect dredge selectivity. According to the landing obligation, once the species, covered by the obligation are on deck they cannot be discarded, with the exception for the species for which scientific evidence demonstrates high survival rates. This is assumed for the venus clam in the Adriatic clam fisheries. However studies on the survivability of this species do not exist and must be carried out. Sala et al. (2014) confirm that it is technically rather unfeasible to select only individuals with a size not smaller than the Minimum Conservation Reference Size (MCRS). Therefore, as already permitted for anchovy and sardine, for which member states may convert the minimum size into specimens per kg, a similar approach (number of clams per kg) should also be allowed for venus clam. As for venus clam, more than 30 % of commercially fished clams showed shell damage (Moschino *et al.,* 2003) and only a small fraction of damaged discarded clams may be able to recover.

This species is distributed in the shallow sandy area along the Italian coast of Central and Northern Adriatic. It is distributed sporadically along the Eastern Adriatic coast on the several shallow sandy areas, but has no significant commercial value (there is no commercial fisheries of this species). The situation is similar all along in the Eastern Adriatic (Slovenia, Albania and Montenegro). On the contrary, the total Italian annual catch in recent years is around 20.000 tons and showing decreasing trend (Figure 6.1.8.1.1). With a medium price of 2-6 EUR/kg and a big annual catch venus clam is a very important fishing resource that should be include in MAP for demersal species for Adriatic and Ionian Seas.

Yearly landings of *C. gallina* in the Adriatic Sea. Data from Romanelli *et al*. (2009) and from Data Collection Program (DCF)

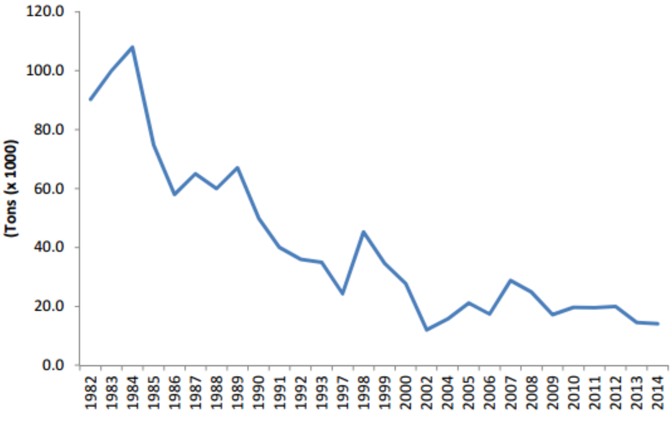


Figure 6.1.8.1.1 - Annual Italian catch of Chamelea gallina (according DCF data).

6.1.8.2 Eledone spp.

Musky octopus (*Eledone moschata*) is among the most important target species of the bottom trawl fleets operating in GSA 17 in Slovenia and Croatia as well as the Italian bottom trawl fleet of GSA 18 (STECF-15-19). The same holds true in the case of species defining the Mediterranean demersal fisheries. It can be seen from the total landing of both species by year for GSAs 17, 18 and 19 presented in Figure 6.1.8.2.1 that the curled octopus (*Eledone cirrhosa*) accounts for a lower proportion of the landings of the two species in the last 7 years.

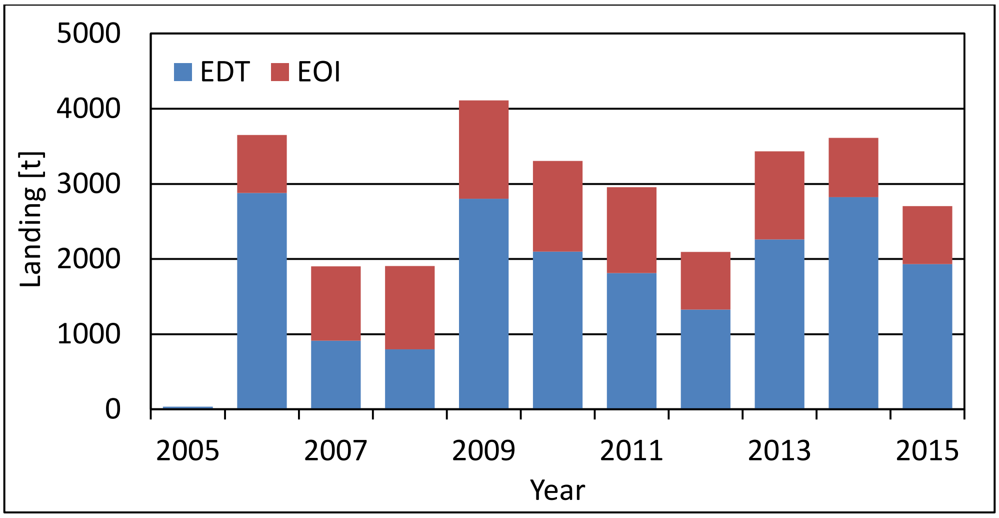


Figure 6.1.8.2.1 - Total landing of genus Eledone for GSAs 17, 18 and 19 for years 2005 – 2015.

6.1.8.3 Common octopus (Octopus vulgaris)

Common octopus (*Octopus vulgaris*) appears among the most important target species in terms of landing value and volume in Italian set gillnet and trammel net fisheries of GSAs 18 and 19. In addition, this species is an important target species in terms of landing value and volume of Greek trammel nets fishery in GSA 20. Furthermore, common octopus appears among the most important target species defining the Mediterranean pots and traps fishery of GSA 19 both in terms of landing value and volume. Finally, it ranks among the important species in set gillnet and trammel net fisheries of GSAs 18 and 19 as well as bottom otter trawl fisheries of GSAs 17, 18 and 19 on the level of Mediterranean Sea. (STECF 15 - 19)

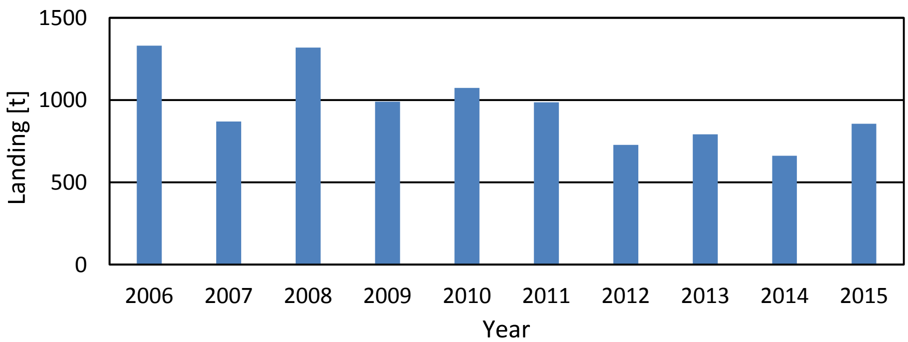


Figure 6.1.8.3.1.1 - Annual landings of common octopus in the Adriatic and Ionian Seas (GSAs 17, 18, 19 and 20)

6.1.9 Additional Fishing gears to be include in the MAP for Adriatic Ionian area

To cover catch of the most important species in the Adriatic Ionian area in addition to the gears noted the following fishing gear should be also include in potential MAP

- **Beam trawls** – In Northern Adriatic beam trawls is very important gear for Italian and Croatian fisheries. Italian fishermen use beam trawl "rapido" mainly for catch of Common Sole, while beam trawl "rampon" is used by Croatian fishermen for catching mainly shellfish (*Pecten jacobeus* and *Ostrea edulis*).

- **Hydraulic dredges** – main fishing gear for exploitation of Chamelea gallina. From Italian DCR/DCF data the hydraulic dredges were approximately 640 in the period 2008-2013, with more than 8,000 total GT and 60,000 total kW (Scarcella and Mosteiro Cabanelas, 2016). Along eastern Adriatic coast there is only two vessel in Croatian fishing fleet. Although hydraulic dredges are strickly a benthic gear, it is assumed that for management benthic and demersal fishing methods are both included within the proposed possible MAP.

- **Boat and shore seine** – it is very important fishing gear in eastern Adriatic for catching different coastal species (*Spicara, Sparidae, Scorpaenidae, Mullus spp*.)

6.1.10 Conclusions

The information provided by the StockMed project was evaluated to define stock boundaries and consequently stock units for all the target species proposed for inclusion in this MAP (Section 5). One exception is spot-tail mantis shrimp which was not included in the StockMed analysis and we don't have enough information to define the stock unit boundaries.

The fishing gears proposed for inclusion in this MAP are the ones that define the demersal fisheries of this area. However, there are additional important gears that are specific in that they only operate in a small area of the different GSAs. Three additional fishing gears that need to be considered are: Beam trawl, hydraulic dredge, shore and boat seine.

All of the target stocks proposed for inclusion in this MAP are important target species of several main Mediterranean fisheries both in terms of landing value and volume. Stock assessment has previously been performed for all of the target species at least once, but not with the same stock unit boundaries as proposed currently.

The relevant by-catch species proposed for inclusion in this MAP are actually target species for some of the gears, but their landing volume and value is lower than the main target species defining the Mediterranean demersal fisheries.

Finally, a few additional species are proposed as relevant for the Adriatic and Ionian Seas, since either their vulnerability, landing value or landing volume is important for specific fishery in this area. Based on value of landings striped venus (vongole - clam) should be added to the main species in the MAP.

Two additional species should be included in the extra species to be monitored as these are considered significant species though are not necessarily primary species these are: Eledone spp. and Octopus spp.

6.2 Possible MAP for small pelagic fisheries in the Western Mediterranean Sea

In regard to the gears suggested for inclusion in this MAP, the landing data suggests that the vast majority of small pelagic species landing volume is fished by the purse seiners (Figure 6.2.1).

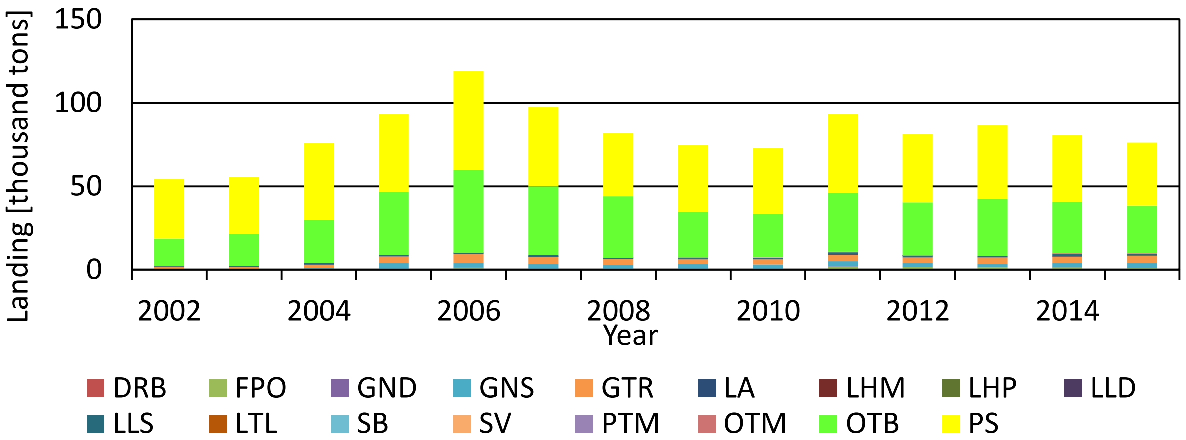


Figure 6.2.1 - Total landing volume by year for GSAs 5 to 11.

6.2.1 European anchovy (*Engraulis encrasicolus*)

StockMed project reports 5 stock units in the Mediterranean in the case of anchovy (Figure 6.2.1.1). In order to reconcile this configuration with the current GSAs, few rectangles from the cluster of GSA 8 expanding to GSA 9 have been associated to this GSA and similarly between GSAs 9 and 10 (rectangles belonging to the cluster of GSA 9 and expanding in GSA 10 should be associated to this GSA). In GSA 18 the rectangles belonging to the cluster of GSAs 19-20 should instead be associated with the cluster of GSA 17 which also includes a part of GSA 18 cluster. Analogous considerations hold for GSA 22, where, in the northernmost part, a cluster is separated from the rest of GSA.

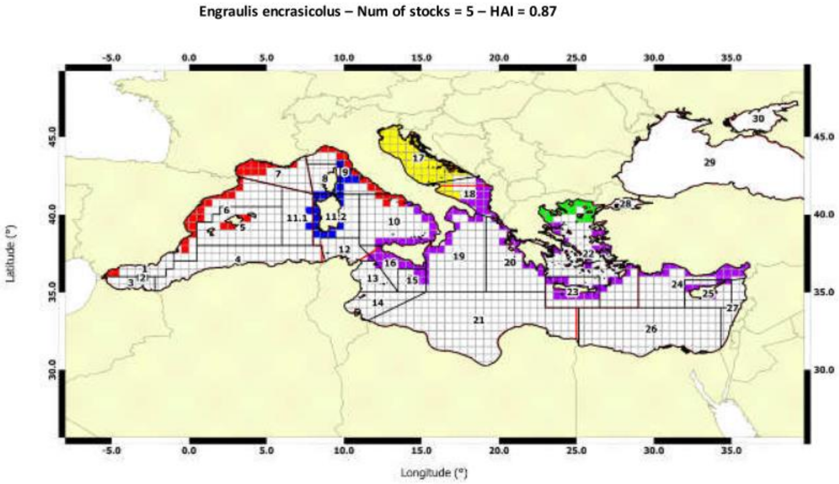


Figure 6.2.1.1. - Anchovy stock units in the Mediterranean (STOCKMED project)

Hence, there are three anchovy stock units in the Western Mediterranean according to StockMed results: one in the Balearic area (GSA 5), Northern Spain (GSA 6), Gulf of Lion (GSA 7) and Ligurian and North Thyrrenian Sea (GSA 9), second in the waters around Sardinia (GSA 11) and Corsica (8) and third in the South Thyrrenian Sea (GSA 10).

6.2.1.1 GSAs 5-6-7-9

In the PSA/Landing value analysis performed in STECF 16-14 anchovy scored the highest value index of all small pelagic species, consequently ranking first in GSAs 5 and 9 and second in GSAs 6 and 7 in the priority list for small pelagic species (STECF-16-14).

The landing of anchovy in GSAs 5 to 7 is presented below (Figure 6.2.1.1.1).

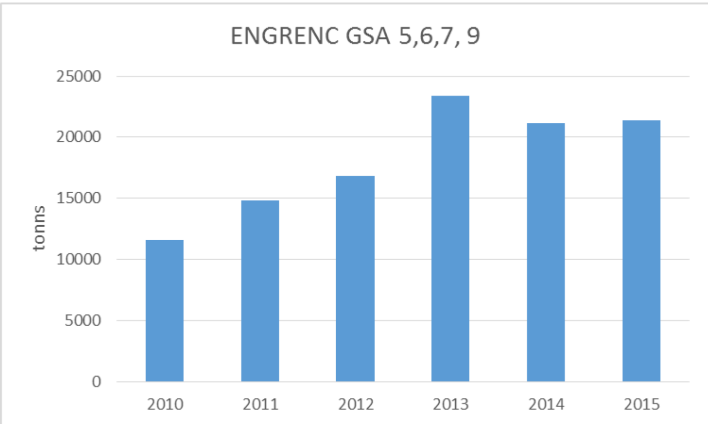


Figure 6.2.1.1.1 - Total landing of anchovy in GSAs 5, 6, 7 and 9 for years 2010 – 2015.

6.2.1.2 GSAs 8-11

Anchovy is less important species in GSAs 8 and 11, ranking next to last and last in the small pelagic species priority list of these GSAs respectively (STECF-16-14). There is no data on landing of the species in this GSAs available in the DCF database.

6.2.1.3 GSA 10

Anchovy scored by far the highest value index in the PSA/Landing value analysis for GSA 10 and consequently ranked first in the priority small pelagic species list for this GSA (STECF-16-14). Total landing of the species in this GSA is presented below (Figure 6.2.1.3.1).

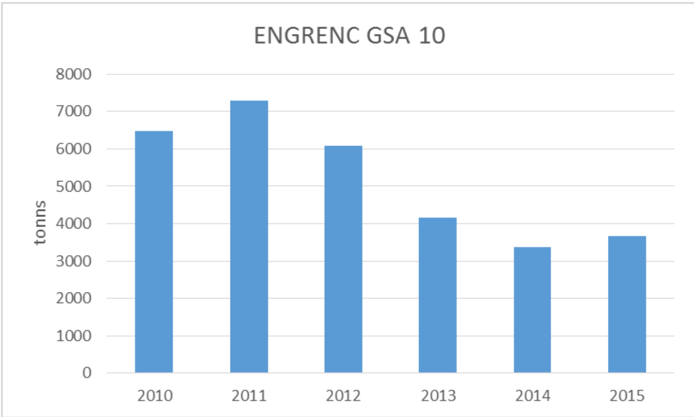


Figure 6.2.1.3.1 - Total landing of anchovy in GSA 10 for years 2010 – 2015.

6.2.2 European pilchard (*Sardina pilchardus*)

In the case of sardine, the "4 stock units" hypothesis has been selected as reasonable from the results of WP4 (fig. 6.2.2.1). Results are based on 3 biological indicators (inverse of CV of density, biomass and mean weight) and 4 thematic layers of information (Correlation of Density Index, Genetics, EFH and connectivity, Oceanographic systems–surface). However, the examined stock units should be considered unreliable, as the semi-quantitative robustness index (RI=1.4) was lower than the upper limit of the 1st quantile.

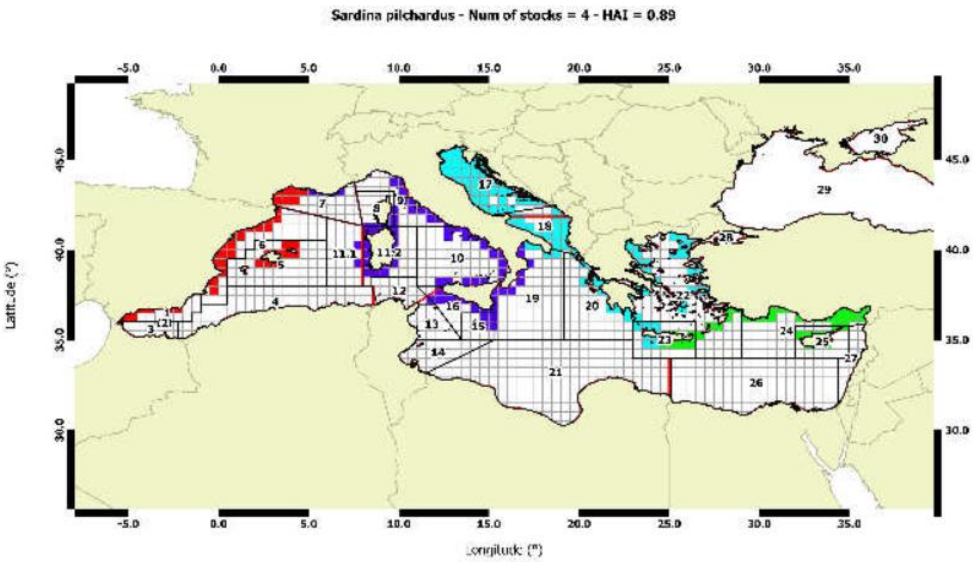


Figure 6.2.2.1 - Sardine stock units in the Mediterranean (STOCKMED project)

According to the StockMed data there are two stock units of sardine in the Western Mediterranean: one in the Balearic Sea and Gulf of Lion (GSAs 5 - 7) and second in the Ligurian and Thyrrenian Seas (GSAs 8 - 11).

6.2.2.1 GSAs 5-6-7

Sardine scored the second highest value index in the PSA/Landing value analysis performed in STECF 16-14 and ranked 7th, 5th and 6th in the small pelagic species priority list in the GSAs 5, 6 and 7 respectively (STECF-16-14). The total landings by year of sardine in GSAs 5, 6 and 7 is presented below (Figure 6.2.2.1.1).

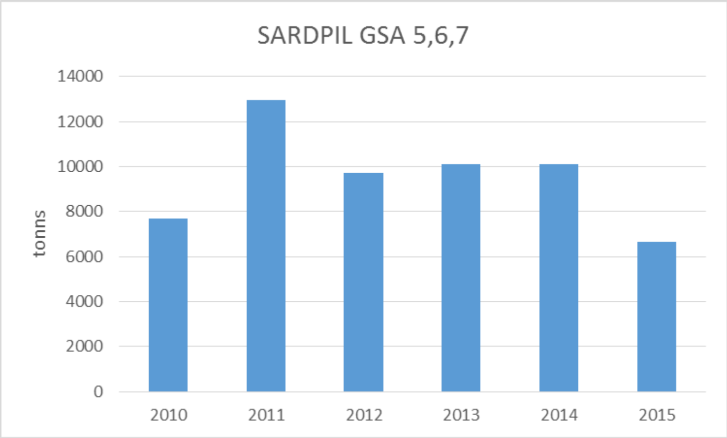


Figure 6.2.2.1.1 - Total landing of sardine in GSAs 5, 6 and 7 for years 2010 – 2015.

6.2.2.2 GSAs 8-9-10-11

Despite the third highest value index of this species in the PSA/Landing value analysis of small pelagic priority list in GSA 8, sardine ranked 6th of a total of 9 species estimated. Additionally, sardine also scored last in both GSA 9 and 10 as well as next to last in GSA 11. While the calculated value index was high for sardine in GSAs 9 and 10 (second and third highest respectively), the vulnerability index was very low, being only higher than the one calculated for anchovy.

The total landing of sardine in GSAs 8 to 11 for years 2010 – 2015 is presented below (Figure 6.2.2.2.1).

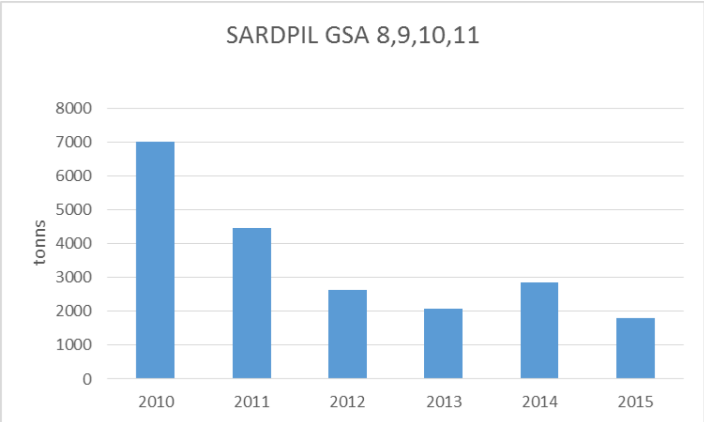


Figure 6.2.2.2.1 - Total landing of sardine in GSAs 8 to 11 for years 2010 – 2015.

6.2.3 Other relevant species

6.2.3.1 Atlantic mackerel (Scomber scombrus) and Chub mackerel (Scomber japonicus)

There is a generally agreed estimation that identification of these two species by the fishermen is not reliable, so even when they are reported to species level, the data cannot be used with confidence. In addition, an important amount of landing of these two species is reported as Scombrus spp.

In the small pelagic priority list developed in STECF 16-14 Atlantic mackerel ranked 3rd in GSAs 5, 6, 9, 10 and 11. In GSA 7, it ranked 1st and in GSA 8 it ranked 7th. Chub mackerel ranked 4th in all the relevant GSAs except in GSA 11, where it was not on the list at all.

Total landing of the genus Scomber in GSAs 5 to 11 is presented below (Figure 6.2.3.1.1).

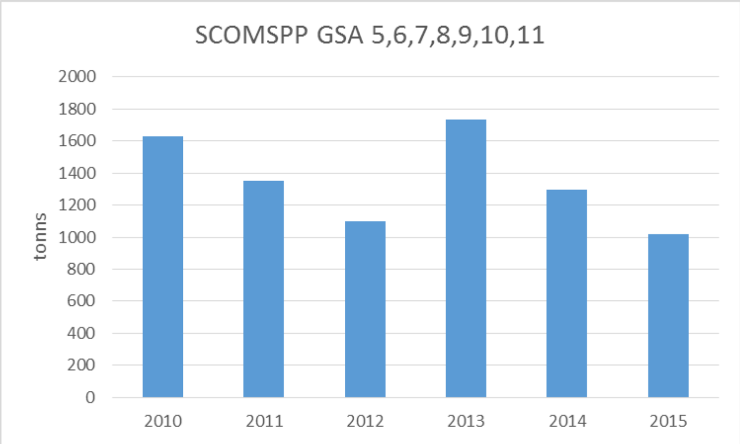


Figure 6.2.3.1.1 - Total landing of genus Scombrus in GSAs 5 to 11 for years 2010 – 2015.

6.2.3.2 Atlantic horse mackerel (Trachurus trachurus) and Mediterranean horse mackerel (Trachurus mediterraneus)

There is a generally agreed estimation that identification of these two species by the fishermen is not reliable, so even when they are reported to species level, the data cannot be used with confidence. In addition, an important amount of landing of these two species is reported as Trachurus spp.

In the small pelagic priority list developed in STECF 16-14 Mediterranean horse mackerel ranked 5th in GSAs 5, 8 and 11; 6th in GSAs 9 and 10 and 7th in GSAs 6 and 7. Atlantic horse mackerel ranked 2nd in GSA 8, 4th in GSA 11, 5th in GSAs 7, 9 and 10 and 6th in GSAs 5 and 6.

The total landing of the two species in GSAs 5 to 11 for the last 6 years is presented below (Figure 6.2.3.2.1).

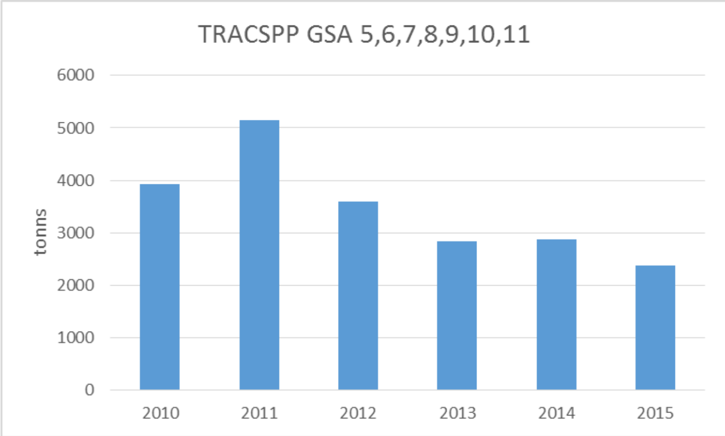


Figure 6.2.3.2.1 - Total landing of genus Trachurus in GSAs 5 to 11 for years 2010 – 2015.

6.2.4 Conclusions

The vast majority of small pelagic species is landed by the purse seine fisheries of the reference GSAs. However, potential exploitation exists from the large Italian pelagic trawlers fleet otherwise operating in the Adriatic.

The EWG supports the gear and species list in the proposed possible small pelagic MAP.

6.3 Possible MAP for demersal fisheries in the Eastern Mediterranean Sea

It should be noted that the stocks of Eastern Mediterranean are also distributed in GSA 24 which is entirely non-EU GSA in which the Turkish fisheries are targeting these species. Managing the shared stocks in a coherent way by including GSA 24 where appropriate is advisable.

6.3.1 Hake (*Merluccius merluccius*) in GSAs 22 and 23

The STOCKMED report indicates hake in the Aegean Sea (GSAs 22 and 23) belong to the same stock unit which is different from the stock unit distributed around Cyprus Island (GSA 25) (Figure 6.1.1.4). Hake was found among the most important target species driving the main Mediterranean demersal fisheries, since it was identified as such in all - set gillnet, trammel net, set longline and bottom otter trawl fisheries (STECF-16-14).

Hake ranked first in the demersal species priority list for GSA 22 and third for GSA 23. It is among the most important target species of the set gillnet and bottom otter trawl fisheries of GSA 22 in terms of landing value and volume and falls just short of the most important species group of the set longline fishery in GSA 22. Furthermore, it is one of the most important target species of the bottom otter trawl fishery of GSA 23 in terms of landing value and volume and is a relevant species in a couple of other fisheries in this GSA – set longline and trammel net fisheries.

6.3.2 Red mullet (Mullus barbatus)

STOCKMED report suggests there is one stock unit of red mullet in the Aegean Sea (GSA 22 and 23) that is different from the stock unit distributed around Cyprus Island (GSA 25) (Figure 6.1.2.1). The mullets are one of the target taxa driving the main Mediterranean demersal fisheries, appearing as such in the analysis of set gillnet, trammel net, pole line and bottom otter trawl fisheries (STECF-16-14).

6.3.2.1 GSAs 22 and 23

Red mullet scored the lowest and second lowest vulnerability index in GSAs 22 and 23 respectively, but ranked 8th and 1st in the priority species list prepared by STECF 16-14 due to the largest susceptibility index in GSA 23 (STECF-16-14). The genus Mullus spp. is the most important taxa in terms of landing value and volume of the set gillnet fisheries of GSAs 22 and 23, trammel net and bottom otter trawl fisheries of GSA 23 and is among the most important target species in the trammel and bottom otter trawl fisheries in GSA 22.

6.3.2.2 GSA 25

Despite the 3rd highest susceptibility index scored in the PSA/Landing value analysis of the STECF 16-14, red mullet ranked 7th in the demersal species priority list due to its vulnerability (second lowest vulnerability index) in GSA 25 (STECF-16-14). The Mullus spp. is the most important taxa in terms of landing value and volume of the trammel net fishery in GSA 25 and the second most important taxa in the bottom otter trawl fishery of the same GSA. Additionally, it is a relevant taxa also in set gillnet fishery of GSA 25.

6.3.3 Striped red mullet (*Mullus surmuletus*)

The STOCKMED report indicates that in the Eastern Mediterranean, there are two different stock units of striped red mullet: one in the Aegean Sea (GSA 22) and around Crete Island (GSA 23) and another in the sea around Cyprus Island (GSA 25) (Figure 6.1.2.2). The mullets are one of the target taxa driving the main Mediterranean demersal fisheries, appearing as such in the analysis of set gillnet, trammel net, pole line and bottom otter trawl fisheries (STECF-16-14).

6.3.3.1 GSAs 22 and 23

Striped red mullet ranked second in both GSA 22 and 23 demersal species priority list prepared by STECF 16-14 (STECF-16-14) due to its high susceptibility index (STECF-16-14). The genus Mullus spp. is the most important taxa in terms of landing value and volume of the set gillnet fisheries of GSAs 22 and 23, trammel net and bottom otter trawl fisheries of GSA 23 and is among the most important target species in the trammel and bottom otter trawl fisheries in GSA 22.

6.3.3.2 GSA 25

Striped red mullet ranks first on the demersal species priority list prepared by STECF 16-14 (STECF 16-14). The Mullus spp. is the most important taxa in terms of landing value and volume of the trammel net fishery in GSA 25 and the second most important taxa in the bottom otter trawl fishery of the same GSA. Additionally, it is a relevant taxa also in set gillnet fishery of GSA 25.

6.3.4 Norway lobster (*Nephrops norvegicus*) GSA 22

The STOCKMED report indicates that there are three different stock units of Norway lobster in the Eastern Mediterranean: one in the Aegean Sea (GSA 22), second unit in the sea around Crete Island (GSA 23) and third in the sea around Cyprus Island (GSA 25) (Figure 6.1.3.1).

Norway lobster ranked 11th on the demersal species priority list of GSA 22 and is the second most important crustacean in this GSA (STECF-16-14). It falls within the 75% most important target species in the set longline fishery of GSA 22 in terms of landing value, but not in terms of landing volume. In the bottom otter trawl fishery of the same GSA it is the first species after the 75% threshold of the cumulative percentage of landing value, but is not an important target species in terms of landing volume of this fishery.

6.3.5 Deep-water rose shrimp (*Parapenaeus longirostris*) in GSAs 22 and 23

The STOCKMED report indicates that in the Eastern Mediterranean, there are two different stock units: one in the Aegean sea (GSA 22 sea around Crete Island (GSA 23) and another in the sea around Cyprus Island (GSA 25).

Deep-water rose shrimp ranked 4th in the demersal species priority list prepared by STECF 16-14 in GSA 22 and it is the highest ranking crustacean species. On the contrary, this species did not appear on the priority list for GSA 23 at all.

Deep-water rose shrimp is the second most important species driving the Mediterranean bottom otter trawl fishery. It is by far the most important target species of the bottom otter trawl fishery of GSA 22 in terms of both landing value and volume. In this GSA it also appears as less important species in set gillnet and trammel net fisheries. A similar situation can be found in GSA 23, where this species is among the most important target species of the bottom otter trawl fishery, but does not appear among the most landed species in any of the other fisheries.

6.3.6 Bogue (*Boops boops*) GSA 25

Bogue is wildly distributed in the whole Mediterranean Sea (Figure 6.3.6.1). There are no information available about boundaries of stock units.

Figure 6.3.6.1: Distribution of Boops boops in the Mediterranean Sea (FAO).

In the Eastern Mediterranean, bogue is a target species of set gillnet and bottom otter trawl fisheries in GSA 25 (Figure 6.3.6.2).

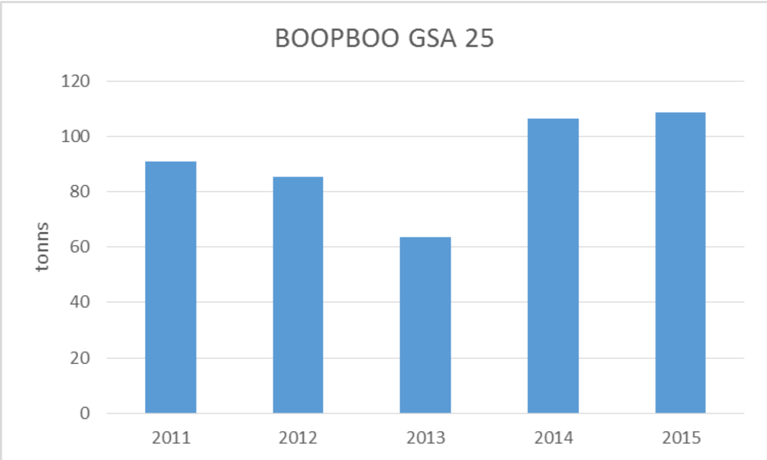


Figure 6.3.6.2 Landing of bogue in GSA 25 for the last 5 years 2011 – 2015.

6.3.7 Other relevant species

6.3.7.1 Gilt-head sea bream (Sparus aurata)

Gilt-head sea bream ranked 10th in the demersal species priority list for GSA 22, was not ranked among the first 20 species in GSA 23, mostly due to the fact that the species is landed in low quantities in this GSA and scored 12th in GSA 25 (STECF-16-14).

Gilt-head sea bream is the most important species in terms of landings value of the Greek set longline fishery in GSA 22. Furthermore, it is among the most important target species in terms of landing value and volume of the Greek trammel net fisheries in GSA 22 and it appears as important species in set gillnet and bottom otter trawl fisheries of GSA 22. On the level of species defining the

Mediterranean fisheries, gilt-head sea bream is highly important in Greek trammel net, set longline and bottom otter trawl fisheries in GSA 22. This species has not been noted as important in any other fishery of the relevant GSAs (22, 23, and 25).

6.3.7.2 Sea bass (Dicentrarchus labrax)

Sea bass scored the highest vulnerability indices in the PSA/Landing value analysis for all the relevant GSAs (STECF 16-14). In the final ranking of priority demersal species prepared by STECF 16-14 it ranked 6th in GSA 22, 5th in GSA 23 and 3rd in GSA 25 (STECF 16-14).

However, this species does not appear on any of the most landed target species lists for any of the reference GSAs, neither in terms of landing value nor landing volume. It is also not among the species defining the Mediterranean demersal fisheries.

6.3.7.3 Common Pandora (Pagellus erythrinus)

Common pandora scored among the highest ranking species in the PSA/Landing value analysis of GSAs 22, 23 and 25, ranking 3rd, 4th and 6th respectively (STECF 16-14).

In the Greek set gillnet fishery, common Pandora ranks among less important species in GSA 22, but is the second most important species by landing value in GSA 23. In addition, it falls within the 75% threshold of cumulative landing values and volumes of trammel net fishery in both these GSAs. Moreover, common pandora is the species with the highest landing volume the Greek set longline fishery in GSA 22, but has a relatively low importance for this fishery in GSA 25. Finally, it also appears as a species of less importance in bottom otter trawl fishery of GSAs 22 and 23 and set gillnet, trammel net and bottom otter trawl fisheries of GSA 25.

On the scale of species defining the Mediterranean demersal fisheries, common Pandora is only important for the Greek set gillnet fishery in GSA 23, the Greek trammel net fisheries of GSAs 22 and 23 and the Greek set longline fishery of GSA 22.

6.3.7.4 Squids (Loligo spp.)

Regarding the non-taxonomic group of squids, the PSA/Landing analysis revealed this group as important only in GSA 25, where it ranked 18th. It was not ranked among the 20 priority demersal species in GSAs 22 and 23 (STECF 16-14).

Squids are among the less important species of the set gillnet, trammel and bottom otter trawl fisheries of GSA 22 and trammel net fishery in GSA 23. Additionally, it is among the most important target species of the Greek bottom otter trawl fishery in GSA 23. On the level of species defining the Mediterranean demersal fisheries it only appears among the important species in the Greek bottom otter trawl fishery of GSA 23.

6.3.7.5 Common cuttlefish (Sepia officinalis)

In the PSA/Landing value analysis performed in STECF 16-14, common cuttlefish ranked 16th in GSA 23 and 13th in GSA 25, while it did not make it among the 20 most important demersal species of GSA 22 (STECF 16-14).

Common cuttlefish is the most important species of the Greek trammel net fisheries in GSAs 22 and 23. Furthermore, it is among the species caught by pots and traps, set gillnet and bottom otter trawl fisheries of GSA 22, as well as bottom otter trawl fishery of GSA 23. On the level of species defining the Mediterranean demersal fisheries, common cuttlefish is only among the important species of the Greek trammel net fisheries in GSAs 22 and 23.

6.3.7.6 Picarels (Spicara spp.)

Picarels are the most important target species of the bottom otter trawl fishery in GSA 25. They have also been identified among the most important target species in the bottom otter trawl fishery in GSA 23 both in terms of landing value and volume. Additionally, they are important in the Greek trammel net fishery in GSA 23 and set gillnet and trammel net fisheries in GSA 25.

The total landing of this species is presented below (Figure 6.3.7.6.1).

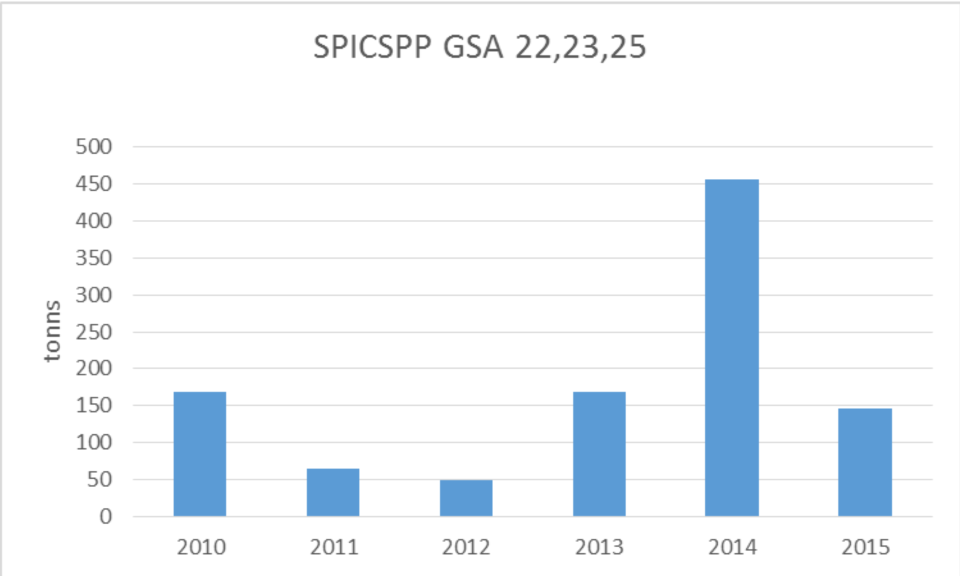


Figure 6.3.7.6.1 - Total landings of genus Spicara in GSAs 22, 23 and 25 for years 2010 – 2015.

6.3.8 Additional relevant species

6.3.8.1 Common octopus (Octopus vulgaris)

The Common octopus (*Octopus vulgaris*) accounts for more than 75 % in terms of value of landings and landed biomass in the Greek pots and traps fishery in GSA 22. Moreover, it is among the most important target species of the Greek trammel net and bottom otter trawl fisheries in the same GSA, both in terms of landing value and volume. On the other hand, it is below the 75% threshold of the cumulative landing value and volume of set gillnet fishery in GSA 22 and trammel net fishery in GSA 23. This species does not appear as important species in any of the fisheries in GSA 25. On the level of species defining the Mediterranean demersal fisheries, common octopus only has high importance in the Greek pots and traps fishery in GSA 22.

6.3.9 Conclusions

There was no expertise for GSAs 22 to 25 present at the EWG 17-02. The MedStock project results suggest the stock units proposed for inclusion in this MAP should be adjusted for most of the target species.

All of the target species proposed are important in driving at least some of the main Mediterranean demersal fisheries of the relevant GSAs.

The relevant by-catch species proposed for inclusion in this MAP are actually target species for some of the gears and scored high in the PSA/Landing value analysis, but their landing volume and value is lower than the main target species defining the Mediterranean demersal fisheries.

Finally, one additional species is proposed as relevant for the Eastern Mediterranean Sea, since its landing value and volume are important for a specific fishery in this area.

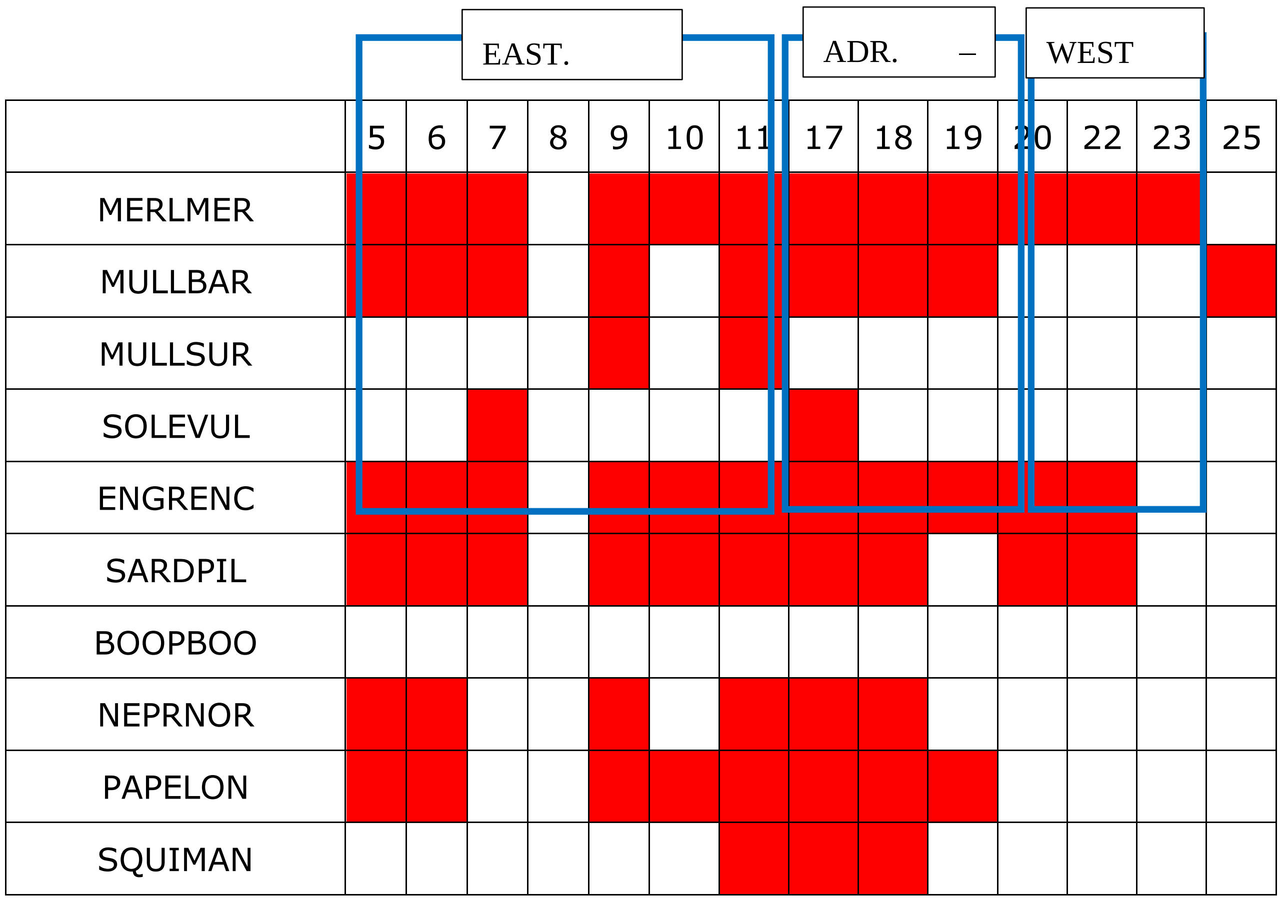
6.4 Distribution of stocks and assessments performed in reference to proposed MAPs

With the exception of bogue, stock assessments have been performed through STECF for all the target species proposed for inclusion in the potential MAPs (Table 6.4.1. The situation is best for hake, striped mullet, sardine and anchovy. Common sole has only been assessed in GSAs 17 and 7 and spot-tail mantis shrimp in GSA 11 and along the Western part of the Adriatic Sea.

All proposed target stocks have been more or less regularly assessed in the Adriatic and the Western Ionian Seas by STECF or GFCM, while only stock assessment of hake is available in the Eastern Ionian Sea (Table 6.4.1). In the Eastern Mediterranean Sea only stock assessment for hake in the Aegean Sea and for red mullet in GSA 25 (around Cyprus Island) have been performed thus far.

Stock assessments of target pelagic species in the Western Mediterranean have been performed by STECF regularly, except for GSA 8.

Table 6.4.1 - Overview of stock assessments performed thus far by STECF for the target species in the relevant GSAs proposed for inclusion in the possible MAPs.



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8 CONTACT DETAILS OF EWG-17-02 PARTICIPANTS

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9 Annex I - Comparing length based indicators to assessment results

STECF EWG 17-02
Annex 1
Comparing length based indicators to assessment results

Finlay Scott - European Commission Joint Research Center

19 giugno, 2017

Contents

1 Introduction

This annex explores the use of the length based indicator *Lmean* relative to *LFeM* (*Lmean / LFeM*) to assess stock status. The indicator was proposed by ICES (2015).

Lmean / LFeM can be used as an indicator of *FMSY* and is recommended to be >= 1, i.e. a value < 1 suggests overfishing. *Lc* is the length at first catch, *Lmean* is the mean length of individuals larger than *Lc* and *LFeM* is calculated as *0.75 Lc + 0.25 Linf*.

The indicator is very dependent on the value of *Lc*. The original calculation of *Lc* used by ICES was based on the mode of the catch distribution. This was found to be extremely sensitive to the length distribution, leading to unstable results (STECF 2016a).

An alternative approach was used in the previous expert working group (STECF 2016b) where the 0.25 quantile of the catch distribution was used as *Lc*. A normal cumulative probability distribution was fitted to the catch-at-length distribution of each year. The estimated mean and standard deviation of the distribution was then used to calculate *Lc* as the 0.25 quantile of the estimated distribution. It was found that this gave a more stable value for *Lc* than the original method that used the first mode in the data, giving greater confidence in the calculated value of the length indicator. Here *Lc* is caluclated using this method.

In this annex, the indicator *Lmean / LFeM* is calculated for the stocks from STECF-16-22 and STECF-17-06 that have accepted analytical assessments. The estimated Fbar is compared to *Lmean / LFeM* across all of the stocks and for individual stocks using a linear mixed effects model.

It is found that the length based indicator is not an effective guide to the Fbar. This reduces confidence in the use of the indicator on its own for managing stocks, agreeing with Jardim et al. (2015). However, it should be noted that only a limited selection of stocks are considered here.

The analysis uses code from the *R4Med* GitHub repository (https://github.com/drfinlayscott/R4Med).

2 The stocks

Stocks with analytical assessments from STECF-16-22 and STECF-17-06 are considered, i.e. stocks that had been assessed using VIT are not included. This gave 12 stocks. To calculate the indicator a value for *Linf* is required. This has to be the same value as that used in the original assessment.

Species	GSA	Linf
MUR	9	32.0
NEP	6	74.1
NEP	9	74.1
NEP	11	74.1
DPS	1	45.0
DPS	9	38.3
DPS	10	43.0
ANE	6	19.0
ANE	9	17.0
ANE	17_18	19.4
PIL	6	25.0
PIL	17_18	19.8

The length frequency data for each stock was extracted from the JRC data base. Some of the stocks have data recorded in different quarters. Ideally, the data should be transformed so that all data come from the same quarter to make them comparable. This requires using the same von Bertalanffy *k* parameter as used in the assessment. Unfortunately, this value was not reported for all stocks. Additionally, it was not clear whether the data had been corrected for quarters in the assessment. Consequently, the quarter correction was not performed.

3 Results

The indicator was designed to be a guide to the exploitation level of the stock. When the indicator is greater than 1 the stock is thought to be underexploited. When the indicator is less than 1 the stock is thought to be overexploited. Therefore, if the indicator was a reliable guide to the exploitation level of the stock, we would expect an inverse relationship between the estimated exploitation level and the indicator.

3.1 Considering stocks together

Plotting the indicator against the estimated stock status (*F / Fref* where *Fref* is the reference *F* level, for example *F0.1*) for all stocks together shows that there is a general inverse relationship between the indicator and the stock status (Figure 1). Additionally, the smoother line almost goes through the (1,1) point, suggesting that the indicator is also a reasonable guide to the transition between over and under exploited.

We are interested in whether the indicator can correctly identify when the stock is over or under exploited, i.e have the points been allocated to the correct quadrant on the plot. The points in the top left quadrant of the plot have been correctly identified as under exploited (16% of all points) and the points in the bottom right quadrant of the plot have been correctly identified as overexploited (48% of all points). The other points are when the indicator and the assessment suggest opposing views on stock status (36% of all points). The points in the top right quadrant are of particular concern as these are points that the indicator identifies as being under exploited but the assessment estimates as being over exploited (24% of all points). These could lead to inappropriate management decisions being taken.

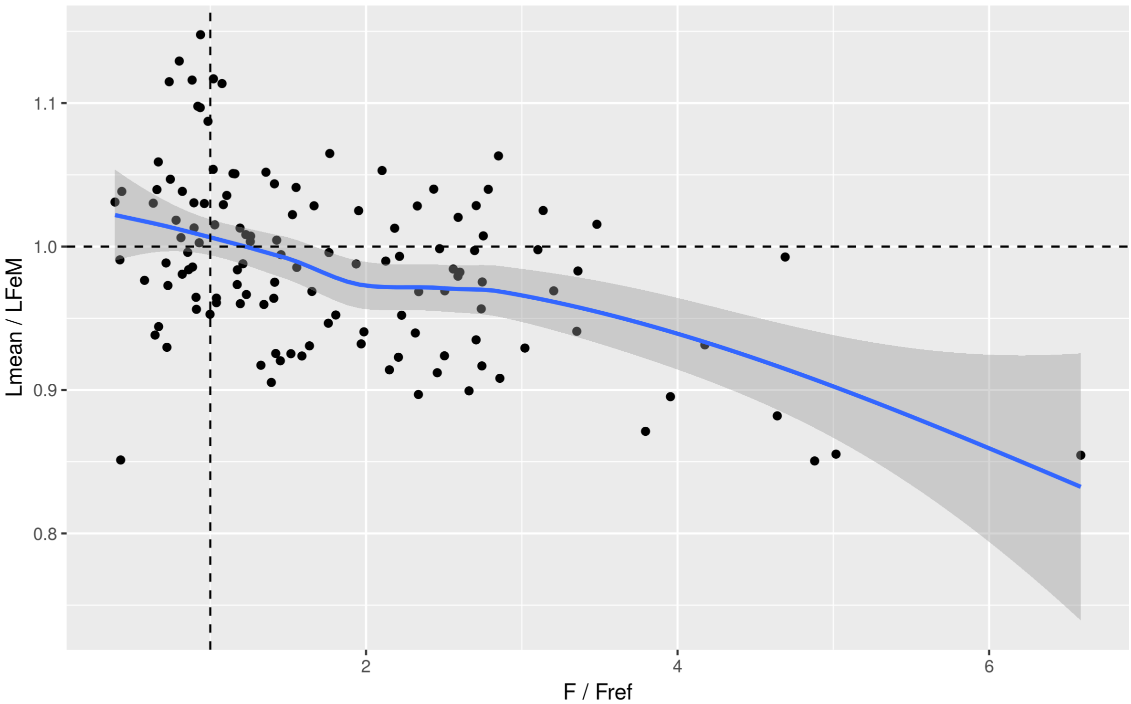

Figure 1: Length indicator against estimated stock exploitation for all stocks together

3.2 Considering stocks separately

When the stocks are considered separately, the indicator is not always a good guide to the estimated stock exploitation (Figure 2). A regression has line has been used instead of a smoother due to the short nature of some of the time series. For some stocks, the regression line does not suggest a negative relationship, nor a y-intercept of x=0.

This can be seen in more clearly by plotting each stock separately (Figure 3). The stocks ANE in GSA 6, DPS in GSA 10, MUR in GSA 9, NEP in GSA 11 and NEP in GSA 9 all have regression lines showing a positive relationship between the indicator and stock exploitation.

3.3 Linear mixed effects model

A linear mixed effect model was fitted where stock was a random effect:

```
library(lme4)
lmind <- lmer(lmean_lfem ~ F_Fref + (F_Fref | .id), data = dat,
    REML = FALSE)
```

The fixed effect has a gradient of almost zero. This implies that after the variability from the individual stocks has been accounted for there is almost no relationship between the length based indicator and the estimated exploitation status. Additionally, six out of the 12 stocks have a positive relationship between the length indicator and the estimated stock exploitation (ANE in GSA 6, DPS in GSA 1, DPS in GSA 10, MUR in GSA 9, NEP in GSA 11 and NEP in GSA 9). The resulting plot shows the line from the fixed effect linear running almost horizontally across the plot (Figure 4).

```
fixef(lmind)
```

```
##   (Intercept)        F_Fref
```

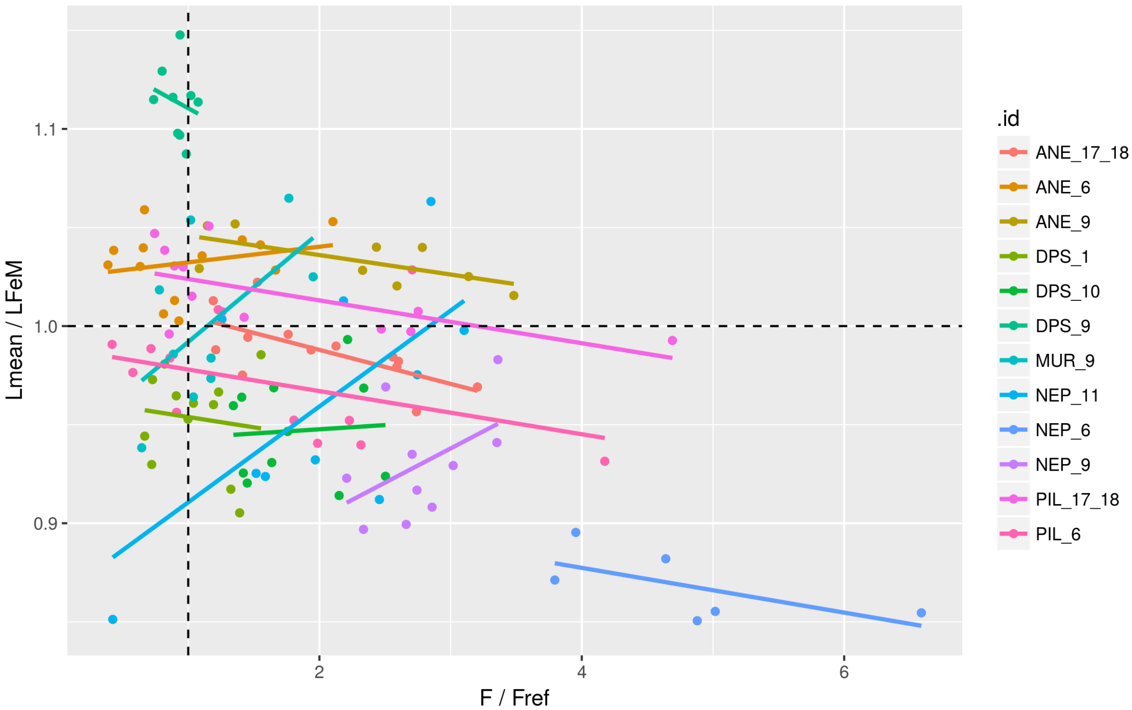

Figure 2: Length indicator against estimated stock exploitation when stocks are considered separately

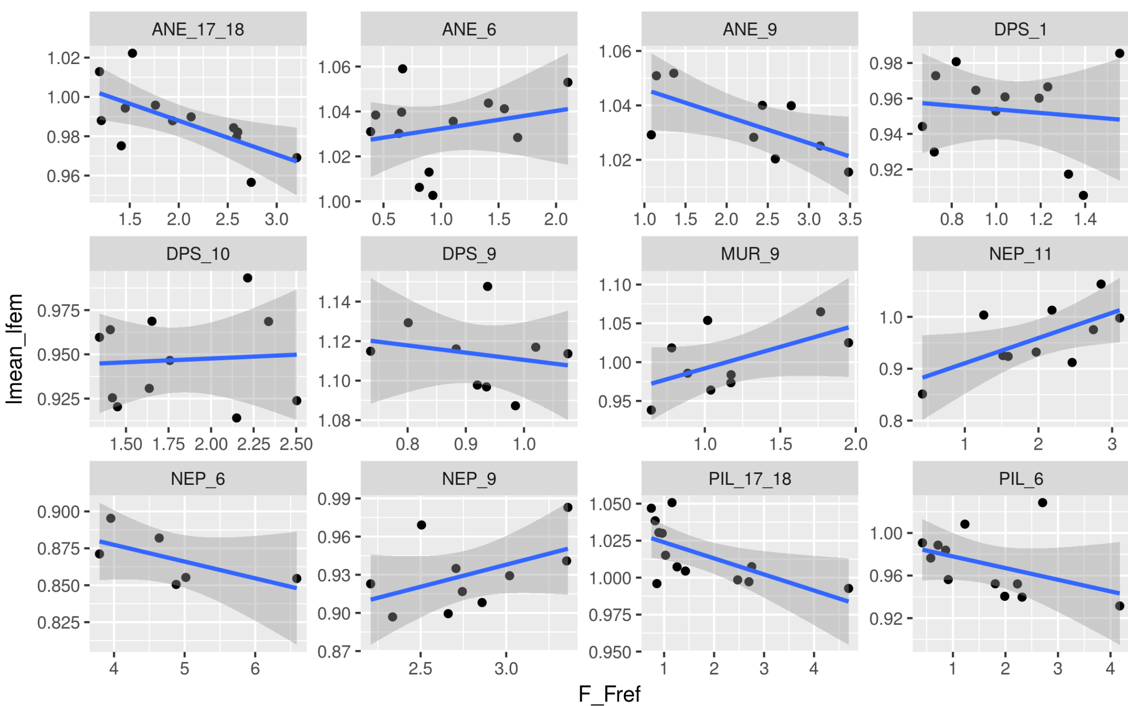

Figure 3: Length indicator against estimated stock exploitation for the individual stocks

```
## 9.864647e-01 -1.246977e-06
```

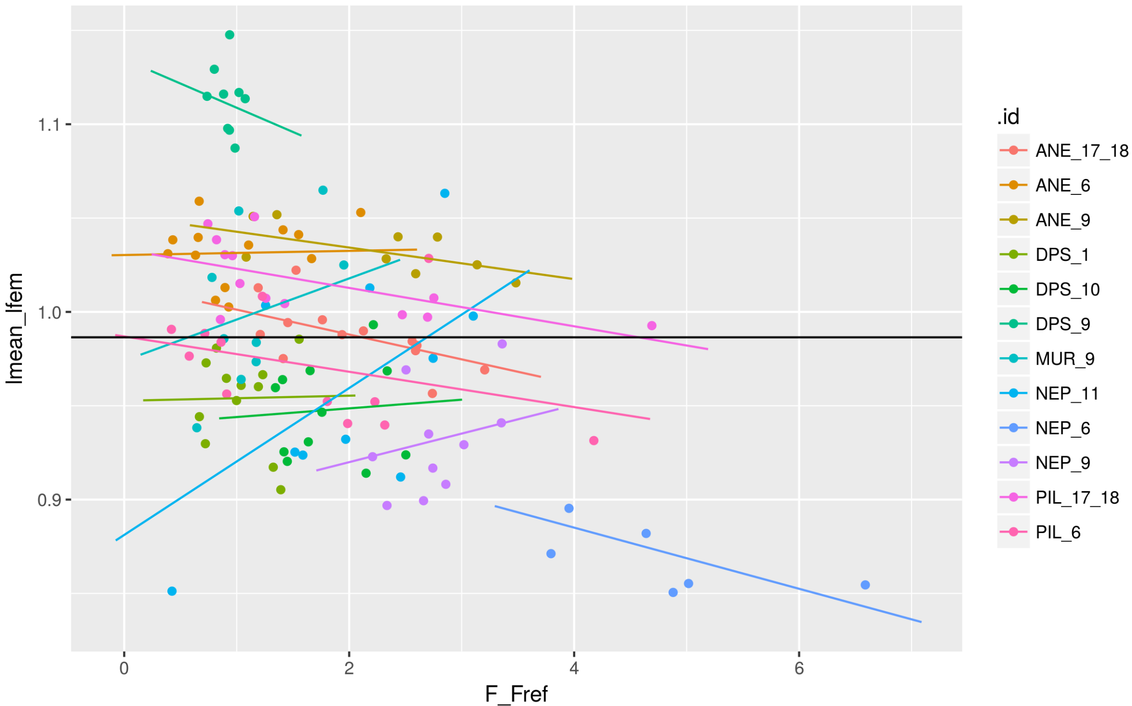

Figure 4: Results of the linear mixed effects model with stock as a random effect. The horizontal black line is the fixed effect

4 Conclusions

Comparing the estimated exploitation status from the stock assessments to the length based indicator *Lmean / LFeM* shows that the indicator is not a consistently reliable guide to the exploitation status of the stock. When all the stocks were analysed together there is a general inverse relationship between the estimated exploitation and the indicator. However, only 66% of points were correctly categorised as being either under or over exploited. More worringly, 25% of points were incorrectly identified as being under exploitated when the assessment suggested that they were over exploitated. Considering the stocks on an individual basis, a linear mixed effect model with stock as a random effect found that only half of the stocks had the desired inverse relationship between estimated exploitation and the indicator.

It should be remembered that only 12 stocks are analysed here. These stocks are not necessarily a good representation across 'stock space'. For example, only 5 species are included and only a limited range of GSAs are explored. However, the current results are not encouraging. A more thorough study with a greater number of species and GSAs will present an opportunity for more insight, for example by including species and GSA as random effects.

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10 Annex II - Length Based Indicators (WKLIFE, October 2015)

Length Based Indicators (WKLIFE, October 2015)

Karolina Molla Gazi

Script sample for Deep Sea Shrimp in GSA 1

```
rm(list = ls())
###########################
# Length-based indicators #
###########################
# Adapted from T. Miethe and C. Silva, WKLIFE-V, Oct2015
###########################

setwd("D:/Files/DTU/Thesis/R/Methods_Sources/LBI/Workspace_all")

library(reshape2)
library(lattice)
library(knitr)
source("D:/Files/DTU/Thesis/R/Methods_Sources/LBI/Workspace_all/functions/ICE_LFD.R")
source("D:/Files/DTU/Thesis/R/Methods_Sources/LBI/Workspace_all/functions/lbi_table.R")
source("D:/Files/DTU/Thesis/R/Methods_Sources/LBI/Workspace_PIL6/Length_format.r")
source("D:/Files/DTU/Thesis/R/Methods_Sources/LBI/Workspace_PIL6/weight_format.r")



####################
# Input parameters #
####################


stock<- "DPS"
S <- "N"
area <- "GSA 1"
# Life history parameters
Linf <- 45
Lmat <- NA
#length-weight for the estimation of Lmaxy
a <- 0.003055
b <- 2.490608
# Years of available data
startyear <- 2003
endyear <- 2015

#load data

length_data <- Length_format(file = "landings.txt",
                             area = area,
                             species = stock,
                             mode = 1,   ### represents the number of GSAs (or SAs). Allowable input 1 t
                             startyear = startyear,
                             endyear = endyear)
```

```r
weight <- Weight_format(file="landings.txt",
                        area= area,
                        species = stock,
                        mode = 1,
                        startyear = startyear,
                        endyear = endyear,
                        a = a,
                        b = b)
#check if needed
ns <- length_data
nsw <- weight

# Choose bin size (ClassInt) width for estimation of Lc [NOT USED ATM]

#############################################################################
# TRUE  if the MeanLength is not the class midpoint but the class lower bound and bin size 1

length_data <- ns
MeanLengthLB = TRUE
sex = "N"

if(MeanLengthLB){
  length_data$MeanLength <- length_data$MeanLength + 0.5
}

############################################################
# step 1 check length distribution plots to decide whether
# regrouping is necessary to determine Lc (Length at first catch= 50% of mode)
############################################################

length_plot <- function(length_data,
                        ClassInt = 1,
                        filename = "DPS1_distribution.png",
                        save_plot = FALSE,
                        units) {


  df0 <- length_data

  df0.long <- melt(df0, id.vars = 'MeanLength') #melts to long format
  print(df0.long)
  df0.long$variable <- gsub("X", "", as.character(df0.long$variable)) #replaces all matches of a string
  print(df0.long$variable)
  minCL <- floor((min(df0$MeanLength) - .5) / ClassInt) * ClassInt  # original data 1mm length class
  print(minCL)
  maxCL <- ceiling((max(df0$MeanLength) + .5) / ClassInt) * ClassInt

  df0$LC <- cut(df0$MeanLength,
                breaks = seq(minCL,
                             maxCL,
                             ClassInt),
                include.lowest = T)
```

```r
  df0.gr <- aggregate(df0[, 2:ncol(df0)-1], by=list(df0$LC), sum)
  names(df0.gr)[1] <- 'lclass'
  df0.gr <- cbind(lclass=df0.gr$lclass,
                  lmidp = as.numeric(substr(df0.gr$lclass,
                                            2, regexpr(",",df0.gr$lclass)-1)) + ClassInt / 2,
                  df0.gr[, 3:ncol(df0.gr)])
  df0.gr.long <- melt(df0.gr[ ,-1], id.var = 'lmidp')
  df0.gr.long$variable <- gsub("X", "", as.character(df0.gr.long$variable))

  names(df0.gr.long)[2:3] <- c('year', 'Number')
  df0.gr.long$year <- as.numeric(as.character(df0.gr.long$year))


  length_bars <- barchart(Number ~ lmidp|as.factor(year),
                          data = df0.gr.long,
                          horizontal = F,
                          as.table = T,
                          ylim = c(0, NA),
                          xlab = 'Length',
                          ylab = 'Proportions',
                          scales = list(x = list(at = seq(1,length(unique(df0.gr.long$lmidp)), 4),
                                                 labels = seq(min(df0.gr.long$lmidp) + ClassInt,
                                                              max(df0.gr.long$lmidp), 4 * ClassInt))),
                          main = paste0("Length class: ", ClassInt, " ", units),
                          cex.main = 1.2)

  if(save_plot) {
    png(filename = filename,
        bg = "white",
        pointsize = 5,
        units = units,
        width = 35,
        height = 18,
        res = 600)

    print(length_bars)
    dev.off()
  } else {
    print(length_bars)
  }
}

length_plot(length_data,
            ClassInt = 1,
            filename = "D:/Files/DTU/Thesis/R/Methods_Sources/LBI/Workspace_all/DPS_1/DPS1_dist.png",
            save_plot = TRUE, units = "cm")

# step 6 final decision on regrouping fill in!
ClassInt <- 1


#######################################################################################
# step 2 Calculate indicators per sex
```

```
Year <- c(startyear:endyear)
Year1 <- c((startyear+1):endyear)

for(s in 1:length(S)){
  sex <- S[s]
  if(sex=="M") final <- m  #numbers
  if(sex=="F") final <- f
  if(sex=="N") final <- ns

  if(sex=="M") weight <- mw   #mean weights
  if(sex=="F") weight <- fw
  if(sex=="N") weight <- nsw

  Ind <- data.frame(matrix(ncol=24, nrow=endyear-startyear+1))
  names(Ind) <- c('Year','L75','L25','Lmed', 'L90', 'L95', 'Lmean','Lc','LFeM','Lmaxy' ,'Lmat', 'Lopt',
  Ind$Year <- startyear:endyear

  #  regrouping with selected length class width
  df0 <- final
  minCL <- floor((min(df0$MeanLength)-.5)/ClassInt)*ClassInt  #originaldat 1mm length class
  maxCL <- ceiling((max(df0$MeanLength)+.5)/ClassInt)*ClassInt
  df0$LC <- cut(df0$MeanLength, breaks=seq(minCL,maxCL,ClassInt), include.lowest=T)
  df0.gr <- aggregate(df0[,2:ncol(df0)-1], by=list(df0$LC), sum)
  names(df0.gr)[1] <- 'lclass'
  df0.gr <- cbind(lclass=df0.gr$lclass,
                  lmidp=as.numeric(substr(df0.gr$lclass,2,
                            regexpr(",",df0.gr$lclass)-1))+ClassInt/2, df0.gr[,3:ncol(df0.gr)])
  df0.gr.long <- melt(df0.gr[,-1], id.var='lmidp')
  names(df0.gr.long)[2:3] <- c('year', 'Number')
  df0.gr.long$year <- as.numeric(as.character(df0.gr.long$year))

  df0.gr.long <- melt(df0.gr[,-1], id.var='lmidp')
  names(df0.gr.long)[2:3] <- c('year', 'Number')
  df0.gr.long$year <- as.numeric(as.character(df0.gr.long$year))
  res <- data.frame(year=min(as.numeric(df0.gr.long$year)):max(as.numeric(df0.gr.long$year)),
                    lmidp=NA, nmax=NA, lc=NA)

  for (j in 3:ncol(df0.gr)) {
    for (i in 2:nrow(df0.gr)) {
      if(df0.gr[i+1,j]-df0.gr[i,j]>=0) {
        next
      } else {
        res$lmidp[j-2] = df0.gr$lmidp[i]
        res$nmax[j-2] = df0.gr[i,j]
        a = res$nmax[j-2]/2
        df1 = df0.gr[,c(2,j)]
        for (k in 1:nrow(df1)) {
          if (df1[k,2] < a) {
            next
          } else {
            res$lc[j-2] = df1[k,1]
          }
```

```
        break
      }
    }
    break
  }
}

Ind$Lc <- res$lc
Ind$Lmat <- Lmat[s]
Ind$Lopt <- 2/3*Linf[s]
Ind$Linf <- Linf[s]

for(jj in (1:length(Year))+1){
  j <- jj-1

  final2 <- final[,c(1,jj)]
  colnames(final2) <- c("lngth","number")

  final2$cumsum <- cumsum(final2[,2])
  final2$cumsum_perc <- final2$cumsum/sum(final2$number)

  # find mean top 5%
  numb <- as.data.frame(final2[rev(order(final2$lngth)),"number"])    # from largest starting
  colnames(numb) <- "number"
  numb$cum <- cumsum(numb$number)
  numb$lngth <- final2[rev(order(final2$lngth)),"lngth"]
  numb$cumperc <- round(numb$cum/sum(numb$number),5)
  numb$num5 <- 0
  numb[numb$cumperc<=0.05,"num5"] <- numb[numb$cumperc<=0.05,"number"]
  numb[max(which(numb$cumperc<=0.05))+1,"num5"] <- (0.05-numb[max(which(numb$cumperc<=0.05)),"cumperc
  Ind[j,"Lmax5"] <- sum(numb$num5*numb$lngth)/sum(numb$num5)

  # indicators
  Ind[j, "L75"] <- min(final2[which(final2$cumsum_perc >= 0.75), "lngth"])
  Ind[j, "L25"] <- min(final2[which(final2$cumsum_perc >= 0.25), "lngth"])
  Ind[j, "Lmed"] <- min(final2[which(final2$cumsum_perc >= 0.5), "lngth"])
  Ind[j, "L95"] <- min(final2[which(final2$cumsum_perc >= 0.95), "lngth"])
  Ind[j, "L90"] <- min(final2[which(final2$cumsum_perc >= 0.90), "lngth"])

  final3 <- final2[final2$lngth >= Ind[j, "L25"], ]    # calculate mean of individuals above Lc
  Ind[j, "Lmean"] <- sum(final3$lngth * final3$number) / sum(final3$number)

  final2$biomass <- final2$number * weight[, jj]
  Ind[j, "Lmaxy"] <- final2[final2$biomass == max(final2$biomass), "lngth"]  # length class with max 

  Lopt <- (2 / 3) * Linf[s]

  Ind[j, "Pmega"] <- sum(final2[which(final2$lngth >= (Lopt + 0.1 * Lopt)),
                                "number"]) / sum(final2$number)   # proportion larger Lopt+10%
  Ind[j, "Year"] <- Year[j]
  Ind[j, "Pmegaref"] <- 0.3   # proxy reference point of 30% in catch
  Ind[j, "LFeM"] <- 0.75 * Ind[j, "L25"] + 0.25 * Ind[j, "Linf"]
}
```

```r
  #calculate various ratios
  Ind$Lmaxy_Lopt <- Ind$Lmaxy / Ind$Lopt
  Ind$L95_Linf <- Ind$L95 / Ind$Linf
  Ind$Lmean_LFeM <- Ind$Lmean / Ind$LFeM
  Ind$Lmean_Lmat <- Ind$Lmean / Ind$Lmat
  Ind$Lmean_Lopt <- Ind$Lmean / Ind$Lopt
  Ind$Lmax5_Linf <- Ind$Lmax5 / Ind$Linf
  Ind$Lc_Lmat <- Ind$Lc / Ind$Lmat
  Ind$L25_Lmat <- Ind$L25 / Ind$Lmat

  if(sex == "M") Males <- Ind
  if(sex == "F") Females <- Ind
  if(sex == "N") Unsexed <- Ind

  write.csv(Ind, file = paste("DPS_1",
                              "\\",
                              "L25",
                              "_IndicatorRatios_table.csv",
                              sep = ""),
            row.names = F)

}

lbi_table(Ind)

###############################################################################
## step 3 plot indicator time series per sex
file_path <- "D:/Files/DTU/Thesis/R/Methods_Sources/LBI/Workspace_all/DPS_1/"


for(s in 1:length(S)){
  sex <- S[s]
  if(sex == "M") Ind <- Males
  if(sex == "F") Ind <- Females
  if(sex == "N") Ind <- Unsexed

  png(paste(file_path,
            stock,
            "_",
            "L25",
            "_timeseries.png",
            sep = ""),
      bg = "white",
      pointsize = 5,
      units = "cm",
      width = 10,
      height = 18,
      res = 600)

  par(mar = c(5, 4, 3, 4),
      mfrow = c(3, 1),
      family = "serif",
      cex = 1.5)
```

```r
plot(Linf ~ Year,
     data = Ind,
     ylab = "Length",
     col = "transparent",
     main = "(a) Conservation",
     xlab = "Year",
     xlim = c(Year[1],
              tail(Year, 1) + 1), ylim = c(min(Ind$Lc) * .9,
                                           unique(Ind$Linf) * 1.1),
     bty = "l")
axis(1, at = Ind$Year,
     labels = FALSE,
     cex.axis = 0.1,
     tick = TRUE)
lines(L95 ~ Year,
      data = Ind,
      lwd = 2,
      col = "purple")
text(tail(Year, 1) + 1,
     tail(Ind$L95, 1),
     expression(L["95%"]),
     col = "purple",
     cex = 1.1)
lines(Lmax5 ~ Year,
      data = Ind,
      lwd = 2,
      col = "black")
text(tail(Year, 1) + 1,
     tail(Ind$Lmax5, 1),
     expression(L["max5%"]),
     col = "black",
     cex = 0.9)
lines(Lmat ~ Year,
      data = Ind,
      lwd = 1,
      col = "black",
      lty = "dashed")
text(tail(Year, 1) + 1,
     tail(Ind$Lmat, 1),
     expression(L["mat"]),
     col = "black",
     cex = 1.1)
lines(Lc~Year, data=Ind, lwd=2, col="blue")
text(tail(Year,1)+1, tail(Ind$Lc,1), expression(L["c"]), col="blue", cex=1.1)
lines(Linf~Year, data=Ind, lwd=1, col="black", lty="dashed")
text(tail(Year,1)+1, tail(Ind$Linf,1), expression(L["inf"]), col="black", cex=1.1)
lines(L25~Year, data=Ind, lwd=1, col="red")
text(tail(Year,1)+1, tail(Ind$L25,1), expression(L["25%"]), col="red", cex=1.1)

plot(Linf~Year, data=Ind, ylab="Length", main="(b) Optimal Yield", col="transparent", xlab="Year", xli
axis(1, at=Ind$Year, labels=FALSE, cex.axis=0.1, tick=TRUE)
lines(L75~Year, data=Ind, lwd=1, col="red")
text(tail(Year,1)+1, tail(Ind$L75,1), expression(L["75%"]), col="red", cex=1.1)
```

```
lines(Lmean~Year, data=Ind, lwd=2, col="darkred")
text(tail(Year,1)+1, tail(Ind$Lmean,1), expression(L["mean"]), col="darkred", cex=1.1)
lines(Lopt~Year, data=Ind, lwd=1, col="black", lty="dashed")
text(tail(Year,1)+1, tail(Ind$Lopt,1), expression(L["opt"]), col="black", cex=1.2)
lines(Lmaxy~Year, data=Ind, lwd=2, col="green")
text(tail(Year,1)+1, tail(Ind$Lmaxy,1), expression(L["maxy"]), col="green", cex=1.2)
lines(Lmat~Year, data=Ind, lwd=1, col="black", lty="dashed")
text(tail(Year,1)+1, tail(Ind$Lmat,1), expression(L["mat"]), col="black", cex=1.1)
lines(L25~Year, data=Ind, lwd=1, col="red")
text(tail(Year,1)+1, tail(Ind$L25,1), expression(L["25%"]), col="red", cex=1.1)

plot(Lmat~Year, data=Ind, type="l", ylab="Length", main="(c) Maximum Sustainable Yield", col="black",
axis(1, at=Ind$Year, labels=FALSE, cex.axis=0.1, tick=TRUE)
text(tail(Year,1)+1, tail(Ind$Lmat,1), expression(L["mat"]), col="black", cex=1.2)
lines(Lmean~Year, data=Ind, lwd=2, col="darkred")
text(tail(Year,1)+1, tail(Ind$Lmean,1), expression(L["mean"]), col="darkred", cex=1.1)
lines(LFeM~Year, data=Ind, lwd=2, col="blue", lty="dashed")
text(tail(Year,1)+1, tail(Ind$LFeM,1), expression(L["F=M"]), col="blue", cex=1.2, lty="dashed")

dev.off()

png(paste(file_path,
          stock,
          "_",
          "L25",
          "_timeseries_ratios.png",
          sep=""),
    bg="white",
    pointsize=5,
    units="cm",
    width=10,
    height=18,
    res = 600)

par( mar = c(5, 4, 3, 4), mfrow=c(3,1), family="serif", cex=1.5)

plot(c(Year[1], tail(Year,1)+3), c(0, 1.5), ylab="Indicator Ratio", col="transparent", main="(a) Cons
axis(1, at=Ind$Year, labels=FALSE, cex.axis=0.1, tick=TRUE)
lines(Lmax5_Linf~Year, data=Ind, lwd=2, col="black")
text(tail(Year,1)+2, tail(Ind$Lmax5_Linf,1), expression(L["max5%"]/L["inf"]), col="black", cex=1.0)
lines(L95_Linf~Year, data=Ind, lwd=2, col="purple")
text(tail(Year,1)+2, tail(Ind$L95_Linf,1), expression(L["95%"]/L["inf"]), col="purple", cex=1.1)
lines(Pmega~Year, data=Ind, lwd=2, col="blue")
text(tail(Year,1)+2, tail(Ind$Pmega,1), expression(P["mega"]), col="blue", cex=1.2)
lines(Pmegaref~Year, data=Ind, lwd=1, col="black", lty="dashed")
text(tail(Year,1)+2, tail(Ind$Pmegaref,1), expression("30%"), col="black", cex=1.0)
lines(Lc_Lmat~Year, data=Ind, lwd=2, col="red")
text(tail(Year,1)+2, tail(Ind$Lc_Lmat,1), expression(L["c"]/L["mat"]), col="red", cex=1.1)
lines(L25_Lmat~Year, data=Ind, lwd=2, col="darkred")
text(tail(Year,1)+2, tail(Ind$L25_Lmat,1), expression(L["25"]/L["mat"]), col="darkred", cex=1.1)

plot(c(Year[1], tail(Year,1)+3), c(0, 1.6), ylab="Indicator Ratio", col="transparent", main="(b) Opti
axis(1, at=Ind$Year, labels=FALSE, cex.axis=0.1, tick=TRUE)
```

```
  lines(Lmean_Lopt~Year, data=Ind, lwd=2, col="darkred")
  text(tail(Year,1)+2, tail(Ind$Lmean_Lopt,1), expression(L["mean"]/L["opt"]), col="darkred", cex=1.1)
  lines(Lmaxy_Lopt~Year, data=Ind, lwd=2, col="green")
  text(tail(Year,1)+2, tail(Ind$Lmaxy_Lopt,1), expression(L["maxy"]/L["opt"]), col="green", cex=1.1)

  plot(c(Year[1], tail(Year,1)+3), c(0, 1.6), ylab="Indicator Ratio", col="transparent", main="(c) Maxim
  axis(1, at=Ind$Year, labels=FALSE, cex.axis=0.1, tick=TRUE)
  lines(Lmean_LFeM~Year, data=Ind, lwd=2, col="blue")
  text(tail(Year,1)+2, tail(Ind$Lmean_LFeM,1), expression(L["mean"]/L["F=M"]), col="blue",cex=1.1)

  dev.off()

}
```

11 ANNEX II - EFFECTS OF VON BERTALANFFY K IN LENGTH BASED STOCK ASSESSMENT RESULTS

Length Based Indicators (WKLIFE, October 2015)

Karolina Molla Gazi

Script sample for Deep Sea Shrimp in GSA 1

```
rm(list = ls())
###########################
# Length-based indicators #
###########################
# Adapted from T. Miethe and C. Silva, WKLIFE-V, Oct2015
###########################

setwd("D:/Files/DTU/Thesis/R/Methods_Sources/LBI/Workspace_all")

library(reshape2)
library(lattice)
library(knitr)
source("D:/Files/DTU/Thesis/R/Methods_Sources/LBI/Workspace_all/functions/ICE_LFD.R")
source("D:/Files/DTU/Thesis/R/Methods_Sources/LBI/Workspace_all/functions/lbi_table.R")
source("D:/Files/DTU/Thesis/R/Methods_Sources/LBI/Workspace_PIL6/Length_format.r")
source("D:/Files/DTU/Thesis/R/Methods_Sources/LBI/Workspace_PIL6/weight_format.r")



####################
# Input parameters #
####################


stock<- "DPS"
S <- "N"
area <- "GSA 1"
# Life history parameters
Linf <- 45
Lmat <- NA
#length-weight for the estimation of Lmaxy
a <- 0.003055
b <- 2.490608
# Years of available data
startyear <- 2003
endyear <- 2015

#load data

length_data <- Length_format(file = "landings.txt",
                             area = area,
                             species = stock,
                             mode = 1,   ### represents the number of GSAs (or SAs). Allowable input 1 t
                             startyear = startyear,
                             endyear = endyear)
```

```r
weight <- Weight_format(file="landings.txt",
                        area= area,
                        species = stock,
                        mode = 1,
                        startyear = startyear,
                        endyear = endyear,
                        a = a,
                        b = b)
#check if needed
ns <- length_data
nsw <- weight

# Choose bin size (ClassInt) width for estimation of Lc [NOT USED ATM]

#############################################################################
# TRUE  if the MeanLength is not the class midpoint but the class lower bound and bin size 1

length_data <- ns
MeanLengthLB = TRUE
sex = "N"

if(MeanLengthLB){
  length_data$MeanLength <- length_data$MeanLength + 0.5
}

############################################################
# step 1 check length distribution plots to decide whether
# regrouping is necessary to determine Lc (Length at first catch= 50% of mode)
############################################################

length_plot <- function(length_data,
                        ClassInt = 1,
                        filename = "DPS1_distribution.png",
                        save_plot = FALSE,
                        units) {


  df0 <- length_data

  df0.long <- melt(df0, id.vars = 'MeanLength') #melts to long format
  print(df0.long)
  df0.long$variable <- gsub("X", "", as.character(df0.long$variable)) #replaces all matches of a string
  print(df0.long$variable)
  minCL <- floor((min(df0$MeanLength) - .5) / ClassInt) * ClassInt  # original data 1mm length class
  print(minCL)
  maxCL <- ceiling((max(df0$MeanLength) + .5) / ClassInt) * ClassInt

  df0$LC <- cut(df0$MeanLength,
                breaks = seq(minCL,
                             maxCL,
                             ClassInt),
                include.lowest = T)
```

```
  df0.gr <- aggregate(df0[, 2:ncol(df0)-1], by=list(df0$LC), sum)
  names(df0.gr)[1] <- 'lclass'
  df0.gr <- cbind(lclass=df0.gr$lclass,
                  lmidp = as.numeric(substr(df0.gr$lclass,
                                            2, regexpr(",",df0.gr$lclass)-1)) + ClassInt / 2,
                  df0.gr[, 3:ncol(df0.gr)])
  df0.gr.long <- melt(df0.gr[ ,-1], id.var = 'lmidp')
  df0.gr.long$variable <- gsub("X", "", as.character(df0.gr.long$variable))

  names(df0.gr.long)[2:3] <- c('year', 'Number')
  df0.gr.long$year <- as.numeric(as.character(df0.gr.long$year))


  length_bars <- barchart(Number ~ lmidp|as.factor(year),
                          data = df0.gr.long,
                          horizontal = F,
                          as.table = T,
                          ylim = c(0, NA),
                          xlab = 'Length',
                          ylab = 'Proportions',
                          scales = list(x = list(at = seq(1,length(unique(df0.gr.long$lmidp)), 4),
                                                 labels = seq(min(df0.gr.long$lmidp) + ClassInt,
                                                              max(df0.gr.long$lmidp), 4 * ClassInt))),
                          main = paste0("Length class: ", ClassInt, " ", units),
                          cex.main = 1.2)

  if(save_plot) {
    png(filename = filename,
        bg = "white",
        pointsize = 5,
        units = units,
        width = 35,
        height = 18,
        res = 600)

    print(length_bars)
    dev.off()
  } else {
    print(length_bars)
  }
}

length_plot(length_data,
            ClassInt = 1,
            filename = "D:/Files/DTU/Thesis/R/Methods_Sources/LBI/Workspace_all/DPS_1/DPS1_dist.png",
            save_plot = TRUE, units = "cm")

# step 6 final decision on regrouping fill in!
ClassInt <- 1


#########################################################################################
# step 2 Calculate indicators per sex
```

```
Year <- c(startyear:endyear)
Year1 <- c((startyear+1):endyear)

for(s in 1:length(S)){
  sex <- S[s]
  if(sex=="M") final <- m  #numbers
  if(sex=="F") final <- f
  if(sex=="N") final <- ns

  if(sex=="M") weight <- mw   #mean weights
  if(sex=="F") weight <- fw
  if(sex=="N") weight <- nsw

  Ind <- data.frame(matrix(ncol=24, nrow=endyear-startyear+1))
  names(Ind) <- c('Year','L75','L25','Lmed', 'L90', 'L95', 'Lmean','Lc','LFeM','Lmaxy' ,'Lmat', 'Lopt',
  Ind$Year <- startyear:endyear

  #  regrouping with selected length class width
  df0 <- final
  minCL <- floor((min(df0$MeanLength)-.5)/ClassInt)*ClassInt  #originaldat 1mm length class
  maxCL <- ceiling((max(df0$MeanLength)+.5)/ClassInt)*ClassInt
  df0$LC <- cut(df0$MeanLength, breaks=seq(minCL,maxCL,ClassInt), include.lowest=T)
  df0.gr <- aggregate(df0[,2:ncol(df0)-1], by=list(df0$LC), sum)
  names(df0.gr)[1] <- 'lclass'
  df0.gr <- cbind(lclass=df0.gr$lclass,
                  lmidp=as.numeric(substr(df0.gr$lclass,2,
                            regexpr(",",df0.gr$lclass)-1))+ClassInt/2, df0.gr[,3:ncol(df0.gr)])
  df0.gr.long <- melt(df0.gr[,-1], id.var='lmidp')
  names(df0.gr.long)[2:3] <- c('year', 'Number')
  df0.gr.long$year <- as.numeric(as.character(df0.gr.long$year))

  df0.gr.long <- melt(df0.gr[,-1], id.var='lmidp')
  names(df0.gr.long)[2:3] <- c('year', 'Number')
  df0.gr.long$year <- as.numeric(as.character(df0.gr.long$year))
  res <- data.frame(year=min(as.numeric(df0.gr.long$year)):max(as.numeric(df0.gr.long$year)),
                    lmidp=NA, nmax=NA, lc=NA)

  for (j in 3:ncol(df0.gr)) {
    for (i in 2:nrow(df0.gr)) {
      if(df0.gr[i+1,j]-df0.gr[i,j]>=0) {
        next
      } else {
        res$lmidp[j-2] = df0.gr$lmidp[i]
        res$nmax[j-2] = df0.gr[i,j]
        a = res$nmax[j-2]/2
        df1 = df0.gr[,c(2,j)]
        for (k in 1:nrow(df1)) {
          if (df1[k,2] < a) {
            next
          } else {
            res$lc[j-2] = df1[k,1]
          }
```

```
        break
      }
    }
    break
  }
}

Ind$Lc <- res$lc
Ind$Lmat <- Lmat[s]
Ind$Lopt <- 2/3*Linf[s]
Ind$Linf <- Linf[s]

for(jj in (1:length(Year))+1){
  j <- jj-1

  final2 <- final[,c(1,jj)]
  colnames(final2) <- c("lngth","number")

  final2$cumsum <- cumsum(final2[,2])
  final2$cumsum_perc <- final2$cumsum/sum(final2$number)

  # find mean top 5%
  numb <- as.data.frame(final2[rev(order(final2$lngth)),"number"])    # from largest starting
  colnames(numb) <- "number"
  numb$cum <- cumsum(numb$number)
  numb$lngth <- final2[rev(order(final2$lngth)),"lngth"]
  numb$cumperc <- round(numb$cum/sum(numb$number),5)
  numb$num5 <- 0
  numb[numb$cumperc<=0.05,"num5"] <- numb[numb$cumperc<=0.05,"number"]
  numb[max(which(numb$cumperc<=0.05))+1,"num5"] <- (0.05-numb[max(which(numb$cumperc<=0.05)),"cumperc
  Ind[j,"Lmax5"] <- sum(numb$num5*numb$lngth)/sum(numb$num5)

  # indicators
  Ind[j, "L75"] <- min(final2[which(final2$cumsum_perc >= 0.75), "lngth"])
  Ind[j, "L25"] <- min(final2[which(final2$cumsum_perc >= 0.25), "lngth"])
  Ind[j, "Lmed"] <- min(final2[which(final2$cumsum_perc >= 0.5), "lngth"])
  Ind[j, "L95"] <- min(final2[which(final2$cumsum_perc >= 0.95), "lngth"])
  Ind[j, "L90"] <- min(final2[which(final2$cumsum_perc >= 0.90), "lngth"])

  final3 <- final2[final2$lngth >= Ind[j, "L25"], ]    # calculate mean of individuals above Lc
  Ind[j, "Lmean"] <- sum(final3$lngth * final3$number) / sum(final3$number)

  final2$biomass <- final2$number * weight[, jj]
  Ind[j, "Lmaxy"] <- final2[final2$biomass == max(final2$biomass), "lngth"]  # length class with max y

  Lopt <- (2 / 3) * Linf[s]

  Ind[j, "Pmega"] <- sum(final2[which(final2$lngth >= (Lopt + 0.1 * Lopt)),
                              "number"]) / sum(final2$number)   # proportion larger Lopt+10%
  Ind[j, "Year"] <- Year[j]
  Ind[j, "Pmegaref"] <- 0.3   # proxy reference point of 30% in catch
  Ind[j, "LFeM"] <- 0.75 * Ind[j, "L25"] + 0.25 * Ind[j, "Linf"]
}
```

```
  #calculate various ratios
  Ind$Lmaxy_Lopt <- Ind$Lmaxy / Ind$Lopt
  Ind$L95_Linf <- Ind$L95 / Ind$Linf
  Ind$Lmean_LFeM <- Ind$Lmean / Ind$LFeM
  Ind$Lmean_Lmat <- Ind$Lmean / Ind$Lmat
  Ind$Lmean_Lopt <- Ind$Lmean / Ind$Lopt
  Ind$Lmax5_Linf <- Ind$Lmax5 / Ind$Linf
  Ind$Lc_Lmat <- Ind$Lc / Ind$Lmat
  Ind$L25_Lmat <- Ind$L25 / Ind$Lmat

  if(sex == "M") Males <- Ind
  if(sex == "F") Females <- Ind
  if(sex == "N") Unsexed <- Ind

  write.csv(Ind, file = paste("DPS_1",
                              "\\",
                              "L25",
                              "_IndicatorRatios_table.csv",
                              sep = ""),
            row.names = F)

}

lbi_table(Ind)

###############################################################################
## step 3 plot indicator time series per sex
file_path <- "D:/Files/DTU/Thesis/R/Methods_Sources/LBI/Workspace_all/DPS_1/"


for(s in 1:length(S)){
  sex <- S[s]
  if(sex == "M") Ind <- Males
  if(sex == "F") Ind <- Females
  if(sex == "N") Ind <- Unsexed

  png(paste(file_path,
            stock,
            "_",
            "L25",
            "_timeseries.png",
            sep = ""),
      bg = "white",
      pointsize = 5,
      units = "cm",
      width = 10,
      height = 18,
      res = 600)

  par(mar = c(5, 4, 3, 4),
      mfrow = c(3, 1),
      family = "serif",
      cex = 1.5)
```

```
plot(Linf ~ Year,
     data = Ind,
     ylab = "Length",
     col = "transparent",
     main = "(a) Conservation",
     xlab = "Year",
     xlim = c(Year[1],
              tail(Year, 1) + 1), ylim = c(min(Ind$Lc) * .9,
                                            unique(Ind$Linf) * 1.1),
     bty = "l")
axis(1, at = Ind$Year,
     labels = FALSE,
     cex.axis = 0.1,
     tick = TRUE)
lines(L95 ~ Year,
      data = Ind,
      lwd = 2,
      col = "purple")
text(tail(Year, 1) + 1,
     tail(Ind$L95, 1),
     expression(L["95%"]),
     col = "purple",
     cex = 1.1)
lines(Lmax5 ~ Year,
      data = Ind,
      lwd = 2,
      col = "black")
text(tail(Year, 1) + 1,
     tail(Ind$Lmax5, 1),
     expression(L["max5%"]),
     col = "black",
     cex = 0.9)
lines(Lmat ~ Year,
      data = Ind,
      lwd = 1,
      col = "black",
      lty = "dashed")
text(tail(Year, 1) + 1,
     tail(Ind$Lmat, 1),
     expression(L["mat"]),
     col = "black",
     cex = 1.1)
lines(Lc~Year, data=Ind, lwd=2, col="blue")
text(tail(Year,1)+1, tail(Ind$Lc,1), expression(L["c"]), col="blue", cex=1.1)
lines(Linf~Year, data=Ind, lwd=1, col="black", lty="dashed")
text(tail(Year,1)+1, tail(Ind$Linf,1), expression(L["inf"]), col="black", cex=1.1)
lines(L25~Year, data=Ind, lwd=1, col="red")
text(tail(Year,1)+1, tail(Ind$L25,1), expression(L["25%"]), col="red", cex=1.1)

plot(Linf~Year, data=Ind, ylab="Length", main="(b) Optimal Yield", col="transparent", xlab="Year", xli
axis(1, at=Ind$Year, labels=FALSE, cex.axis=0.1, tick=TRUE)
lines(L75~Year, data=Ind, lwd=1, col="red")
text(tail(Year,1)+1, tail(Ind$L75,1), expression(L["75%"]), col="red", cex=1.1)
```

```
lines(Lmean~Year, data=Ind, lwd=2, col="darkred")
text(tail(Year,1)+1, tail(Ind$Lmean,1), expression(L["mean"]), col="darkred", cex=1.1)
lines(Lopt~Year, data=Ind, lwd=1, col="black", lty="dashed")
text(tail(Year,1)+1, tail(Ind$Lopt,1), expression(L["opt"]), col="black", cex=1.2)
lines(Lmaxy~Year, data=Ind, lwd=2, col="green")
text(tail(Year,1)+1, tail(Ind$Lmaxy,1), expression(L["maxy"]), col="green", cex=1.2)
lines(Lmat~Year, data=Ind, lwd=1, col="black", lty="dashed")
text(tail(Year,1)+1, tail(Ind$Lmat,1), expression(L["mat"]), col="black", cex=1.1)
lines(L25~Year, data=Ind, lwd=1, col="red")
text(tail(Year,1)+1, tail(Ind$L25,1), expression(L["25%"]), col="red", cex=1.1)

plot(Lmat~Year, data=Ind, type="l", ylab="Length", main="(c) Maximum Sustainable Yield", col="black",
axis(1, at=Ind$Year, labels=FALSE, cex.axis=0.1, tick=TRUE)
text(tail(Year,1)+1, tail(Ind$Lmat,1), expression(L["mat"]), col="black", cex=1.2)
lines(Lmean~Year, data=Ind, lwd=2, col="darkred")
text(tail(Year,1)+1, tail(Ind$Lmean,1), expression(L["mean"]), col="darkred", cex=1.1)
lines(LFeM~Year, data=Ind, lwd=2, col="blue", lty="dashed")
text(tail(Year,1)+1, tail(Ind$LFeM,1), expression(L["F=M"]), col="blue", cex=1.2, lty="dashed")

dev.off()

png(paste(file_path,
          stock,
          "_",
          "L25",
          "_timeseries_ratios.png",
          sep=""),
    bg="white",
    pointsize=5,
    units="cm",
    width=10,
    height=18,
    res = 600)

par( mar = c(5, 4, 3, 4), mfrow=c(3,1), family="serif", cex=1.5)

plot(c(Year[1], tail(Year,1)+3), c(0, 1.5), ylab="Indicator Ratio", col="transparent", main="(a) Cons
axis(1, at=Ind$Year, labels=FALSE, cex.axis=0.1, tick=TRUE)
lines(Lmax5_Linf~Year, data=Ind, lwd=2, col="black")
text(tail(Year,1)+2, tail(Ind$Lmax5_Linf,1), expression(L["max5%"]/L["inf"]), col="black", cex=1.0)
lines(L95_Linf~Year, data=Ind, lwd=2, col="purple")
text(tail(Year,1)+2, tail(Ind$L95_Linf,1), expression(L["95%"]/L["inf"]), col="purple", cex=1.1)
lines(Pmega~Year, data=Ind, lwd=2, col="blue")
text(tail(Year,1)+2, tail(Ind$Pmega,1), expression(P["mega"]), col="blue", cex=1.2)
lines(Pmegaref~Year, data=Ind, lwd=1, col="black", lty="dashed")
text(tail(Year,1)+2, tail(Ind$Pmegaref,1), expression("30%"), col="black", cex=1.0)
lines(Lc_Lmat~Year, data=Ind, lwd=2, col="red")
text(tail(Year,1)+2, tail(Ind$Lc_Lmat,1), expression(L["c"]/L["mat"]), col="red", cex=1.1)
lines(L25_Lmat~Year, data=Ind, lwd=2, col="darkred")
text(tail(Year,1)+2, tail(Ind$L25_Lmat,1), expression(L["25"]/L["mat"]), col="darkred", cex=1.1)

plot(c(Year[1], tail(Year,1)+3), c(0, 1.6), ylab="Indicator Ratio", col="transparent", main="(b) Opti
axis(1, at=Ind$Year, labels=FALSE, cex.axis=0.1, tick=TRUE)
```

```
  lines(Lmean_Lopt~Year, data=Ind, lwd=2, col="darkred")
  text(tail(Year,1)+2, tail(Ind$Lmean_Lopt,1), expression(L["mean"]/L["opt"]), col="darkred", cex=1.1)
  lines(Lmaxy_Lopt~Year, data=Ind, lwd=2, col="green")
  text(tail(Year,1)+2, tail(Ind$Lmaxy_Lopt,1), expression(L["maxy"]/L["opt"]), col="green", cex=1.1)

  plot(c(Year[1], tail(Year,1)+3), c(0, 1.6), ylab="Indicator Ratio", col="transparent", main="(c) Maxim
  axis(1, at=Ind$Year, labels=FALSE, cex.axis=0.1, tick=TRUE)
  lines(Lmean_LFeM~Year, data=Ind, lwd=2, col="blue")
  text(tail(Year,1)+2, tail(Ind$Lmean_LFeM,1), expression(L["mean"]/L["F=M"]), col="blue",cex=1.1)

  dev.off()

}
```

12 LIST OF BACKGROUND DOCUMENTS

Background documents are published on the meeting's web site on:
http://stecf.jrc.ec.europa.eu/web/stecf/ewg08

List of background documents:

EWG-17-02 – Doc 1 - Declarations of invited and JRC experts (see also section 8 of this report – List of participants)

LB-AX-17-007-EN-N

STECF

The Scientific, Technical and Economic Committee for Fisheries (STECF) has been established by the European Commission. The STECF is being consulted at regular intervals on matters pertaining to the conservation and management of living aquatic resources, including biological, economic, environmental, social and technical considerations.

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