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Scientific, Technical and Economic Committee for Fisheries (STECF)

Mediterranean assessments part 1 (STECF 15-18)

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This report was reviewed by the STECF during its 50TH plenary meeting held from 9 to 13 November 2015 in Brussels

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Abstract
The Expert Working Group meeting of the Scientific, Technical and Economic Committee for Fisheries EWG 15-11 was held from 31 Aug-04 Sep 2015 in Palma de Mallorca, Spain to assess the status of demersal and small pelagic stocks in the Mediterranean Sea against the proposed F_{MSY} reference points. The report was reviewed by the STECF plenary in November 2015.

TABLE OF CONTENTS

SCIENTIFIC, TECHNICAL AND ECONOMIC COMMITTEE FOR FISHERIES (STECF)

Mediterranean assessments part 1 (STECF-15-18)

THIS REPORT WAS REVIEWED BY THE STECF DURING ITS 50TH PLENARY MEETING HELD FROM 9 TO 13 NOVEMBER 2015 IN BRUSSELS

Request to the STECF

STECF is requested to review the report of the STECF Expert Working Group meeting 15-11, evaluate the findings and make any appropriate comments and recommendations.

Observations of the STECF

The meeting was held in Palma de Mallorca, Spain, from 31 Aug - 4 Sep 2015 and hosted by the Centro Oceanográfico de Baleares - Instituto Español de Oceanografía. It was the first of the STECF expert meetings, within STECF's 2015 work programme, planned to undertake stock assessments in the Mediterranean Sea. The meeting was chaired by Massimiliano Cardinale and attended by 22 experts, including 4 STECF members. Furthermore, two JRC experts and one DG MARE representative were also present. Data of historical fisheries and scientific surveys derived from the official Mediterranean DCF data call issued to Member States on April 2015 with deadline on 2nd of July 2015 and 'operational deadline' on 17th of August.

The terms of reference for EWG-15-11of the meeting were:

For the 15 stocks given in Table 4.1.1, the STECF-EWG 15-11 is requested to:
ToR 1 – Assess trends in historic and recent stock parameters for the longest time series possible available up to and including 2014, for the stocks proposed in the Table below. This shall cover the evaluation of the level of fishing mortality at age, spawning stock biomass, stock biomass, and recruits at age. Data on fishing effort shall be provided by fleet segments and shall be the most detailed possible to support the establishment of a fishing effort or capacity baseline. Different assessment models should be applied as appropriate, including analyses of retrospective effects.

List of proposed stocks

Nb	Geographical Sub-Areas	Common name	Scientific name	Priority
1	GSA 1	Hake	*Merluccius merluccius*	High
2	GSA 5	Hake	*Merluccius merluccius*	High
3	GSA 6	Hake	*Merluccius merluccius*	High
4	GSA 7	Hake	*Merluccius merluccius*	High
5	GSA 8[1]	Hake	*Merluccius merluccius*	High
6	GSA 9	Hake	*Merluccius merluccius*	High
7	GSA 10	Hake	*Merluccius merluccius*	High
8	GSA 11	Hake	*Merluccius merluccius*	High
9	GSAs 1-7	Hake	*Merluccius merluccius*	High
10	GSAs 8-11	Hake	*Merluccius merluccius*	High
11	GSA 9	Giant red shrimp	*Aristaeomorpha foliacea*	Medium
12	GSA 10	Giant red shrimp	*Aristaeomorpha foliacea*	Medium
13	GSA 11	Giant red shrimp	*Aristaeomorpha foliacea*	Medium
14	GSA 6	Blue and red shrimp	*Aristeus antennatus*	High
15	GSA 1	Blue and red shrimp	*Aristeus antennatus*	High

[1] *Although a full analytical assessment may not be possible to perform for hake in GSA 8, the EWG is requested to provide a preliminary analysis with some elements such as the level of fishing mortality, fishing effort, CPUE or survey indexes, even if the time series are limited.*

In case it is not possible to carry out an evaluation of those stocks listed in table 4.1.1, is provided a reserve list of stocks

ToR 2 – Propose and evaluate candidate MSY value or range of values and safeguard points in terms of fishing mortality and stock biomass. The proposed values shall be related to long-term high yields and low risk of stock/fishery collapse and ensure that the exploitation levels restore and maintain marine biological resources at least at levels which can produce the maximum sustainable yield.

ToR 3 – Provide short and medium term forecasts of spawning stock biomass, stock biomass and catches. The forecasts shall include different management scenarios, inter alia: zero catch, the status quo fishing mortality, and target to F_{MSY} or other appropriate proxy by 2018 and 2020. In particular, predict:

i) The level of fishing mortality which minimize the risk of SSB falling below B_{lim} with a 5% probability and provide MSY or maximize the total yield from the stock in the long term; and

ii) The level of fishing effort exerted by different fleet segments which is commensurate to the sustainable short-term and medium-term forecasts of the proposed changes.

ToR 4 – On the basis of the existing information, prepare and/or up-date maps showing areas and periods with high occurrence of juveniles and/or spawners of *Merluccius merluccius*, *Aristeus antennatus* and *Aristaeomorpha foliacea*.

ToR 5 – Provide a synoptic overview of: (i) the fishery; (ii) the most recent state of the stock (spawning stock biomass, stock biomass, recruits, and, if possible, exploitation level by fleet segment); (iii) the source of data and methods and; (iv) the management advice, including MSY value or range of values and safeguard points.

ToR 6 - Summarize and concisely describe all data quality deficiencies, including possible limitations with the surveys, of relevance for the assessment of stocks and fisheries. Such review and description are to be based on the data format of the official DCF data calls for the Mediterranean Sea issued on April 2015.

Comments of the STECF

Based on the findings in the EWG-14-19 report, STECF observes that the EWG 15-11 undertook the stock assessment of 15 stocks. Mediterranean hake was assessed in the individual GFCM GSAs 1, 5, 6, 7, 8, 9, 10, 11 and jointly for GSA 1, 5, 6, 7 and 9, 10, 11. Giant red shrimp was assessed in GSA 9, 10, 11 and Blue and red shrimp in GSA 1 and 6.

For 1 stock (Hake in GSA 8), the assessment was conducted but not accepted due to insufficient length data being available. STECF notes that hake only constitute ~2% of total demersal landings in GSA8.

A total of 13 out of 14 stocks for which assessment was accepted were classified as exploited unsustainably with the exception of Giant red shrimp in GSA 9 (see Table 0-1 for details).

STECF notes that partial fishing mortality by fleet is presented for the main fisheries that exploit each single stock in the area. There were also estimated ranges for F_{MSY} based on empirical relationship for F0.1 based on information of stocks of ICES area.

Table 0-1 Synoptic table of the stock assessed during EWG 15-11. In red are stocks for which current F is larger than F_{MSY}.

Stock area	Common name	Assessment	F*	F trawlers**	F trawlers**	F gillnets**	F trammel**	F longlines	F_{MSY}	F_{MSY} range	F/F_{MSY}	B_{lim}	B_{curr}	B/B_{lim}	Short term
GSA 1	Hake	XSA	1.20	0.91		0.05		0.11	0.21	0.14-0.29	5.71	220	220	1.00	Yes
GSA 5	Hake	XSA	1.12						0.15	0.10-0.21	7.47	31	75	2.41	Yes
GSA 6	Hake	XSA	1.39	1.62		0.10¤			0.26	0.17-0.36	5.35	1533	1599	1.04	Yes
GSA 7	Hake	XSA	1.64	1.40?	0.16??	0.17		0.03	0.11	0.08-0.16	14.91	769	1115	1.45	Yes
GSA 8	Hake	Surba					**not accepted**								
GSA 9	Hake	XSA	1.03	0.77		0.15	0.03		0.23	0.16-0.32	4.48	1569	2197	1.40	Yes
GSA 10	Hake	XSA	1.10	0.26		0.44		0.21	0.20	0.13-0.27	5.56	967	1635	1.69	Yes
GSA 11	Hake	XSA	1.60						0.17	0.11-0.24	9.41	73	73	1.00	Yes
GSAs 1_7	Hake	XSA	1.40	1.03		0.07		0.05¦	0.39	0.26-0.53	3.59	5186	8133	1.57	Yes
GSAs 9_11	Hake	XSA	1.10	0.50		0.10	0.24	0.12	0.20	0.14-0.28	5.50	2355	2912	1.24	Yes
GSA 9	Giant red shrimp	XSA	0.13						0.51	0.34-0.69	0.25	80	94	1.18	Yes
GSA 10	Giant red shrimp	XSA	0.91	0.50		0.01			0.65	0.43-0.88	1.40	265	265	1.00	Yes
GSA 11	Giant red shrimp	XSA	0.50						0.31	0.21-0.43	1.61	26	46	1.77	Yes
GSA 1	Blue and red shrimp	XSA	1.40						0.41	0.27-0.56	3.41	224	322	1.44	Yes
GSA 6	Blue and red shrimp	XSA	0.75						0.36	0.24-0.49	2.08	1287	3848	2.99	Yes

*Last year

**Average of the last 3 years

? French trawlers

?? Spanish trawlers

¤Gillnet and longliners

¦ Longliners also included other gears

***Probability of SSB to fall below Blim

STECF notes that for hake in GSA7 and GSA 11, very high F/F_{MSY} ratios were estimated (F/F_{MSY} >> 5~15). No explanations as to why the ratios are so high (besides assuming that these are correctly estimated by the assessment model) are given in the report but it is possible that the high ratios are due to inappropriate stock boundary definitions. Current GSAs boundaries may be not necessarily encompass the entire stock, which may in fact be spread across more than one GSA. The results of the assessments conducted over wider areas (i.e. GSAs 1, 5, 6, and 7 combined and GSAs 9, 10 and 11 combined for hake) have shown lower F/F_{MSY} ratios compared to the single GSAs (**Table 0-1**), and may partially explain the very high ratios observed in some of the single GSA assessments e.g. Hake in GSA7. While the high F/F_{MSY} rations could also be influenced by other factors such as data quality or assumptions in the assessment models, (i.e. constrained selection pattern, growth parameters, mortality at age, etc.), STECF notes that the ratios of F/F_{MSY} for the GSA combined assessments for hake are still very high, 3.59 and 5.5 for GSAs 1_7 and GSAa 9_11, respectively meaning that these stocks are heavily overexploited irrespective of stock boundary assumptions.

STECF notes that EWG 15-11 prepared or up-dated maps showing areas and periods with high occurrence of juveniles and/or spawners of *Merluccius merluccius*, *Aristeus antennatus* and *Aristaeomorpha foliacea*. The TOR was addressed by creating new maps using MEDITS data showing the main concentrations of juveniles and adults. STECF notes the intrinsic limitations of the distribution maps when trying to infer spatial distribution of these species. MEDITS surveys are conducted only in late spring-summer and are therefore unlikely to be representative of the spatial distributions at other times of the year.

STECF also notes that in fulfilment of TOR (6), stock specific evaluations of the data quality were conducted for all stocks requested under ToR (1-5) by the experts. Deficient DCF data were observed for Hake for GSA 8 (i.e. Corsica), and no MEDITS data for Italian GSA 17 prior to 2002 were available. However, STECF acknowledges that hake catches in GSA 7 are typically only 2% of total demersal catches.

STECF notes that stock-specific evaluations of the data quality were conducted for all stocks requested under ToR (1-5) by the experts and endorses the main findings. STECF notes that some unresolved issues remain, in particular relating to data quality and delays in data submission.

Conclusions of the STECF

STECF concludes that the EWG-14-19 adequately addressed the Terms of Reference.

Report to the STECF

EXPERT WORKING GROUP ON Mediterranean assessments part 1 (EWG-15-11)

Palma de Mallorca, Spain, 31 Aug-4 Sep 2015

1. Executive summary

The meeting was the first of two STECF expert meetings, within STECF's 2015 work programme, planned to undertake stock assessments of demersal/small pelagic species in the Mediterranean Sea. The meeting was organized by JRC in Palma de Mallorca from 31st of August to 4th of Septmber 2015 and was kindly hosted by the Centro Oceanográfico de Baleares - Instituto Español de Oceanografía. The meeting was chaired by Massimiliano Cardinale and attended by 22 experts in total, including 4 STECF members. Furthermore, two JRC experts and one DG MARE representative were present (see Chapter 13).

Historical fisheries and scientific survey data were obtained from the official Mediterranean DCF data call issued to Member States on April 2015 with deadline on 2nd of July 2015 and 'operational deadline' on 17th of August.

In fulfilment of **TORs 1** and 5 the EWG 15-11 undertook the stock assessment of 15 stocks. Mediterranean hake was assessed in the individual GFCM GSAs 1, 5, 6, 7, 8, 9, 10, 11 and jointly for GSA 1, 5, 6, 7 and 9, 10, 11. Giant red shrimp was assessed in GSA 9, 10, 11 and Blue and red shrimp in GSA 1 and 6.
For 1 stocks (Hake in GSA 8), the assessment was conducted but not accepted due to data issues, while a total of 13 out of 14 stocks with an accepted assessment were classified as exploited unsustainably with the exception of Giant red shrimp in GSA 9 (see Table 1 for details).

Table 1 *. Synoptic table of the stock assessed during EWG 15-11. In red are stocks for which current F is larger than F_{MSY}.

Stock area	Common name	Assessment	F*	F trawlers**	F trawlers**	F gillnets**	F trammel**	F longlines	F_{MSY}	F_{MSY} range	F/F_{MSY}	B_{lim}	B_{curr}	B/B_{lim}	Short term	MSE
GSA 1	Hake	XSA	1.20	0.91		0.05		0.11	0.21	0.14-0.29	5.71	220	220	1.00	Yes	0
GSA 5	Hake	XSA	1.12						0.15	0.10-0.21	7.47	31	75	2.41	Yes	0
GSA 6	Hake	XSA	1.39	1.62		0.10¤			0.26	0.17-0.36	5.35	1533	1599	1.04	Yes	0
GSA 7	Hake	XSA	1.64	1.40‡	0.16‡‡	0.17		0.03	0.11	0.08-0.16	14.91	769	1115	1.45	Yes	0
GSA 8	Hake	Surba					**not accepted**									
GSA 9	Hake	XSA	1.03	0.77		0.15	0.03		0.23	0.16-0.32	4.48	1569	2197	1.40	Yes	0
GSA 10	Hake	XSA	1.10	0.26		0.44		0.21	0.20	0.13-0.27	5.56	967	1635	1.69	Yes	0
GSA 11	Hake	XSA	1.60						0.17	0.11-0.24	9.41	73	73	1.00	Yes	0
GSAs 1_7	Hake	XSA	1.40	1.03		0.07		0.05¦	0.39	0.26-0.53	3.59	5186	8133	1.57	Yes	0
GSAs 9_11	Hake	XSA	1.10	0.50		0.10	0.24	0.12	0.20	0.14-0.28	5.50	2355	2912	1.24	Yes	0
GSA 9	Giant red shrimp	XSA	0.13						0.51	0.34-0.69	0.25	80	94	1.18	Yes	0
GSA 10	Giant red shrimp	XSA	0.91	0.50		0.01			0.65	0.43-0.88	1.40	265	265	1.00	Yes	0
GSA 11	Giant red shrimp	XSA	0.50						0.31	0.21-0.43	1.61	26	46	1.77	Yes	0
GSA 1	Blue and red shrimp	XSA	1.40						0.41	0.27-0.56	3.41	224	322	1.44	Yes	0
GSA 6	Blue and red shrimp	XSA	0.75						0.36	0.24-0.49	2.08	1287	3848	2.99	Yes	0

*Last year
**Average of the last 3 years
‡ French trawlers
‡‡ Spanish trawlers
¤Gillnet and longliners
¦ Longliners also included other gears
***Probability of SSB to fall below Blim
*ToRs requested GSA 8-11, however lack of analytical data for GSA 8 limited the assessment to GSA 9 to 11.

TOR 2 requested to propose and evaluate candidate MSY values or ranges and safeguard points in terms of fishing mortality and stock biomass. This was requested for the first time to the EWG MED assessment working group and was addressed by using Management Strategy Evaluation to evaluate if the MSY ranges are precautionary or not. The MSE functions were run using R scripts developed for and tested during STECF 15-09. The management strategy evaluation included uncertainty in: a)

recruitment around a mean level resulting from the geometric mean of the last 3 years of data, b) uncertainty in the MEDITS tuning fleet indices, and c) uncertainty in the perceived stock status.
F_{msy} ranges were proposed and tested for robustness of the higher F (F_{upper}) for all assessed stocks. F_{upper} was considered safe if the probability of SSB to fall below B_{lim} at F = F_{upper} was equal to 0, which was the case for all stocks. F_{MSY} ranges are summarized in Table 1.

Following **TOR 3** the EWG 15-11 also conducted short term forecasts of stock size and catches for 14 stocks. For the first time the forecasts were also produced by fleet. No medium term forecasts were carried out for any of the stocks assessed at the meeting because no meaningful stock-recruitment relationship was estimated for any of the stock assessed. However the MSE where F_{upper} would be reached in 2020 is a long term forecast under the assumption of mean recruitment which is effectively a conservative projection of stock trends at the upper range of F_{MSY}.

TOR 4 requested to **prepare and/or up-date maps** showing areas and periods with high occurrence of juveniles and/or spawners of *Merluccius merluccius, Aristeus antennatus* and *Aristaeomorpha foliacea.* The TOR was addressed by creating new maps using MEDITS data (1994-2014) and calculating yearly maps of high occurrence of juveniles and spawners, defined base on a length threshold. An intrinsic limitation of the perceived spatial distribution of these species is due to the limited seasonal span of the MEDITS survey (May-September). For Mediterranean hake the identified areas of high juvenile occurrence include parts of the Catalan coast (GSA 6), the gulf of Lions (GSA 7), and the Ligurian sea (GSA 9), while there is high variability in occurrence around the Balearic Islands (GSA 5) and Sardinia (GSA 11). These results are consistent with Colloca (2013) and Druon (2015). Sardinia (GSA 11) and the gulf of Lions (GSA 7) exhibited the highest concentrations of hake spawners.
Aristaeomorpha. foliacea occurrence in MEDITS showed relatively high concentrations of juveniles in every year in Sardinia (GSA 11) and the Tyrrhenian sea (GSA 10). GSAs 10 and 11 appear to be the main areas of occurrence of *A. foliacea* spawners, while there have been a few years when spawning aggregations occurred in GSA 9 as well, especially after 2004. These findings for *A. foliacea* are in general agreement with previous studies (Colloca et al. 2013; 2015).
For *Aristeus. antennatus* juveniles, the timing of the MEDITS survey is not considered suitable. Also, recruitment for this species takes place mostly at depths beyond 900m, which are not accessed by MEDITS (Sarda and Company, 2012). Therefore, the maps produced are not considered truly representative of the actual nursery areas. Annual maps of spatial occurrence of *A. antennatus* juveniles exhibit great variability from year to year, with Sardinia (GSA 11) exhibiting the most persistent occurrence of juveniles.
High occurrence of individuals compatible with spawning occurred in almost every year in Sardinia (GSA 11), gulf of Lions (GSA 7) and Ligurian Sea (GSA 9), while in the Spanish GSAs (1, 5, 6) there was a greater interannual variability.

TOR 6, the data call was issued on April 2015. The 'legal' deadline for submissions was the 2nd of July 2015. Upon communication with the member states some data tables were corrected and re-uploaded in relation to the 'operational' deadline of the 17th August 2015. Data was uploaded by each country according to the following table:

Timeline of data upload from Mediterranean Member States, data call '**legal' deadline of the 2^{h} of July 2015; 'operational' deadline 17 August 2015**.

COUNTRY	First Upload	Last Upload
ITA	29 June 2015	12 August 2015

ESP	01 July 2015	05 August 2015
FRA	19 June 2015	02 July 2015
SVN	05 June 2015	23 July 2015
MLT	02 July 2015	02 July 2015
CYP	01 July 2015	06 August 2015
GRC	02 July 2015	31 Aug 2015
HRV	27 June 2015	31 July 2015*

*: *additional submissions on 4 Sep 2015 upon a request by the EWG*

The overall 2015 Data Call performance of data coverage, timeliness and progress of submissions by member state and main table/variable will be made available by the end of the year and after the completion of the EWG 15-16 Mediterranean stock assessments part 2, on the dedicated weblink: http://datacollection.jrc.ec.europa.eu/coverage

In fulfilment of TOR (6), stock specific evaluations of the data quality were conducted for all stocks requested under ToR (1-5) by the EWG 15-11 experts. Moreover, JRC team examined the data coverage and quality of the fisheries and survey data. Results of the evaluations are reported under Chapter 7 and at the end of the assessment section of each stock. The main issues found by EWG 15-11 were: deficient DCF data for Hake for GSA 8 (i.e. Corsica), although for the first time some data was reported for this area; moreover effort data for all French GSA's are absent prior to 2009. There were some missing information for hake in GSA 9, 10 and 11 (see details in Chapter 7) and no MEDITS data for Italian GSA 17 prior to 2002. More detailed issues identified in the data are described at the end of each stock assessment sections.

2. Findings And Conclusions Of The Working Group

Stock-Specific Findings & Conclusions

See the stock specific summary sheets.

3. Follow Up Items

The text below highlights some issues that arose during the EWG 15-11 meeting, which created difficulties for the meeting or for the process of completing the report. The EWG offers the following suggestions for next year to improve the process for preparing assessments of the Mediterranean Sea stocks:

(1) The increasing demand for Management Strategy Evaluations (MSE) on Mediterranean stocks makes it absolutely essential that experts receive specialized training on the principles behind MSE and its specific application to Mediterranean fisheries. To this end, JRC experts could provide dedicated training courses for selected experts.

(2) DCF data calls need to reconsider the length of the time series called to avoid that the historical survey and fisheries data are continuously changed, with no clear indication of the reasons, creating an extra work burden for Memebr States and JRC during the data calls and the experts at the start of each meeting. In principle, data calls in the future should only include the last year of data (both survey and fisheries data). However given the amount of errors still detected in many DCF data sources, it should be still possible to upload corrections. To prevent the abuse of the system, any changes to the historical survey and fisheries data should be clearly justified by the MS and changes to the database should be made by JRC.

4. Introduction

The expert working group on Mediterranean stock and fisheries assessment part 1 STECF EWG 15-11 held its first meeting planned for 2015 in Palma de Mallorca (Spain), 31 Aug-04 Sep 2015.

The chairman opened the meeting at 09:00 on Monday, 31 Aug 2015, and adjourned the meeting by 16:00 on Friday, 04 Sep 2015. The meeting was attended by 22 experts in total, including 4 STECF members and an additional 2 JRC experts.

The structure of the present report is in accordance with the terms of reference to STECF, as defined in the following chapter.

4.1 Terms Of Reference For Ewg-15-11

For the 15 stocks given in Table 4.1.1, the STECF-EWG 15-11 is requested to:

ToR 1 – **Assess trends in historic and recent stock parameters** for the longest time series possible available up to and including 2014, for the stocks proposed in Table 4.1.1. This shall cover the evaluation of the level of fishing mortality at age, spawning stock biomass, stock biomass, and recruits at age. Data on fishing effort shall be provided by fleet segments and shall be the most detailed possible to support the establishment of a fishing effort or capacity baseline. Different assessment models should be applied as appropriate, including analyses of retrospective effects.

Table 4.1.1 – List of proposed stocks

Nb	Geographical Sub-Areas	Common name	Scientific name	Priority
1	GSA 1	Hake	*Merluccius merluccius*	High
2	GSA 5	Hake	*Merluccius merluccius*	High
3	GSA 6	Hake	*Merluccius merluccius*	High
4	GSA 7	Hake	*Merluccius merluccius*	High
5	GSA 8[2]	Hake	*Merluccius merluccius*	High
6	GSA 9	Hake	*Merluccius merluccius*	High
7	GSA 10	Hake	*Merluccius merluccius*	High
8	GSA 11	Hake	*Merluccius merluccius*	High
9	GSAs 1-7	Hake	*Merluccius merluccius*	High
10	GSAs 8-11	Hake	*Merluccius merluccius*	High
11	GSA 9	Giant red shrimp	*Aristaeomorpha foliacea*	Medium
12	GSA 10	Giant red shrimp	*Aristaeomorpha foliacea*	Medium
13	GSA 11	Giant red shrimp	*Aristaeomorpha foliacea*	Medium
14	GSA 6	Blue and red shrimp	*Aristeus antennatus*	High
15	GSA 1	Blue and red shrimp	*Aristeus antennatus*	High

[2] *Although a full analytical assessment may not be possible to perform for hake in GSA 8, the EWG is requested to provide a preliminary analysis with some elements such as the level of fishing mortality, fishing effort, CPUE or survey indexes, even if the time series are limited.*

In case it is not possible to carry out an evaluation of those stocks listed in table 4.1.1, below is provided a reserve list of stocks (Table 4.1.2.).

Table 4.1.2. – Reserve stock list

Geographical Sub-Areas	Common name	Scientific name	Priority
GSA 7	Sole	*Solea solea*	High
GSA 1	Deep water pink shrimp	*Parapenaeus longirostris*	High
GSA 6	Deep water pink shrimp	*Parapenaeus longirostris*	High
GSA 10	Deep water pink shrimp	*Parapenaeus longirostris*	High
GSA 1	Anglerfish	*Lophius budegassa*	Medium
GSA 5	Anglerfish	*Lophius budegassa*	Medium
GSA 6	Anglerfish	*Lophius budegassa*	Medium

ToR 2 – **Propose and evaluate candidate MSY value or range of values and safeguard points** in terms of fishing mortality and stock biomass. The proposed values shall be related to long-term high yields and low risk of stock/fishery collapse and ensure that the exploitation levels restore and maintain marine biological resources at least at levels which can produce the maximum sustainable yield.

ToR 3 – **Provide short and medium[3] term forecasts of spawning stock biomass, stock biomass and catches**. The forecasts shall include different management scenarios, inter alia: zero catch, the status quo fishing mortality, and target to FMSY or other appropriate proxy by 2018 and 2020. In particular, predict:

i) The level of fishing mortality which minimize the risk of SSB falling below Blim with a 5% probability and provide MSY or maximize the total yield from the stock in the long term; and

ii) The level of fishing effort exerted by different fleet segments which is commensurate to the sustainable short-term and medium-term forecasts of the proposed changes.

ToR 4 – On the basis of the existing information, **prepare and/or up-date maps** showing areas and periods with high occurrence of juveniles and/or spawners of *Merluccius merluccius, Aristeus antennatus* and *Aristaeomorpha foliacea.*

ToR 5 – Provide a synoptic overview of: (i) the fishery; (ii) the most recent state of the stock (spawning stock biomass, stock biomass, recruits, and, if possible, exploitation level by fleet segment); (iii) the source of data and methods and; (iv) the management advice, including MSY value or range of values and safeguard points.

ToR 6 - Summarize and concisely describe all data quality deficiencies, including possible limitations with the surveys, of relevance for the assessment of stocks and fisheries. Such review and description

[3] *Medium term forecast only when an acceptable stock-recruitment relationship is identifiable.*

are to be based on the data format of the official DCF data calls for the Mediterranean Sea issued on April 2015.

5 ASSESS TRENDS IN HISTORIC AND RECENT STOCK PARAMETERS

5.1 SUMMARY SHEETS

5.1.1 SUMMARY SHEET OF HAKE IN GSA 1

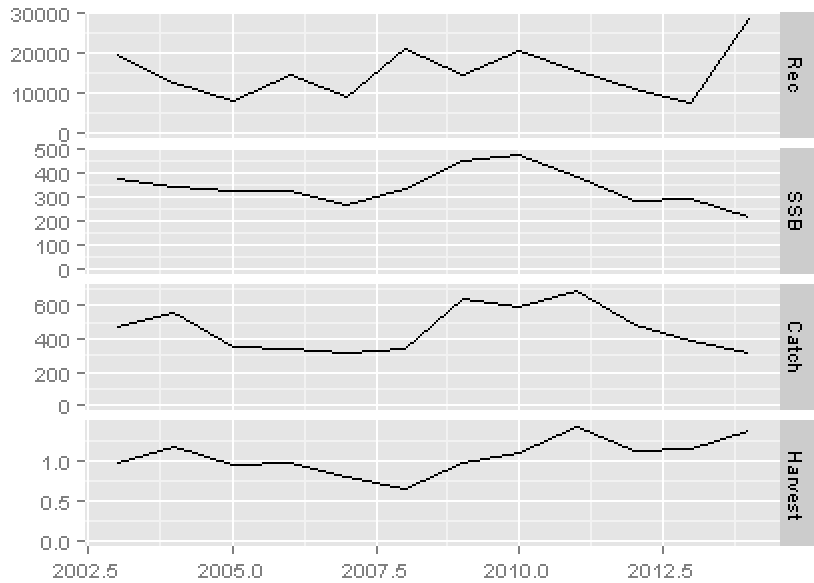
Species common name: European Hake
Species scientific name: *Merluccius merluccius*
Geographical Sub-area(s) GSA(s): 1

5.1.1.1 Stock development over time

State of the adult abundance and biomass
SSB is decreasing in the last years, from a maximum of 480 tonnes in 2010 to a minimum of 220 tonnes in 2014.

State of the juveniles (recruits)
Recruitment has a fluctuating trend with a mean recruitment of 15177 thousand individuals. The recruitment of the last year (2014) is the maximum of the series (28673 thousand individuals).

State of exploitation
The current F (1.20) is larger than F_{MSY} (0.21), which indicates that European hake in GSA 1 is being fished above F_{MSY}.



Hake in GSA 1. XSA summary results. SSB and catch are in tonnes, recruitment in 1000s individuals.

5.1.1.2 Stock advice

STECF EWG 15-11 advises the relevant fleets' catches and/or effort to be reduced until fishing mortality is below or at the proposed F_{MSY} level (0.21), in order to avoid future loss in stock productivity and landings. This should be achieved by means of a multi-annual management plan taking into account mixed-fisheries considerations. Catches of European hake in GSA 1 in 2016 consistent with F_{MSY} should not exceed 160 t.

5.1.1.3 Basis of the assessment

The state of exploitation was assessed for the period 2003-2014 applying the Extended Survivor Analysis (XSA) method calibrated with fishery independent survey abundance indices (MEDITS). In addition, a yield-per-recruit (Y/R) analysis was carried out. Both methods were performed from the size composition of trawl, gillnet and longline catches, transforming length data into ages by slicing (L2AGE program).

Input data on landings, discards and size structure by gear were taken from DCF. Natural mortality (vector) was estimated using PRODBIOM. Von Bertalanffy growth parameters used in the assessment correspond to fast growth (L_{inf}= 110.0 cm; k= 0.178).

5.1.1.4 Catch options

Catch options are summarized in the following table 5.1.1.4.1.

Table 5.1.1.4.1. Short term forecast in different F scenarios computed for hake in GSA 1. Basis: F(2015) = mean(F_{bar} 0-2 2012-2014)= 1.20; R(2015) = geometric mean of the recruitment of the last 3 years; R = 13364 thousands; SSB(2014) = 220 t, Catch (2014)= 313 t.

Rationale	Ffactor	Fbar	Catch 2015	Catch 2016	Catch 2017	SSB 2016	SSB 2017	Change SSB_2016-2017(%)	Change Catch_2014-2016(%)
Zero catch	0	0	726	0	0	367	1158	215.56	-100.00
High long term yield (F_{MSY})	0.18	0.21	726	160	281	367	883	140.49	-48.93
Status quo	1	1.20	726	550	459	367	273	-25.72	75.47
Different Scenarios	0.1	0.12	726	96	185	367	991	170.01	-69.21
	0.2	0.24	726	180	307	367	850	131.47	-42.68
	0.3	0.36	726	251	385	367	730	98.85	-19.76
	0.4	0.48	726	314	433	367	628	71.21	0.08
	0.5	0.60	726	367	459	367	542	47.80	17.29
	0.6	0.72	726	414	472	367	470	27.94	32.25
	0.7	0.84	726	455	476	367	408	11.09	45.29
	0.8	0.96	726	491	474	367	355	-3.22	56.69
	0.9	1.08	726	522	468	367	311	-15.38	66.68
	1.1	1.32	726	574	450	367	240	-34.53	83.22
	1.2	1.44	726	596	440	367	213	-42.04	90.07
	1.3	1.56	726	615	430	367	189	-48.45	96.16
	1.4	1.68	726	632	420	367	169	-53.93	101.59
	1.5	1.80	726	647	411	367	152	-58.62	106.44
	1.6	1.92	726	660	402	367	137	-62.64	110.80
	1.7	2.04	726	673	394	367	124	-66.10	114.73
	1.8	2.16	726	684	387	367	113	-69.08	118.28
	1.9	2.28	726	694	380	367	104	-71.64	121.51
	2	2.40	726	703	373	367	96	-73.87	124.46

5.1.1.5 Reference points

Table 5.1.1.5.1. Hake in GSA 1. Reference points, values and their technical basis.

Framework	Reference point	Value	Technical basis	Source
MSY approach	MSY $B_{trigger}$			
	F_{MSY}	0.21	$F_{0.1}$ estimated with YPR	Present assessment
Precautionary approach	B_{lim}	220 t	B_{loss}	Present assessment
	B_{pa}			
	F_{lim}			
	F_{pa}			
EU-GFCM management strategy	SSB_{lower}			
	SSB_{upper}			
	F_{lower}	0.14	Empirical relationship	Present assessment
	F_{upper}	0.29	Empirical relationship	Present assessment

5.1.1.6 Quality of the assessment

The detailed assessment can be found in section 5.2.1.

5.1.2 SUMMARY SHEET OF HAKE IN GSA 5

Species common name: European hake
Species scientific name: *Merluccius merluccius*
Geographical Sub-area(s) GSA(s): 5

5.1.2.1 Stock development over time

State of the adult abundance and biomass
SSB oscillated without trend between 30 and 115 tons.

State of the juveniles (recruits)
Recruitment varied between 2 and 11 millions during the time series with a slight declining trend. In the last 20 years, recruitment never showed the high values found in the middle 1980s and early 1990s, where catches also reach maximum values.

State of exploitation
F has declined from around 2 in the beginning of the time series to around 1 in the latest years. The current F (1.12) is larger than F_{MSY} (0.15), which indicates that hake in GSA 5 is being fished above $F_{MSY.}$

Hake in GSA 5. XSA summary results. SSB and catch are in tonnes, recruitment in 1000s individuals.

5.1.2.2 Stock advice
STECF EWG 15-11 recommends the relevant fleets' catches and/or effort to be reduced until fishing mortality is below or at the proposed F_{MSY} level, in order to avoid future loss in stock productivity and landings. This should be achieved by means of a multi-annual management plan taking into account

mixed-fisheries considerations. Catches of European hake in GSA 5 in 2016 consistent with F_{MSY} should not exceed 31.9 t.

5.1.2.3 *Basis of the assessment*

The data used in the assessment were: (i) Catches time series 1980-2014 from OTB; (ii) Age distributions obtained from slicing of length distributions 1980-2014 (Figure 5.2.2.7.1); (iii) BALAR-MEDITS survey used as tuning fleet.

The assessment has been performed with an Extended Survivor Analysis (XSA) using the FLR library in R.

5.1.2.4 *Catch options*

Catch options are summarized in the following table 5.1.2.4.1.

Table 5.1.2.4.1. Short term forecast in different F scenarios computed for hake in GSA 5. Basis: F(2015) = mean(F_{bar}0-3 2012-2014)= 1.06; R(2015) = geometric mean of the recruitment of the last 3 years; R = 4600 thousands; SSB(2014) = 67 t, Catch (2014)= 124 t.

Rationale	F_{factor}	F_{bar}	Catch 2016	Catch 2017	SSB 2017	Change SSB 2016-2017 (%)	Change Catch 2014-2016 (%)
Zero catch	0.0	0.00	0.0	0.0	341.18	331.84	-100.00
High long-term yield (F_{MSY})	0.1	0.16	31.9	63.9	273.43	246.08	-74.21
Status quo	1.0	1.06	131.6	135.0	84.19	6.55	6.34
Different scenarios	0.1	0.11	22.6	47.3	293.07	270.94	-81.78
	0.2	0.21	42.1	80.0	252.27	219.30	-65.97
	0.3	0.32	59.2	102.3	217.64	175.47	-52.22
	0.4	0.43	74.0	116.9	188.24	138.25	-40.24
	0.5	0.53	86.9	126.3	163.25	106.63	-29.77
	0.6	0.64	98.3	131.8	142.00	79.73	-20.60
	0.7	0.75	108.3	134.8	123.92	56.85	-12.55
	0.8	0.85	117.0	135.9	108.52	37.35	-5.47
	0.9	0.96	124.8	135.9	95.39	20.73	0.79
	1.0	1.06	131.6	135.0	84.19	6.55	6.34
	1.1	1.17	137.8	133.7	74.62	-5.55	11.27
	1.2	1.28	143.2	132.2	66.44	-15.91	15.66
	1.3	1.38	148.1	130.5	59.44	-24.76	19.59
	1.4	1.49	152.4	128.9	53.44	-32.35	23.12
	1.5	1.60	156.4	127.2	48.30	-38.87	26.30
	1.6	1.70	159.9	125.7	43.88	-44.46	29.18
	1.7	1.81	163.1	124.2	40.08	-49.27	31.78
	1.8	1.92	166.1	122.9	36.81	-53.41	34.16
	1.9	2.02	168.8	121.7	33.98	-56.99	36.33
	2.0	2.13	171.2	120.6	31.54	-60.08	38.33

5.1.2.5 Reference points

Table 5.1.1.5.1 Hake in GSA 5. Reference points, values and their technical basis.

Framework	Reference point	Value	Technical basis	Source
MSY approach	MSY $B_{trigger}$			
	F_{MSY}	0.15	$F_{0.1}$ estimated with YPR.	Present assessment
Precautionary approach	B_{lim}	31 t	B_{loss}	Present assessment
	B_{pa}			
	F_{lim}			
	F_{pa}			
EU-GFCM management strategy	SSB_{lower}			
	SSB_{upper}			
	F_{lower}	0.10	Empirical relationship	Present assessment
	F_{upper}	0.21	Empirical relationship	Present assessment

5.1.2.6 Quality of the assessment

The detailed assessment can be found in section 5.2.2.

5.1.3 SUMMARY SHEET OF HAKE IN GSA 6

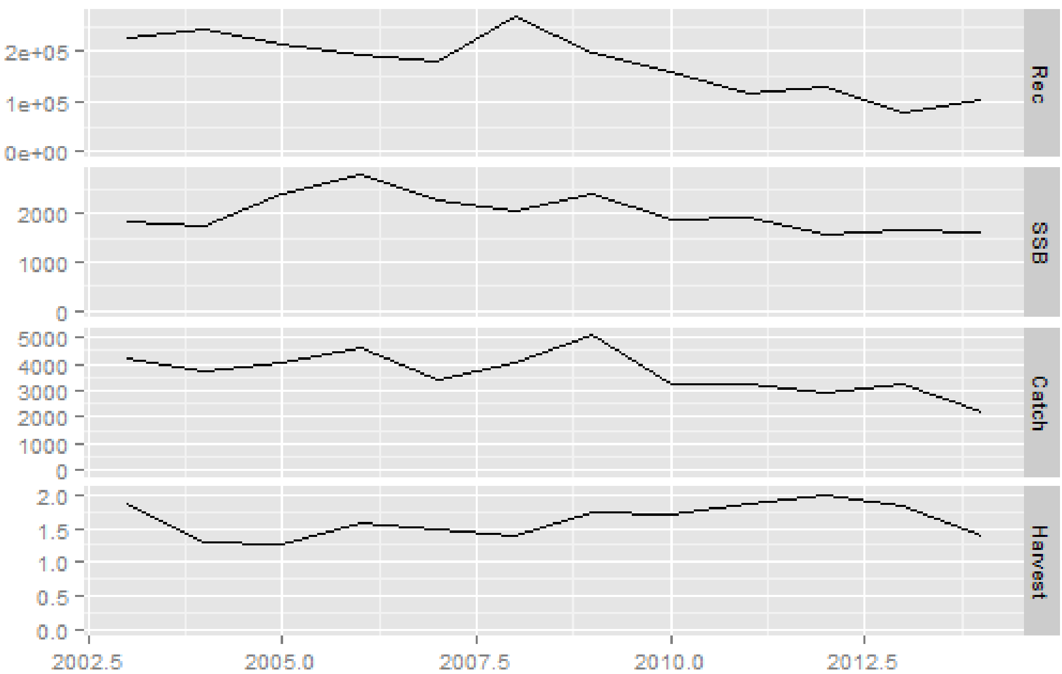
Species common name: European hake
Species scientific name *Merluccius merluccius*
Geographical Sub-area(s) GSA(s): 6

5.1.3.1 Stock development over time

State of the adult abundance and biomass
SSB increased from 2003 to 2006 but then decreased progressively down to a minimum in 2012.

State of the juveniles (recruits)
Recruitment showed an important decrease from 2003 to 2013 with a peak in 2008.

State of exploitation
F increased from 1.29 in 2004 to 2.0 in 2012 and then decreased to 1.39 in 2014. The current F (1.72) is larger than F_{MSY} (0.260), which indicates that hake from GSA 6 is is being fished above F_{MSY}.



Hake in GSA 6. XSA summary results. SSB and catch are in tonnes, recruitment in 1000s individuals.

5.1.3.2 Stock advice
STECF EWG 15-11 recommends the relevant fleets' catches and/or effort to be reduced until fishing mortality is below or at the proposed F_{MSY} level, in order to avoid future loss in stock productivity and landings. This should be achieved by means of a multi-annual management plan taking into account mixed-fisheries considerations. Catches of European hake in GSA 6 in 2016 consistent with F_{MSY} should not exceed 785 t.

5.1.3.3 Basis of the assessment

The assessment includes landings from all main fleets (trawlers, longliners, gillnetters). However, as size distributions from longliners are only available for the most recent years (2009-2014), the assessment was done considering two fleets: trawlers and others (longliners and gillnetters combined).

Growth parameters were from Mellon et al (2010). Maturity and length-weight parameters were from the Spanish DCF. Natural mortality was obtained from PRODBIOM. XSA, Y/R and projections were carried out using R.

5.1.3.4 Catch options

Catch options are summarized in the following table 5.1.3.4.1.

Table 5.1.3.4.1. Short term forecast in different F scenarios computed for hake in GSA 6. Basis: F(2015) = mean(F_{bar}1-3 2012-2014)= 1.74; R(2015) = geometric mean of the recruitment of the last 3 years; R = 100806 thousands; SSB(2014) = 1600 t, Catch (2014)= 2230 t.

Rationale	Ffactor	fbar	Catch 2016	Catch 2017	SSB 2017	Change SSB 2016-2017 (%)	Change Catch 2014-2016 (%)
Zero catch	0.0	0.0	0.0	0.0	7276	305.4	-100.0
High long-term yield (F_{MSY})	0.15	0.260	785	1718	5763	221.0	-64.8
Status quo	1.0	1.721	3101	3047	1727	-3.8	39.1
Different scenarios	0.10	0.172	538	1255	6234	247.3	-75.8
	0.20	0.344	1003	2070	5350	198.1	-55.0
	0.30	0.516	1406	2583	4601	156.3	-37.0
	0.40	0.688	1755	2891	3966	120.9	-21.3
	0.50	0.860	2060	3061	3426	90.9	-7.6
	0.60	1.032	2325	3139	2968	65.3	4.3
	0.70	1.204	2558	3158	2579	43.7	14.7
	0.80	1.376	2762.	3139	2248	25.2	23.9
	0.90	1.548	2942	3099	1967	9.6	31.9
	1.00	1.721	3101	3047	1727	-3.8	39.1
	1.10	1.893	3242	2989	1523	-15.1	45.4
	1.20	2.065	3368	2930	1349	-24.8	51.0
	1.30	2.237	3480	2873	1201	-33.2	56.1
	1.40	2.409	3581	2819	1074	-40.2	60.6
	1.50	2.581	3672	2768	965	-46.2	64.7
	1.60	2.753	3754	2722	872	-51.4	68.4
	1.70	2.925	3829	2680	793	-55.8	71.7
	1.80	3.097	3898	2642	724	-59.7	74.8
	1.90	3.269	3960	2608	665	-62.9	77.6
	2.00	3.441	4018	2577	614	-65.8	80.2

5.1.3.5 Reference points

Table 5.1.3.5.1 Hake in GSA 6. Reference points, values and their technical basis.

Framework	Reference point	Value	Technical basis	Source
MSY approach	MSY $B_{trigger}$			
	F_{MSY}	0.26	$F_{0.1}$ estimated with YPR.	Present assessment
Precautionary approach	B_{lim}	1133 t	B_{loss}	Present assessment
	B_{pa}			
	F_{lim}			
	F_{pa}			
EU-GFCM management strategy	SSB_{lower}			
	SSB_{upper}			
	F_{lower}	0.17	Empirical relationship	Present assessment
	F_{upper}	0.36	Empirical relationship	Present assessment

5.1.3.6 Quality of the assessment

The detailed assessment can be found in section 5.2.3.

5.1.4 SUMMARY SHEET OF HAKE IN GSA 7

Species common name: Hake
Species scientific name: *Merluccius merluccius*
Geographical Sub-area(s) GSA(s): 7

5.1.4.1 Stock development over time

State of the adult abundance and biomass
The stock spawning biomass (SSB) displays a decreasing trend over the analysed period, with a slight increase in 2014.

State of the juvenile (recruits)
The highest recruitment values observed over the period are in 1998, 2002-2003 and 2007. Since 2007, the recruitment follows a decreasing trend and is currently at a low level. The recruitment estimated for 2014 is 40913 thousands individuals, which is below the average of the time series (47449 thousands).

State of exploitation
F increased from around 1 to 2 over the time period analysed, with a peak in 2013. The current F (1.64) is larger than F_{MSY} (0.11), which indicates that hake from GSA 7 is is being fished above F_{MSY}.

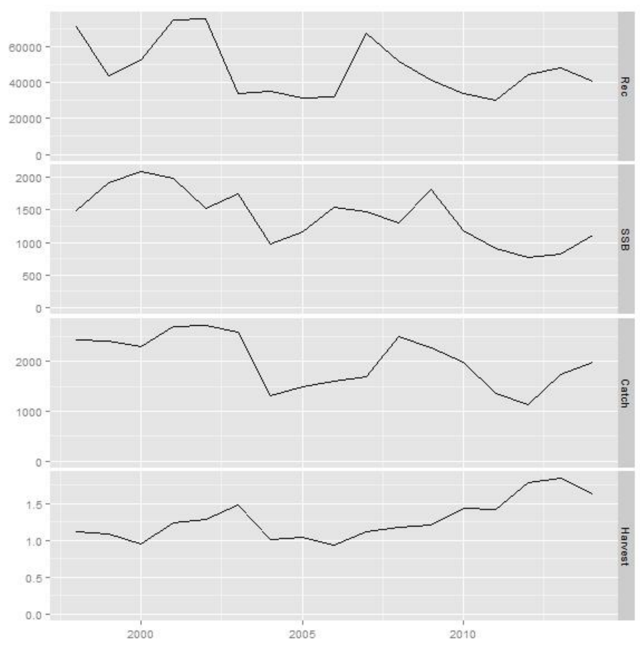


Figure 5.2.4.1.1. Hake in GS 7. XSA summary results. SSB and catch (tons), recruitment (numbers in thousands).

5.1.4.2 Stock advice
STECF EWG 15-11 advise the relevant fleets’ cacthes and/or effort to be reduced until fishing mortality is below or at the proposed F_{MSY} level in order to avoid future loss in stock productivity and

landings. This should be achieved by means of a multi-annual management plan taking into account mixed-fisheries considerations. Catches of European hake in GSA 7 in 2016 consistent with F_{MSY} should not exceed 209 t.

5.1.4.3 Basis of the assessment

The stock of European hake in GSA 7 was assessed using data coming from DCF (catch at age from French and Spanish trawlers, French gillnetters and Spanish longliners) for the period 1998-2014 and applying an XSA analysis calibrated with fishery independent survey abundance indices (MEDITS). In addition, a yield-per-recruit (Y/R) analysis was carried out. Discards were included in the catches. Growth parameters were derived from tagging experiments (Mellon et al, 2010) conducted in GSA 07, length-weight relationship and maturity ogive from the Data Collection Framework (DCF). Natural mortality was estimated using PROBIOM (Abella 1997).

Growth parameters (Mellon et al., 2010)	
L_{inf}	72.8 (males); 100.7 (females)
K	0.233 (males); 0.236 (females)
t_0	0
Length-Weight- parameters (from DCF data, 2002-2014)	
A	0.0085
B	2.97
Natural mortality (PROBIOM; Abella, 1997)	
Age 0	0.88
Age 1	0.43
Age 2	0.33
Age 3	0.25
Age 4	0.22
Age 5+	0.20
Maturity ogive (from DCF data, 2002-2014)	
Age 0	0,066
Age 1	0,308
Age 2	0,685
Age 3	0,907
Age 4	0,986
Age 5+	0,996

5.1.4.4 Catch options

Catch options are summarized in the following table 5.1.4.4.1.

Table 5.1.4.4.1. Short term forecast in different F scenarios computed for hake in GSA 7. Basis: F(2015) = mean(F_{bar}0-2 2012-2014)= 1.75; R(2015) = geometric mean of the recruitment of the last 3 years; R = 44364 thousands; SSB(2014) = 1115 t, Catch (2014)= 1983 t.

Rationale	Ffactor	Fbar	Catch 2014	Catch 2015	Catch 2016	Catch 2017	SSB 2016	SSB 2017	Change SSB 2016-2017(%)	Change Catch 2014-2016(%)
Zero catch	0,00	0.00	1981	1871	0	0	740	2798	278	-100.00
High long term yield (F_{MSY})	0.06	0.11	1981	1871	209	598	740	2499	238	-89.47
Status quo	0.10	0.18	1981	1871	320	858	740	2343	217	-83.87
Different Scenarios	0.20	0.35	1981	1871	586	1329	740	1980	168	-70.43
	0.30	0.53	1981	1871	809	1578	740	1689	128	-59.16

	0.40	0.70	1981	1871	998	1699	740	1455	97	-49.63
	0.50	0.88	1981	1871	1159	1749	740	1265	71	-41.51
	0.60	1.05	1981	1871	1297	1758	740	1109	50	-34.53
	0.70	1.23	1981	1871	1417	1746	740	982	33	-28.50
	0.80	1.40	1981	1871	1521	1723	740	877	18	-23.24
	0.90	1.58	1981	1871	1612	1695	740	790	7	-18.62
	1.00	1.75	1981	1871	1693	1666	740	716	-3	-14.53
	1.10	1.93	1981	1871	1766	1637	740	655	-12	-10.89
	1.20	2.10	1981	1871	1830	1610	740	602	-19	-7.62
	1.30	2.28	1981	1871	1889	1584	740	558	-25	-4.67
	1.40	2.45	1981	1871	1942	1560	740	519	-30	-1.98
	1.50	2.63	1981	1871	1991	1538	740	486	-34	0.47
	1.60	2.81	1981	1871	2035	1518	740	456	-38	2.72
	1.70	2.98	1981	1871	2077	1499	740	431	-42	4.81
	1.80	3.16	1981	1871	2115	1482	740	408	-45	6.74
	1.90	3.33	1981	1871	2151	1466	740	388	-48	8.54
	2.00	3.51	1981	1871	2184	1451	740	369	-50	10.23

5.1.4.5 Reference points

Table 5.1.1.5.1 Hake in GSA 7. Reference points, values and their technical basis.

Framework	Reference point	Value	Technical basis	Source
MSY approach	MSY $B_{trigger}$			
	F_{MSY}	0.11	$F_{0.1}$ estimated with YPR.	Present assesment
Precautionary approach	B_{lim}	769	B_{loss}	Present assesment
	B_{pa}			
	F_{lim}			
	F_{pa}			
EU-GFCM management strategy	SSB_{lower}			
	SSB_{upper}			
	F_{lower}	0.08	Empirical relationship	Present assesment
	F_{upper}	0.16	Empirical relationship	Present assesment

5.1.4.6 Quality of the assessment

The detailed assessment can be found in section 5.2.4.

5.1.5 SUMMARY SHEET OF HAKE IN GSA 8

Species common name: European hake
Species scientific name: *Merluccius merluccius*
Geographical Sub-area(s) GSA(s): 8

5.1.5.1 Stock development over time

No assessment was conducted due to data limitations.

5.1.5.2 Stock advice

No assessment was conducted due to data limitations.

5.1.5.3 Basis of the assessment

No assessment was conducted due to data limitations.

5.1.5.4 Catch options

No assessment was conducted due to data limitations.

5.1.5.5 Reference points

No assessment was conducted due to data limitations.

Table 5.1.1.5.1 Hake in GSA 8. Reference points, values and their technical basis.

Framework	Reference point	Value	Technical basis	Source
MSY approach	MSY $B_{trigger}$			
	F_{MSY}			
Precautionary approach	B_{lim}			
	B_{pa}			
	F_{lim}			
	F_{pa}			
EU-GFCM management strategy	SSB_{lower}			
	SSB_{upper}			
	F_{lower}			
	F_{upper}			

5.1.5.6 Quality of the assessment

The detailed assessment can be found in section 5.2.5.

5.1.6 SUMMARY SHEET OF HAKE IN GSA 9

Species common name: European hake
Species scientific name: *Merluccius merluccius*
Geographical Sub-area(s) GSA(s): 9

5.1.6.1 Stock development over time

State of the adult abundance and biomass

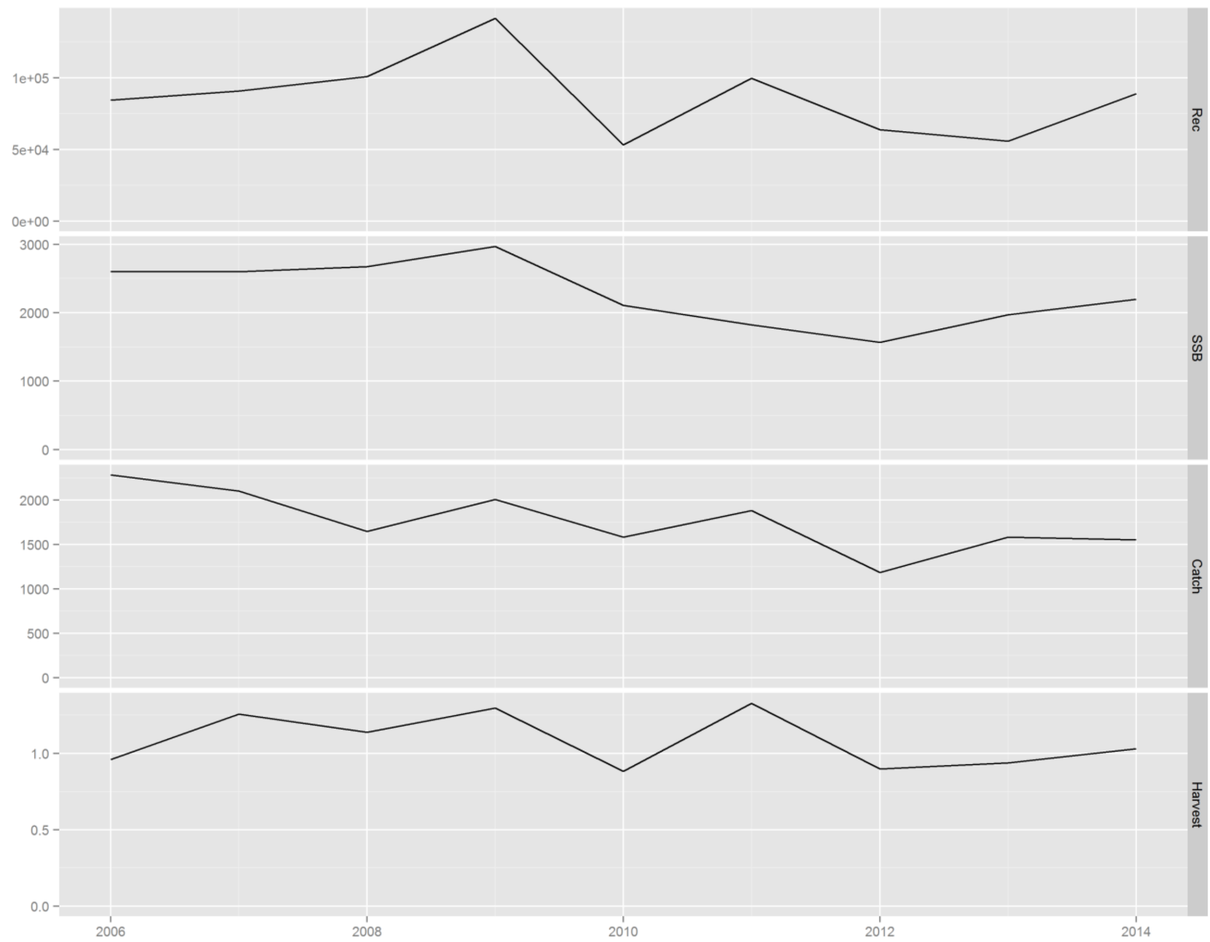
The SSB is fluctuating along the series with an average of 2278 t.

State of the juveniles (recruits)

The recruitment estimated for 2014 is 88907 thousand individuals, slightly higher compared to the series average (86615 thousand).

State of exploitation

The current F (1.03) is larger than F_{MSY} (0.23), , which indicates that European hake in GSA 9 is is being fished above F_{MSY}.



European hake in GSA 9. XSA summary results. SSB and catch are in tonnes, recruitment in 1000s individuals.

5.1.6.2 Stock advice

STECF EWG 15-11 advises the relevant fleets' catches and/or effort to be reduced until fishing mortality is below or at the proposed F_{MSY} level in order to avoid future loss in stock productivity and landings. Catches of European hake in 2016 in GSA 9 consistent with F_{MSY} should not exceed 635 tonnes.

5.1.6.3 Basis of the assessment

The stock of European hake in GSA 9 was assessed applying an Extended Survivor Analysis (XSA) method calibrated with fishery independent survey abundance indices (MEDITS). In addition, a yield-per-recruit (Y/R) analysis was carried out. Both methods were performed from the size composition of landings and discards, transforming length data to ages using the LFDA 5.0 slicing software.
Input data landings, discards and length frequencies were taken from DCF. Von Bertalanffy growth parameters and length-weight relationship were taken from parameters estimated for European hake in GSA 9. Natural mortality (vector) was estimated using PROBIOM.

5.1.6.4 Catch options

Catch options are summarized in the following table 5.1.6.4.1.

Table 5.1.6.4.1. Short term forecast in different F scenarios computed for hake in GSA 9. Basis: F(2015) = mean(F_{bar} 0-2 2012-2014)= 0.95; R(2015) = geometric mean of the recruitment of the last 3 years; R = 68172 thousands; SSB(2014) = 2197 t, Catch (2014)= 1553 t.

Rationale	Ffactor	Fbar	Catch 2015	Catch 2016	Catch 2017	SSB 2016	SSB 2017	Change SSB 2016-2017(%)	Change Catch 2014-2016(%)
Zero catch	0	0.00	1821	0	0	2567	6175	140.52	-100.00
High long term yield (F0.1)	0.24	0.23	1821	635	1136	2567	4891	90.52	-59.10
Status quo	1	0.95	1821	1867	1911	2567	2649	3.16	20.28
Different Scenarios	0.1	0.10	1821	282	566	2567	5596	117.98	-81.82
	0.2	0.19	1821	536	991	2567	5088	98.18	-65.51
	0.3	0.29	1821	763	1305	2567	4640	80.74	-50.82
	0.4	0.38	1821	969	1532	2567	4245	65.35	-37.56
	0.5	0.48	1821	1156	1692	2567	3896	51.74	-25.56
	0.6	0.57	1821	1325	1800	2567	3586	39.67	-14.66
	0.7	0.67	1821	1479	1867	2567	3310	28.94	-4.73
	0.8	0.76	1821	1620	1903	2567	3065	19.37	4.34
	0.9	0.86	1821	1749	1916	2567	2845	10.82	12.64
	1.1	1.05	1821	1977	1894	2567	2472	-3.72	27.31
	1.2	1.14	1821	2077	1866	2567	2312	-9.93	33.81
	1.3	1.24	1821	2171	1832	2567	2168	-15.54	39.84
	1.4	1.33	1821	2258	1793	2567	2038	-20.62	45.43
	1.5	1.43	1821	2339	1751	2567	1919	-25.24	50.64
	1.6	1.53	1821	2414	1708	2567	1811	-29.45	55.51
	1.7	1.62	1821	2485	1663	2567	1712	-33.30	60.06
	1.8	1.72	1821	2551	1619	2567	1622	-36.83	64.33
	1.9	1.81	1821	2614	1575	2567	1538	-40.08	68.35

	2	1.91	1821	2672	1532	2567	1462	-43.07	72.13

5.1.6.5 Reference points

Table 5.1.6.5.1 Hake in GSA 9. Reference points, values and their technical basis.

Framework	Reference point	Value	Technical basis	Source
MSY approach	MSY $B_{trigger}$			
	F_{MSY}	0.23	$F_{0.1}$ estimated with YPR.	Present assesment
Precautionary approach	B_{lim}	1569	B_{loss}	Present assessment
	B_{pa}			
	F_{lim}			
	F_{pa}			
EU-GFCM management strategy	SSB_{lower}			
	SSB_{upper}			
	F_{lower}	0.16	Empirical relationship	Present assesment
	F_{upper}	0.32	Empirical relationship	Present assessment

5.1.6.6 Quality of the assessment

The detailed assessment can be found in section 5.2.6.

5.1.7 SUMMARY SHEET OF HAKE IN GSA 10

Species common name: European hake
Species scientific name: *Merluccius merluccius*
Geographical Sub-area(s) GSA(s): 10

5.1.7.1 Stock development over time

State of the adult abundance and biomass

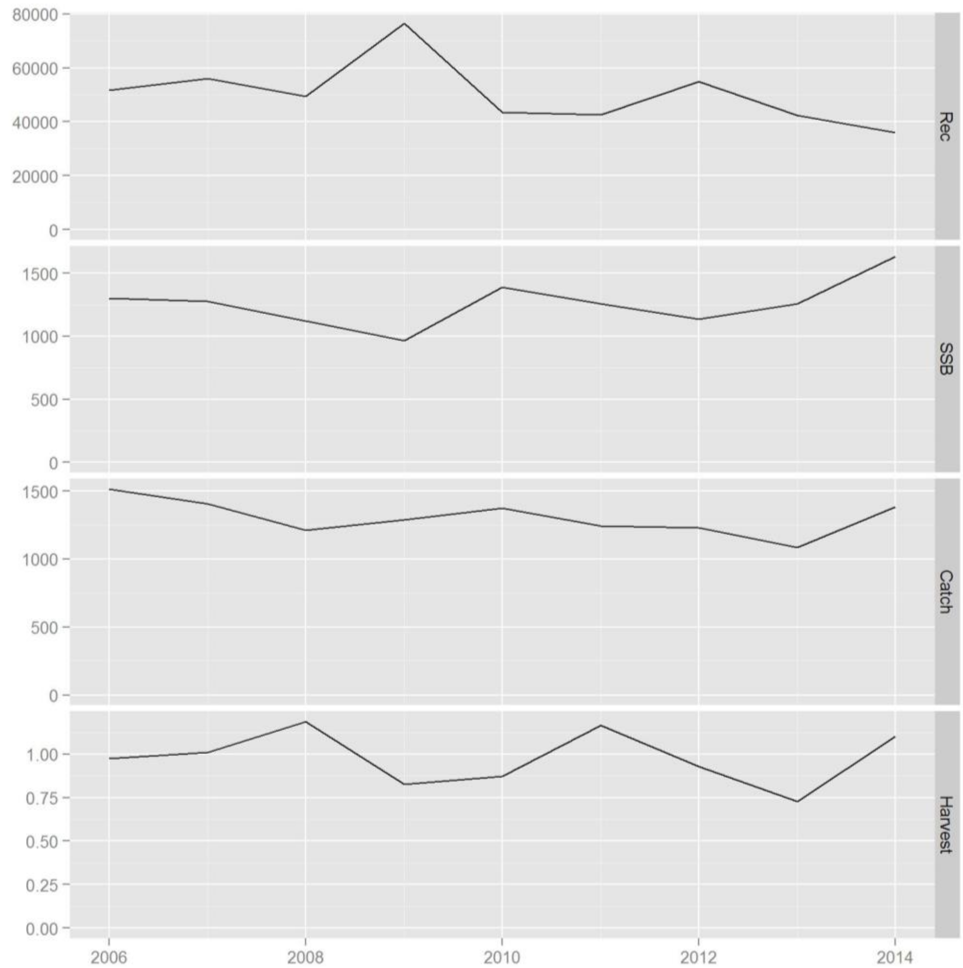
The SSB showed a slight increase over tme and it estimated at about 1,635 t in 2014, being the average along the time series equal to 1261.

State of the juveniles (recruits)

The recruitment has a slightly decreasing trend, even if in 2012 it increased again to a value equal to 51,400. The maximum recruitment is reached in 2009 and it is equal to 76,500 thousands individuals, while in 2014 it is 35919.

State of exploitation

The average F along the time series is 0.98, with a minimum of 0.73 in 2013 and a maximum of 1.19 in 2008 and no particular trend. The current F (1.10) is larger than F_{MSY} (0.20) , which indicates that European hake in GSA 10 is is being fished above F_{MSY}.



5.1.7.1.1. Hake in GSA 10. XSA summary results. SSB and catch are in tonnes, recruitment in 1000s individuals, harvest is F_{1-4}.

5.1.7.2 Stock advice

STECF EWG 15-11 recommends the relevant fleets' catches and/or effort to be reduced until fishing mortality is below or at the proposed F_{MSY} level, in order to avoid future loss in stock productivity and landings. This should be achieved by means of a multi-annual management plan taking into account mixed-fisheries considerations. Catches of European hake in GSA 10 in 2016 consistent with F_{MSY} should not exceed 404 t.

5.1.7.3 Basis of the assessment

The stock assessment was performed applying an Extended Survivor Analysis (XSA) method calibrated with fishery independent survey abundance indices (MEDITS) and CPUE of longlines. In addition, a yield-per-recruit (Y/R) analysis was carried out. Both methods were performed from the size composition of landings and discards, transforming length data to ages using slicing technique. Input data of length frequencies of landings and discards and were taken from DCF. Von Bertalanffy growth parameters and length-weight relationship were taken from parameters estimated for hake in GSA 10. Natural mortality (vector) was estimated using PROBIOM

5.1.7.4 Catch options

Catch options are summarized in the following table 5.1.7.4.1.

Table 5.1.7.4.1. Short term forecast in different F scenarios computed for *M. merluccius* in GSA 10. Basis: F(2015) = mean(F_{bar}1-4 2012-2014)= 0.906; R(2015) = geometric mean of the recruitment of the last 3years; R = 43764 (thousands); SSB(2014) = 1382 t, Catch (2014)= 1635 t.

Rationale	Ffactor	fbar	Catch 2016	Catch 2017	SSB 2017	Change SSB 2016-2017 (%)	Change Catch 2014-2016 (%)
Zero catch	0	0.000	0	0	3770	192.42	-100.00
High long-term yield (F0.1)	0.218	0.198	404	769	2927	127.03	-70.80
Status quo	1	0.906	1289	1297	1296	0.50	-6.74
Different scenarios	0.1	0.091	197	419	3352	160.03	-85.74
	0.2	0.181	374	724	2988	131.74	-72.97
	0.3	0.272	532	941	2669	107.00	-61.50
	0.4	0.362	675	1092	2389	85.34	-51.17
	0.5	0.453	804	1193	2144	66.34	-41.86
	0.6	0.543	920	1257	1929	49.65	-33.43
	0.7	0.634	1026	1293	1740	34.96	-25.79
	0.8	0.725	1122	1308	1573	22.02	-18.85
	0.9	0.815	1209	1308	1426	10.60	-12.52
	1.1	0.996	1362	1279	1180	-8.45	-1.44
	1.2	1.087	1430	1256	1078	-16.39	3.42
	1.3	1.178	1491	1229	987	-23.46	7.90
	1.4	1.268	1549	1201	905	-29.76	12.03
	1.5	1.359	1601	1171	833	-35.39	15.86
	1.6	1.449	1650	1141	768	-40.43	19.40
	1.7	1.540	1696	1112	710	-44.96	22.69

	1.8	1.630	1738	1083	657	-49.03	25.76
	1.9	1.721	1778	1055	610	-52.69	28.62
	2	1.812	1815	1028	567	-56.01	31.30

5.1.7.5 Reference points

Insert the reference point table

Table 5.1.1.5.1 Hake in GSA 10. Reference points, values and their technical basis.

Framework	Reference point	Value	Technical basis	Source
MSY approach	MSY $B_{trigger}$			
	F_{MSY}	0.20	$F_{0.1}$ estimated with Yield-per-Recruit analyses	Present assessment
Precautionary approach	B_{lim}	967	B_{loss}	Present assessment
	B_{pa}			
	F_{lim}			
	F_{pa}			
EU-GFCM management strategy	SSB_{lower}			
	SSB_{upper}			
	F_{lower}	0.13	Empirical relationship	Present assessment
	F_{upper}	0.27	Empirical relationship	Present assessment

5.1.7.6 Quality of the assessment

The detailed assessment can be found in section 5.2.7.

5.1.8 SUMMARY SHEET OF HAKE IN GSA 11

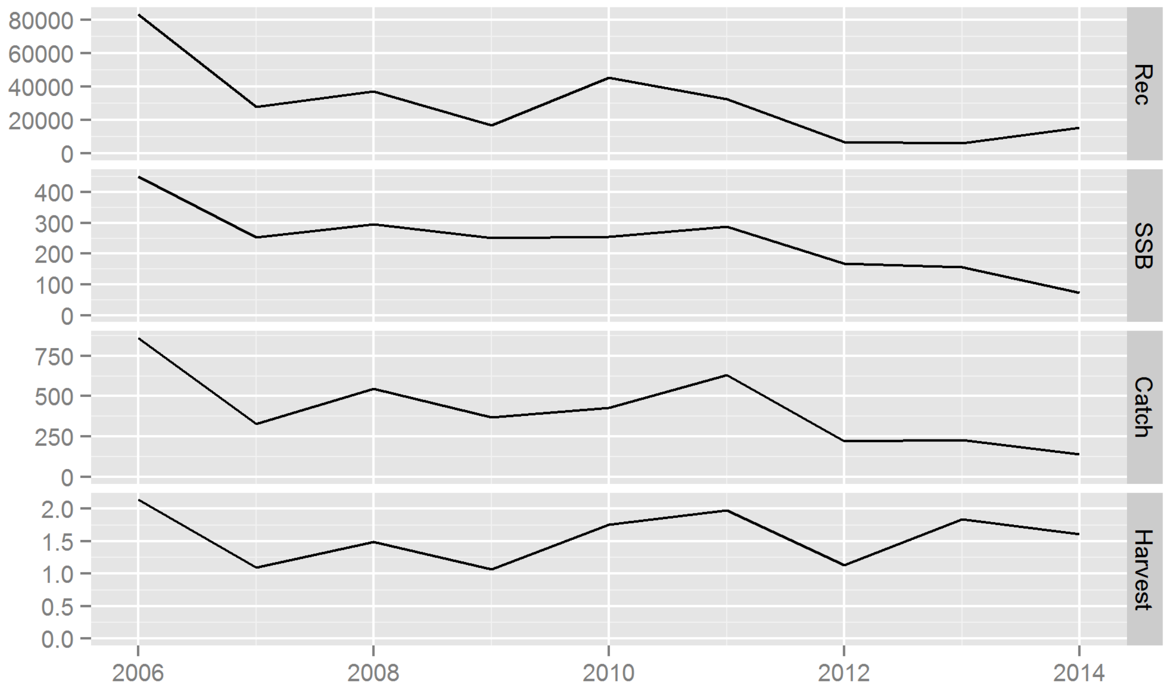
Species common name: European hake
Species scientific name: *Merluccius merluccius*
Geographical Sub-area(s) GSA(s): 11

5.1.8.1 Stock development over time

State of the adult abundance and biomass
SSB estimates showed a decreasing pattern, with a minimum in 2014. MEDITS indices show fluctuations, with lower values in the last period.

State of the juveniles (recruits)
Recruitment declined over the time series, reaching a minimum value in 2013.

State of exploitation
F oscillates between 2 and 1.5 over the entire time series, without any particular trend. The current F (1.61) is larger than F_{MSY} (0.17), , which indicates that European hake in GSA 11 is being fished above F_{MSY}.



European hake in GSA 11. XSA results. SSB and catch are in tonnes, recruitment in 1000s individuals.

5.1.8.2 Stock advice

STECF EWG 15-11 recommends the relevant fleets' catches and/or effort to be reduced until fishing mortality is below or at the proposed F_{MSY} level, in order to avoid future loss in stock productivity and landings. This should be achieved by means of a multi-annual management plan taking into account mixed-fisheries considerations. Catches of European hake in GSA 11 in 2016 consistent with F_{MSY} should not exceed 41 t.

5.1.8.3 Basis of the assessment

Stock assessment has been performed applying Extended Survivors Analysis (XSA) to the DCF data of size landings age-sliced for the period 2006-2014. DCF data adjusted to avoid misreporting and errors (biomass landed and size composition of the catches sliced according to the growth parameters), tuned with fishery independent abundance indices (MEDITS survey). A vector of natural mortality was obtained applying PRODBIOM. In addition, Yield-per-Recruit (YPR) analysis was performed for the estimation of $F_{0.1}$ (proxy of F_{MSY}).

5.1.8.4 Catch options

Catch options are summarized in the following table (Table 5.1.8.4.1).

Table 5.1.8.4.1. Short term forecast in different F scenarios computed for hake in GSA 11. Basis: F(2015) = mean (F_{bar} 0-3 2012-2014)= 1.49; R(2015) = geometric mean of the recruitment of the last 3 years; R = 8720 thousands; SSB(2014) = 73 t, Catch (2014)= 140 t.

Rationale	Ffactor	Fbar	Catch 2015	Catch 2016	Catch 2017	SSB 2016	SSB 2017	Change SSB 2016-2017(%)	Change Catch 2014-2016(%)
Zero catch	0	0	229	0	0	95	470	395.49	-100
High long term yield (F_{MSY})	0.11	0.17	229	41	107	95	381	301.21	-70.66
Status quo	1	1.49	229	190	182	95	86	-9.45	36.08
Different Scenarios	0.1	0.15	229	37	99	95	389	309.93	-73.41
	0.2	0.30	229	68	158	95	323	240.42	-51.32
	0.3	0.45	229	94	192	95	269	183.84	-32.92
	0.4	0.60	229	115	208	95	226	137.68	-17.52
	0.5	0.75	229	134	214	95	190	99.92	-4.58
	0.6	0.90	229	149	213	95	160	68.95	6.35
	0.7	1.05	229	162	208	95	136	43.47	15.61
	0.8	1.20	229	173	200	95	116	22.45	23.50
	0.9	1.34	229	182	191	95	100	5.03	30.26
	1.1	1.64	229	198	172	95	74	-21.54	41.13
	1.2	1.79	229	204	163	95	65	-31.67	45.52
	1.3	1.94	229	209	154	95	57	-40.21	49.36
	1.4	2.09	229	214	146	95	50	-47.43	52.75
	1.5	2.24	229	218	138	95	44	-53.57	55.75
	1.6	2.39	229	222	131	95	39	-58.81	58.42
	1.7	2.54	229	225	124	95	35	-63.32	60.81
	1.8	2.69	229	228	118	95	31	-67.20	62.96
	1.9	2.84	229	231	113	95	28	-70.57	64.90
	2	2.99	229	233	107	95	25	-73.51	66.67

5.1.8.5 Reference points

Table 5.1.8.5.1 Hake in GSA 11. Reference points, values and their technical basis.

Framework	Reference point	Value	Technical basis	Source
MSY approach	MSY $B_{trigger}$	-		
	F_{MSY}	0.17	$F_{0.1}$ estimated with Yield-per-Recruit analyses	Present assessment
Precautionary approach	B_{lim}	73 t	B_{loss}	Present assessment
	B_{pa}			
	F_{lim}			
	F_{pa}			
EU-GFCM management strategy	SSB_{lower}			
	SSB_{upper}			
	F_{lower}	0.11	Empirical relationship	Present assessment
	F_{upper}	0.24	Empirical relationship	Present assessment

5.1.8.6 Quality of the assessment

The detailed assessment can be found in section 5.2.8.

5.1.9 SUMMARY SHEET OF HAKE IN GSA 1-7

Species common name: European hake
Species scientific name *Merluccius merluccius*
Geographical Sub-area(s) GSA(s): 1, 5, 6 and 7.

5.1.9.1 Stock development over time

State of the adult abundance and biomass

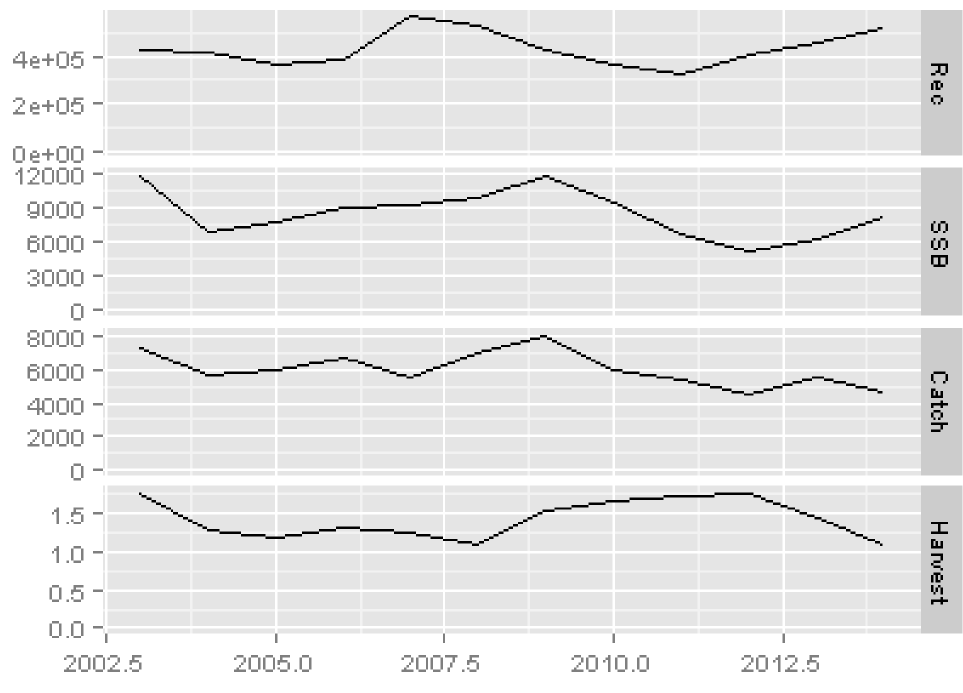
SSB fluctuated over 2003-2014 with no clear trend. In the most recent years, SSB increased and F decreased.

State of the juveniles (recruits)

Recruits fluctuated over 2003-2014 with no clear trend. In the most recent years, the number of recruits has increased.

State of exploitation

The current F (1.40) is larger than F_{MSY} (0.39), which indicates that European hake in GSAs 1-7 is being fished above F_{MSY}.



Hake in GSAs 1-7. XSA summary results. SSB and catch are in tonnes, recruitment in 1000s individuals.

5.1.9.2 Stock advice

STECF EWG 15-11 advises the relevant fleets' effort and/ or catches to be reduced until fishing mortality is below or at the proposed F_{MSY} level in other to avoid future loss in stock productivity and landings. This should be achieved by means of a multi-annual management plan taking into account mixed-fisheries considerations. Catches of European hake in 2016 consistent with $F_{0.1}$ (0.39) should not exceed 2416 tonnes.

5.1.9.3 *Basis of the assessment*

The state of exploitation was assessed for the period 2003-2014 applying the Extended Survivor Analysis (XSA) method calibrated with fishery independent survey abundance indices (MEDITS). Catch and catch numbers at age input data were the merging of the XSA input data used in the assessments performed by GSA. Four tuning MEDITS files were used, one per GSA, the same as used in the assessments by GSA. In addition, a yield-per-recruit (Y/R) analysis was carried out.

5.1.9.4 *Catch options*

The catch options for the European hake stock in GSAs 1-7 are summarized in Table 5.1.9.4.1.

Table 5.1.9.4.1. Short term forecast in different F scenarios computed for hake in GSA 1-7. Basis: F(2015) = mean (F_{bar} 1-3 2012-2014)= 1.40; R(2015) = geometric mean of the recruitment of the last 3 years; R = 459070 thousands; SSB(2014) = 8133 t, Catch (2014)= 4650 t.

Rationale	Ffactor	Fbar	Catch 2015	Catch 2016	Catch 2017	SSB 2016	SSB 2017	Change SSB 2016-2017(%)	Change Catch 2014-2016(%)
Zero catch	0	0.00	6221	0	0	7843	21566	174.99	-100.00
High long term yield (F_{MSY})	0.28	0.39	6221	2416	3901	7843	15746	100.78	-48.04
Status quo	1	1.40	6221	6192	6162	7843	7758	-1.08	33.15
Different scenarios	0.1	0.14	6221	953	1807	7843	19225	145.13	-79.51
	0.2	0.28	6221	1805	3123	7843	17179	119.05	-61.18
	0.3	0.42	6221	2569	4076	7843	15391	96.25	-44.74
	0.4	0.56	6221	3256	4760	7843	13827	76.31	-29.98
	0.5	0.70	6221	3874	5247	7843	12458	58.85	-16.68
	0.6	0.84	6221	4432	5589	7843	11258	43.55	-4.68
	0.7	0.98	6221	4937	5826	7843	10206	30.13	6.18
	0.8	1.12	6221	5395	5987	7843	9282	18.36	16.03
	0.9	1.26	6221	5812	6094	7843	8471	8.01	24.99
	1.1	1.54	6221	6539	6203	7843	7130	-9.09	40.62
	1.2	1.68	6221	6857	6225	7843	6577	-16.14	47.46
	1.3	1.82	6221	7149	6236	7843	6089	-22.36	53.75
	1.4	1.96	6221	7419	6239	7843	5659	-27.84	59.54
	1.5	2.10	6221	7667	6237	7843	5279	-32.69	64.89
	1.6	2.24	6221	7898	6233	7843	4942	-36.98	69.85
	1.7	2.38	6221	8112	6228	7843	4644	-40.79	74.46
	1.8	2.52	6221	8312	6223	7843	4380	-44.16	78.75
	1.9	2.66	6221	8498	6219	7843	4145	-47.15	82.75
	2	2.79	6221	8672	6216	7843	3936	-49.81	86.50

5.1.9.5 *Reference points*

Table 5.1.1.5.1 Hake in GSA 1-7. Reference points, values and their technical basis.

Framework	Reference point	Value	Technical basis	Source
MSY approach	MSY $B_{trigger}$			

	F_{MSY}	0.39	$F_{0.1}$ estimated with YPR	Present assessment
Precautionary approach	B_{lim}	5186	B_{loss}	Present assessment
	B_{pa}			
	F_{lim}			
	F_{pa}			
EU-GFCM management strategy	SSB_{lower}			
	SSB_{upper}			
	F_{lower}	0.26	Empirical relationship	Present assessment
	F_{upper}	0.53	Empirical relationship	Present assessment

5.1.9.6 Quality of the assessment

The detailed assessment can be found in section 5.2.9.

5.1.10 SUMMARY SHEET OF HAKE IN GSA 9-11

Species common name: European hake
Species scientific name: *Merluccius merluccius*
Geographical Sub-area(s) GSA(s): 9, 10, and 11

5.1.10.1 Stock development over time

State of the adult abundance and biomass

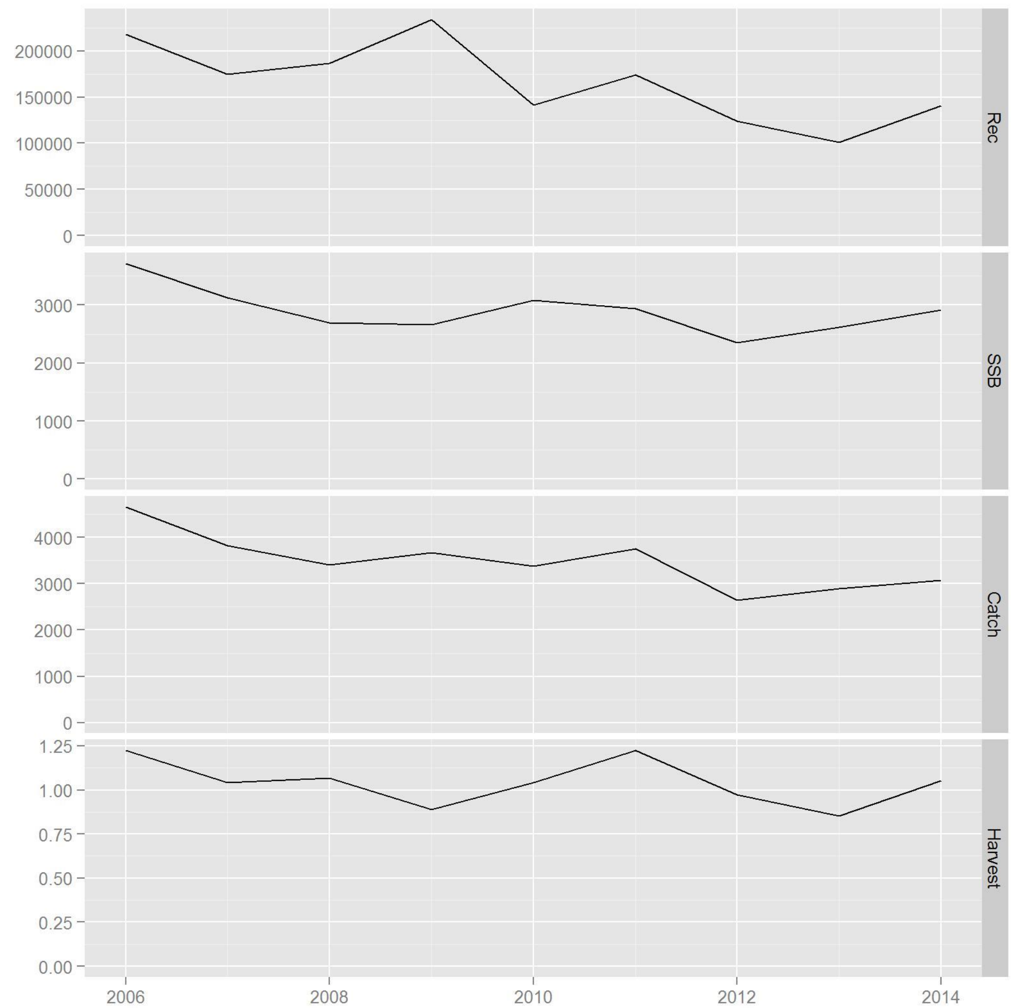
The SSB showed a slight decline over the time series, with an average of 2900 t.

State of the juveniles (recruits)

The recruitment estimated for 2014 is 140913 thousand individuals, slightly lower compared to the series average (166055 thousand individuals, period 2006-2014). Recruitment has generally declined over the time series.

State of exploitation

The current F (1.10) is larger than F_{MSY} (0.20), which indicates that European hake stock in GSAs 9, 10 and 11 is being fished above F_{MSY}.



Hake in GSAs 9-11. XSA summary results. SSB and catch are in tonnes, recruitment in 1000s individuals.

5.1.10.2 *Stock advice*

STECF EWG 15-11 advises the relevant fleets' effort and/or catches to be reduced until fishing mortality is below or at the proposed F_{MSY} level in order to avoid future loss in stock productivity and landings. This should be achieved by means of a multi-annual management plan taking into account mixed-fisheries considerations. Catches of European hake in 2016 consistent with F_{MSY} should not exceed 1029 tonnes in GSAs 9, 10, and 11.

5.1.10.3 *Basis of the assessment*

The stock of European hake in GSAs 9, 10, and 11 was assessed applying an Extended Survivor Analysis (XSA) method calibrated with fishery independent survey abundance indices (MEDITS in GSAs 9, 10, and 11), and CPUE by long-liners in GSA 10. Input data on landings, discards and length frequencies were taken from DCF. Von Bertalanffy growth parameters and length-weight relationship were taken from parameters agreed and used in previous EWGs.

5.1.10.4 *Catch options*

The catch options for the European hake stock in GSAs 9, 10, and 11 are summarized in Table 5.1.10.4.1.

Table 5.1.10.4.1. Short term forecast in different F scenarios computed for hake in GSA 9-11. Basis: F(2015) = mean (F_{bar} 1-4 2012-2014)= 0.96; R(2015) = geometric mean of the recruitment of the last 3 years; R = 120861 thousands; SSB(2014) = 2911 t, Catch (2014)= 3075 t.

Rationale	Ffactor	Fbar	Catch 2015	Catch 2016	Catch 2017	SSB 2016	SSB 2017	Change SSB 2016-2017(%)	Change Catch 2014-2016(%)
Zero catch	0.00	0.00	3185	0	0	2739	8656	216.01	-100.00
High long term yield (F_{MSY})	0.21	0.20	3185	1029	2040	2739	6622	141.76	-66.52
Status quo	1.00	0.96	3185	3218	3233	2739	2755	0.57	4.66
Different Scenarios	0.10	0.10	3185	522	1151	2739	7613	177.94	-83.04
	0.20	0.19	3185	981	1964	2739	6716	145.20	-68.11
	0.30	0.29	3185	1386	2526	2739	5943	116.97	-54.93
	0.40	0.38	3185	1744	2899	2739	5275	92.59	-43.26
	0.50	0.48	3185	2063	3133	2739	4697	71.48	-32.90
	0.60	0.57	3185	2347	3265	2739	4195	53.17	-23.67
	0.70	0.67	3185	2601	3323	2739	3759	37.24	-15.41
	0.80	0.76	3185	2828	3327	2739	3379	23.35	-8.01
	0.90	0.86	3185	3033	3293	2739	3046	11.21	-1.35
	1.10	1.05	3185	3385	3156	2739	2498	-8.79	10.11
	1.20	1.15	3185	3538	3068	2739	2273	-17.03	15.06
	1.30	1.24	3185	3676	2974	2739	2073	-24.32	19.57
	1.40	1.34	3185	3803	2877	2739	1896	-30.78	23.69
	1.50	1.43	3185	3919	2780	2739	1739	-36.53	27.47
	1.60	1.53	3185	4026	2684	2739	1598	-41.65	30.95
	1.70	1.62	3185	4125	2590	2739	1473	-46.23	34.15
	1.80	1.72	3185	4216	2500	2739	1360	-50.33	37.12

	1.90	1.82	3185	4300	2414	2739	1259	-54.03	39.87
	2.00	1.91	3185	4379	2332	2739	1168	-57.36	42.42

5.1.10.5 Reference points

Table 5.1.10.5.1 Hake in GSA 9_11. Reference points, values and their technical basis.

Framework	Reference point	Value	Technical basis	Source
MSY approach	MSY $B_{trigger}$			
	F_{MSY}	0.20	$F_{0.1}$ estimated with YPR.	Present assesment
Precautionary approach	B_{lim}	2355	B_{loss}	Present assessment
	B_{pa}			
	F_{lim}			
	F_{pa}			
EU-GFCM management strategy	SSB_{lower}			
	SSB_{upper}			
	F_{lower}	0.14	Empirical relationship	Present assesment
	F_{upper}	0.28	Empirical relationship	Present assessment

5.1.10.6 Quality of the assessment

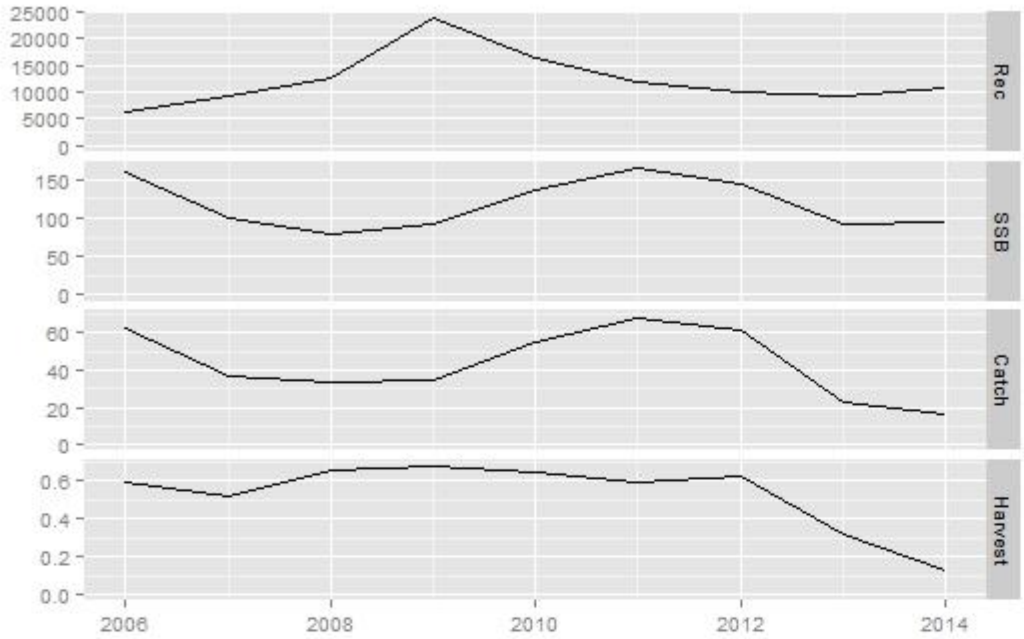
The detailed assessment can be found in section 5.2.10.

5.1.11 SUMMARY SHEET OF GIANT RED SHRIMP IN GSA 9

Species common name: Giant red shrimp
Species scientific name: *Aristaeomorpha foliacea*
Geographical Sub-area(s) GSA(s): 9

5.1.11.1 Stock development over time

State of the adult abundance and biomass
SSB estimates showed an increasing pattern between 2008 and 2011 followed by a decline. In the last two years the values were quite stable.



Giant red shrimp in GSA 9. XSA summary results. SSB and catch are in tonnes, recruitment in 1000s individuals.

State of the juveniles (recruits)
Recruitment does not show any particular trend over the times series, with a peck between 2008 and 2010.

State of exploitation
F has largely declined from 2012 to 2104. The current F (0.13) is lower than F_{MSY} (0.51), which indicates that Giant red shrimp in GSA 9 is being fished below F_{MSY}.

5.1.11.2 Stock advice
STECF EWG 15-11 advises the relevant fleets' effort and/or catches to be reduced until fishing mortality is below or at the proposed F_{MSY} level in order to avoid future loss in stock productivity and landings. Catches of Giant red shrimp in 2016 consistent with F_{MSY} should not exceed 44 tonnes in GSAs 9.

5.1.11.3 Basis of the assessment

An XSA analysis was performed using 2006-2014 DCF data using catch at age data provided and tuned with fishery independent abundance indices (MEDITS survey). A vector of natural mortality was obtained applying PRODBIOM. In addition, Yield per Recruit (YPR) analysis was performed for the estimation of $F_{0.1}$ (i.e. proxy of F_{MSY}).

5.1.11.4 Catch options

Catch options are summarized in the following table (Table 5.1.11.4.1).

Table 5.1.11.4.1. Short term forecast in different F scenarios computed for Giant red shrimp in GSA 9. Basis: F(2015) = mean (F_{bar} 1-3 2012-2014)= 0.51; R(2015) = geometric mean of the recruitment of the last 3 years; R = 10018 thousands; SSB(2014) = 94 t, Catch (2014)= 17 t.

Rationale	Ffactor	Fbar	Catch 2016	Catch 2017	SSB 2017	Change SSB 2016-2017(%)	Change Catch 2014-2016(%)
Zero catch	0.000	0.000	0.00	0.00	142.79	25.96	-100.00
High long term yield F_{MSY}	1.744	0.514	43.89	38.07	96.42	-14.94	160.94
Status quo	1.000	0.295	27.53	27.47	113.36	0.00	63.68
Different scenarios	0.100	0.029	3.09	3.71	139.45	23.01	-81.64
	0.200	0.059	6.10	7.16	136.19	20.14	-63.76
	0.300	0.088	9.02	10.38	133.04	17.35	-46.34
	0.400	0.118	11.88	13.38	129.97	14.65	-29.38
	0.500	0.147	14.66	16.18	127.00	12.03	-12.85
	0.600	0.177	17.37	18.78	124.11	9.48	3.26
	0.700	0.206	20.01	21.19	121.30	7.00	18.95
	0.800	0.236	22.58	23.44	118.58	4.60	34.25
	0.900	0.265	25.09	25.53	115.93	2.27	49.15
	1.100	0.324	29.91	29.27	110.87	-2.20	77.85
	1.200	0.354	32.23	30.94	108.44	-4.34	91.66
	1.300	0.383	34.50	32.49	106.09	-6.42	105.12
	1.400	0.412	36.71	33.92	103.80	-8.44	118.25
	1.500	0.442	38.86	35.25	101.58	-10.40	131.05
	1.600	0.471	40.96	36.47	99.42	-12.30	143.54
	1.700	0.501	43.01	37.61	97.32	-14.15	155.73
	1.800	0.530	45.01	38.65	95.28	-15.95	167.61
	1.900	0.560	46.96	39.62	93.30	-17.70	179.20
	2.000	0.589	48.86	40.50	91.38	-19.40	190.52

5.1.11.5 Reference points

Table 5.1.11.5.1 Giant red shrimp in GSA 9. Reference points, values and their technical basis.

Framework	Reference point	Value	Technical basis	Source
MSY approach	MSY $B_{trigger}$			
	F_{MSY}	0.51	F0.1 estimated with Yield per Recruit analyses	Present assessment
Precautionary approach	B_{lim}	80	Bloss	Present assessment
	B_{pa}			
	F_{lim}			
	F_{pa}			
EU-GFCM management	SSB_{lower}			
	SSB_{upper}			

strategy	F_{lower}	0.34	Empirical relationship	Present assessment
	F_{upper}	0.69	Empirical relationship	Present assessment

5.1.11.6 Quality of the assessment

The detailed assessment can be found in section 5.2.11.

5.1.12 SUMMARY SHEET OF GIANT RED SHRIMP IN GSA 10

Species common name: Giant red shrimp
Species scientific name: *Aristaeomorpha foliacea*
Geographical Sub-area(s) GSA(s): 10

5.1.12.1 Stock development over time

State of the adult abundance and biomass

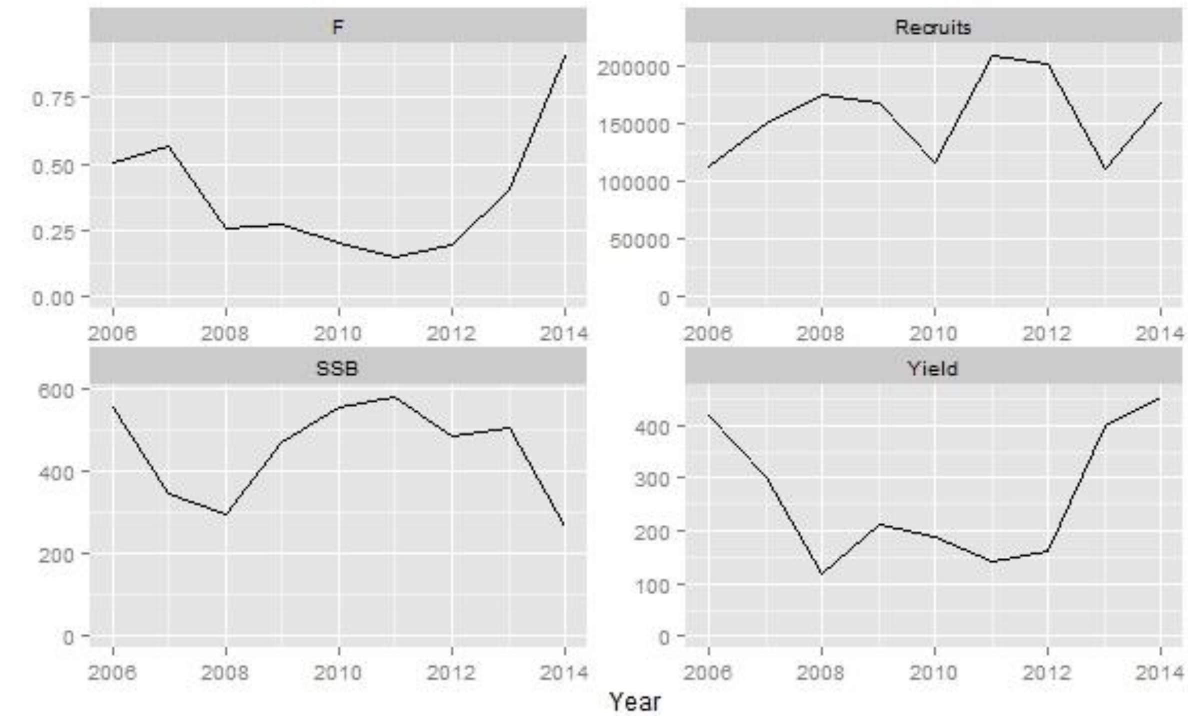
SSB showed an increasing trend up to 2011 followed by a constant decrease up to the minimum in 2014 (265.3 t).

State of the juveniles (recruits)

Recruitment is characterised by a fluctuating trend, varying from a minimum of 113 millions in 2006 to 209 millions in 2011.

State of exploitation

Fishing mortality showed an evident increasing trend in the last three years. The current F (0.91) is larger than F_{MSY} (0.65), which indicates that Giant red shrimp stock in GSAs 10 is being fished above F_{MSY}.



Giant red shrimp in GSA 10. XSA summary results. SSB and catch are in tons, recruitment in 1000s individuals.

5.1.12.2 Stock advice

STECF EWG 15-11 advises the relevant fleets' effort and/or catches to be reduced until fishing mortality is below or at the proposed F_{MSY} level in order to avoid future loss in stock productivity and landings. Catches of European Giant red shrimp in 2016 consistent with F_{MSY} should not exceed 314 tonnes in GSAs 10.

5.1.12.3 Basis of the assessment

The stock assessment of giant red shrimp in GSA 10 was performed applying an Extended Survivor Analysis (XSA) method calibrated with fishery independent survey abundance indices (MEDITS). In addition, a yield-per-recruit (Y/R) analysis was carried out. Both methods were performed from the size composition of landings and discards, transforming length data to ages using slicing technique.

Input data landings, discards and length frequencies were taken from DCF. Von Bertalanffy growth parameters and length-weight relationship were taken from parameters estimated for giant red shrimp in GSA 10. Natural mortality (vector) was estimated using PROBIOM.

5.1.12.4 Catch options

The catch options for giant red shrimp stock in GSA 10 are summarised in Table 5.1.12.4.1.

Table 5.1.12.4.1. Short term forecast in different F scenarios computed for giant red shrimp stock in GSA 10. Basis: F(2015) = mean (F_{bar} 0-3 2012-2014)= 0.65; R(2015) = geometric mean of the recruitment of the last 3 years; R = 156034 thousands; SSB(2014) = 265 t, Catch (2014)= 465 t.

Rationale	Ffactor	Fbar	Catch 2016	Catch 2017	SSB 2017	Change SSB 2016-2017(%)	Change Catch 2014-2016(%)
Zero catch	0.0	0.00	0.00	0.0	580	99.3	-100
High long term yield F(0.1)	0.72	0.65	315	333	201	10.0	-30.6
Status quo	1	0.91	396	376	139	-8.7	-12.9
Different scenarios	0.1	0.09	57.5	84	494	81.7	-87.3
	0.2	0.18	110	151	423	66.1	-75.8
	0.3	0.27	157	24	363	52.3	-65.4
	0.4	0.36	200	246	313	40.1	-55.9
	0.5	0.45	240	280	271	29.3	-47.1
	0.6	0.54	276	307	235	19.7	-39.1
	0.7	0.64	310	330	205	11.2	-31.8
	0.8	0.73	341	348	179	3.7	-25.0
	0.9	0.82	369	363	158	-2.9	-18.7
	1.1	1.00	420	387	123	-13.9	-7.4
	1.2	1.09	443	396	110	-18.4	-2.4
	1.3	1.18	465	404	99	-22.4	2.3
	1.4	1.27	485	411	88	-26.0	6.8
	1.5	1.36	503	418	80	-29.1	10.9
	1.6	1.45	521	423	72	-318	14.8
	1.7	1.54	538	428	66	-34.3	18.5
	1.8	1.63	554	432	60	-36.4	22.0
	1.9	1.72	569	437	55	-38.3	25.2
	2	1.82	583	440	50	-39.9	28.4

5.1.12.5 Reference points

Table 5.1.12.5.1 Giant red shrimp in GSA 10. Reference points, values and their technical basis.

Framework	Reference point	Value	Technical basis	Source
MSY approach	MSY $B_{trigger}$			
	F_{MSY}	0.65	$F_{0.1}$ estimated with YpR	Present assessment
Precautionary approach	B_{lim}	265	B_{loss}	Present assessment
	B_{pa}			

	F_{lim}			
	F_{pa}			
EU-GFCM management strategy	SSB_{lower}			
	SSB_{upper}			
	F_{lower}	0.43	Empirical relationship	Present assessment
	F_{upper}	0.88	Empirical relationship	Present assessment

5.1.12.6 Quality of the assessment

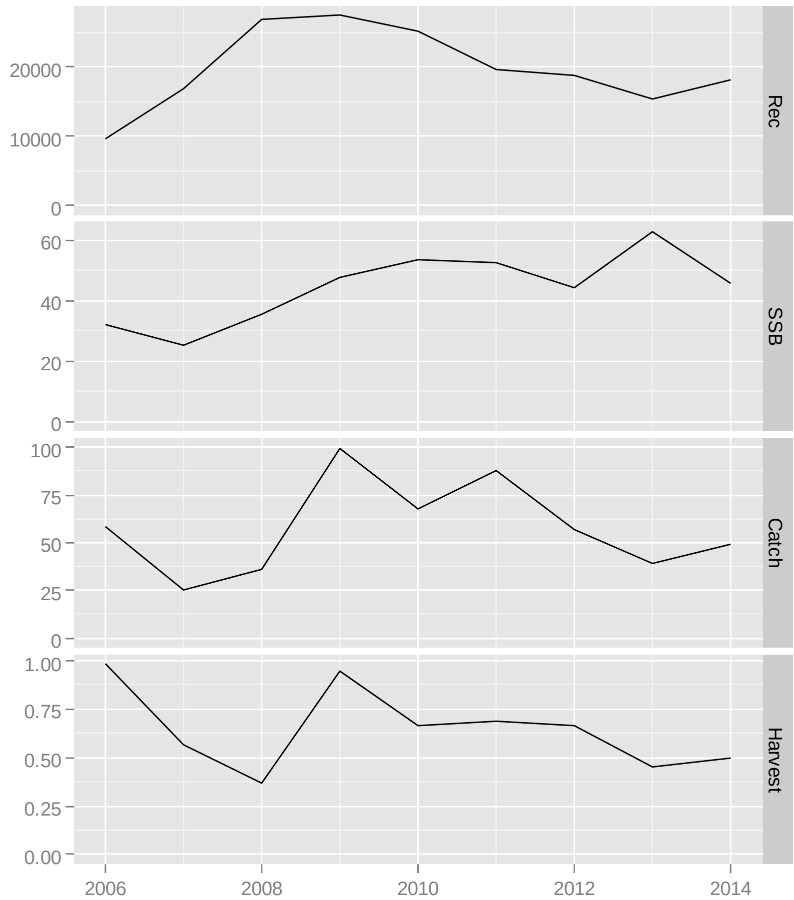
The detailed assessment can be found in section 5.2.12.

5.1.13 SUMMARY SHEET OF GIANT RED SHRIMP IN GSA 11

Species common name: Giant red shrimp
Species scientific name: *Aristeomorpha foliacea*
Geographical Sub-area GSA: 11

5.1.13.1 Stock development over time

SSB estimates showed an increasing pattern since 2007, with a peak in 2013.



Giant red shrimp GSA 11. XSA summary results. SSB and catch are in tonnes, recruitment in 1000s individuals.

State of the juveniles (recruits)

Recruitment has increased until 2009, followed by a decreasing trend.

State of exploitation

The current F (0.50) is larger than F_{MSY} (0.31), which indicates that Giant red shrimp stock in GSAs 11, is being fished above F_{MSY}.

5.1.13.2 Stock advice

STECF EWG 15-11 advises the relevant fleets' effort and/or catches to be reduced until fishing mortality is below or at the proposed F_{MSY} level in order to avoid future loss in stock productivity and landings. Catches of Giant red shrimp stock in 2016 consistent with F_{MSY} should not exceed 36 tonnes in GSAs 11.

5.1.13.3 Basis of the assessment

An XSA analysis was performed using 2006-2013 DCF data (biomass landed and size composition of the catches sliced according to the growth parameters and the sex-ratio reported in the data call), tuned with fishery independent abundance indices (MEDITS survey). A vector of natural mortality was obtained applying PRODBIOM. In addition, Yield-per-Recruit (YPR) analysis was performed for the estimation of $F_{0.1}$ (proxy of F_{MSY}).

5.1.13.4 Catch options

Catch options are summarized in the following table (Table 5.1.13.4.1).

Table 5.1.13.4.1 Short term forecast in different F scenarios computed for Giant red shrimp in GSA 11. Basis: F(2015) = mean (F_{bar} 0-3 2012-2014)= 0.53; R(2015) = geometric mean of the recruitment of the last 3 years; R = 17374 thousands; SSB(2014) = 46 t, Catch (2014)= 49 t.

Scenarios	**Ffactor**	**Fbar**	**Catch**				**SSB**		**% change in SSB**	**% change in Catch**
				2015	**2016**	**2017**	**2016**	**2017**	**2016-2017**	**2014-2016**
No fishery	0	0		53.49	0	0	75.47	128.05	69.66	-100
F status quo	1	0.53		53.49	55.31	55.15	54.28	54.20	-0.15	12.00
F_{MSY}	0.58	0.31		53.49	35.83	41.51	62.22	76.83	23.48	-27.44
Different scenarios	0.1	0.05		53.49	6.98	9.89	73.01	117.14	60.44	-85.87
	0.2	0.11		53.49	13.58	18.41	70.63	107.23	51.81	-72.50
	0.3	0.16		53.49	19.82	25.76	68.34	98.23	43.74	-59.86
	0.4	0.21		53.49	25.73	32.08	66.12	90.04	36.18	-47.89
	0.5	0.27		53.49	31.33	37.51	63.97	82.59	29.11	-36.55
	0.6	0.32		53.49	36.64	42.19	61.90	75.81	22.48	-25.81
	0.7	0.37		53.49	41.67	46.21	59.90	69.64	16.26	-15.61
	0.8	0.42		53.49	46.45	49.65	57.96	64.01	10.44	-5.93
	0.9	0.48		53.49	50.99	52.61	56.09	58.88	4.98	3.26
	1.1	0.58		53.49	59.41	57.32	52.53	49.93	-4.97	20.32
	1.2	0.64		53.49	63.32	59.18	50.85	46.02	-9.49	28.23
	1.3	0.69		53.49	67.05	60.77	49.21	42.45	-13.74	35.78
	1.4	0.74		53.49	70.60	62.14	47.64	39.19	-17.73	42.97
	1.5	0.80		53.49	73.99	63.31	46.11	36.20	-21.49	49.83
	1.6	0.85		53.49	77.22	64.31	44.64	33.47	-25.02	56.39
	1.7	0.90		53.49	80.32	65.17	43.21	30.96	-28.35	62.65
	1.8	0.95		53.49	83.28	65.91	41.83	28.66	-31.49	68.65
	1.9	1.01		53.49	86.11	66.54	40.50	26.55	-34.45	74.38
	2	1.06		53.49	88.82	67.09	39.21	24.61	-37.24	79.88

5.1.13.5 Reference points

Table 5.1.13.5.1 Giant red shrimp in GSA 11. Reference points, values and their technical basis.

Framework	**Reference point**	**Value**	**Technical basis**	**Source**

MSY approach	MSY $B_{trigger}$	-		
	F_{MSY}	0.31	$F_{0.1}$ estimated with Yield-per-Recruit analyses	Present assessment
Precautionary approach	B_{lim}	26 t	B_{loss}	Present assessment
	B_{pa}			
	F_{lim}			
	F_{pa}			
EU-GFCM management strategy	SSB_{lower}			
	SSB_{upper}			
	F_{lower}	0.21	Empirical relationship	Present assessment
	F_{upper}	0.43	Empirical relationship	Present assessment

5.1.13.6 Quality of the assessment

The detailed assessment can be found in section 5.2.13.

5.1.14 SUMMARY SHEET OF BLUE AND RED SHRIMP IN GSA 1

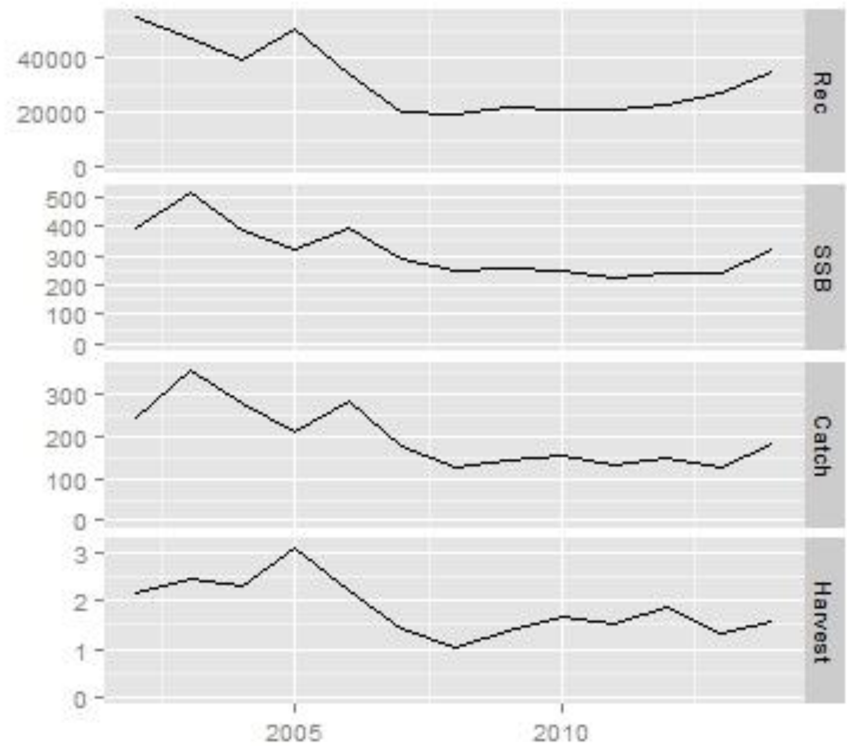
Species common name: Blue and red shrimp
Species scientific name *Aristeus antennatus*
Geographical Sub-area(s) GSA(s): 1

5.1.14.1 Stock development over time

State of the adult abundance and biomass
The SSB is fluctuating along the series between 200 and 400 tons, with an average of 313 tonnes and a final value (2014) of 322 t.

State of the juveniles (recruits)
The recruitment estimated for 2014 is around 35000 individuals, slightly higher than the time series average (32000).

State of exploitation
The current F (1.40) is larger than F_{MSY} (0.41), which indicates that Blue and red shrimp in GSAs 1 is being fished above F_{MSY}.



Blue and red shrimp in GSA 1. XSA summary results. SSB and catch are in tonnes, recruitment in 1000s individuals.

5.1.14.2 Stock advice

STECF EWG 15-11 advises the relevant fleets' effort and/or catches to be reduced until fishing mortality is below or at the proposed F_{MSY} level in order to avoid future loss in stock productivity and landings. Catches of European hake in 2016 consistent with F_{MSY} should not exceed 96 tonnes in GSA 1.

5.1.14.3 Basis of the assessment

- Number of ages: 5 (0-4+)
- Number of years: 13 (2002-2014)
- One single gear: bottom otter trawl
- No discards, all catches are landed
- M= 0.46 $year^{-1}$ for all ages
- Growth parameters: L_{inf}=80 mm, K=0.37 $year^{-1}$, t_0=0.032 year
- Length to age by slicing
- Length-weight relationship: a=0.002038 gr b=2.506 (DCF 2015, Spain)
- Maturity ogive: (0) 0.22, (1) 0.95, (2) 1.0, (3) 1.0, (4+) 1.0 (L_{50}=23.5mm)
- Tuning MEDITS numb/km^2

Assessment method: XSA using FLR.
Analysis of YPR using FLR andYield per Recruit v 3.3 NOAA
MSE (Management Strategies Evaluation) input from XSA, and using a4a inside iterations loop.

5.1.14.4 Catch options

Catch options are summarized in the following table (Table 5.1.14.4.1).

Table 5.1.9.4.1. Short term forecast in different F scenarios computed for hake in GSA 1. Basis: F(2015) = mean (F_{bar} 1-2 2012-2014)= 1.40; R(2015) = geometric mean of the recruitment of the last 3 years; R = 2838 thousands; SSB(2014) = 322 t, Catch (2014)= 184 t.

Rationale	F scenario	F factor	Catch 2016	Catch 2017	SSB 2017	Change SSB 2016-2017 (%)	Change catch 2014-2016 (%)
Zero catch	0.0	0.0	0.0	0.0	674	93.6	-100
High long-term yield (F_{MSY})	0.40	0.3	96	146	517	48.4	-47.7
Status quo	1.40	0.9	204	203	349	0.2	10.8
Different scenarios	0.15	0.1	36	66	615	76.5	-80.4
	0.31	0.2	68	113	563	61.7	-63.2
	0.62	0.4	120	168	479	37.6	-34.9
	0.77	0.5	141	182	445	27.9	-23.4
	0.93	0.6	160	192	416	19.5	-13.2
	1.08	0.7	176	198	390	12.1	-4.2
	1.24	0.8	191	201.15	368	5.7	3.8
	1.54	1	215	202.96	332	-4.7	17.0
	1.7	1.1	226	202.48	317	-9.0	22.6
	1.85	1.2	235	201.51	304	-12.7	27.5
	2.01	1.3	243	200.26	293	-16.0	31.9
	2.16	1.4	250	198.88	283	-18.8	35.8

	2.32	1.5	256	197.45	274	-21.3	39.4
	2.47	1.6	262	196.06	267	-23.6	42.6
	2.63	1.7	268	194.73	259	-25.5	45.4
	2.78	1.8	272	193.5	253	-27.2	48.0
	2.93	1.9	277	192.36	248	-28.8	50.4
	3.09	2	281	191.34	243	-30.1	52.5

5.1.14.5 Reference points

Table 5.1.14.5.1 Blue and red shrimp in GSA 1. Reference points, values and their technical basis.

Framework	Reference point	Value	Technical basis	Source
MSY approach	MSY $B_{trigger}$			
	F_{MSY}	0.41	$F_{0.1}$ estimated with Yield-per-Recruit analyses	Present assessment
Precautionary approach	B_{lim}	224	B_{loss}	Present assessment
	B_{pa}			
	F_{lim}			
	F_{pa}			
EU-GFCM management strategy	SSB_{lower}			
	SSB_{upper}			
	F_{lower}	0.27	Empirical relationship	Present assessment
	F_{upper}	0.56	Empirical relationship	Present assessment

5.1.14.6 Quality of the assessment

The detailed assessment can be found in section 5.2.14.

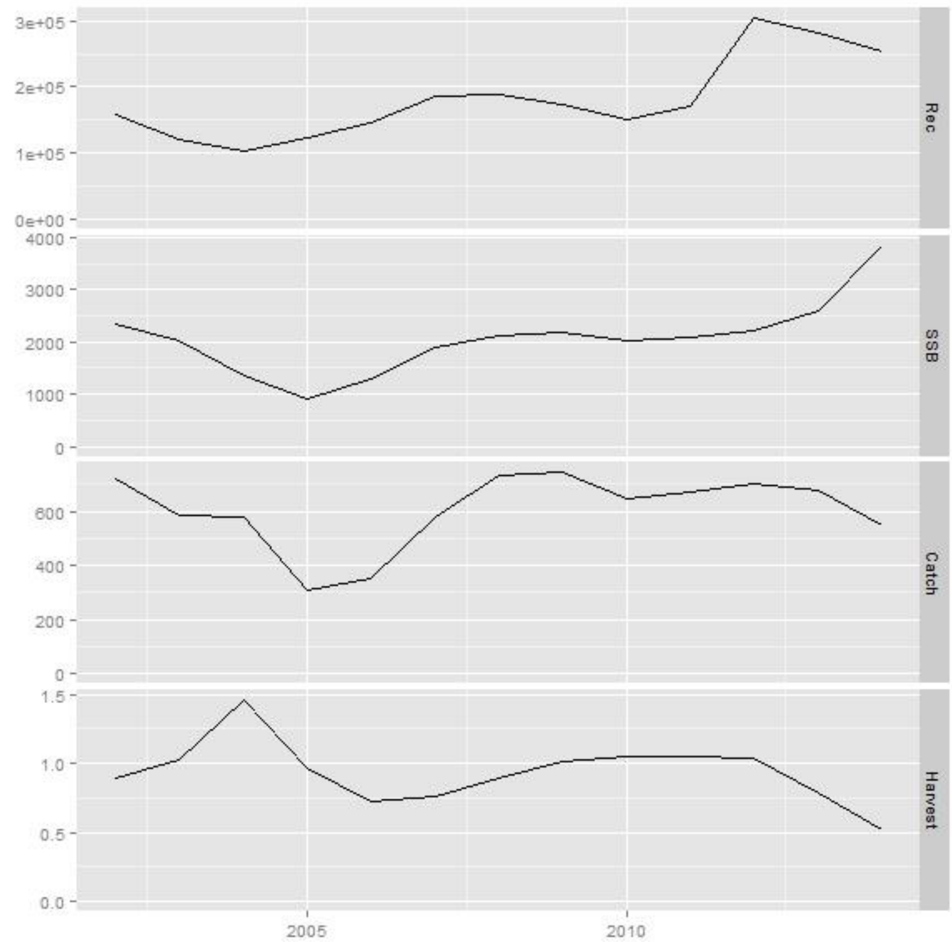
5.1.15 SUMMARY SHEET OF BLUE AND RED SHRIMP IN GSA 6

Species common name: Blue and red shrimp
Species scientific name: *Aristeus antennatus*
Geographical Sub-area(s) GSA(s): 06

5.1.15.1 Stock development over time

State of the adult abundance and biomass
SSB increased since 2006 from 919 t in 2005 to 3848 t in 2014, the highest value over the whole period (2002-2014).
State of the juveniles (recruits)
Recruitment (age 0 individuals) has been steadily increasing over the entire period 2002 – 2014, with a low value of 103 million individuals in 2004 and a high of 304 million in 2012.

State of exploitation
Fishing mortality oscillated between 0.52 and 1.5, with the lowest values observed in the 2 most recent years (2013, 2014). The current F (0.78) is larger than F_{MSY} (0.36), which indicates that Blue and red shrimp stock in GSAs 6 is being fished above F_{MSY}.



Blue and red shrimp in GSA 6. XSA summary results. SSB and catch are in tonnes, recruitment in 1000s individuals.

5.1.15.2 Stock advice

STECF EWG 15-11 advises the relevant fleets' effort and/or catches to be reduced until fishing mortality is below or at the proposed F_{MSY} level in order to avoid future loss in stock productivity and landings. This should be achieved by means of a multi-annual management plan taking into account mixed-fisheries considerations. Catches of Blue and red shrimp in 2016 consistent with F_{MSY} should not exceed 525 tonnes in GSAs 6.

5.1.15.3 Basis of the assessment

The state of exploitation was assessed for the period 2002-2014 applying the Extended Survivor Analysis (XSA) tuned with fishery independent abundance indices (MEDITS survey). In addition, Yield per Recruit (YPR) analysis was carried out. Both methods were performed from the size composition of bottom trawl landings, transforming length data to ages using knife edge slicing. Input fishery data were taken from DCF 2015 Data Call, complemented with specific data from other sources. In particular, total catches have been reconstructed for the period 2002-2009 from data sources of local Fisheries Directorates (Catalonia and Valencia). Discards are very low or nil because of the high economic value of the species and were considered 0 in the assessment.

5.1.15.4 Catch options

Catch options are summarized in the following table (Table 5.1.15.4.1).

Table 5.1.15.4.1. Short term forecast in different F scenarios computed for Blue and red shrimp in GSA 6. Basis: F(2015) = mean (F_{bar} 1-3 2012-2014)= 0.52; R(2015) = geometric mean of the recruitment of the last 3 years; R = 278633 thousands; SSB(2014) = 3848 t, Catch (2014)= 547 t.

	Ffactor	Fbar	Catch_2015	Catch_2016	Catch_2017	SSB_2016	SSB_2017	Change_SSB_2016-2017(%)	Change_Catch_2014-2016(%)
	0	0.00	0	0	0	4375	7172	63.91	-100.00
	0.1	0.08	93	124	190	4375	6764	54.58	-77.25
	0.2	0.15	182	240	347	4375	6385	45.93	-56.02
	0.3	0.23	266	349	477	4375	6034	37.91	-36.20
	0.4	0.30	346	450	584	4375	5709	30.48	-17.69
	0.5	0.38	422	544	671	4375	5407	23.58	-0.40
	0.6	0.45	494	633	741	4375	5127	17.18	15.75
	0.7	0.53	563	715	797	4375	4868	11.25	30.85
	0.8	0.60	628	792	842	4375	4627	5.75	44.96
	0.9	0.68	690	864	877	4375	4404	0.65	58.15
status quo	1	0.78	749	932	903	4375	4197	-4.09	70.49
	1.1	0.83	805	995	923	4375	4004	-8.48	82.03
	1.2	0.90	858	1054	938	4375	3826	-12.55	92.84
	1.3	0.98	909	1109	947	4375	3661	-16.33	102.95
	1.4	1.05	957	1161	953	4375	3508	-19.84	112.43
	1.5	1.13	1003	1210	956	4375	3365	-23.09	121.30
	1.6	1.20	1047	1255	956	4375	3233	-26.10	129.62
	1.7	1.28	1089	1298	954	4375	3111	-28.90	137.42

	1.8	1.35	1130	1338	951	4375	2997	-31.50	144.73
	1.9	1.43	1168	1375	946	4375	2892	-33.91	151.59
	2	1.50	1204	1410	941	4375	2794	-36.14	158.03
F_{MSY}	0.48	0.36	407	525	654	4375	5468	24.97	-3.90

5.1.15.5 Reference points

Table 5.1.15.5.1 Blue and red shrimp in GSA 6. Reference points, values and their technical basis.

Framework	Reference point	Value	Technical basis	Source
MSY approach	MSY $B_{trigger}$			
	F_{MSY}	0.36	$F_{0.1}$ estimated with Yield-per-Recruit analyses	Present assessment
Precautionary approach	B_{lim}	1287	B_{loss}	Present assessment
	B_{pa}			
	F_{lim}			
	F_{pa}			
EU-GFCM management strategy	SSB_{lower}			
	SSB_{upper}			
	F_{lower}	0.24	Empirical relationship	Present assessment
	F_{upper}	0.49	Empirical relationship	Present assessment

5.1.15.6 Quality of the assessment

The detailed assessment can be found in section 5.2.15.

5.2 STOCK ASSESSMENT

5.2.1 STOCK ASSESSMENT OF HAKE IN GSA 1

5.2.1.1 Stock Identification

The delimitation of the hake stock in GSA 1 is considered largely unknown (Fig.5.2.1.1.1). Likely connections with hake in GSA 6 may exist, because of the continuity of shelf. Large exchanges with the south Alboran Sea (GSA 3) are instead believed to be insignificant.

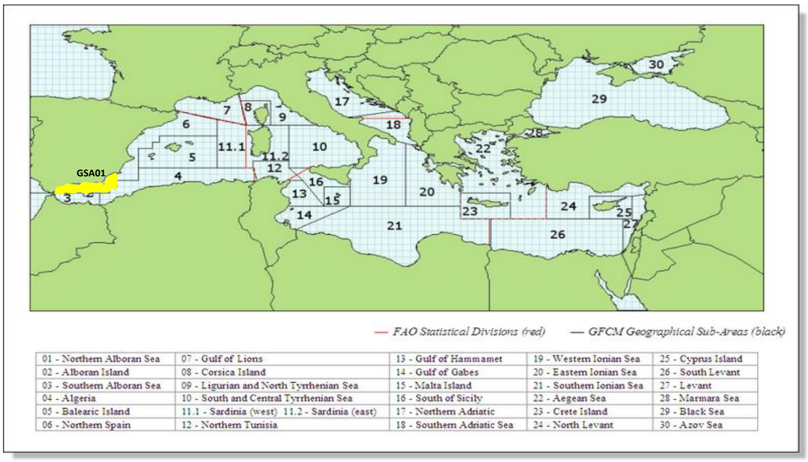


Figure.5.2.1.1.1. Geographical location of GSA 1.

5.2.1.2 Growth

Growth parameters (L_{inf}=110; k=0.178; males and females combined) were taken from Mellon-Duval et al. (2010). These growth parameters were estimated through tagging in the Gulf of Lions and correspond to fast growth for the species. The length-weight relationship parameters used are a=0.00677 and b=3.035097 (DCF 2011).

5.2.1.3 Maturity

Maturity ogive was taken from García-Rodríguez and Esteban (1995), with size at first maturity (50 %) at 33 cm TL.

Age	0	1	2	3	4	5+
% mature	0	0.15	0.82	0.98	1	1

5.2.1.4 Natural mortality

Natural mortality was estimated using PRODBIOM (Abella et al. 1997). M at the mid-point of the year was selected as M representative for that annual class.

	Natural Mortality (M) at age					
Age	0	1	2	3	4	5+
	1.24	0.58	0.45	0.40	0.37	0.35

5.2.1.5 Fisheries

5.2.1.5.1 General description of the fisheries

European hake is one of most important demersal target species of the Mediterranean fishing fleets, exploited in GSA 1 mainly by trawlers (87% landings) on the shelf and slope, and by small-scale fisheries using small scale nets (gillnet and trammel nets; 8%) and long lines (3%) on the shelf (average 2002-2014).

5.2.1.5.2 Management regulations applicable in 2015

In addition to the regulations specified in (CE) regulation nº 1967/2006, trawl fisheries in GSA01 are regulated by "Orden AAA/2808/2012" published in the Spanish Official Bulletin (BOE nº 313 29 December 2012), that establishes an Integral Management Plan for Mediterranean fishery resources. Regulations include trawling fishing license linked fishing area, engine power limited to 316 KW or 500 HP, codend mesh size (40 mm square or 50 mm rhomboidal), fishing forbidden within upper 50 m depth, time at sea (12 hours per day and 5 days per week) and minimum legal size for hake (20 cm TL). This Management Plan proposes a reduction of fishing effort by at least 20% over the period 2013-2017, based on the number of vessels active on 1 January 2013. Fishing effort reduction will be measured in terms of number of vessels, engine power and tonnage.

5.2.1.5.3 Catches

Hake annual catches (in tons) by gear in GSA 1 from DCF are shown in Table 5.2.1.5.3.1.

Table 5.2.1.5.3.1. Hake catches (t) by gear: artisanal nets (GNS+GTR), longlines (LLS) and otter trawls (OTB) in GSA 1.

Year	GNS+GTR	LLS	OTB
2002	40	44	451
2003	37	14	416
2004	31	2	516
2005	35	6	313
2006	48	12	283
2007	39	6	275
2008	37	7	295
2009	50	6	584
2010	26	21	545
2011	19	16	654
2012	15	9	458
2013	26	11	347
2014	25	13	275

5.2.1.5.4 Landings (by fleet if posible)

Table 5.2.1.5.4.1. Hake landings (t) by gear: artisanal nets (GNS+GTR), longlines (LLS) and otter trawls (OTB) in GSA 1.

Year	GNS+GTR	LLS	OTB
2002	40	44	451
2003	37	14	416
2004	31	2	516
2005	35	6	296
2006	48	12	283
2007	39	6	275
2008	37	7	282
2009	50	6	564
2010	26	21	530
2011	19	16	648
2012	15	9	437
2013	26	11	337
2014	25	13	245

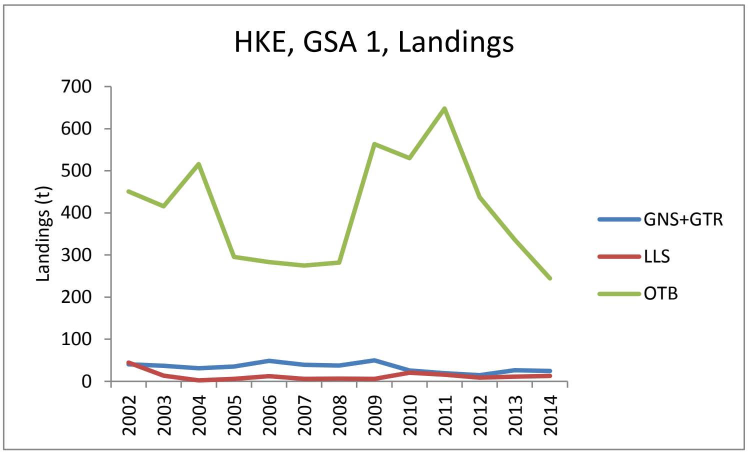


Figure 5.2.1.5.4.1. European hake in GSA 1. Annual landings by gear for the period 2002-2014.

5.2.1.5.5 Discards (by fleet if posible)

OTB data on discards are available for 2005 and 2008 to 2014. Discards represented around ≤5% of the OTB catch, in weight, except on 2014 when discards represented 11% of the total catch. No data was provided on the discards sizes. Data on discards for small scale nets were available for 2011 and 2014 and represented 0.2% of the total catch.

Table 5.2.1.5.5.1. European hake in GSA 1. Discards by gear for the period 2005- 2014.

Discards	GNS+GTR	OTB
2005		17.4
2006		
2007		

2008		12.5
2009		20.7
2010		14.9
2011	0.2	5.8
2012		20.8
2013		10.4
2014	0.2	30.5

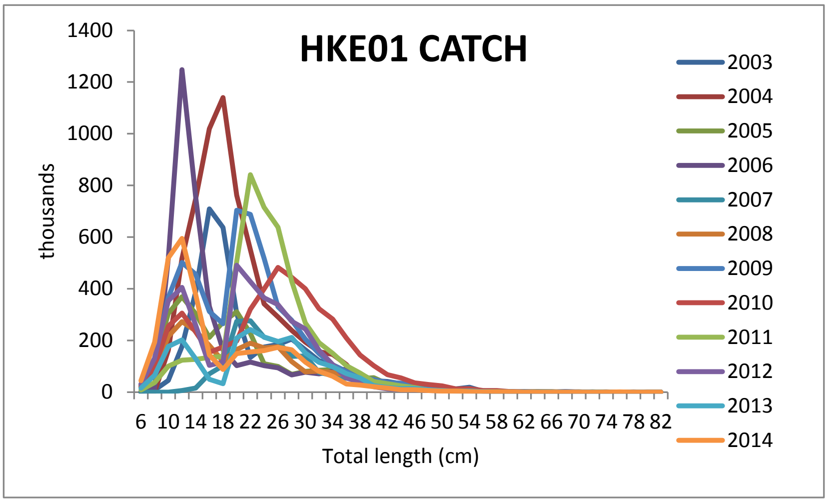


Figure 5.2.1.5.5.1 Hake in GSA 1. Size structure of the landings over the period 2003- 2014 (see section 5.2.1.7.2).

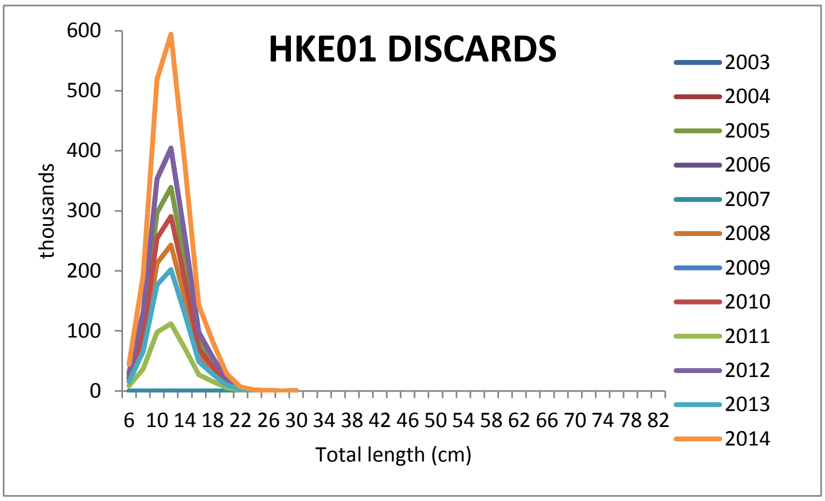


Figure 5.2.1.5.5.2. Hake in GSA 1. Size structure of the discards over the period 2003- 2014 (see section 5.2.1.7.2).

5.2.1.5.6 Fishing effort (by fleet if possible)

Data on fishing effort in GSA 1 by fleet are available from 2009 to 2014. No details for species were provided.

Table 5.2.1.5.6.1. Annual fishing effort (GT*days at sea) in GSA 1 over 2009- 2014.

	GTR+GNS	LLS	OTB
2009	12365.55	5468.06	363674.9
2010	14064.84	6209.44	441135.9
2011	10267.43	7070.66	355930.3
2012	10065.19	1494.42	383345
2013	11223.85	951.2	315009.9
2014	15934.76	1780.63	320447.5

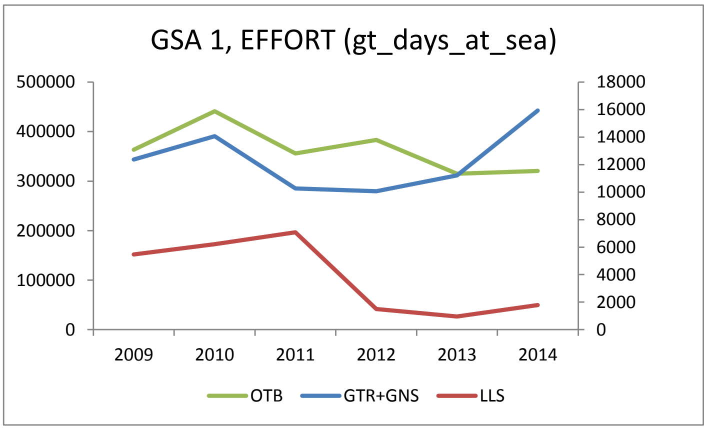


Figure 5.2.1.5.6.1. Annual fishing effort (GT*days at sea) for OTB (left axis) and GTR+GNS and LLS (right axis) in GSA 1 over 2009-2014.

5.2.1.6 Scientific surveys

5.2.1.6.1 Survey #1 (MEDITS)

5.2.1.6.1.1 Methods

Based on the DCF data call, abundance and biomass indices were recalculated. In GSA 1 the following number of hauls was reported per depth stratum:

Table 5.2.1.6.1.1. Number of hauls per year and depth stratum in GSA 1, 1994-2012.

STRATUM	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
GSA01_010-050	2	1	2	2	2	2	2	4	4	4	4	2	4	4	4	2	3	3	3
GSA01_050-100	5	5	5	6	6	9	6	6	8	12	8	8	8	8	7	8	6	6	8
GSA01_100-200	3	3	3	5	5	5	5	5	8	6	5	6	6	7	7	7	4	4	4
GSA01_200-500	8	9	11	10	7	11	13	10	11	11	13	11	13	13	13	13	6	8	8
GSA01_500-800	8	9	12	10	12	12	12	13	13	14	13	11	19	13	9	9	6	7	8

Data were assigned to strata based upon the shooting position and average depth (between shooting and hauling depth). Catches by haul were standardized to 60 minutes hauling duration. The abundance and biomass indices by GSA were calculated through stratified means (Cochran, 1953; Saville, 1977). This implies weighting of the average values of the individual standardized catches and the variation of each stratum by the respective stratum areas in each GSA:

$$Yst = \Sigma (Yi*Ai) / A$$
$$V(Yst) = \Sigma (Ai^2 * si^2 / ni) / A^2$$

Where:
A=total survey area
Ai=area of the i-th stratum
si=standard deviation of the i-th stratum
ni=number of valid hauls of the i-th stratum
n=number of hauls in the GSA
Yi=mean of the i-th stratum
Yst=stratified mean abundance
V(Yst)=variance of the stratified mean
The variation of the stratified mean is then expressed as the 95 % confidence interval:
Confidence interval = Yst ± t(student distribution) * V(Yst) / n
Length distributions represented an aggregation (sum) of all standardized length frequencies (subsamples raised to standardized haul abundance per km2) over the stations of each stratum. Aggregated length frequencies were then raised to stratum abundance and finally aggregated (sum) over the strata to the GSA.

5.2.1.6.1.2 Geographical distribution

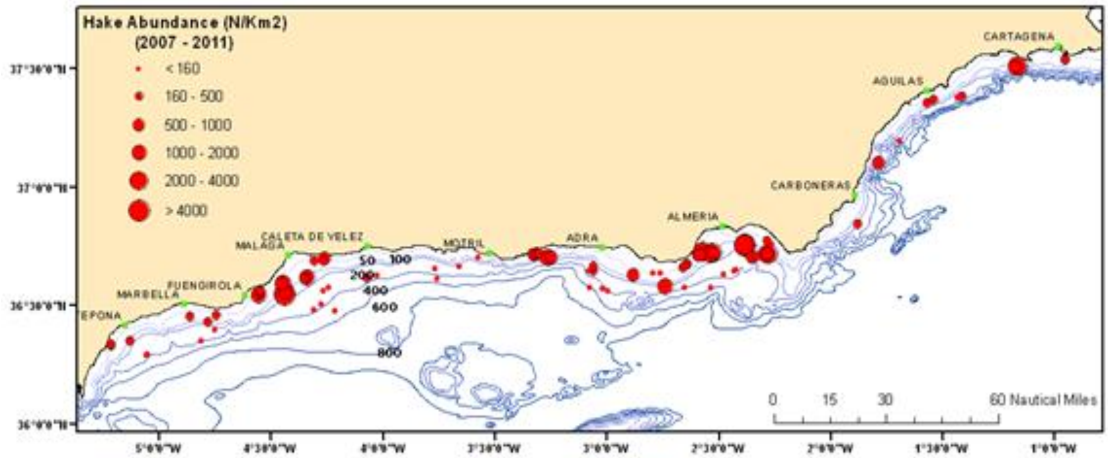


Figure 5.2.1.6.1.2.1. Hake in GSA 1. spatial distribution of estimated abundances indices (N/Km^2) for the period 2007-2011. MEDITS_ES trawl surveys. (GSA 1, Northern Alboran Sea).

5.2.1.6.1.3 Trends in abundance and biomass

Fishery independent information regarding the state of the European hake in GSA 1 was derived from the international survey MEDITS. Figure 5.2.1.6.1.3.1 displays the estimated trend in hake abundance and biomass in GSA 1 over 1994- 2014.

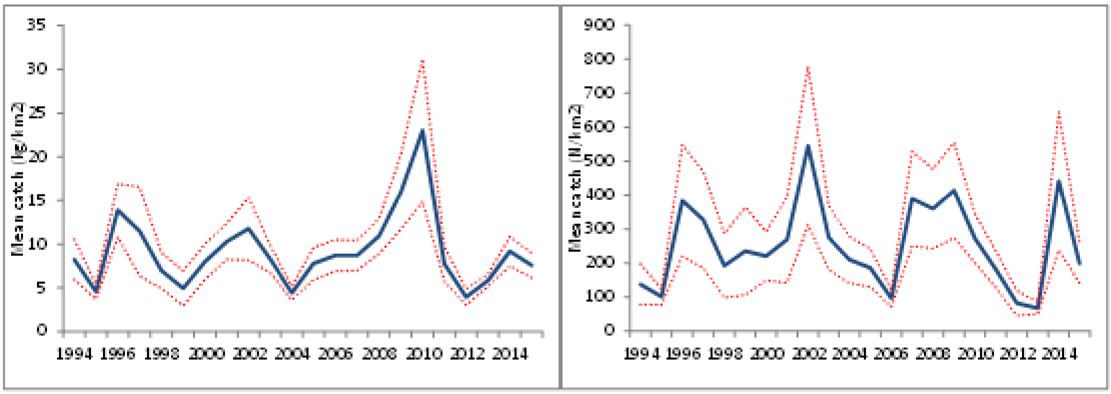
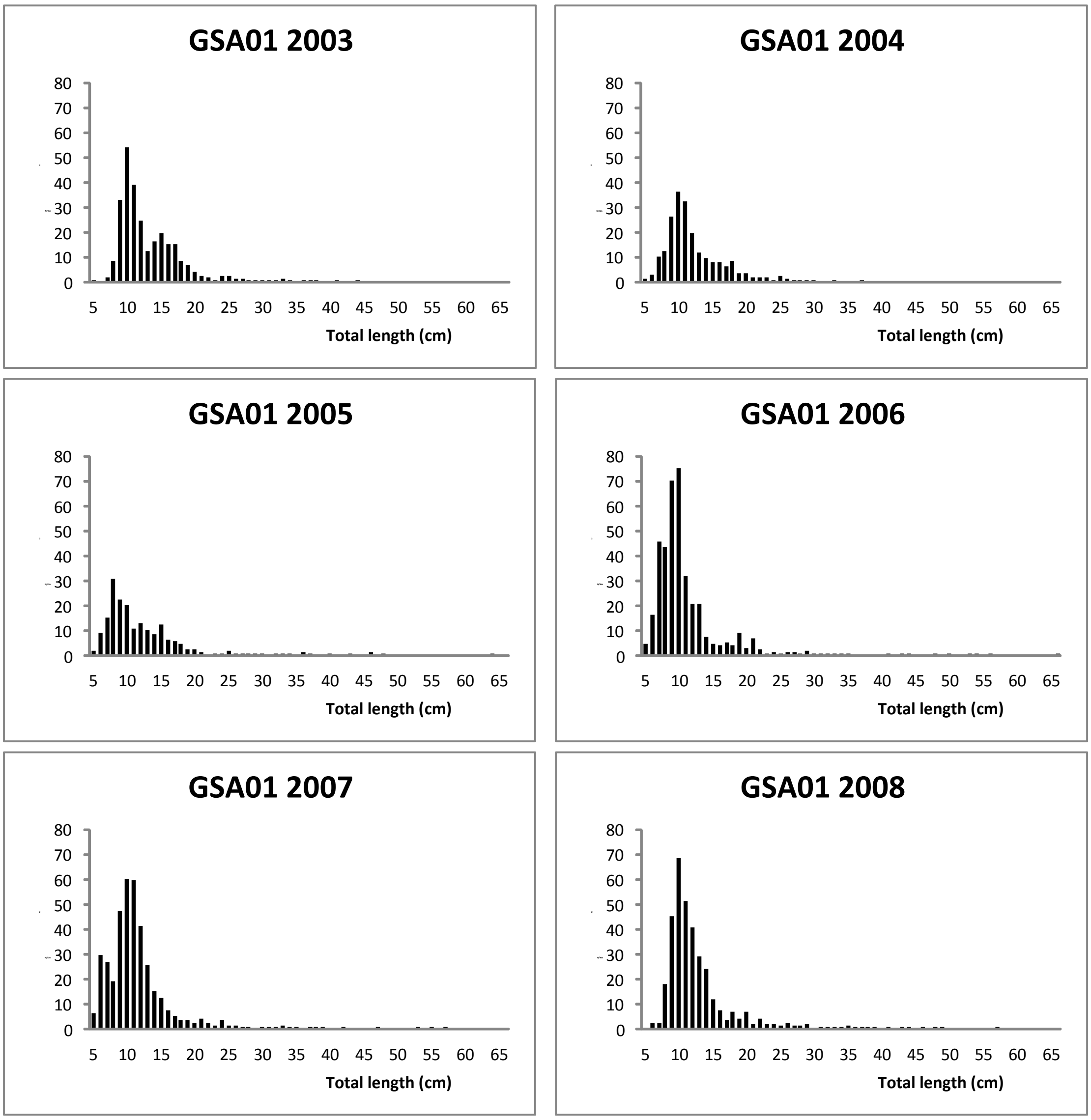


Figure 5.2.1.6.1.3.1 Hake in GSA 1. Abundance and biomass trend during 1994-2014 as estimated from the MEDITS survey data.

5.2.1.6.1.4 Trends in abundance by length or age



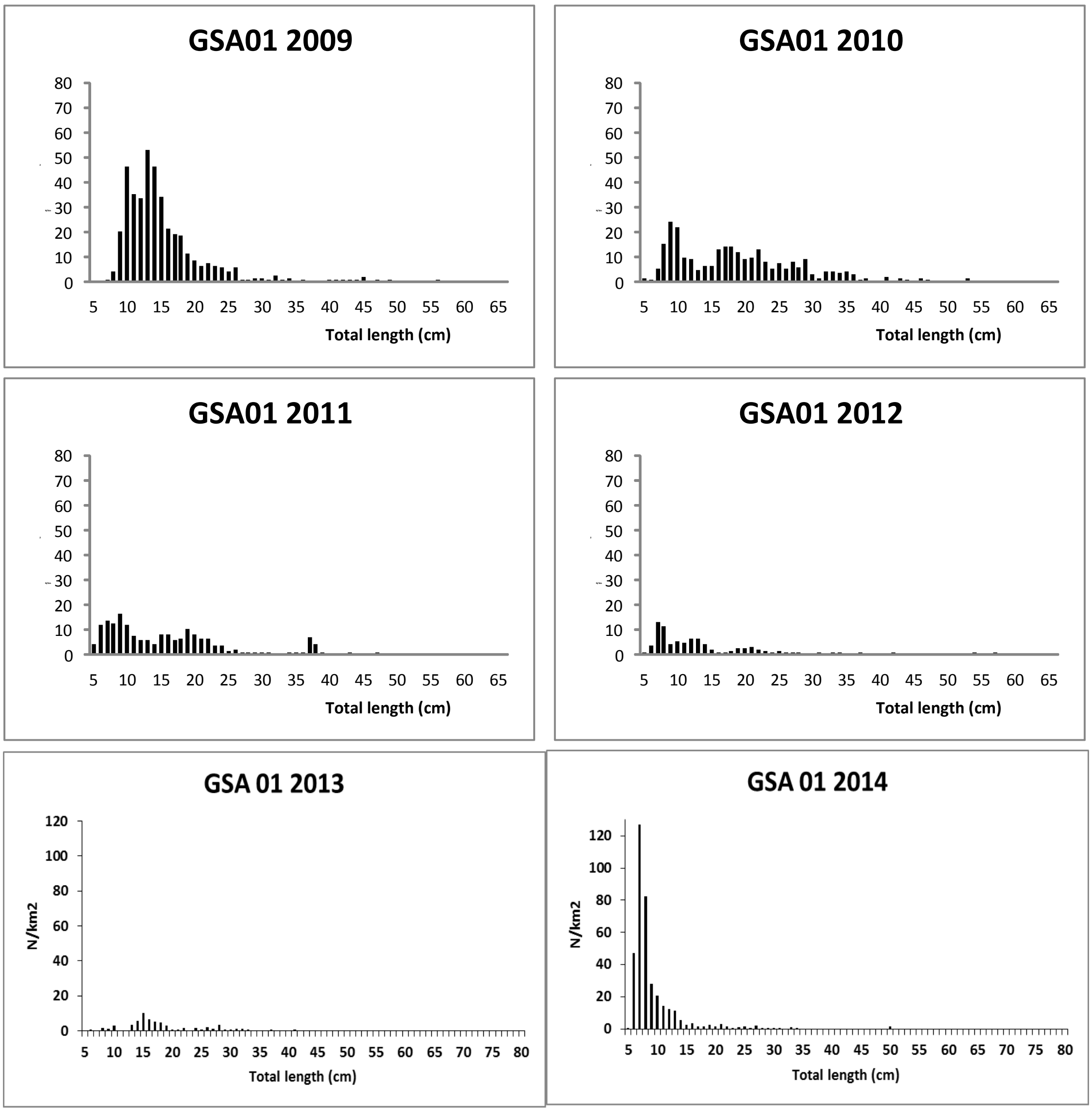


Figure 5.2.1.6.1.4.1. Hake in GSA 1. Trends in abundance (n/km2) during 2003-2014 (data source: MEDITS survey).

5.2.1.7 Stock Assessment

5.2.1.7.1 Methods: XSA

This stock was assessed through XSA by EWG15-11, using an ad-hoc R-script. SOP correction was made before running the analysis. XSA was run considering age classes 0 to 5+, the same as in the assessment performed in 2013 (EWG13-09), and input data over the period 2003-2014.

5.2.1.7.2 Input data

Hake in GSA 1 is exploited by OTB and small scale gears (GNS+GTR; LL). As explained above, discards are relevant for OTB and negligible for the small- scale gears. Data on size distributions were available for OTB landings over 2003-2014, and (GNS+GTR) in 2009, 2010 and 2014. So as to include all catch data in the assessment, when missing, the size distributions of the small scale gears and OTB discards were built taking as reference the size structure of (GNS+TRB) and LL in GSA 6 (the closest area to GSA 1) and of OTB discards in GSA7 (the only GSA where OTB discards sizes were available). Size frequencies distributions were transformed into age by slicing using L2A routine.

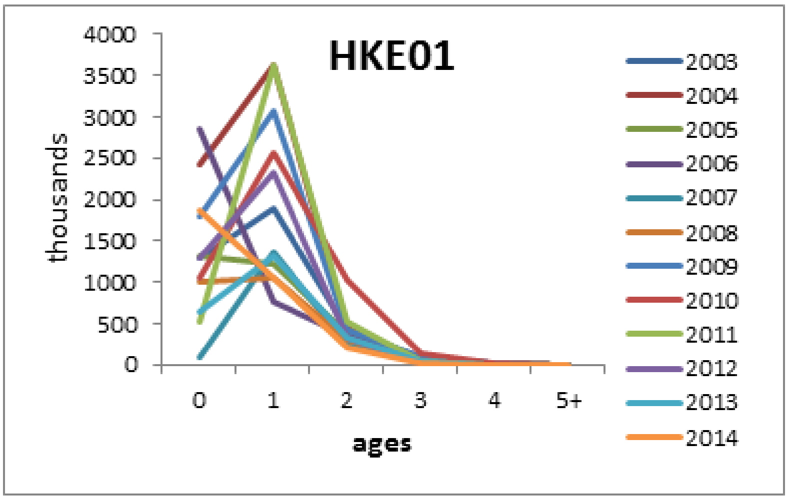


Figure 5.2.1.7.2.1. Hake in GSA 1. Catch at age.

Natural mortality was estimated using PROBIOM. M at the mid-point of the year was selected as M representative for that annual class.

Table 5.2.1.7.2.1. Hake in GSA 1. XSA input parameters: catch; catch numbers at age; weight at age; natural mortality at age; and tuning parameters (MEDITS survey 2003- 2012).

Catch (t)

2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
466.4	549	354.6	343.8	320	338.8	639.9	591.2	689	483.6	384.9	313.3

Catch numbers at age (thousands)

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
0	1301	2414	1318	2857	90	996	1787	1058	525	1279	635	1868
1	1882	3626	1212	764	1374	1058	3067	2573	3631	2334	1309	1046
2	430	448	371	361	263	315	432	1015	518	324	337	205
3	90	53	60	51	46	46	84	127	43	25	38	26
4	5	7	5	2	6	8	6	14	4	2	2	1
5+	1	1	1	2	2	4	1	1	1	0	0	0

Weight at age (kg)

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
0	0.029	0.027	0.019	0.02	0.033	0.019	0.02	0.018	0.021	0.016	0.016	0.016
1	0.11	0.098	0.104	0.12	0.125	0.124	0.116	0.15	0.128	0.129	0.139	0.135
2	0.423	0.387	0.43	0.425	0.416	0.423	0.417	0.405	0.395	0.371	0.394	0.397
3	1.011	0.975	0.934	0.966	0.91	0.951	0.917	0.946	0.911	0.916	0.924	0.93
4	1.605	1.631	1.518	1.591	1.685	1.598	1.633	1.57	1.604	1.587	1.514	1.519
5+	2.36	3.741	2.781	2.655	2.248	2.788	2.58	2.644	2.413	2.297	2.543	3.6

Natural Mortality (M) at age and Maturity vectors

Age	0	1	2	3	4	5+
M	1.24	0.58	0.45	0.40	0.37	0.35
Maturity	0	0.15	0.82	0.98	1	1

MEDITS number at age (2003-2014)

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
0	1238.5	1184.7	1166.3	1348.7	1355.2	1303.9	1311.7	1130.2	1113.9	62.3	36.6	382.9
1	35.8	27.6	18.6	34.7	26.8	36.6	81.4	113.9	49.7	17.4	22.6	23
2	4.1	0.8	3.8	2.8	4.1	6.2	5.4	19.7	13	1.6	NA	2.8
3	0	0	1.9	2	1.5	1.2	1.6	3	0.7	0.5	0.1	2.8
4+	0	0	0.6	0.6	0.3	0.3	0.2	0	0	0.5	0	1

5.2.1.7.3 Results

Different sensitivity analyses were performed before running the final XSA, considering different shrinkage weight from 0.5 to 2.5 (0.5 increasing), shrinkage ages (1,2,3), rage (-1,0,1) and qage (2,3,4). Comparison of trends between settings has been done. Different combinations between the settings that looked more stable were tested.

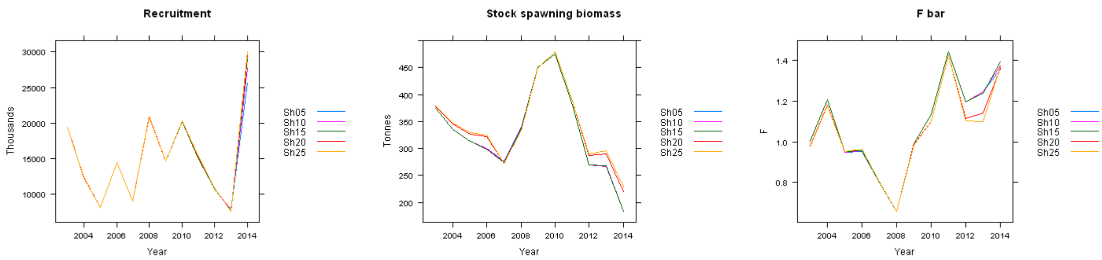


Figure 5.2.1.7.3.1. Hake in GSA 1. Sensitivity on shrinkage weight.

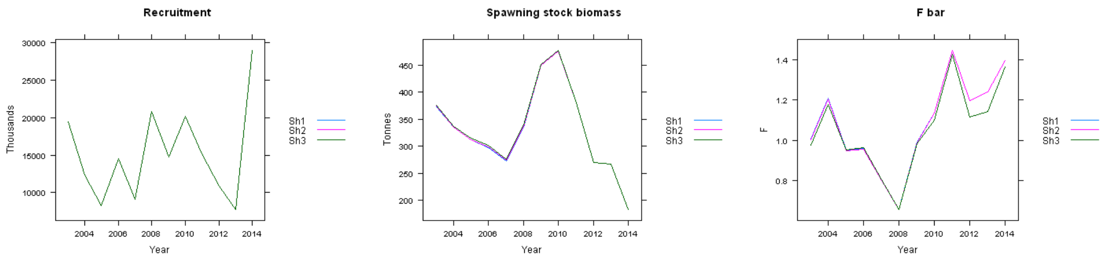


Figure 5.2.1.7.3.2. Hake in GSA 1. Sensitivity on shrinkage age.

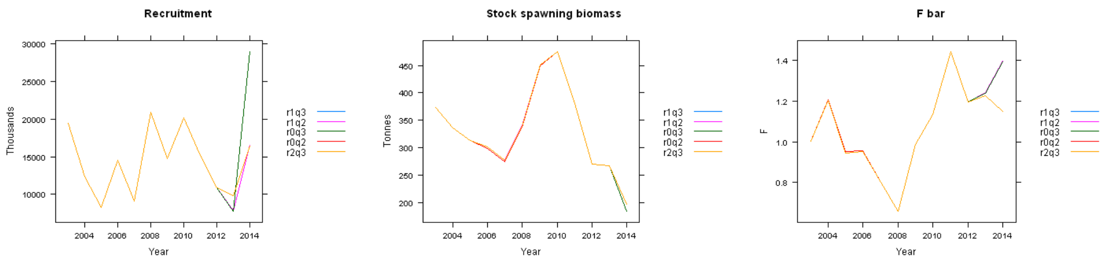


Figure 5.2.1.7.3.3. Hake in GSA 1. Sensitivity on rage and qage.

The following settings that minimized the residuals and showed the best diagnostics outpout were used for the final XSA final run:

Fbar	fse	rage	qage	Shk.n	Shk.f	Shk.yrs	shrk ages
0-2	2	-1	4	TRUE	TRUE	3	2

The residuals pattern of the MEDITS trawl survey is shown in Fig. 5.2.1.7.3.4.

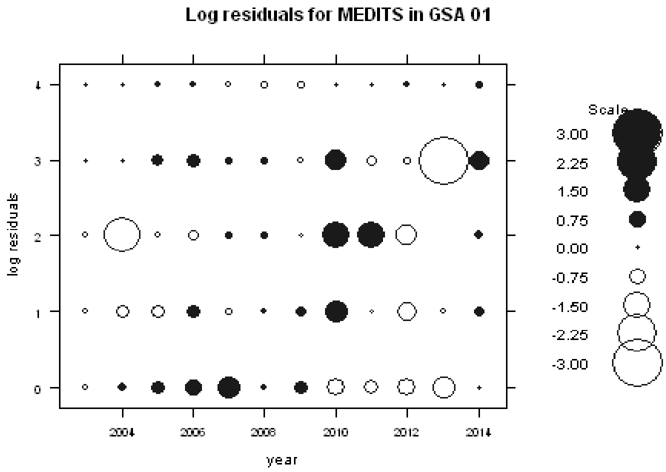


Figure 5.2.1.7.3.4. Hake in GSA 1. XSA residuals for MEDITS survey from 2003 to 2014.

The results of the retrospective analysis are shown in Figure 5.2.1.7.3.5.

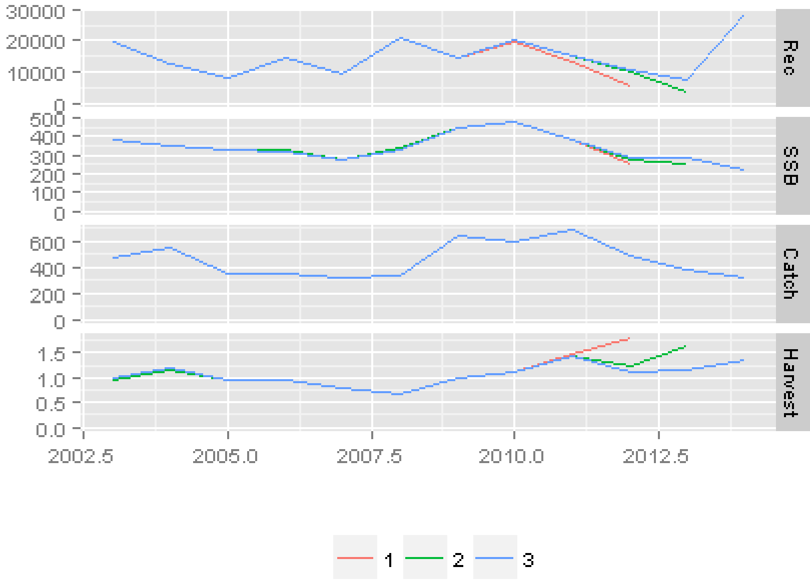


Figure 5.2.1.7.3.5. Hake in GSA 1. XSA retrospective analysis.

The results of the XSA are shown in the following figure.

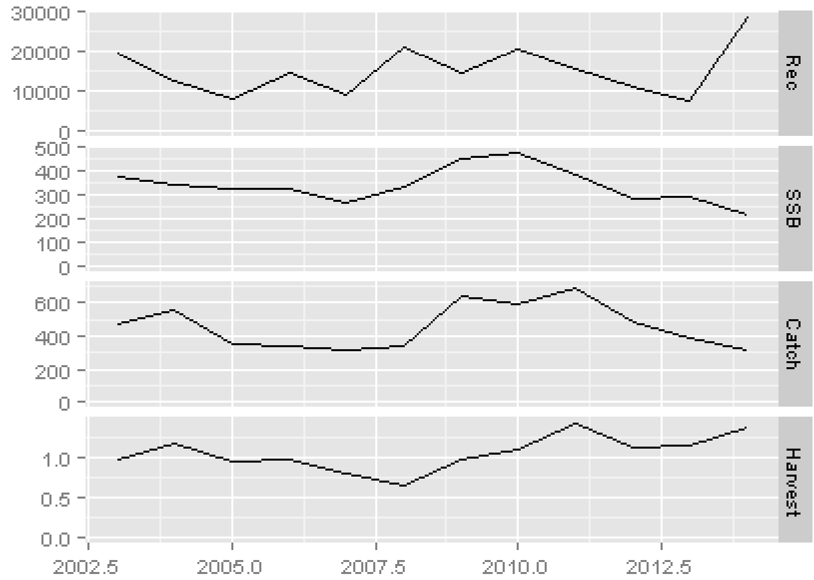


Figure 5.2.1.7.3.6. Hake in GSA 1. XSA results. SSB and catch are in tonnes, recruitment in 1000s individuals.

In the tables 5.2.1.7.3.1 and 2 the population estimates of hake in GSA 1 obtained by XSA are provided.

Table 5.2.1.7.3.1. European hake in GSA 1. Stock numbers at age (thousands) as estimated by XSA.

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
0	19461.00	12318.00	8218.10	14506.00	9092.30	20929.00	14704.00	20343.00	15341.00	10895.00	7640.70	28673.00
1	3281.60	5014.10	2483.40	1712.60	2729.50	2585.70	5539.70	3324.00	5536.00	4171.70	2442.30	1849.40
2	583.57	594.69	547.99	539.15	412.78	560.29	684.26	878.44	674.22	524.00	533.00	329.92
3	109.18	68.94	81.24	71.65	68.20	65.35	115.03	102.47	60.59	37.53	66.87	55.32
4	6.40	8.24	10.29	8.20	8.07	10.57	7.25	10.88	4.53	7.00	3.69	12.23
5+	1.27	1.08	2.07	8.98	2.45	4.88	1.57	0.45	0.61	1.22	0.30	1.73

Table 5.2.1.7.3.2. Hake in GSA 1. XSA summary results

	Fbar 0-2	Recruitment (thousands)	SSB (t)	TB (t)
2003	1.41	19461	378.0	1295.8
2004	1.59	12318	345.8	1138.8
2005	1.27	8218	327.7	747.3
2006	1.23	14506	323.4	830.9
2007	1.20	9092	271.9	894.1
2008	0.94	20929	333.9	1047.9
2009	1.36	14704	449.6	1343.4
2010	1.62	20343	479.8	1335.7
2011	2.11	15341	387.5	1361.0
2012	1.54	10895	287.7	955.2
2013	1.62	7641	290.0	739.9
2014	1.97	28673	220.1	915.7

	F at age

	0	1	2	3	4	5+
2003	0.12	1.13	1.69	2.18	1.99	1.99
2004	0.36	1.63	1.54	1.50	1.56	1.56
2005	0.33	0.95	1.58	1.89	0.87	0.87
2006	0.43	0.84	1.62	1.78	0.29	0.29
2007	0.02	1.00	1.39	1.46	1.76	1.76
2008	0.09	0.75	1.13	1.80	2.20	2.20
2009	0.25	1.26	1.45	1.96	2.31	2.31
2010	0.06	1.02	2.22	2.72	2.54	2.54
2011	0.06	1.78	2.44	1.76	2.12	2.12
2012	0.26	1.48	1.61	1.92	0.36	0.36
2013	0.18	1.42	1.82	1.30	1.58	1.58
2014	0.15	1.89	2.05	1.02	0.17	0.17

The XSA results summarized in Tables 5.2.1.7.3.1 and 2 and in Figure 5.2.1.7.3.6. show a decreasing trend in SSB since 2010, a fluctuation of recruitment with 2014 as the highest recruitment over 2003-2014, as well as decreasing landings in the most recent years and an estimated F_{curr} of 1.20.

5.2.1.8 Reference points

5.2.1.8.1 Methods

The XSA package used allowed a Yield per recruit analysis and an estimate of some F-based Reference Points as F_{max} and $F_{0.1}$. Yield per Recruit computation was made by R project software and the FLR libraries. The fishing mortality rate corresponding to $F_{0.1}$ in the yield per recruit curve is considered here as a proxy of F_{MSY}.

5.2.1.8.2 Input data

The input parameters were the same used for the XSA stock assessment and its results.

5.2.1.8.3 Results

Table 5.2.1.8.3.1. Hake in GSA 1. Main reference points defined with the yield per recruit analysis.

refpt	harvest	yield	rec	ssb	biomass
virgin	0.00	0.00	1.00	0.71	0.78
msy	0.32	0.05	1.00	0.17	0.23
crash	41.93	0.01	1.00	0.00	0.02
f0.1	0.21	0.04	1.00	0.26	0.32
fmax	0.32	0.05	1.00	0.17	0.23
spr.30	0.26	0.05	1.00	0.21	0.27

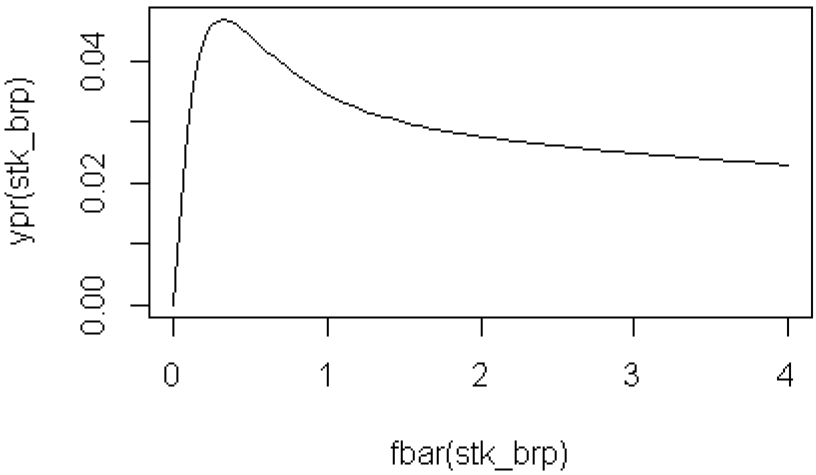


Figure 5.2.1.8.3.1. Hake in GSA 1. Yield per recruit curve.

5.2.1.9 Data quality

Data from DCF 2014 as submitted through the Official data call in 2015 were used.
A number of errors were detected in the MEDITS database (e.g. an error in the 2013 size frequencies abundances in length class 38 cm/age class 3, not considered in the analysis; 2013-2014 data submitted twice). Because of this, Medits data used in the assessment were provided by EWG15-11 invited experts. No data on OTB discarded sizes of European hake in GSA 1 available. No data on LL landings sizes available. Concerning GNS+GTR, size data were available for 2009, 2010 and 2014. For more details see section 5.2.1.7.2.

5.2.1.10 Short term predictions 2016-2018

5.2.1.10.1 Method

A deterministic short term prediction for the period 2015 to 2017 was performed using the FLR routines provided by JRC and based on the results of the XSA stock assessments performed during EWG 15-11.

5.2.1.10.2 Input parameters

Input parameters were the same used for the XSA stock assessment and its results. An average of the last three years has been used for weight at age, maturity at age and F at age.
Recruitment (age 0) has been estimated from the population results as the geometric mean of the last 3 years (13364.21 thousand individuals).

5.2.1.10.3 Results

Table 5.2.1.10.3.1. Hake in GSA 1. Short term forecast in different F scenarios Basis: F(2015) = mean (F_{bar} 0-2 2012-2014)= 1.20; R(2015) = geometric mean of the recruitment of the last 3 years; R = 13364 thousands; SSB(2014) = 220 t, Catch (2014)= 313 t.

Rationale	F factor	Fbar	Catch 2015	Catch 2016	Catch 2017	SSB 2016	SSB 2017	Change SSB_2016-2017(%)	Change Catch_2014-2016(%)
Zero catch	0	0	726	0	0	367	1158	215.56	-100.00
High long term yield (F0.1)	0.18	0.21	726	160	281	367	883	140.49	-48.93
Status quo	1	1.20	726	550	459	367	273	-25.72	75.47
Different Scenarios	0.1	0.12	726	96	185	367	991	170.01	-69.21
	0.2	0.24	726	180	307	367	850	131.47	-42.68
	0.3	0.36	726	251	385	367	730	98.85	-19.76
	0.4	0.48	726	314	433	367	628	71.21	0.08
	0.5	0.60	726	367	459	367	542	47.80	17.29
	0.6	0.72	726	414	472	367	470	27.94	32.25
	0.7	0.84	726	455	476	367	408	11.09	45.29
	0.8	0.96	726	491	474	367	355	-3.22	56.69
	0.9	1.08	726	522	468	367	311	-15.38	66.68
	1.1	1.32	726	574	450	367	240	-34.53	83.22
	1.2	1.44	726	596	440	367	213	-42.04	90.07
	1.3	1.56	726	615	430	367	189	-48.45	96.16
	1.4	1.68	726	632	420	367	169	-53.93	101.59
	1.5	1.80	726	647	411	367	152	-58.62	106.44
	1.6	1.92	726	660	402	367	137	-62.64	110.80
	1.7	2.04	726	673	394	367	124	-66.10	114.73
	1.8	2.16	726	684	387	367	113	-69.08	118.28
	1.9	2.28	726	694	380	367	104	-71.64	121.51
	2	2.40	726	703	373	367	96	-73.87	124.46

5.2.1.11 Short term predictions 2015-2017 by fleet

5.2.1.11.1 Method

A deterministic short term prediction by fleet for the period 2015 to 2017 was performed using the FLR routines provided by JRC and based on the results of the XSA stock assessments performed during EWG 15-11.

5.2.1.11.2 Input parameters

The same parameters used in the short term by single fleet were used.

5.2.1.11.3 Results

Table 5.2.1.11.3.1. Hake in GSA 1. Short term forecast by fleet.

fleet	year	catches	Partial_F
OTB	2015	699.8	1.13
GNS	2015	7.5	0.05
LL	2015	9.9	0.02

OTB	2016	112.6	0.13
GNS	2016	4.5	0.01
LL	2016	2.1	0.002
OTB	2017	219.3	0.13
GNS	2017	12.7	0.01
LL	2017	7.4	0.002

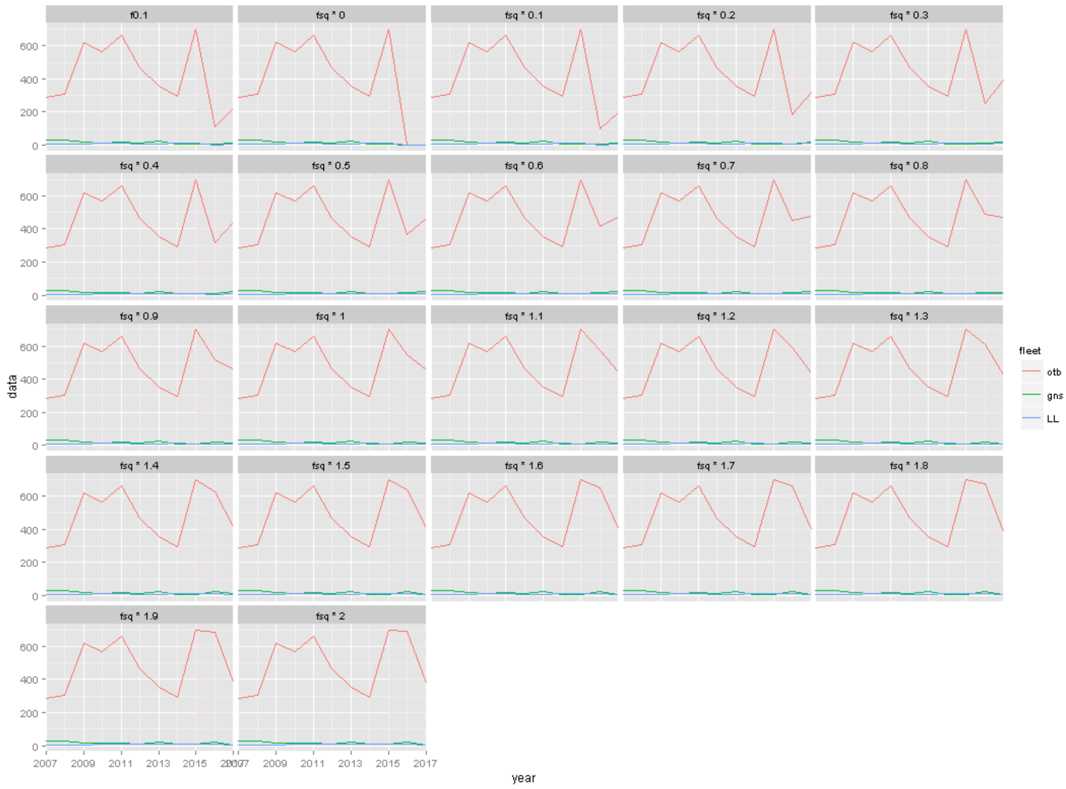


Figure 5.2.1.11.3.1. Hake in GSA 1. Short term forecast by fleet.

5.2.1.12 Medium term predictions

5.2.1.12.1 Method

Medium term was not conducted because no meaningful stock-recruitment relationship was estimated.

5.2.1.13 Stock advice

The current F (1.20) is larger than $F_{0.1}$ (0.21), chosen as proxy of F_{MSY} and as the exploitation reference point consistent with long term yields (F_{MSY}), which indicates that European hake in GSA 1 is is being fished above F_{MSY}. Catches of European hake in 2016 consistent with F_{MSY} should not exceed 160 tonnes.

5.2.1.14 Management strategy evaluation

A Management Strategy Evaluation (MSE) was conducted to evaluate if the MSY ranges were precautionary. The F_{MSY} ranges were derived using the formula provided by STECF 15-09. F ranges results were F_{upper} = 0.29 and F_{lower} = 0.14. B_{lim} was estimated as B_{loss} = 220 (t). The following figure shows the results of the MSE of the F_{upper}.

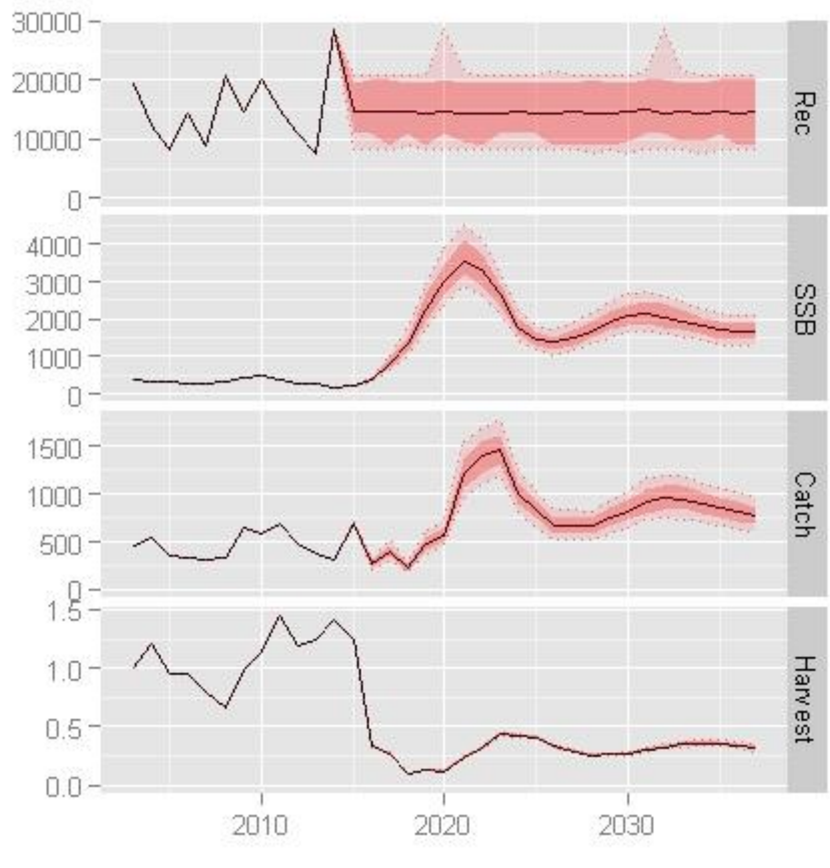


Figure 5.2.1.14.1. European hake in GSA 1. Marine Strategy Evaluation.

The probability of SSB to fall below B_{lim} at F = F_{upper} is equal to 0.

5.2.2 STOCK ASSESSMENT OF HAKE IN GSA 5

5.2.2.1 Stock Identification

GSA 5 (Figure 5.2.2.1.1) has been pointed as an individualized area for assessment and management purposes in the western Mediterranean (Quetglas *et al.*, 2012) due to its main specificities. These include: 1) Geomorphologically, the Balearic Islands (GSA 5) are clearly separated from the Iberian Peninsula (GSA 6) by depths between 800 and 2000 m, which would constitute a natural barrier to the interchange of adult stages of demersal resources; 2) Physical geographically-related characteristics, such as the lack of terrigenous inputs from rivers and submarine canyons in GSA 5 compared to GSA 6, give rise to differences in the structure and composition of the trawling grounds and hence in the benthic assemblages; 3) Owing to these physical differences, the faunistic assemblages exploited by trawl fisheries differ between GSA 5 and GSA 6, resulting in large differences in the relative importance of the main commercial species; 4) There are no important or general interactions between the demersal fishing fleets in the two areas, with only local cases of vessels targeting red shrimp in GSA 5 but landing their catches in GSA 6; 5) Trawl fishing exploitation in GSA 5 is much lower than in GSA 6; the density of trawlers around the Balearic Islands is one order of magnitude lower than in adjacent waters; and 6) Due to this lower fishing exploitation, the demersal resources and ecosystems in GSA 5 are in a healthier state than in GSA 6, which is reflected in the population structure of the main commercial species (populations from the Balearic Islands have larger modal sizes and lower percentages of small-sized individuals), and in the higher abundance and diversity of elasmobranch assemblages.

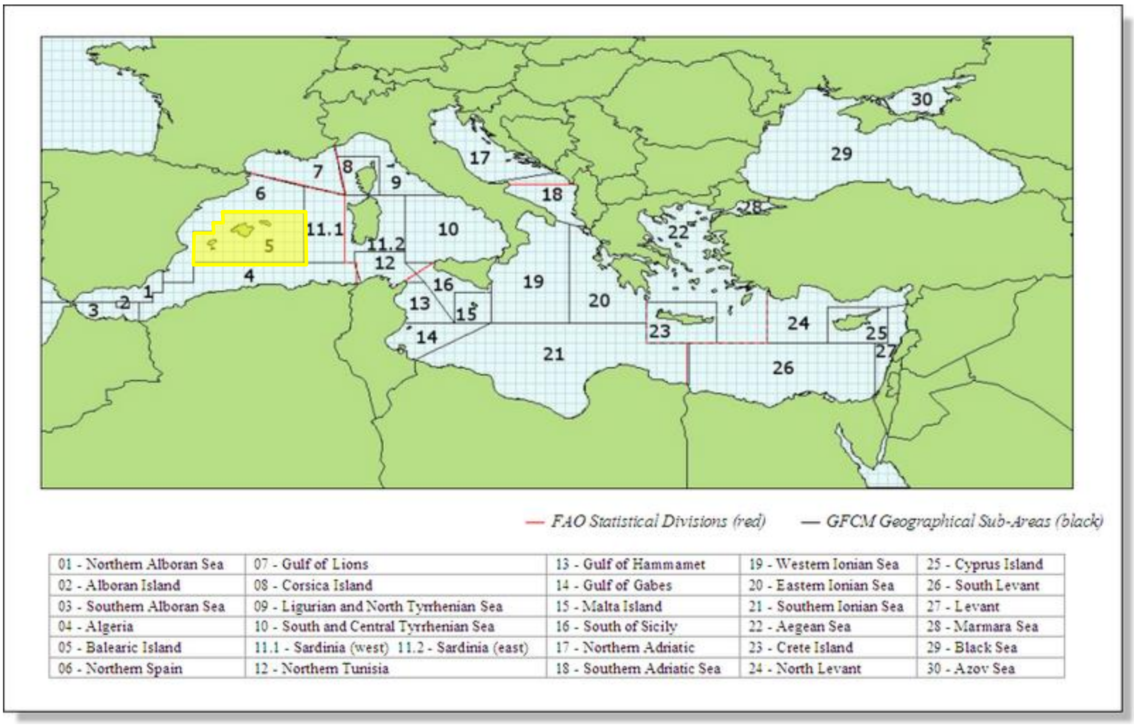


Figure 5.2.2.1.1. Geographical localization of GSA 5.

5.2.2.2 Growth

The growth parameters used during the EWG 15-11 were those estimated by Mellon-Duval et al. (2010) from tagging experiments in the Gulf of Lions, L_{inf}= 110 cm, k= 0.178. Length-weight relationship parameters were those estimated in the Spanish Data Collection Framework: a=0.00677 and b=3.035097.

5.2.2.3 Maturity

Maturity ogive was estimated in the Spanish Data Collection Framework:

Maturity oogive						
Age	0	1	2	3	4	5+
Prop. Matures	0	0.15	0.82	0.98	1	1

5.2.2.4 Natural mortality

Natural mortality was estimated using PRODBIOM:

Natural mortality						
Age	0	1	2	3	4	5+
Prop. Matures	1.24	0.58	0.45	0.40	0.37	0.35

5.2.2.5 Fisheries

5.2.2.5.1 General description of the fisheries

In the Balearic Islands (western Mediterranean), commercial trawlers develop up to four different fishing tactics, which are associated with the shallow shelf (SS), deep shelf (DS), upper slope (US) and middle slope (MS) (Guijarro and Massutí 2006; Ordines et al. 2006), mainly targeted to: (i) *Spicara smaris*, *Mullus surmuletus*, *Octopus vulgaris* and a mixed fish category on the shallow shelf (50-80 m); (ii) *Merluccius merluccius*, *Mullus* spp., *Zeus faber* and a mixed fish category on the deep shelf (80-250 m); (iii) *Nephrops norvegicus*, but with an important by-catch of big *M. merluccius*, *Lepidorhombus* spp., *Lophius* spp. and *Micromesistius poutassou* on the upper slope (350-600 m) and (iv) *Aristeus antennatus* on the middle slope (600-750 m). The MS fishing tactics coincides with the metier OTB_DWSP; OTB_DEMSP corresponds to those days in one of the other fishing tactics is present (SS, DS and/or US) and OTB_MDDWSP corresponds to those days in which one haul in MS and at least one of the other fishing tactics is performed.

5.2.2.5.2 Management regulations applicable in 2015

- Fishing license: number of licenses observed
- Engine power limited to 316 KW or 500 HP: not fully observed.
- Mesh size in the codend (40 mm square or 50 mm diamond -by derogation-): fully observed.
- Time at sea (12 hours per day and 5 days per week): fully observed.
- Minimum landing size (EC regulation 1967/2006, 20 mm CL): mostly fully observed.

5.2.2.5.3 Catches

Hake catches came exclusively from bottom trawlers (OTB) in GSA 5. They show important oscillations along the data series, between 50 and 250 tons. These oscillations seem to be related to environmental conditions, as hake recruitment seems to be benefitted by a certain scenario of enhanced productivity resulted from particularly cold years, which determines the regional circulation around the Balearic Islands and from certain climatic conditions on the areas where Western Intermediate Waters (the main water mass where hake population is found) are formed

(Massutí *et al.*, 2008). By métier, landings in OTB_DEMSP represent 94%, OTB_DWSP 3% and OTB_MDDWSP 3%.

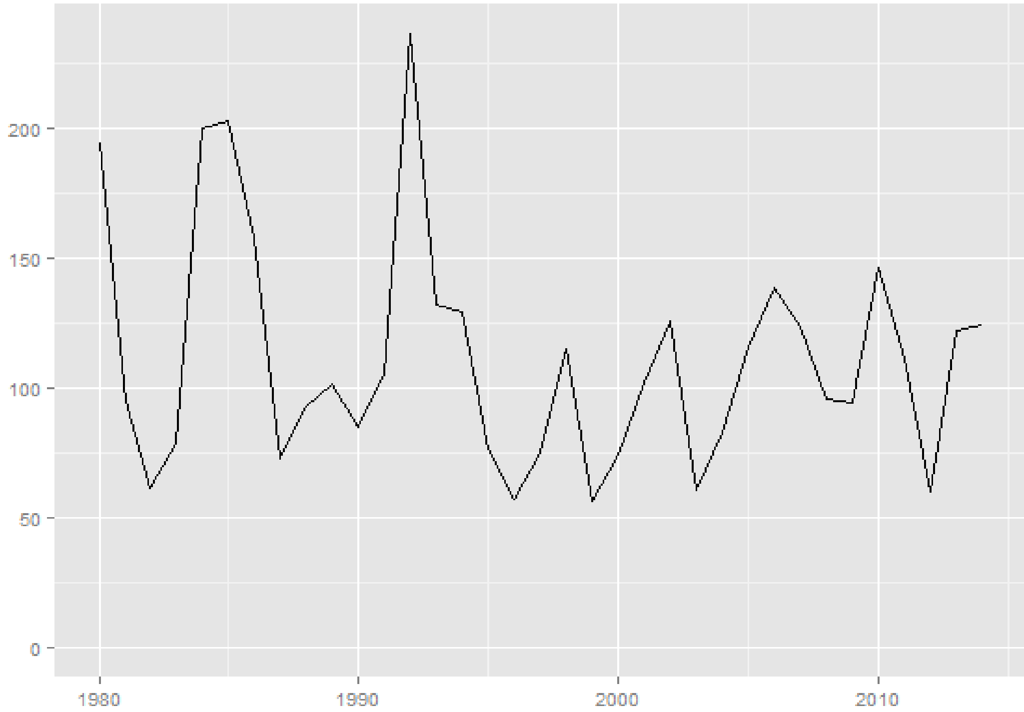


Figure 5.2.2.5.3.1. Hake in GSA 5. Historical catches.

5.2.2.5.4 Discards

Discards represent around 3-5% of the catches of hake for the metiers OTB_DEMSP and OTB_MDDWSP and are almost null for OTB_DWSP.

5.2.2.5.5 Fishing effort

Fishing effort available from the Data Call included years 2009-2014. Table 5.2.2.5.6.1 summarizes the effort data for the gear OTB according to the DCF Data Call in terms of nominal effort and GT days at sea. Number of boats cannot be calculated from the information available in the Data Call as it is disaggregated by quarter and my métier (OTB_DEMSP, OTB_MDDWSP and OTB_DWSP) and so it cannot be accumulated, as the same boat may be included in different quarters and/or in different métiers.

Table 5.2.2.5.6.1. Effort data for OTB in GSA 5 according to the DCF Data Call.

	2009	2010	2011	2012	2013	2014
Nominal effort	2784175	2927650	2694399	2675591	2745967	2828550
GT days at sea	648577	672070	616593	630595	641523	670025

5.2.2.6 Scientific surveys

5.2.2.6.1 Survey #1 (BALAR- MEDITS)

5.2.2.6.1.1 Methods

Although MEDITS survey started in Spain in 1994, it did not cover the Balearic Islands, except for a small number of hauls (2-4) carried out some of the years in the Ibiza channel, in waters deeper than 200 m. From 2001, the Spanish Institute of Oceanography (IEO) has performed annual bottom trawl surveys following the same methodology and sampling gear described in the MEDITS protocol (BALAR surveys, Massutí and Reñones, 2005). Since 2007, this survey has been included in the MEDITS program (Bertrand *et al.*, 2002). The abundance indices used here has been calculated from IEO data bases, using data collected in the Balearic Islands during BALAR surveys in the first years and MEDITS in the lasts, in order to have the most complete series of abundance indices available.
Mean stratified abundances and biomasses by km^2 has been computed using the methodology described by Grosslein and Laurec (1982), with the following formula:

- Mean catch by stratum: $$\overline{Y}_{st} = \frac{1}{N_h} * \sum Y_h$$
- Variance by stratum: $$S^2(\overline{Y}_{st}) = \frac{1}{N_{h-1}} * \sum (Y_h - \overline{Y}_{st})^2$$
- Mean total catch: $$Y_t = \frac{1}{A} * \sum (\overline{Y}_{st} * A_h)$$
- Total variance: $$S^2(\overline{Y}_t) = \frac{1}{A^2} * \sum \frac{S^2(\overline{Y}_{st}) * A_h^{\,2}}{N_h}$$
- SE (standard error): $$SE = \sqrt{S^2(\overline{Y}_{st})}$$

Nh: number of hauls in each sub-stratum; Yh: mean catch by haul in each sub-stratum; A: total stratum area; Ah: sub-estratum area; $S^2(\overline{Y}_{st})$ variance in each sub-stratum.

Abundance indices were available during the meeting from the information in the Data Call and both sources of information have been compared for years 2007-2014, when it is expected to have a high agreement. For these years, the only differences between both data bases should be the incorporation in the Data Call of the above-mentioned hauls carried out some years in the Ibiza channel. The results of this comparison are described in the data quality section.

5.2.2.6.1.2 Geographical distribution

Hake is mainly distributed in the fishing grounds sited in the Menorca channel (NE Mallorca) and in the south of Mallorca (Figure 5.2.2.6.2.1).

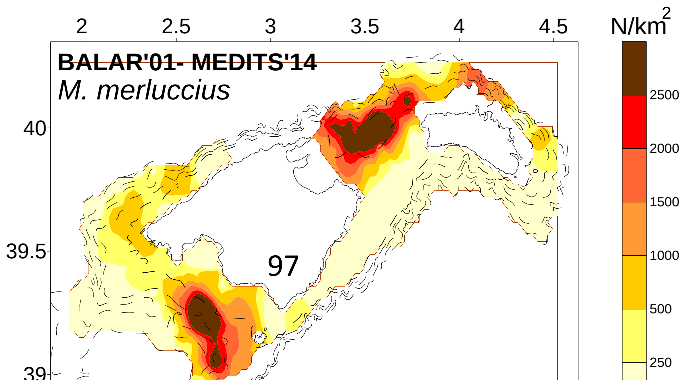


Figure 5.2.2.6.2.1. Hake in GSA 5. Geographical distribution based on bottom trawl surveys (2001-2014).

5.2.2.6.1.3 Trends in abundance and biomass

Both abundance indices from the scientific surveys and landings per unit of effort obtained from the fishing fleet in Alcúdia (which mainly targets hake) showed similar results, especially for the smaller size category (as a proxy of recruitment). Indices showed oscillations along the data series, with the highest values in 2006 and 2013. For 2014, survey indices showed a drop to practically half values of the previous year, which can also seem (but to a lesser extent) in the small commercial category (Figure 5.2.2.6.1.3.2).

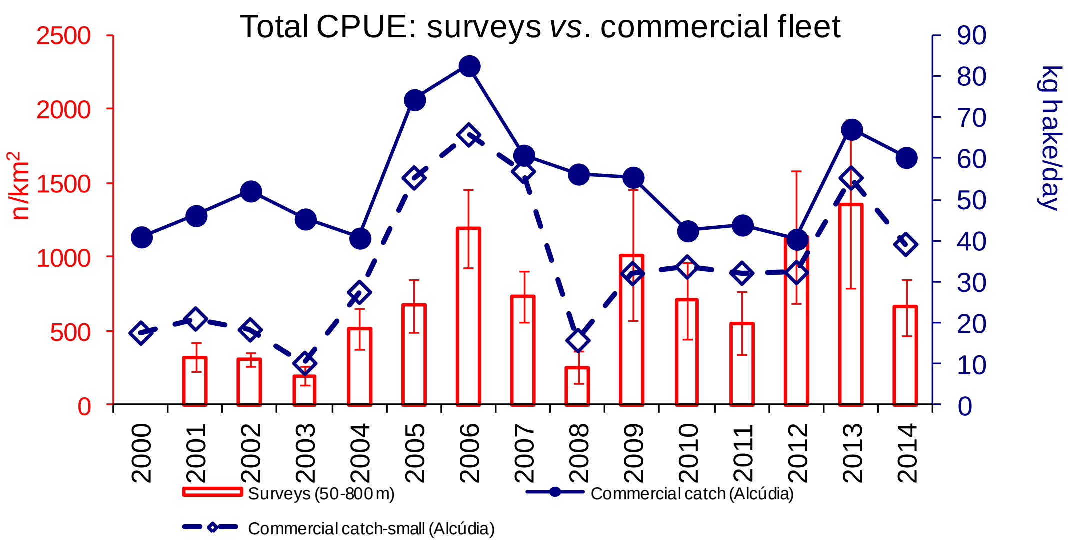


Figure 5.2.2.6.1.3.2. Hake in GSA 5. Standardized abundance indices (n/km2) from scientific surveys and landings per unit of effort (kg/day·boat) for the total catch and for the small category (as a proxy of recruitment) in the Alcúdia port (NE Mallorca)

5.2.2.6.1.4 Trends in abundance by length or age

No analysis were conducted during EWG 15-11.

5.2.2.7 Stock Assessment

5.2.2.7.1 Methods

The assessment has been performed with an Extended Survivor Analysis (XSA) using the FLR library in R. This stock is an update of the one presented in the GFCM Working Group of Demersal Species in 2014 (WGSAD, 2014) and was assessed for the last time by the STECF in 2010 (STECF SGMED 10-02, 2010).

5.2.2.7.2 Input data

The data used in the assessment were: (i) Catches time series 1980-2014 from OTB; (ii) Age distributions obtained from slicing of length distributions 1980-2014 (Figure 5.2.2.7.2.1); (iii) BALAR-MEDITS survey used as tuning fleet (abundances by age in n/km^2, Figure 5.2.2.7.2.1).

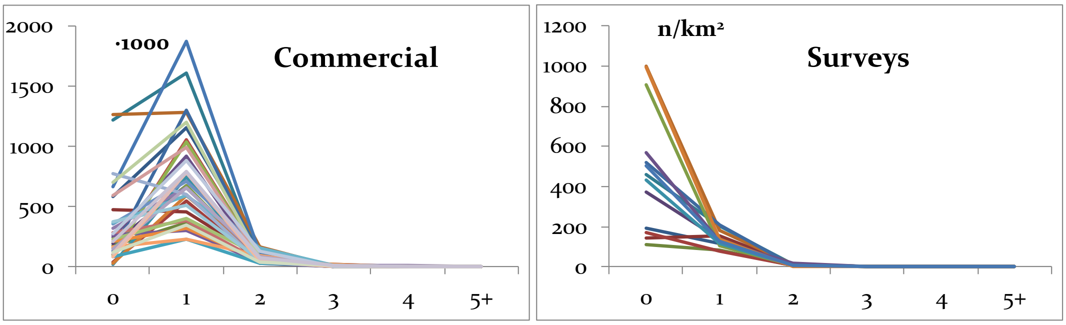


Figure 5.2.2.7.2.1 Hake. GSA 5. Age distribution by year for the commercial and survey data.

Mean weight in catch					
0	1	2	3	4	5+
0.028	0.101	0.406	0.943	1.642	2.474

Growth parameters		
L_∞	k	t_0
110	0.178	-

Length-weight relationship	
a	b
0.00677	3.035097

Maturity oogive						
Age	0	1	2	3	4	5+
Prop. Matures	0	0.15	0.82	0.98	1	1

Natural mortality (PROBIOM; Abella et al., 1997)						
Age	0	1	2	3	4	5+
M	1.24	0.58	0.45	0.4	0.37	0.35

The number of individuals by age was SOP corrected [SOP = Landings / Σ*a* (total catch numbers at age *a* x catch weight-at-age *a*)] before performing any analysis.

Different sensitivity analyses were performed before running the final XSA, considering different weights and ages for shrinkage and different ages for catchability. In all the cases (weight shrinkage: Figure 5.2.2.7.2.2; age shrinkage: Figure 5.2.2.7.2.3; catchability: Figure 5.2.2.7.2.4) the results were very robust.

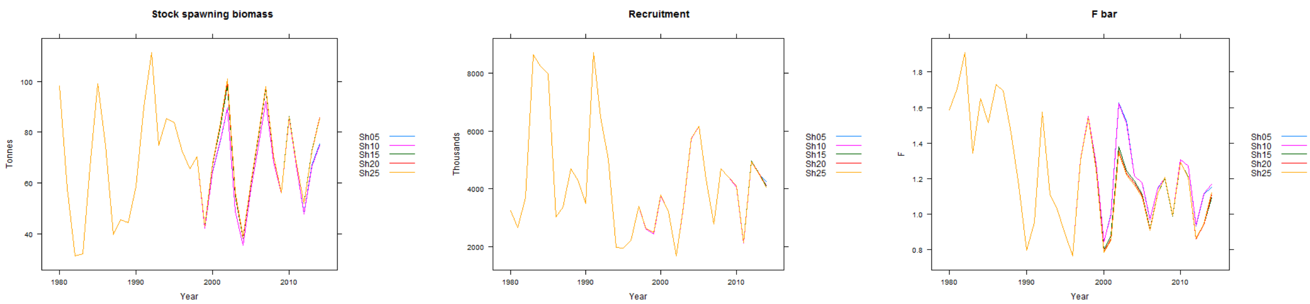


Figure 5.2.2.7.2.2. Hake in GSA 5. Sensitivity analysis for F, R and SSB considering different weights for shrinkage.

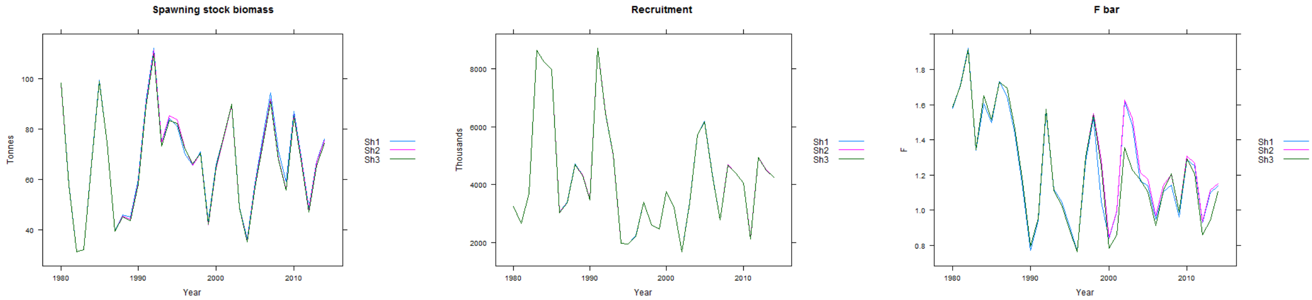


Figure 5.2.2.7.2.3. Hake. GSA 5. Sensitivity analysis for F, R and SSB considering different ages for shrinkage.

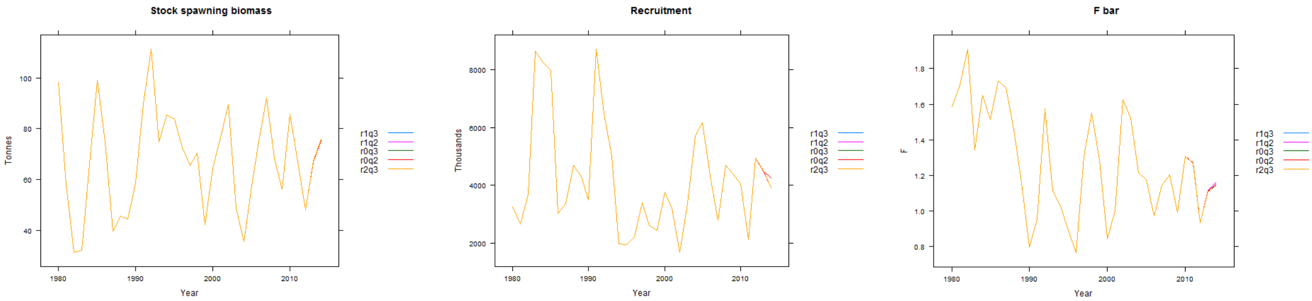


Figure 5.2.2.7.2.4. Hake. GSA 5. Sensitivity analysis for F, R and SSB considering different ages for catchability.

For the final XSA run, the following settings were used:

fse	rage	qage	shk.n	shk.f	shk.yrs	shl
0.5	-1	2	TRUE	TRUE	3	

5.2.2.7.3 Results

Recruitment showed important oscillations between 2 and 11 millions for all the data series and SSB between 30 and 115 tons. In the last 20 years, recruitment never showed the high values found in the middle 1980s and early 1990s, with not-so-marked oscillations. Recruitment show very similar values for last two years and SSB showed an increasing trend for the last 2 years (Figure 5.2.2.7.3.1, Table 5.2.2.7.3.1). F has oscillated between 0.8 and 2.

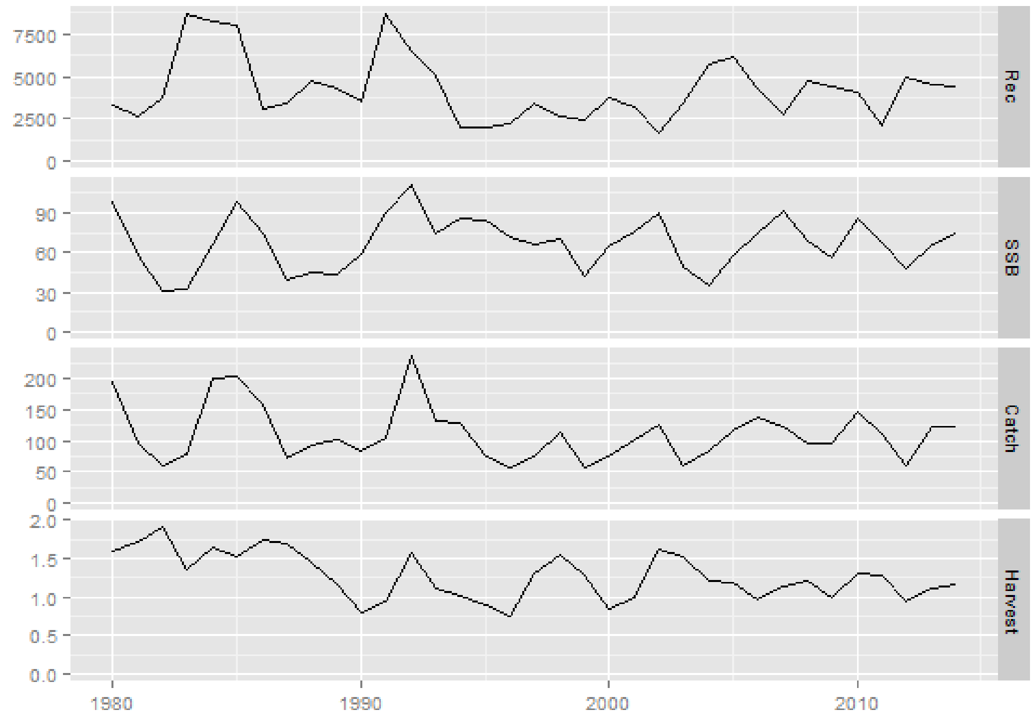


Figure 5.2.2.7.3.1. Hake. GSA 5. XSA results.

Table 5.2.2.7.3.1. Hake GSA 5. XSA results.

	Population in number (thousands)	Population in weight (tons)	Recruitment number (age 0, thousands)	SSB	F_{0-3}
1980	5052.1	367.5	3256.8	98.29	1.58
1981	3422.1	190.9	2661.3	57.83	1.71
1982	4282.0	191.5	3691.5	31.17	1.91
1983	9664.9	374.7	8636.6	32.16	1.34
1984	10736.9	505.3	8241.5	66.27	1.65
1985	9978.8	479.6	7987.0	99.11	1.51
1986	4849.5	321.0	3040.3	74.70	1.73
1987	4263.2	230.1	3380.3	39.51	1.69
1988	5745.9	282.2	4705.1	45.47	1.46
1989	5670.5	293.8	4315.9	44.28	1.16
1990	4721.2	279.7	3488.4	58.75	0.80
1991	9883.2	531.2	8724.2	89.77	0.95
1992	9157.5	516.5	6475.8	111.47	1.58
1993	6690.9	378.4	5020.8	74.75	1.11
1994	3536.5	276.4	1973.8	85.51	1.03
1995	2589.0	182.1	1945.2	83.84	0.89
1996	2755.5	176.1	2226.0	72.44	0.76
1997	4085.7	203.2	3385.3	65.63	1.30
1998	3657.3	220.9	2614.1	70.37	1.55

1999	3140.3	155.2	2451.9	42.06	1.29
2001	4482.1	213.5	3763.1	64.53	0.84
2002	4307.1	250.5	3201.9	76.61	1.00
2003	2652.7	218.3	1672.6	89.62	1.62
2004	3815.2	164.3	3379.6	48.85	1.52
2005	6692.7	253.2	5724.2	35.52	1.22
2006	7537.5	286.5	6164.0	57.51	1.18
2007	5988.2	315.1	4334.2	75.11	0.97
2008	3896.6	281.9	2781.7	92.03	1.14
2009	5523.1	252.4	4683.7	68.41	1.20
2010	5661.6	310.6	4406.1	56.16	0.99
2011	5473.4	308.5	4059.1	85.72	1.31
2012	3291.4	226.6	2131.2	66.94	1.27
2013	5584.9	229.1	4942.8	47.92	0.93
2014	5961.8	319.9	4509.1	66.78	1.12

Residuals from the scientific survey tuning fleet showed low values for all the ages and years considered (Figure 5.2.2.7.3.2). Ages 0-4 from the MEDITS survey were considered for the assessment.

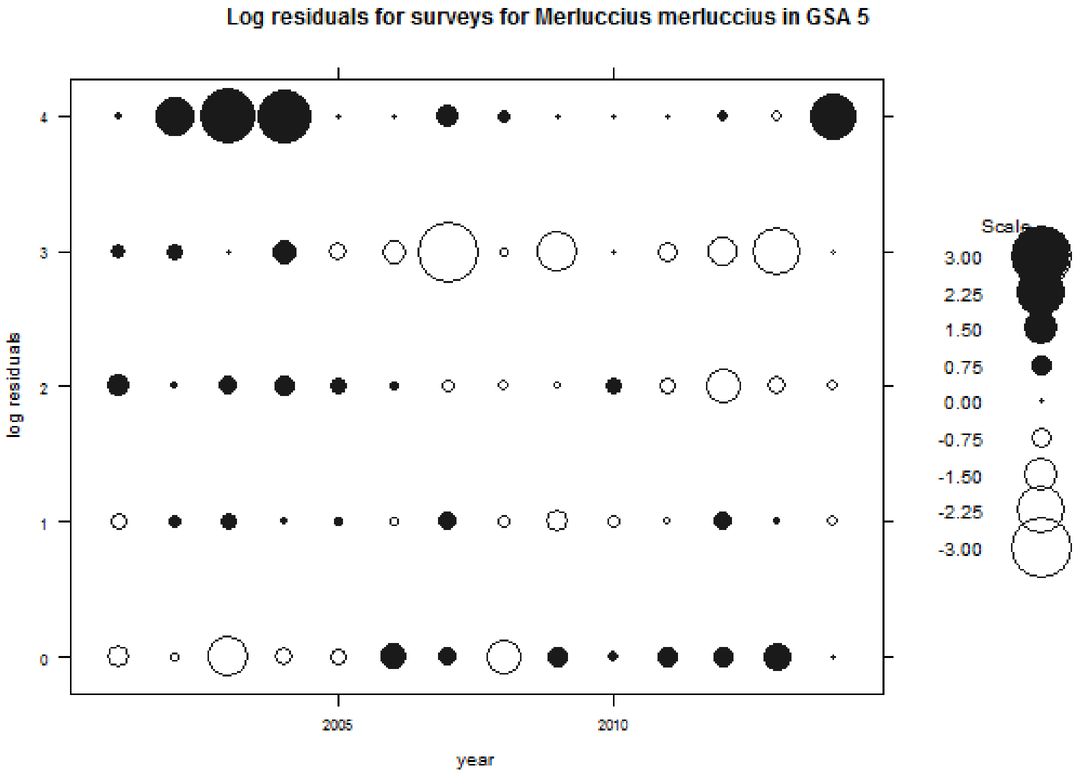


Figure 5.2.2.7.3.2. Hake. GSA 5. Log catchability residual plots (XSA) for scientific surveys.

The diagnostics of the stock were as follows:

```
FLR XSA Diagnostics 2015-09-02 11:57:27

CPUE data from indices
```

```
Catch data for 35 years 1980 to 2014. Ages 0 to 5.

    fleet first age last age first year last year alpha beta
1 FLEET 1         0         4       2001      2014  <NA> <NA>


 Time series weights :

    Tapered time weighting not applied

 Catchability analysis :

     Catchability independent of size for all ages

     Catchability independent of age for ages >   2

 Terminal population estimation :

     Survivor estimates shrunk towards the mean F
    of the final   3 years or the  2 oldest ages.

    S.E. of the mean to which the estimates are shrunk =   0.5

    Minimum standard error for population
    estimates derived from each fleet =  0.3

    prior weighting not applied

Regression weights
     year
age   2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
  all    1    1    1    1    1    1    1    1    1    1


 Fishing mortalities
   year
age  2005  2006  2007  2008  2009  2010  2011  2012  2013  2014
  0 0.155 0.277 0.094 0.143 0.029 0.118 0.092 0.045 0.112 0.088
  1 1.844 1.856 1.898 1.842 1.388 1.929 2.243 1.526 1.869 1.965
  2 1.658 1.025 1.414 1.512 1.646 2.039 1.474 1.273 1.183 1.379
  3 1.047 0.725 1.172 1.315 0.900 1.145 1.274 0.892 1.299 1.200
  4 1.376 0.891 1.313 1.463 1.310 1.652 1.410 1.108 1.302 1.308
  5 1.376 0.891 1.313 1.463 1.310 1.652 1.410 1.108 1.302 1.308


 XSA population number (Thousand)
      age
year      0    1   2  3 4 5
  2005 6164 1273  92  7 1 0
  2006 4334 1528 113 11 2 0
  2007 2782  951 134 26 4 1
  2008 4684  733  80 21 5 1
  2009 4406 1175  65 11 4 0
  2010 4059 1239 164  8 3 0
  2011 2131 1044 101 14 2 0
  2012 4943  562  62 15 3 0
  2013 4509 1367  68 11 4 2
  2014 4366 1167 118 13 2 0


 Estimated population abundance at 1st Jan  2015
      age
year   0    1  2  3 4 5
  2015 0 1157 92 19 3 0


 Fleet:  FLEET 1

 Log catchability residuals.

   year
```

	2001	2002	2003	2004	2005	2006	2007
0	-0.603	-0.155	-1.273	-0.485	-0.4	0.782	0.494
1	-0.393	0.247	0.383	0.041	0.169	-0.133	0.506
2	0.633	0.076	0.469	0.529	0.446	0.146	-0.255
3	0.365	0.438	0	0.701	-0.515	-0.709	-2.064
4	0.062	1.242	1.83	1.817	0	0	0.629

year

	2008	2009	2010	2011	2012	2013	2014
0	-1.134	0.573	0.218	0.581	0.557	0.829	0.016
1	-0.241	-0.604	-0.243	-0.055	0.457	0.042	-0.176
2	-0.174	-0.039	0.413	-0.441	-1.092	-0.505	-0.205
3	-0.117	-1.335	0	-0.54	-0.917	-1.576	-0.01
4	0.3	0	0	0	0.212	-0.173	1.502

Mean log catchability and standard error of ages with catchability independent of year class strength and constant w.r.t. time

	0	1	2	3	4
Mean_Logq	-1.6626	-1.0725	-1.7850	-1.7850	-1.7850
S.E_Logq	0.6913	0.6913	0.6913	0.6913	0.6913

Terminal year survivor and F summaries:

,Age 0 Year class =2014

source

	scaledWts	survivors	yrcls
FLEET 1	0.307	1175	2014
fshk	0.693	1148	2014

,Age 1 Year class =2013

source

	scaledWts	survivors	yrcls
FLEET 1	0.234	77	2013
fshk	0.766	92	2013

,Age 2 Year class =2012

source

	scaledWts	survivors	yrcls
FLEET 1	0.199	15	2012
fshk	0.801	20	2012

,Age 3 Year class =2011

source

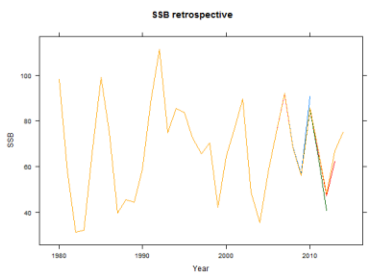
	scaledWts	survivors	yrcls
FLEET 1	0.064	3	2011
fshk	0.936	3	2011

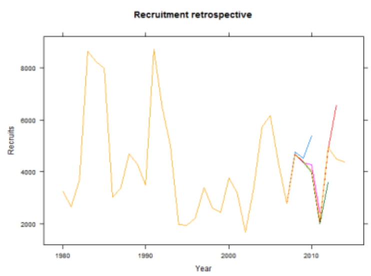
,Age 4 Year class =2010

source

	scaledWts	survivors	yrcls
FLEET 1	0.042	2	2010
fshk	0.958	0	2010

Retrospective analysis was performed and showed robust results for all the parameters considered (Figure 5.2.2.7.3.3).





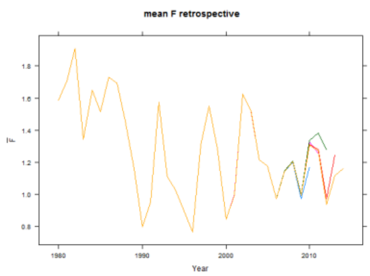


Figure 5.2.2.7.3.3. Hake. GSA 5. Restrospective analysis for SSB, recruitment and F.

5.2.2.8 Reference points

5.2.2.8.1 Methods

Yield per recruit was calculated using FLR. As the last year that the reference point $F_{0.1}$ was calculated in the framework of STECF, it was recalculated again.

5.2.2.8.2 Input data

The input parameters were the same used for the XSA stock assessment and its results.

5.2.2.8.3 Results

Table 5.2.2.8.3.1 shows the reference F (F_{ref}) as well as the reference point $F_{0.1}$ (as a proxy of F_{MSY}). Figure 5.2.2.8.3.1 shows the yield per recruit graph.

Table 5.2.2.8.3.1. Hake. GSA 5. Reference F and reference point ($F_{0.1}$).

$F_{ref\ (0\text{-}3)}$	0.15
$F_{0.1}$	1.12

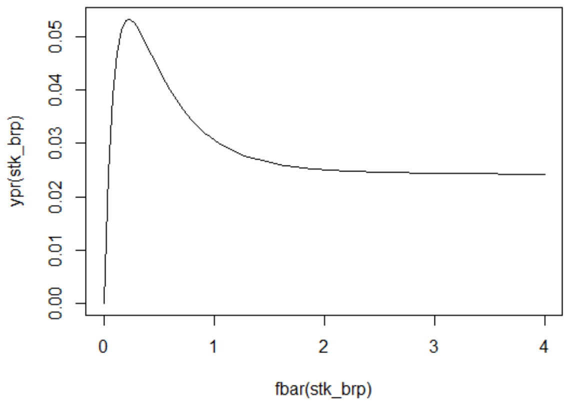


Figure 5.2.2.8.3.1. Hake. GSA 5. Yield per recruit.

5.2.2.9 Data quality

Information about catches, discards, and length and age frequency distributions was available through the Official Data Call for all the years. However, discarded biomass for 2014 showed values unusually low and should be further checked. Effort information was available for 2009-2014. MEDITS data was also available. A comparison of the abundance indices by size from the surveys covering the period 2007-2014 between the Data Call and the national database was performed. They showed high agreement for the last years, but inconsistent values for 2007-2008, which should also be checked.

5.2.2.10 Short term predictions 2016-2018

5.2.2.10.1 Method

A deterministic short term prediction for the period 2016 to 2018 was performed using the FLR routines, which takes into account the catch and landings in numbers and weight and the discards, and based on the results of the XSA stock assessment performed.

5.2.2.10.2 Input parameters

The input parameters were the same used for the XSA stock assessment and its results. Different scenarios of constant harvest strategy with F_{bar} calculated as the average of ages 0 to 2 (F_{bar} ages 0-3) and F status quo (F_{stq} =0.15) were performed. Recruitment (class 0) has been estimated from the population results from the geometric mean of the last three years 2012-2014 estimated with FLR.

5.2.2.10.3 Results

A short term projection (Table 5.2.2.10.3.1), assuming an F_{stq} of 1.06 (as a geometric average 2012-2014) in 2015 and a recruitment of 4600 thousands individuals shows that:

- Fishing at the F_{stq} (1.06) generates an increase of the catch of 6% from 2014 to 2016 along with an increase of the spawning stock biomass of 6% from 2016 to 2017.
- Fishing at $F_{0.1}$ (0.16) generates a decrease of the catch of 74% from 2014 to 2016 and an increase of the spawning stock biomass of 246% from 2016 to 2017.

Table 5.2.2.10.3.1. Hake. GSA 5. Short term forecast in different F scenarios.
Basis: F(2015) = mean(F_{bar} 0-3 2012-2014)= 1.06; R(2015) = geometric mean of the recruitment of the last 3 years; R = 4600 (thousands); SSB(2014) = 67 t; Catch (2014)= 124 t.

Rationale	F_{factor}	F_{bar}	Catch 2016	Catch 2017	SSB 2017	Change SSB 2016-2017 (%)	Change Catch 2014-2016 (%)
Zero catch	0.0	0.00	0.0	0.0	341.18	331.84	-100.00
High long-term yield (F_{MSY})	0.1	0.16	31.9	63.9	273.43	246.08	-74.21
Status quo	1.0	1.06	131.6	135.0	84.19	6.55	6.34
Different scenarios	0.1	0.11	22.6	47.3	293.07	270.94	-81.78
	0.2	0.21	42.1	80.0	252.27	219.30	-65.97
	0.3	0.32	59.2	102.3	217.64	175.47	-52.22
	0.4	0.43	74.0	116.9	188.24	138.25	-40.24
	0.5	0.53	86.9	126.3	163.25	106.63	-29.77
	0.6	0.64	98.3	131.8	142.00	79.73	-20.60

	0.7	0.75	108.3	134.8	123.92	56.85	-12.55
	0.8	0.85	117.0	135.9	108.52	37.35	-5.47
	0.9	0.96	124.8	135.9	95.39	20.73	0.79
	1.0	1.06	131.6	135.0	84.19	6.55	6.34
	1.1	1.17	137.8	133.7	74.62	-5.55	11.27
	1.2	1.28	143.2	132.2	66.44	-15.91	15.66
	1.3	1.38	148.1	130.5	59.44	-24.76	19.59
	1.4	1.49	152.4	128.9	53.44	-32.35	23.12
	1.5	1.60	156.4	127.2	48.30	-38.87	26.30
	1.6	1.70	159.9	125.7	43.88	-44.46	29.18
	1.7	1.81	163.1	124.2	40.08	-49.27	31.78
	1.8	1.92	166.1	122.9	36.81	-53.41	34.16
	1.9	2.02	168.8	121.7	33.98	-56.99	36.33
	2.0	2.13	171.2	120.6	31.54	-60.08	38.33

5.2.2.11 Medium term predictions

5.2.2.11.1 Method

Following the agreement reached during the discussions of the EWG-12-19, medium term prediction would only be performed if there is a reliably fit of a stock-recruitment relationship. In the case of hake in GSA 5, no medium term predictions were made as such relationship was not adequate to fit a model (Figure 5.2.2.11.1).

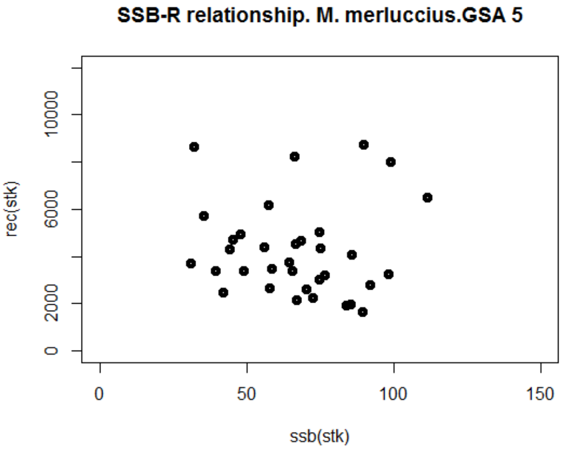


Figure 5.2.2.11.1. Hake. GSA 5. Spawning stock biomass (SSB) and recruitment (R) relationship.

5.2.2.12 Stock advice

The current F (1.12) is larger than F_{MSY}(0.15), which indicates that hake in GSA 5 is being fished above F_{MSY}. STECF EWG 15-11 recommends the relevant fleets' effort to be reduced until fishing mortality is below or at the proposed F_{MSY} level, in order to avoid future loss in stock productivity and landings. This should be achieved by means of a multi-annual management plan taking into account mixed-fisheries considerations. Catches of European hake in GSA 5 in 2016 consistent with F_{MSY} should not exceed 32 t.

5.2.2.13 Management strategy evaluations

The Management Strategy Evaluation to evaluate if the MSY ranges are precautionary were run using R script provided during by STECF 15-09. F ranges results were F_{upper}= 0.10 and F_{lower}= 0.21. B_{lim} was estimated in 31.2 t. Figure 5.2.2.13.1 show the results of the MSE.

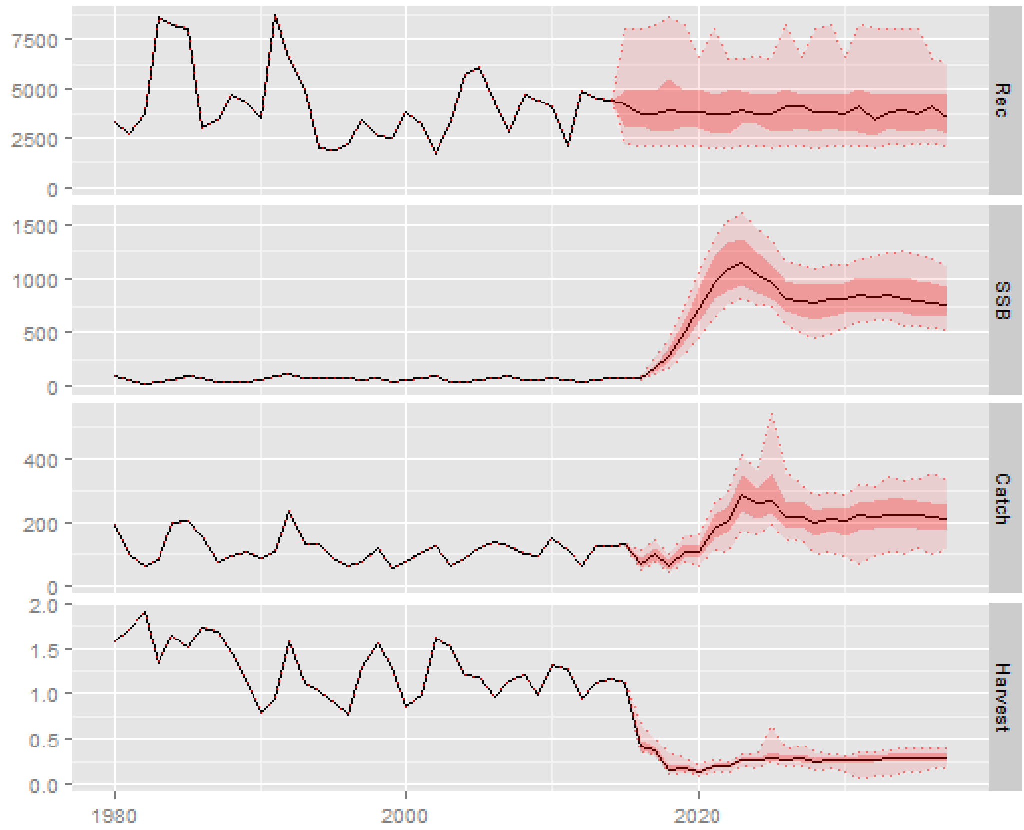


Figure 5.2.2.13.1. Hake. GSA 5. Marine Strategy Evaluation.

The probability of SSB to fall below B_{lim} at F = F_{upper} is equal to 0.

5.2.3 STOCK ASSESSMENT OF HAKE IN GSA 6

5.2.3.1 Stock Identification

Due to the lack of information about the structure of hake (*Merluccius merluccius*) population in the western Mediterranean, this stock was assumed to be confined within the GSA 6 boundaries (**Figure 5.2.3.1.1**).

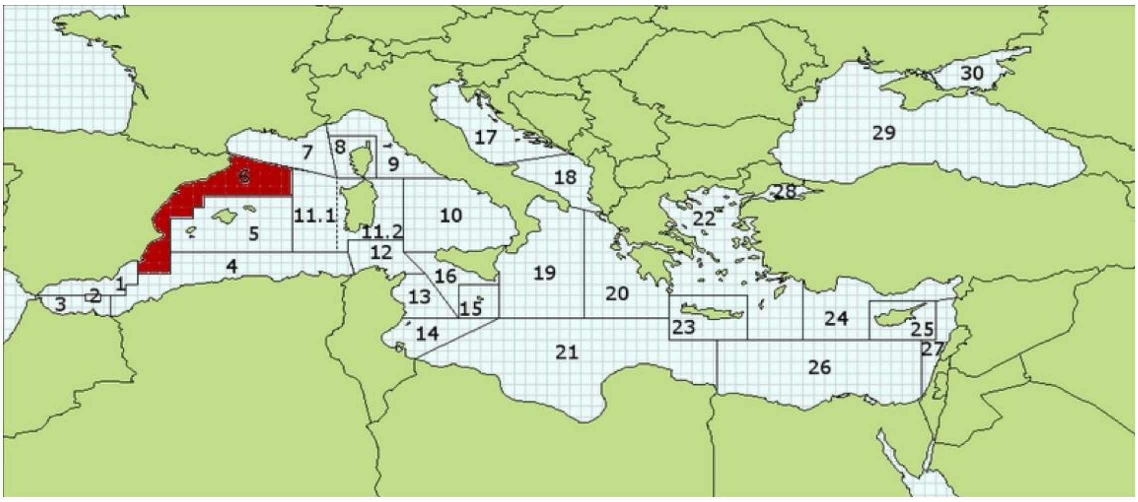


Figure 5.2.3.1.1. Geographical localization of GSA 6.

5.2.3.2 Growth

Growth parameters were taken from Mellon et al. (2010) and the length-weight parameters from the Spanish DCF (see tables below).

5.2.3.3 Maturity

Maturity parameters were also taken from the Spanish DCF (see tables below).

5.2.3.4 Natural mortality

Natural mortality was obtained from PRODBIOM (see tables below).

5.2.3.5 Fisheries

5.2.3.5.1 General description of the fisheries

European hake is largely exploited in GSA 6, mainly by trawlers on the shelf and slope (91% landings), but also by small-scale fisheries using long lines (6%) and gill nets and trammel nets (3%) (average percentages estimated between 2009 and 2013). According to official statistics, around 1000 boats are involved in this fishery, with total annual landings oscillating around an average value of 3667 tons for the period 2003-2014. The trawl fleet is the largest in number of boats and landings (472 trawlers and 2966 tons in 2013).

5.2.3.5.2 Management regulations applicable in 2015

Trawl fisheries in GSA 6 are regulated by “Orden AAA/2808/2012” published in the Spanish Official Bulletin (BOE nº 313 29 December 2012) containing an Integral Management Plan for Mediterranean fishery resources. To the traditional fisheries regulations already in place (e.g. the daily and weekly fishing effort limited to 12 hours per day five days a week; trawl cod end 40 mm square mesh or 50 mm diamond stretched mesh; engine power of maximum 373 kW; license system; minimum landing size of 20 cm TL), this plan adds that fishing mortality for *Merluccius merlucicus* in GSA 6 should be kept at or below the reference value F_{01} = 0.15 and that fishing effort be reduced by 20% or more over the period 2013-2017 (based on the effort established on 1 January 2013). This fishing effort reduction will be measured in terms of number of vessels, engine power and tonnage.

5.2.3.5.3 Landings

During 2003 and 2014, the annual landings of hake in GSA 6 showed a general decreasing trend punctuated by important peaks in 2006 and 2009 (Fig. 5.2.3.5.4.1A). The size structure of the population taken by the fishery shows a modal size of 13 cm (Fig. 5.2.3.5.4.1 B).

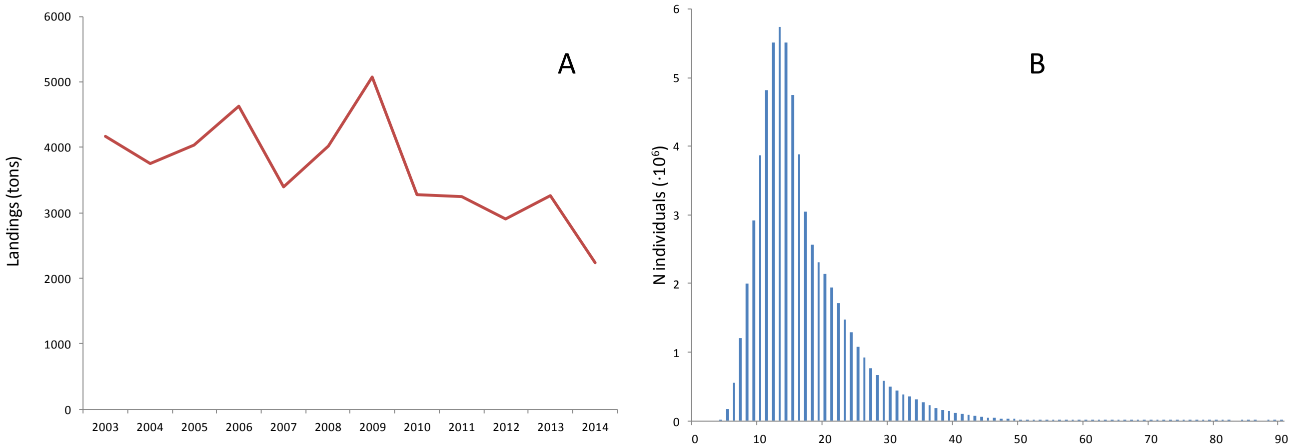


Fig. 5.2.3.5.4.1. Hake in GSA 6. Total annual landings (A) and mean size distribution (B) during 2003-2014.

5.2.3.5.4 Discards

Discards were included in the analysis. Reported discards of hake from trawlers in GSA 06 were 141.6 t in 2011, 194.3 in 2012 and 156.6 t in 2013. These amounts represented 4.7%, 7.3% and 5.5% respectively of the trawl fleet annual catch.

5.2.3.5.5 Fishing effort

The fishing effort (number of days) shows a marked decreasing trend during 2003-2014 (Fig. 5.2.3.5.6.1).

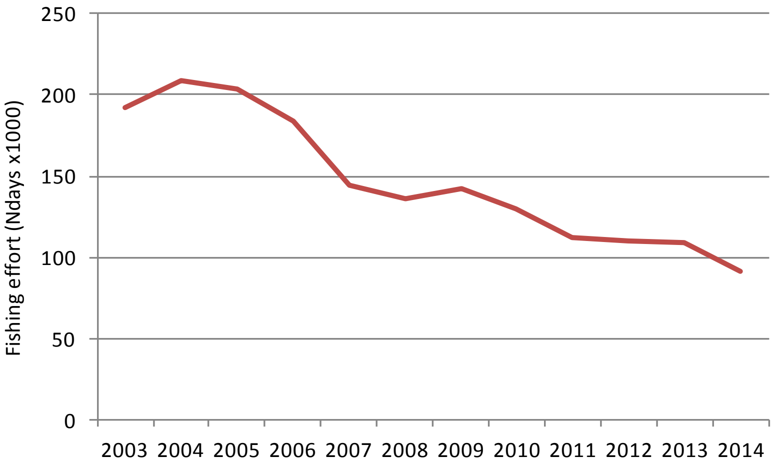


Fig. 5.2.3.5.6.1. Hake in GSA 6. Fishing effort in days during 2003-2014.

5.2.3.6 Scientific surveys

5.2.3.6.1 Survey #1 (MEDITS)

5.2.3.6.1.1 Methods

Since 1994 standard bottom trawl surveys have been conducted in GSA 6 in spring, following the general methodology of the MEDITS protocol described in Bertrand et al. (2002).

5.2.3.6.1.2 Trends in abundance and biomass

Abundance and biomass indices from MEDITS showed a general decreasing trend (Fig. 5.2.3.6.1.3.1) punctuated by a maximum in 2006.

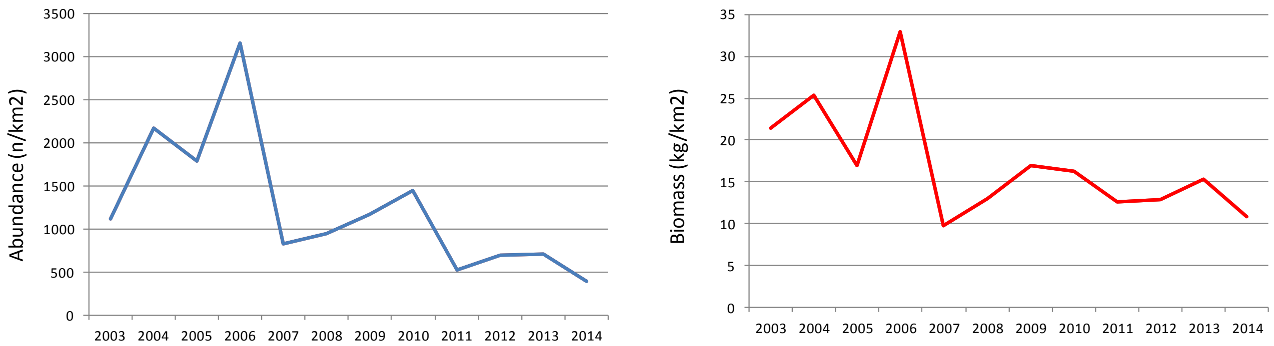


Fig. 5.2.3.6.1.3.1. Hake in GSA 6: Abundance and biomass indices from MEDITS surveys during 2003-2014.

5.2.3.6.1.3 Trends in abundance by length or age

Important changes were observed in the size structure during the study period since modal size during 2012-2014 (about 20 cm) were markedly higher than the previous years (about 13 cm) (Fig. 5.2.3.6.1.4.1).

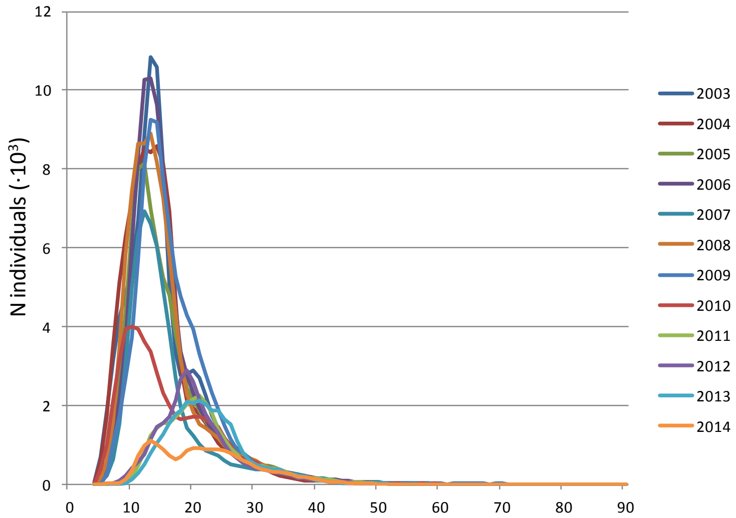


Fig. 5.2.3.6.1.4.1. Hake in GSA 6. Size-structure of catches during 2003-2014.

5.2.3.7 Stock Assessment

5.2.3.7.1 Methods

An XSA was applied using the R libraries developed in the framework of the EWG.

5.2.3.7.2 Input data

The length of the available data series (12 years, from 2003 to 2014) allowed the use of a VPA tuned with MEDITS data. Although there exist catch and MEDITS data from previous years, size-frequency distributions are only available from 2003.

The assessment includes landings from all main fleets (trawlers, longliners, gillnetters). However, as size distributions from longliners are only available for the most recent years (2009-2014), the assessment was done considering two fleets: trawlers and others (longliners and gillnetters combined; see below).

Landing time series: 2003-2014.

Size-distributions were sliced to age-distributions using the L2AGE4 software.

Group plus was set at age 5.

The number of individuals by age was SOP corrected [SOP = Landings / Σ_a (total catch numbers at age *a* x catch weight-at-age *a*)].

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
SOP	0.935	0.932	0.929	0.935	0.943	0.929	0.933	0.938	0.948	0.941	0.941	0.947

Growth parameters (from Mellon et al 2010)		
L_{inf}	K	t_0
110	0.178	

LWR (from Spanish DCF)	
a	b
0.00677	3.035097

Natural mortality (from PRODBIOM)					
0	1	2	3	4	5+
1.24	0.58	0.45	0.4	0.37	0.35

The input data are shown in the table below:

Maturity (from DCF 2003-2012)					
0	1	2	3	4	5+
0.00	0.15	0.82	0.98	1.00	1.00

CATCH	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
	4176	3750	4035	4635	3391	4021	5082	3278	3254	2900	3256	2230

CATNUM	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
0	73465	77534	58311	70282	47735	70579	60702	34250	8862	9913	7245	6589
1	22025	18211	19610	20704	11695	18501	29946	16868	18868	19564	20993	10610
2	1835	1497	2333	2643	2482	2113	2085	2160	2481	1867	2126	1997
3	225	211	303	424	371	240	233	191	236	180	172	124
4	68	16	29	30	58	50	101	56	20	27	11	9
5+	5	13	10	9	14	3	79	6	6	1	2	3

CATWT	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
0	0.017	0.017	0.018	0.019	0.018	0.018	0.021	0.015	0.026	0.026	0.028	0.022
1	0.096	0.101	0.101	0.099	0.103	0.102	0.091	0.107	0.102	0.095	0.107	0.12
2	0.414	0.409	0.399	0.415	0.42	0.401	0.399	0.412	0.409	0.403	0.389	0.401
3	0.966	0.91	0.936	0.924	0.957	0.989	0.97	0.93	0.904	0.903	0.933	0.911
4	1.603	1.645	1.634	1.581	1.62	1.559	1.693	1.684	1.699	1.665	1.599	1.622
5+	2.814	2.8	2.702	2.904	2.499	2.772	2.508	2.544	2.585	2.239	2.456	2.814

XSA

Tuning index was obtained using abundance indices from MEDITS (N/km^2) carried out in GSA 6 during 2003–2014.

Based on the log catch curves results (Fig. 5.2.3.7.2.1), ages 1 to 3 were selected as the F_{bar}.

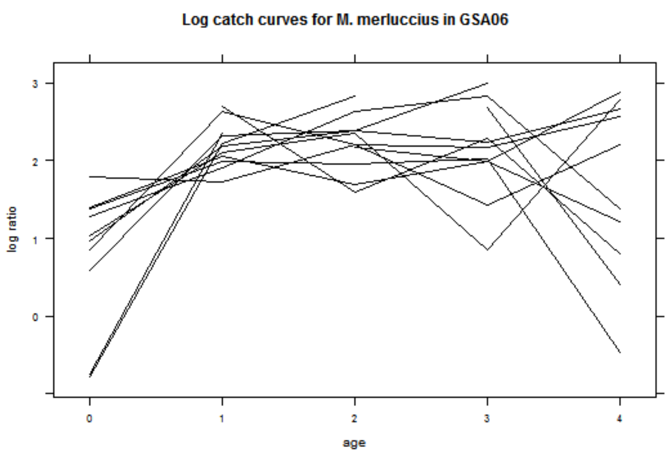


Fig. 5.2.3.7.2.1. Hake GSA 6. Log catch curves.

Different sensitivity analyses were performed before running the final XSA. The first sensitivity analysis tested different qages and the best fit was obtained using qage=2. The second sensitivity analysis tested different shrinkage weights (0.5, 1.0, 1.5, 2.0 and 2.5); the two first values (0.5, 1.0) showed slightly higher residuals (range: 3 to -3) than the remaining values (range: 2 to -2) (Fig. 5.2.3.7.2.2A) and gave a rather different trend in the Fbar (Fig. 5.2.3.7.2.2A). As no differences were observed using 1.5, 2.0 and 2.5 values, the middle value (2.0) was chosen. The third sensitivity analysis tested different shrinkage ages (1, 2 and 3) using shrinkage weight of 2.0; again, as the first option showed slightly higher residuals (range: 3 to -3) than the remaining values (range: 2 to -2) (Fig. 5.2.3.7.2.2B), the option of 2 ages shrinkage was selected. Based on these simulation analyses, the following inputs were selected to run the final XSA:

fse	rage	qage	shk.n	shk.f	shk.yrs	shk.ages
2.0	1	2	TRUE	TRUE	3	2

Log residuals of the sensitivity analyses of a set of trials for the shrinkage weights (0.5, 1.5 and 2.5) and the three shrinkage ages (1, 2 and 3) are shown in Figure 5.2.3.7.2.3.

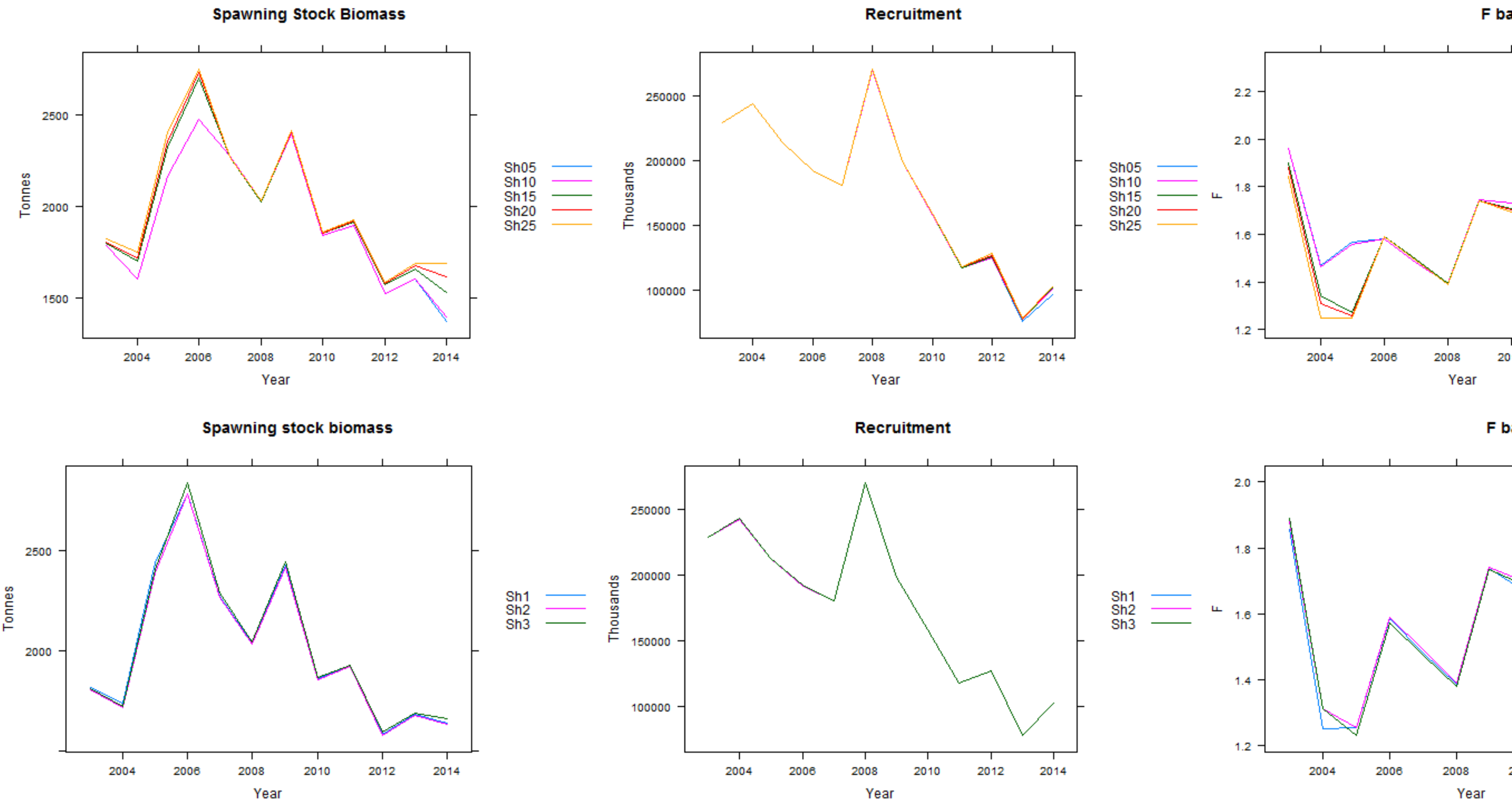


Fig. 5.2.3.7.2.2. Hake in GSA 6. Sensitivity analyses using different shrinkage weights (A) and shrinkage ages (B). Shrinkage weights modeled were 0.5, 1.0, 1.5, 2.0 and 2.5 (Sh05 to Sh25) and shrinkage ages were 1, 2 and 3 (Sh1, Sh2 and Sh3).

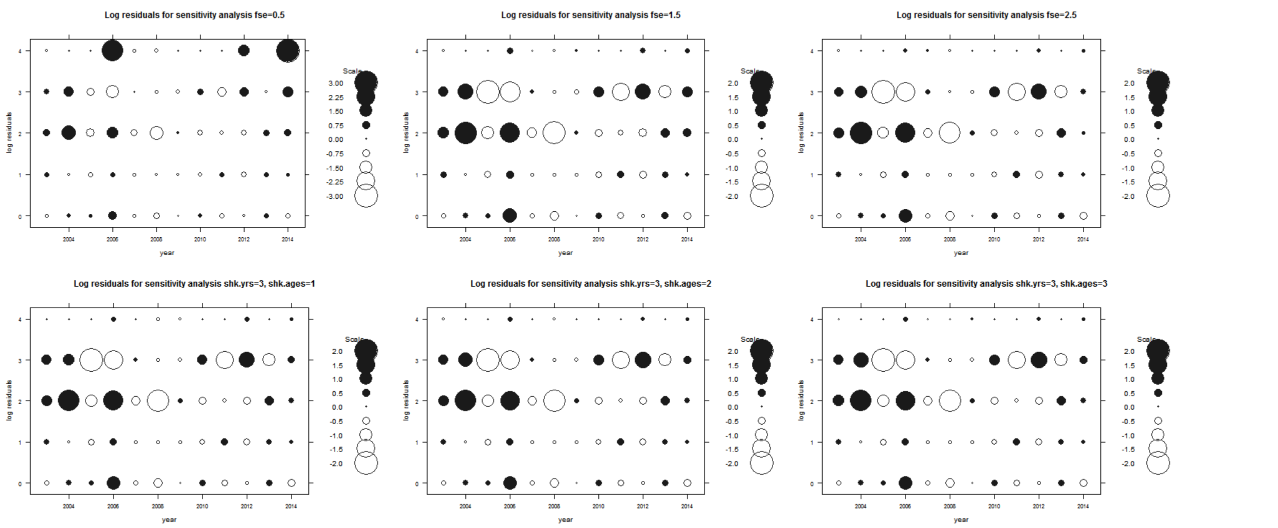


Fig. 5.2.3.7.2.3. Hake in GSA 6. Log residuals of the sensitivity analyses of a set of trials for the shrinkage weights (0.5, 1.5 and 2.5) and the three shrinkage ages (1, 2 and 3).

5.2.3.7.3 Results

The residuals per age and year of the tuning fleet were relatively low, ranging from 2 to -2, and did not show any tendency with time (Fig. 5.2.3.7.3.1).

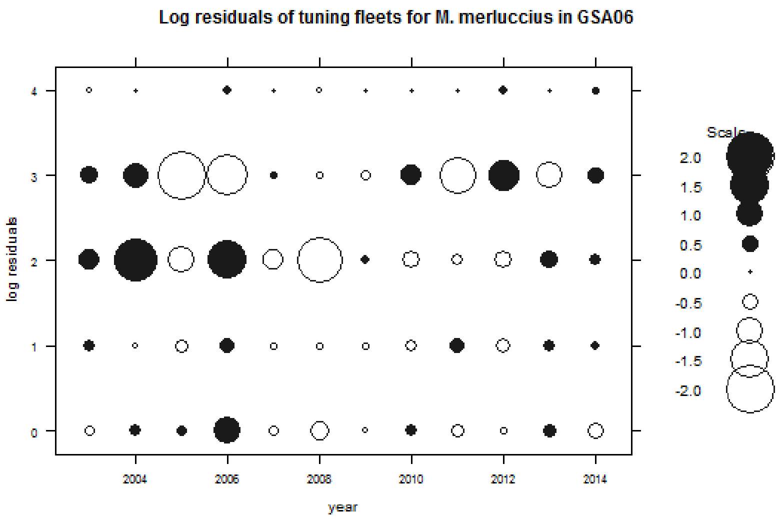


Fig. 5.2.3.7.3.1. Hake in GSA 6. Log residuals for the tuning fleets.

Results of XSA (Fig. 5.2.3.7.3.2) revealed that all main population parameters (recruitment, SSB and catch) showed a decreasing trend punctuated by some important peak. The fishing mortality increased from 1.29 in 2004 to 2.0 in 2012 and then decreased progressively down to 1.39 in 2014.

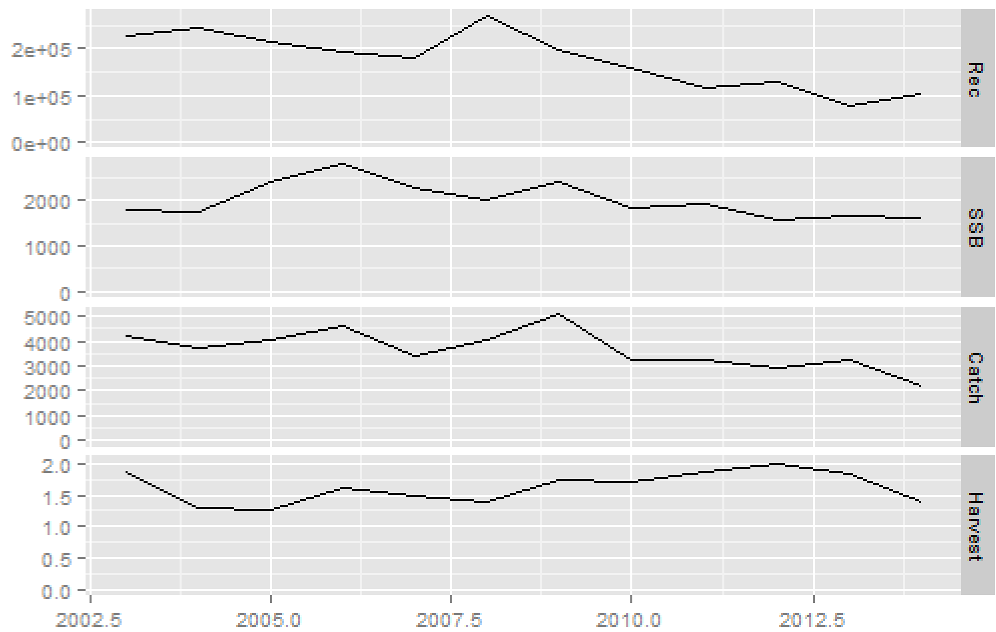


Fig. 5.2.3.7.3.2. Hake in GSA 6. XSA summary results. SSB and catch are in tonnes, recruitment in 1000s individuals.

.

The XSA dignostics are reported below:

```
FLR XSA Diagnostics 2015-09-02 14:34:18

CPUE data from indices

Catch data for 12 years 2003 to 2014. Ages 0 to 5.

            fleet first age last age first year last year alpha beta
1 Surveys (N/km2)         0        4       2003      2014  <NA> <NA>


 Time series weights :

    Tapered time weighting not applied

 Catchability analysis :

     Catchability independent of size for ages >   1

     Catchability independent of age for ages >   2

 Terminal population estimation :

     Survivor estimates shrunk towards the mean F
    of the final   3 years or the  2 oldest ages.

    S.E. of the mean to which the estimates are shrunk =   2

    Minimum standard error for population
    estimates derived from each fleet =  0.3

    prior weighting not applied

Regression weights
     year
age   2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
  all    1    1    1    1    1    1    1    1    1    1
```

```
 Fishing mortalities
    year
age  2005  2006  2007  2008  2009  2010  2011  2012  2013  2014
  0 0.640 1.012 0.623 0.601 0.754 0.473 0.142 0.147 0.177 0.119
  1 1.496 1.594 1.311 1.709 2.052 1.522 1.815 1.775 1.790 1.227
  2 1.355 1.546 1.582 1.647 1.944 1.732 2.219 1.868 2.223 1.605
  3 0.929 1.641 1.608 0.826 1.233 1.857 1.547 2.363 1.474 1.340
  4 0.746 0.258 1.845 1.500 1.611 1.960 1.862 0.976 1.826 0.283
  5 0.746 0.258 1.845 1.500 1.611 1.960 1.862 0.976 1.826 0.283
```

```
 XSA population number (Thousand)
      age
year        0     1    2   3   4   5
  2005 212879 31368 3656 569  62  21
  2006 191923 32468 3934 601 151  42
  2007 180636 20183 3691 535  78  17
  2008 269904 28048 3045 484  72   5
  2009 198692 42831 2842 374 142 105
  2010 158367 27041 3081 259  73   8
  2011 118018 28551 3304 348  27   8
  2012 126909 29634 2603 229  50   2
  2013  78292 31705 2811 256  14   3
  2014 103099 18987 2962 194  39  12
```

```
 Estimated population abundance at 1st Jan  2015
      age
year    0     1    2   3  4  5
  2015 22 26480 3116 379 34 20
```

```
 Fleet:  Surveys (N/km2)

 Log catchability residuals.

    year
age   2003   2004   2005   2006   2007   2008   2009   2010   2011   2012
2013   2014
  0 -0.153  0.184  0.146  0.600 -0.165 -0.392 -0.027  0.213 -0.245 -0.094
0.240 -0.307
  1  0.187 -0.041 -0.239  0.245 -0.073 -0.074 -0.086 -0.186  0.248 -0.274
0.190  0.103
  2  0.431  1.017 -0.593  0.924 -0.453 -1.136  0.117 -0.349 -0.168 -0.370
0.378  0.202
  3  0.369  0.553 -1.216 -1.001  0.084 -0.113 -0.170  0.431 -0.895  0.745 -
0.617  0.303
  4 -0.035  0.000  0.000  0.132  0.007 -0.040  0.013  0.000  0.000  0.131
0.000  0.097

 Regression statistics
 Ages with q dependent on year class strength
[1] "0.735167328470271" "0.747942826143583" "6.44771215187117"
"6.76939357385684"
```

```
 Terminal year survivor and F summaries:

 ,Age 0 Year class =2014

source
                scaledWts survivors yrcls
Surveys (N/km2)     0.157     17432  2014
fshk                0.010     18468  2014
nshk                0.834     28761  2014

 ,Age 1 Year class =2013

source
                scaledWts survivors yrcls
```

```
Surveys (N/km2)        0.929       3576  2013
fshk                   0.071       1365  2013

 ,Age 2 Year class =2012

source
                scaledWts survivors yrcls
Surveys (N/km2)        0.649        464  2012
fshk                   0.351        194  2012

 ,Age 3 Year class =2011

source
                scaledWts survivors yrcls
Surveys (N/km2)        0.681         46  2011
fshk                   0.319         18  2011

 ,Age 4 Year class =2010

source
                scaledWts survivors yrcls
Surveys (N/km2)        0.971         23  2010
fshk                   0.029          2  2010
```

Year	Stock numbers $(\cdot 10^3)$	Stock biomass	Recruitment numbers $(\cdot 10^3)$	SSB (t)	F1-3
2003	263987	8533.6	228682	1810.2	1.8659
2004	274957	8559.2	242726	1724.6	1.2885
2005	248555	9199.2	212879	2401.2	1.2602
2006	229119	9454.3	191923	2770.6	1.5937
2007	205140	7568.7	180636	2261	1.5003
2008	301556	9541.9	269904	2022.6	1.3942
2009	244986	10099.7	198692	2402.8	1.7431
2010	188830	6922.1	158367	1853.8	1.7037
2011	150255	7712	118018	1918.7	1.8604
2012	159427	7459.4	126909	1573.9	2.0022
2013	113082	6946.4	78292	1669	1.8292
2014	125294	6021.9	103099	1599.7	1.3906

Finally, retrospective analyses showed rather consistent results except for the mean F during the first years (Fig. 5.2.3.7.3.3).

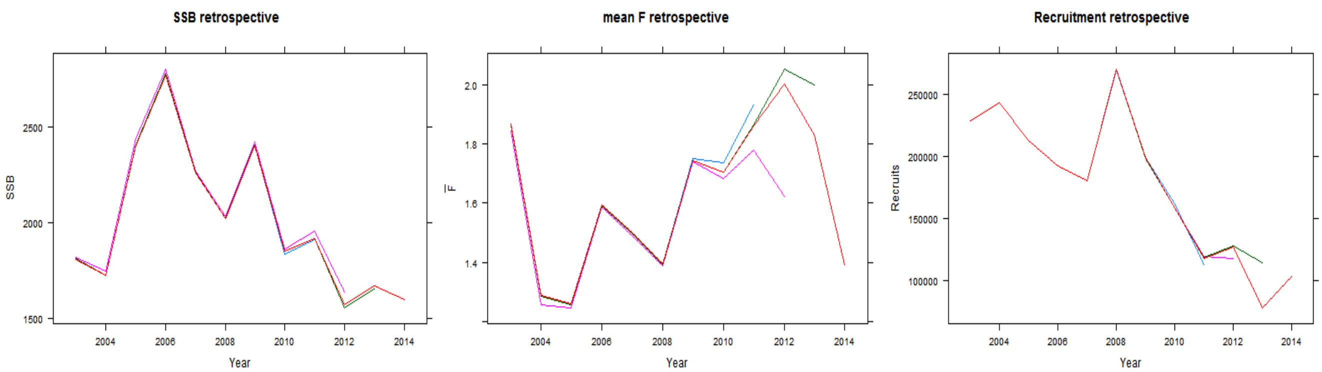


Fig. 5.2.3.7.3.3. Hake in GSA 6. XSA retrospective analyses.

5.2.3.8 Reference points

5.2.3.8.1 Methods

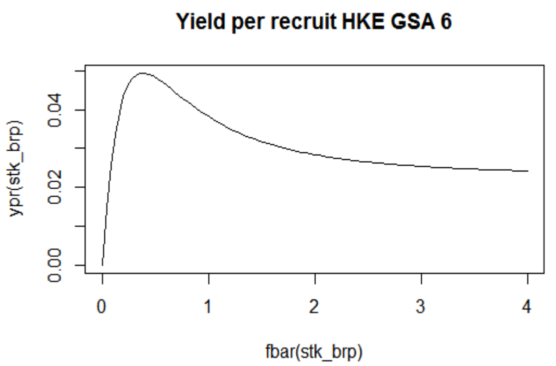
Yield per recruit analysis was used to calculate the reference point $F_{0.1}$ and the estimated reference fishing mortality (F_{ref}).

5.2.3.8.2 Input data

Reference F was estimated using the R script provided by STECF EWG, which used the default assumptions agreed in the meeting, e.g., weights are means of the last 3 years and future recruitment are obtained as the geometric mean of the last 3 years.

5.2.3.8.3 Results

The yield per recruit graph, together with the reference point $F_{0.1}$ and the estimated reference fishing mortality (F_{ref}), revealed a highly overexploited stock (Fig. 5.2.3.8.3.1).



$F_{0.1}$	0.260
F_{ref} (2014; ages 1-3)	1.391

Fig. 5.2.3.8.3.1. Hake in GSA 6. yield per recruit.

5.2.3.9 Data quality

Data from DCF 2014 were used. The data available are of sufficient quality to perform XSA. The data submitted to the EWG 15-11 are in general of good quality.

5.2.3.10 Short term predictions 2015-2017

5.2.3.10.1 Method

A deterministic short term prediction for the period 2015 to 2017 was performed using the FLR routines provided by JRC, which takes into account the catch and landings in numbers and weight and the discards.

5.2.3.10.2 Input parameters

The same input parameters used in the XSA analysis shown above were used. Different scenarios of constant harvest strategy with F_{bar} calculated as the average of ages 1 to 3 and F status quo (F_{stq} = 1.72) were performed.

5.2.3.10.3 Results

A short term projection (Table 5.2.3.10.3.1), assuming an F_{stq} of 1.720 in 2014 and a recruitment of 100806.2 thousand individuals shows that:

- Fishing at the F_{stq} (1.720) generates an increase of the catch of 39.06% from 2014 to 2016 along with a decrease of the spawning stock biomass of 3.77% from 2016 to 2017.
- Fishing at $F_{0.1}$ (0.260) generates a decrease of the catch of 64.80% from 2014 to 2016 and an increase of the spawning stock biomass of 221.04% from 2016 to 2017.

Table 5.2.3.10.3.1. Hake in GSA 6. Short term forecast in different F scenarios. Basis: F(2015) = mean(F_{bar}1-3 2012-2014)= 1.740; R(2015) = geometric mean of the recruitment of the last 3 years; R = 100806 thousand; SSB(2014) = 1600 t, Catch (2014)= 2230 t.

Rationale	Ffactor	fbar	Catch 2016	Catch 2017	SSB 2017	Change SSB 2016-2017 (%)	Change Catch 2014-2016 (%)
Zero catch	0.000	0.000	0.000	0.000	7276.159	305.363	-100.000
High long-term yield (F_{MSY})	0.151	0.260	784.862	1718.155	5762.505	221.036	-64.804
Status quo	1.000	1.721	3100.981	3046.672	1727.233	-3.774	39.057
Different scenarios	0.100	0.172	538.021	1255.012	6233.791	247.291	-75.873
	0.200	0.344	1002.983	2070.175	5350.261	198.069	-55.023
	0.300	0.516	1405.701	2583.372	4601.065	156.330	-36.964
	0.400	0.688	1755.343	2891.092	3965.507	120.923	-21.285
	0.500	0.860	2059.683	3060.623	3426.103	90.872	-7.638
	0.600	1.032	2325.320	3138.687	2968.079	65.355	4.274
	0.700	1.204	2557.854	3157.544	2578.946	43.676	14.702
	0.800	1.376	2762.046	3139.310	2248.149	25.247	23.859
	0.900	1.548	2941.941	3098.997	1966.761	9.570	31.926
	1.000	1.721	3100.981	3046.672	1727.233	-3.774	39.057
	1.100	1.893	3242.096	2988.966	1523.179	-15.142	45.385
	1.200	2.065	3367.783	2930.140	1349.195	-24.835	51.022
	1.300	2.237	3480.169	2872.835	1200.708	-33.107	56.061
	1.400	2.409	3581.071	2818.594	1073.847	-40.175	60.586
	1.500	2.581	3672.041	2768.224	965.335	-46.220	64.666
	1.600	2.753	3754.402	2722.053	872.396	-51.398	68.359
	1.700	2.925	3829.290	2680.100	792.677	-55.839	71.717
	1.800	3.097	3897.677	2642.197	724.188	-59.655	74.784
	1.900	3.269	3960.394	2608.069	665.240	-62.939	77.596
	2.000	3.441	4018.156	2577.388	614.402	-65.771	80.186

5.2.3.11 Short term predictions 2015-2017 by fleet

5.2.3.11.1 Method

A deterministic short term prediction by fleet for the period 2015 to 2017 was performed using the FLR routines provided by JRC and based on the results of the XSA stock assessments performed during EWG 15-11.

5.2.3.11.2 Input parameters

The same parameters used in the short term by single fleet were used. As reported above, two fleets were analysed: trawlers and others (longliners and gillnetters combined).

5.2.3.11.3 Results

Table 5.2.3.11.3.1. Hake in GSA 6. Short term forecast by fleet: trawl (OTB) and others (including longliners (LLS) and gillnetters (GNS) combined).

Fleet	Year	Catches	Partial F
Others (LLS+GNS)	2015	98.074	0.099
Trawl (OTB)	2015	3180.659	1.621
Others (LLS+GNS)	2016	23.756	0.014
Trawl (OTB)	2016	733.512	0.234
Others (LLS+GNS)	2017	91.187	0.014
Trawl (OTB)	2017	1584.807	0.234

Figure 5.2.3.11.3.1. Hake in GSA 6. Short term forecast by fleet.

5.2.3.12 Medium term predictions

The medium term projection was not conducted because no meaningful stock-recruitment relationship was found.

5.2.3.13 Stock advice

The current F (1.72) is larger than F_{MSY} (0.260), which indicates that hake in GSA 6 is being fished above F_{MSY}. STECF EWG 15-11 recommends the relevant fleets' effort to be reduced until fishing mortality is below or at the proposed F_{MSY} level, in order to avoid future loss in stock productivity and landings. This should be achieved by means of a multi-annual management plan taking into account mixed-fisheries considerations. Catches of European hake in 2016 consistent with F_{MSY} should not exceed 785 tonnes in GSAs 6.

5.2.3.14 Management strategy evaluation

Management Strategy Evaluation was carried out to evaluate if the MSY ranges were precautionary. The F_{MSY} ranges were derived using the formula provided by STECF 15-09. F ranges results were F_{upper}=0.358 and F_{lower}=0.175. B_{lim} was estimated as B_{loss}=1532.7 (t).The following figure shows the results of the MSE.

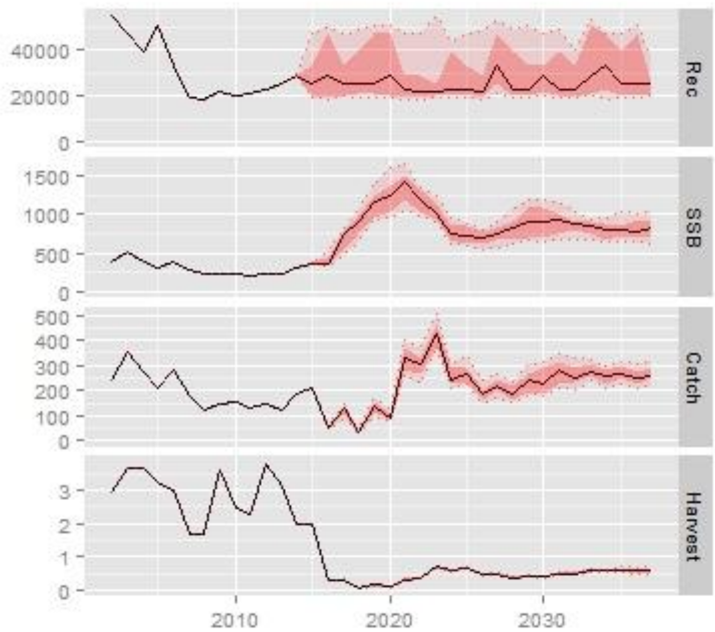


Figure 5.2.3.14.1. Hake in GSA 6. Marine Strategy Evaluation.

The probability of SSB to fall below B_{lim} at F = F_{upper} is equal to 0.

5.2.4 STOCK ASSESSMENT OF HAKE IN GSA 7

5.2.4.1 Stock Identification

Due to the lack of information about the structure of hake population in the western Mediterranean, this stock was assumed to be confined within the GSA 7 boundaries. (Figure 5.2.4.1.1).

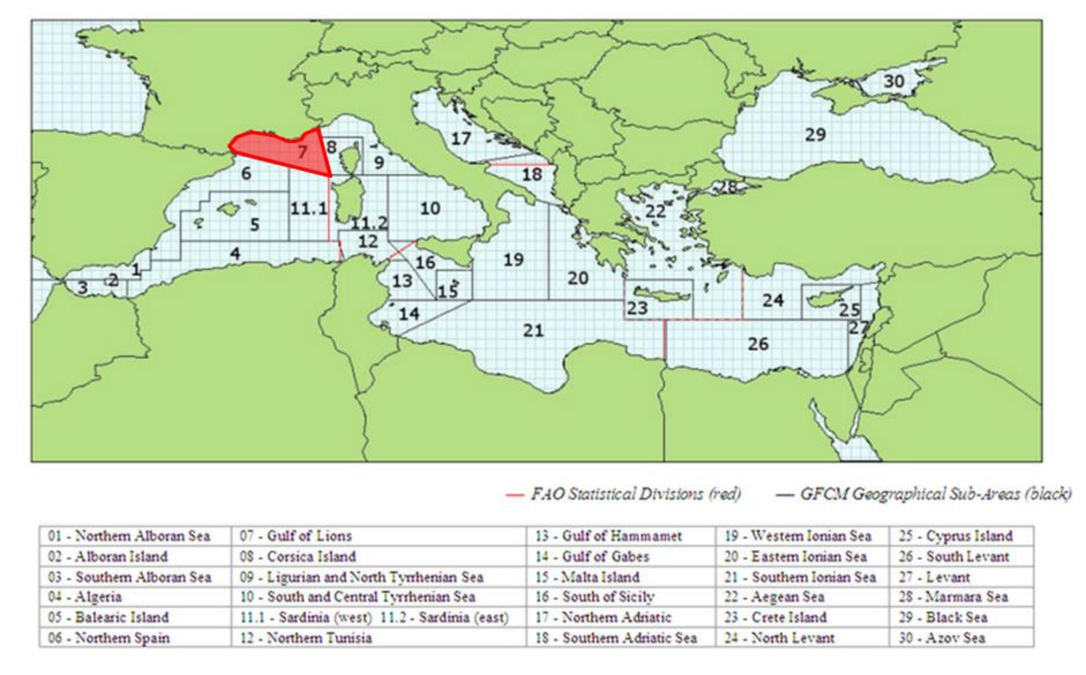


Figure 5.2.4.1.1. Geographical location of GSA 7.

5.2.4.2 Growth

The growth of European Hake (*Merluccius merluccius*) in the Gulf of Lions was reestimated from tagging experiments carried out by IFREMER (Mellon-Duval et al., 2010). The new parameters have not been yet compared to a re-analysis of otoliths readings, because of the uncertainty on otoliths readings. Therefore, the data sent to the data call were in length and were converted in age using the length-to-age slicing functions available in the R package a4a. The growth parameters used during the EWG 15-11 are indicated in the following table.

	Females	Males
Linf	100.7	72.8
K	0.236	0.233
t0	-	-

5.2.4.3 Maturity

The maturity was calculated using data collected within the DCF (2002-2014).

Table 5.2.4.3.1. Hake in GSA 7. Maturity at age.

	0	1	2	3	4	5+
1998	0.06	0.23	0.72	0.92	0.99	1.00
1999	0.06	0.33	0.69	0.91	0.99	1.00
2000	0.06	0.34	0.74	0.92	0.99	1.00
2001	0.06	0.33	0.70	0.90	0.99	1.00
2002	0.05	0.25	0.67	0.91	0.99	1.00
2003	0.08	0.34	0.67	0.90	0.99	1.00
2004	0.06	0.32	0.70	0.90	0.98	0.99
2005	0.06	0.32	0.71	0.90	0.98	0.99
2006	0.07	0.37	0.78	0.91	0.98	0.99
2007	0.08	0.32	0.70	0.92	0.98	0.99
2008	0.09	0.22	0.65	0.91	0.98	1.00
2009	0.08	0.38	0.69	0.89	0.98	0.99
2010	0.08	0.29	0.65	0.89	0.98	0.99
2011	0.09	0.33	0.64	0.88	0.98	0.99
2012	0.11	0.27	0.64	0.89	0.98	0.99
2013	0.03	0.25	0.61	0.94	1.00	1.00
2014	0.01	0.34	0.68	0.92	1.00	1.00

5.2.4.4 Natural mortality

Table 5.2.4.4.1. Hake in GSA 7. Natural Mortality (M) at age (PRODBIOM).

	0	1	2	3	4	5+
1998	0.88	0.43	0.33	0.25	0.22	0.20
1999	0.88	0.43	0.33	0.25	0.22	0.20
2000	0.88	0.43	0.33	0.25	0.22	0.20
2001	0.88	0.43	0.33	0.25	0.22	0.20
2002	0.88	0.43	0.33	0.25	0.22	0.20
2003	0.88	0.43	0.33	0.25	0.22	0.20
2004	0.88	0.43	0.33	0.25	0.22	0.20
2005	0.88	0.43	0.33	0.25	0.22	0.20
2006	0.88	0.43	0.33	0.25	0.22	0.20
2007	0.88	0.43	0.33	0.25	0.22	0.20
2008	0.88	0.43	0.33	0.25	0.22	0.20
2009	0.88	0.43	0.33	0.25	0.22	0.20
2010	0.88	0.43	0.33	0.25	0.22	0.20
2011	0.88	0.43	0.33	0.25	0.22	0.20
2012	0.88	0.43	0.33	0.25	0.22	0.20
2013	0.88	0.43	0.33	0.25	0.22	0.20
2014	0.88	0.43	0.33	0.25	0.22	0.20

5.2.4.5 Fisheries

5.2.4.5.1 General description of the fisheries

Hake is one of the most important demersal target species for the commercial fisheries in the Gulf of Lions (GSA 7). In this area, hake is exploited by French trawlers, French gillnetters, Spanish trawlers and Spanish longliners. Since 1998, an average of 243 boats are involved in this fishery and, according to official statistics, the total annual catches for the period 1998-2014 have oscillated around an average value of 2012 tons (1983 tons in 2014). In 2009, because of the large decline of small pelagic fish species in the area, the trawlers fishing small pelagic have diverted their effort on demersal species. Between 1998 and 2014, the number of French trawlers operating in the GSA 7 has decreased by 39%, while it decreased by 20% between 2010 and 2013.The French trawler fleet is the largest considering catches realized, the proportion of boats and catches are respectively (27% and 73%). The length of hake in the trawler catches ranges between 3 and 92 cm total length (TL), with an average size of 21 cm TL. The second largest fleet is the French gillnetters (41 and 16% respectively, range 13-86 cm TL and average size 39 cm TL), followed by the Spanish trawlers (9 and 10%, respectively, range 5-88 cm TL, and average size 24 cm TL), and the Spanish longliners (4 and 1%, respectively, range 22-96 cm TL and average size 52 cm TL). The hake trawlers exploit a highly diversified species assemblage: Striped red mullet (*Mullus surmuletus*), red mullet (*M. barbatus*), angler fish (*L. piscatorius*), blackbellied angler fish (*L. budegassa*), european conger (*Conger conger*), poor-cod (*Trisopterus minutus capelanus*), fourspotted megrim (*Lepidorhombus boscii*), soles (*Solea spp.*), horned octopus (*Eledone cirrhosa*), squids (*Illex coindetii*), gilthead seabream (*Sparus aurata*), European seabass (*Dicentrarchus labrax*), seabreams (*Pagellus spp.*), blue whiting (*Micromesistius poutassou*), tub gurnard (*Chelidonichtys lucerna*).

5.2.4.5.2 Management regulations applicable in 2015

French Trawlers:

Fishing license: fully observed
Engine power limited to 316 KW or 500 CV: Not full compliance
Cod-end mesh size (bottom trawl: square 40 mm or 50 mm diamond, by derogation): not fully observed
Fishing forbidden within 3 miles (France): not fully observed
Time at sea: fully observed
Temporal bans depending on years (2011 and 2012, 1 month/year): fully observed

French gillnetters:

Fishing license: fully observed
Maximum length of net: not fully observed

Spanish trawlers:

Fishing license: fully observed
Engine power limited to 316 KW or 500 CV: not observed
Mesh size in the codend (before Jun 1st 2010: 40 mm diamond: after Jun 1st 2010: 40 mm square or 50 mm diamond, by derogation): fully observed
Fishing forbidden <50 m depth: fully observed
Time at sea: fully observed
Temporal bans depending on years (2014, 1 month): fully observed

Spanish longliners:
Fishing license: fully observed
Number of hook per boat: not fully observed

In 2009, GFCM proposed the creation of a High Sea Fishery Restricted Area (FRA, GFCM/33/2009/1) in which the fishing effort for demersal stocks of vessels using towed nets, bottom and mid-water longlines, bottom-set nets shall not exceed the level of fishing effort applied in 2008 in the fisheries restricted area of the eastern Gulf of Lions as bounded by lines joining the following geographic coordinates: 42°40'N, 4°20' E; 42°40'N, 5°00' E; 43°00'N, 4°20' E; 43°00'N, 5°00' E. In the article 4 from the EU Regulation No. 1343/2011 of the European Parliament and of the Council of 13 December 2011, this fisheries restricted area was established and in 2012 both French (Arrêté du 28 décembre 2012, NOR: TRAM1240493A) and Spanish (Orden AAA/1857/2012 de 22 de agosto) governments published their own laws regulating this FRA.

5.2.4.5.3 Catches

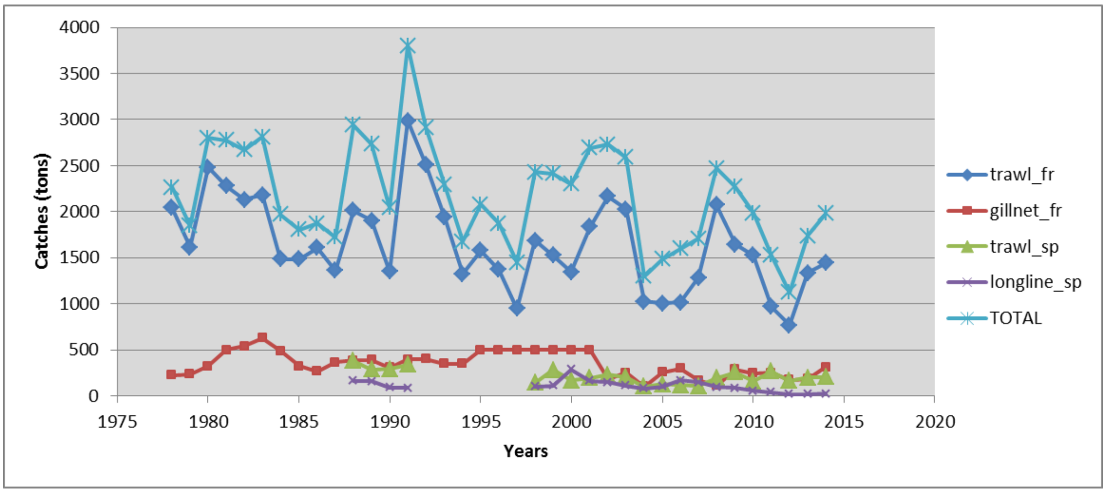


Figure 5.2.4.5.3.1. Hake in GSA 7. Catch by gear in tons (1978-2014).

Table 5.2.4.5.3.1. Hake in GSA 7. Annual catches (t) by gear (DCF data).

Gears/Years	OTB-French	OTB-Spanish	GNS-French	GTR-French	LLS-Spanish
1998	1688	140	500	-	101
1999	1525	279	500	-	109
2000	1347	166	500	-	285
2001	1835	196	500	-	163
2002	2168	231	182	-	146
2003	2024	206	248	-	112
2004	1023	101	99	-	78
2005	1002	126	255	-	101
2006	1014	116	299	-	170
2007	1282	107	168	-	143
2008	2071	227	111	-	97
2009	1642	258	286	-	84
2010	1527	156	247	-	54
2011	970	116	245	5	29
2012	768	163	175	-	18
2013	1337	198	161	21	18

2014	1441	202	284	32	24

5.2.4.5.4 *Landing*

Table 5.2.4.5.4.1. Hake in GSA 7. Annual landings (t) by gear (DCF data).

Gears/Years	OTB-French	OTB-Spanish	GNS-French	GTR-French	LLS-Spanish
1998	1688	140	500		101
1999	1525	279	500		109
2000	1347	166	500		285
2001	1835	196	500		163
2002	2168	231	182	-	146
2003	2024	206	248	-	112
2004	1023	101	99	-	78
2005	1002	125	255	-	101
2006	1014	116	299	-	170
2007	1282	107	168	-	143
2008	1898	192	111	-	97
2009	1633	258	286	-	83
2010	1527	156	247	-	53
2011	970	113	245	5	29
2012	759	162	175	-	18
2013	1292	198	161	21	18
2014	1392	200	284	32	24

5.2.4.5.5 *Discards*

The French discards were not included before 2008 as as they represented a negligible amount.

Table 5.2.4.5.5.1. Hake in GSA 7. Annual discards (t) by gear (DCF data).

Gears/Years	OTB-French	OTB-Spanish	GNS-French	GTR-French	LLS-Spanish
1998					
1999					
2000					
2001					
2002					
2003	0	-	-	-	-
2004	-	-	-	-	-
2005	0	1	-	-	-
2006	0	-	-	-	-
2007	0	-	-	-	-
2008	173	35	-	-	-
2009	9	0	-	-	1
2010	-	0	-	-	1
2011	-	3	-	-	-
2012	9	1	-	-	-
2013	46	0	-	-	-
2014	49	2	-	-	-

5.2.4.5.6 Fishing effort

Table 5.2.4.5.6.1. Hake in GSA 7. Fishing effort (kW·days) by gear for France and Spain, 2009-2014.

GNS	OTB-French	OTB-Spanish	GNS-French	GTR-French	LLS-Spanish
2009	-	1623651	-	-	52941
2010	-	1456054	-	-	175962
2011	-	1630298	-	-	137453
2012	-	1339565	3081607	2908493	115316
2013	3121214	1302803	30200	30507	126165
2014	2819032	1386059	40683	39284	144669

5.2.4.6 Scientific surveys

5.2.4.6.1 Survey #1 (MEDITS)

5.2.4.6.1.1 Methods

Fishery independent information regarding the state of the hake in GSA 07 was derived from the international survey MEDITS.

The data was assigned to strata based upon the shooting position and average depth (between shooting and hauling depth). Catches by haul were standardized to 60 minutes hauling duration. The abundance and biomass indices by GSA were calculated through stratified means (Cochran, 1953; Saville, 1977). This involves weighting the average values of the individual standardized catches and the variation of each stratum by the respective stratum areas in each GSA:

$Yst = \Sigma (Yi*Ai) / A$
$V(Yst) = \Sigma (Ai^2 * si^2 / ni) / A^2$
Where:
A=total survey area
Ai=area of the i-th stratum
si=standard deviation of the i-th stratum
ni=number of valid hauls of the i-th stratum
n=number of hauls in the GSA
Yi=mean of the i-th stratum
Yst=stratified mean abundance
V(Yst)=variance of the stratified mean

The variation of the stratified mean is then expressed as the 95 % confidence interval:
Confidence interval = Yst ± t(student distribution) * V(Yst) / n
Length distributions were obtained by the sum of all standardized length frequencies (subsamples raised to standardized haul abundance per hour) over the stations of each stratum. Aggregated length frequencies were then raised to stratum abundance * 100 (because of low numbers in most strata) and finally aggregated (sum) over the GSA strata.

5.2.4.6.1.2 Trends in abundance and biomass

Fishery independent information regarding the state of the hake in GSA 7 was derived from the international survey MEDITS. Figure 5.2.4.6.1.3.1. displays the time series of abundance in GSA 7. No clear trend can be detected over the total period, but since 2012, lowest value observed in the time series, the index shows some slight increase. The age structure (fig. 5.2.4.6.1.4.1.) did not exhibit any substantial change in 2014 compared to the other years.

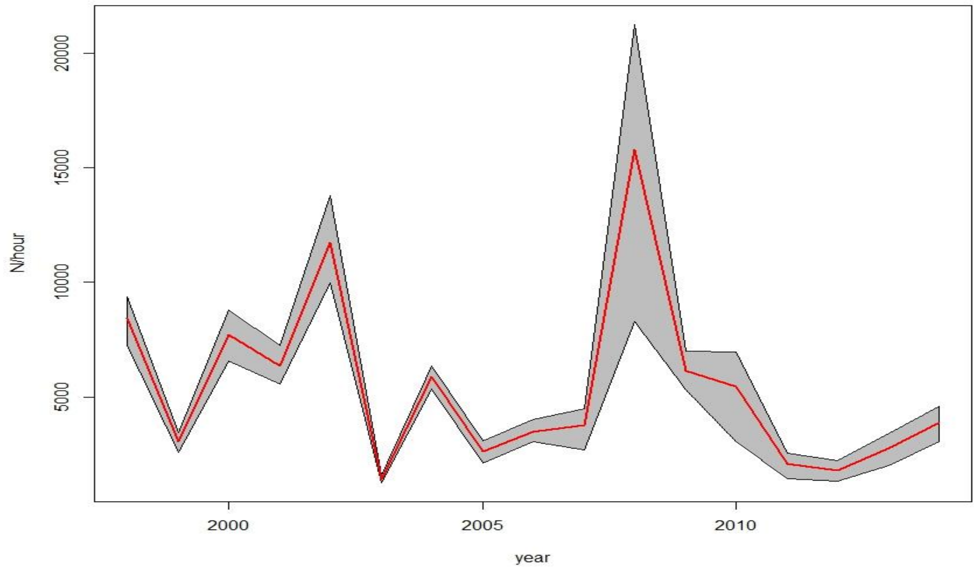


Figure 5.2.4.6.1.3.1. Hake in GSA 7. Medits abundance index (N/hour) for hake.

5.2.4.6.1.3 Trends in abundance by length or age

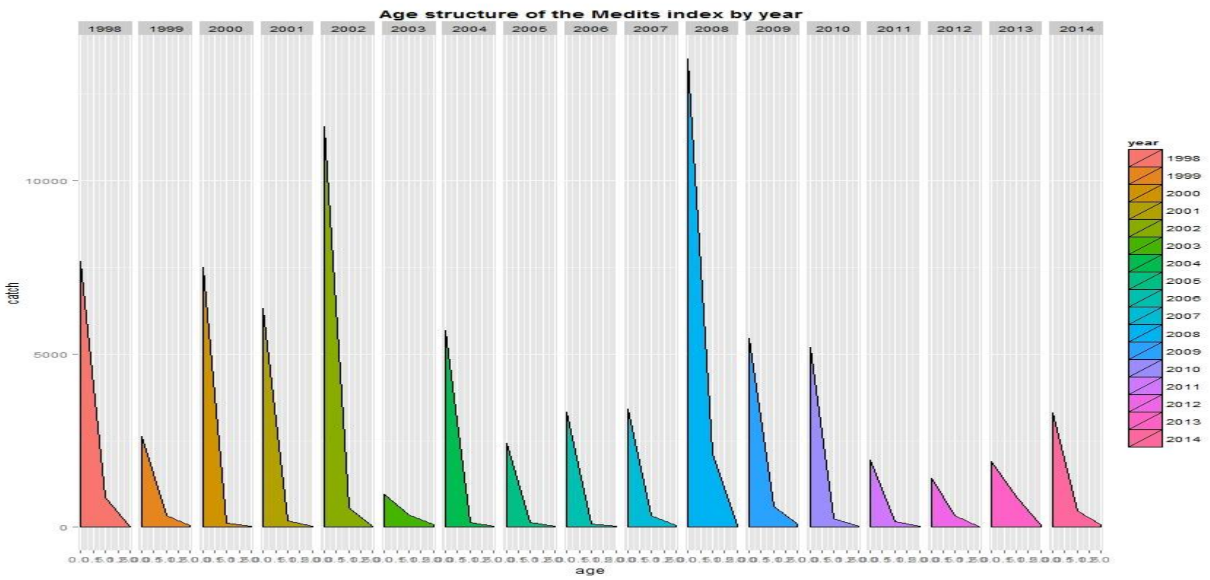


Figure 5.2.4.6.1.4.1. Hake in GSA 7. Age structure of the MEDITS abundance index (n/hour).

5.2.4.7 Stock Assessment

5.2.4.7.1 Methods

During EWG 15-11, the stock assessment was performed over the period 1998-2014 using an XSA model over age classes ranging from 0 to 5+ and with MEDITS index, as tuning fleet (ages 0-2). An attempt was made to use the a4a model, developed by the Joint Research Center, instead of XSA for assessing the stock. a4a is a statistical catch at age model, which flexibility allows to fit a wide range of models to the data. A comparison between the 2 methods of the results can be find in the section 5.2.4.7.3 (Results). The final diagnosis is based upon XSA analysis.

5.2.4.7.2 Input data

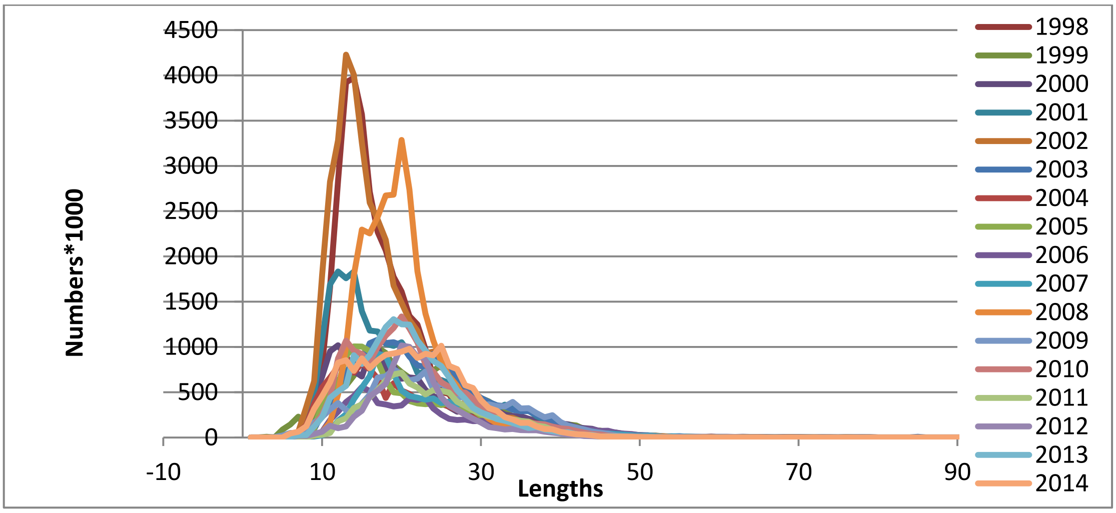


Figure 5.2.4.7.2.1. Hake in GSA 7. Length distribution of total catch.

Table 5.2.4.7.2.1. Hake in GSA 7. Catch at age in numbers (thousands).

	0	1	2	3	4	5+
1998	21010	13203	1554	228	39	12
1999	6571	8996	2644	281	34	8
2000	7575	6992	2080	330	60	24
2001	12526	9850	2561	344	39	21
2002	24183	14310	2066	231	25	13
2003	6190	10323	2561	347	23	16
2004	6225	5269	1284	162	12	3
2005	5826	5691	1565	177	15	3
2006	2816	4452	1616	240	28	6
2007	3211	6097	1821	232	21	7
2008	12079	16923	1595	148	13	5
2009	3841	7804	2371	375	15	4
2010	7289	9621	1924	210	12	2
2011	2679	6188	1403	163	5	1
2012	2912	6558	915	101	4	1
2013	6287	10374	1440	13	3	0
2014	6476	10591	1953	24	1	0

Table 5.2.4.7.2.2. Hake in GSA 7. Weight at age (kg) in the catch and stock (kg).

	0	1	2	3	4	5+
1998	0.0236	0.0858	0.3509	0.6866	1.7755	2.5426
1999	0.0263	0.1257	0.3283	0.6165	1.5267	2.0843
2000	0.0242	0.1304	0.3788	0.7348	1.8415	2.5966
2001	0.0225	0.1264	0.3300	0.5755	1.7442	2.6060
2002	0.0216	0.0940	0.3088	0.6580	1.6604	2.1780
2003	0.0316	0.1286	0.3024	0.5954	1.6092	2.4015
2004	0.0228	0.1197	0.3234	0.5858	1.1613	1.6772
2005	0.0248	0.1211	0.3397	0.5625	0.9783	1.3058
2006	0.0304	0.1441	0.4206	0.6452	1.0535	1.3081
2007	0.0351	0.1237	0.3492	0.7019	1.1964	1.2715
2008	0.0380	0.0846	0.3047	0.6905	1.3747	1.8235
2009	0.0323	0.1505	0.3170	0.5286	1.0419	1.4363
2010	0.0317	0.1122	0.2850	0.5196	1.2359	1.2238
2011	0.0394	0.1285	0.2694	0.4846	1.2260	1.1589
2012	0.0434	0.1036	0.2793	0.5615	1.1225	1.2012
2013	0.0358	0.1060	0.2705	1.0979	1.2002	1.3687
2014	0.0259	0.1216	0.2571	0.8088	1.2002	1.3687

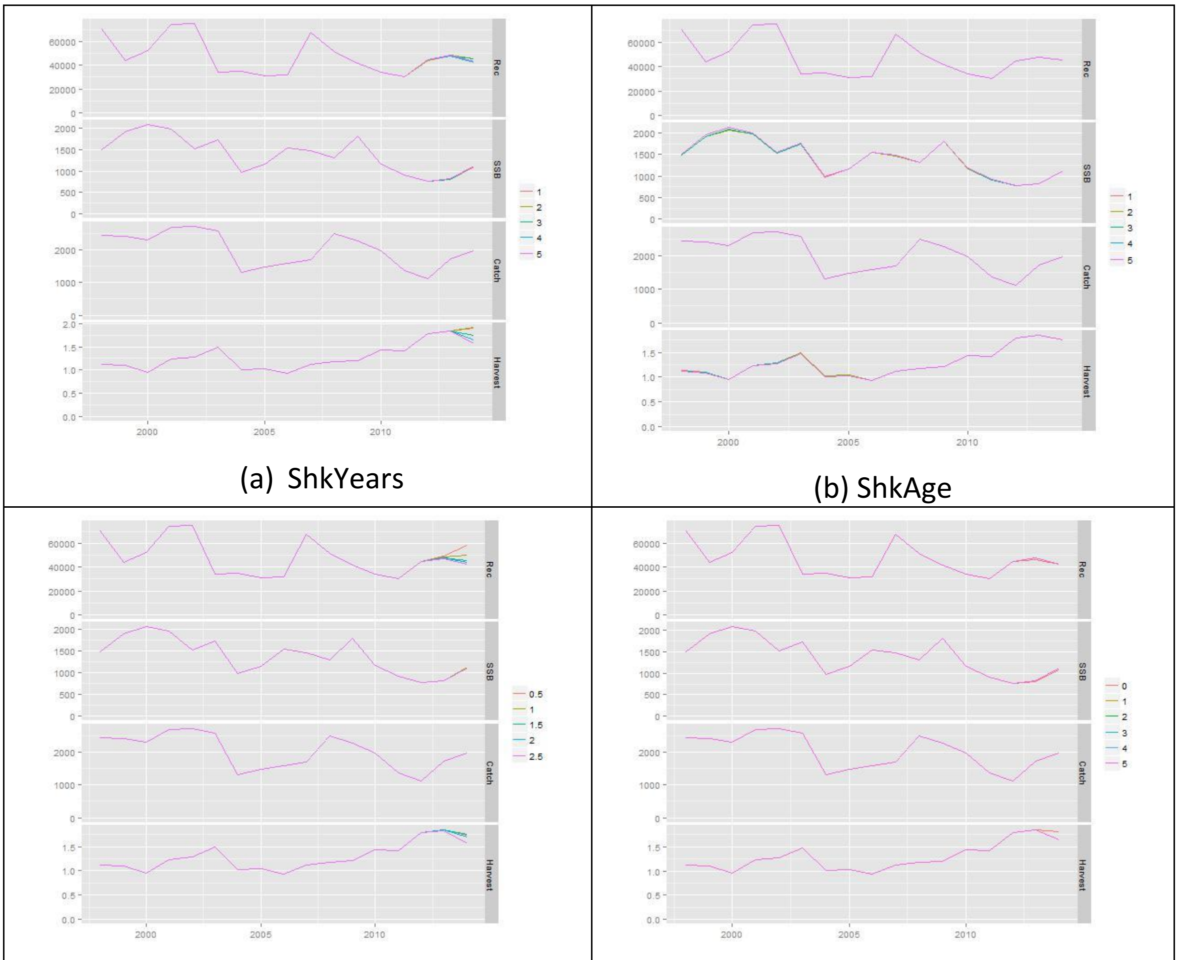
Table 5.2.4.7.2.3. Hake in GSA 7. MEDITS index at age (1998-2014).

	0	1	2
1998	7678	860	19
1999	2622	346	51
2000	7493	127	39
2001	6317	181	42
2002	11549	563	41
2003	952	365	74
2004	5681	140	24
2005	2428	150	22
2006	3331	94	30
2007	3414	330	55
2008	13518	2115	43
2009	5460	595	104
2010	5188	247	40
2011	1951	164	35
2012	1425	336	15
2013	1902	877	52
2014	3295	460	84

5.2.4.7.3 Results

<u>Model: XSA</u>

Same settings as last year (Shrinkage on the last 4 years, Shrinkage on the last 3 ages, weight of shrinkage fse=1.5, Constant catchability for all ages) after performing sensitivity analysis (figure 5.2.4.7.3.1).



(a) ShkYears

(b) ShkAge

(b) fse

(d) Qage

Figure 5.2.4.7.3.1. Hake in GSA 7. Sensitivity analysis on shrinkage on the last years (a), last ages (b), weight of the shrinkage (c), catchability at age (d).

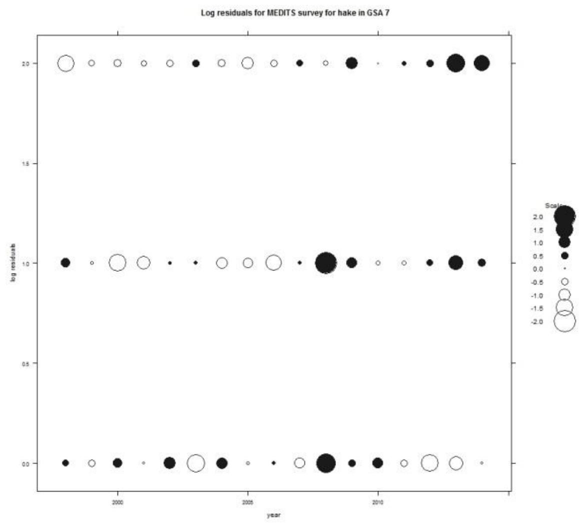


Figure 5.2.4.7.3.2. Hake in GSA 7. Log-residuals of the MEDITS survey.

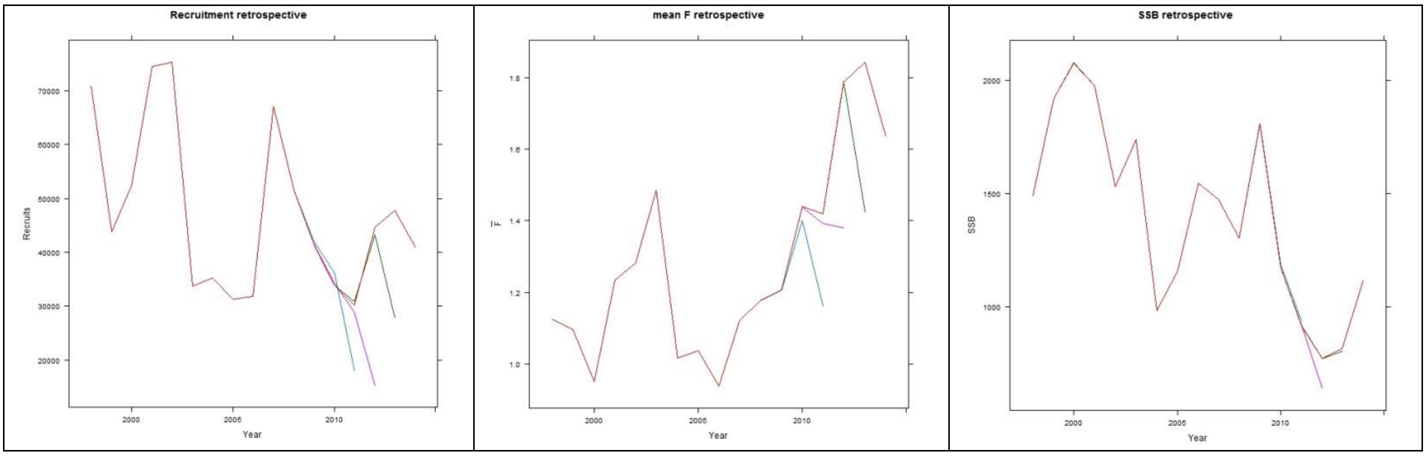


Figure 5.2.4.7.3.3. Hake in GSA 7. Retrospective analysis performed with XSA.

Table 5.2.4.7.3.1. Hake in GSA 7. Fishing mortality at age estimated by XSA.

	0	1	2	3	4	5+
1998	0.617224	1.349275	1.407172	1.625985	1.482131	1.482131
1999	0.264897	1.216579	1.808165	1.36651	1.485128	1.485128
2000	0.254349	0.9712	1.624713	1.900198	1.582999	1.582999
2001	0.302475	1.29112	2.111476	2.326604	1.942937	1.942937
2002	0.690336	1.499851	1.65378	2.093304	1.782153	1.782153
2003	0.33476	1.699181	2.419613	2.966352	2.404276	2.404276
2004	0.320939	1.054164	1.676628	2.003908	1.605981	1.605981
2005	0.341007	1.096407	1.672051	1.620607	1.479304	1.479304
2006	0.147654	0.910785	1.758312	2.164633	1.646954	1.646954
2007	0.077083	1.088087	2.198621	2.520462	1.982981	1.982981
2008	0.453101	1.676924	1.399298	2.055486	1.741229	1.741229
2009	0.155278	1.24791	2.217939	3.179168	2.249941	2.249941
2010	0.406231	1.660899	2.254655	3.432401	2.489042	2.489042
2011	0.14819	1.709571	2.402282	3.402128	2.543168	2.543168
2012	0.106754	1.397943	3.855902	3.34125	2.909915	2.909915
2013	0.228469	1.481432	3.817109	2.290177	2.569422	2.569422
2014	0.281063	1.789523	2.842383	3.165804	2.640126	2.640126

Table 5.2.4.7.3.2. Hake in GSA 7. Stock number at age estimated by XSA.

	0	1	2	3	4	5+
1998	70831	22104	2427	321	57	16
1999	43839	15848	3730	427	49	11
2000	52373	13952	3054	440	85	32
2001	74512	16845	3436	432	51	27
2002	75309	22839	3013	299	33	17
2003	33783	15662	3316	414	29	18
2004	35210	10026	1863	212	17	4
2005	31309	10595	2273	250	22	4
2006	31855	9234	2303	307	39	8
2007	67203	11399	2416	285	27	9
2008	51477	25807	2498	193	18	7
2009	41466	13572	3138	443	19	4
2010	33902	14726	2535	246	14	2
2011	30197	9367	1820	191	6	1
2012	44654	10800	1103	118	5	1
2013	47795	16646	1736	17	3	0
2014	40913	15775	2461	27	1	0

Table 5.2.4.7.3.3. Hake in GSA 7. Summary of the XSA analysis.

	SSB (tons)	Fbar(0-2)	Rec. (thousands)
1998	1491	1,12	70831
1999	1920	1,10	43839
2000	2079	0,95	52373
2001	1980	1,24	74512
2002	1529	1,28	75309
2003	1741	1,48	33783
2004	983	1,02	35210
2005	1158	1,04	31309
2006	1545	0,94	31855
2007	1473	1,12	67203
2008	1305	1,18	51477
2009	1809	1,21	41466
2010	1173	1,44	33902
2011	915	1,42	30197
2012	769	1,79	44654
2013	816	1,84	47795
2014	1115	1,64	40913

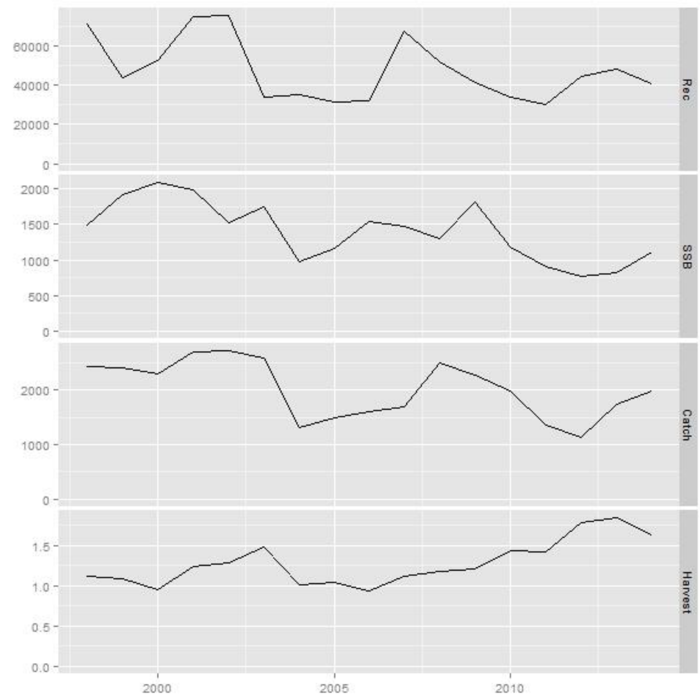


Figure 5.2.4.7.3.4. Hake in GSA 7. Time series of the estimated parameters from XSA. SSB and catch (tons), recruitment (numbers in thousands).

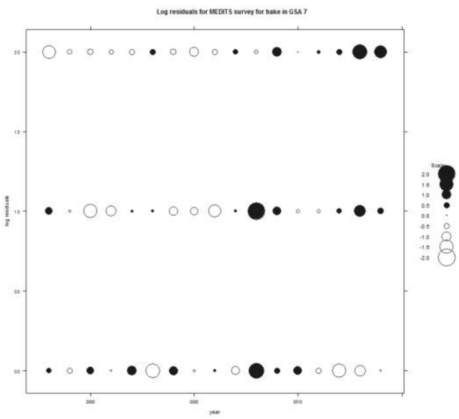


Figure 5.2.4.7.3.5. Hake in GSA 7. Residuals for MEDITS data from XSA.

Model: a4a

During EWG 15-11 the stock assessment was also performed over the period 1998-2014, over age classes ranging from 0 to 5+, using a4a model and the MEDITS index, as tuning fleet. The a4a model, developed by the Joint Research Center is a statistical catch at age model, which flexibility allows to fit a wide range of models to the data. Compared to XSA, a4a runs forward and allows to reach a better stability for last years estimates. The results were compared to XSA run. The general specification of the model, in R language, was the following:

```
index <- hke.idx
qmod <- list(~s(age, k = 3, by=breakpts(year, 2011)) + s(year, k=3, by=as.numeric(age==2)))
fmod <- ~ s(year, k=10, by=breakpts(age, 0.5))+ s(age, k=4, by=breakpts(year, 2011)) + te(year, age, k = c(3, 3))

fit <- a4aSCA(stock = hke, indices = index, fmodel = fmod, qmodel = qmod)
```

This model allowed for an effect of age for the catchability of the MEDITS index (submodel qmod). The model also allowed for an effect of time and age and a combined effect of both these variables on the fishing mortality estimates (submodel fmod). The flexibility parameters for the smoother effects (k) for the qmod and vmod were set to constant values to ensure the fit of a reasonable model. We assessed the quality of the model fits using model residuals, MEDITS index and catches, figure 5.2.4.7.3.7. Time series of the estimated parameters from the a4a analysis are presented in figure 5.2.4.7.3.6.

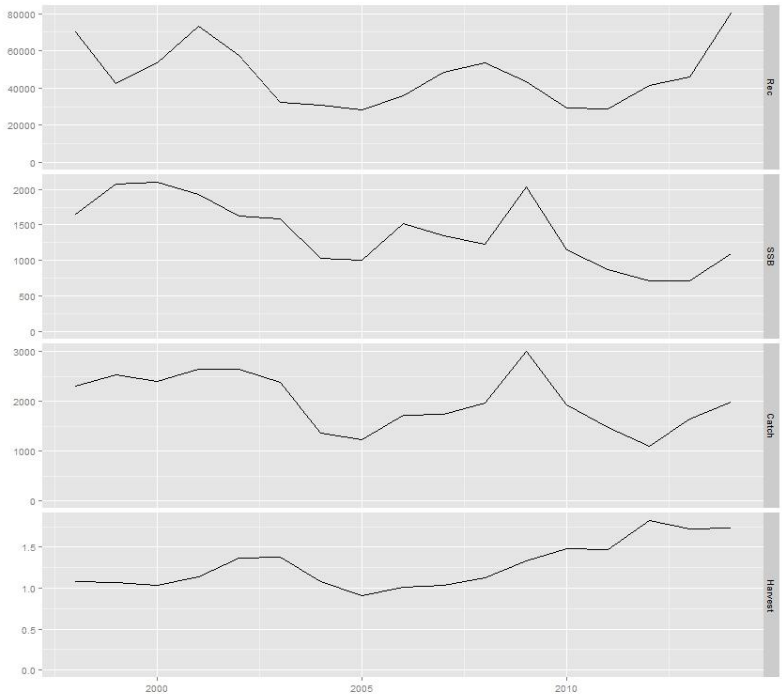


Figure 5.2.4.7.3.6. Hake in GSA 7. Time series of the estimated parameters from the a4a analysis.

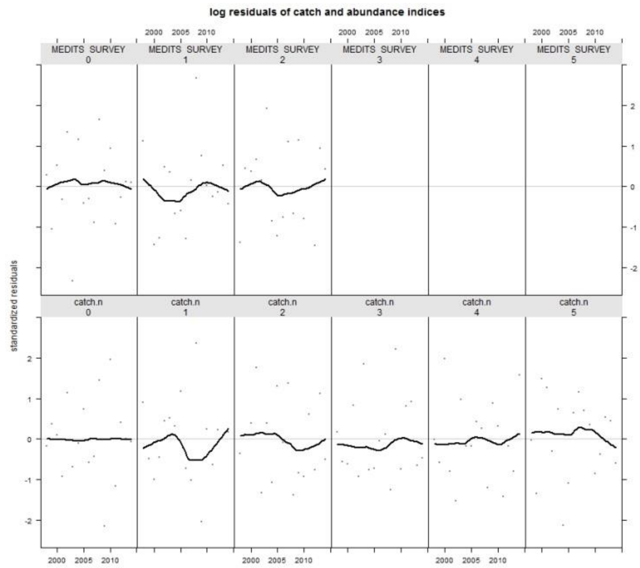


Figure 5.2.4.7.3.7. Hake in GSA 7. Residuals for the catch and MEDITS data from the a4a analysis.

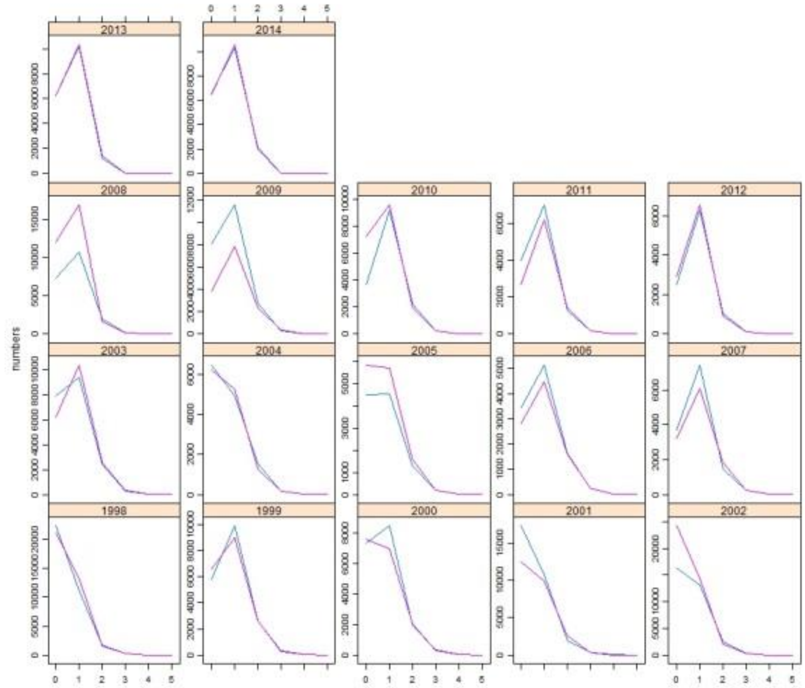


Figure 5.2.4.7.3.8. Hake in GSA 7. Predicted and observed catch by age class.

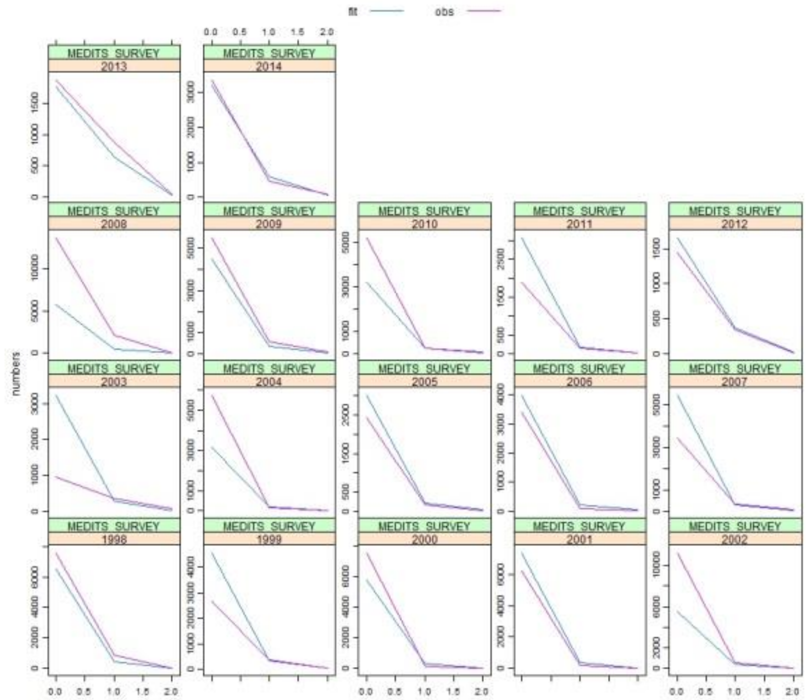


Figure 5.2.4.7.3.9. Hake in GSA 7. Predicted and observed MEDITS index by age class.

Comparison with XSA

The 'best' a4a model has similar results to XSA in terms of catch, fishing mortality and spawning stock biomass but gives higher estimates of recruitment, especially in the last year (figure 5.2.4.7.3.10.). Residuals patterns of this model was generally good with no extreme values. XSA was finally kept as the base-case model for the hake stock assessment this year.

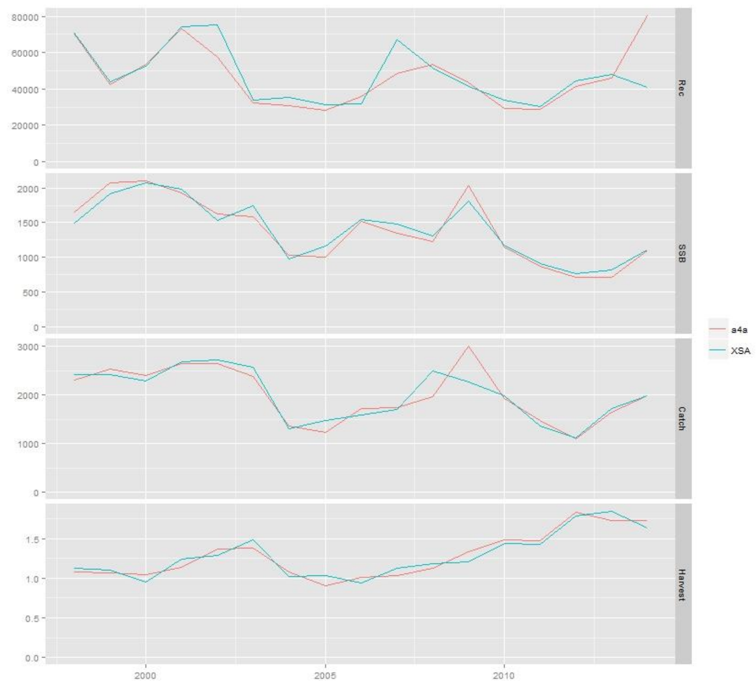


Figure 5.2.4.7.3.10. Hake in GSA 7. Comparison of the XSA and a4a run.

5.2.4.8 Reference points

5.2.4.8.1 Methods

Yield per recruit analysis was used (FLBRP) to calculate the reference point ($F_{0.1}$) and the estimated reference fishing mortality (Fcurrent). Last year the final diagnosis was based upon a4a analysis. For that reason $F_{0.1}$, was re-estimated this year using the input parameters of XSA model.

5.2.4.8.2 Input data

The same population parameters used for the XSA model and exploitation pattern derived from the final model were used as input for the yield per recruit analysis.

5.2.4.8.3 Results

Table 5.2.4.8.3.1. Hake in GSA 7. Reference points.

Year of assessement	Model	F0.1	Fcur	Ratio
2015	XSA	0.11	1.64	14.9
2014	*a4a*	*0.17*	*1.67*	*9.8*
2013	*XSA*	*0.11*	*1.83*	*16.6*

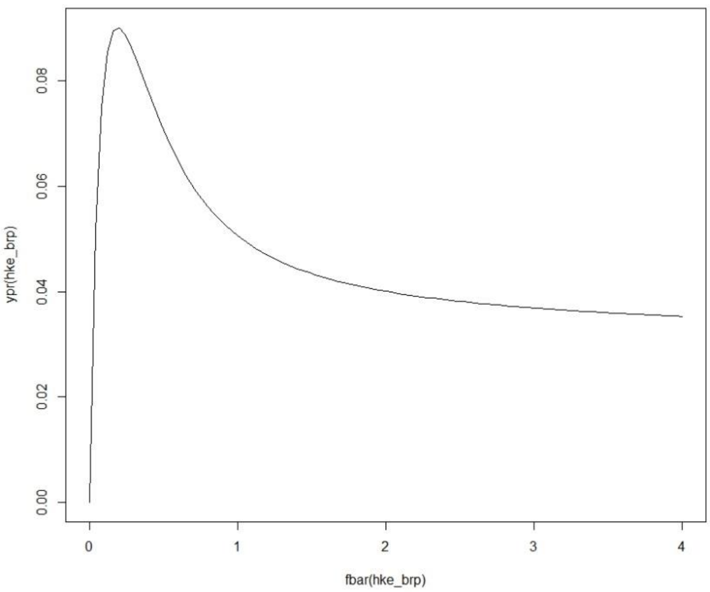


Figure 5.2.4.8.3.1. Hake in GSA 7. Yield per recruit curve.

With the estimated value for $F_{0.1}$ of 0.11, the current level of F of 1.64 is higher, and hence, the stok is being fished above F_{MSY}.

5.2.4.9 Data quality

All the length data was available in the database. Effort data were missing before 2009. The growth of European Hake (*Merluccius merluccius*) in the Gulf of Lions were reestimated from tagging experiments carried out by IFREMER (Mellon-Duval et al., 2010). The new parameters have not been yet compared to a re-analysis of otoliths readings, because of the uncertainty on otoliths readings. Therefore, the data sent to the data call were in length and were converted in age using the length-to-age slicing functions available in the R package a4a and parameters from Mellon et al. The other biological parameters (sex-ratio, length-weight and maturity) are coming from the DCF and were present in the data call.

5.2.4.10 Short term predictions 2015-2017

5.2.4.10.1 Method

A deterministic short term prediction for the period 2015 to 2017 was performed using the FLR routines provided by JRC and based on the results of the XSA stock assessments performed during EWG 15-11.

5.2.4.10.2 Input parameters

The input parameters were the same used for the XSA stock assessment and its results. An average of the last three years has been used for weight at age, maturity at age and F at age. Recruitment (age 0) has been estimated from the population results as the geometric mean of the last 3 years (44364.16 thousands individuals).

5.2.4.10.3 Results

Table 5.2.4.10.3.1. European hake in GSA 7. Short term forecast in different F scenarios. Basis: F(2015) = mean (F_{bar} 0-2 2012-2014)= 1.75; R(2015) = geometric mean of the recruitment of the last 3 years; R = 44364 thousands; SSB(2014) = 1115 t, Catch (2014)= 1983 t.

Rationale	Ffactor	Fbar	Catch 2015	Catch 2016	Catch 2017	SSB 2016	SSB 2017	Change SSB 2016-2017(%)	Change Catch 2014-2016(%)
Zero catch	0,00	0,00	1871	0	0	740	2798	278	-100,00
High long term yield (F0.1)	0,06	0,11	1871	209	598	740	2499	238	-89,47
	0,10	0,18	1871	320	858	740	2343	217	-83,87
Different Scenarios	0,20	0,35	1871	586	1329	740	1980	168	-70,43
	0,30	0,53	1871	809	1578	740	1689	128	-59,16
	0,40	0,70	1871	998	1699	740	1455	97	-49,63
	0,50	0,88	1871	1159	1749	740	1265	71	-41,51
	0,60	1,05	1871	1297	1758	740	1109	50	-34,53
	0,70	1,23	1871	1417	1746	740	982	33	-28,50
	0,80	1,40	1871	1521	1723	740	877	18	-23,24
	0,90	1,58	1871	1612	1695	740	790	7	-18,62
	1,00	1,75	1871	1693	1666	740	716	-3	-14,53
	1,10	1,93	1871	1766	1637	740	655	-12	-10,89
	1,20	2,10	1871	1830	1610	740	602	-19	-7,62
	1,30	2,28	1871	1889	1584	740	558	-25	-4,67
	1,40	2,45	1871	1942	1560	740	519	-30	-1,98
	1,50	2,63	1871	1991	1538	740	486	-34	0,47
	1,60	2,81	1871	2035	1518	740	456	-38	2,72
	1,70	2,98	1871	2077	1499	740	431	-42	4,81
	1,80	3,16	1871	2115	1482	740	408	-45	6,74
	1,90	3,33	1871	2151	1466	740	388	-48	8,54
	2,00	3,51	1871	2184	1451	740	369	-50	10,23

5.2.4.11 Short term predictions 2015-2017 by fleet

5.2.4.11.1 Method

A deterministic short term prediction by fleet for the period 2015 to 2017 was performed using the FLR routines provided by JRC and based on the results of the XSA stock assessments performed during EWG 15-11.

5.2.4.11.2 Input parameters

The same parameters used in the short term by single fleet were used.

5.2.4.11.3 Results

Table 5.2.4.11.3.1. European hake in GSA 7. Short term forecast by fleet.

Fleet	Year	Catches	Partial_f
FR_OTB	2015	1538	1.399
FR_GN	2015	125	0.170

SP_OTB	2015	195	0.160
SP_LL	2015	12	0.025
FR_OTB	2016	169	0.088
FR_GN	2016	15	0.011
SP_OTB	2016	22	0.010
SP_LL	2016	1	0.002
FR_OTB	2017	423	0.088
FR_GN	2017	89	0.011
SP_OTB	2017	73	0.010
SP_LL	2017	13	0.002

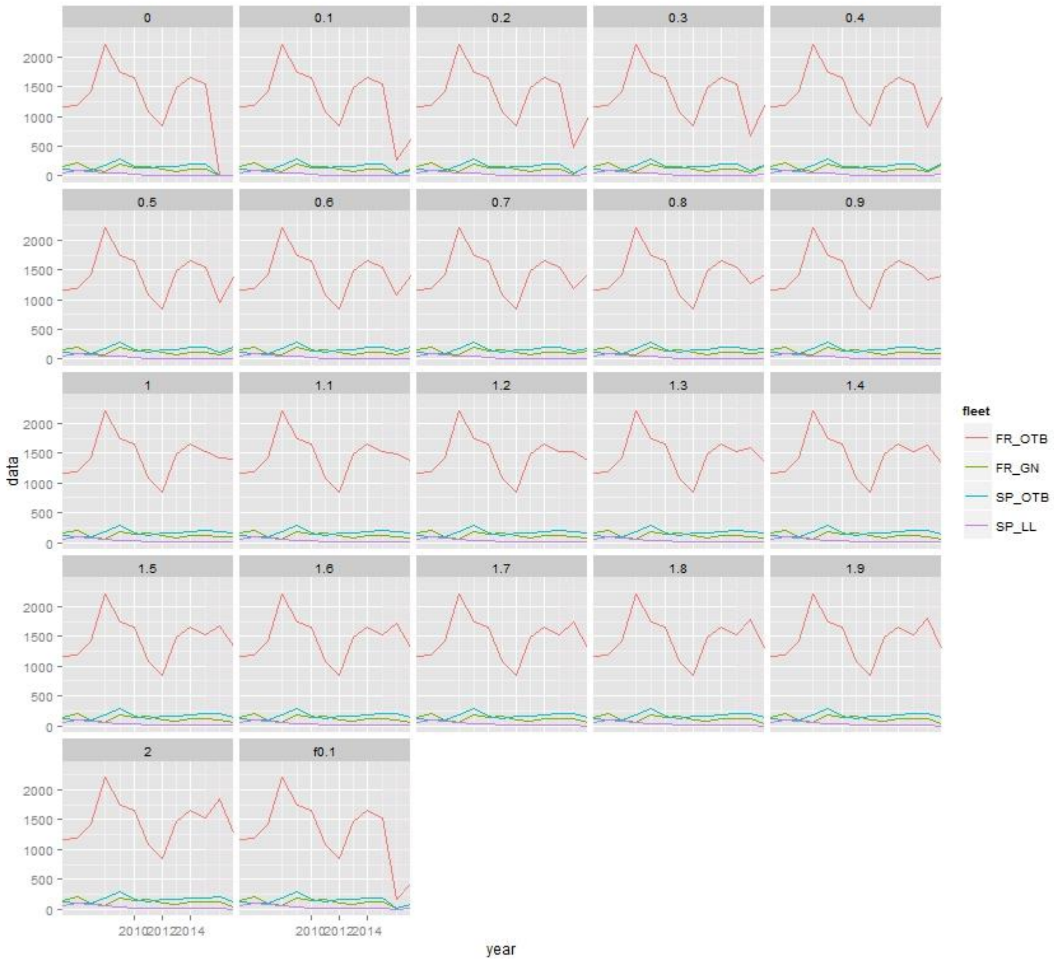


Figure 5.2.4.11.3.1. European hake in GSA 7. Short term forecast by fleet.

5.2.4.12 Medium term predictions 2015-2017 by fleet

5.2.4.12.1 Method

Medium term was not conducted because no meaningful stock-recruitment relationship was estimated.

5.2.4.13 Stock advice

The current F (1.64) is larger than $F_{0.1}$ (0.11), chosen as proxy of F_{MSY} and as the exploitation reference point consistent with high long term yields, which indicates that European hake in GSA 7 is being fished above F_{MSY}. Catches of European hake in 2016 consistent with F_{MSY} would not exceed 209 tons.

5.2.4.14 Management strategy evaluation

We ran the Management Strategy Evaluation to evaluate if the MSY ranges were precautionary. The F_{MSY} ranges were derived using the formula provided by STECF 15-09. F ranges results were F_{upper}=0.16 and F_{lower}=0.08. B_{lim} was estimated as B_{loss}=769 (t). The following figure shows the results of the MSE.

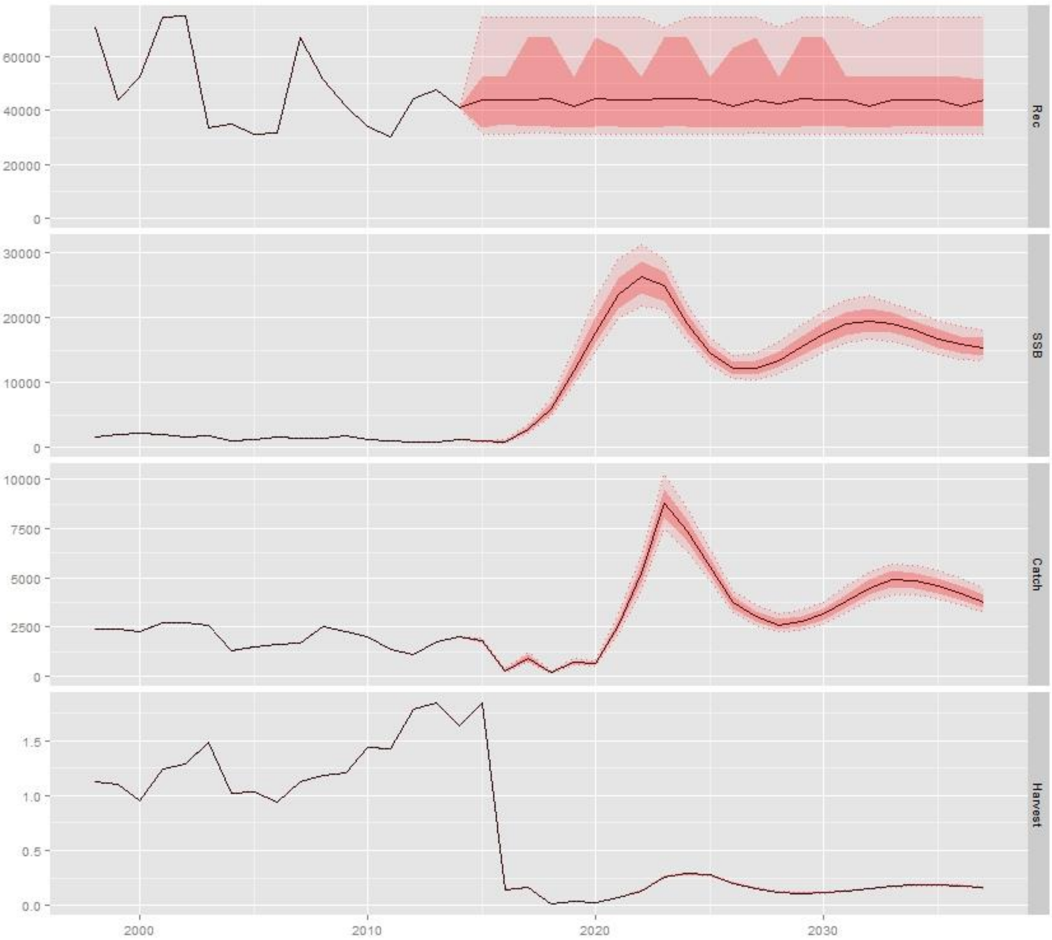


Figure 5.2.4.13.1. European hake in GSA 7. Short term forecast by fleet.

The probability of SSB to fall below B_{lim} at F = F_{upper} is equal to 0.

5.2.5 STOCK ASSESSMENT OF HAKE IN GSA 8

5.2.5.1 Stock Identification

Hake is distributed along the narrow Mediterranean shelves and slope at depths up to 1000m, but is mainly concentrated in the depth range 0-400m. There is not any evidence that inside GSA 8 boundaries inhabits a single, homogeneous hake stock that behaves as a single well-mixed and self-perpetuating population. The GSA boundaries are, as those for other areas, arbitrary and do not consider neither the existence of local biological features nor differences in the spatial allocation in fishing pressure within it. It is likely some connectivity as larval drifts, movements of individuals and sharing of spawning areas in particular with GSA 9.

5.2.5.2 Growth

Since growth parameters are not estimated for this GSA, it was decided to use parameters estimated for the GSA 7, which assume a fast growing performance. They were estimated from tagging experiments carried out by IFREMER (Mellon-Duval et al., 2010).

Females	L_∞=100.7	K=0.236	t_0=0
Males	L_∞=72.8	K=0.233	t_0=0

5.2.5.3 Maturity

The estimates of the proportion mature-at-age were derived from GSA 7. With the assumption of fast-growing, hake mature massively at 3 years old.

age	0	1	2	3	4	5+
Maturity at age	0.06	0.23	0.72	0.92	0.99	1

Natural mortality

A vector of natural mortality rates is not available for hake in GSA 8. For natural mortality, the vector of natural morality declining at age used for GSA7 derived from PRODBIOM (Abella et al.,1997) was used.

age	0	1	2	3	4	5+
M value	0.88	0.43	0.33	0.25	0.22	0.20

5.2.5.4 Fisheries

5.2.5.4.1 General description of the fisheries

The semi-industrial fisheries are not well developed in Corsica (GSA8) area and very few trawlers (about 7) operate targeting demersal species (Norway lobster, striped red mullet) including some very few catches of hake (around 2% of the catches for the period 2012_2014).

Even though small-scale fisheries are quite important along the coasts, fishers targets are other resources (lobster, finfish living on hard bottoms) and the choice regarding targets conditions the gears to be utilised and the operation areas. There are no available data for the size structure of the landings of hake, likely as a consequence of their negligible amount of landings, since it is not a target species of trawlers and it is absent from other gears catches. It is possible that the species is not included among the main landed commercial species that needs to be reported in the DCF. Moreover, it is important to notice that trawlers can only work on the eastern part of Corsica since the western part almost doesn’t have a continental shelf.

5.2.5.4.2 Management regulations applicable in 2015

Minimum landing sizes: EC regulation 1967/2006 defined 20 cm TL as minimum legal landed size.
Cod end mesh size of trawl nets: the 50 mm (stretched, diamond meshes) or alternatively a 40 mm codend with square mesh geometry.
Trawling is not allowed within three nautical miles from the coast or at depths less than 50 m when this depth is reached at a distance less than 3 miles from the coast.

5.2.5.4.3 Landings

Landings information is available for hake only for the more recent years in the area. Total amounts are extremely small and only concentrated on OTB.

landings (tons)					
Gear	**2010**	**2011**	**2012**	**2013**	**2014**
GNS	0.018923	0.021366	0.041591	0.019372	0.010131
GTR	0.024518	0.028342	0.257626	0.032025	0.271475
LLD		0.013			0.003118
LLS	0.017936		0.0083		0.098814
OTB	9.813483	12.98548	11.57596	0.849828	6.13496
OTM	0.1	0.190796			0.051299
Total	**9.97486**	**13.23899**	**11.88347**	**0.901225**	**6.569797**

5.2.5.4.4 Discards

No discards information is available for hake in GSA 8.

5.2.5.4.5 Fishing effort

Noinformation is available for hake in GSA 8.

5.2.5.5 Scientific surveys

5.2.5.5.1 Survey #1 (MEDITS)

5.2.5.5.1.1 Methods

French contribution to the internationally coordinated MEDITS (International bottom Trawl Surveys in the Mediterranean) survey in Corsica area (GSA9), is constituted by about one week of operations occurring in the second quarter every year since 1994 excluding in 2002. A GOV bottom trawl with short wings is utilized. On average 20 hauls are carried out; haul duration is half an hour above 200 m depth which corresponds to about 0.05 km² and one hour for bottom depths greater than 200 m (about 0.1 km²). MEDITS provides a representative picture of the 4 562 km² of Eastern Corsican island plateau. See 5.2.5.6.2 for details.

5.2.5.6 Stock Assessment

5.2.5.6.1 Methods

Several problems were found in order to perform a complete and sound stock assessment of hake in GSA8 as the species is not a target species in Corsica. Only few trawlers are operating in the area without targeting hake. Moreover, small scale fisheries are the only well developed fisheries targeting other species than hake. Hence, hake is not included among the stock for which collection of sizes is compulsory, because of the extremely limited quantities landed. Neither long time series of such landings is available (2010-2014).

It was suggested in the WG to facilitate survey-based analyses of the fishery and in particular to made an attempt to use trawl surveys data and to run SURBA. SURBA is a VPA-based model that assumes fishery mortality separable into an age (s) and a year effect (f) (Needle, 2003; Beare, 2005). The method can be considered a useful technique for investigating the dynamics of the fishery independently of the commercial catch and CPUE data. The model estimates the mean-standardised survey abundance indices by age and year, the trend in mean F, the trend in F by age group, the trend in relative SSB and the trend in model parameters (F, SSB and Recruitment)

MEDITS time series data is in principle suitable for performing such analysis. Even though MEDITS started in 1994, the time series of abundance indices from MEDITS shows an interruption in year 2002, because of a technical problem with the boat that made impossible the conduction of the cruise such year. This fact precludes the use of the complete series. In consequence, data used here regards only the period 2003 to 2014. The period 1994-2001 is shorter and the number of individuals caught more limited. Moreover, efficiency of the used gear was lower in the first surveys and hence the reconstruction of numbers at size per square kilometers less comparable with those obtained in successive cruises and more difficult to follow the cohorts decline with time.

The number of hauls performed every year in GSA 8 is relatively modest (generally 20-23 tows). Moreover, the MEDITS gear in use is not suitable for the catch of all year classes in the same proportion as are actually present in the swept area and such limitation may produce a distorted image of the size structure which imply consequently important errors in the Z estimates from one age class to the successive. A corrective procedure is hence necessary and the software allows such action by changing in input the catchabilities at age. A vector of catchability at age was constructed based on the information of selection capability and availability of the different age classes observed in neighbouring areas. There were made several trials of alternative changes in q(age) trying to avoid negative F estimates and reducing size and trends in residuals.

5.2.5.6.2 Input data

Input data consists in capture by age for each survey. Data was standardized in numbers per Km^2. Such numbers were derived from the database, which included separate data for males, females and undetermined sex. Hake shows an important sex dimorphism in maximum size sexes may reach and hence, the use of a single growth model for transforming sizes in age is not considered optimal. Age splitting was performed by sex and successively the two age compositions combined. Undetermined individuals were assigned to both sexes based in sex ratios by size.

Table 5.2.5.7.2.1 and Figure *5.2.5.7.2.2* shows the age structure in each year.

Table 5.2.5.7.2.1. Hake in GSA 8. Age structure of MEDITS surveys data.

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
age 0	58.03	5.01	8.27	10.24	8.97	35.58	23.27	52.51		2.81
age 1	69.13	27.75	21.31	9.63	5.69	21.03	46.41	28.36		11.69
age 2	2.83	4.17	1.06	0.75	0.68	1.73	3.42	4.56		4.82
age 3	0.00	0.89	0.79	0.80	0.24	1.27	3.01	1.24		2.41
age 4	0.00	0.52	0.00	0.59	0.08	0.00	0.72	0.53		0.04
age 5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.68
age 6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00
age 7	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.00		0.00
age 8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00
age 9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
age 0	11.91	31.75	49.58	88.99	46.41	13.91	13.19	27.32	2.56	8.42	12.22
age 1	10.29	15.02	104.63	31.92	35.57	24.10	14.77	20.64	14.13	17.27	18.82
age 2	4.74	1.85	6.69	10.23	1.91	7.37	1.55	2.11	1.45	0.89	4.64
age 3	1.10	0.89	0.86	2.55	1.82	0.20	1.35	1.36	0.96	0.19	2.06
age 4	0.46	0.61	0.08	2.26	1.09	0.10	0.00	0.00	0.00	0.00	0.06
age 5	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.58	0.00	0.00	0.88
age 6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
age 7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
age 8	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
age 9	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

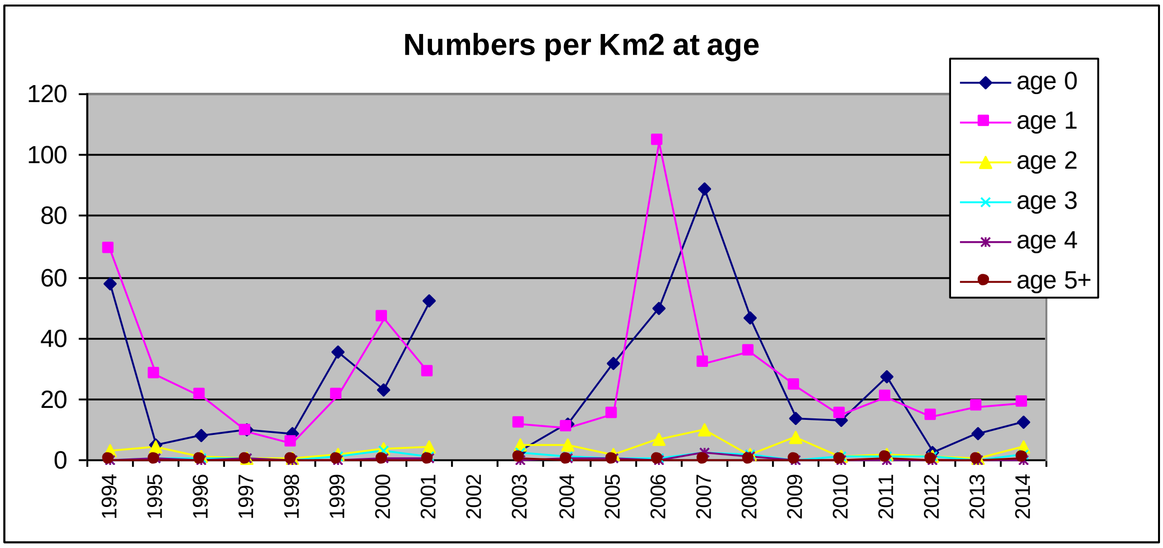


Figure 5.2.5.7.2.2. Hake in GSA 8. Numbers by age per km^2 of MEDITS surveys data.

Figure 5.2.5.7.2.3. shows the trend of overall numbers per Km^2.

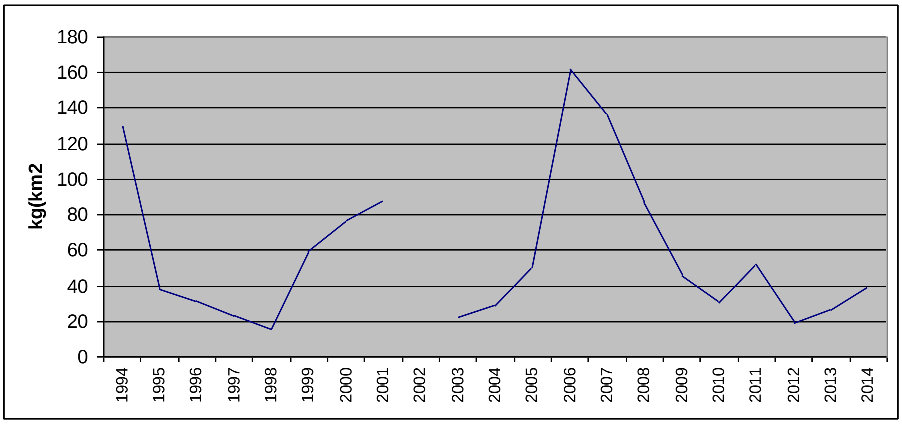


Figure 5.2.5.7.2.3. Overall total numbers per km^2 of MEDITS surveys data.

SURBA needs of information on maturity at age, estimates of natural mortality rates and of mean weight at age. Such information was not available for the area and hence, in order to allow computations, vectors estimated for GSA 7 were used here. The vectors of maturity at age, M and stock weight at age were as follows:

MATURITY AT AGE

	0	1	2	3	4	5+
2003	0.06	0.23	0.72	0.92	0.99	1
2004	0.06	0.23	0.72	0.92	0.99	1
2005	0.06	0.23	0.72	0.92	0.99	1
2006	0.06	0.23	0.72	0.92	0.99	1
2007	0.06	0.23	0.72	0.92	0.99	1
2008	0.06	0.23	0.72	0.92	0.99	1
2009	0.06	0.23	0.72	0.92	0.99	1
2010	0.06	0.23	0.72	0.92	0.99	1
2011	0.06	0.23	0.72	0.92	0.99	1
2012	0.06	0.23	0.72	0.92	0.99	1
2013	0.06	0.23	0.72	0.92	0.99	1
2014	0.06	0.23	0.72	0.92	0.99	1

NATURAL MORTALITY

2003	0.88	0.43	0.33	0.25	0.22	0.2
2004	0.88	0.43	0.33	0.25	0.22	0.2
2005	0.88	0.43	0.33	0.25	0.22	0.2
2006	0.88	0.43	0.33	0.25	0.22	0.2
2007	0.88	0.43	0.33	0.25	0.22	0.2
2008	0.88	0.43	0.33	0.25	0.22	0.2
2009	0.88	0.43	0.33	0.25	0.22	0.2
2010	0.88	0.43	0.33	0.25	0.22	0.2
2011	0.88	0.43	0.33	0.25	0.22	0.2
2012	0.88	0.43	0.33	0.25	0.22	0.2
2013	0.88	0.43	0.33	0.25	0.22	0.2
2014	0.88	0.43	0.33	0.25	0.22	0.2

WEIGHT AT AGE

2003	0.024	0.086	0.351	0.687	1.776	2.603
2004	0.024	0.086	0.351	0.687	1.776	2.603
2005	0.024	0.086	0.351	0.687	1.776	2.603
2006	0.024	0.086	0.351	0.687	1.776	2.603
2007	0.024	0.086	0.351	0.687	1.776	2.603
2008	0.024	0.086	0.351	0.687	1.776	2.603
2009	0.024	0.086	0.351	0.687	1.776	2.603
2010	0.024	0.086	0.351	0.687	1.776	2.603
2011	0.024	0.086	0.351	0.687	1.776	2.603
2012	0.024	0.086	0.351	0.687	1.776	2.603
2013	0.024	0.086	0.351	0.687	1.776	2.603
2014	0.024	0.086	0.351	0.687	1.776	2.603

Different hypothesis of catchability at age were tested. Values set as (q(0) = 0.5, 1.0 for age classes 1 and 2 and 0.8, 0,55, and 0,4 respectively for the successive age classes constituted the vector producing the better fitting. For the age classes not well represented in the samples, a lower weight (influence) was assigned for the computations.

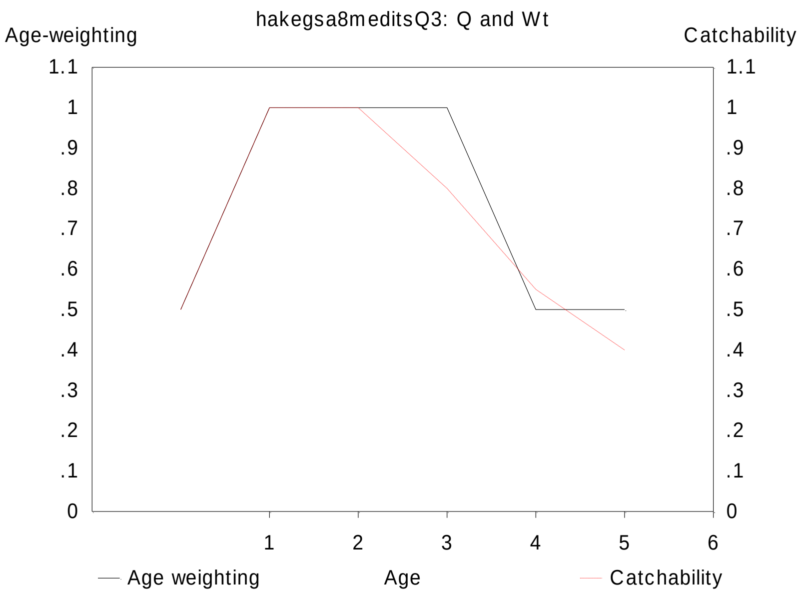


Fig. 5.2.5.7.3.1. Hake in GSA 8. Hypotheses for catchability and weight of the different age classes in the computations used in the SURBA analysis.

5.2.5.6.3 Results

Due to the limited number of hauls and overall number of caught individuals, the decline in numbers did not always follow the expected exponential decline nor linear after the Log transformation shape.

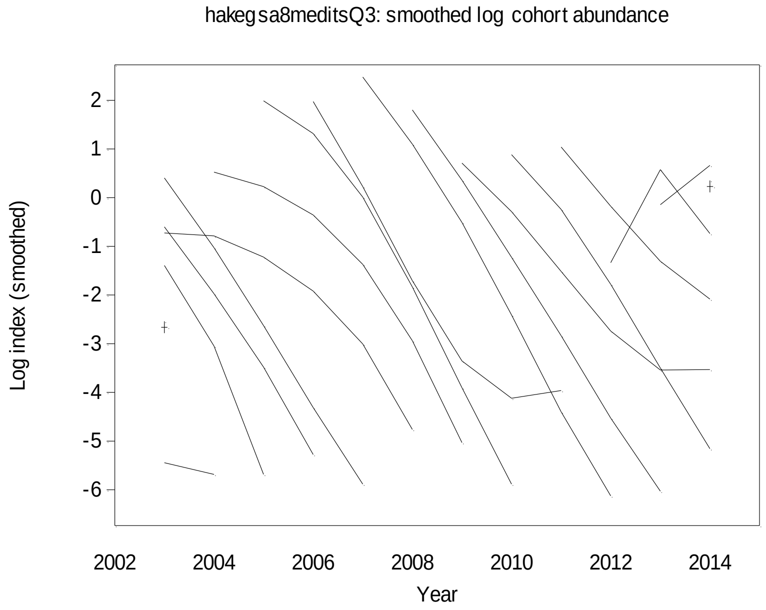


Fig. 5.2.5.7.3.1. Hake in GSA 8. Log cohort abundances at age from the SURBA analysis.

There were analysed the residuals by age. In figure 5.2.5.7.3.2 it is observed that age 0 is rather noisy, and that there are large residuals for ages 4 and 5, but that there is no overall pattern in residuals. These high residuals persisted even after imposed alternative selection patterns by age.

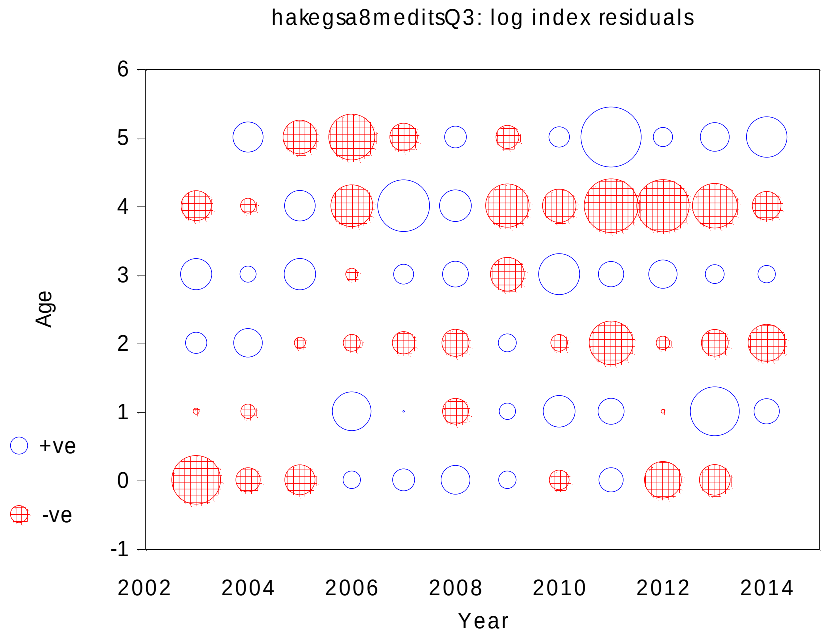


Fig. 5.2.5.7.3.2. Hake in GSA 8. Residuals by age of the SURBA analysis.

Figure 5.2.5.7.3.3. Hake in GSA 8. Fitting of the different cohorts from the SURBA analysis.

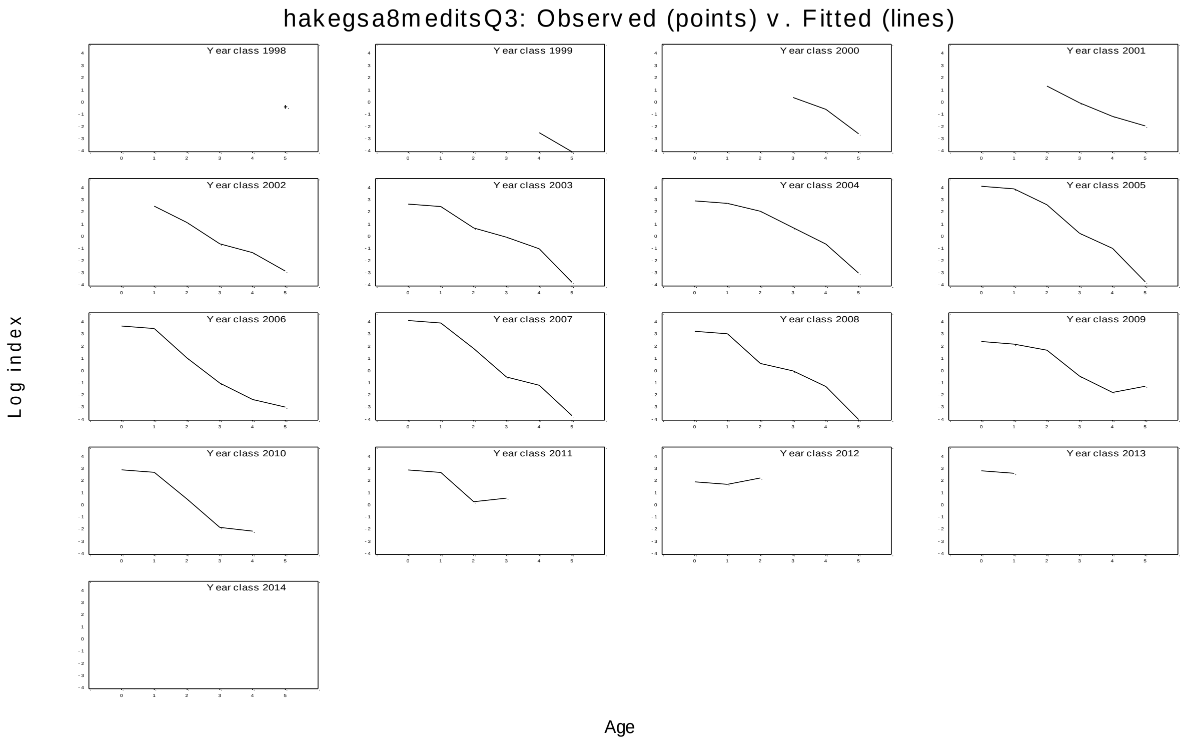
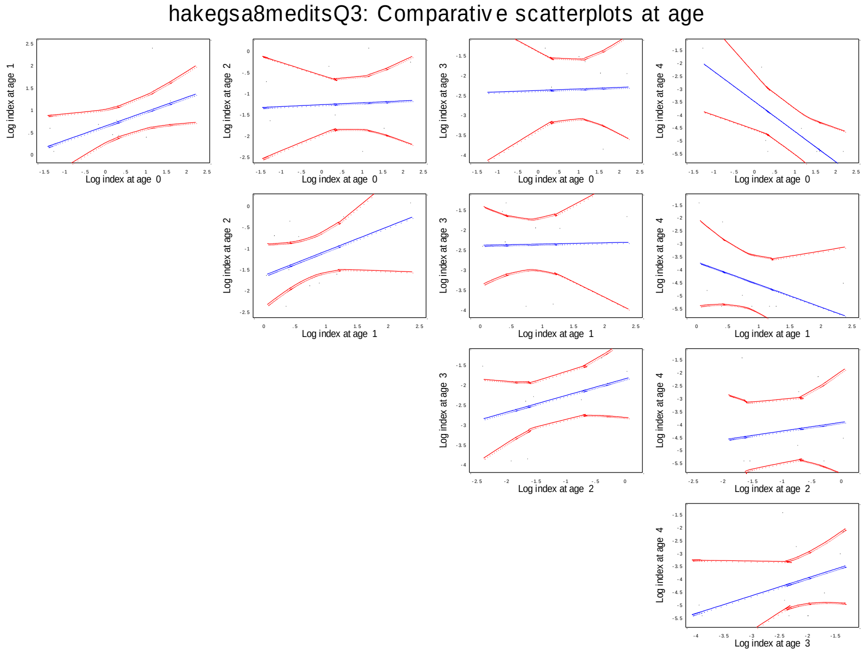


Fig. 5.2.5.7.3.3. Hake in GSA 8. Scatter plots of log indices at consecutive ages from the SURBA analysis.

Figure 5.2.5.7.3.4 illustrates comparative scatterplots of Log indices between different ages.

Fig. 5.2.5.7.3.4. Hake in GSA 8. Cohorts comparison from the SURBA analysis.



The retrospective analysis results are shown in the next figure.

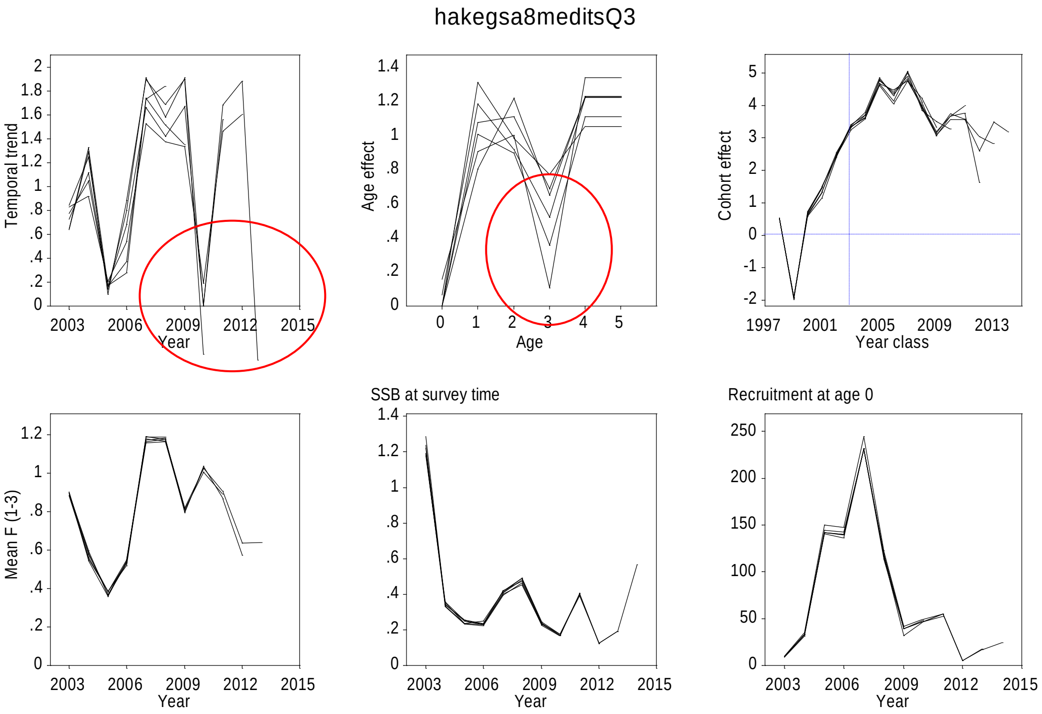


Fig. 5.2.5.7.3.5. Hake in GSA 8. Retrospective analysis from the SURBA analysis.

Figure *5.2.5.7.3.6* shows the residuals for each age. We can notice clear trends in some ages which indicates a poor fitting of the model.

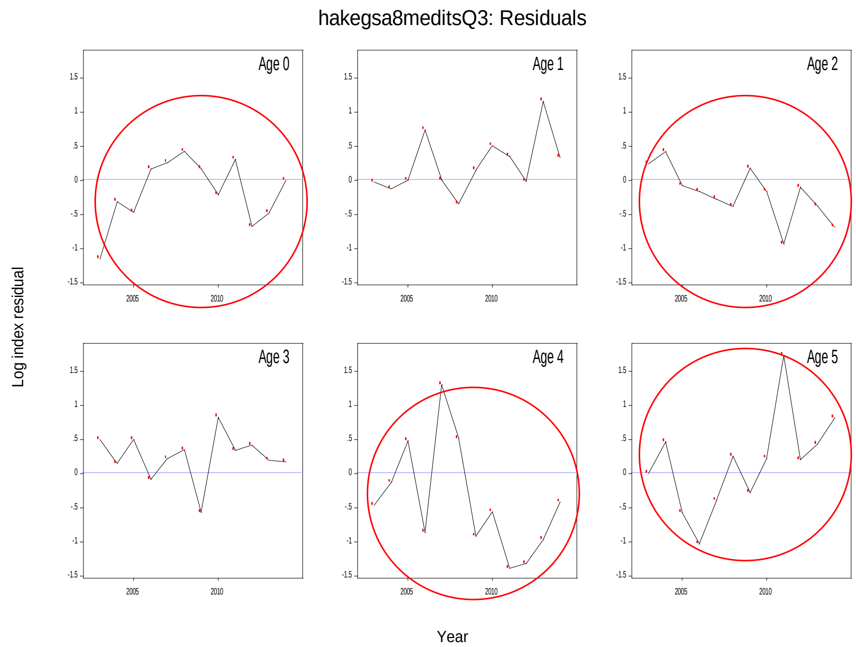


Fig. 5.2.5.7.3.6. Hake in GSA 8. Residuals by age from the SURBA analysis.

Despite the bad fitting of the model, results (even though uncertain) suggest for SSB a relative higher initial value and a drastic drop in the successive year (2004) followed by a period of fairly stable low levels. F in the study period (2003-2014) varied between a minimum of about 0.4 in 2005 to a maximum of 1.2 in years 2007-2008. There are observed two extremely low values for years 2010 and 2014 (Fig . 5.2.5.7.3.7).

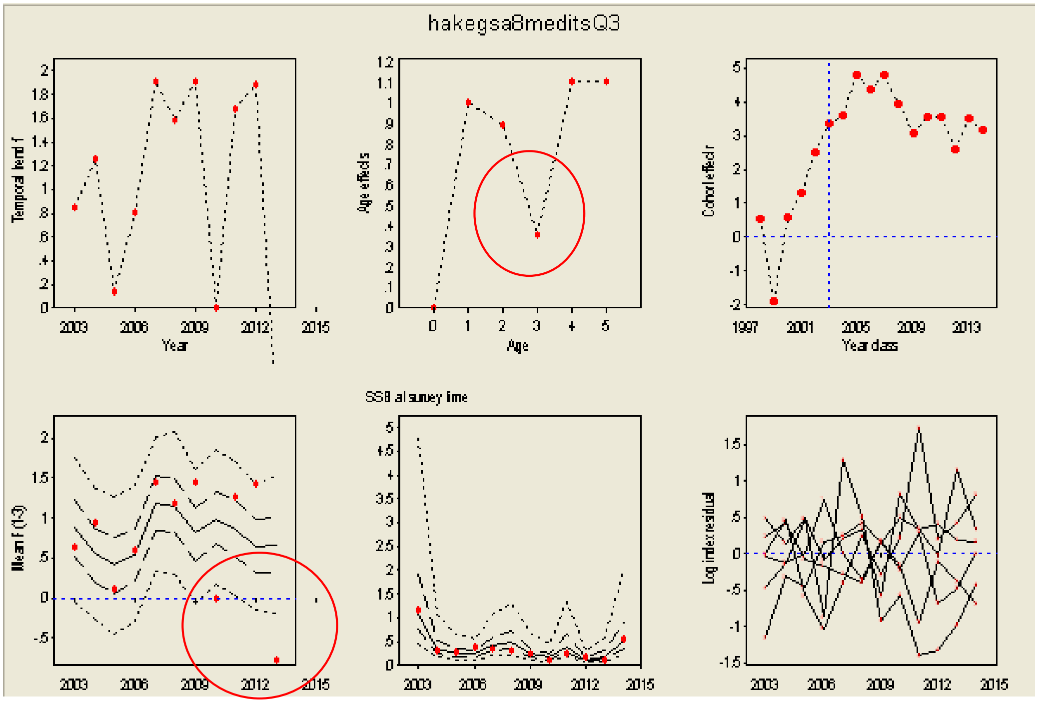


Fig. 5.2.5.7.3.7. Hake in GSA 8. Main outputs of the SURBA analysis.

5.2.5.7 Reference points

5.2.5.7.1 Methods

No reference points were defined because the model was not accepted. In any case, estimation of such RPs was unfeasible as F vectors for defining the exploitation pattern are not available for the stock.

5.2.5.8 Data quality

DCF data quality is deficient for this particular species. Catch data, proceeding from the limited number of trawlers cover only the period 2010-2014. Landings are too low in all the years where data are available. Age structure of the catch is not available due to the scarce commercial interest of this species in the area. Surveys data were used for performing a rough assessment of the exploitation status of the stock and evolution of some parameters, but results cannot be considered reliable due to the bad fitting of data to the model. Such uncertain results can be mainly due to the limited number of individuals caught in the scarce number of tows (23) that each year are carried out in this area. Moreover, the presence of a gap in the time series, due to a technical problem that made impossible the utilization of the research vessel to carry out the cruise in 2002, likely had a negative effect in the quality of the analysis.

5.2.5.9 Short term predictions 2016-2018

Not conducted due to the fact that the assessment was not accepted.

5.2.5.10 Medium term predictions

Not conducted due to the fact that the assessment was not accepted.

5.2.5.11 Stock advice

No advice is given for this stock because the assessment was not accepted.

5.2.6 STOCK ASSESSMENT OF HAKE IN GSA 9

5.2.6.1 Stock Identification

Due to a lack of information about the structure of hake population in the western Mediterranean, this stock was assumed to be confined within the GSA 9 boundaries (Figure 5.2.6.1.1).

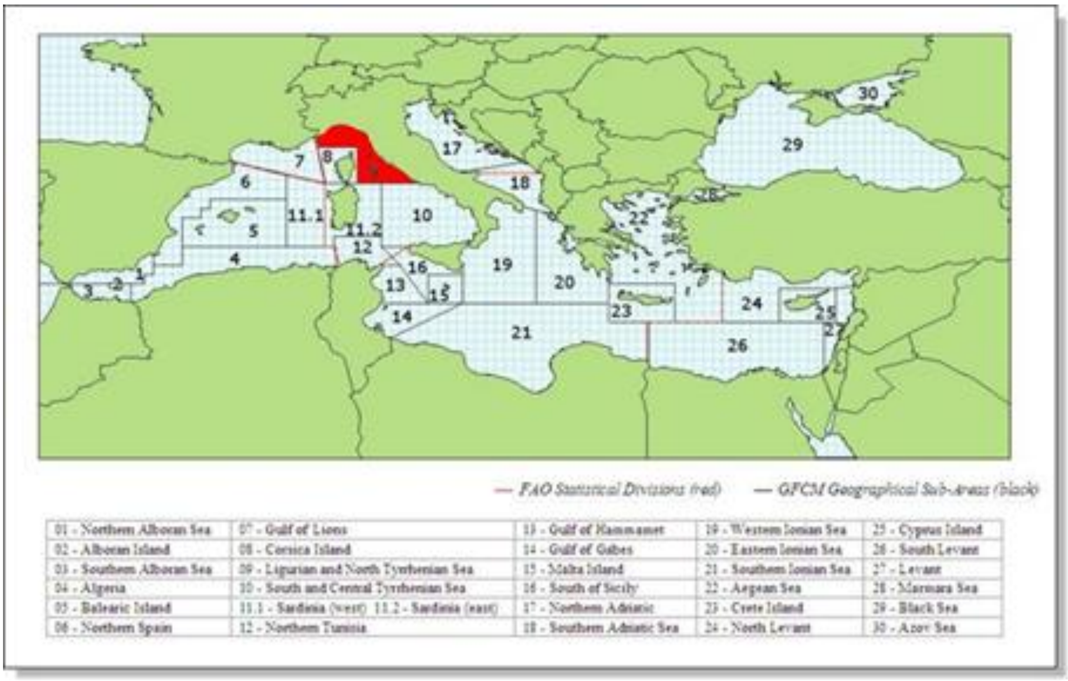


Figure 5.2.6.1.1. Geographical location of GSA 9.

Hake is distributed in the whole area between 10 and 800 m depth (Biagi *et al.,* 2002; Colloca *et al.,* 2003). Recruits peak in abundance between 150 and 250 m depth over the continental shelf-break and appear to move slightly deeper when they reach 10 cm total length. Crinoid (*Leptometra phalangium*) bottoms over the shelf-break are the main settlement habitat for hake in the area (Colloca *et al.,* 2004, 2006; Reale *et al.,* 2005). Migration from nurseries takes place when juveniles attained a critical size between 13 and 15.5 cm TL (Bartolino *et al.,* 2008a). Maturing hakes (15-35 cm TL) persist on the continental shelf with a preference for water of 70-100 m depth, while larger hakes can be found in a larger depth range from the shelf to the upper slope. Juveniles show a patchy distribution with some main density hot spots (i.e. nurseries areas) showing a high spatio-temporal persistence (Abella *et al.,* 2005; Colloca *et al.,* 2006; 2009; Jona Lasinio *et al.,* 2007) as also highlighted by the MEDISEH project in areas with frontal systems and other oceanographic structures that can enhance larval transport and retention (Abella *et al.,* 2008).

Although hakes are demersal fish feeding typically upon fast-moving pelagic preys while ambushed in the water column (Alheit and Pitcher, 1995), there is evidence that hakes feed in mid-water or at the surface during night-time, undertaking daily vertical migrations (Orsi-Relini *et al*., 1989, Carpentieri *et al*., 2008) which are more intense for juveniles. In GSA 9 many different studies are available on hake diet. Results from stomach data collected in the 1996-2001 period can be found in Sartor et al. (2003) and Carpentieri et al. (2005). Hake diet shifts from euphausids and mysiids consumed by smaller hake (<16 cm TL), to fishes consumed by larger hake.

Before the transition to the complete ichthyophagous phase (TL> 36 cm) hake shows more generalized feeding habits where decapods, benthic (Gobiidae, *Callionymus* spp.,) and necktonic

fish (*S. pilchardus, E. encrasicolus*) dominated the diet, whereas cephalopods had a lower incidence.
Estimation of cannibalism rate has been provided for the southern part of the GSA (Latium, EU Because project). Cannibalism increased with size and can be considered significant for hakes between 30 and 40 cm TL (up to 20% by weight in diet) and seems to relate closely to hake recruitment density and level of spatial overlapping.
Consumption rate has been estimated for juveniles and piscivorous hakes. Daily consumption of juveniles, calculated in proportion of body weight (%BW), varied between 5 (July) and 5.9 % BW (Carpentieri et al., 2008). The estimated relative daily consumption for hake between 14 and 40 cm TL, using a bioenergetic approach (EU Because project), was between 2.9 and 2.3 BW%.

5.2.6.2 Growth

Juvenile growth rate was estimated to be about 1.5 cm per month using daily growth increments on otoliths (Belcari et al., 2006). According to this growth rate, hake reaches an average length of about 18 cm TL at the end of the first year. According to these observations, the growth of hake in the GSA 9 seems to follow the pattern estimated in the NW Mediterranean (Garcia-Rodriguez and Esteban, 2002) adopting the hypothesis that two rings are laid down on otoliths each year. This new interpretation of otolith ring patterns returns a growth rate (L_{inf} = 103.9, k = 0.212, t_0 =0.031) almost double than that assumed in the past.

5.2.6.3 Maturity

The catchability of hake spawners to the Mediterranean trawl nets is rather limited. The distribution of adults which are more abundant on deeper or untrawlable grounds, or the ability of larger fish to avoid capture have been claimed as causes of the observed extremely reduced catch of adult hake by trawlers in the Mediterranean (Abella *et al.*, 1997). Also during trawl surveys (MEDITS and GRUND) the catch rate of mature specimens was very low, reducing the possibility of use trawl survey data to explore patterns in gonad development as well as the relationships between growth rate and maturation processes.
Large size hake are targets of a specifically targeted gillnet fishery carried out by several vessels working in the southern part (northern and central Tyrrhenian Sea) of the GSA 9 (Sartor *et al*., 2001a).
Reproductive biology and fecundity of hake have been studied in northern Tyrrhenian Sea (Biagi *et al*., 1995; Nannini *et al.*, 2001; Recasens *et al*., 2008) by monthly samplings of adults caught by trawling and gillnets.
Females in advanced maturity stages, spawning and partial post-spawning are present all year round, but reproductive activity is concentrated from January to May, with two peaks of spawning in February and May. The presence of hake spawners seems to be more concentrated in the southern part of GSA 9.
Female length at first maturity was estimated at 35 cm TL in northern Tyrrhenian Sea (Recasens *et al*., 2008). This value is consistent with the observations obtained from trawl surveys over the Latium (Colloca, pers. comm.) reporting first maturity from 31 to 37 cm TL for females and from 21 to 25 cm TL for males.
Batch fecundity was about 200 eggs per gonad-free female gram, with asynchronous oocyte development (Recasens *et al*., 2008).

5.2.6.4 Natural mortality

Natural mortality was estimated using PRODBIOM (Abella *et al.*, 1998) and is shown in Table 5.2.6.4.1. The input parameters used were L_{inf} = 103.9, k = 0.212, t_0 =0.031, a = 0.006657 and b = 3.028.

Table 5.2.6.4.1. Hake in GSA 9. Natural mortality.

Age	M
0	1.2
1	0.62
2	0.44
3	0.37
4	0.33
5	0.31
6+	0.29

5.2.6.5 Fisheries

5.2.6.5.1 General description of the fisheries

Hake is one of the main target species of bottom trawlers in the GSA 9 in terms of landings, incomes and vessels involved. The analysis of available information suggests that about 50% of landings of hake are obtained by bottom trawl vessels, the remaining fraction being provided by artisanal vessels using set nets, in particular gillnets.

The trawl fleet of GSA 9 accounted for 197 vessels in 2014 based in several ports: Viareggio, Livorno, Porto Santo Stefano, Civitavecchia, Fiumicino, Anzio, Terracina, Gaeta, Formia. They accomplish daily fishing trips exploiting both continental shelf and slope areas. Hake fishing grounds comprise all the soft bottoms of continental shelves and the upper part of continental slope. Fishing pressure shows a spatial pattern inside the GSA 9 according to the consistency of the fleets and the distance of the fishing grounds from the main ports.

The artisanal fleets, according to the last official data (2014), accounted for 1006 vessels that operate in several harbours along the continental and insular coasts.

5.2.6.5.2 Management regulations applicable in 2015

- Fishing closure for trawling: 45 days in late summer (not every year have been enforced).
- Minimum landing sizes: EC regulation 1967/2006: 20 cm TL for hake.
- Cod end mesh size of trawl nets: 40 mm square meshes or 50 mm (stretched) diamond meshes.
- Towed gears are not allowed within three nautical miles from the coast or at depths less than 50 m when this depth is reached at a distance less than 3 miles from the coast.
- Two small No Take Zones (“Zone di Tutela Biologica”, ZTB) are present inside the GSA 9; one off the Giglio Island (50 km^2, northern Tyrrhenian Sea) another off Gaeta, (125 km^2, central Tyrrhenian Sea). Bottom fishing was not allowed in the two ZTB. A recent regulation of the Italian Ministry of Agricultural, Food and Forestry Policies has established that fishing activity can be carried out in these two areas from July 1^{st} to December 31^{st}.

5.2.6.5.3 Landings

Landings data were reported to STECF EWG 15-11 through the DCF. In GSA 09 the bulk of catches (64% in weight) are from otter trawl, while artisanal fisheries represents the rest of the catches. The largest individuals are caught by gillnets.

Table 5.2.6.5.4.1. Hake in GSA 9. Annual landings (t) by gear in GSA 9 from the DCF data.

	OTB	GNS	GTR	PS
2002	508.16	154.32	236.15	7.21
2003	1147.56	658.51	258.39	15.40
2004				
2005				
2006	1179.96	592.57	403.96	
2007	1024.96	576.22	131.85	
2008	914.77	345.23	61.12	
2009	853.24	401.26	53.98	
2010	834.14	576.26	56.71	
2011	795.36	502.08	54.30	
2012	653.57	309.33	48.62	
2013	1044.30	199.21	98.12	
2014	1010.37	177.73	76.85	

Before 2006 the data are incomplete and will not be used for the stock assessment. The time series of landings data (tons) by gear for the period 2006-2014 is shown in Figure 5.2.6.5.4.1. Maximum landings values are observed in 2006 and minimum values in 2012.

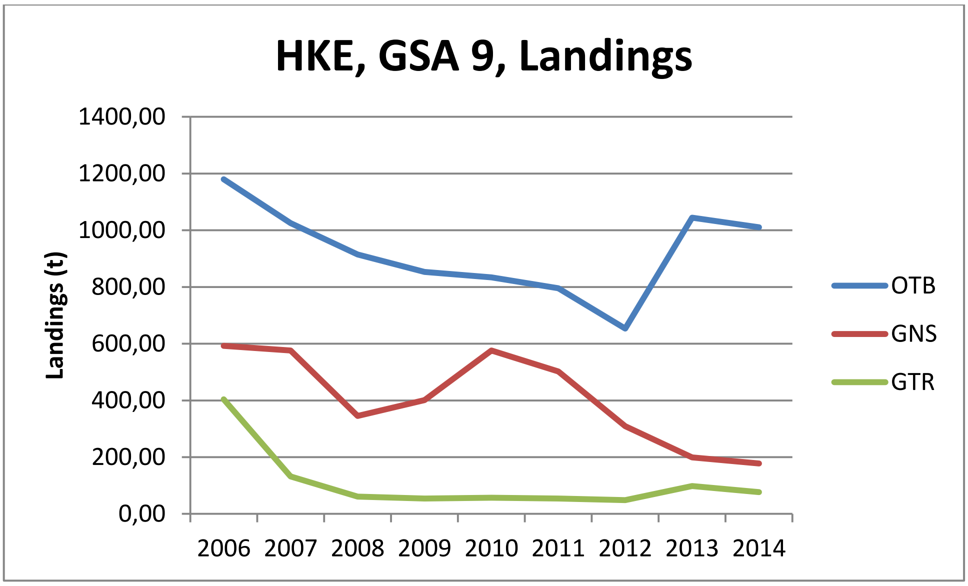


Figure 5.2.6.5.4.1. Hake in GSA 9. Total annual landings by gear for the period 2006-2014.

Figure 5.2.6.5.4.2 shows the size structure of landings from 2006 to 2014. The landing composition of fisheries exploiting hake is showed in Figure 5.2.6.5.4.3.

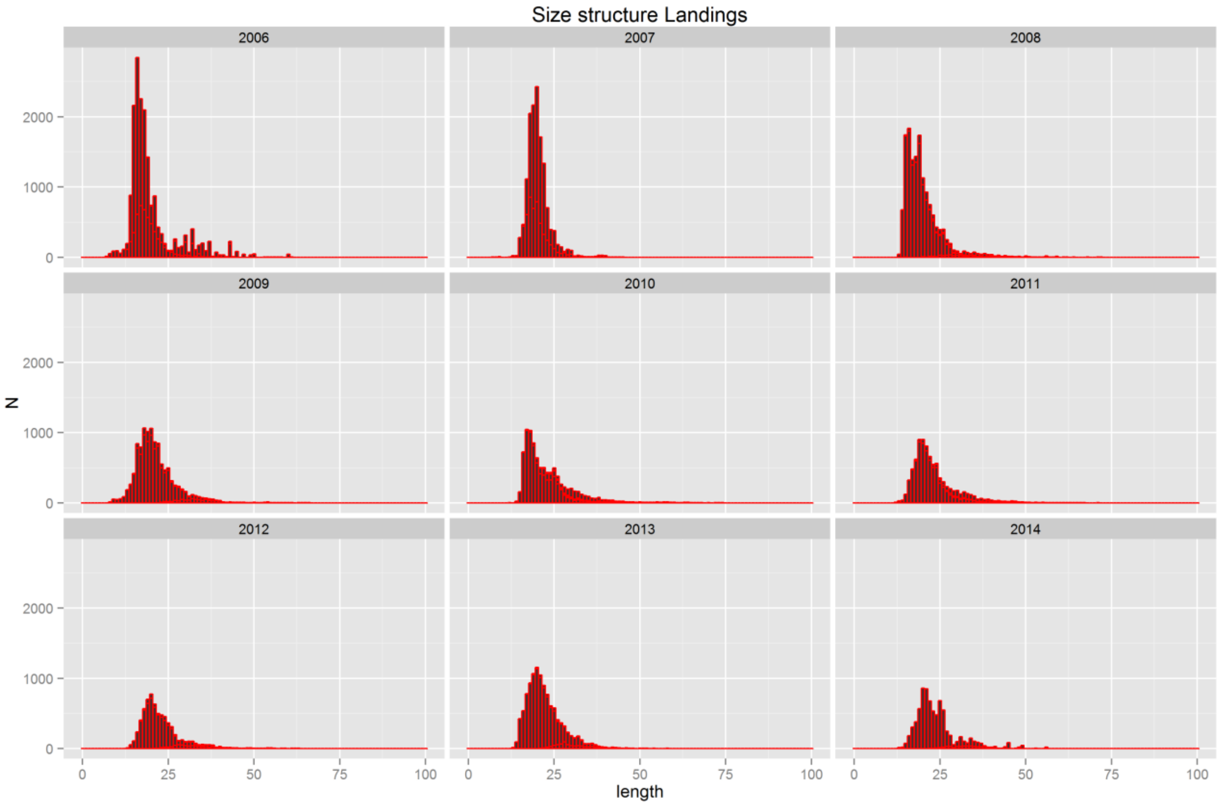
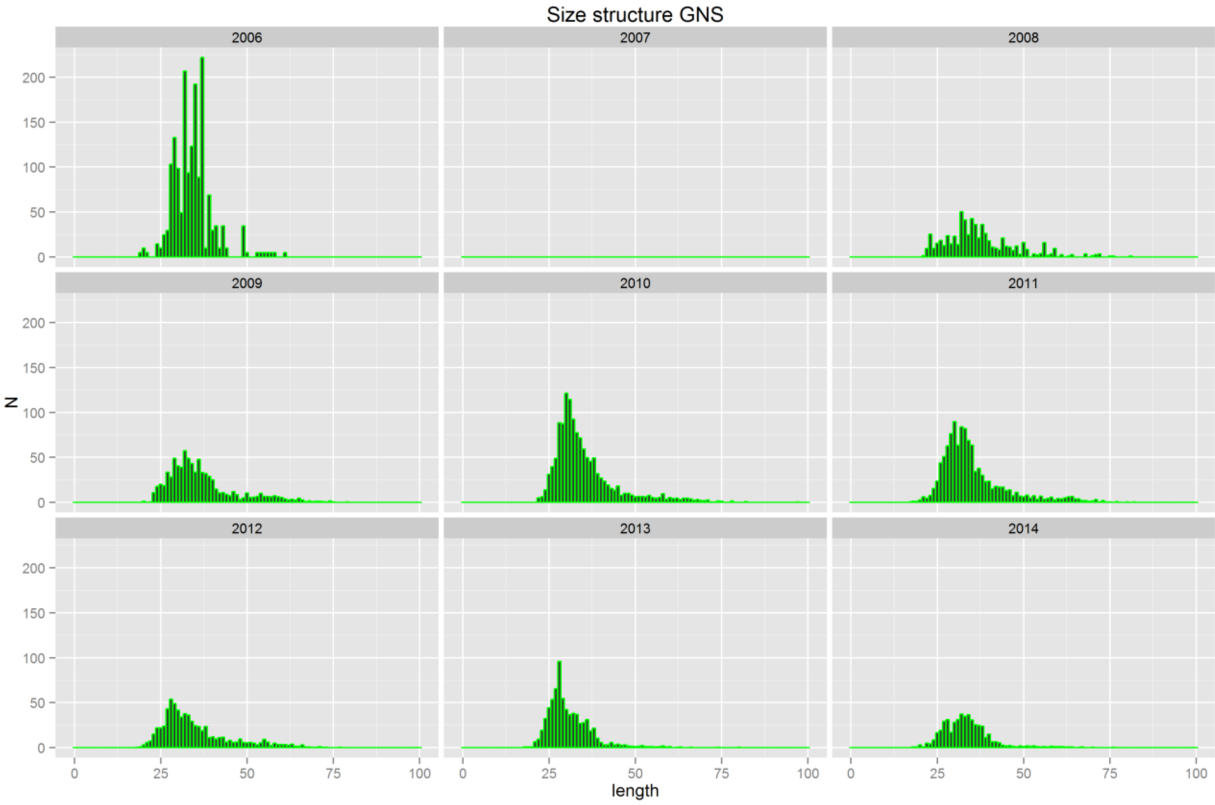
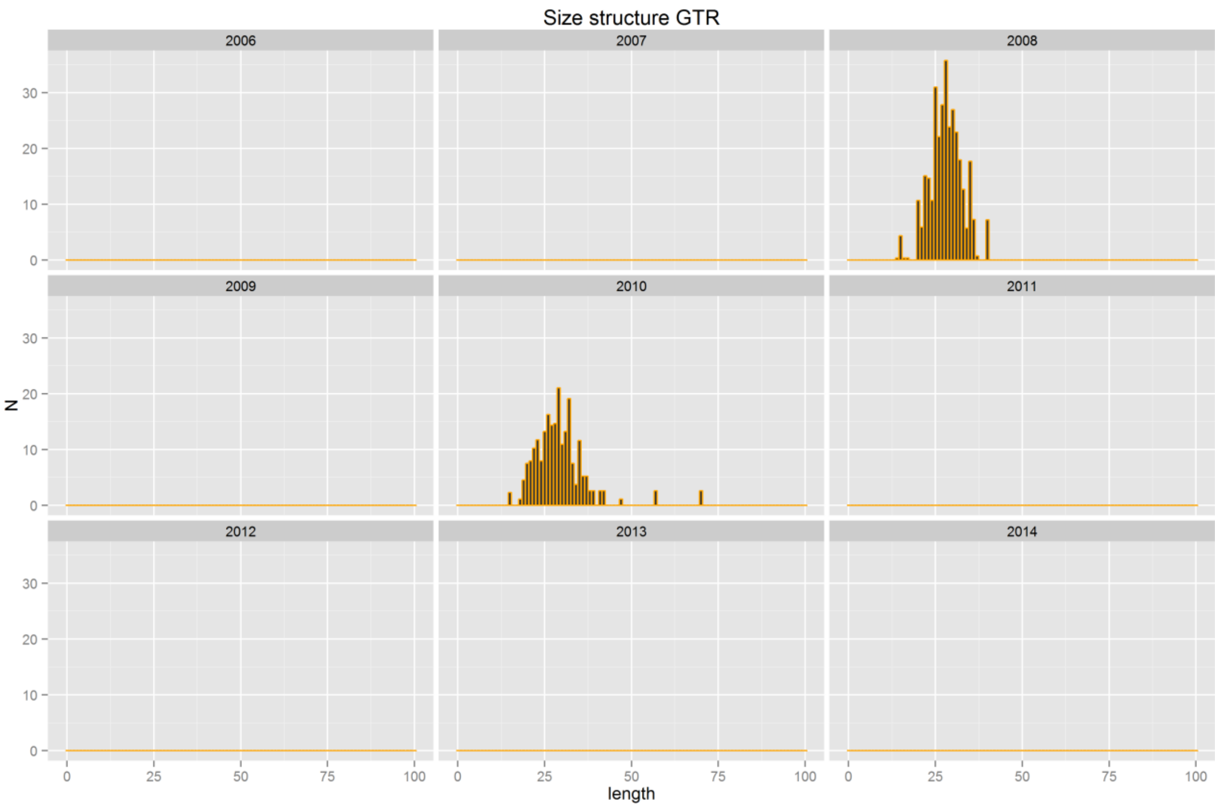


Figure 5.2.6.5.4.2. Hake in GSA 9. Size structure of the landings from 2006 to 2014.


Size structure GNS
2006
2007
2008
2009
2010
2011
2012
2013
2014
N
length


Size structure GTR
2006
2007
2008
2009
2010
2011
2012
2013
2014
N
length

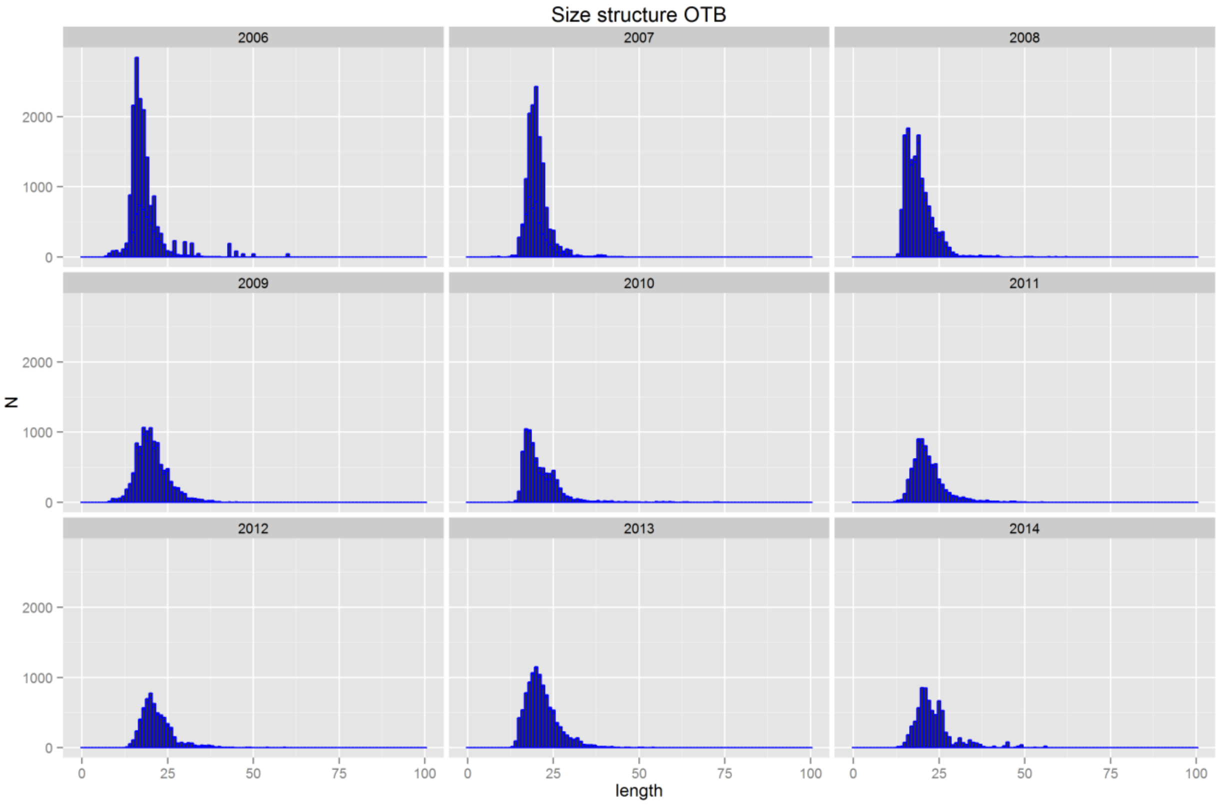


Figure 5.2.6.5.4.3. Hake in GSA 9. Size composition of the landings by year and fishery.

DCF data on age structure of European hake landings in GSA 9 were available for the period 2006-2014, and are shown in Figure 5.2.6.5.4.4.

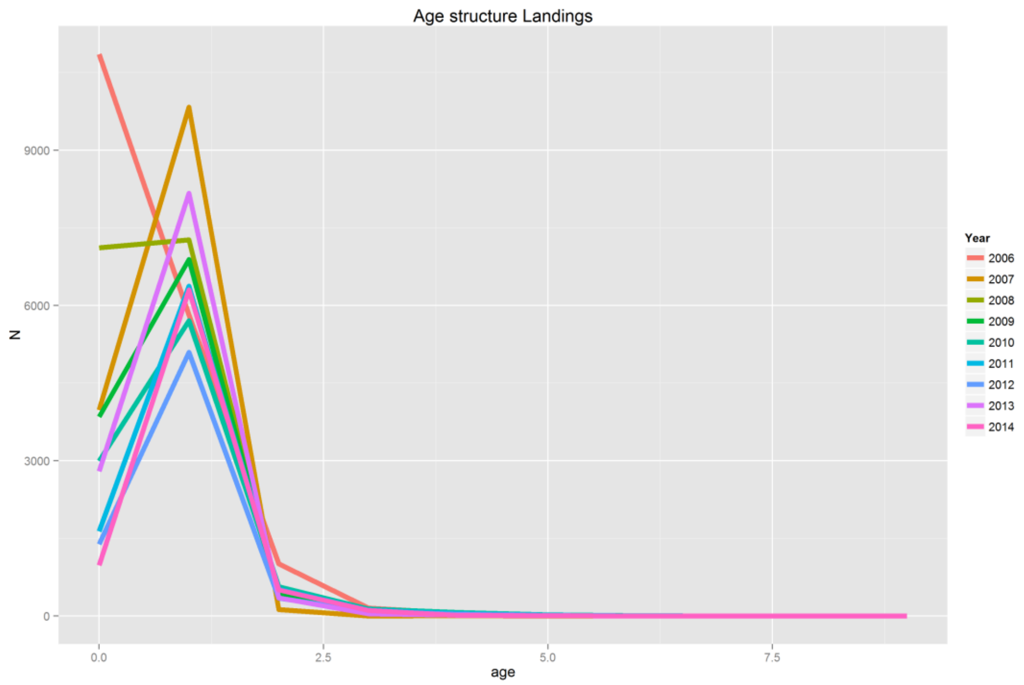


Figure 5.2.6.5.4.4. Hake in GSA 9. Age frequency distribution of the landings from 2006 to 2014 as obtained from the DCF.

5.2.6.5.4 Discards (by fleet if posible)

Discards data were reported to STECF EWG 15-11 through the DCF. Information on OTB discards was available for 2006 and from 2009 to 2014.

Several EU and national projects carried out in GSA 9 highlighted the problem of hake trawl discards. High quantities of hake are routinely discarded, especially in summer and on the fishing grounds located near the main nursery areas (Table 5.2.6.5.5.1).

The size at which 50% of the specimens caught is discarded is progressively increased in the last years from about 11 cm TL in 1995 (Sartor *et al*., 2001b) to about 17 cm TL in 2006 (De Ranieri, 2007), due to the introduction of the EU Regulations on minimum sizes. This phenomenon might be also explained by a reduction of the fishing pressure on the nursery areas.

Table 5.2.6.5.5.1. Hake in GSA 9. Annual OTB landings and discards in tons.

	OTB	**OTB Discards**
2006	1179.96	105.20
2007	1024.96	
2008	914.77	
2009	853.24	697.27
2010	834.14	116.41
2011	795.36	527.79
2012	653.57	174.23
2013	1044.30	242.43
2014	1010.37	285.84

Data on the length frequency of discards is available for the same years and is shown in Figure 5.2.6.5.5.1.

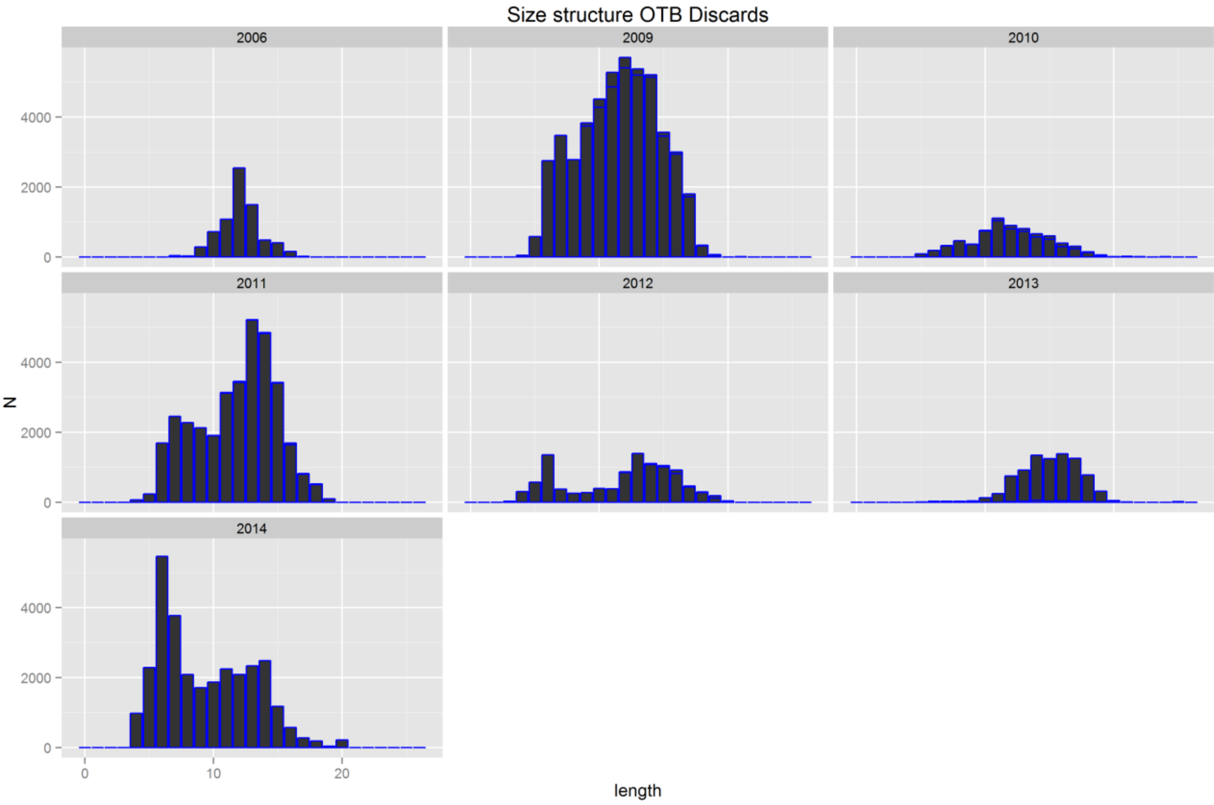


Figure 5.2.6.5.5.1. Hake in GSA 9. Size composition of the OTB discards by year.

5.2.6.5.5 Fishing effort

The fishing capacity of the GSA 9 has shown in these last 20 years a progressive decrease. Fishing effort (kW*fishing days) performed by the GSA 09 trawlers decreased of 26% since 2004, from about 15,000,000 to 11,000,000 in 2014. The effort displayed by the artisanal fleet exploiting hake remained constant for vessels using trammel nets (GTR) whereas the effort of gillnetters decreased abruptly (-61%) from 2011 (Figure 5.2.6.5.6.1).

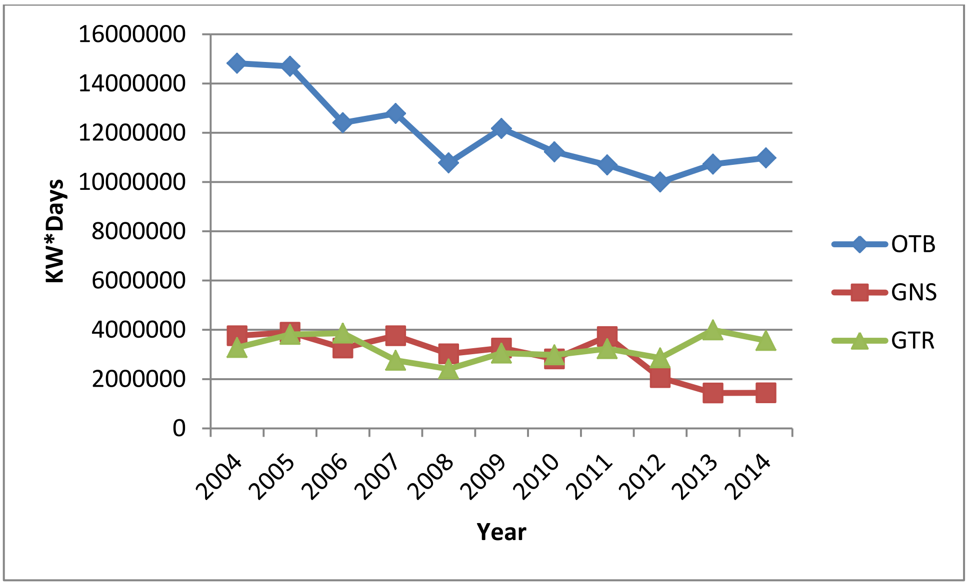


Figure 5.2.6.5.6.1. Effort trends (days and kW*days) by major fleets, 2004-2014.

5.2.6.6 Scientific surveys

5.2.6.6.1 Survey #1 (MEDITS)

5.2.6.6.1.1 Methods

Based on the DCF data call, abundance and biomass indices were recalculated. In GSA 9 the following numbers of hauls were reported per depth stratum (Table 5.2.6.6.1.1.1).

Table 5.2.6.6.1.1.1. Numbers of hauls per year and depth stratum in GSA 9, 1994-2014.

Row Labels	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
GSA09_010-050	21	20	20	20	21	20	20	20	15	15	15
GSA09_050-100	21	21	20	22	20	21	22	22	17	17	17
GSA09_100-200	38	39	40	38	39	39	38	38	30	30	30
GSA09_200-500	40	40	40	41	40	41	42	42	33	31	34
GSA09_500-800	33	33	33	32	33	32	31	31	25	27	24

Row Labels	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
GSA09_010-050	16	15	15	16	16	15	15	15	16	15
GSA09_050-100	16	18	18	16	16	19	18	17	17	19
GSA09_100-200	31	29	29	31	31	29	30	31	30	29
GSA09_200-500	34	35	35	34	34	34	33	35	35	36
GSA09_500-800	23	23	23	23	23	23	24	22	22	21

Data were assigned to strata based upon the shooting position and average depth (between shooting and hauling depth). Catches by haul were standardized to 60 minutes hauling duration. Hauls noted as valid were used only, including stations with no catches of hake, red mullet or pink shrimp (zero catches are included).

The abundance and biomass indices by GSA were calculated through stratified means (Cochran, 1953; Saville, 1977). This implies weighting of the average values of the individual standardized catches and the variation of each stratum by the respective stratum areas in each GSA:

$$Yst = \Sigma (Yi*Ai) / A$$

$$V(Yst) = \Sigma (Ai^2 * si^2 / ni) / A^2$$

Where:
A=total survey area
Ai=area of the i-th stratum
si=standard deviation of the i-th stratum
ni=number of valid hauls of the i-th stratum
n=number of hauls in the GSA
Yi=mean of the i-th stratum
Yst=stratified mean abundance
V(Yst)=variance of the stratified mean

The variation of the stratified mean is then expressed as the 95 % confidence interval: Confidence interval = Yst ± t(student distribution) * V(Yst) / n.

It was noted that while this is a standard approach, the calculation may be biased due to the assumptions over zero catch stations, and hence assumptions over the distribution of data. A normal distribution is often assumed, whereas data may be better described by a delta-distribution, quasi-poisson. Indeed, data may be better modelled using the idea of conditionality and the negative binomial (e.g. O'Brien et al. 2004).
Length distributions represented an aggregation (sum) of all standardized length frequencies (subsamples raised to standardized haul abundance per hour) over the stations of each stratum. Aggregated length frequencies were then raised to stratum abundance * 100 (because of low numbers in most strata) and finally aggregated (sum) over the strata to the GSA. Given the sheer number of plots generated, these distributions are not presented in this report.

5.2.6.6.1.2 Geographical distribution

According to recent studies (Orsi Relini *et al.*, 2002), the density of hake recruits concentrations in nursery areas in GSA 9 is by far higher than that of the other GSAs of the western Mediterranean and, probably, also of the other Mediterranean GSAs (Figure 5.2.6.6.1.2.1).

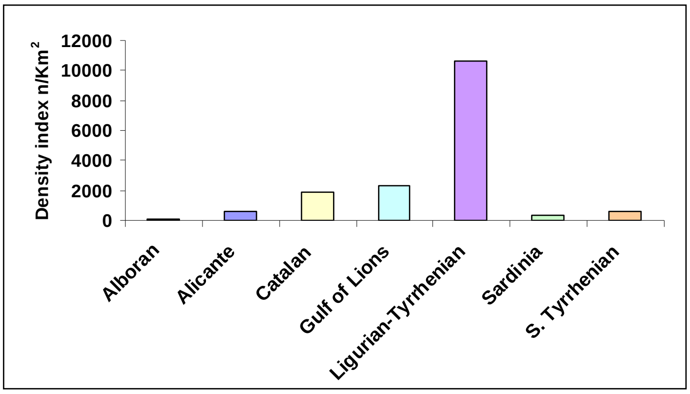


Figure 5.2.6.6.1.2.1. Hake in GSA 9. MEDITS density indices of the hake recruits (<12 cm TL) obtained in different Mediterranean GSAs (from Orsi-Relini et al., 2002, modified).

Generalized additive models were developed to investigate hake recruitment dynamics in the Tyrrhenian Sea in relation to spawner abundance and selected key oceanographic variables. Thermal anomalies in summer, characterized by high peaks in water temperature, revealed a negative effect on the abundance of recruits in autumn, probably due to a reduction in hake egg and larval survival rate. Recruitment was reduced when elevated sea-surface temperatures were coupled with lower levels of water circulation. Enhanced spring primary production, related to late winter low temperatures could affect water mass productivity in the following months, thus influencing spring recruitment. In the central Tyrrhenian a dome-shaped relationship between wind mixing in early spring and recruitment could be interpreted as an "optimal environmental window" in which intermediate water mixing level played a positive role in phytoplankton displacement, larval feeding rate and appropriate larval drift (Bartolino *et al.*, 2008b) (Figure 5.2.6.6.1.2.2).

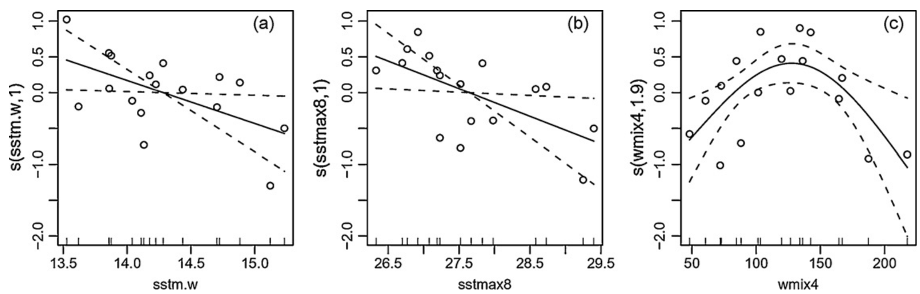


Figure 5.2.6.6.1.2.2. Hake in GSA 9. Effects of: (a) sstm.w, (b) sstmax8 and (c) wmix4 on hake recruitment in the central Tyrrhenian (from Bartolino *et al.,* 2008b).

The temporal trend in spatial distribution of hake > 26 cm TL showed a clear reduction of distribution area, particularly in the Tyrrhenian part of the GSA (GRUND data, Figure 5.2.6.6.1.2.3).

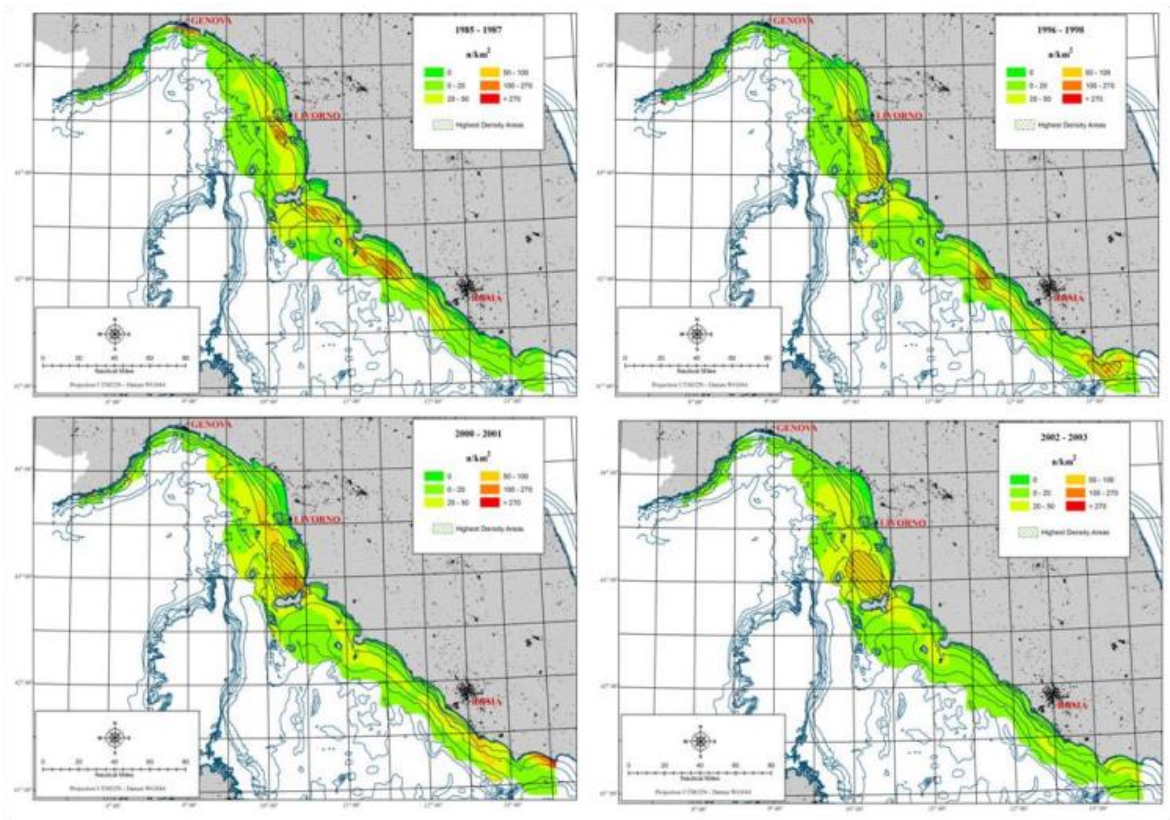
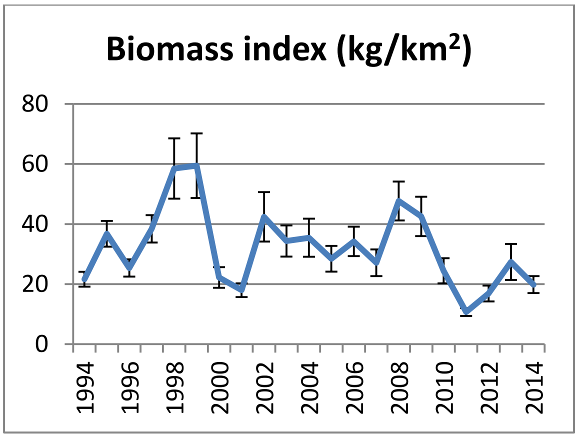


Figure 5.2.6.6.1.2.3. Hake in GSA 9. Distribution of individuals larger than 26 cm TL in 1985-87, 1996-98, 2000-01, 2002-03.

5.2.6.6.1.3 Trends in abundance and biomass

Figure 5.2.6.6.1.3.2 displays the re-estimated trend in hake abundance and biomass in GSA 9 (kg/km^2) based on the MEDITS DCR data call. Both biomass and density showed large fluctuations without temporal trends.



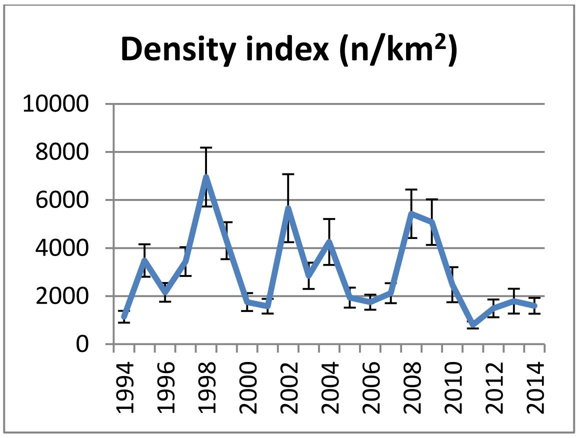


Figure 5.2.6.6.1.3.2. Hake in GSA 9. MEDITS time series of survey biomass and density indices (mean +/- standard deviation).

5.2.6.6.1.4 Trends in abundance by length or age

The following Figure 5.2.6.6.1.4.1 displays the stratified abundance indices of European hake in GSA 9 from 1994 to 2014.

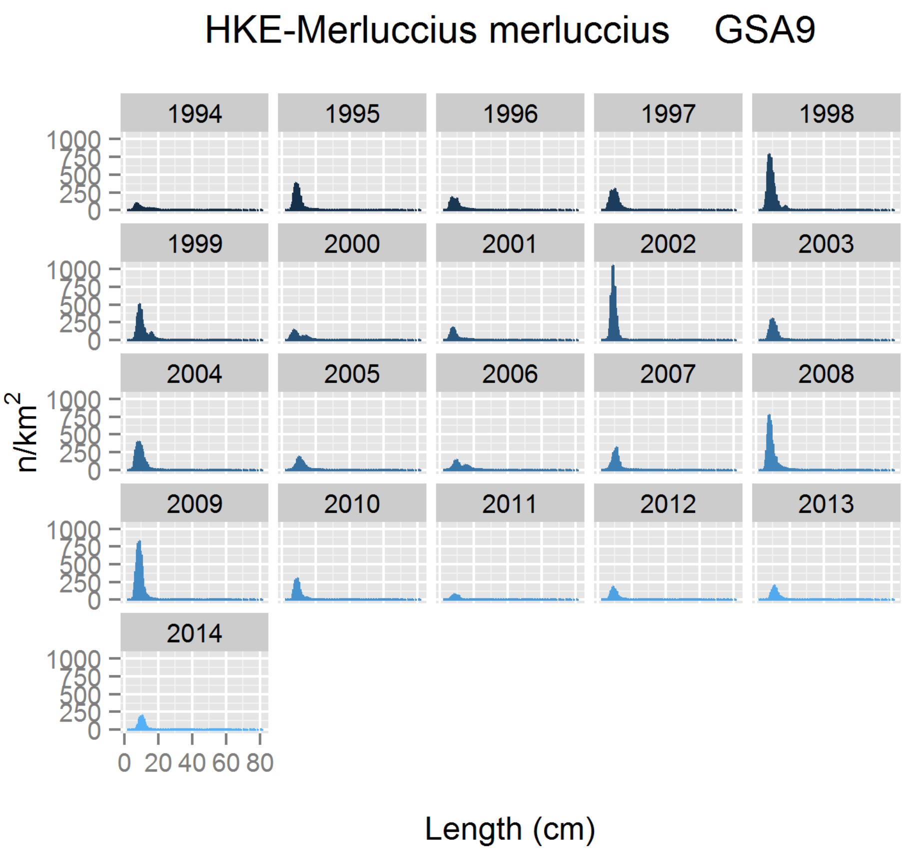


Figure 5.2.6.6.1.4.1. Hake in GSA 9. Stratified abundance indices by size, 1994-2014.

5.2.6.7 *Stock Assessment*

5.2.6.7.1 *Method: XSA*

FLR libraries were employed in order to carry out an XSA based assessment (Darby and Flatman, 1994). This stock was assessed for the last time during in EWG 14-09: XSA was performed using as input data the period 2005-2013. XSA has been carried out this time using as input data the period 2006-2014 for the catch data and 2006-2014 for the tuning file because the data in the database have been changed.

5.2.6.7.2 *Input data*

The growth parameters used for VBGF were L_{inf}= 103.9 cm TL; K = 0.212 yr^{-1}; t_0= 0.031 yr. The length-to-weight coefficients used were a= 0.006657, b= 3.028.
Catch numbers have been raised taking into account the LFD that were missing for some years and gears. For GNS and GTR in 2007 the LFD of GNS 2006 was used to raise the landings, for GTR of the other missing years the LFD of GNS of the same years were used. Discards for OTB in 2007 and 2008 were estimated as the mean discard % of the entire time-series (35.59%, 2007=364 tons and 2008=325 tons). The LFD of OTB discards of 2009 were used to raise the discards.
LFDA 5.0 slicing software has been used to transform the annual size distribution of the landings and MEDITS LFDs in age distributions in order to apply XSA model.
Zero values in the catch at age have been substituted with the lowest value in the time series.
Table 5.2.6.7.2.1 lists the input parameters to the XSA, namely landings, catch number at age, weight at age, maturity at age, natural mortality at age and the tuning series at age (MEDITS). Natural mortality values (vector) were computed with the PROBIOM routine.

Table 5.2.6.7.2.1. Hake in GSA 9. Input data to the XSA model.

Catch (t)

2006	2007	2008	2009	2010	2011	2012	2013	2014
2281.69	2097.81	1646.69	2005.74	1583.52	1879.53	1185.75	1584.06	1550.79

Catch number at age matrix (thousands)

Age	2006	2007	2008	2009	2010	2011
0	23197.434	32439.190	35592.882	60804.151	11959.687	41216.305
1	5961.151	7990.058	5751.982	6327.486	5038.450	5913.918
2	1351.802	691.831	383.198	403.203	514.133	529.379
3	170.594	73.124	92.520	105.076	132.456	96.099
4	59.429	10.484	15.488	39.848	53.847	52.529
5	1.704	1.704	11.567	9.220	25.831	13.009
6+	1.101	1.101	3.590	1.935	5.523	2.465

Age	2012	2013	2014
0	12689.716	13083.162	30613.053
1	4275.239	7206.196	5584.203
2	319.563	326.750	439.276
3	82.431	40.263	77.032
4	34.292	18.262	11.562

5	7.632	3.101	2.793
6+	0.888	0.533	0.670

Weight at age (kg)

Age	2006	2007	2008	2009	2010	2011
0	0.008	0.008	0.008	0.008	0.008	0.008
1	0.166	0.166	0.166	0.166	0.166	0.166
2	0.578	0.578	0.578	0.578	0.578	0.578
3	1.200	1.200	1.200	1.200	1.200	1.200
4	1.949	1.949	1.949	1.949	1.949	1.949
5	2.745	2.745	2.745	2.745	2.745	2.745
6+	3.529	3.529	3.529	3.529	3.529	3.529

Age	2012	2013	2014
0	0.008	0.008	0.008
1	0.166	0.166	0.166
2	0.578	0.578	0.578
3	1.200	1.200	1.200
4	1.949	1.949	1.949
5	2.745	2.745	2.745
6+	3.529	3.529	3.529

Maturity and natural mortality vectors.

Age	0	1	2	3	4	5	6+
Maturity	0	0.25	0.9	1	1	1	1
M	1.2	0.62	0.44	0.37	0.33	0.31	0.29

MEDITS number at age.

Age	2006	2007	2008	2009	2010	2011	2012	2013	2014
0	1686.571	2514.259	5871.627	6573.9	2469.127	769.899	1464.35	1743.236	1564.17
1	58.583	38.88	57.216	52.838	37.298	29.391	21.931	35.288	27.137
2	2.502	2.24	1.241	1.085	2.573	1.29	0.991	1.001	1.901
3+	0.442	1.635	0.766	0.533	0.178	0.429	0.796	0.429	0.512

5.2.6.7.3 Results

Sensitivity analyses were conducted to assess the effect of the main parameters. Values ranging from 0.5 to 3 (0.5 increasing) for the shrinkage, values ranging from 1 to 3 for shrinkage years and a combination of values between 2 to 4 for the qage parameter and from -1 to 1 for the rage parameter have been tested. Comparison of trends between the settings has been done. Different combinations between the settings that looked more stable were tested.

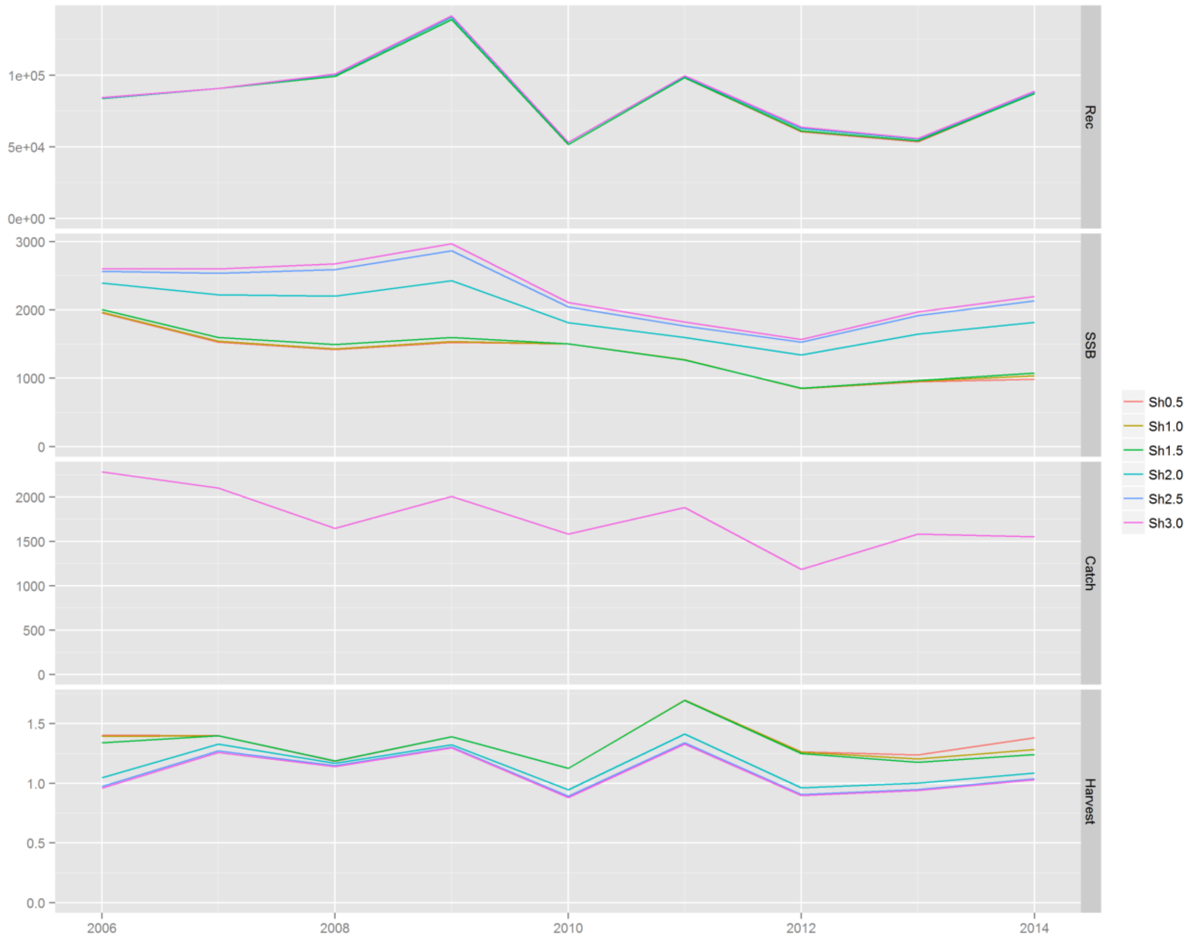


Figure 5.2.6.7.3.1. Hake in GSA 9. Sensitivity on shrinkage weight.

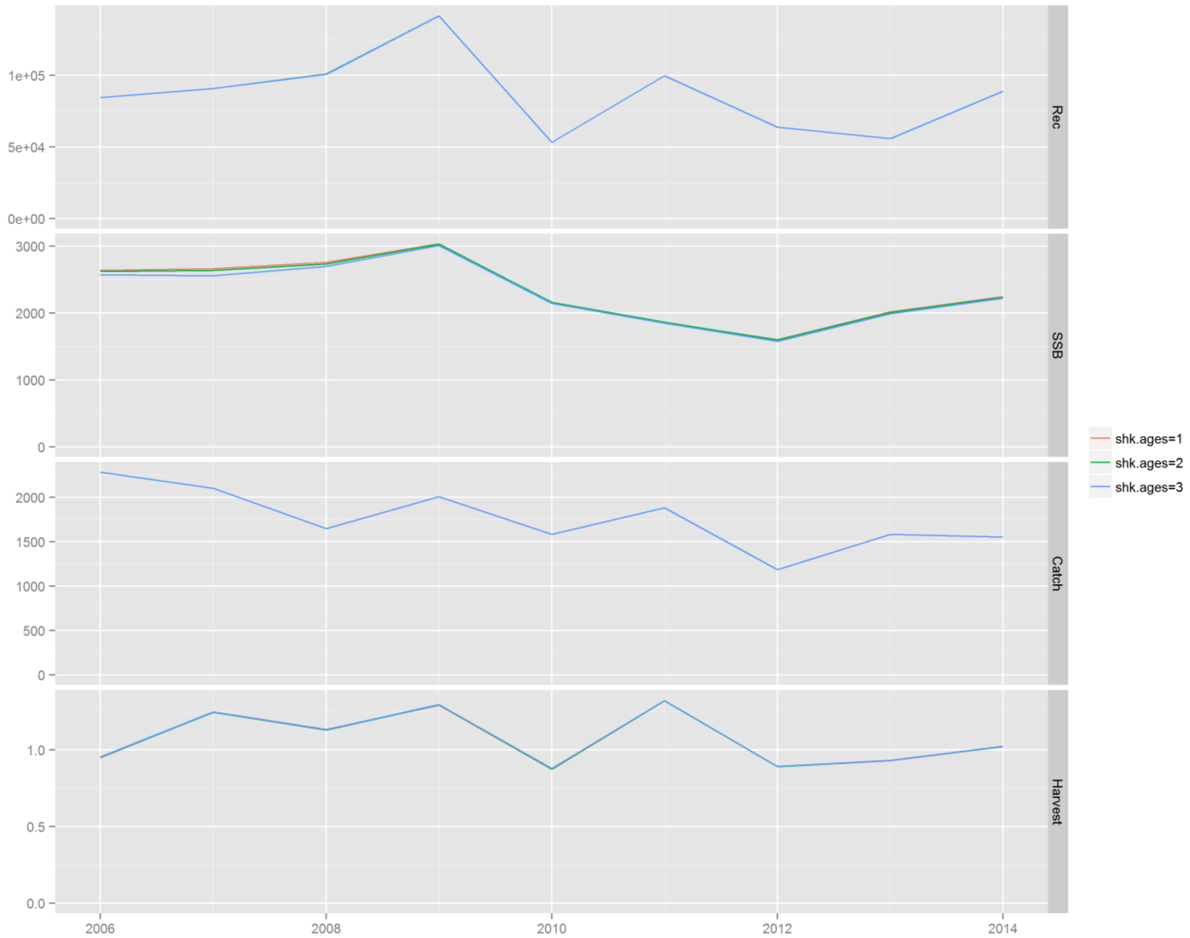


Figure 5.2.6.7.3.2. Hake in GSA 9. Sensitivity on shrinkage age.

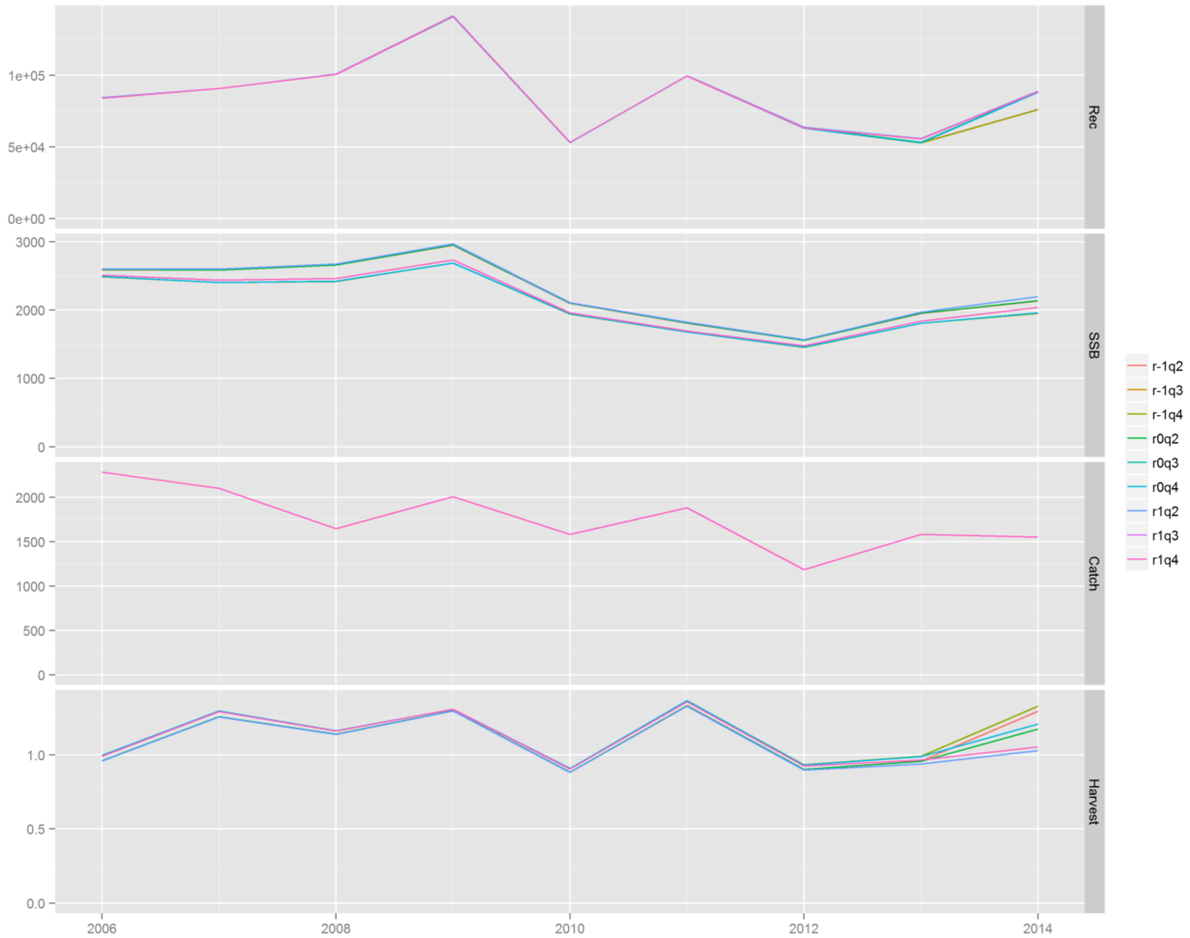


Figure 5.2.6.7.3.3. Hake in GSA 9. Sensitivity on qage and rage.

As a result, the settings that minimized the residuals and showed the best diagnostics output were used for the final assessment, and are the following:

Fbar	fse	rage	qage	shk.yrs	shk.age
0-2	3	1	2	3	2

The residuals pattern of the MEDITS trawl survey is shown in Figure 5.2.6.7.3.4.

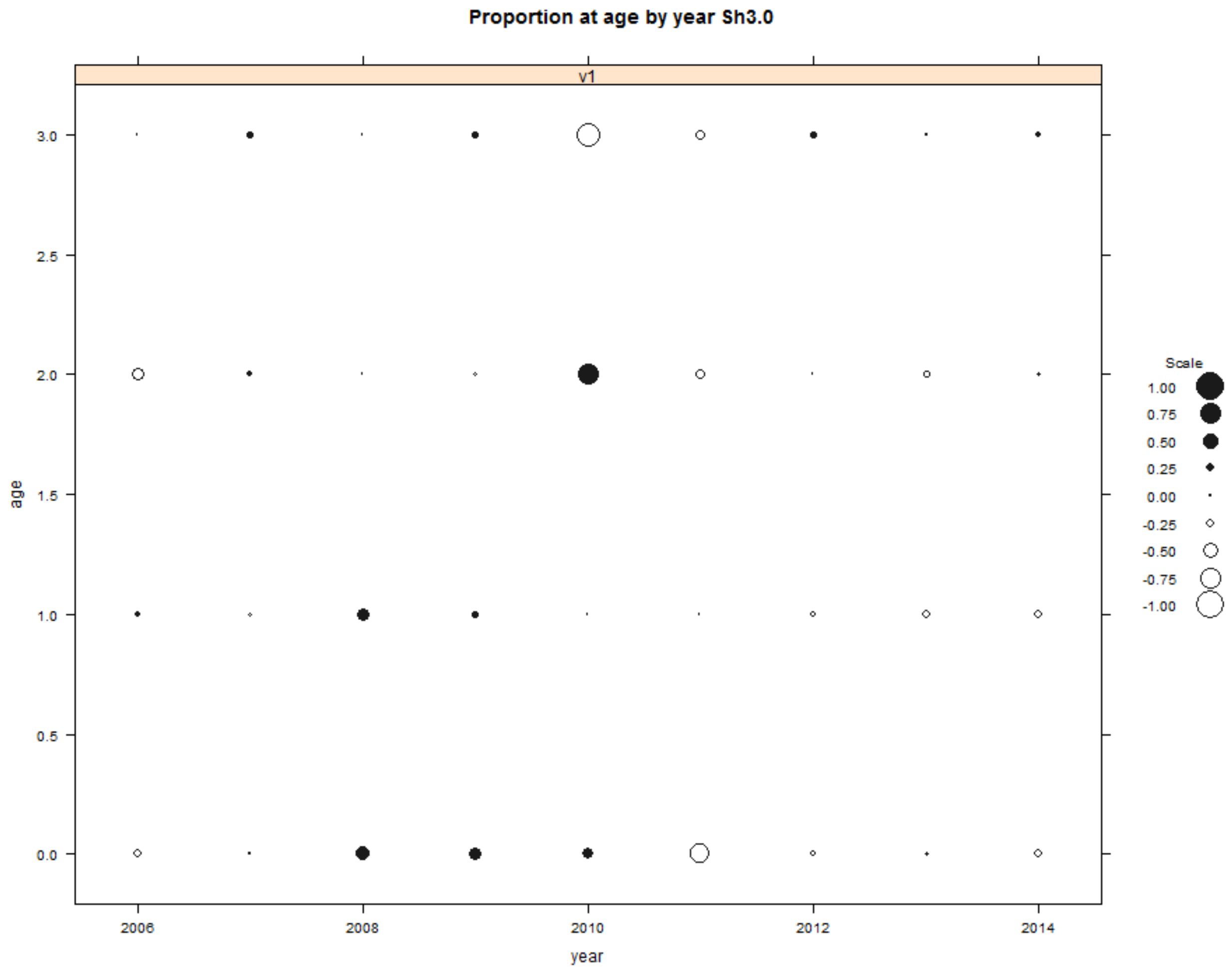


Figure 5.2.6.7.3.4. Hake in GSA 9. XSA residuals for the MEDITS survey from 2006 to 2014.

The results of the retrospective analysis are shown in Figure 5.2.6.7.3.5.

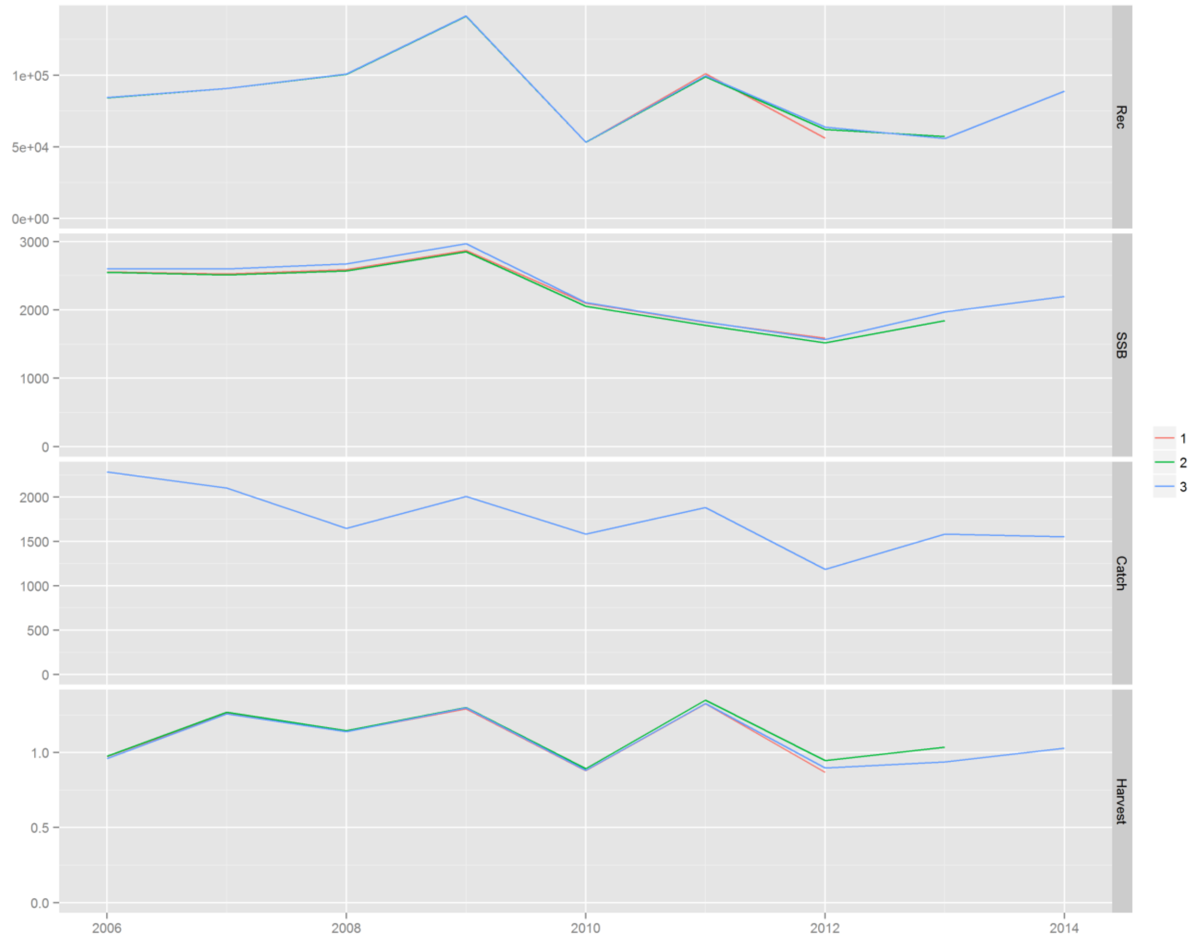


Figure 5.2.6.7.3.5. Hake in GSA 9. XSA retrospective analysis.

The results of the XSA are shown in the following figure.

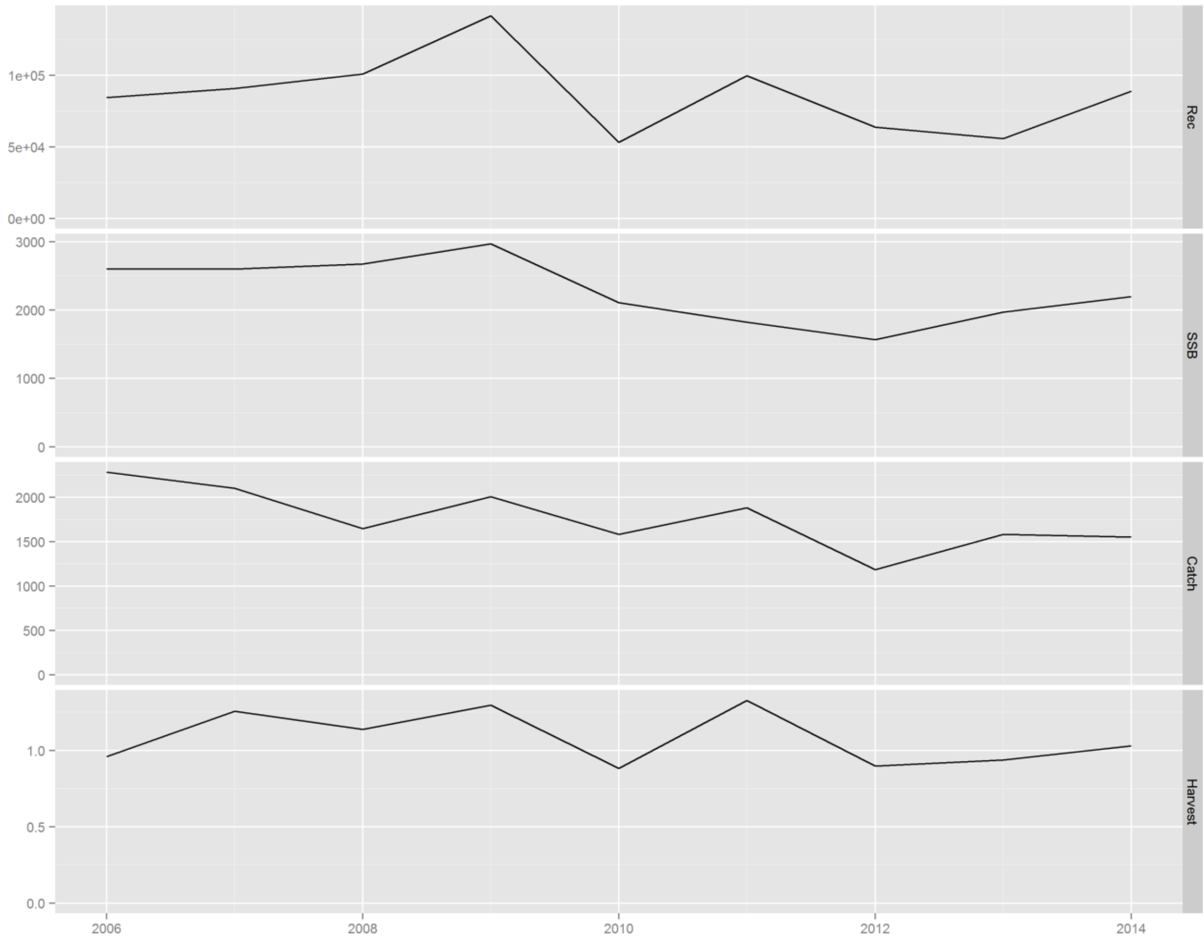


Figure 5.2.6.7.3.6. Hake in GSA 9. XSA summary results. SSB and catch are in tonnes, recruitment in 1000s individuals.

In the tables 5.2.6.7.3.1 and 2 the population estimates of hake obtained by XSA are provided.

Table 5.2.6.7.3.1. Hake in GSA 9. Stock numbers at age (thousands) as estimated by XSA.

Age	2006	2007	2008	2009	2010	2011
0	84450.000	90885.000	100830.000	141620.000	53382.000	99813.000
1	11107.000	12705.000	9571.000	10836.000	9284.600	9514.900
2	2902.000	1602.800	974.140	929.920	1188.100	1299.200
3	360.770	784.160	477.070	319.860	275.320	352.580
4	94.190	107.410	480.870	252.630	133.610	80.091
5	2.944	17.326	68.333	332.580	147.840	50.397
6+	1.842	11.118	21.003	69.464	31.298	9.425

Age	2012	2013	2014
0	63723.000	55923.000	88907.000
1	7443.100	12229.000	9663.600
2	780.930	868.340	1293.000
3	411.880	246.490	297.020
4	163.670	215.990	136.800
5	13.040	88.592	139.800

6+	1.468	15.161	33.381

Table 5.2.6.7.3.2. Hake in GSA 9. XSA summary results.

	Fbar0-2	Recruitment (thousands)	SSB (t)	TB (t)
2006	0.96	84450	2599.8	4833.0
2007	1.26	90885	2596.9	5005.9
2008	1.14	100830	2674.6	4738.4
2009	1.30	141618	2966.8	5516.1
2010	0.88	53382	2109.4	3765.1
2011	1.33	99813	1820.4	3887.8
2012	0.90	63723	1568.7	3055.9
2013	0.94	55923	1971.6	3995.3
2014	1.03	88907	2197.2	4194.2

	F at age						
	0	**1**	**2**	**3**	**4**	**5**	**6+**
2006	0.69	1.32	0.87	0.84	1.36	1.13	1.13
2007	1.05	1.95	0.77	0.12	0.12	0.12	0.12
2008	1.03	1.71	0.67	0.27	0.04	0.22	0.22
2009	1.52	1.59	0.78	0.50	0.21	0.03	0.03
2010	0.52	1.35	0.77	0.86	0.64	0.23	0.23
2011	1.40	1.88	0.71	0.40	1.49	0.36	0.36
2012	0.45	1.53	0.71	0.28	0.28	1.15	1.15
2013	0.56	1.63	0.63	0.22	0.11	0.04	0.04
2014	0.99	1.55	0.55	0.37	0.11	0.02	0.02

The XSA results summarized in Table 5.2.6.7.3.2 and in Figure 5.2.6.7.3.6 show a decreasing trend in the catches, a fluctuation on recruitment, SSB and an estimated F_{curr} of 1.03.

5.2.6.8 Reference points

5.2.6.8.1 Methods

The XSA package used allowed a Yield per recruit analysis and an estimate of some F-based Reference Points as F_{max} and $F_{0.1}$. Yield per Recruit computation was made by R project software and the FLR libraries. The fishing mortality rate corresponding to $F_{0.1}$ in the yield per recruit curve is considered here as a proxy of $F_{MSY.}$

5.2.6.8.2 Input data

The input parameters were the same used for the XSA stock assessment and its results.

5.2.6.8.3 Results

Table 5.2.6.8.3.1. Hake in GSA 9. Main reference points defined with the Yield per recruit analysis.

refpt	harvest	yield	rec	ssb	biomass

virgin	0.00	0.00	1.00	1.04	1.09
msy	0.32	0.04	1.00	0.30	0.34
crash	11.77	0.01	1.00	0.00	0.01
f0.1	0.23	0.04	1.00	0.42	0.46
fmax	0.32	0.04	1.00	0.30	0.34
spr.30	0.31	0.04	1.00	0.31	0.35

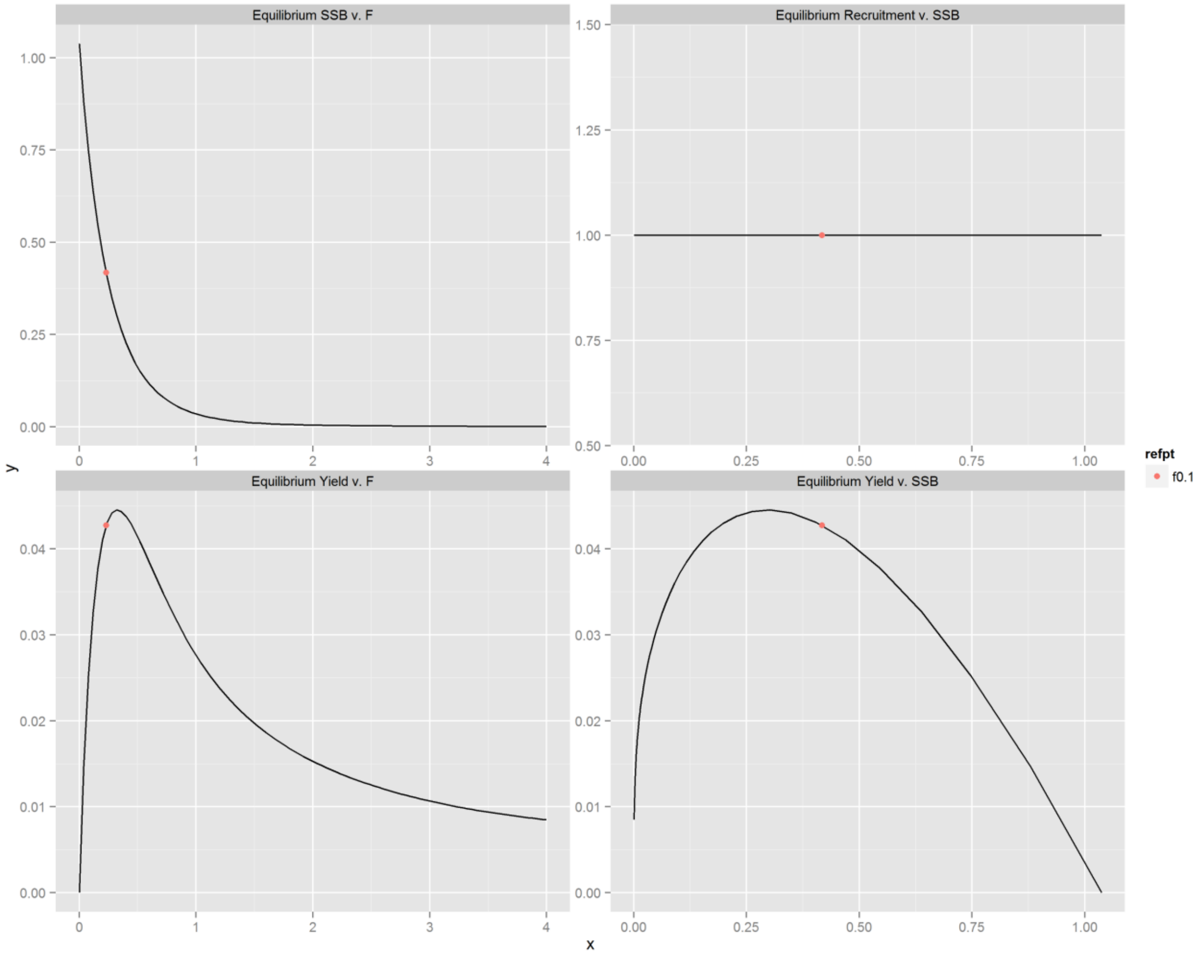


Figure 5.2.6.8.3.1. Hake in GSA 9. Yield per recruit curve.

5.2.6.9 Data quality

Data from DCF 2014 as submitted through the Official data call in 2015 were used. Length frequencies distributions that were missing are presented in the following table.

Table 5.2.6.9.1. Hake in GSA 9. Missing LFD in the landings.

Year	Gear	Fishery	Area	Species	Landings
2008	OTB	DWSP	GSA 9	HKE	4.11279
2010	OTB	DWSP	GSA 9	HKE	3.21425
2011	OTB	DWSP	GSA 9	HKE	3.97375
2012	OTB	DWSP	GSA 9	HKE	3.00489
2013	OTB	DWSP	GSA 9	HKE	5.35848

2014	OTB	DWSP	GSA 9	HKE	3.10412
2007	GNS	DEMF	GSA 9	HKE	576.223
2006	GTR	DEMSP	GSA 9	HKE	403.9606
2007	GTR	DEMSP	GSA 9	HKE	131.8538
2009	GTR	DEMSP	GSA 9	HKE	53.97693
2011	GTR	DEMSP	GSA 9	HKE	54.30141
2012	GTR	DEMSP	GSA 9	HKE	48.61781
2013	GTR	DEMSP	GSA 9	HKE	98.11776
2014	GTR	DEMSP	GSA 9	HKE	76.84722

Discard data were missing for 2007 and 2008.

5.2.6.10 Short term predictions 2015-2017

5.2.6.10.1 Method

A deterministic short term prediction for the period 2015 to 2017 was performed using the FLR routines provided by JRC and based on the results of the XSA stock assessments performed during EWG 15-11.

5.2.6.10.2 Input parameters

The input parameters were the same used for the XSA stock assessment and its results. An average of the last three years has been used for weight at age, maturity at age and F at age. Recruitment (age 0) has been estimated from the population results as the geometric mean of the last 3 years (68172 thousand individuals).

5.2.6.10.3 Results

Table 5.2.6.10.3.1. Hake in GSA 9. Short term forecast in different F scenarios. Basis: F(2015) = mean (F_{bar} 0-2 2012-2014)= 0.95; R(2015) = geometric mean of the recruitment of the last 3 years; R = 68172 thousands; SSB(2014) = 2197 t, Catch (2014)= 1553 t.

Rationale	Ffactor	Fbar	Catch 2015	Catch 2016	Catch 2017	SSB 2016	SSB 2017	Change SSB 2016-2017(%)	Change Catch 2014-2016(%)
Zero catch	0	0.00	1821	0	0	2567	6175	140.52	-100.00
High long term yield (F0.1)	0.24	0.23	1821	635	1136	2567	4891	90.52	-59.10
Status quo	1	0.95	1821	1867	1911	2567	2649	3.16	20.28
Different Scenarios	0.1	0.10	1821	282	566	2567	5596	117.98	-81.82
	0.2	0.19	1821	536	991	2567	5088	98.18	-65.51
	0.3	0.29	1821	763	1305	2567	4640	80.74	-50.82
	0.4	0.38	1821	969	1532	2567	4245	65.35	-37.56
	0.5	0.48	1821	1156	1692	2567	3896	51.74	-25.56
	0.6	0.57	1821	1325	1800	2567	3586	39.67	-14.66
	0.7	0.67	1821	1479	1867	2567	3310	28.94	-4.73
	0.8	0.76	1821	1620	1903	2567	3065	19.37	4.34

	0.9	0.86	1821	1749	1916	2567	2845	10.82	12.64
	1.1	1.05	1821	1977	1894	2567	2472	-3.72	27.31
	1.2	1.14	1821	2077	1866	2567	2312	-9.93	33.81
	1.3	1.24	1821	2171	1832	2567	2168	-15.54	39.84
	1.4	1.33	1821	2258	1793	2567	2038	-20.62	45.43
	1.5	1.43	1821	2339	1751	2567	1919	-25.24	50.64
	1.6	1.53	1821	2414	1708	2567	1811	-29.45	55.51
	1.7	1.62	1821	2485	1663	2567	1712	-33.30	60.06
	1.8	1.72	1821	2551	1619	2567	1622	-36.83	64.33
	1.9	1.81	1821	2614	1575	2567	1538	-40.08	68.35
	2	1.91	1821	2672	1532	2567	1462	-43.07	72.13

5.2.6.11 Short term predictions 2015-2017 by fleet

5.2.6.11.1 Method

A deterministic short term prediction by fleet for the period 2015 to 2017 was performed using the FLR routines provided by JRC and based on the results of the XSA stock assessments performed during EWG 15-11.

5.2.6.11.2 Input parameters

The same parameters used in the short term by single fleet were used.

5.2.6.11.3 Results

Table 5.2.6.11.3.1. European hake in GSA 9. Short term forecast by fleet.

Fleet	Year	Catches	Partial F
GNS	2015	466	0.15
OTB	2015	1257	0.77
GTR	2015	75	0.03
GNS	2016	142	0.04
OTB	2016	405	0.19
GTR	2016	24	0.01
GNS	2017	269	0.04
OTB	2017	724	0.19
GTR	2017	47	0.01

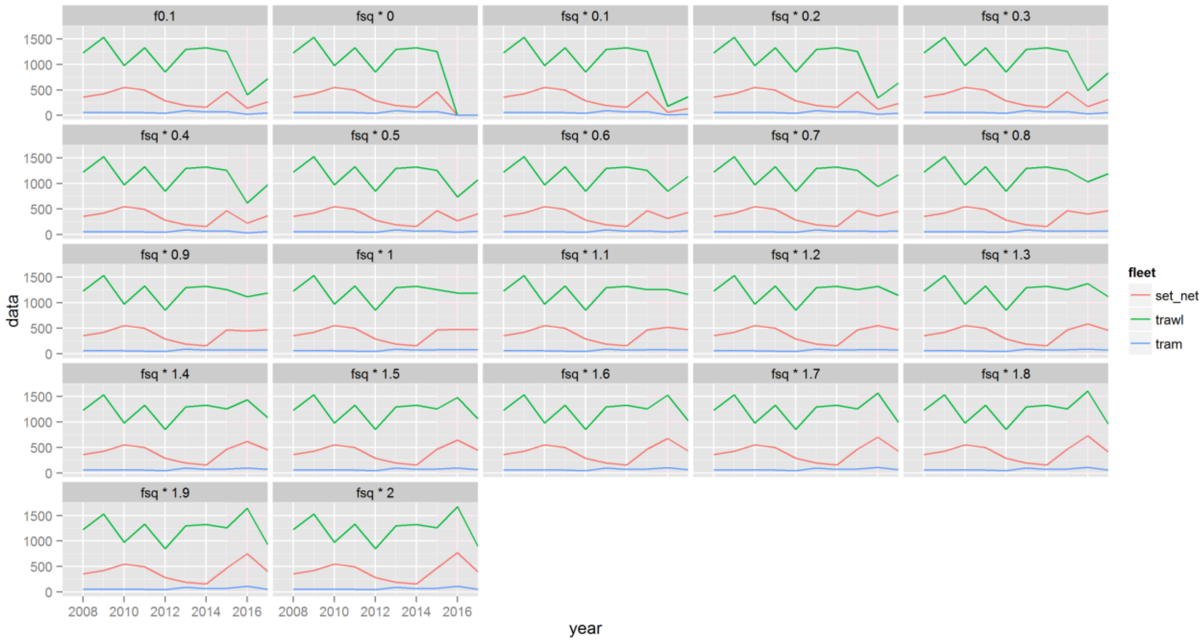


Figure 5.2.6.11.3.1. Hake in GSA 9. Short term forecast by fleet.

5.2.6.12 Medium term predictions

5.2.6.12.1 Method

Medium term was not conducted because no meaningful stock-recruitment relationship was estimated.

5.2.6.13 Stock advice

The current F (1.03) is larger than $F_{0.1}$ (0.23), chosen as proxy of F_{MSY} and as the exploitation reference point consistent with high long term yields, which indicates that European hake in GSA 9 is being fished above F_{MSY}. Catches of European hake in 2016 consistent with F_{MSY} (0.23) would not exceed 635 tonnes.

5.2.6.14 Management strategy evaluation

Management Strategy Evaluation was conducted to evaluate if the MSY ranges were precautionary. The F_{MSY} ranges were derived using the formula provided by STECF 15-09. F ranges results were F_{upper}=0.32 and F_{lower}=0.16. B_{lim} was estimated as B_{loss}=1569 (t). The following figure shows the results of the MSE.

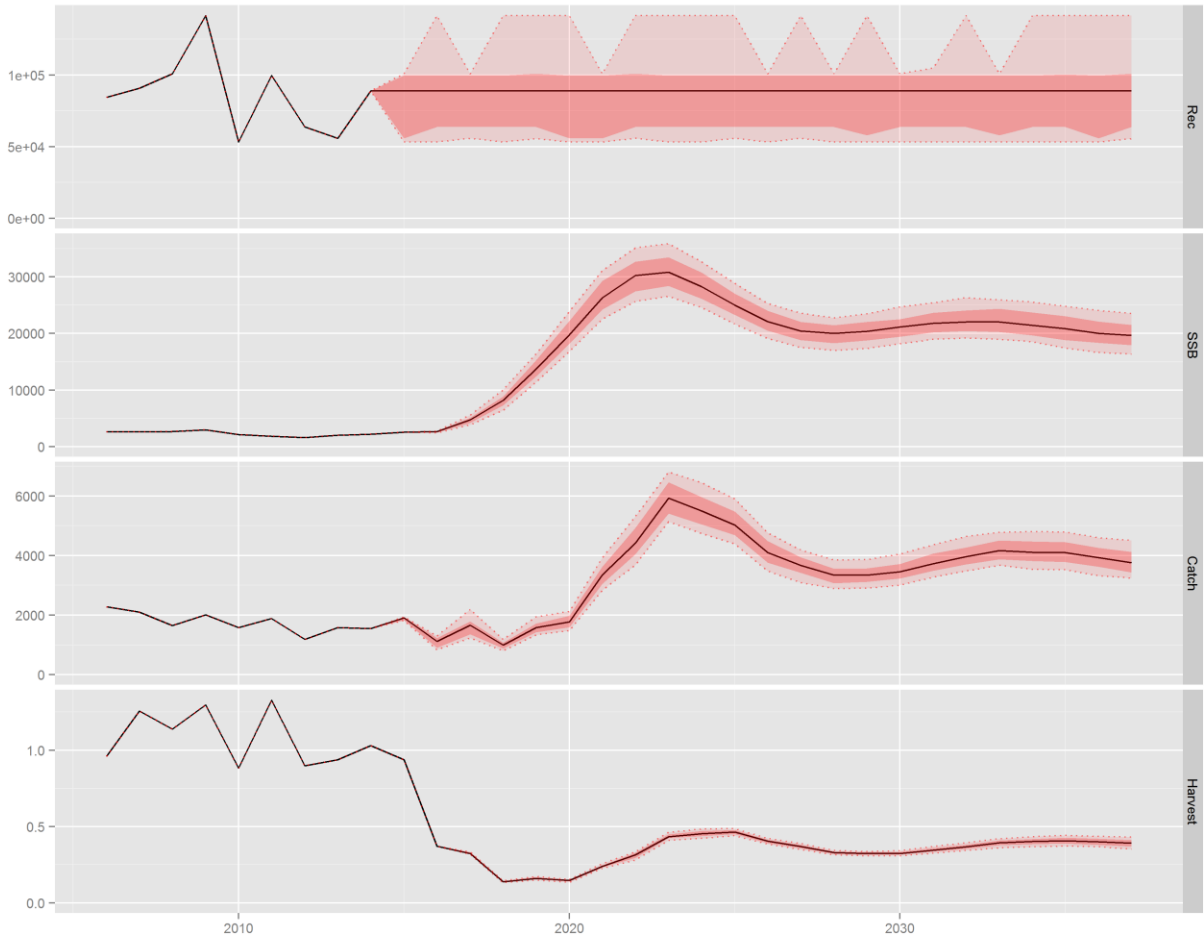


Figure 5.2.6.14.1. Hake in GSA 9. Marine Strategy Evaluation.

The probability of SSB to fall below B_{lim} at F = F_{upper} is equal to 0.

5.2.7 STOCK ASSESSMENT OF HAKE IN GSA 10

5.2.7.1 Stock Identification

The stock of European hake was assumed in the boundaries of the whole GSA 10. *M. merluccius* is with red mullet and deep-water pink shrimp a key species of fishing assemblages in the central-southern Tyrrhenian Sea (GSA 10) (Figure 5.2.7.1.1).

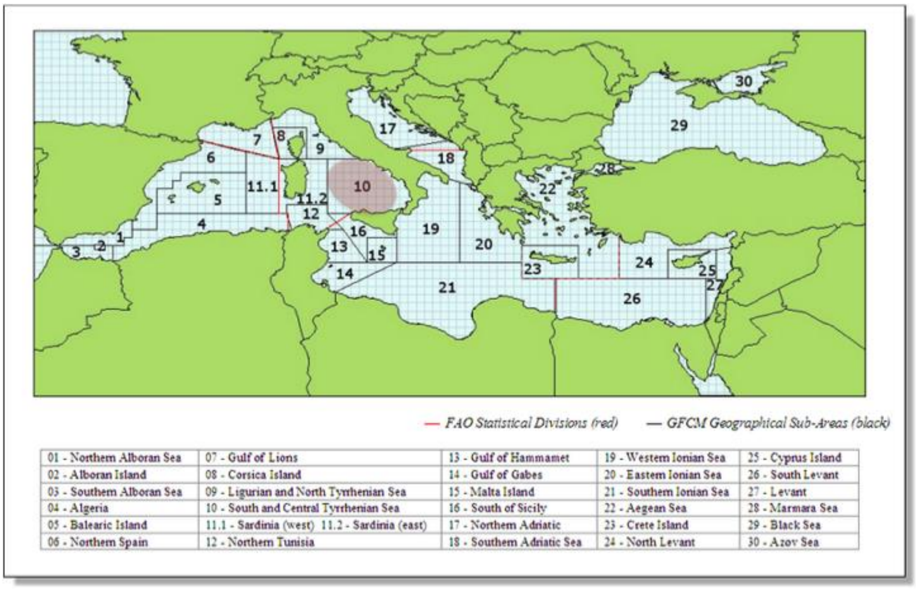


Figure 5.2.7.1.1. Geographical location of GSA 10.

European hake is generally also ranked among species with higher abundance indices in the trawl surveys (e.g. Spedicato and Lembo, 2011). It is a long lived fish mainly exploited by trawlers, especially on the continental shelves of the Gulfs (e.g. Gaeta, Salerno, Palermo) but also by artisanal fishers using fixed gears (gillnets, bottom long-line).

Trawl-survey data have evidenced highest biomass indices on the continental shelf of the GSA 10 (100-200 m; Spedicato and Lembo, 2011), where juveniles (less than 12 cm total length) are mainly concentrated. During autumn trawl surveys, one of the main recruitment pulses of this species is observed. Two main recruitment events (in spring and autumn; Spedicato and Lembo, 2011) are reported in GSA 10 as for other Mediterranean areas. European hake is considered fully recruited to the bottom at 10 cm TL (from SAMED, 2002). The length structures from trawl surveys are generally dominated by juveniles, while large size individuals are rare. This pattern might be also due to the different vulnerability of older fish (Abella and Serena, 1998) beside the effect of high exploitation rates. The few large European hake caught during trawl surveys are generally females and inhabit deeper waters. The overall sex ratio (~0.41-0.47) estimated from trawl survey data is slightly skewed towards males.

5.2.7.2 Growth

Estimates of growth parameters were achieved during the SAMED project (SAMED, 2002) by the analysis of length frequency distributions.

In the DCF framework the growth has been studied ageing fish by otolith readings using the whole sagitta and thin sections for older individuals. Length frequency distributions were also analyzed using techniques as Batthacharya for separation of modal components.

DCF Von Bertalanffy growth parameters for each sex were estimated from average length at age using an iterative non-liner procedure that minimizes the sum of the square differences between observed and expected values.
The table 5.2.7.2.1 summarizes the estimated obtained by the DCF Data Call for the von Bertalanffy growth parameters and the length-weight relationship.

Table 5.2.7.2.1. Hake in GSA 10. Summary of the estimated obtained by the DCF Data Call for the von Bertalanffy growth parameters and the length-weight relationships.

START _YEAR	END_ YEAR	SEX	VB_LINF	VB_K	VB_T0	VB_SIZE_ RANGE	A	B	L_W_SIZE_RAN GE (g)
2003	2005	F	97.9	0.134	-0.39	13-83 cm	0.0035	3.2100	8-3820
2003	2005	M	50.8	0.25	-0.39	13-45 cm	0.0036	3.2150	12-665
2003	2005	C	97.9	0.13	-0.39	8-83 cm	0.0038	3.1890	4-3820
2006	2006	C	98	0.109	-0.78	5-88 cm	0.0036	3.1998	2-2900
2006	2006	F	98	0.118	-0.69	5-88 cm	0.0038	3.1911	12-2900
2006	2006	M	71.5	0.134	-1.04	5-65 cm	0.0034	3.2269	12-463
2007	2007	C	98	0.109	-0.78	5-88 cm	0.0036	3.1998	4-3828
2007	2007	F	98	0.118	-0.69	5-88 cm	0.0038	3.1911	9-3828
2007	2007	M	71.5	0.134	-1.04	5-65 cm	0.0034	3.2269	12-449
2008	2008	C	98	0.109	-0.78	5-88 cm	0.0036	3.1998	3-3787
2008	2008	F	98	0.118	-0.69	5-88 cm	0.0038	3.1911	9-3787
2008	2008	M	71.5	0.134	-1.04	5-65 cm	0.0034	3.2269	9-766
2009	2009	C	98	0.109	-0.78	5-88 cm	0.0038	3.1866	1-4950
2009	2009	F	98	0.118	-0.69	5-88 cm	0.0040	3.1770	12-4950
2009	2009	M	71.5	0.134	-1.04	5-65 cm	0.0043	3.1493	13-991
2010	2010	C	98	0.109	-0.78	5-88 cm	0.0038	3.1765	2-5494
2010	2010	F	98	0.118	-0.69	5-88 cm	0.0040	3.1698	13-5494
2010	2010	M	71.5	0.134	-1.04	5-65 cm	0.0045	3.1240	13-2049
2011	2011	C	98	0.109	-0.78	5-88 cm	0.0047	3.1220	1-5399
2011	2011	F	98	0.118	-0.69	5-88 cm	0.0037	3.1976	13-5399
2011	2011	M	71.5	0.134	-1.04	5-65 cm	0.0045	3.1296	13-1192
2012	2012	C	98	0.109	-0.78	5-88 cm	0.0045	3.1297	1-3977
2012	2012	F	98	0.118	-0.69	5-88 cm	0.0044	3.1325	14-3977
2012	2012	M	71.5	0.134	-1.04	5-65 cm	0.0047	3.1129	13-999
2013	2013	C	98	0.109	-0.78	5-88 cm	0.0040	3.1696	1-3523
2013	2013	F	98	0.118	-0.69	5-88 cm	0.0040	3.1703	14-3523
2013	2013	M	71.5	0.134	-1.04	5-65 cm	0.0038	3.1909	14-476
2014	2014	C	98	0.109	-0.78	5-88 cm	0.0038	3.1952	2-4420
2014	2014	F	98	0.118	-0.69	5-88 cm	0.0037	3.1931	15-4420
2014	2014	M	71.5	0.134	-1.04	5-65 cm	0.0028	3.1093	14-392

The observed maximum length of European hake was 88 cm for females and 58 cm for males both registered in the landings (bottom long-lines).

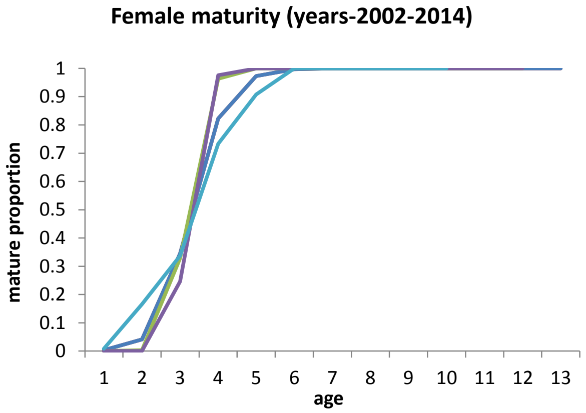
For the present assessment, in line with the previous ones, the fast growth parameters have been used and the length weight relationship parameters as reported in the table 5.2.7.2.2.

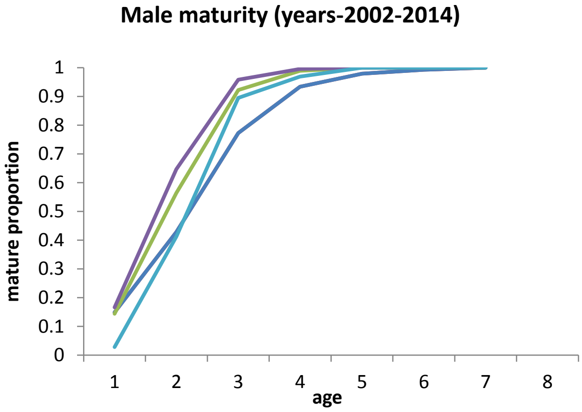
Table 5.2.7.2.2. Hake in GSA 10. Growth parameters used in the present assessment.

SEX	VB_LINF	VB_K	VB_T0	A	B
C	104	0.2	-0.01	0.00437	3.154

5.2.7.3 Maturity

A proxy of size at first maturity was estimated in the SAMED project (SAMED, 2002) using the average length at stage 2 (females with gonads at developing stage) that indicates an average length of about 30 cm. According to the data obtained in the DCF maturity at age is reported in figure 5.2.7.3.1.





For the present assessment, in line with the previous ones, the fast growth parameters have been used to estimate maturity at age as reported in the table 5.2.7.3.1

Table 5.2.7.3.1. Hake in GSA 10. Maturity proportion at age used in the present assessment.

Age	Proportion of matures
0	0
1	0.19
2	0.86
3	1
4	1
5	1
6+	1

5.2.7.4 Natural mortality

For the present assessment, in line with the previous ones, the vector of natural mortality estimated according to prodbiom and reported in the table 5.2.7.4.1 has been adopted. It is based on fast growth parameters.

Table 5.2.7.4.1. Hake in GSA 10. Vector of natural mortality used in the present assessment.

Age	Natural mortality
0	1.16
1	0.53
2	0.4
3	0.35
4	0.32
5	0.3
6+	0.3

5.2.7.5 Fisheries

5.2.7.5.1 General description of the fisheries

European hake is mostly targeted by trawlers, but also by small scale fisheries using nets and bottom long-lines. Fishing grounds are located on the soft bottoms of continental shelves and the upper part of continental slope along the coasts of the whole GSA. Catches from trawlers are from a depth range between 50-60 and 500 m and hake occurs with other important commercial species as *Illex coindetii*, *M. barbatus*, *P. longirostris*, *Eledone* spp., *Todaropsis eblanae*, *Lophius* spp., *Pagellus* spp., *P. blennoides*, *N. norvegicus*.

5.2.7.5.2 Management regulations applicable in 2015

Management regulations are based on technical measures, closed number of fishing licenses for the fleet and area limitation (distance from the coast and depth). In order to limit the over-capacity of fishing fleet, the Italian fishing licenses have been fixed since the late eighties. Other measures on which the management regulations are based regard technical measures (mesh size) and minimum landing sizes (EC 1967/06).

After 2000, in agreement with the European Common Policy of Fisheries, a gradual decreasing of the fleet capacity was implemented. Along northern Sicily coasts two main Gulfs (Patti and Castellammare) have been closed to the trawl fishery up 200 m depth, since 1990. In the GSA 10 the fishing ban has not been mandatory along the time, and from one year to the other it was adopted on a voluntary basis by fishers, whilst in the last three years it was mandatory. Regarding long-lines the management regulations are based on technical measures related to the number of hooks and the minimum landing sizes (EC 1967/06), besides the regulated number of fishing licences.

In 2008 a management plan was adopted, that foresaw the reduction of fleet capacity associated with a reduction of the time at sea. Two biological conservation zone (ZTB) were permanently established in 2009 (Decree of Ministry of Agriculture, Food and Forestry Policy of 22.01.2009; GU n. 37 of 14.02.2009). One is located along the mainland, in front of Sorrento peninsula in the vicinity of the MPA of Punta Campanella (Napoli Gulf, 60 km^2, within 200 m depth) and a second one is along the coasts of Amantea (Calabrian coasts, 75 km^2 up to 250 m depth). In these areas trawling is forbidden and other fishing activities are allowed under permission. Since June 2010 the rules implemented in the EU regulation (EC 1967/06) regarding the cod-end mesh size and the operative distance of fishing from the coasts are enforced.

5.2.7.5.3 Catches

Catches and landing are reported in Figure 5.2.7.5.3.1. Catches include the discards of OTB gear, given that discard is not present in the nets and LLS gear.

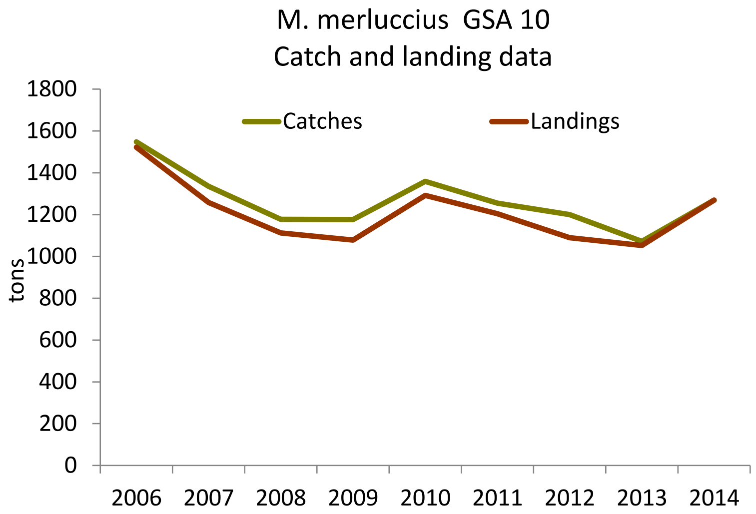


Figure 5.2.7.5.3.1 Hake in GSA 10. Catches and total landings of OTB gear.

5.2.7.5.4 Landings

Available landing data are from DCF regulations. EWG 15-11 received Italian landings data for GSA 10 by fishing gears, which are listed in Table 5.2.7.5.4.1.

The landings fluctuates around 1,100 and 1,500 tons with the maximum in 2006 and the minimum in 2013. Most part of the landings of hake is distributed almost homogenously between trawlers, nets (GNS and GTR) and longlines (LLS) (Figure 5.2.7.5.4.1). Landings of gears other than OTB, LLS, GNS and GTR can be considered negligible or misreporting.

Table 5.2.7.5.4.1. Hake in GSA 10. Annual landings (t) by major gear type, 2004-2014.

Landings	tons											
SPECIES	GEAR	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
HKE	-1			8.3						0.2		
	GND	6.6	8.0	12.0	10.6	8.1	9.2	1.6				
	GNS	177.2	293.8	322.7	219.8	311.3	283.2	431.0	290.8	317.8	237.8	486.1
	GTR	202.2	124.2	152.1	157.3	67.6	107.5	202.0	152.8	138.2	354.7	158.9
	LLD		0.5			1.5	2.9	36.1	72.6	14.3		
	LLS	266.4	269.2	287.7	240.2	232.3	246.6	183.6	318.0	214.4	145.1	277.7
	OTB	485.9	611.9	759.3	640.7	500.6	441.2	475.1	442.7	418.9	314.4	346.2
	PS	1.3		2.0					1.5	1.5	0.2	
	PTM									0.3		
	SB	0.7				0.7				0.8		1.1
	SV	0.7				0.7				0.8		1.1
		1140.8	1307.7	1544.1	1268.7	1122.8	1090.5	1329.5	1278.5	1107.2	1052.2	1271

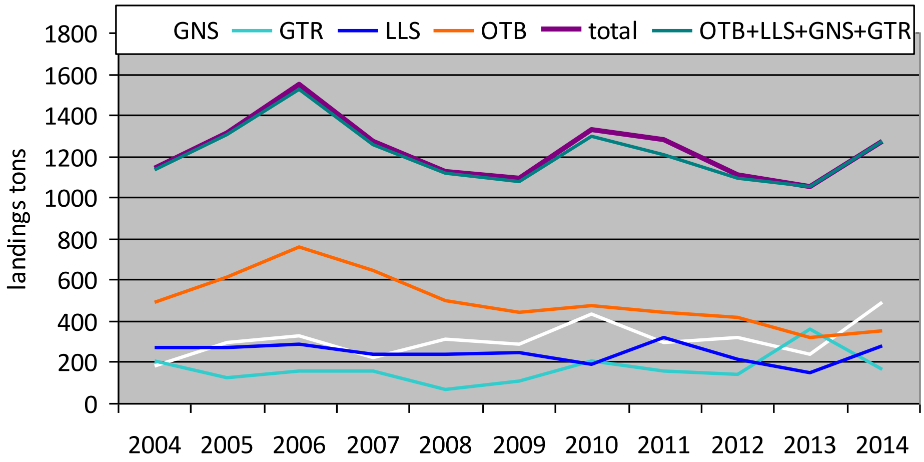


Figure 5.2.7.5.4.1. Hake in GSA 10. Landings by gear and total landings.

5.2.7.5.5 Discards

The discards of hake in the GSA 10 are reported for 2006, 2009-2014, as in 2007 and 2008 DCF did not foresee collection of discard data. The volume of discards is rather variable among years.

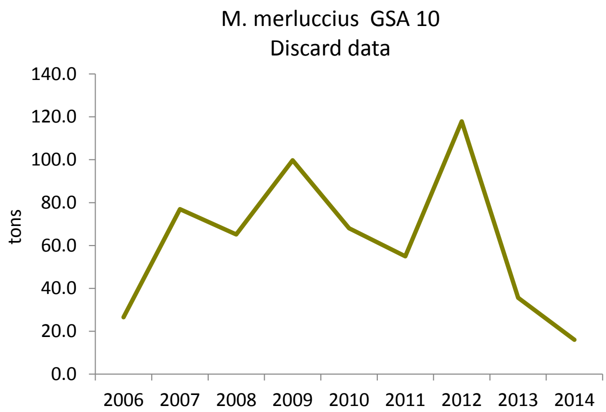


Figure 5.2.7.5.5.1. Hake in GSA 10. Discards by year (gear OTB).

5.2.7.5.6 Fishing effort (by fleet if possible)

The trends in fishing effort by year and major gear type is listed in Table 5.2.7.5.6.1 and shown in Figure 5.2.7.5.5.1 The total fishing effort in kW*days from 2004 to 2009 is decreasing. From this year onward is variable around $20*10^6$ kw*days.

Table 5.2.7.5.6.1. Hake in GSA 10. Trend in fishing effort (kW*days) for the GSA 10 by fleet level, 2002-2014.

Nominal effort		year												
area	gear	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
SA 10	-1	1E+07	8E+06	6E+06	4E+06	4E+06	3E+06	3E+06	3E+06	3E+06	2E+06	1E+06	600716	447521
	DRB	94663	29540	86505	294424	312180	144186	238122	188909	209574	196692	241145	59508	88658
	FPO			0	314508	149669					156	71997	438492	130683
	GND			282086	127345	623598	454015	496680	435913	112632	44621	53742	7667	38343
	GNS			4E+06	5E+06	3E+06	2E+06	3E+06	3E+06	3E+06	3E+06	3E+06	2E+06	2E+06
	GTR	6E+06	7E+06	3E+06	2E+06	4E+06	4E+06	3E+06	2E+06	3E+06	3E+06	3E+06	3E+06	3E+06
	LLD			1E+06	1E+06	793563	363731	387768	1E+06	2E+06	2E+06	2E+06	1E+06	1E+06
	LLS			5E+06	2E+06	1E+06	1E+06	1E+06	1E+06	1E+06	2E+06	1E+06	1E+06	3E+06
	LTL			0							6324	893		12334
	OTB	7E+06	7E+06	8E+06	8E+06	8E+06	7E+06	6E+06	6E+06	6E+06	5E+06	6E+06	6E+06	9E+06
	OTM													383607
	PS	3E+06	3E+06	4E+06	3E+06	2E+06	2E+06	1E+06	2E+06	2E+06	6E+06	2E+06	2E+06	2E+06
	PTM			6173								902		
Total		3E+07	3E+07	3E+07	3E+07	2E+07	2E+07	2E+07	2E+07	2E+07	2E+07	2E+07	2E+07	2E+07

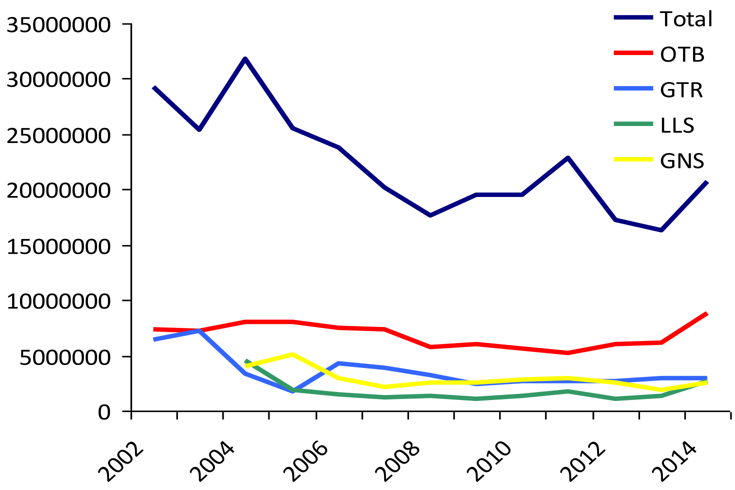


Figure 5.2.7.5.6.1. Hake in GSA 10. Trend in nominal fishing effort for the pulled fleet, from 2002 to 2014.

5.2.7.6 Scientific surveys

5.2.7.6.1 Survey #1 (MEDITS)

5.2.7.6.1.1 Methods

According to the MEDITS protocol (Bertrand *et al.*, 2002), trawl surveys were yearly (May-July) carried out, applying a random stratified sampling by depth (5 strata with depth limits at: 50, 100, 200, 500 and 800 m; each haul position randomly selected in small sub-areas and maintained fixed throughout the time). Haul allocation was proportional to the stratum area. The same gear (GOC 73, by P.Y. Dremière, IFREMER-Sète), with a 20 mm stretched mesh size in the cod-end, was employed throughout the years. Detailed data on the gear characteristics, operational parameters and performance are reported in Dremière and Fiorentini (1996). Considering the small mesh size a complete retention was assumed. All the abundance data (number of fish per surface unit) were standardized to square kilometer, using the swept area method.

Based on the DCF data call, abundance and biomass indices were recalculated. In GSA 10 the following number of hauls was reported per depth stratum (Table 5.2.7.6.1.1.1).

Table 5.2.7.6.1.1.1. Hake in GSA 10. Number of hauls per year and depth stratum in GSA 10, 1994-2014.

STRATUM	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
GSA10_010-050	7	8	8	8	8	8	8	8	7	7	7	7	7	7
GSA10_050-100	10	10	10	10	10	10	10	10	8	8	8	8	8	8
GSA10_100-200	17	17	17	17	17	17	17	17	14	14	14	14	14	14
GSA10_200-500	22	23	22	22	22	22	22	24	18	18	18	18	18	18
GSA10_500-800	28	27	28	28	28	27	28	26	23	23	23	23	23	23

STRATUM	2008	2009	2010	2011	2012	2013	2014
GSA10_010-050	7	7	7	7	7	7	7
GSA10_050-100	8	8	8	8	8	7	8
GSA10_100-200	14	14	14	14	14	14	14
GSA10_200-500	19	18	18	18	18	18	18
GSA10_500-800	22	23	23	23	23	23	23

Data were assigned to strata based upon the shooting position and average depth (between shooting and hauling depth). Catches by haul were standardized to 60 minutes hauling duration. Hauls noted as valid were used only, including stations with no catches of hake, red mullet or pink shrimp (zero catches are included).
The abundance and biomass indices by GSA were calculated through stratified means (Cochran, 1953; Saville, 1977). This implies weighting of the average values of the individual standardized catches and the variation of each stratum by the respective stratum areas in the GSA:

$Yst = \Sigma (Yi*Ai) / A$
$V(Yst) = \Sigma (Ai^2 * si^2 / ni) / A^2$

Where:
A=total survey area
Ai=area of the i-th stratum
si=standard deviation of the i-th stratum
ni=number of valid hauls of the i-th stratum
n=number of hauls in the GSA
Yi=mean of the i-th stratum
Yst=stratified mean abundance
V(Yst)=variance of the stratified mean

The variation of the stratified mean is then expressed as ± standard deviation.
It was noted that while this is a standard approach, the calculation may be biased due to the assumptions over zero catch stations, and hence assumptions over the distribution of data. A normal distribution is often assumed, whereas data may be better described by a delta-distribution, quasi-poisson. Indeed, data may be better modelled using the idea of conditionality and the negative binomial (e.g. O'Brien *et al*. 2004).
Length distributions represented an aggregation (sum) of standardized length frequencies distribution raised to standardized haul abundance per square km over the stations of each stratum.

5.2.7.6.1.2 Geographical distribution

The geographical distribution pattern of European hake has been studied in the area using trawl-survey data and applying geostatistical methods. In these studies both the total abundance indices and the abundance indices of recruits were analysed (Lembo *et al*., 2000).

Recently in the STOCKMED project (MAREA Framework; Fiorentino et al., 2015) biomass trends (average of the last 10 years) have been estimated (Figure 5.2.7.6.1.2.1).

If recruits are considered, the higher concentration in the GSA 10 was localised in the northern side (Gulfs of Napoli and Gaeta). Recent estimations (MEDISEH Project, MAREA Framework; Giannoulaki et al., 2013) have confirmed the presence of important zone for recruits in the northernmost part of the GSA, although sites with a high probability of locating a nursery appeared also along the coasts of southern part of the mainland and North Sicily.

From GRUND data (autumn survey) the higher abundance of recruits were instead localised in the central part of the GSA, along the mainland coasts. Persistence of the nursery areas along the time was estimated from the indicator kriging (Figure 5.2.7.6.1.2.2).

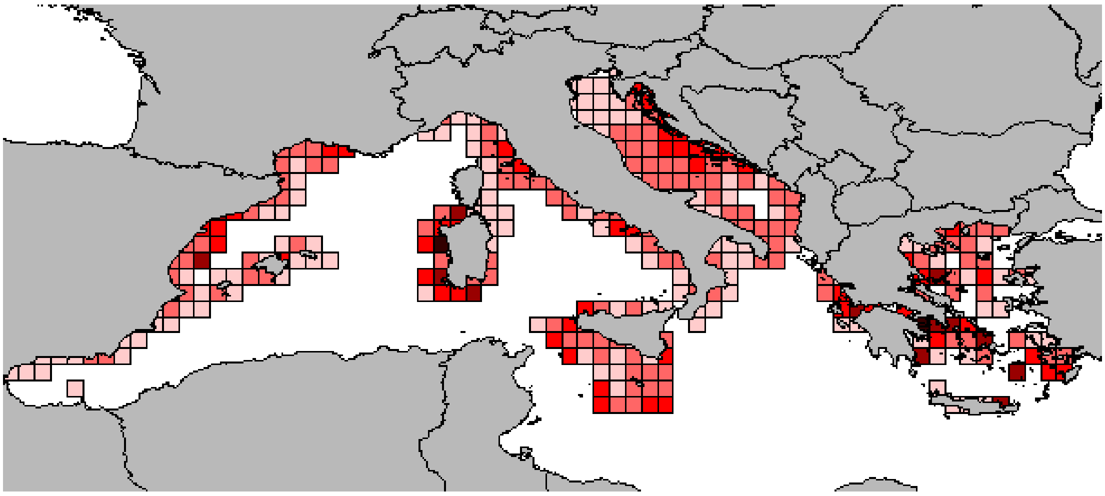


Figure 5.2.7.6.1.2.1. Hake in GSA 10. Geographical distribution of hake in the Mediterranean basin.

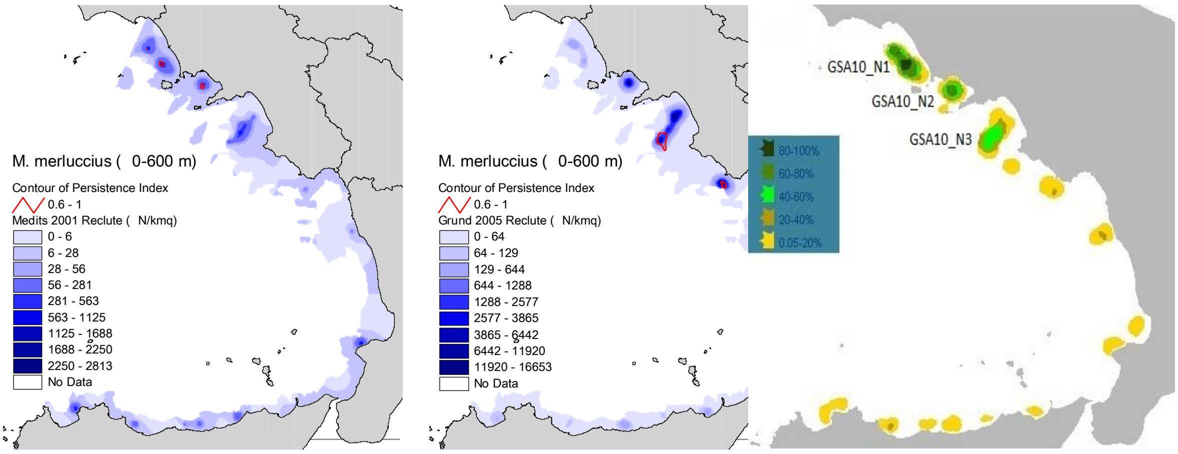


Figure 5.2.7.6.1.2.2. Hake in GSA 10. Nursery areas of hake in GSA 10 with the persistence along time.

5.2.7.6.1.3 Trends in abundance and biomass

Fishery independent information regarding the state of the hake in GSA 10 was derived from the international survey MEDITS. Figure 5.2.7.6.1.3.1 displays the estimated trend of hake abundance and biomass indices standardized to the surface unit in the GSA10. Indices from MEDITS trawl-surveys show an increasing pattern up to 2009, although variability is high, and a decrease in 2010-2011. The value of 2014 are low (Figure 5.2.7.6.1.3.1).

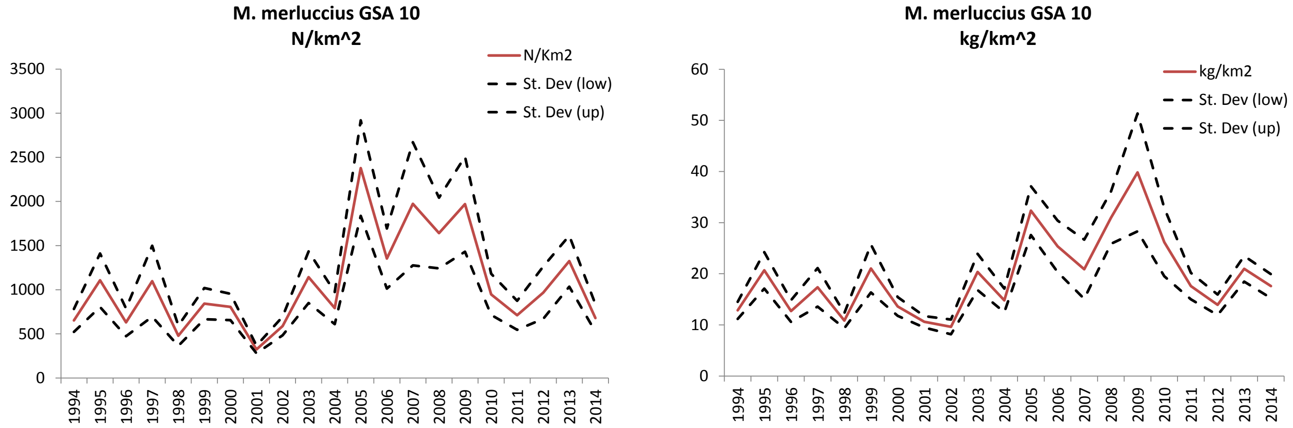
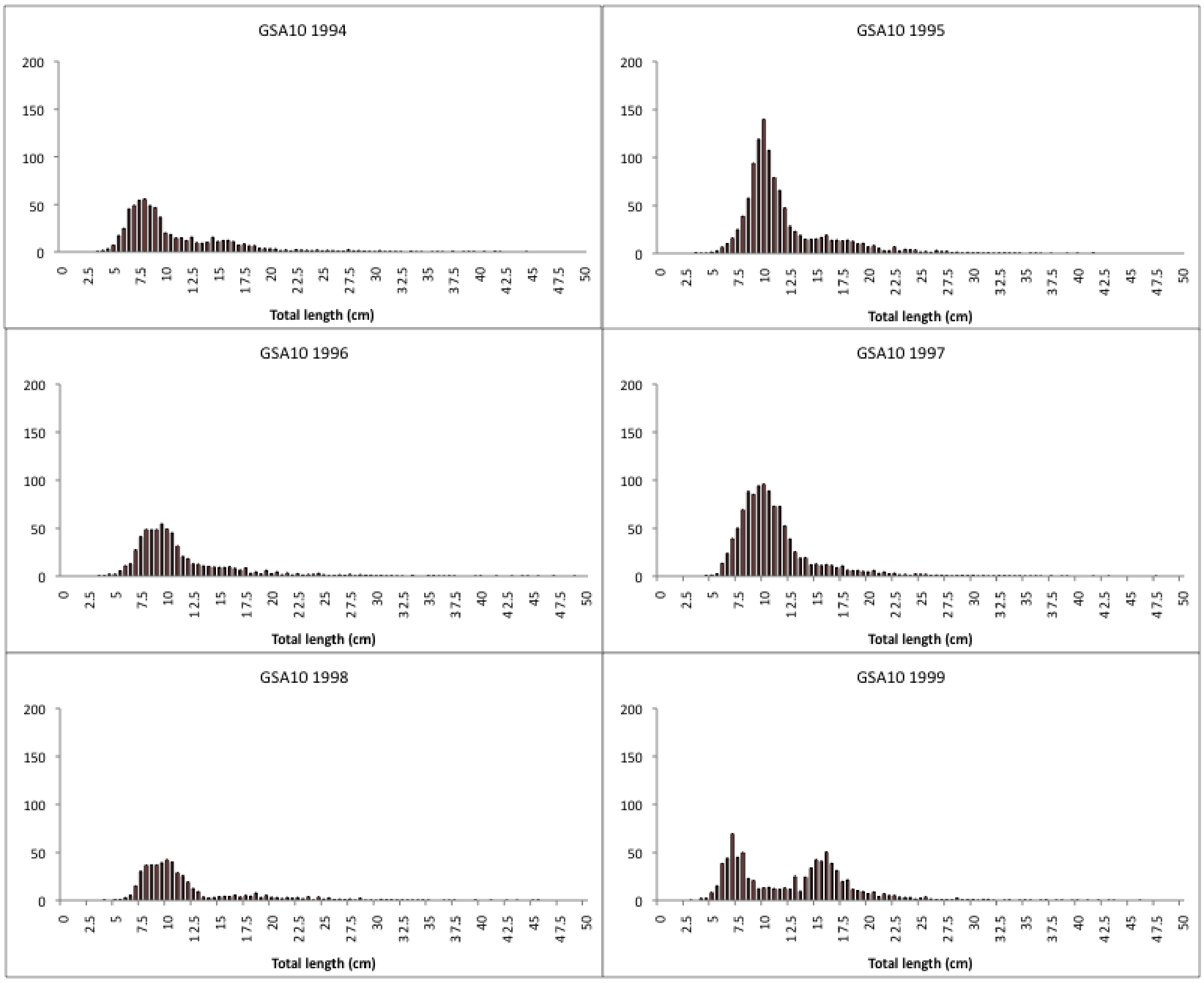
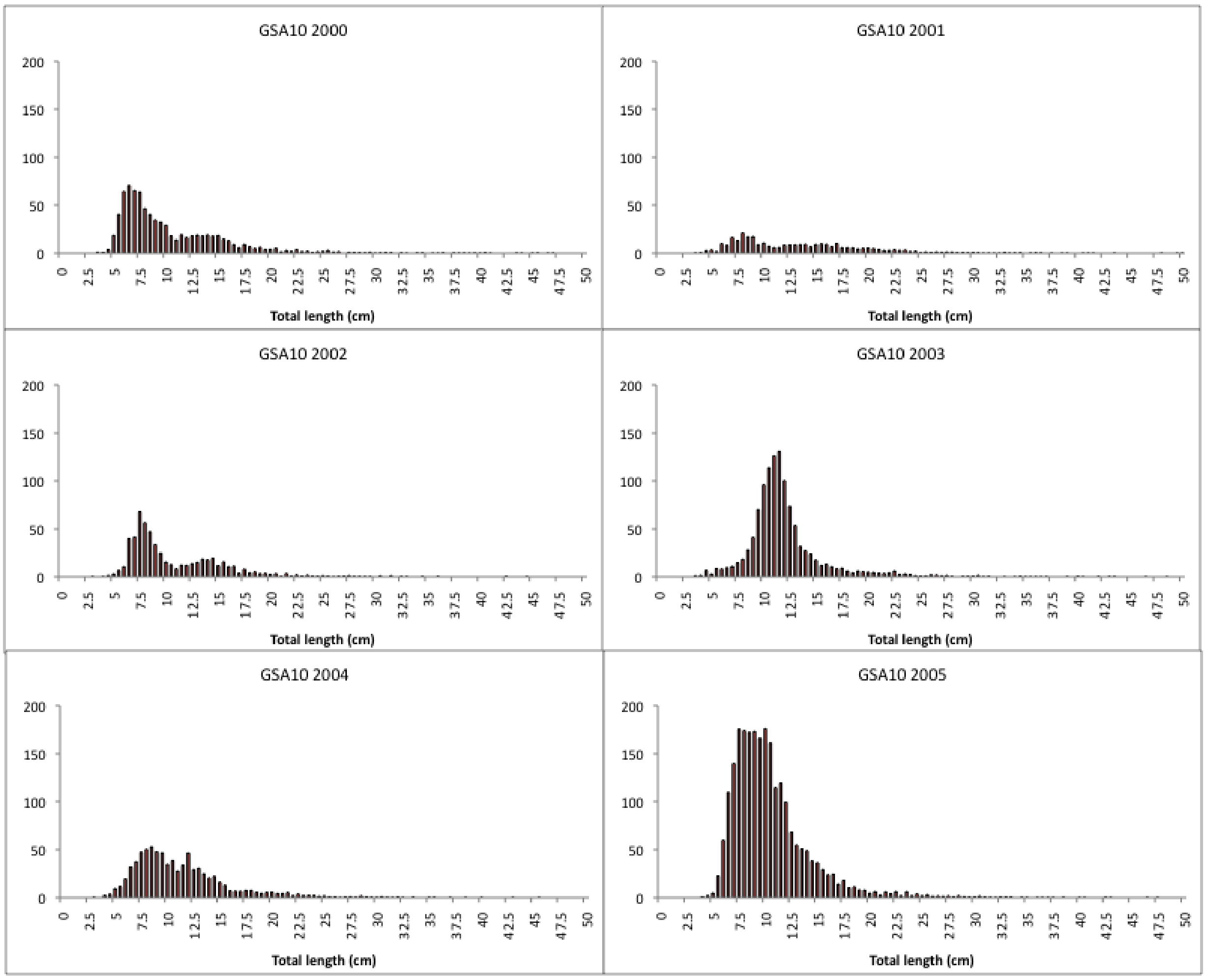


Fig. 5.2.7.6.1.3.1. Hake GSA 10. Abundance and biomass time series of hake in GSA 10 derived from MEDITS (dotted lines indicated standard deviation).

5.2.7.6.1.4 Trends in abundance by length or age

The following figure display the stratified abundance indices of GSA 10 in 1994-2014.




GSA10 2000
GSA10 2001
GSA10 2002
GSA10 2003
GSA10 2004
GSA10 2005
200
150
100
50
0
0
2.5
5
7.5
10
12.5
15
17.5
20
22.5
25
27.5
30
32.5
35
37.5
40
42.5
45
47.5
50
Total length (cm)

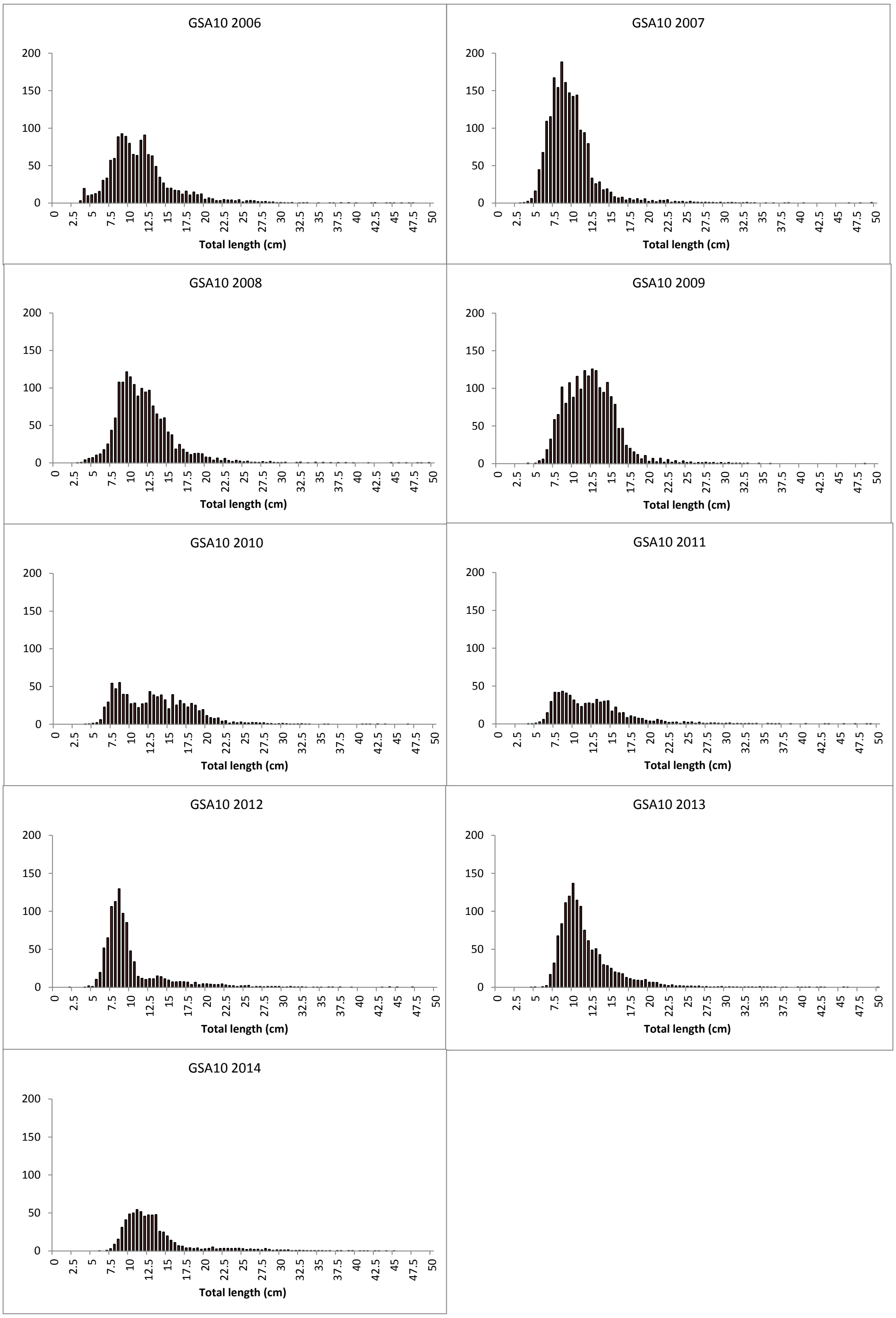


Fig. 5.2.7.6.1.4.1. Hake in GSA 10. Stratified abundance indices by size, 1994-2014.

5.2.7.6.2 Survey #2 (GRUND - historical information)

5.2.7.6.2.1 Methods

Under DCF Grund surveys was conducted since 2003 to 2008 using the same vessel and gear in the whole GSA. Sampling scheme, stratification and protocols were similar as in MEDITS. All the abundance data (number of fish and weight per surface unit) were standardised to square kilometre, using the swept area method.

5.2.7.6.2.2 Geographical distribution

Mapping of the hake recruits obtained applying the indicator kriging technique with contouring that represents probability (in percentage) is reported in the figure 5.2.7.6.1.2.2.

5.2.7.6.2.3 Trends in abundance and biomass

Trends derived from the GRUND surveys are shown in Figure 5.2.7.6.2.3.1. Abundance indices increased significantly (p<0.05 on ln-transformed data), as well as recruitment indices, while biomass indices were almost stationary.

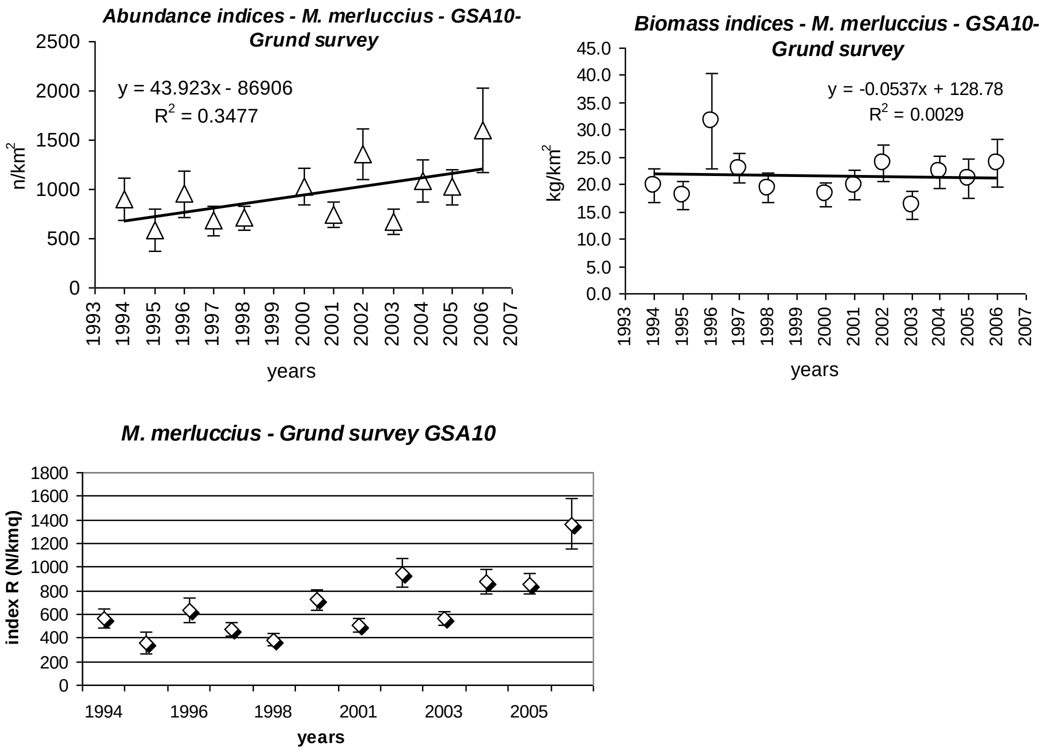


Figure 5.2.7.6.2.3.1. Hake in GSA 10. Abundance and biomass indices of hake in GSA 10 derived from GRUND surveys. Recruitment indices (N/km^2) with standard deviation are also reported.

5.2.7.6.2.4 Trends in abundance by length or age

No trend in the mean length was observed in GRUND survey (Figure 6.7.9.), nor at the third quantile lengths as obtained from the length structures of GRUND time series from 1994 to 2006 (Figure 5.2.7.6.2.4.1.).

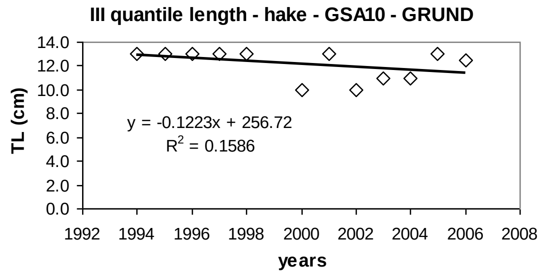


Figure 5.2.7.6.2.4.1. Hake in GSA 10. Quantile derived from the GRUND length structures in 1994-2006.

5.2.7.7 Stock Assessment

5.2.7.7.1 Methods

Stock assessment has been conducted using 2 methods XSA and a4a.

Method: XSA

The Extended Survivors Analysis (XSA – Darby and Flatman, 1994) has been used with an age range from 0 to 6+. Discard was included in the analysis. Since no discard data were available for 2007 and 2008, an estimate based on the length structures of the previous and following years has been done.

Method: a4a

An attempt was made to use the a4a framework developed by the Joint Research Centre to fit an assessment model for this stock. a4a is a framework that allows to compute statistical catch at age models. Its flexibility allows to fit a wide range of models to the data. Compared to XSA, a4a runs forward and allows to reach a better stability for last years estimates. As it is the first year this method was used, the results were compared to an XSA run.

5.2.7.7.2 Input data

For the assessment of hake in GSA 10 the DCF official data on the length structure has been used: no SOP correction has been applied as differences were far less than 10%. The age distribution has been estimated using the knife-edge slicing method (LFDA algorithm) with the growth parameters used in the past assessment. A sex-combined analysis was carried out.

The survey indices from MEDITS data from 2006 to 2014 have been used for the tuning and LLS CPUE

The age distribution of catches is showed in Figure 5.2.7.7.2.1 and Table 5.2.7.7.2.1. The age distribution of the tuning indices (MEDITS and LLS CPUE) are reported in the Figures 5.2.7.7.2.2. and 5.2.7.7.2.3, as well as in the tables 5.2.7.7.2.4 and 5.2.7.7.2.5.

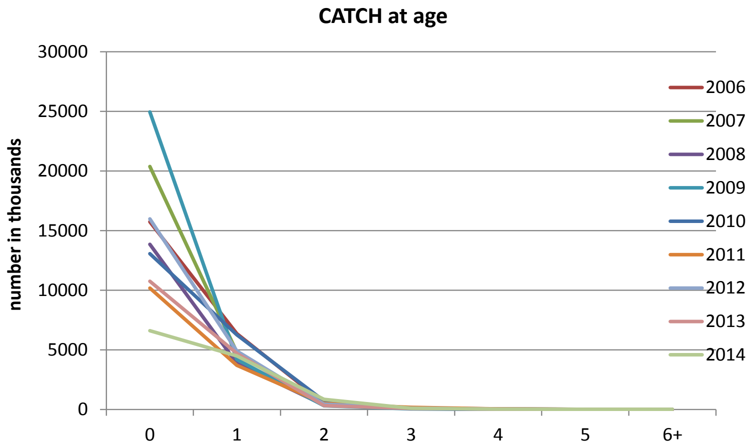


Figure 5.2.7.7.2.1. Hake in GSA 10. Catch (including discard) in numbers (thousands) by age and year used in the XSA.

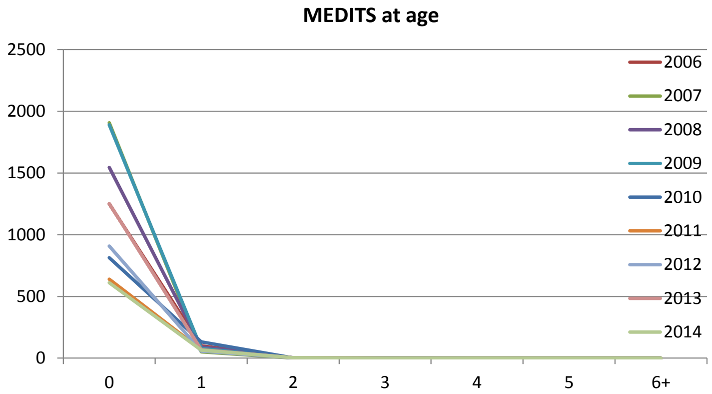


Figure 5.2.7.7.2.2. Hake in GSA 10. MEDITS in numbers (thousands) by age and year used in the XSA.

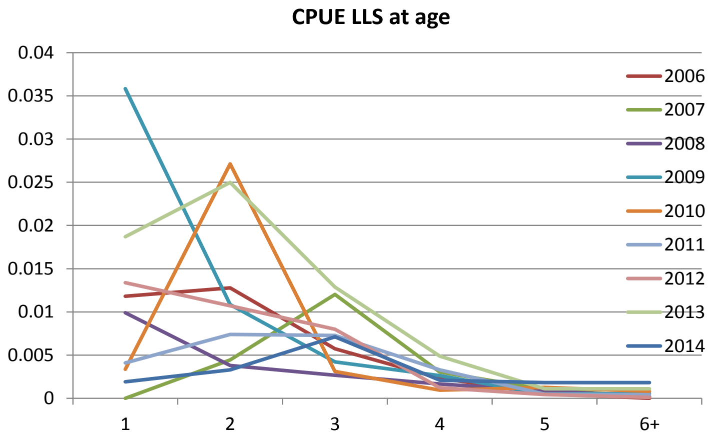


Figure 5.2.7.7.2.3. Hake in GSA 10. LLS CPUES by age and year used in the XSA.

Table 5.2.7.7.2.1. Hake in GSA 10. Catch in numbers (thousands, including discards) by age and year used in the XSA.

Year	**0**	**1**	**2**	**3**	**4**	**5**	**6+**
2006	15744.1	6355.5	561.9	89.1	34.8	19.0	0.0
2007	20385.0	4805.3	450.8	121.9	41.1	9.3	1.5

2008	13856.9	3864.8	367.6	138.0	54.3	22.1	4.2
2009	24960.6	4205.5	317.0	57.6	34.4	10.4	7.3
2010	13062.0	6267.7	723.7	65.8	6.7	8.9	7.6
2011	10180.3	3711.8	506.6	175.4	46.2	23.2	5.9
2012	15987.9	4895.6	448.7	117.4	17.6	5.0	1.5
2013	10749.6	4711.3	326.1	77.5	28.0	3.3	3.9
2014	6604.1	4488.5	847.2	105.7	25.5	19.1	19.1

Table 5.2.7.7.2.2. Hake in GSA 10. Weights at age (kg) in the catche used in the XSA.

Year/age	0	1	2	3	4	5	6+
2006	0.020	0.115	0.430	1.200	1.935	2.760	2.760
2007	0.018	0.118	0.471	1.195	1.813	3.003	5.921
2008	0.018	0.118	0.469	1.115	1.918	2.723	3.730
2009	0.018	0.122	0.439	1.112	1.881	2.721	3.763
2010	0.016	0.108	0.481	1.101	2.007	2.935	4.379
2011	0.016	0.129	0.443	1.164	1.860	2.684	4.262
2012	0.016	0.120	0.458	1.106	1.920	2.991	4.058
2013	0.016	0.121	0.539	1.165	1.818	2.964	4.520
2014	0.016	0.143	0.406	1.115	1.827	2.718	3.877

Table 5.2.7.7.2.3. Hake in GSA 10. Weights at age (kg) in the stock used in the XSA.

Year/age	0	1	2	3	4	5	6+
2006	0.006	0.137	0.519	1.141	1.931	2.808	3.704
2007	0.006	0.137	0.519	1.141	1.931	2.808	3.704
2008	0.006	0.137	0.519	1.141	1.931	2.808	3.704
2009	0.006	0.137	0.519	1.141	1.931	2.808	3.704
2010	0.006	0.137	0.519	1.141	1.931	2.808	3.704
2011	0.006	0.137	0.519	1.141	1.931	2.808	3.704
2012	0.006	0.137	0.519	1.141	1.931	2.808	3.704
2013	0.006	0.137	0.519	1.141	1.931	2.808	3.704
2014	0.006	0.137	0.519	1.141	1.931	2.808	3.704

Table 5.2.7.7.2.4. Hake in GSA 10. Indices from MEDITS survey used in the XSA.

Year/age	0	1	2	3	4	5	6+
2006	1250.42	99.67	2.32	0.49	0.01	0.01	0.01
2007	1907.19	51.52	0.95	0.97	0.14	0.14	0.01
2008	1544.78	92.69	2.97	1.52	0.01	0.01	0.4
2009	1890.43	78.11	0.38	0.32	0.01	0.32	0.01
2010	813.51	131.46	1.46	0.3	0.17	0.15	0.24
2011	639.35	67.18	2.45	1.2	0.01	0.01	0.01
2012	907.4	56.44	2.37	0.29	0.01	0.16	0.01
2013	1252.29	67.21	4.37	0.29	0.01	0.22	0.01
2014	610.5	64.50	4.00	0.20	0.30	0.01	0.01

Table 5.2.7.7.2.5. Hake in GSA 10. Indices from LLS (CPUE).

Year	1	2	3	4	5	6+
2006	0.011819	0.012778	0.005738	0.002327	0.000583	0
2007	0	0.004451	0.012014	0.003051	0.001027	0.000171
2008	0.009911	0.003799	0.002676	0.00165	0.000871	0.000236
2009	0.035813	0.010841	0.00422	0.002638	0.000486	0.000574
2010	0.003372	0.027127	0.003106	0.000952	0.001266	0.000806
2011	0.004089	0.007395	0.007279	0.003293	0.00049	0.000427
2012	0.013372	0.010703	0.007996	0.001233	0.000428	0.000107
2013	0.018687	0.024985	0.012861	0.004887	0.001097	0.001097
2014	0.001902	0.003283	0.007114	0.002094	0.001818	0.001818

For this assessment, as in that carried out in EWG 13_09 the fast growth parameters have been used. These as well as maturity and natural mortality vectors are those reported in the tables 5.2.7.2.2, 5.2.7.3.1 and 5.2.7.4.1. The stock object resulting from the XSA run with shrinkage 2 and Fbar 1-4 was used as input file for the a4a approach.

5.2.7.7.3 Results

Method: XSA

The XSA run with the following settings has been performed:
- Catchability (rage) independent on stock size for all ages =0.
- Catchability (qage) independent of age for ages >= 5.
- Minimum standard error for population estimates derived from each fleet = 0.300.
- shk.n=TRUE, shk.f=TRUE, shk.yrs=3, shk.ages=2

Sensitivity analysis have been performed with S.E. of the mean to which the estimates are shrunk equal to 0.5, 1, 1.5 and 2.

Shrinkage	Minimum	Maximux	Average
0.5	-2.128	2.588	0.721
1	-2.438	2.238	0.702
1.5	-2.473	2.222	0.699
2	-2.491	2.225	0.697

The run with shrinkage 2 has been chosen on the basis of the residuals and of the retrospective analysis.

- Shrinkage of the mean (fse): 2.

The log-catchability residuals at age and the retrospective analysis results are shown in Figure 5.2.7.7.3.1 and Figure 5.2.7.7.3.2.

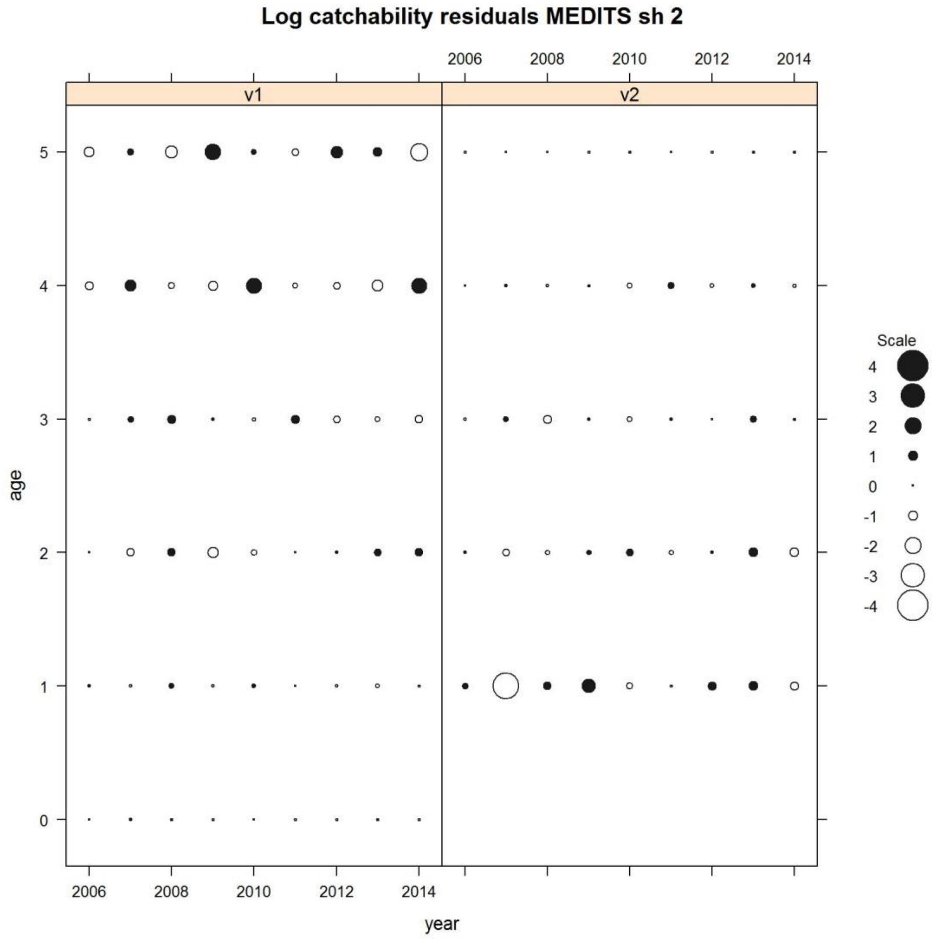


Figure 5.2.7.7.3.1. Hake in GSA 10. Log-catchability residuals at age for the tuning index, XSA of hake in GSA 10.

The residuals do not show any trend and overall the absolute values are low. As expected some relatively larger values were observed in the older ages of MEDITS and in the younger age (age 1) of LLS. The retrospective analysis shows also a consistent pattern. Fbar was set both between 0-5 ages and 1-4. The second setting gave more stable value and thus it was used in the final XSA model.

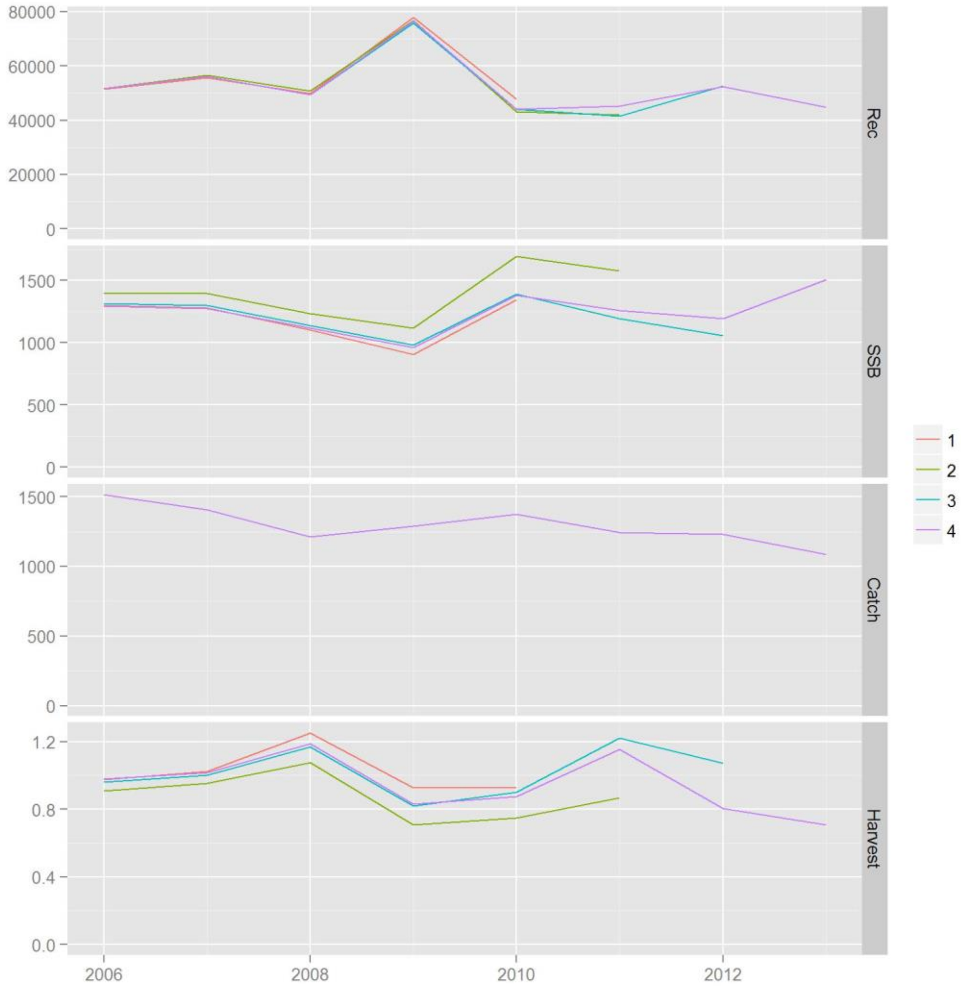


Figure 5.2.7.7.3.2. Hake in GSA 10. XSA Retrospective analysis (2010-2013).

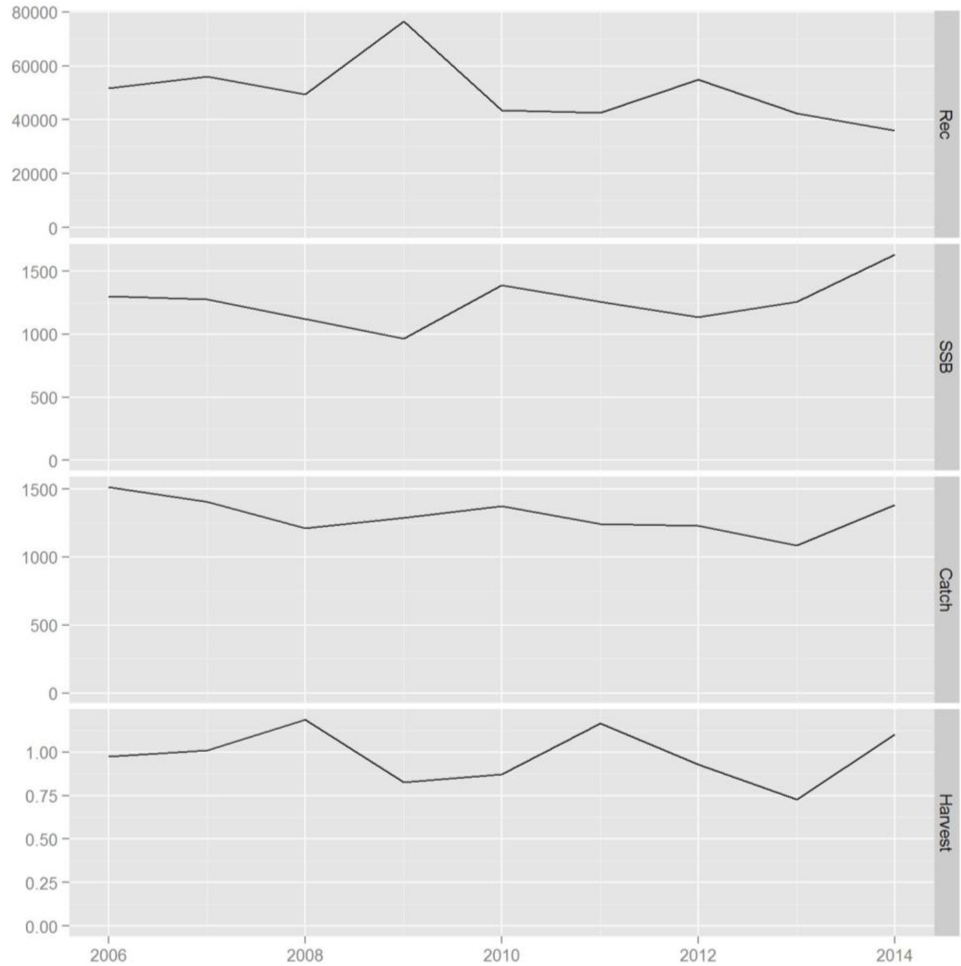


Figure 5.2.7.7.3.3. Hake in GSA 10. XSA summary results. SSB and catch are in tonnes, recruitment in 1000s individuals.

Both the $F_{bar(1\text{-}4)}$ and the SSB are varying along the time with F, catch and recruitment slightly decreasing and SSB slightly increasing. The F_{bar} along the time series is 0.98, with a minimum of 0.73 in 2013 and a maximum of 1.19 in 2008 (Table 5.2.7.7.3.1). The SSB is about 1,635 t in 2014, being the average along the time series equal to 1261. The recruitment has a slightly decreasing trend, even if in 2012 it increased again to a value equal to 51,400. The maximum recruitment is reached in 2009 and it is equal to 76,500 thousands individuals, while in 2014 it is 35919 (Table 5.2.7.7.3.1).

Table 5.2.7.7.3.1. Hake in GSA 10. Fishing mortality at age by year, $F_{bar(1\text{-}4)}$, spawning stock biomass (SSB, t) and Recruitment (R, thousands) estimated with XSA.

	Age0	Age1	Age2	Age3	Age4	Age5	Age6+	$f_{bar\ (1\text{-}4)}$	SSB	R
2006	0.786	1.047	0.694	0.874	0.766	0.554	0.733	0.974	1301	51675
2007	1.771	1.885	1.692	1.231	1.695	1.432	1.769	1.011	1278	56104
2008	0.973	0.800	1.141	0.864	1.092	0.850	0.951	1.186	1122	49445
2009	0.543	0.733	0.790	0.666	0.535	1.198	0.601	0.826	967	76498
2010	0.610	0.627	1.121	0.543	0.166	1.188	0.392	0.872	1389	43602
2011	1.237	0.363	1.016	0.781	0.293	1.954	0.411	1.167	1257	42722
2012	1.237	0.363	1.016	0.781	0.293	1.954	0.411	0.928	1138	54977

2013	0.786	1.047	0.694	0.874	0.766	0.554	0.733	0.727	1258	42445
2014	1.771	1.885	1.692	1.231	1.695	1.432	1.769	1.101	1635	35919

Model: a4a

In order to achieve the best results, different models were fitted to the data until reaching results that were both statistically sound and biologically interpretable. Five of the models run are presented here, and the general specifications of the models in R were the following:

```
qmod1 <- list(~ factor(age),~ factor(age) )
qmod2 <- list(~ factor(age),~ s(age, k=5))
qmod3 <- list(~ factor( replace(age, age>3,3) ),~ factor(replace(age, age>3,3)))
qmod4 <- list(~ factor(age)+year,~ factor(replace(age, age>3,3) ))

fmod1 <- ~ factor(age) + factor(year)
fmod2 <- ~ factor(age) + s(year, k=4)

srmod1 <- ~ factor(year)
srmod2 <- ~ s(year, k=4)

fit1 <- a4aSCA(stock=spe.stk, indices=spe.idx, fmodel=fmod1, qmodel=qmod1, srmodel=srmod1)
fit2  <- a4aSCA(stock=spe.stk, indices=spe.idx,fmodel=fmod2, qmodel=qmod1, srmodel=srmod2)
fit3<-a4aSCA(stock=spe.stk, indices=spe.idx,fmodel=fmod2,qmodel=qmod2,srmodel=srmod2)
fit4<-a4aSCA(stock=spe.stk, indices=spe.idx,fmodel=fmod2,qmodel=qmod3,srmodel=srmod2)
fit5<-a4aSCA(stock=spe.stk, indices=spe.idx,fmodel=fmod2,qmodel=qmod4,srmodel=srmod2)
```

The best model of the five models was selected in terms of residuals pattern, retrospective analysis, consistency with the XSA outputs, AIC, and BIC (Table 5.2.7.7.3.3). Although the model 5 not resulted as the best model according to AIC and BIC, it was the fitting with best results in terms of residuals pattern, retrospective analysis and consistency with the results obtained by XSA. Therefore, it was selected as the best a4a model for the hake stock in GSA 10.

This model allows the catchability of the MEDITS survey to be estimated by age and year, while fixing the catchability of the older age classes in the long-lines CPUE. Fishing mortality can vary by age and is modelled by a smoothing function on year. Recruitment is also modelled by a smoother on year.

Table 5.2.7.7.3.2. Hake in GSA 10. Summary table of the a4a models fitted.

Model	Problem with residuals	F	SSB	Retrospective analysis	Notes	AIC	BIC
Fit1	Catch 0 and 1	0.4-0.6	3000-4000 t	Not reliable	Different from XSA	471.7	624.9
Fit2	Medits	Around 1	900-1000 t	Not reliable	Similar to XSA	488.7	610.0

Fit3	Medits	Around 1	900-1000 t	Not reliable	Similar to XSA	486.7	604.8
Fit4	Medits	0.8-1.2	1000-1500 t	Consistent	Very similar to XSA	494.9	597.2
Fit5	Medits (age 2 and 3 only)	0.6-1.0	1000-1700 t	Consistent	Very similar to XSA	483.2	598.1

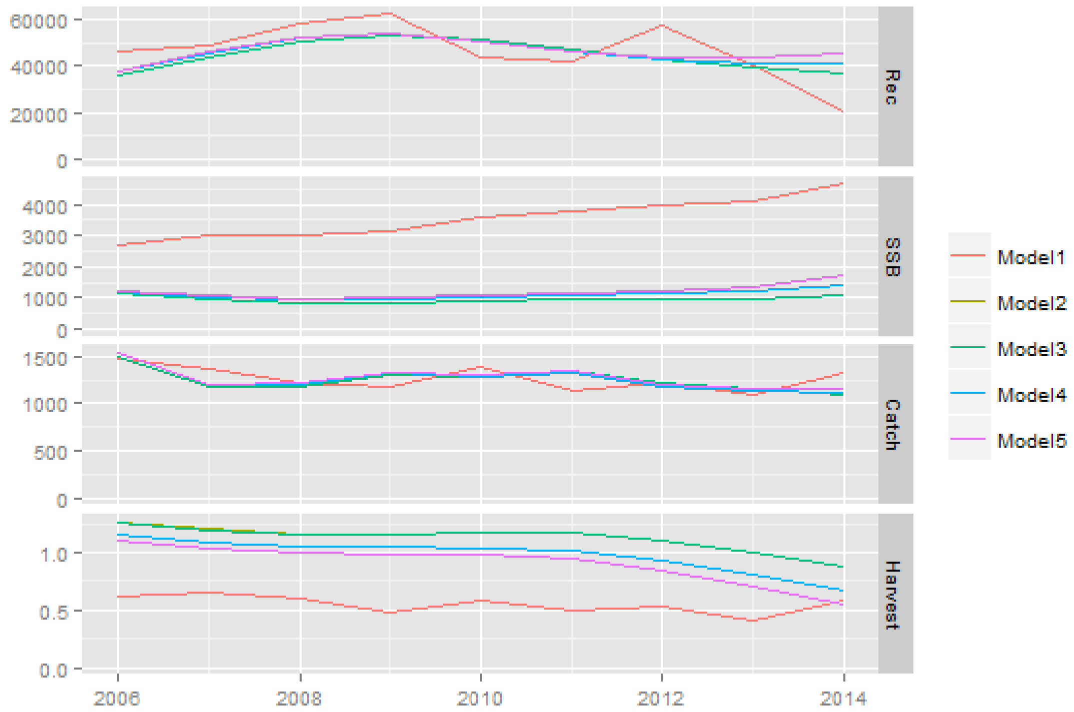


Figure 5.2.7.7.3.4. Hake in GSA 10. Plot of the stock parameters estimated by the five a4a models fitted.

The diagnostics and the outputs of the best a4a model for hake in GSA 10 are shown in Figure 5.2.7.7.3.5-5.2.7.7.3.12.

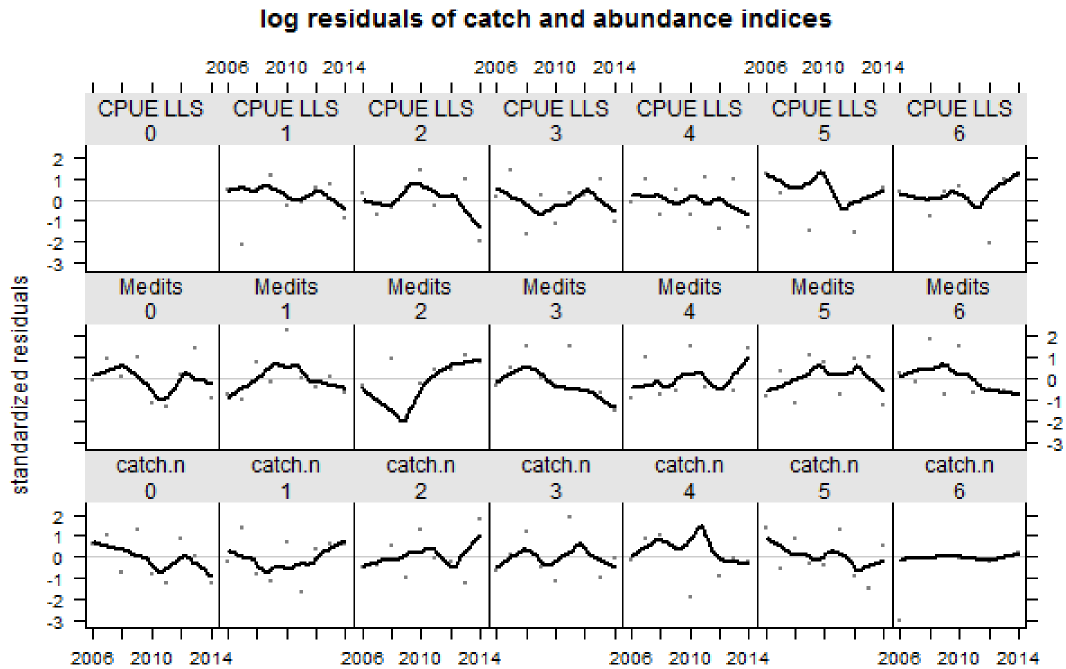


Figure 5.2.7.7.3.5. Hake in GSA 10. Log residuals for catch-, Medits indices-, and long-lines CPUE-at-age from the a4a best model.

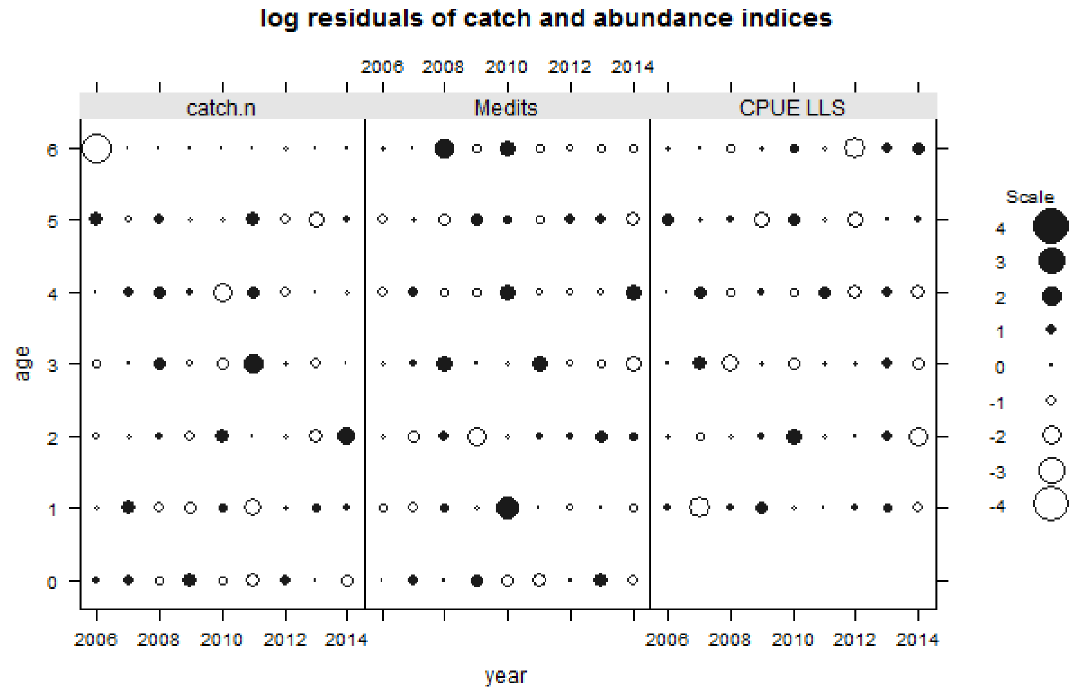


Figure 5.2.7.7.3.6. Hake in GSA 10. Bubble plot of log residuals for catch-, Medits indices-, and long-lines CPUE-at-age from the a4a best model.

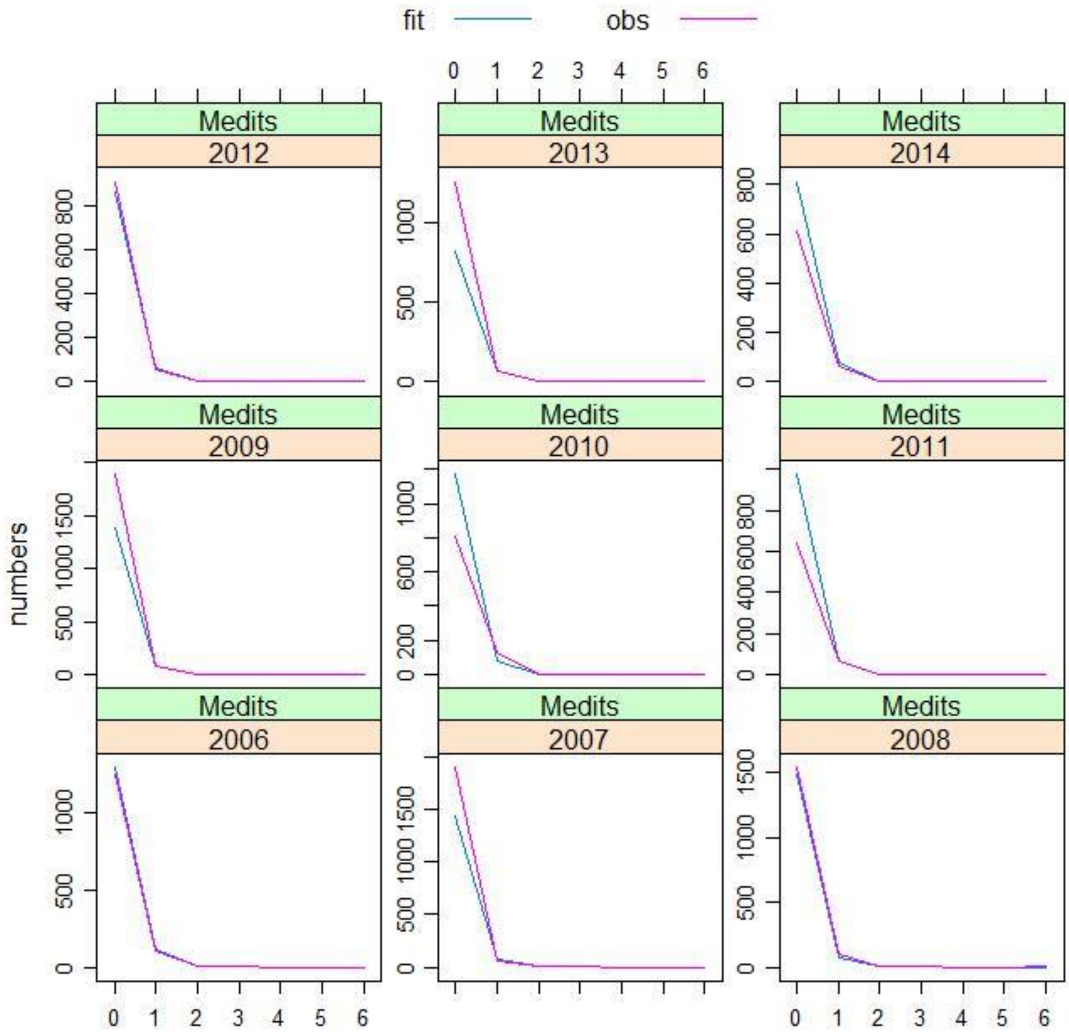


Figure 5.2.7.7.3.7. Hake in GSA 10. Observed *vs* fitted MEDITS indices-at-age.

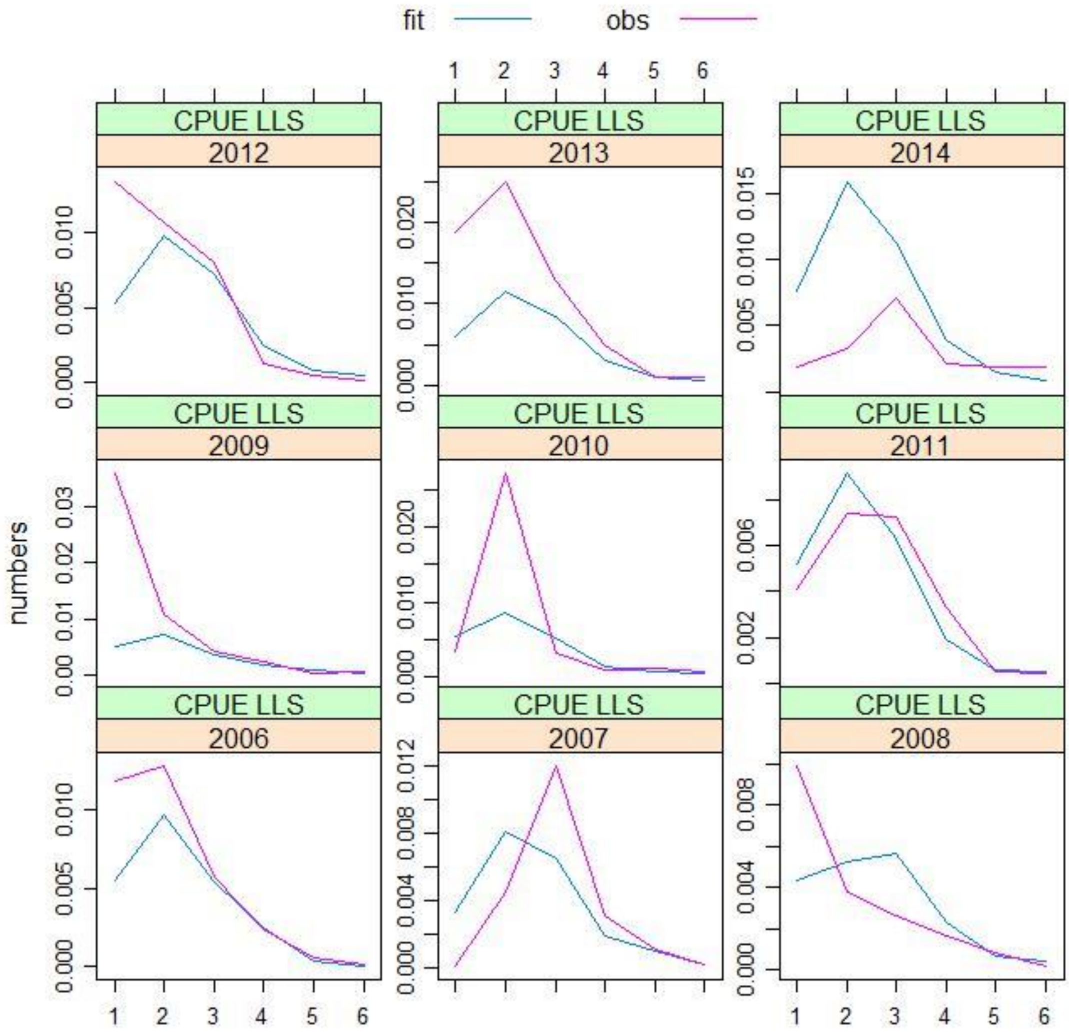


Figure 5.2.7.7.3.8. Hake in GSA 10. Observed *vs* fitted long-lines CPUE-at-age.

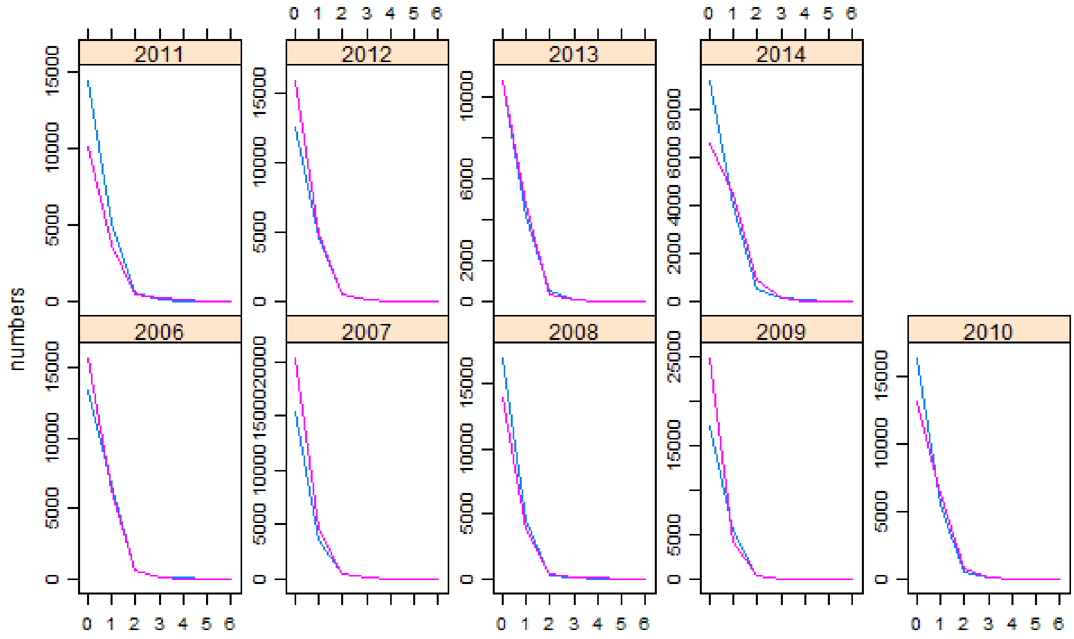


Figure 5.2.7.7.3.9. Hake in GSA 10. Observed catch-at-age *vs* catch-at-age fitted by the a4a best model.

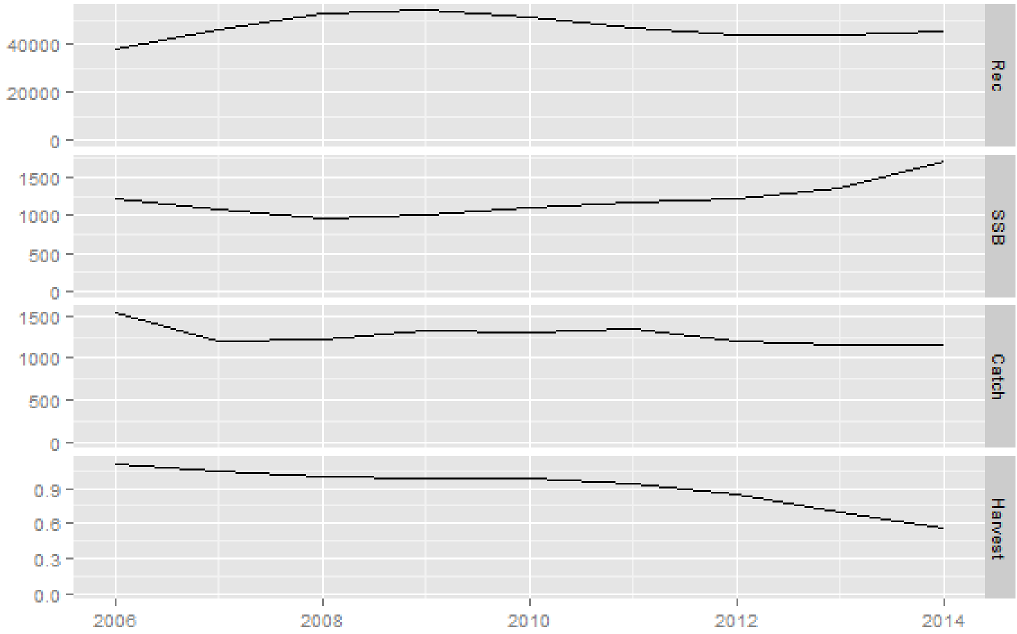


Figure 5.2.7.7.3.10. Hake in GSA 10. Time series of estimated parameters by means of a4a analysis.

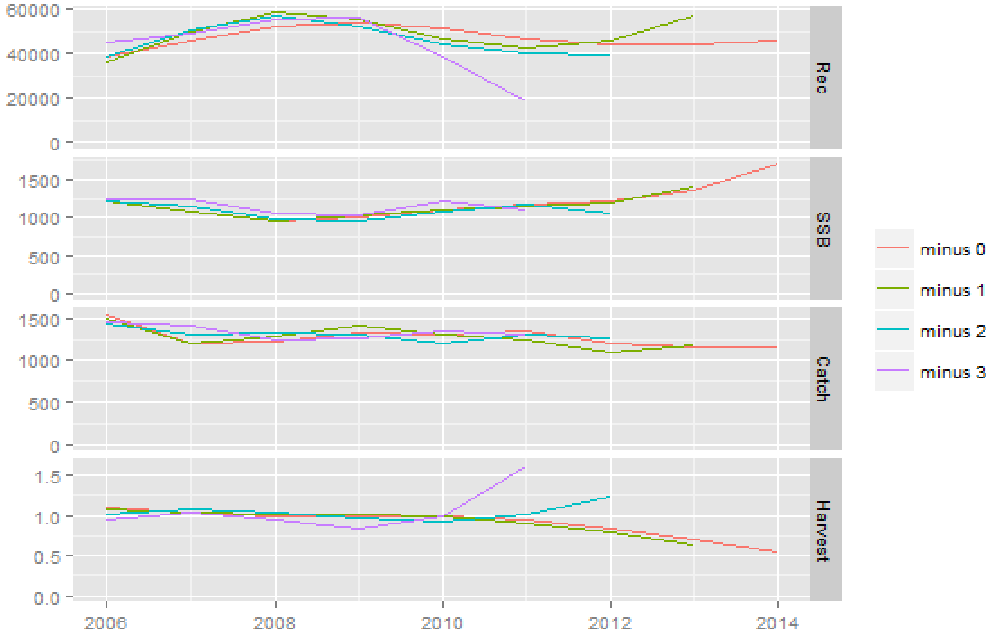


Figure 5.2.7.7.3.11. Hake in GSA 10. Retrospective analysis with a4a best model.

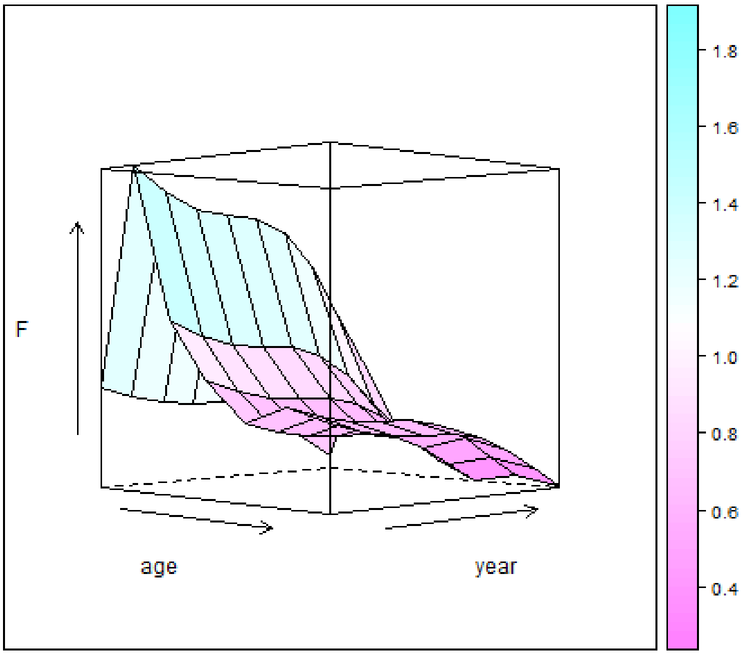


Figure 5.2.7.7.3.12. Hake in GSA 10. F-at-age estimated by the a4a best model.

Comparison with XSA

An XSA run was performed following the approach classically used for this stock, involving sensitivity analyses on parameters to select the best run. The comparison of the a4a results with those from the XSA run displayed a good consistency as the trends for the various variables were found to be the same.

However, due to the presence of some patterns in the residuals in the best of the a4a models fitted, it was decided to base the assessment on the XSA results.
Because of the still short time series of data used in the assessment (and the associated limited number of degrees of freedom) it was not possible to use complex smoother functions to model catchability and F-at-age in the a4a framework in order to improve the residuals.

5.2.7.8 Reference points

5.2.7.8.1 Methods

Yield Per Recruit in XSA

To predict the effect of changes in fishing effort of future yields and to define reference points F_{01} (as a proxy for F_{MSY}) and F_{max} a Yield per Recruit analysis (YPR) was carried out in R.

5.2.7.8.2 Input data

As input the same population parameters used for the XSA and its output of the exploitation pattern were used.

5.2.7.8.3 Results

The reference points are shown in table 5.2.7.8.3.1. The reference points computed from the a4a model are also shown, although the assessment and advice for hake in GSA 10 are based on XSA.

Table 5.2.7.8.3.1. Hake in GSA 10. Reference Points estimated on the Fbar 1-4 using XSA.

shrinkage	f0.1	Total.Yield	Recruitment	SSB	Biomass
0.5	0.177	2886	49011	25451	27737
1	0.196	2388	49316	23873	26088
1.5	0.198	2344	49306	23701	25910
2	0.198	2347	49274	23682	25892

Table 5.2.7.8.3.2. Hake in GSA 10. Reference Points estimated on the F_{bar} 1-4 using a4a.

	F	Total Yield	Recruitment	SSB	Biomass
virgin	0	0	46628	58180	60707
msy	0.229	2812	46628	18075	20096
crash	25.030	701	46628	0	280
f0.1	0.164	2703	46628	24605	26751
fmax	0.229	2812	46628	18075	20095
spr.30	0.236	2811	46628	17454	19461

5.2.7.9 Data quality

Data from DCF 2015 were used. Raw upload data with success were used, because those stored in the databases supplied by JRC showed some inconsistency (fishery data). A difference in the sum of products compared to landings was always far less than 10%. Discards data of 2006, 2009, 2010, 2011, 2012, 2013 and 2014 were available. Information on number of samples for landings, discards and catches, as well as the number of measurements by length for landings, discards and catches were also available. Number of otoliths was also available. MEDITS raw data used for this assessment have been processed by the expert using the software FishTrawl (used to validate the routine for estimating indices by MEDITS files). Growth, maturity by length and age and sex ratio were available for the whole time series (2002-2014).

5.2.7.10 Short term predictions 2016-2018

5.2.7.10.1 Method

A deterministic short term prediction for the period 2015 to 2017 was performed using the FLR routines provided by JRC, which takes into account the catch and landings in numbers and weight and the discards. This routine performs short terms for the whole fleet.

A generic approximate multifleet projections with FLR provided by JRC was also used to split the fishing mortality by fleet using proportion of catch in number by age and fleet.

5.2.7.10.2 Input parameters

The same input parameters used in the XSA analysis shown above were used. Different scenarios of constant harvest strategy with F_{bar} calculated as the average of ages 1 to 4 and F status quo (F_{stq} = 0.906; geometric mean of the last three years) were performed. Recruitment (class 0) has been estimated from the population results from the geometric mean of the last three years 2012-2014 (43764 thousands individuals) estimated using XSA.

5.2.7.10.3 Results

The results of the short term forecasts related to the whole fleet are summarised in the table Table 5.2.7.10.3.1 and in the figure 5.2.7.10.3.1.

Table 5.2.7.10.3.1. Hake in GSA 10. Short term forecast in different F scenarios computed for *M. merluccius* in GSA 10. Basis: F(2015) = mean(F_{bar}1-4 2012-2014)= 0.906; R(2015) = geometric mean of the recruitment of the last 3 years; R = 43764 (thousands); SSB(2014) = 1382 t, Catch (2014)= 1635 t.

Rationale	Ffactor	fbar	Catch 2016	Catch 2017	SSB 2017	Change SSB 2016-2017 (%)	Change Catch 2014-2016 (%)
Zero catch	0	0.000	0	0	3770	192.42	-100.00
High long-term yield (F0.1)	0.218	0.198	404	769	2927	127.03	-70.80
Status quo	1	0.906	1289	1297	1296	0.50	-6.74
Different scenarios	0.1	0.091	197	419	3352	160.03	-85.74
	0.2	0.181	374	724	2988	131.74	-72.97
	0.3	0.272	532	941	2669	107.00	-61.50
	0.4	0.362	675	1092	2389	85.34	-51.17
	0.5	0.453	804	1193	2144	66.34	-41.86
	0.6	0.543	920	1257	1929	49.65	-33.43
	0.7	0.634	1026	1293	1740	34.96	-25.79
	0.8	0.725	1122	1308	1573	22.02	-18.85

	0.9	0.815	1209	1308	1426	10.60	-12.52
	1.1	0.996	1362	1279	1180	-8.45	-1.44
	1.2	1.087	1430	1256	1078	-16.39	3.42
	1.3	1.178	1491	1229	987	-23.46	7.90
	1.4	1.268	1549	1201	905	-29.76	12.03
	1.5	1.359	1601	1171	833	-35.39	15.86
	1.6	1.449	1650	1141	768	-40.43	19.40
	1.7	1.540	1696	1112	710	-44.96	22.69
	1.8	1.630	1738	1083	657	-49.03	25.76
	1.9	1.721	1778	1055	610	-52.69	28.62
	2	1.812	1815	1028	567	-56.01	31.30

A short term projection of the whole fleet (table 5.2.7.10.3.1), assuming an F_{stq} of 0.91 in 2014 and a recruitment of 43764 thousands individuals shows that:

- Fishing at the Fstq (0.906) generates a decrease of the catch of 6.74% from 2014 to 2016 along with an approximately stable spawning stock biomass (change +0.5%) from 2016 to 2017.
- Fishing at F0.1 (0.2) generates a decrease of the catch of 70.8% from 2014 to 2016 and an increase of the spawning stock biomass of 127% from 2016 to 2017.

Results of the short term multifleet projections are reported in the table 5.2.7.10.3.2 and Figure 5.2.7.10.3.2.

Table 5.2.7.10.3.2. Hake GSA 10. Short term forecast by fleet.

Fbar 1-4	2006	2007	2008	2009	2010	2011	2012	2013	2014	Mean of last three years
trawl	0.32	0.40	0.48	0.22	0.26	0.27	0.30	0.17	0.29	0.26
nets	0.31	0.32	0.41	0.29	0.45	0.38	0.37	0.40	0.55	0.44
lls	0.34	0.28	0.29	0.31	0.16	0.50	0.25	0.15	0.22	0.21
overall	0.97	1.01	1.19	0.83	0.87	1.17	0.93	0.73	1.10	0.92

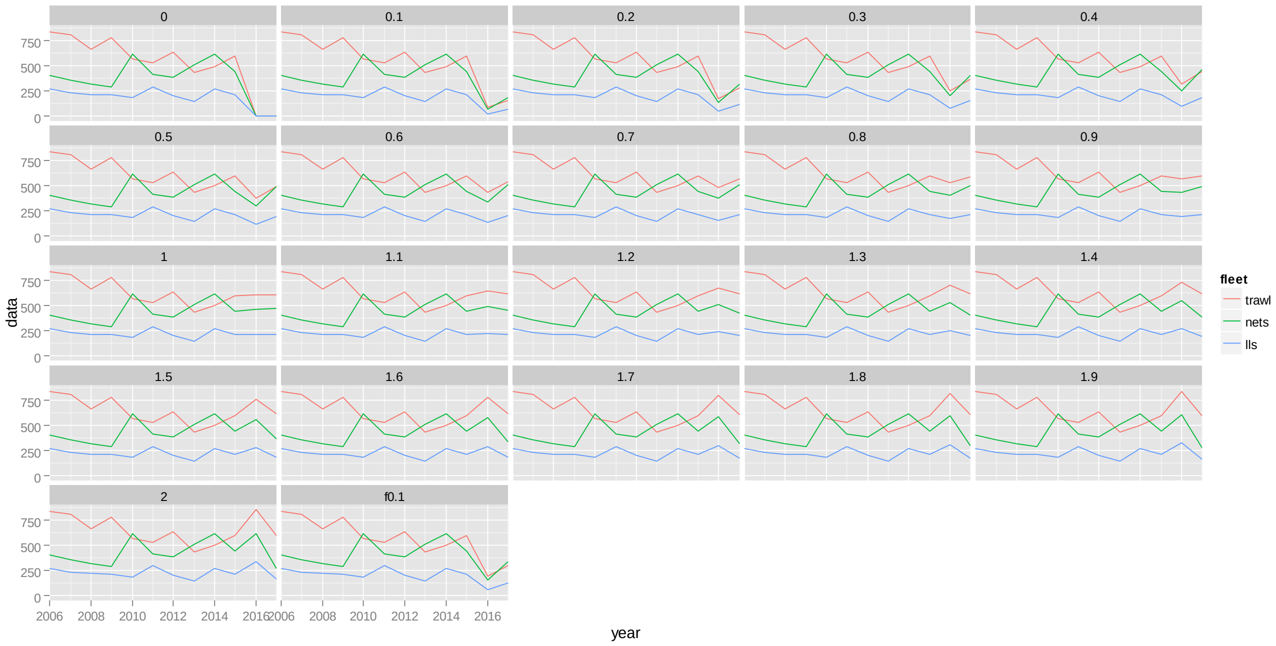


Figure 5.2.7.10.3.2. Hake in GSA 10. Short term forecast by fleet.

5.2.7.11 Medium term predictions

5.2.7.11.1 Method

Medium term was not conducted because no meaningful stock-recruitment relationship was estimated.

5.2.7.12 Stock advice

STECF-EWG 15-11 proposes $F_{0.1}$=0.20 as limit management reference point consistent with high long term yield and lower risk of stock collapse.

SSB showed an increasing trend in the last years while recruitment fluctuated and was slightly decreasing. Also F was decreasing in the recent years except the last one. According to the F estimates obtained using landing, discard data and survey indices in XSA, in the last year of the time series (2014) F (1.10) was above the estimated reference value of $F_{0.1}$=0.20.

STECF-EWG 15-11 considers the stock in overfishing situation and advises to reduce the current level of effort of the relevant fleets in order to avoid future loss in stock productivity. Catches of hake in 2016 consistent with F_{MSY} should not exceed 404 tonnes.

5.2.7.13 Management strategy evaluation

F ranges results were F_{upper}=0.27 and F_{lower}=0.13. B_{lim} (967 t) was estimated as was estimated as the minimum SSB estimated in XSA assessment.

A management strategy was conducted with an FLR script distributed during the meeting. The Management Strategy Evaluation was ran to evaluate if the MSY ranges were precautionary. The F_{MSY} ranges were derived using the formula provided by STECF 15-09.

The management strategy evaluation included uncertainty in the recruitment around a mean level resulting from the geometric mean of the last 3 years of data and uncertainty in the MEDITS and longlines CPUE tuning fleet indices. The stock was assessed by XSA, with the same settings of the assessment at each iteration. The number of iterations was 250. The following figure 5.2.3.13.1

shows the evolution of the main four stock indicators. The probability of SSB going below B_{lim} was estimated at 0.

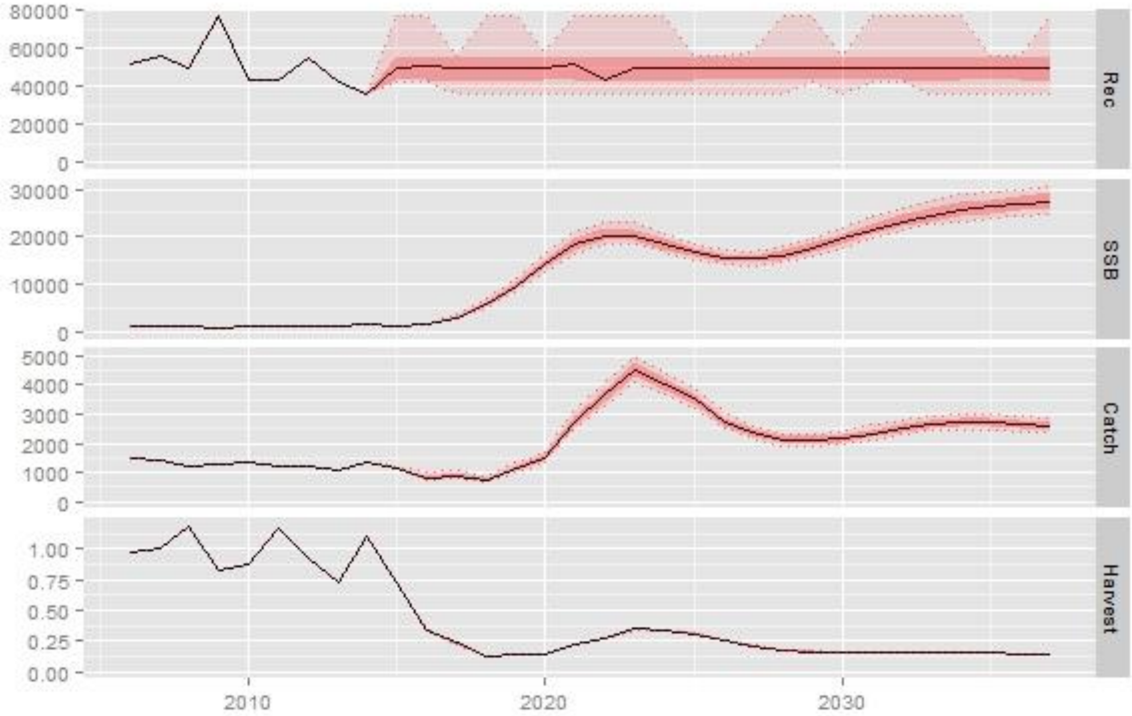


Figure 5.2.3.13.1. Hake GSA 10. Management Strategy Evaluation.

5.2.8 STOCK ASSESSMENT OF HAKE IN GSA 11

5.2.8.1 Stock Identification

Due to a lack of information about the structure of hake population in the western Mediterranean, this stock was assumed to be confined within the GSA 11 boundaries (Figure 5.2.8.1.1).

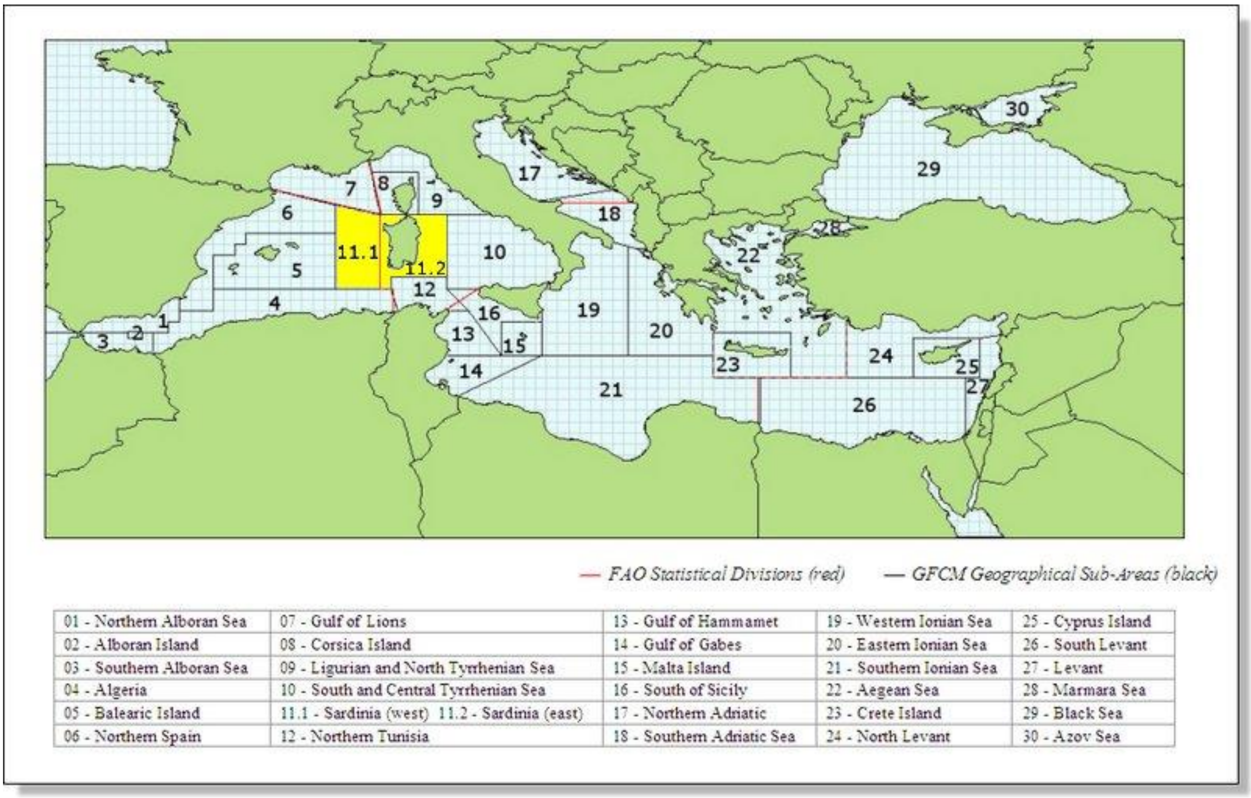


Figure 5.2.8.1.1. Geographical location of GSA 11.

Hake is distributed in the whole area between 10 and 800 m depth. Recruits peak in abundance over the continental shelf-break (between 150 and 250 m depth). The stock is mainly exploited by the local fishing fleet, although seasonally and occasionally some other Italian fleet use to fish in some areas of the GSA 11. Spawning is taking place almost all year round, with a peak during winter–spring. Juveniles showed a patchy distribution with some main density hot spots (nurseries) showing a high spatio-temporal persistence (Murenu et al., 2010a) in western areas.

5.2.8.2 Growth

There are no specific studies on the growth pattern of the species in Sardinian waters. The same fast growth of the previous SGMED meetings have been used in this assessment (Linf=100.7 cm, K=0.2, t0= -0.01).

5.2.8.3 Maturity

Due to the low catchability of large hake in the trawl, the catch rate of mature specimens during the MEDITS trawl survey is usually very low, influencing the identification of gonad development and growth rate for large individuals. Female length at first maturity is estimated at around 36 cm. Although spawning around Sardinian coasts (GSA 11) occurs nearly all over the year (January to September), a maturity peak is usually observed in winter and spring (February-May).

5.2.8.4 Natural mortality

Natural mortality was estimated using PRODBIOM (Abella *et al.*, 1998) and is shown in Table 5.2.8.4.1. The input parameters used were L_{inf} = 100.7, k = 0.2, t_0 =-0.01, a = 0.004 and b = 3.1672.

Table 5.2.8.4.1. European hake in GSA 11. Natural mortality.

Age	0	1	2	3	4	5+
M	1.15	0.57	0.46	0.41	0.38	0.37

5.2.8.5 Fisheries

5.2.8.5.1 General description of the fisheries

The fleet of GSA 11 is composed of about 1311 boats. Trawlers (n=155) account for about 11 % of the fleet. Most of them (n=79) are based on the main southern fishery ports (Cagliari and Sant'Antioco). From 1994 to 2004, the trawl fleet showed remarkable changes in GSA 11. Those mostly consisted of a general increase in the number of vessels and by the replacement of the old, low tonnage wooden boats by larger steel boats. For the entire GSA an increase of 85% for boats >70 tons class occurred. A decrease of 20% for the smaller boats (<30 GRT) was also observed.

In GSA 11 most of the trawlers utilize nets similar to the original commercial "Italian trawl net". The main differences lie in overall size, mesh dimensions and some hanging details. The dimensions of the commercial trawl net can change in relation to the trawlers engine power and bottom characteristic also. Generally the Italian trawl nets have a maximum vertical opening of about 2 m while the horizontal net opening is more variable (around 25 m).

Detailed maps of the fishing-grounds of trawlers are reported in Murenu et al. (2010b). Most of the effort is concentrated within a relative short distance around the major fishing ports (Cagliari, Alghero, Porto Torres, La Caletta, Sant'antioco, Oristano, Alghero). Moreover, some large trawlers move seasonally in different fishing grounds far from the usual ports.

Although hake is not a target of a specific fishery in GSA 11, it is the third species in terms of biomass landed (Murenu M., pers. com.) and it is caught exclusively by a mixed bottom trawl fishery that operates at depth between 50 and 800 m. No gillnet or longline fleets target this species while it can be find as a by catch of gillnet fleets targeting other species (ex. Palinurus spp.).

5.2.8.5.2 Management regulations applicable in 2015

As in other areas of the Mediterranean, management is based on the control of fishing capacity (licenses), fishing effort (fishing activity), technical measures (mesh size and area closures), and minimum landing sizes (EC 1967/06).

By the actual regulation, cod end mesh size of trawl nets are 40 mm square meshes or 50 mm (stretched) diamond meshes. The minimum landing size for hake is 20 cm TL.

In the GSA 11 there are five coastal Marine Protected Areas (Asinara, Capo Caccia-Isola Piana, Penisola del Sinis-Maldiventre, Capo Carbonara, Tavolara) and two small offshore closed areas established to protect Norway lobster. Moreover the use of trawl nets and towed gears is not allowed within 1.5 nautical miles of the coast (EU council regulation No 1967/2006) or at depths less than 50 m when this depth is reached within the distance above mentioned.

Since 1991, a fishing closure for trawlers had been enforced almost every year. From 1991 to 2004 and in 2006 and 2011 the fishing closure was for 45 trawling days. From 2008 to 2015 (2011 excluded) the fishing closure was for 30 trawling days. In 2005 and 2007 the fishing closures had not been enforced.

5.2.8.5.3 Landings

Landings data were reported to STECF EWG 15-11 through the DCF. In GSA 11 the bulk of catches are from otter trawl, while artisanal fisheries represents the smallest part of the catches. Further, catch data for artisanal fisheries are discontinuous and variable in time (table 5.2.8.5.4.1). The time series of landings data (tons) by gear for the period 2005-2014 is shown in Figure 5.2.8.5.4.1. For the OTB, maximum landings values are observed in 2005 and minimum values (45t) in 2014.

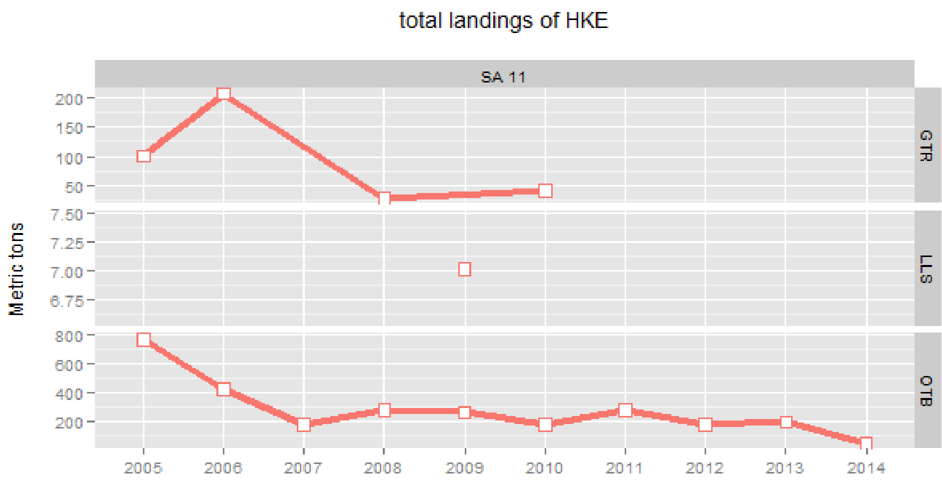


Figure 5.2.8.5.4.1. European hake in GSA 11. Total annual landings by gear for the period 2005-2014.

Table 5.2.8.5.4.1. European hake in GSA 11. Annual landings (t) by gear in GSA 11 from the DCF data.

Gear/Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
GTR	100.6	206.0		28.6		42.5				
LLS					7.0					
OTB	765.4	421.7	176.7	278.7	260.5	175.9	277.4	175.9	195.8	45.0
total	866.0	627.7	176.7	307.3	267.5	218.4	277.4	175.9	195.8	45.0

The available information of the size structure of landings is shown in Figure 5.2.8.5.4.2.

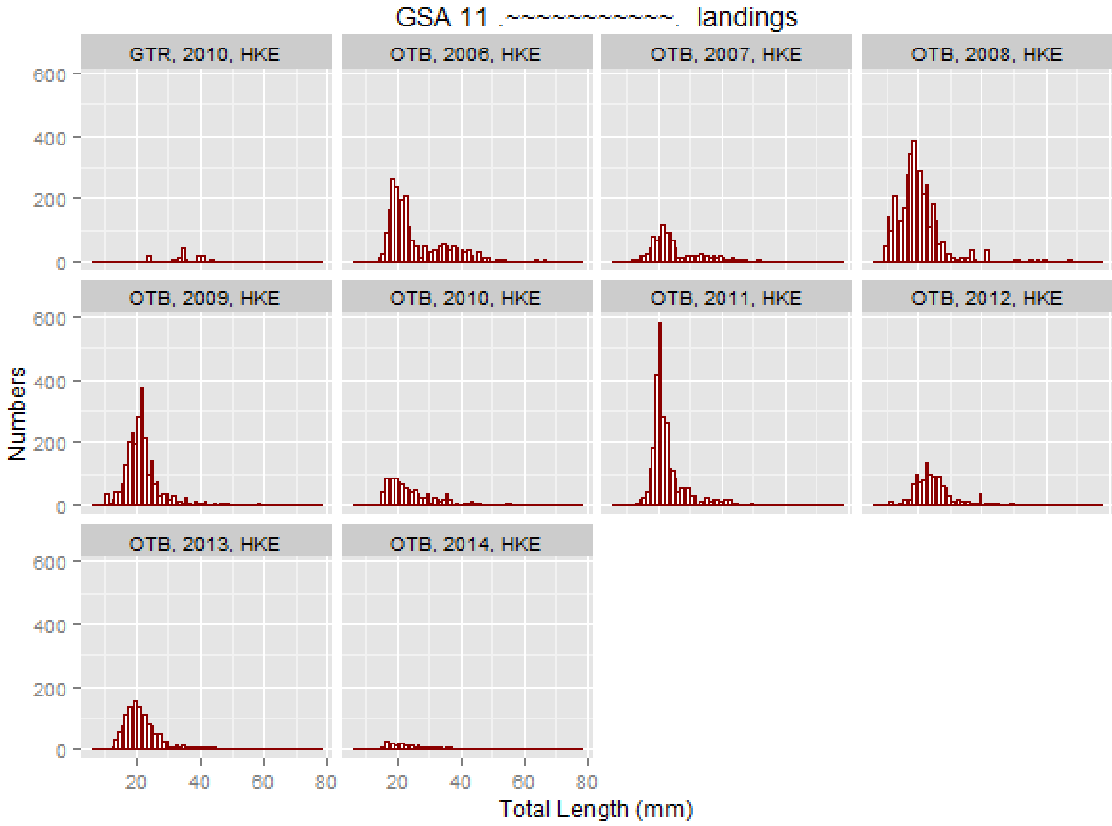


Figure 5.2.8.5.4.2. European hake in GSA 11. Size structure of the landings from 2006 to 2014 from DCF.

Comparing the information of total landings with those on lengths of landings it is clear that length data are missing for OTB in 2005 and for GTR in 2005, 2006 and 2008. To overcome this problem EWG 15-11 decides to exclude the 2005 from the analysis and to reconstruct the length information for landings only for the years where total values have been reported. Furthermore, since the size distribution of GTR landings in 2010 seems to be unrealistic, EWG 15-11 decided to use the OTB size distribution of landing to reconstruct and fill the gap of the missing data (see the data quality paragraph).

5.2.8.5.4 Discards

Discards data were reported to STECF EWG 15-11 through the DCF. Information on OTB discards was available for 2006 and from 2009 to 2014, and on GTR only for 2005 (Figure 5.2.8.5.5.1, Table 5.2.8.5.5.1). Furthermore in 2006 the reported value for discard in OTB seems to be overestimated.

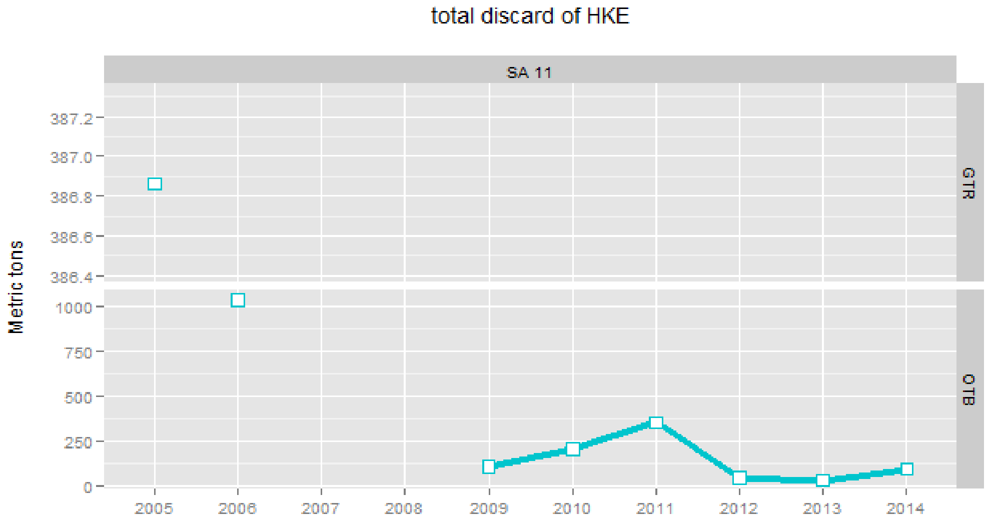


Table 5.2.8.5.5.1. European hake in GSA 11. Annual discards in tons by gear from DCF.

Gear/Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
GTR	386.9									
LLS										
OTB		1036.7			106.8	208.7	353.8	47.0	32.3	95.0
total	386.9	1036.7			106.8	208.7	353.8	47.0	32.3	95.0

Data on the length frequency of discards by gear is available for the same time period of data on total values for OTB while for the GTR the LFD of discards of 2010 is not coherent with total values (Figure 5.2.8.5.5.2).

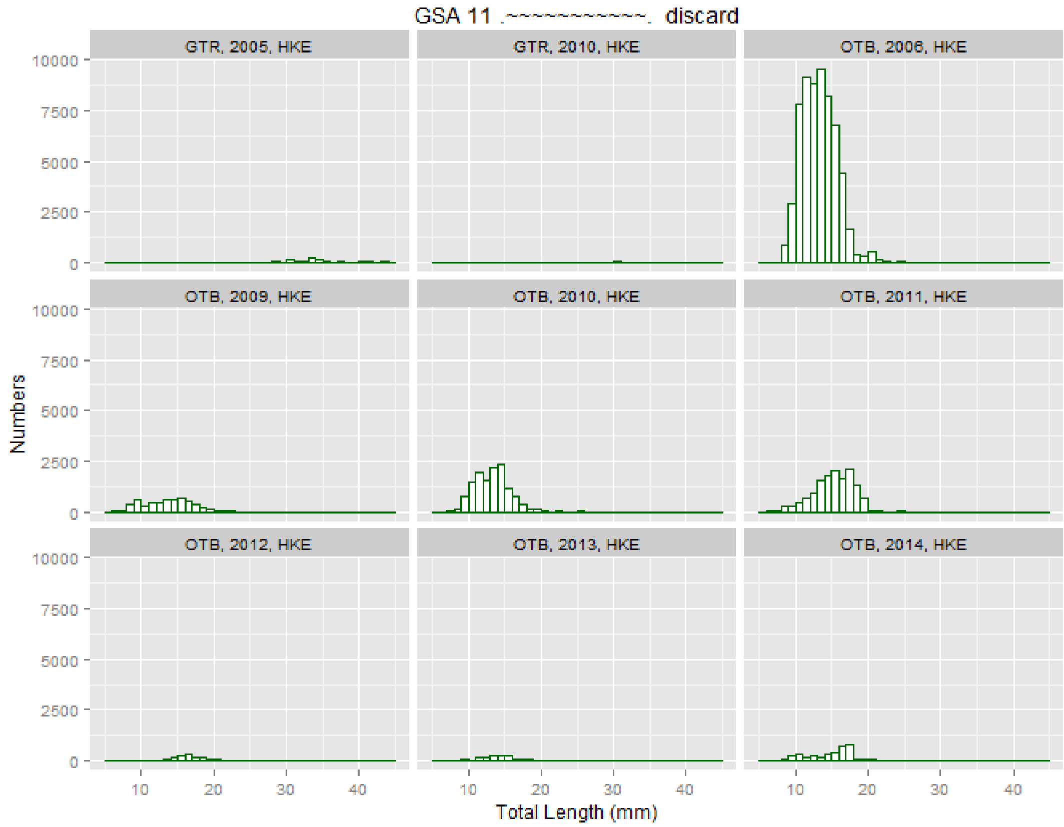


Figure 5.2.8.5.5.2. European hake in GSA 11. Size composition of the OTB discards by year from DCF.

Looking at the discard information by length for GTR EWG 15-11 considers it as misreported and decided to exclude it for the assessment. Further, to fill the gap of missing years for the discard of OTB was decided to apply a raising procedure (see next paragraphs, input data for stock assessment and data quality).

5.2.8.5.5 Fishing effort

The fishing capacity of the GSA 11 has shown in these last 10 years a progressive decrease. Fishing effort (kW*fishing days) performed by the GSA 11 trawlers decreased of 43% since 2006, from about 6 milion to 3 milion in 2014. The effort displayed by the artisanal fleet showed an increase in the last two years for vessels using trammel nets (GTR) whereas the effort of gillnetters (GNS) in 2014 increase 3 times of the values registered in 2006 but shows an anomalous drop in 2013 (Figure 5.2.8.5.6.1).

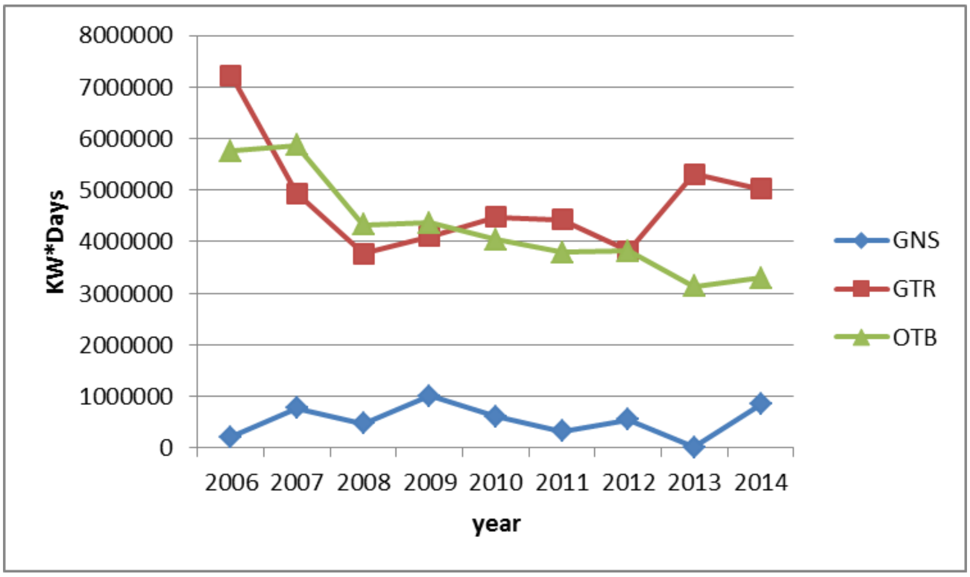


Figure 5.2.8.5.6.1 Effort trends (days and kW*days) by major fleets, 2006-2014.

5.2.8.6 Scientific surveys

5.2.8.6.1 Survey #1 (MEDITS)

5.2.8.6.1.1 Methods

Based on the DCF data call, abundance and biomass indices were recalculated. In GSA 11 the following numbers of hauls were reported per depth stratum (Table 5.2.8.6.1.1.1).

Table 5.2.8.6.1.1.1. Numbers of hauls per year and depth stratum in GSA 11, 1994-2014.

Strata	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
A	16	18	20	21	20	19	19	17	20	18	15	17	19	20	17	18	19	20	19	20	21
B	25	20	23	23	22	22	22	25	19	19	20	22	19	19	19	20	19	18	20	19	19
C	20	24	31	31	31	30	31	29	24	24	24	23	24	24	22	24	24	25	23	24	24
D	26	22	24	24	23	23	21	22	20	20	18	20	20	21	21	19	20	20	21	21	21
E	29	23	27	27	27	26	30	29	19	18	18	15	16	16	16	16	17	18	18	17	17

Data were assigned to strata based upon the shooting position and average depth (between shooting and hauling depth). Catches by haul were standardized to 60 minutes hauling duration. Hauls noted as valid were used only, including stations with no catches of hake, red mullet or pink shrimp (zero catches are included).

The abundance and biomass indices by GSA were calculated through stratified means (Cochran, 1953; Saville, 1977). This implies weighting of the average values of the individual standardized catches and the variation of each stratum by the respective stratum areas in each GSA:

$$Yst = \Sigma (Yi*Ai) / A$$

$$V(Yst) = \Sigma (Ai^2 * si^2 / ni) / A^2$$

Where:

A=total survey area
Ai=area of the i-th stratum
si=standard deviation of the i-th stratum
ni=number of valid hauls of the i-th stratum
n=number of hauls in the GSA
Yi=mean of the i-th stratum
Yst=stratified mean abundance
V(Yst)=variance of the stratified mean

The variation of the stratified mean is then expressed as the 95 % confidence interval: Confidence interval = Yst ± t(student distribution) * V(Yst) / n
It was noted that while this is a standard approach, the calculation may be biased due to the assumptions over zero catch stations, and hence assumptions over the distribution of data. A normal distribution is often assumed, whereas data may be better described by a delta-distribution, quasi-poisson. Indeed, data may be better modelled using the idea of conditionality and the negative binomial (e.g. O'Brien et al. 2004).
Length distributions represented an aggregation (sum) of all standardized length frequencies (subsamples raised to standardized haul abundance per hour) over the stations of each stratum. Aggregated length frequencies were then raised to stratum abundance * 100 (because of low numbers in most strata) and finally aggregated (sum) over the strata to the GSA. Given the sheer number of plots generated, these distributions are not presented in this report.

5.2.8.6.1.2 Geographical distribution
The spatial distribution of European hake has been described by modeling the spatial correlation structure of the abundance indices using geostatistical techniques (i.e. kriging). In different studies either total abundance index or abundances of recruits and adults were analysed (Murenu et al., 2007).
On average, considering the analyzed yearly distributions (1994-2005), the recruits were considered individuals smaller than 12.3 cm (±1.41). These individual are belonging to the age 0 group. Persistence of the nursery areas along the years was studied by applying indicator kriging technique (Journel 1983, Goovaerts, 1997) to abundance estimations of recruits (Murenu et al., 2010a). Main results and maps are reported in the "nursery section" of the SGMED 09-02 report.

5.2.8.6.1.3 Trends in abundance and biomass
Fishery independent information regarding the state of hake in GSA 11 was derived from the international survey MEDITS. Figure 5.2.8.6.1.3.1 displays the estimated trend in hake abundance and biomass in GSA 11. As shown below both for biomass and abundance in some years a high level of variability is evident. The estimated abundance and biomass indices since 1999 show high variation without any trend.

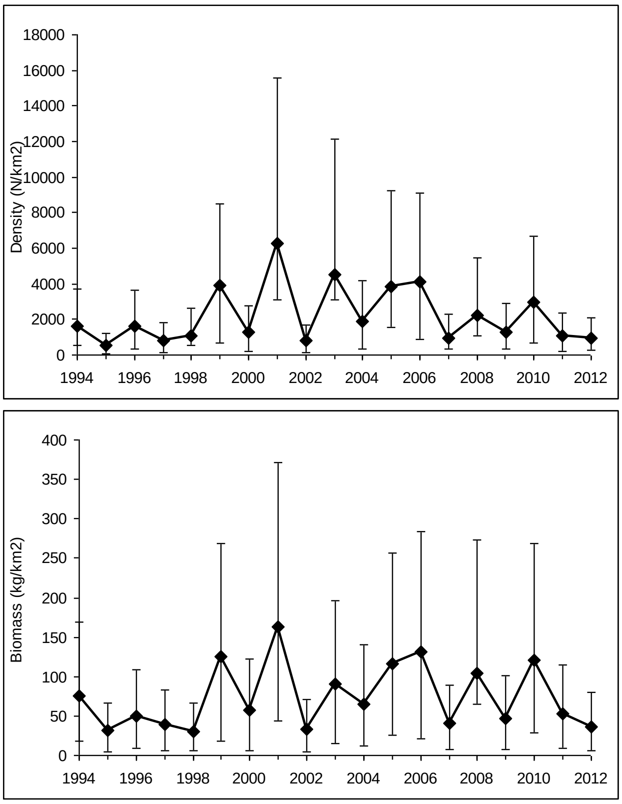


Figure 5.2.8.6.1.3.1. Hake in GSA 11. MEDITS time series of survey biomass and density indices (mean +/- standard deviation).

5.2.8.6.1.4 Trends in abundance by length or age

Boxplots and histograms of the MEDITS standardized length frequencies distributions (LFD) are shown in Figure 5.2.8.6.1.4.1. All distributions are characterized by a various numbers of superior outliers. The median show a small variability, as well as a small variation of the degree of dispersion along the time series. The greater variability is to account to the total abundances (box sizes are proportional to numbers).

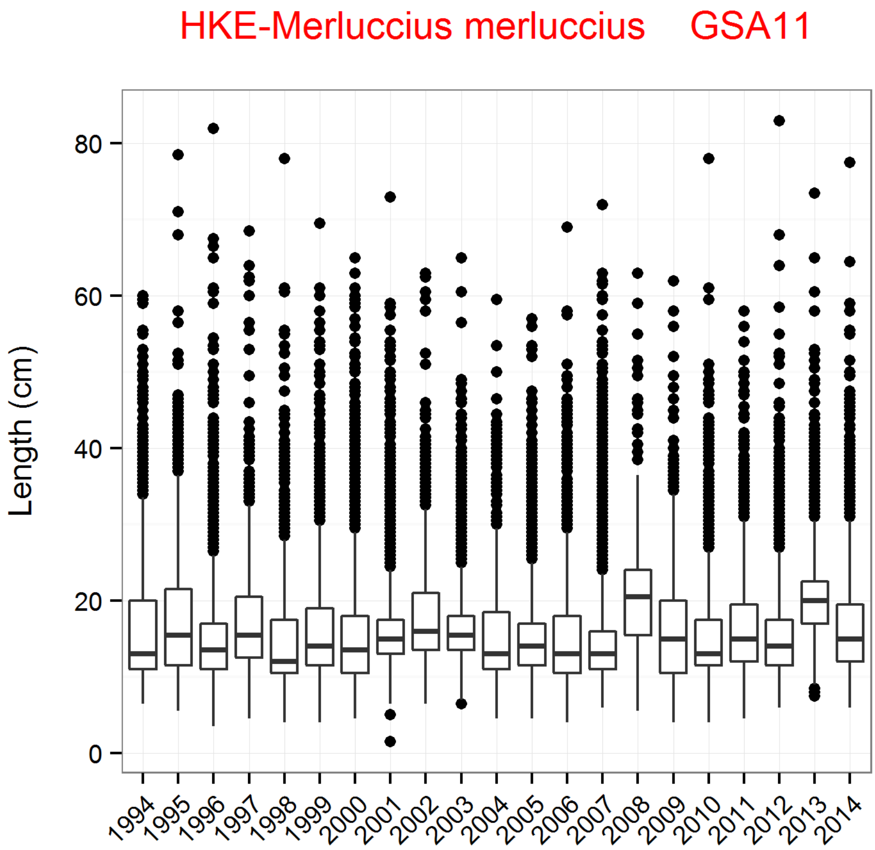


Figure 5.2.8.6.1.4.1. Hake in GSA 11. Boxplot of the stratified length frequency distributions (MEDITS).

The following Figure 5.2.8.6.1.4.2 displays the stratified abundance indices of European hake in GSA 11 from 1994 to 2014.

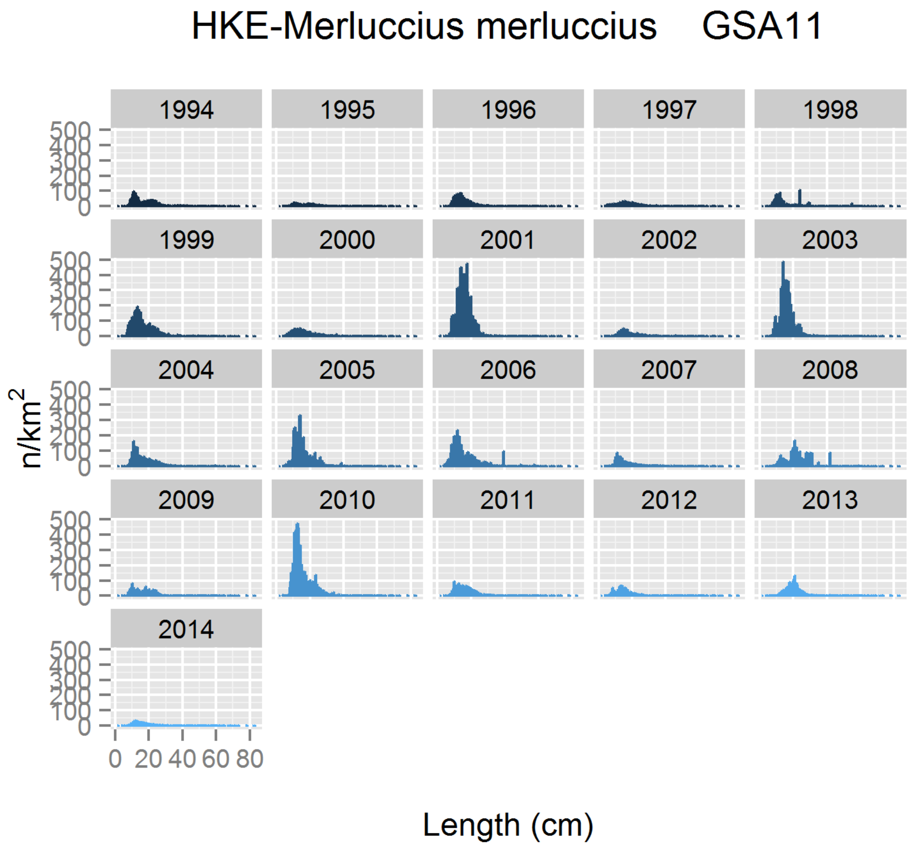


Figure 5.2.8.6.1.4.1. Hake in GSA 11. Stratified abundance indices by size, 1994-2014.

5.2.8.7 Stock Assessment

5.2.8.7.1 Method: XSA

The hake stock was assessed for the last time during in EWG 13-09 using as input data the period 2005-2012, but due to the poor quality of data the assessment was not accepted.

During in EWG 15-11 the quality of landings and discard information was checked again, and unfortunately the problems were not solved (see the paragraphs on catches and data quality).

To overcome this situation and use as much as possible the available information EWG 15-11 decided to operate some changes in the discard database and to use as a proxy the information of others years and gears to reconstruct the missing pieces of information needed for the assessment.

Once the data have been corrected the FLR libraries were used to carry out an XSA based assessment (Darby and Flatman, 1994). XSA has been carried out using as input data the period 2006-2014 both for the catch data and for the tuning file.

5.2.8.7.2 Input data

The growth parameters used for VBGF were L_{inf}= 100.7 cm TL; K = 0.2 yr^{-1}; t_0= -0.01 yr. The length-to-weight coefficients used were a= 0.0044, b= 3.1457.

Catch numbers have been raised taking into account the LFD that were missing for some years and gears (see data quality for details).

LFDA 5.0 slicing software has been used to transform the annual size distribution of the landings and MEDITS LFDs in age distributions in order to apply XSA model. Since the catches in numbers and weight at age were not consistent with total landings at age, a rescaling procedure using Sum Of Product correction (SOP) was carried out.

A vector of natural mortality value by age was obtained using ProdBiom (Abella et al., 1997). Finally, zero values in the catch at age have been substituted with the lowest value in the time series. Table 5.2.8.7.2.1 lists the input parameters to the XSA, namely landings, catch number at age, weight at age, maturity at age, natural mortality at age and the tuning series at age (MEDITS).

Table 5.2.8.7.2.1. Hake in GSA 11. Input data to the XSA model.

xsa initial settings

min	max	plusgroup	minyear	maxyear	minfbar	maxfbar
0	5	5	2006	2014	0	3

Maturity and natural mortality vectors

age	0	1	2	3	4	5
M	1.15	0.57	0.46	0.41	0.38	0.37
Maturity	0	0.25	0.9	1	1	1

Catch (t)

2006	2007	2008	2009	2010	2011	2012	2013	2014
860	327.33	544.89	367.33	427.09	631.27	222.85	228.06	139.96

Catch number at age matrix (thousands)

age	2006	2007	2008	2009	2010	2011	2012	2013	2014
0	43482	9196	15672	5896	17473	15351	1291	2222	5346
1	2286	1181	2506	1827	1216	3195	1101	982	516
2	386	171	120	92	214	168	112	91	45
3	39	14	21	9	27	14	9	16	4
4	9	3	11	12	8	2	2	7	3
5+	9	3	4	6	2	2	1	5	2

Mean weight at age (kg)

age	2006	2007	2008	2009	2010	2011	2012	2013	2014
0	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007
1	0.133	0.133	0.133	0.133	0.133	0.133	0.133	0.133	0.133
2	0.466	0.466	0.466	0.466	0.466	0.466	0.466	0.466	0.466
3	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
4	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61
5	2.292	2.292	2.292	2.292	2.292	2.292	2.292	2.292	2.292

MEDITS number at age

age	2006	2007	2008	2009	2010	2011	2012	2013	2014
0	670.5	41.5	15.6	169.9	425.3	131.2	177.1	3.6	33.7
1	2937.1	894.6	1789.6	1096.9	5498.6	1448	932.3	1588.5	531.8
2	318.9	52.1	331.4	41	325.5	108.3	44.4	125.8	48.6
3	9.7	9.4	86.1	2.4	11.1	10.7	2.4	9.9	5

4	8.3	1.2	5	1	0.2	2.6	0.5	0.9	0.7
5+	0.3	0.6	0.1	0.1	0.2	0.1	0.3	0.4	0.2

5.2.8.7.3 Results

Sensitivity analyses were conducted to assess the effect of the main parameters on the assessment. Values ranging from 0.5 to 3 (0.5 increasing) for the shrinkage (Figure 5.2.8.7.3.1**)**, values ranging from 1 to 3 for shrinkage years (Figure 5.2.8.7.3.2**)** and a combination of values between 2 to 4 for the qage parameter and from -1 to 1 for the rage parameter (Figure 5.2.8.7.3.3**)** have been compared and tested. Different combinations between the settings that looked more stable were tested.

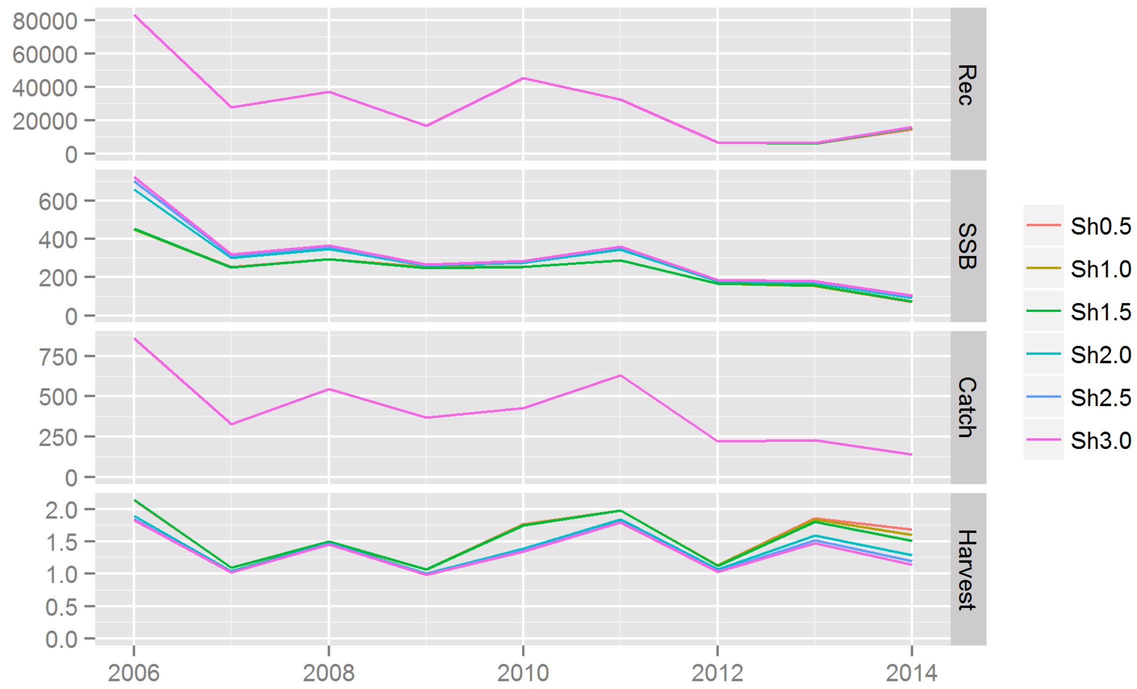


Figure 5.2.8.7.3.1. Hake in GSA 11. Sensitivity on shrinkage weight.

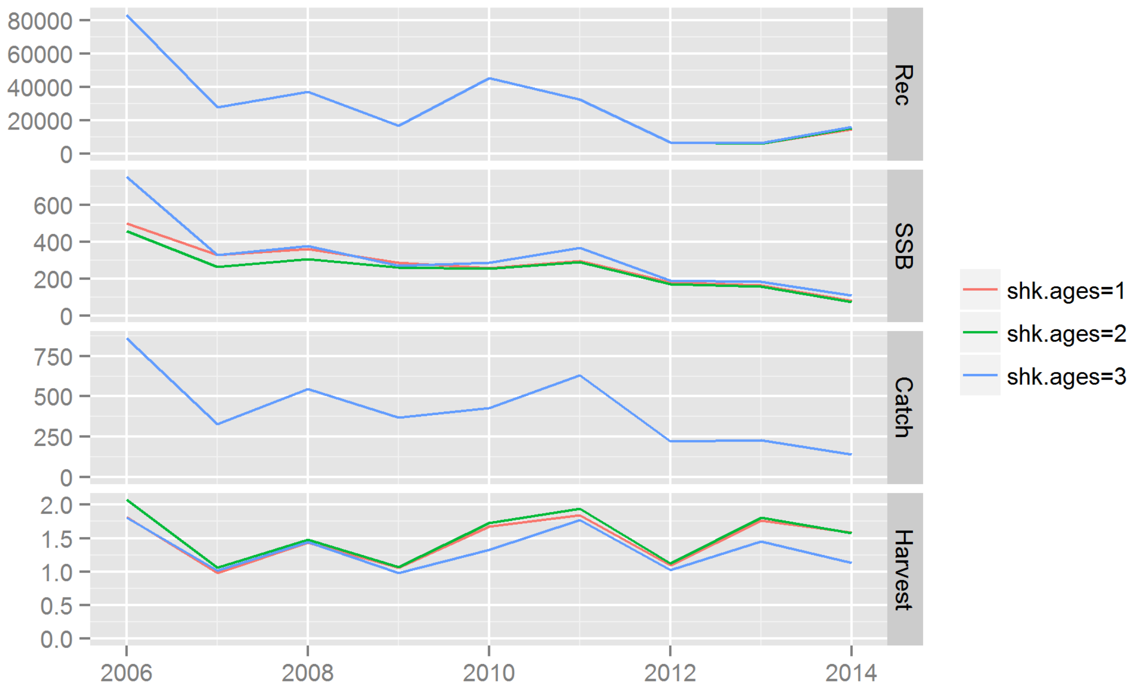


Figure 5.2.8.7.3.2. Hake in GSA 11. Sensitivity on shrinkage age.

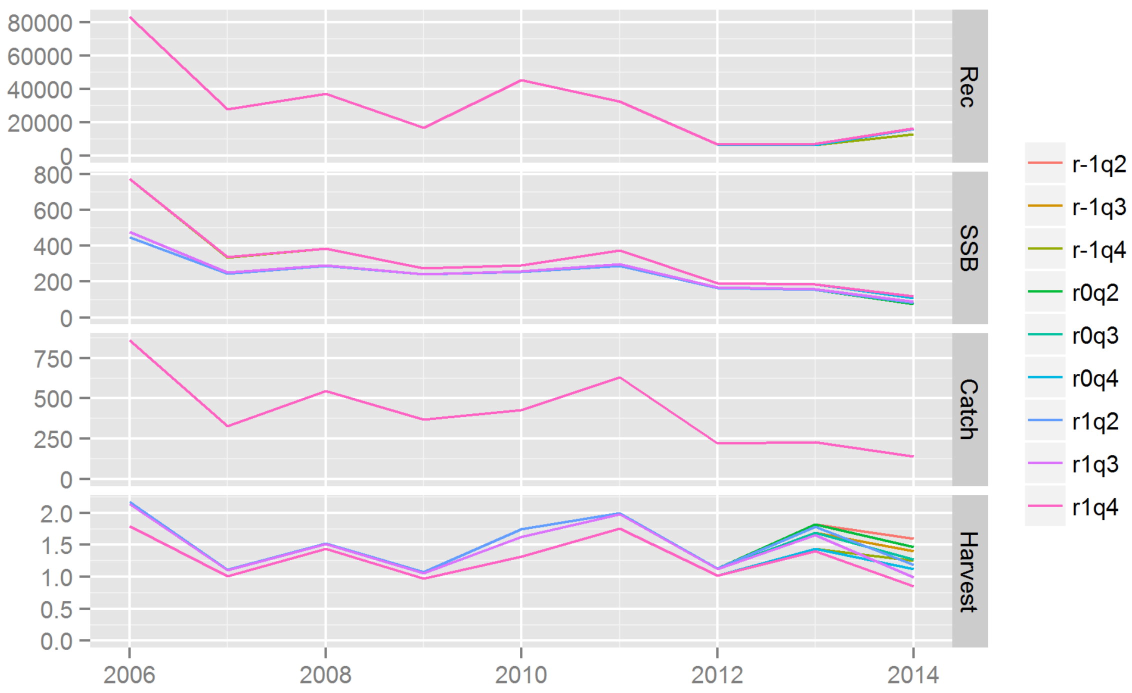


Figure 5.2.8.7.3.3. Hake in GSA 11. Sensitivity on qage and rage.

As a result, the settings that minimized the residuals and showed the best diagnostics output were used for the final assessment, and these were the following:

Fbar	fse	rage	qage	Shk.n	Shk.f	shk.yrs	shk.age
0-3	1	0	4	true	true	3	3

The residuals pattern of the MEDITS trawl survey is shown in Figure 5.2.8.7.3.4.

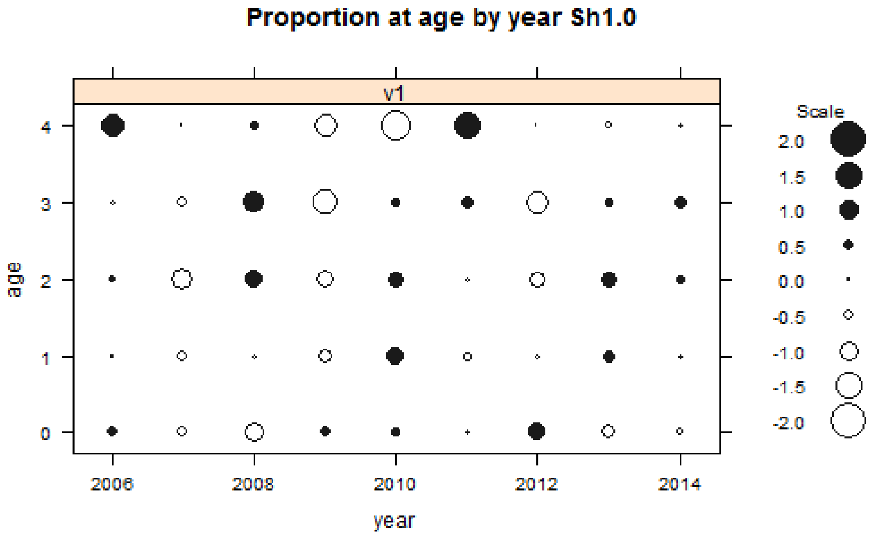


Figure 5.2.8.7.3.4. Hake in GSA 11. XSA residuals for the MEDITS survey from 2006 to 2014.

The results of the retrospective analysis are shown in Figure 5.2.8.7.3.5.

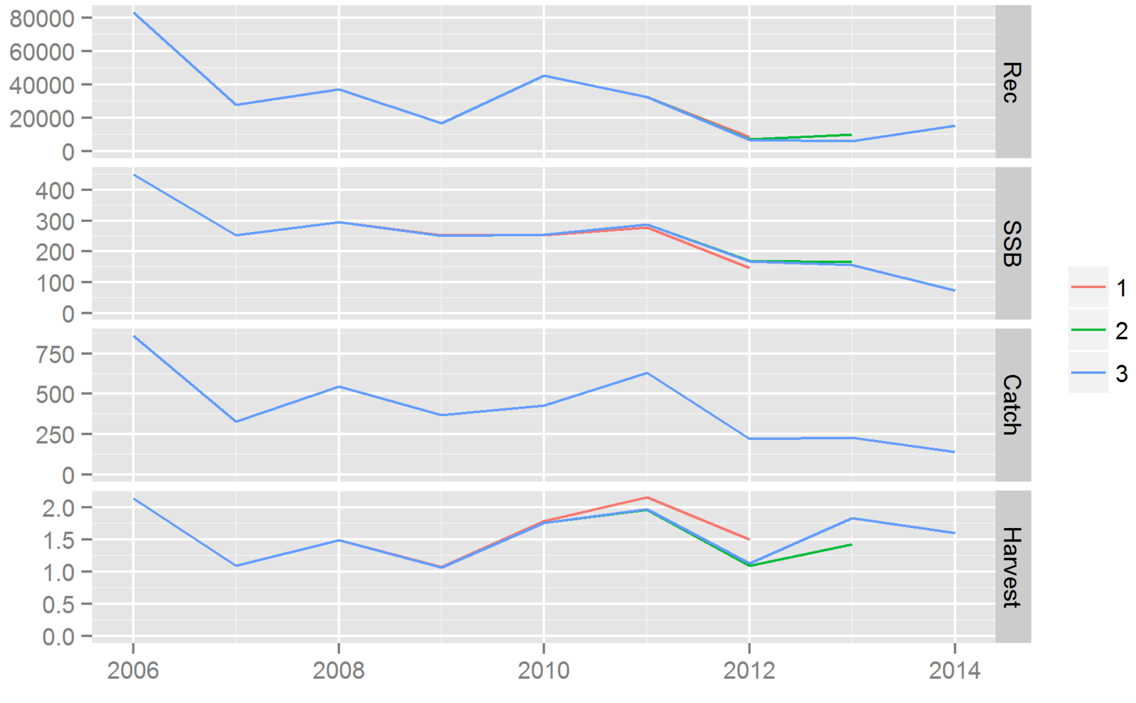


Figure 5.2.8.7.3.5. Hake in GSA 11. XSA retrospective analysis.

The results of the XSA are shown in the figure 5.2.8.7.3.6.

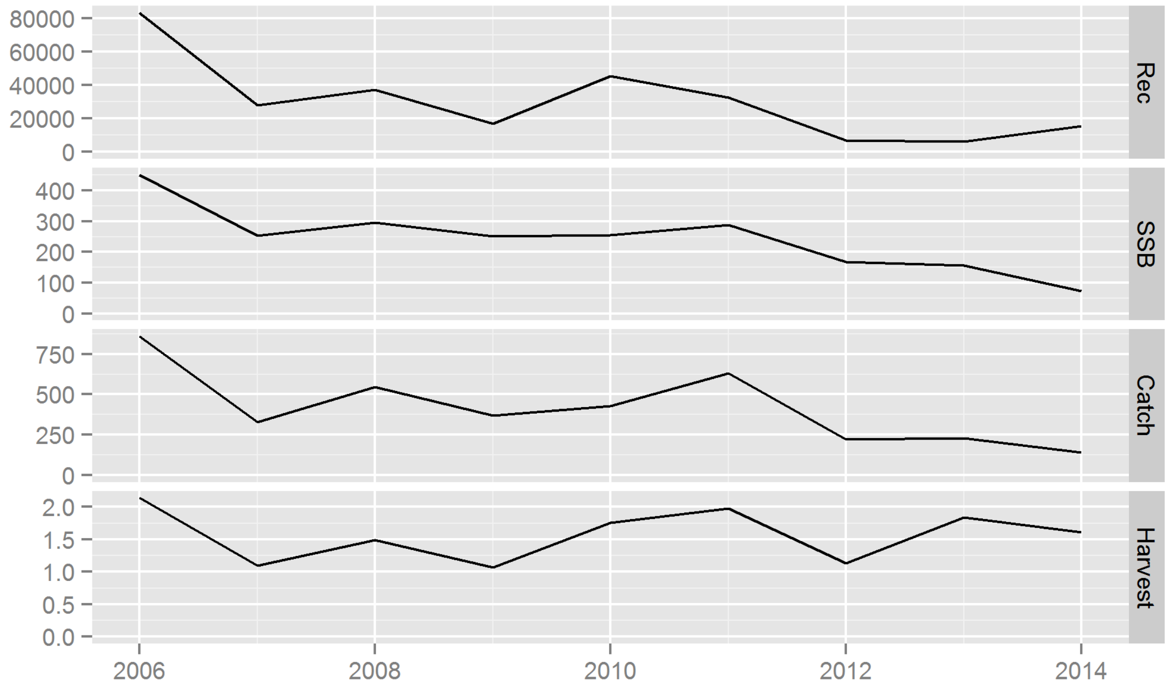


Figure 5.2.8.7.3.6. Hake in GSA 11. XSA summary results. SSB and catch are in tonnes, recruitment in 1000s individuals.

In the tables 5.2.8.7.3.1, 5.2.8.7.3.2 and 5.2.8.7.3.3 the population estimates of hake obtained by XSA are provided.

Table 5.2.8.7.3.1. Hake in GSA 11. Stock numbers at age (thousands) as estimated by XSA.

Age	2006	2007	2008	2009	2010	2011	2012	2013	2014
0	83307.6	27844.2	37213.8	16992.3	45482	32613.7	6787	6315.2	15474.6
1	3576.2	1910.6	3641.9	2964.8	2062.9	4569.3	1688.7	1422.6	749.5
2	551.4	303.1	192.6	174.9	302.5	251.9	181.6	127.3	66.1
3	56	41.8	55.2	26.7	37.3	21.1	25.6	25.6	7.7
4	12.3	5.5	16.3	19.9	10.5	2.9	2.8	9.4	3.7
5+	11.6	5.3	5.6	9.1	2.6	2.2	2.2	6.6	2.9

Table 5.2.8.7.3.2. Hake in GSA 11. XSA summary results.

Age	2006	2007	2008	2009	2010	2011	2012	2013	2014
Fbar(0-3)	2.14	1.10	1.49	1.07	1.76	1.98	1.13	1.84	1.61
rec	83307.6	27844.2	37213.8	16992.3	45482	32613.7	6787	6315.2	15474.6
SSB (t)	451.4	252.5	295.1	251.0	254.8	288.0	166.9	156.1	72.7

Table 5.2.8.7.3.1. Hake in GSA 11. F at age as estimated by XSA.

Age	2006	2007	2008	2009	2010	2011	2012	2013	2014
0	2.63	0.88	1.38	0.96	1.15	1.81	0.41	0.98	0.95
1	1.90	1.72	2.47	1.71	1.53	2.66	2.02	2.50	2.47
2	2.12	1.24	1.52	1.08	2.20	1.83	1.50	2.35	1.88
3	1.91	0.53	0.61	0.52	2.16	1.62	0.59	1.53	1.12
4	1.94	1.20	1.57	1.23	2.20	1.96	1.38	2.26	1.86

5	1.94	1.20	1.57	1.23	2.20	1.96	1.38	2.26	1.86

The XSA results summarized in Table 5.2.8.7.3.2 show a decreasing trend in the SSB, a great fluctuation on recruitment and an estimated F_{curr} of 1.61.

5.2.8.8 Reference points

5.2.8.8.1 Methods

The XSA package used allowed a Yield per recruit analysis and an estimate of some F-based Reference Points as F_{max} and $F_{0.1}$. Yield per Recruit computation was made by R project software and the FLR libraries. The fishing mortality rate corresponding to $F_{0.1}$ in the yield per recruit curve is considered here as a proxy of $F_{MSY.}$

5.2.8.8.2 Input data

The input parameters were the same used for the XSA stock assessment and its results.

5.2.8.8.3 Results

Table 5.2.8.8.3.1. Hake in GSA 11. Main reference points defined with the Yield per recruit analysis.

refpt	harvest	yield	rec	ssb	biomass
virgin	0	0	1	0.7	0.74
msy	0.25	0.05	1	0.22	0.26
crash	15.64	0.01	1	0	0.01
f0.1	0.17	0.05	1	0.3	0.34
fmax	0.25	0.05	1	0.22	0.26
spr.30	0.25	0.05	1	0.21	0.25

The current level of F is about 1.61, which is higher than the estimated value for F_{MSY} (0.17) and hence the stock of hake in GSA 11 is being fished above F_{MSY}.

5.2.8.9 Data quality

Data from DCF 2014 as submitted through the Official data call in 2015 were checked for hake. As already highlighted in the text before, catches information for the artisanal fleets (GTR and LSS) are represented only in some years (Figure 5.2.8.9.1) and sometimes there is no relation in time with the data on lengths of catches.

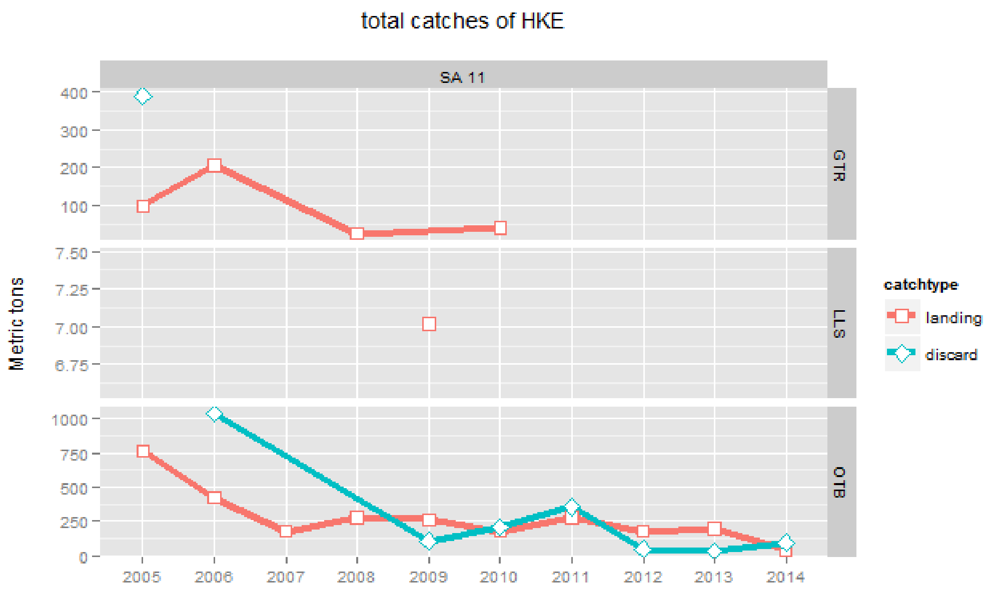


Figure 5.2.8.9.1. Hake in GSA 11. Total annual catches by gear for the period 2005-2014 from the DCF (original values not modified).

In particular, although the DCR database has values for total landings of hake in GSA 11, data at length are missing for some years and gears (OTB in 2005 and for GTR in 2005, 2006 and 2008). Similarly a gap for total values of discards (GTR 2010) was detected while some data of discard at length were present. It was also noted that the size distribution of both GTR landings (2010) and GTR discard (2005, 2010) seems to be unrealistic for this species.
The last problem identified were some unusual value for total discards and numbers of discards at age in some years (OTB, 2006; GTR, 2005).
To overcome these data quality problems of GSA 11, a deep check of information was made in the first days of the meeting and it was decided to fill gaps and correct records in order to be able to successfully perform the assessment.
In the catch table some records (OTB 2006, id 224701 and GTR 2005, id: 2266154) were identified as errors and were modified (Table 5.2.8.9.1).

Table 5.2.8.9.1. Hake in GSA 11. Revision of catch data information.

area	SA 11	species	HKE										
ORIGINAL													
id_temp_catch	year	gear	landings	discards	age1_no_discard	age1_wt_discard	age1_len_discard	age2_no_discard	age2_wt_discard	age2_len_discard	age3_no_discard	age3_wt_discard	age3_len_discard
224701	2006	OTB	421.669	1036.68	59564.53	0.015	13.38	2329.725	0.051	19.65	0	0	0
266154	2005	GTR	100.578	386.863	-1	-1	-1	1034.395	0.245	33.7	270.584	0.495	41.9
REVISED													
id_temp_catch	year	gear	landings	**discards**	**age1_no_discard**	age1_wt_discard	age1_len_discard	**age2_no_discard**	age2_wt_discard	age2_len_discard	**age3_no_discard**	age3_wt_discard	age3_len_discard
224701	2006	OTB	421.669	232.562	5956.453	0.015	13.38	2329.725	0.051	19.65	0	0	0
266154	2005	GTR	100.578	1.08996	-1	-1	-1	1.034395	0.245	33.7	2.70584	0.495	41.9

After these changes, a raising procedure was applied to fill the gaps in total values of discard when was not compulsory to collect discards (2007 and 2008). Using the mean discard % calculated for the time series 2006 and 2009-2014, a rising factor of 85% was applied to landing values for deriving discard total quantities in the missing years (Table 5.2.8.9.2, Figure 5.2.8.5.4.2). The same rising factor was also applied to 2005 because total discard was missing.

Table 5.2.8.9.2. Hake in GSA 11. Revision of catch data information (*new values derived from the raising; # new correct value).

Catches	Gear/Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
landing	GTR	100.6	206.0		28.6		42.5				
landing	OTB	765.4	421.7	176.7	278.7	260.5	175.9	277.4	175.9	195.8	45.0
discard	OTB	652.6*	232.6#	150.6*	237.6*	106.8	208.7	353.8	47.0	32.3	95.0
	total	1519	860.3	327.3	544.9	367.3	427.1	631.3	222.9	228.1	140.0

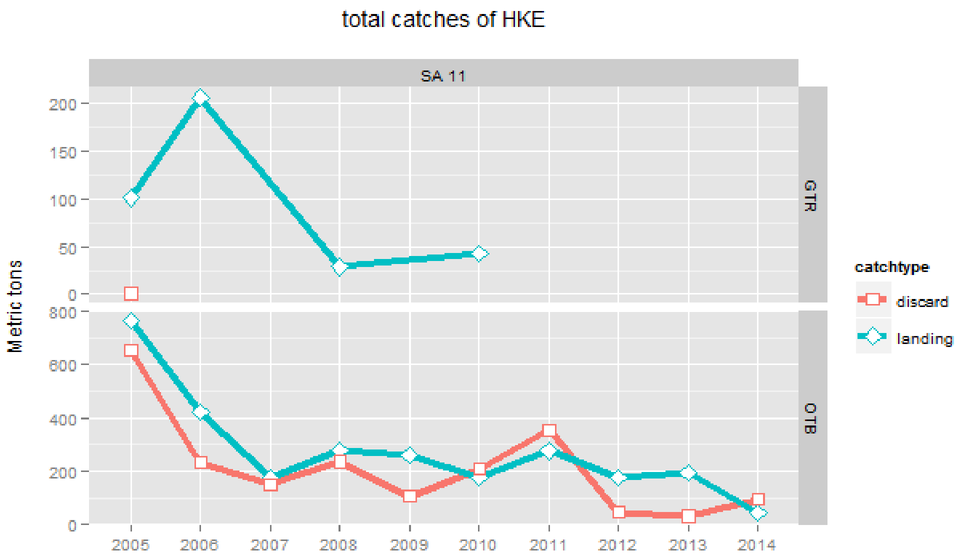


Figure 5.2.8.5.4.2. Hake in GSA 11. Total annual landings by gear corrected for the period 2006-2014 (values corrected by EWG 15-11).

Once all the gaps of total catches were filled the LFD of OTB discards of 2009 were used to raise the LFD of discards for OTB in 2007 and 2008 (Figure 5.2.8.5.4.3).

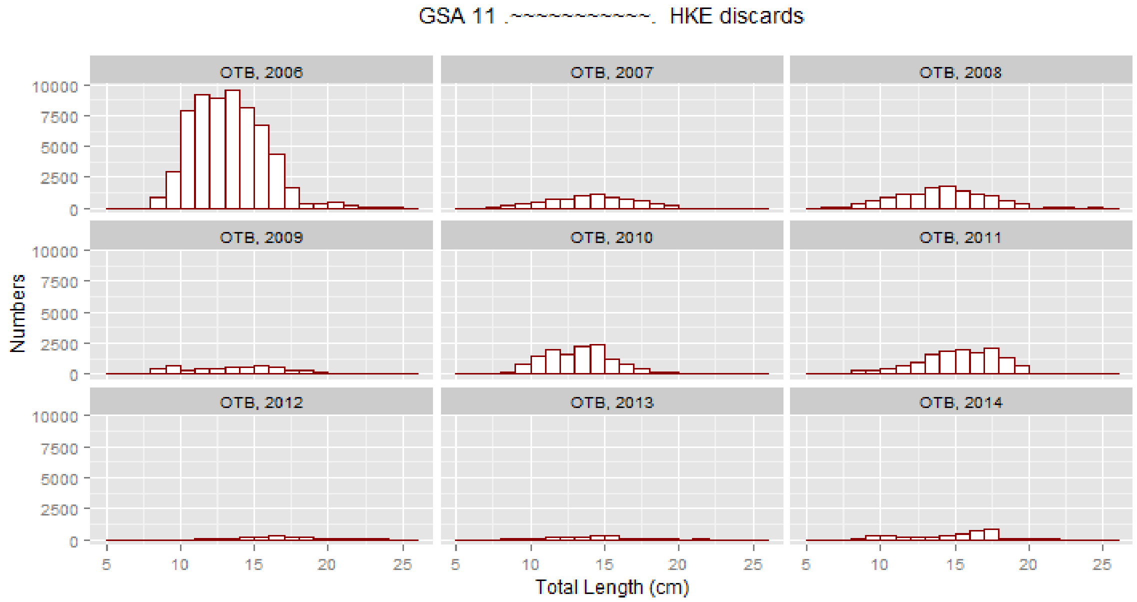


Figure 5.2.8.5.4.3. Hake in GSA 11. Corrected size composition of discards for OTB (period 2006-2014).

Finally to derive the LFD of landings for GTR (years 2006, 2008 and 2010) the ratio of total landings between GTR and OTB was used by year as a rising factor for each size class of the LFD of OTB landings (Figure 5.2.8.5.4.4).

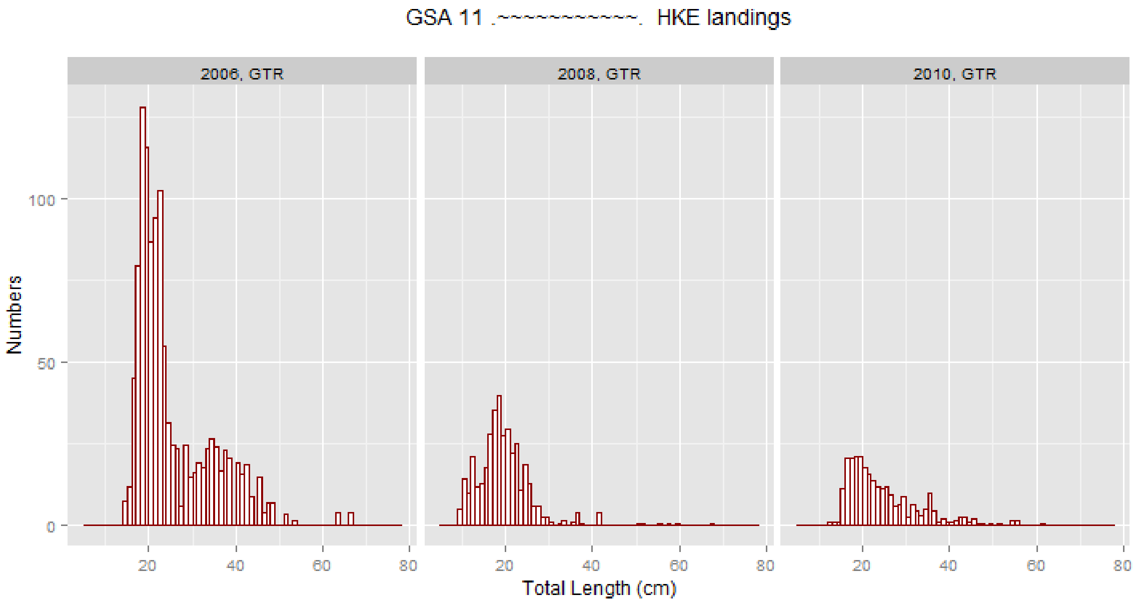


Figure 5.2.8.5.4.4. Hake in GSA 11. Corrected size composition of landings for GTR (period 2006-2014).

5.2.8.10 Short term predictions 2015-2017

5.2.8.10.1 Method

A deterministic short term prediction for the period 2015 to 2017 was performed using the FLR routines provided by JRC and based on the results of the XSA stock assessments performed during EWG 15-11.

5.2.8.10.2 Input parameters

The input parameters were the same used for the XSA stock assessment and its results. An average of the last three years has been used for weight at age, maturity at age and F at age.

Recruitment (age 0) has been estimated from the population results as the geometric mean of the last 3 years (8720.879 thousand individuals).

5.2.8.10.3 Results

Table 5.2.8.10.3.1. Hake in GSA 11. Short term forecast in different F scenarios. Basis: F(2015) = mean(F_{bar}0-3 2012-2014)= 0.294; R(2015) = geometric mean of the recruitment of the last 3years; R = 8720 (thousands); SSB(2015) = 73 t, Catch (2014)= 140 t.

Rationale	Ffactor	Fbar	Catch 2015	Catch 2016	Catch 2017	SSB 2016	SSB 2017	Change SSB 2016-2017(%)	Change Catch 2014-2016(%)
Zero catch	0	0	229	0	0	95	470	395.49	-100
High long term yield (F0.1)	0.11	0.166	229	41	107	95	381	301.21	-70.66
Status quo	1	1.49	229	190	182	95	86	-9.45	36.08
Different Scenarios	0.1	0.15	229	37	99	95	389	309.93	-73.41
	0.2	0.30	229	68	158	95	323	240.42	-51.32
	0.3	0.45	229	94	192	95	269	183.84	-32.92
	0.4	0.60	229	115	208	95	226	137.68	-17.52
	0.5	0.75	229	134	214	95	190	99.92	-4.58
	0.6	0.90	229	149	213	95	160	68.95	6.35
	0.7	1.05	229	162	208	95	136	43.47	15.61
	0.8	1.20	229	173	200	95	116	22.45	23.50
	0.9	1.34	229	182	191	95	100	5.03	30.26
	1.1	1.64	229	198	172	95	74	-21.54	41.13
	1.2	1.79	229	204	163	95	65	-31.67	45.52
	1.3	1.94	229	209	154	95	57	-40.21	49.36
	1.4	2.09	229	214	146	95	50	-47.43	52.75
	1.5	2.24	229	218	138	95	44	-53.57	55.75
	1.6	2.39	229	222	131	95	39	-58.81	58.42
	1.7	2.54	229	225	124	95	35	-63.32	60.81
	1.8	2.69	229	228	118	95	31	-67.20	62.96
	1.9	2.84	229	231	113	95	28	-70.57	64.90
	2	2.99	229	233	107	95	25	-73.51	66.67

A short term projection (Table 5.2.8.10.3.1), assuming an F_{stq} of 0.166 in 2015 and a recruitment of 8720 thousands individuals show that:

- Fishing at the F_{stq} (1.49) generates an increase of the catch of about 36% from 2014 to 2016 along with a small decrease of the spawning stock biomass from 2016 to 2017.
- Fishing at $F_{0.1}$ (0.166) generates a decrease of the catch of about 70% from 2014 to 2016 and an increase of the spawning stock biomass of about 300% from 2016 to 2017.

5.2.8.11 Medium term predictions

5.2.8.11.1 Method

Medium term was not conducted because no meaningful stock-recruitment relationship was estimated.

5.2.8.12 Stock advice

The current F (1.6) is larger than $F_{0.1}$ (0.17), chosen as proxy of F_{MSY} and as the exploitation reference point consistent with high long term yields, which indicates that European hake in GSA 11 is being fished above F_{MSY}. Catches of European hake in 2016 consistent with F_{MSY} should not exceed 41 tonnes.

5.2.8.13 Management strategy evaluation

Management Strategy Evaluation was conducted to evaluate if the MSY ranges were precautionary. The F_{MSY} ranges were derived using the formula provided by STECF 15-09. F ranges results were F_{upper}=0.24 and F_{lower}=0.12. B_{lim} was estimated as B_{loss}=73 (t). The following figure shows the results of the MSE.

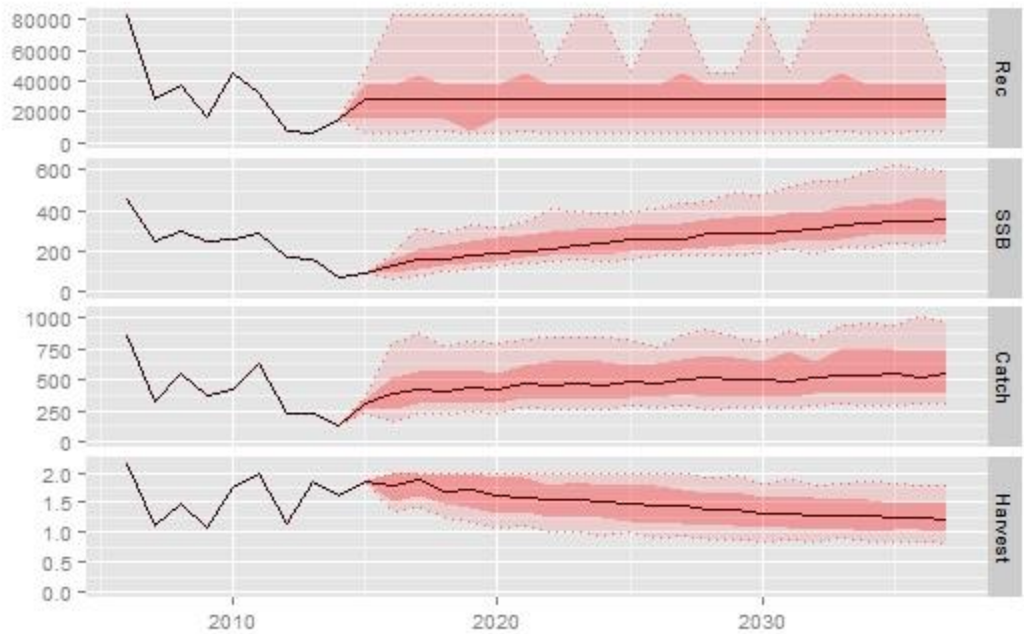


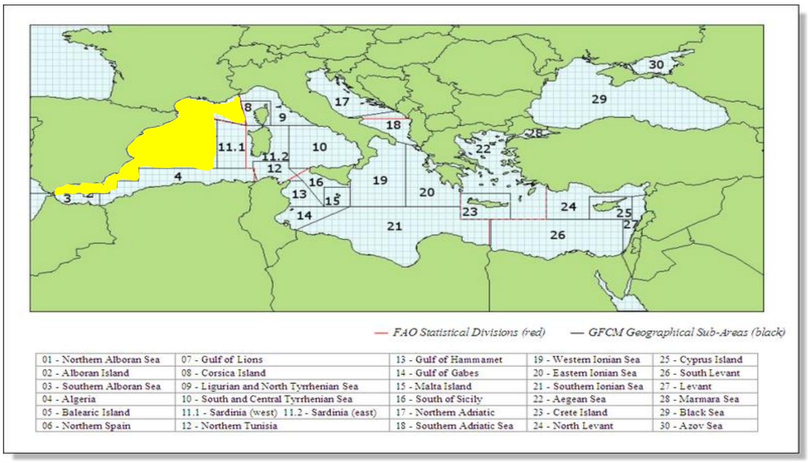
Figure 5.2.8.14.1. Hake in GSA 11. Marine Strategy Evaluation.

The probability of SSB to fall below B_{lim} at F > F_{upper} is equal to 0, even if the F never reaches the F upper estimated by the empirical relationship. The dynamics observed for this stock are the result of the stock assessment model (i.e. XSA) settings used inside the MSE becoming less appropriate as the stock status changes in time (i.e. stock assessment settings are often specific to a particular range of stock status). This leads to an increasing difference between the perceived stock and the operating model (i.e. the 'true' stock). To avoid this behaviour in the future, for some of the stocks as it is the case here, a more general stock assessment method should be used in the MSE loop that is less sensitive to the stock status.

5.2.9 STOCK ASSESSMENT OF HAKE IN GSA 1-7

5.2.9.1 Stock Identification

The delimitation of the hake stock in GSAs 1-7 (GSA 1, GSA 5, GSA 6 and GSA 7) is considered unknown. A parallel study (STOCKMED: Fiorentino et al., 2015) on the European hake (and other commercial species) stock potential distribution in the Mediterranean Sea has been funded by the EU and undertaken under the framework of the MAREA Project. This study suggested that there are two stocks of European hake in the Western Mediterranean Sea: one distributed from the Alboráan Sea to the Gulf of Lions and another one from the Gulf of Lions to the Strait of Sicily and beyond. In the view of those findings, STECF EWG 15-11 was asked to assess the state of European hake stocks in the Western Mediterranean Sea following two approaches: by single GSAs and GSAs combined. The present assessment will investigate the state of the hake stock in GSAs 1, 5, 6 and 7.



5.2.9.2 Growth

Growth parameters are those used in each GSA (see sections of GSA1, GSA5, GSA6 and GSA7 assessments).

5.2.9.3 Maturity

Maturity ogives were taken from each GSA (see sections of GSA1, GSA5, GSA6 and GSA7 assessments). Combined maturity at age were calculated as a weighted average using the stock numbers.

5.2.9.4 Natural mortality

Natural mortality was taken from each GSA (see sections of GSA1, GSA5, GSA6 and GSA7 assessments). Combined natural mortality at age were calculated as a weighted average using the stock numbers.

5.2.9.5 Fisheries

5.2.9.5.1 General description of the fisheries

See sections of GSA 1, GSA 5, GSA 6 and GSA 7 assessments.

5.2.9.5.2 Management regulations applicable in 2015

See sections of GSA 1, GSA 5, GSA 6 and GSA 7 assessments.

5.2.9.5.3 Catches

Hake annual catches (t) by fleet over the period 2003 to 2014 are the sum of those in each GSA (see sections of GSA 1, GSA 5, GSA 6 and GSA 7 assessments).

5.2.9.5.4 Landings

Hake annual landings (t) by fleet over the period 2003 to 2014 are the sum of those in each GSA (see sections of GSA 1, GSA 5, GSA 6 and GSA 7 assessments).

5.2.9.5.5 Discards

Hake annual discards (t) by fleet over the period 2003 to 2014 are the sum of those in each GSA (see sections of GSA 1, GSA 5, GSA 6 and GSA 7 assessments).

5.2.9.5.6 Fishing effort

See fishing effort by fleet and GSA in the corresponding sections of GSA 1, GSA 5, GSA 6 and GSA 7 assessments.

5.2.9.6 Scientific surveys

5.2.9.6.1 Survey #1 (MEDITS)

5.2.9.6.1.1 Methods

See sections of GSA 1, GSA 5, GSA 6 and GSA 7 assessments for data description. Individual MEDITS tuning indexes from the different GSAs were used in the assessment model separately so that timing of the sureys could be accommodated and catchability could vary across surveys. Numbers at age by survey (Figure 5.2.9.6.1.1) show poor tracking of yearly cohorts within and across surveys, with the exception of a strong cohort in 2008 in GSA 7. There is a general increase in the last two years of age class 2 in GSA 7 and age class 3-4 in GSA 1 and 5, which is difficult to observe in younger ages in previous years.

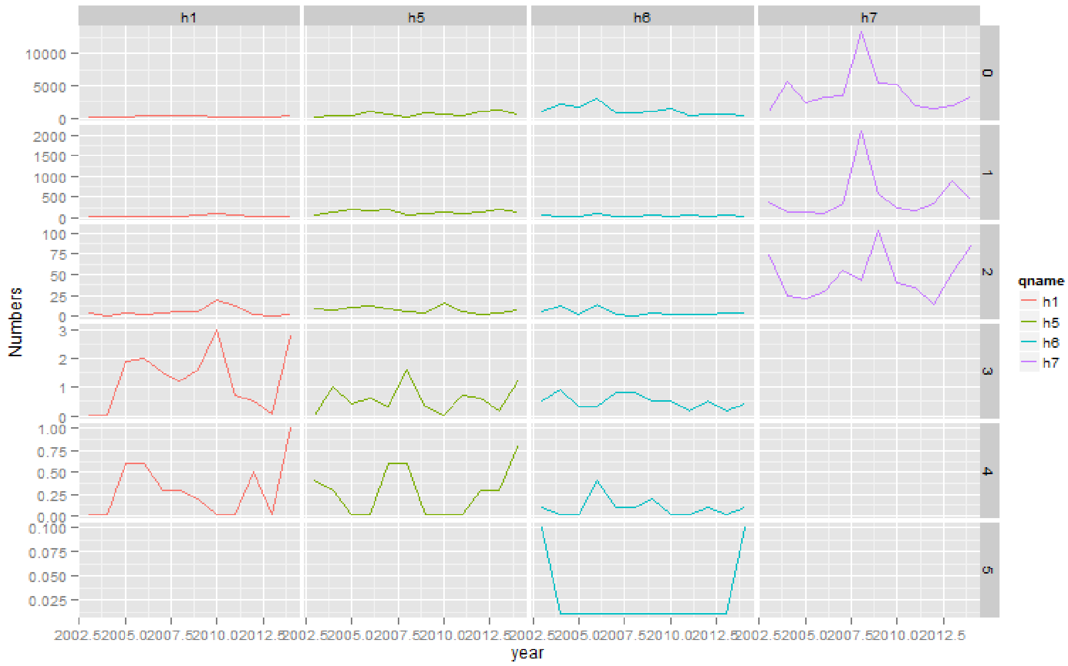


Fig. 5.2.9.6.1.1. Hake in GSA 1-7. MEDITS tuning indices (numbers at age(1-5+)) for different GSAs, h1= GSA 1, h5= GSA 5, h6 = GSA 6, h7 = GSA 7.

Overall the internal consistency of the surveys is not high. MEDITS GSA 1, is not able of tracking the cohorts except for a weak signal between age 0-1 and 1-2 (Figure **5.2.9.6.1.2**).

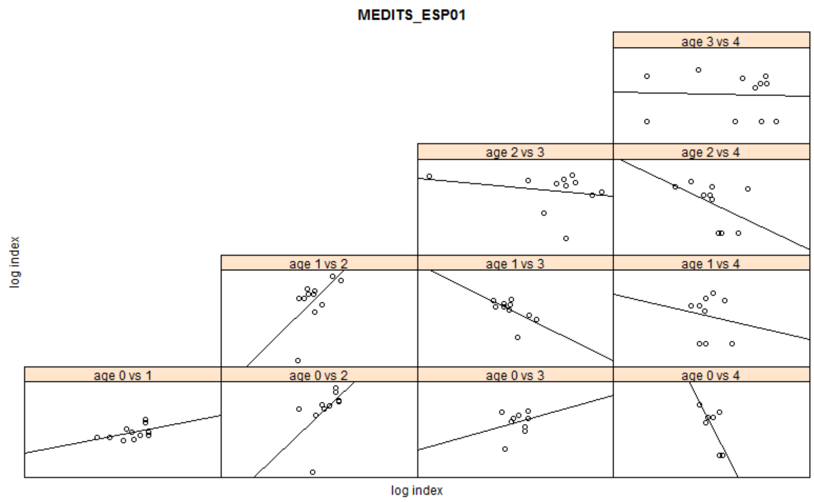


Figure *5.2.9.6.1.2.* Hake in GSA 1-7. Internal consistency of MEDITS in GSA 1 for Mediterranean hake.

MEDITS GSA 5 is not able of tracking the cohorts except for a weak signal in age 1-2 and 2-3 (Figure ***5.2.9.6.1.3***).

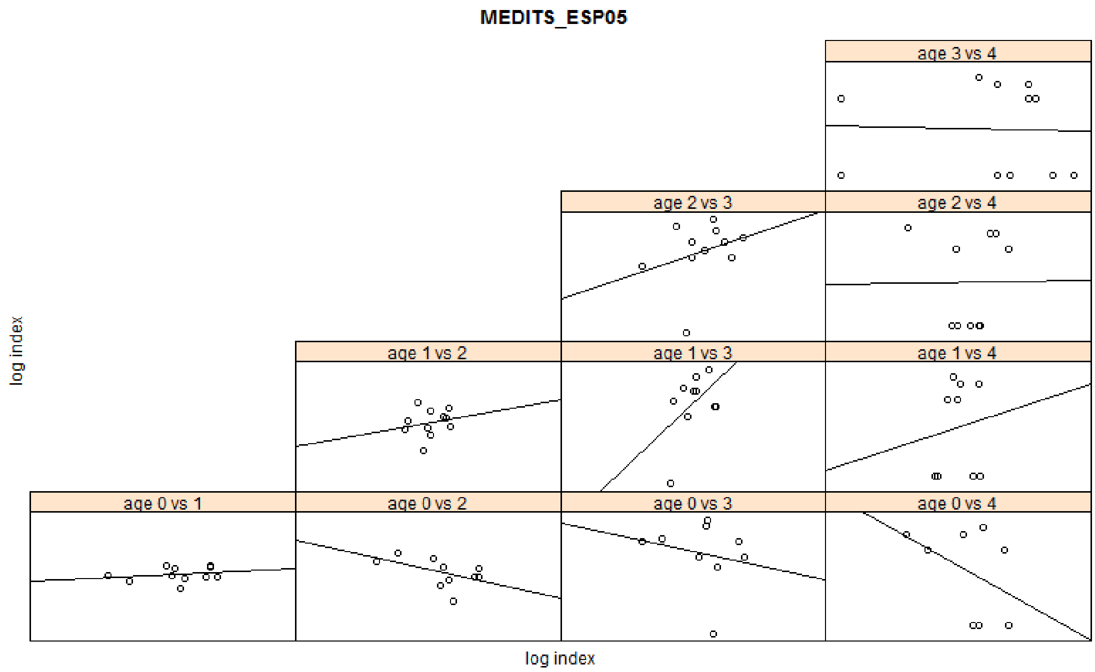


Figure *5.2.9.6.1.3.* Hake in GSA 1-7. Internal consistency of MEDITS in GSA 5 for Mediterranean hake.

In MEDITS GSA 6 is not able of tracking the cohorts except for a weak signal in age 1-2 and 2-3 (Figure ***5.2.9.6.1.4***).

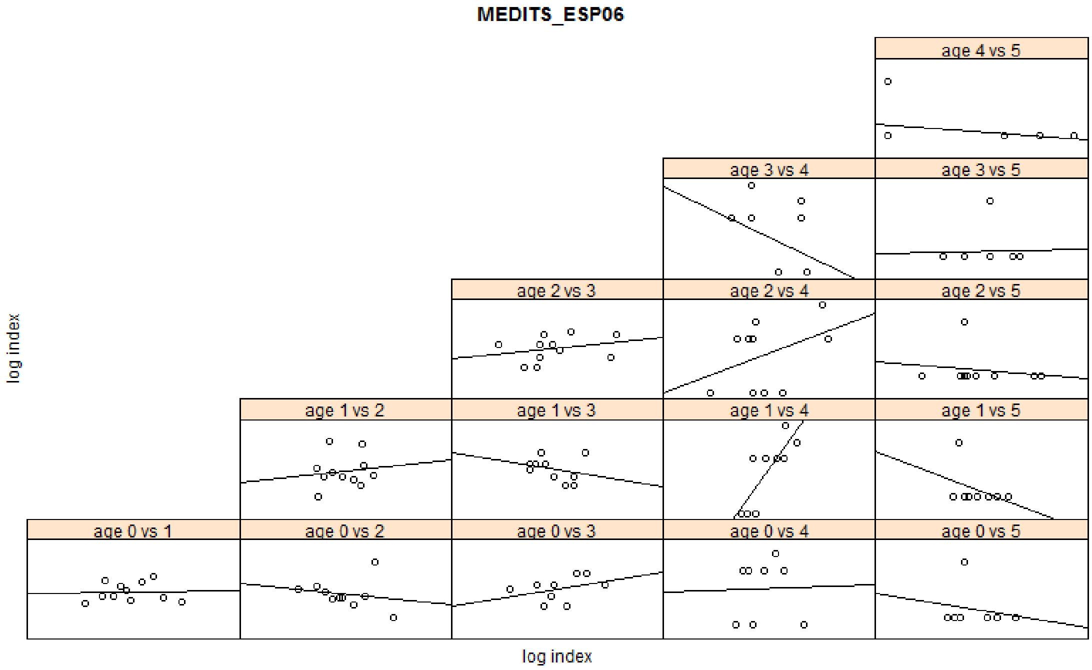


Figure *5.2.9.6.1.4.* Hake in GSA 1-7. Internal consistency of MEDITS in GSA 6 for Mediterranean hake.

MEDITS GSA 7 is not able of tracking the cohorts except for a weak signal in age 1-2 (Figure ***5.2.9.6.1.5***)

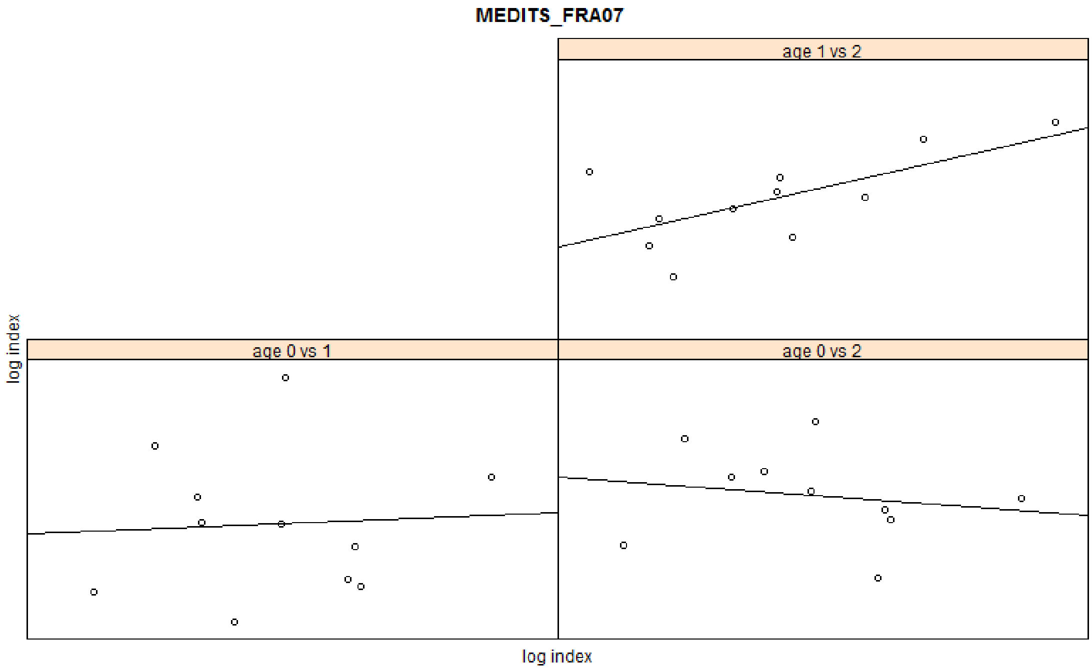


Figure *5.2.9.6.1.5.* Hake in GSA 1-7. Internal consistency of MEDITS in GSA 7 for Mediterranean hake.

5.2.9.6.1.2 Geographical distribution

See sections of GSA1, GSA5, GSA6 and GSA7 assessments.

5.2.9.6.1.3 Trends in abundance and biomass

See sections of GSA1, GSA5, GSA6 and GSA7 assessments.

5.2.9.6.1.4 Trends in abundance by length or age

See sections of GSA1, GSA5, GSA6 and GSA7 assessments.

5.2.9.7 Stock Assessment: XSA

5.2.9.7.1 Method: XSA

This stock was assessed through XSA, using an *ad hoc* R-script and input data over the period 2003-2014.

5.2.9.7.2 Input data

Catch and catch numbers at age input data were generated merging the XSA input data used in the assessments performed by single GSA. Four tuning MEDITS files were used, one per each GSA, the same as used in the assessments by single GSA (see sections of GSA1, GSA5, GSA6 and GSA7 assessments).

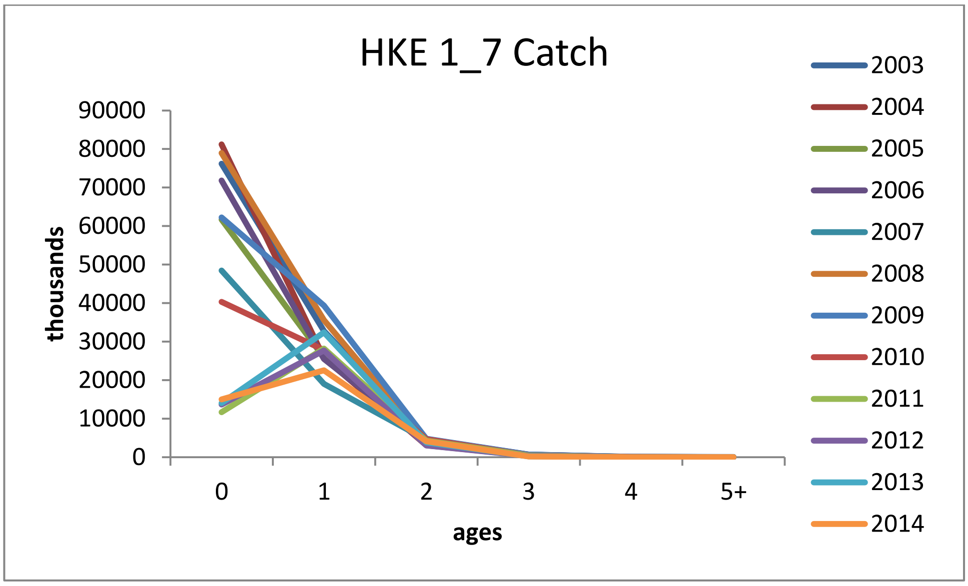


Figure 5.2.9.7.2.1. Hake in GSAs 1-7. Catch at age.

Table 5.2.9.7.2.1. Hake in GSA 1-7. Lists the input parameters to the XSA, namely landings, catch numbers at age and weight at age.

Table 5.2.9.7.2.1. Hake in GSA 1-7. Input data to the XSA.

Catch (t)

2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
7293	5683.1	5989.2	6716.3	5534.2	6961.9	8085.9	5999.6	5419.2	4567.6	5497.6	4649.9

Catch number at age matrix (thousands)

Age	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
0	76179.8	81210.0	61699.8	71834.6	48463.3	78948.7	62256.3	40304.5	11676.7	13682.3	14037.6	15006.9

1	32757.6	25817.2	25844.2	25508.0	19028.6	35593.2	39365.6	27817.6	28213.3	27713.6	32390.5	22558.6
2	4726.8	3086.3	4139.5	4490.5	4491.3	3911.3	4776.3	4688.7	4308.3	3042.8	3835.7	4143.0
3	644.2	406.1	519.2	690.1	639.1	428.2	678.0	471.6	436.2	304.0	221.5	177.5
4	92.8	32.1	48.0	58.9	83.6	70.8	117.6	74.3	28.5	33.1	17.7	11.9
5+	21.7	15.6	13.6	16.4	22.2	12.6	79.1	7.9	7.4	2.8	3.6	3.2

Weight at age (kg)

Age	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
0	0.018	0.018	0.019	0.020	0.019	0.021	0.022	0.018	0.029	0.029	0.031	0.023
1	0.107	0.104	0.105	0.107	0.111	0.094	0.105	0.111	0.111	0.100	0.108	0.121
2	0.354	0.371	0.379	0.418	0.391	0.363	0.360	0.358	0.362	0.362	0.345	0.333
3	0.772	0.788	0.808	0.830	0.861	0.881	0.720	0.751	0.749	0.792	0.942	0.908
4	1.605	1.462	1.411	1.332	1.517	1.531	1.604	1.602	1.607	1.592	1.691	1.711
5+	2.976	2.654	4.027	2.794	2.312	2.305	2.708	2.268	2.375	2.052	2.751	3.636

5.2.9.7.3 Results

Different sensitivity analyses were performed before running the final XSA, considering different shrinkage weight (0.5-2.5), shrinkage ages (1,2,3), rage (-1,0,1) and qage (2,3,4). Comparison of trends between settings has been done. Different combinations between the settings that looked more stable were further tested.

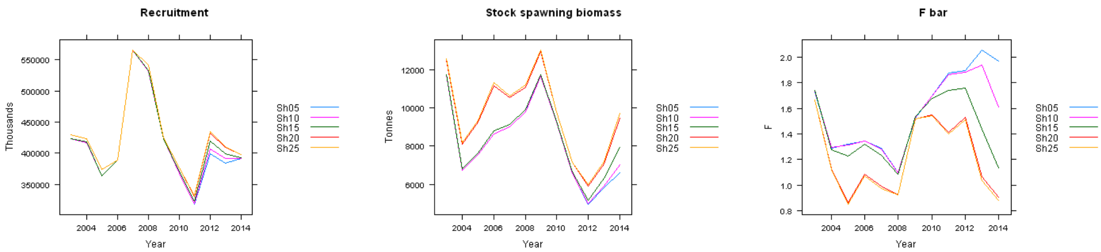


Figure 5.2.9.7.3.1. Hake in GSAs 1-7. Sensitivity on shrinkage weight.

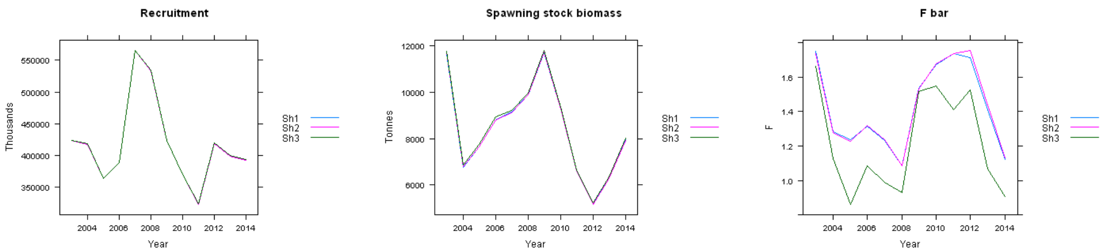


Figure 5.2.9.7.3.2. Hake in GSAs 1-7. Sensitivity on shrinkage age.

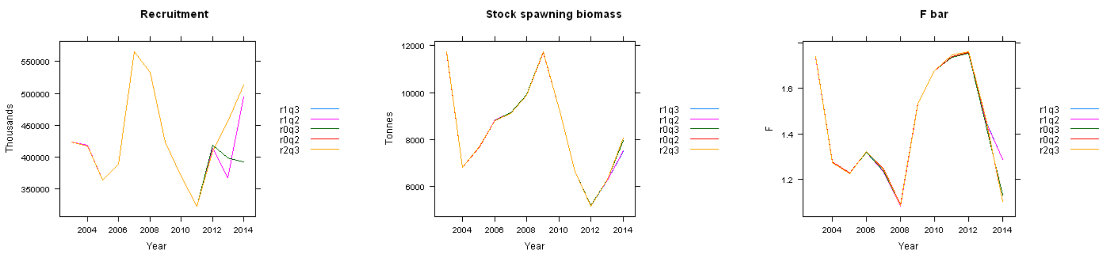
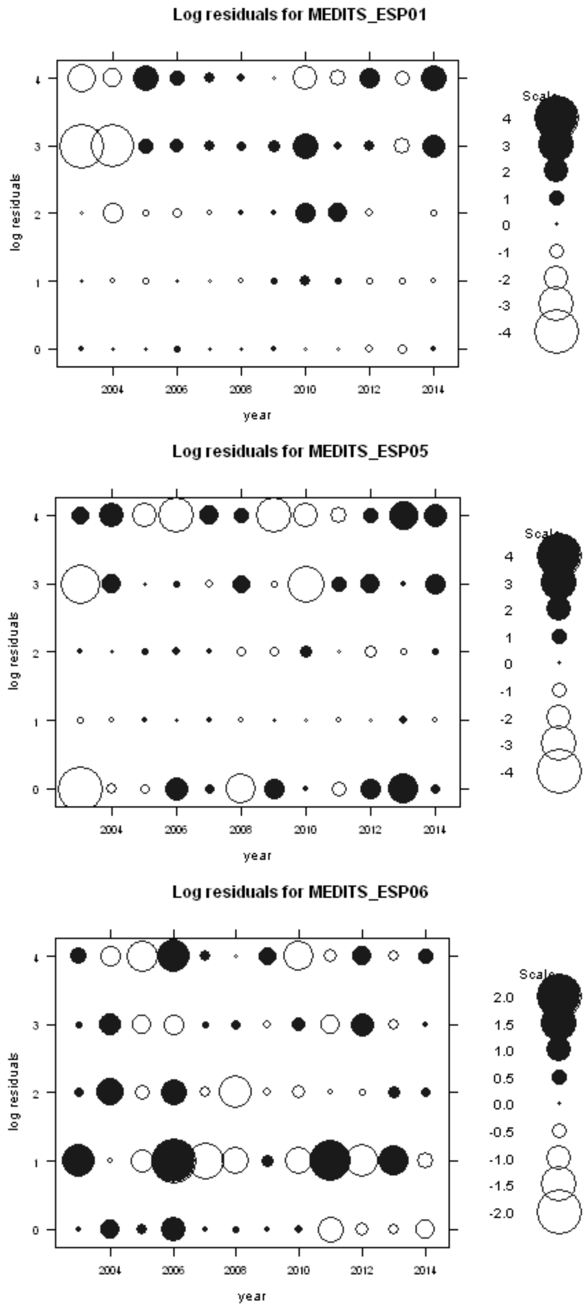


Figure 5.2.9.7.3.3. Hake in GSAs 1-7. Sensitivity on rage and qage.

The following settings that minimized the residuals and showed the best diagnostics outpout were used for the final XSA final run:

Fbar	fse	rage	qage	Shk.n	Shk.f	Shk.yrs	Shk ages
1-3	1.5	1	4	TRUE	TRUE	3	2

The residuals pattern of the MEDITS trawl survey in each GSA are shown in Figure 5.2.9.7.3.4.



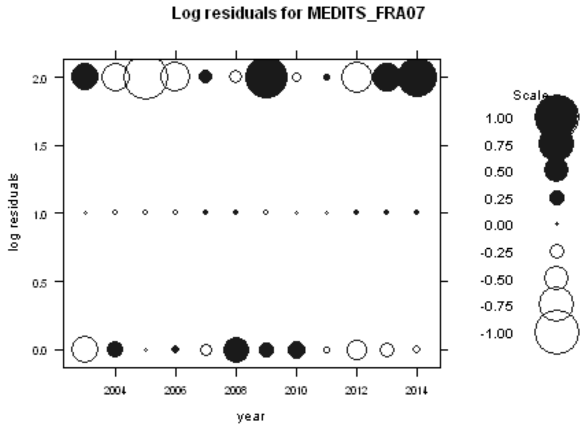


Figure 5.2.9.7.3.4. Hake in GSA 1-7. XSA residuals for MEDITS survey in each GSA.

The results of the retrospective analysis are shown in Figure 5.2.9.7.3.5.

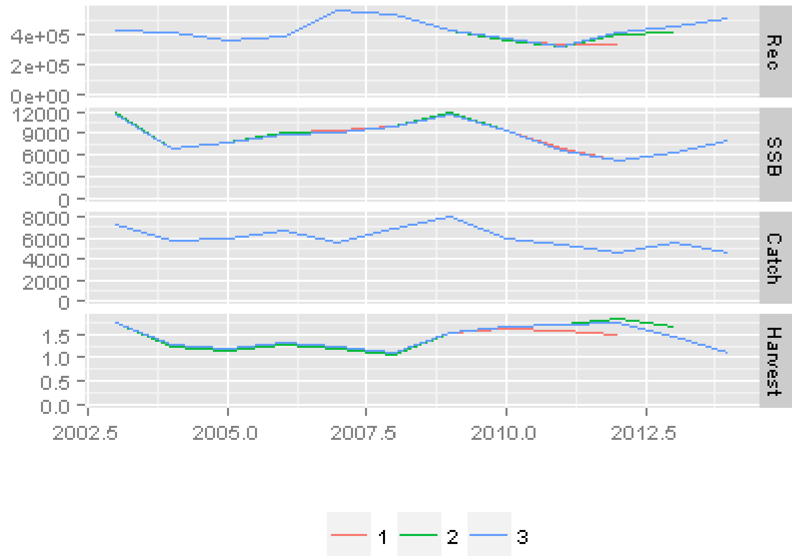


Figure 5.2.9.7.3.5. Hake in GSA 1-7. XSA retrospective analysis.

The results of the XSA are shown in the following figure.

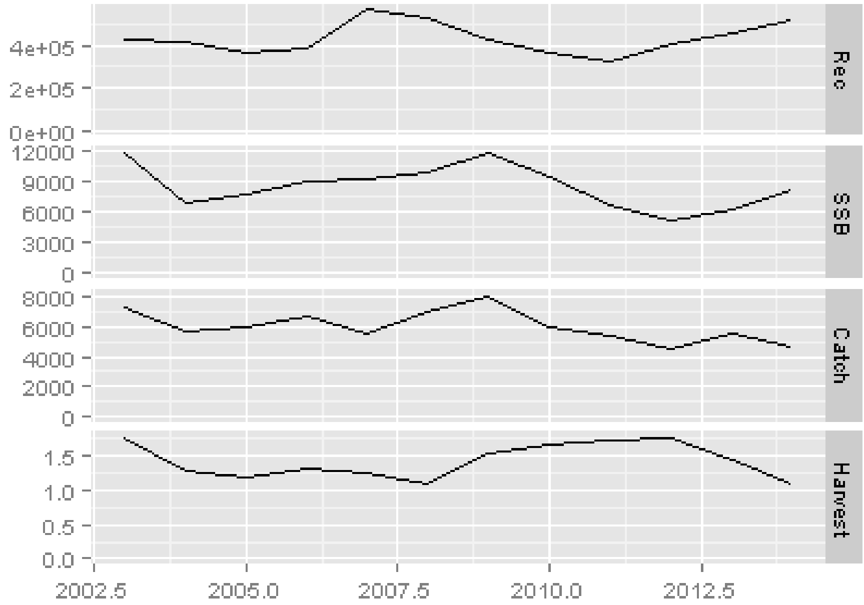


Figure 5.2.9.7.3.6. Hake in GSA 1-7. XSA summary results. SSB and catch are in tonnes, recruitment in 1000s individuals.

In tables 5.2.9.7.3.1 and 2 the population estimates of hake in GSAs 1-7 obtained by XSA are given.

Table 5.2.9.7.3.1 European hake in GSAs 1-7. Stock numbers at age (thousands) as estimated by XSA.

age	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
0	423850	418100	363900	389290	565160	533400	424010	370190	323600	410250	457670	515270
1	66007	59062	57976	55252	52388	87408	79199	61851	55365	57104	68812	58620
2	9578	6730	8447	8819	8393	8738	9648	9039	7215	5151	6609	7770
3	1147	711	968	1187	1166	920	1265	799	743	472	427	485
4	138	53	78	156	147	165	198	103	42	79	31	80
5+	30	23	21	42	37	28	126	10	10	7	6	21

Table 5.2.9.7.3.2. Hake in GSAs 1-7. XSA summary results.

	Fbar 1-3	Recruitment (thousands)	SSB (t)	TB (t)
2003	1.74	423850	11736.3	19445
2004	1.27	418100	6837.2	16772
2005	1.19	363900	7716.3	17086
2006	1.31	389290	8888.7	18532
2007	1.23	565160	9159.3	21278
2008	1.08	533400	9919.1	23809
2009	1.53	424010	11750.2	22538
2010	1.67	370190	9316	17622
2011	1.71	323600	6650.9	18750
2012	1.75	410250	5186.1	19882

2013	1.43	457670	6318.6	24335
2014	1.09	515270	8113	22128

	F at age					
	0	1	2	3	4	5+
2003	0.48	1.43	1.63	2.17	1.92	1.92
2004	0.52	1.10	1.15	1.56	1.81	1.81
2005	0.43	1.09	1.23	1.25	1.59	1.59
2006	0.50	1.12	1.31	1.51	0.64	0.64
2007	0.22	0.86	1.48	1.35	1.32	1.32
2008	0.38	1.16	1.12	0.96	0.80	0.80
2009	0.38	1.36	1.56	1.67	1.33	1.33
2010	0.28	1.24	1.62	2.15	2.50	2.50
2011	0.09	1.52	1.99	1.62	2.14	2.14
2012	0.08	1.33	1.80	2.11	0.75	0.75
2013	0.09	1.31	1.86	1.14	1.52	1.52
2014	0.08	1.03	1.57	0.67	0.21	0.21

The XSA results summarized in Table 5.2.9.7.3.2 and in Figure 5.2.9.7.3.6. show a decreasing trend in landings since the peak in 2009, a fluctuation of recruitment and SSB, increasing in the last years, and an estimated F_{sq} of 1.40.

5.2.9.8 Stock Assessment: a4a

5.2.9.8.1 Method: a4a

The assessment was run with the FLR a4a model on the same input data as in the XSA run for the combined Mediterranean Hake assessment (GSA 1-7).

5.2.9.8.2 Input data

Different settings in the model runs were specified to get to the best fitting model. The stock recruitment model (srmod) was kept fixed across models and allowed to change yearly. The fishing mortality model (fmod) was specified with different splines and or breakpoints. The catchability model (qmod) was mainly allowing catchability to vary by age class or year.

```
# Mod 1
fmod <- ~factor(year) + factor(age)
srmod <- ~factor(year)
fit1 <- sca(stock = stk, indices = flq.idx, fmodel = fmod,  fit = "assessment")

# Mod 2
qmod <- list(~factor(age), ~factor(age), ~factor(age), ~factor(age))
fit2 <- sca(stock = stk, indices = flq.idx, fmodel = fmod, qmodel = qmod,  fit
= "assessment")

# Mod 3
qmod <- list(~s(age, k=3), ~s(age, k=3),  ~s(age, k=3),  ~s(age, k=3))
fit3 <- sca(stock = stk, indices = flq.idx, fmodel = fmod, qmodel = qmod,  fit
= "assessment")

# Mod 4
```

```
fmod <- ~s(year, k=5) + s(age, k=3)
qmod <- list(~s(age, k=3), ~s(age, k=3), ~s(age, k=3), ~s(age, k=3))
fit4 <- sca(stock = stk, indices = flq.idx, fmodel = fmod, qmodel = qmod,  fit
= "assessment")

# Mod 41
fmod <- ~s(year, k=10) + s(age, by=breakpts(year, 2009), k=6)
qmod <- list(~s(age, k=3), ~s(age, k=5), ~s(age, k=5), ~s(age, k=3))
fit41 <- sca(stock = stk, indices = flq.idx, fmodel = fmod, qmodel = qmod,  fit
= "assessment")

# Mod 5
fmod <- ~ s(year, k=10) + s(age, k=5)
fit5 <- sca(stock = stk, indices = flq.idx, fmodel = fmod, qmodel = qmod,  fit
= "assessment")

# Mod 6
fmod <- ~ s(year, k=10) + s(age, k=5)
qmodel <- list(~ te(age, year, k = c(5,10)), ~ te(age, year, k = c(5,10)),
               ~ te(age, year, k = c(5,10)),  ~ te(age, year, k = c(5,10)))
fit6 <- sca(stock = stk, indices = flq.idx, fmodel = fmod, qmodel = qmod,  fit
= "assessment")

# Mod 7
fmod <- ~s(year, k=10) + s(age,  k=5)
qmod <- list(~s(age, k=3), ~s(age, k=3),~s(age, k=3),~s(age, k=3))
fit7 <- sca(stock = stk, indices = flq.idx, fmodel = fmod, qmodel = qmod,  fit
= "assessment")

# Mod 8
fmod <- ~s(year, k=10) + s(age,  k=5)
qmod <- list(~s(age, k=3), ~s(age, k=3),~s(age, k=3),~s(age, k=3))
fit8 <- sca(stock = stk, indices = flq.idx, fmodel = fmod, qmodel = qmod,
srmodel=srmod,  fit = "assessment")

# Mod 10
fmod <- ~s(year, by=breakpts(age, 2), k=10) + s(age,  k=4)
#qmod <- list(~s(age, k=3), ~s(age, k=3))
qmod <- list(~ s(age, k=5) + s(year, k=10), ~ s(age, k=5), ~ s(age, k=5), ~
s(age, k=3))
fit10 <- sca(stock = stk, indices = flq.idx, fmodel = fmod, qmodel = qmod,
srmodel=srmod,  fit = "assessment")

# Mod 12
fmod <- ~s(year, by=breakpts(age, 2), k=10) + s(age,  k=4)
qmod <- list(~ s(age, k=5) + s(year, k=10), ~ s(age, k=5), ~ s(age, k=5), ~
s(age, k=3))
fit12 <- sca(stock = stk, indices = flq.idx, fmodel = fmod, qmodel = qmod,
srmodel=srmod,  fit = "assessment")
```

Based on model fitting and residual patterns, Model 41, were F is modelled as a function of smooth of year and smooth of age with a breakpoint in 2009 and catchability is modelled as a spline of age, with variable degrees of freedom (k), depending from survey.

5.2.9.8.3 Results

The log residuals of the abundance indices (Figure 5.2.9.8.3.1) don't show any clear trends, except in the age 0 in from the Alboran Sea survey (M1), which was not possible to improve. The residuals of the catch are acceptable.

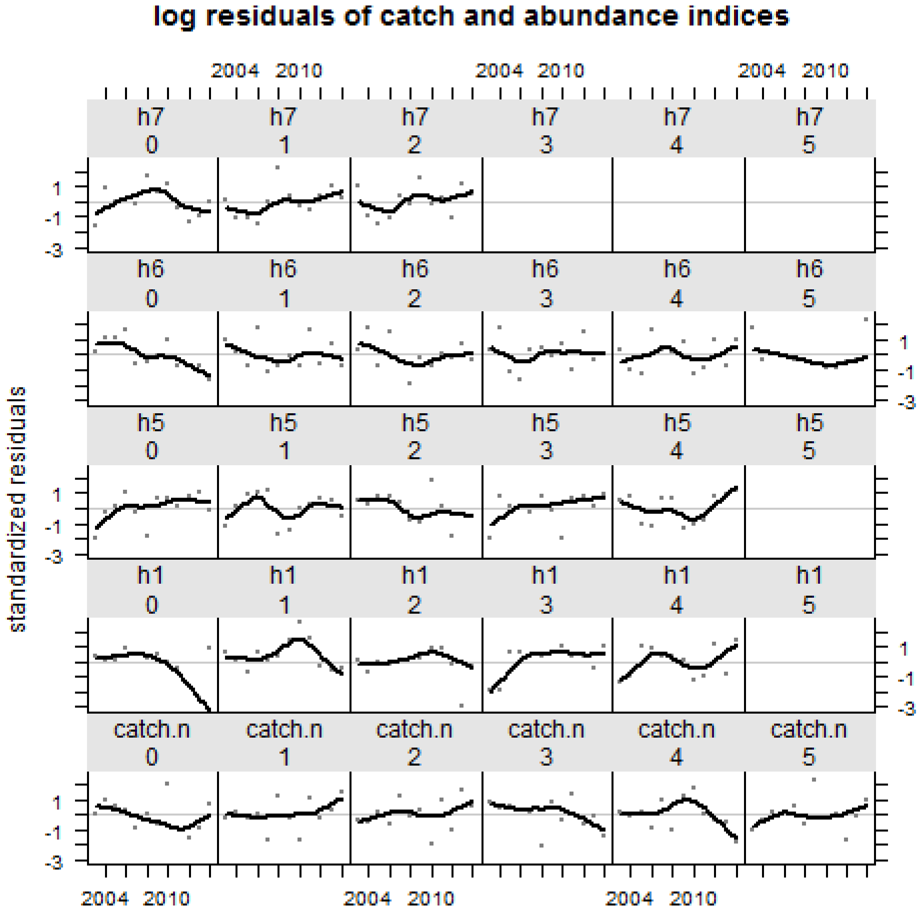


Figure *5.2.9.8.3.1.* Hake in GSA 1-7. Log Catch residual of catch and abundance indices (H7 = Gulf of Lions (GSA 7), H6 = Catalan Sea (GSA 6), H5 = Balearic Islands (GSA 5), H1 = Alboran Sea (GSA 1).

Model fit 41 is also able of predicting the catch numbers reasonably well in all years except 204 and 2010 (Figure ***5.2.9.8.3.2***).

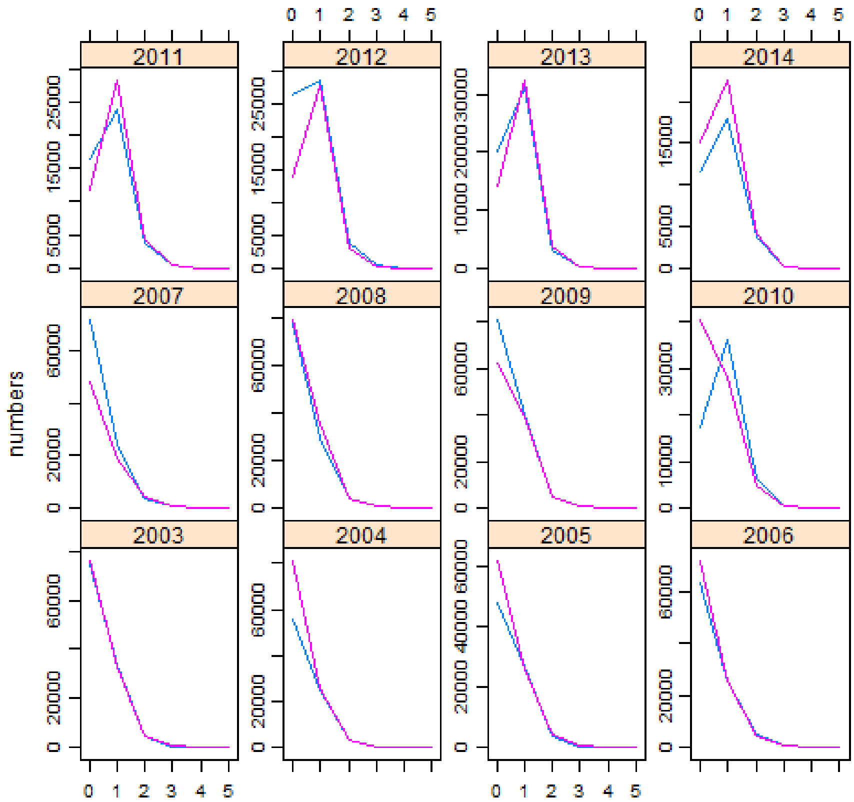


Figure 5.2.9.8.3.2. Hake in GSA 1-7. Predicted vs observed catch numbers for all areas combined.

The a4a model prediction of the catches in the MEDITS survey does not fit well the observed catches in 2013, 2008 and 2003 in the GSA 5 survey (Figure 5.2.9.8.3.3).

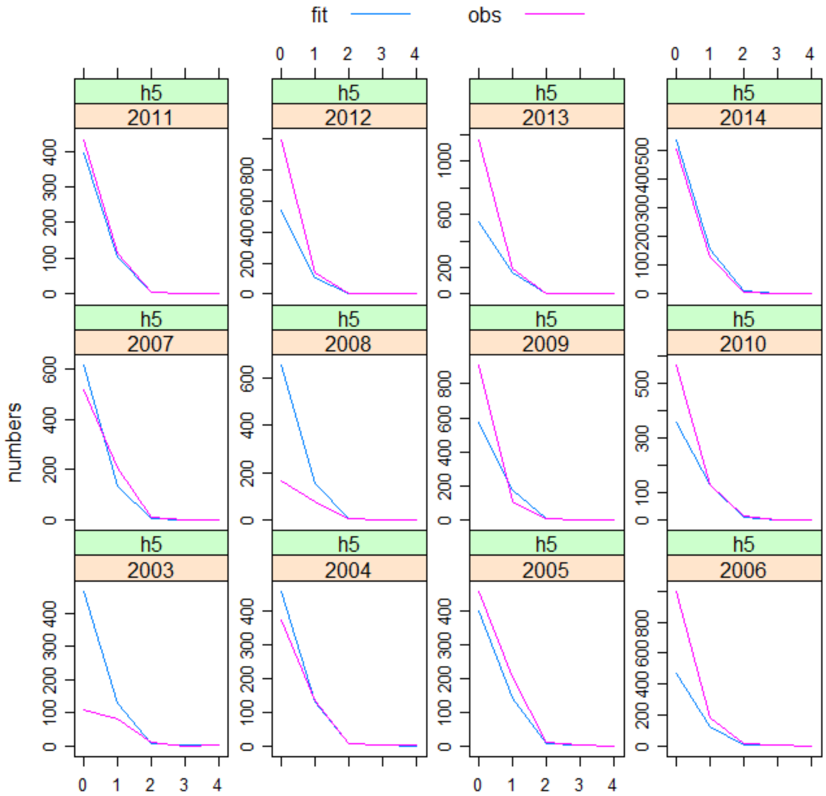


Figure ***5.2.9.8****.3.3.* Hake in GSA 1-7. Fitted vs observed caches in MEDITS survey in the GSA 5 MEDITS.

The a4a model prediction of the catches in the MEDITS survey in GSA 6 does not fit well the observed catches except in 2003 and 2009 (Figure 5.2.9.8.3.4).

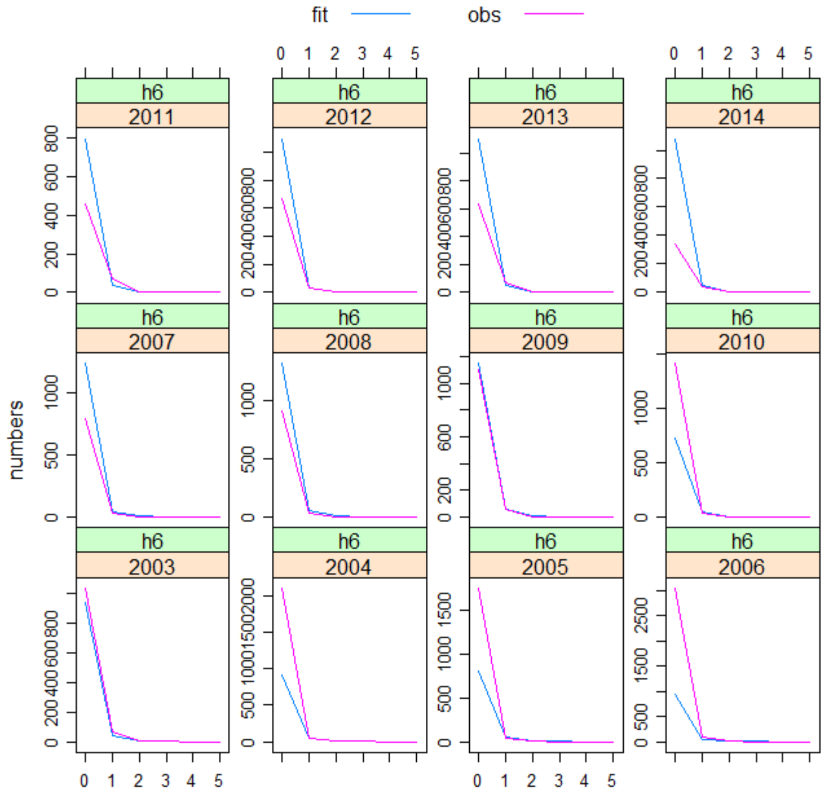


Figure *5.2.9.8.3.4.* Hake in GSA 1-7. Observed and predicted catch in numbers in MEDITS performed in the Catalan Sea (GSA 6).

The a4a model prediction of the catches in the MEDITS survey in GSA 1 does not fit well the observed catches except in 2004-2005 and 2008 (Figure 5.2.9.8.3.5).

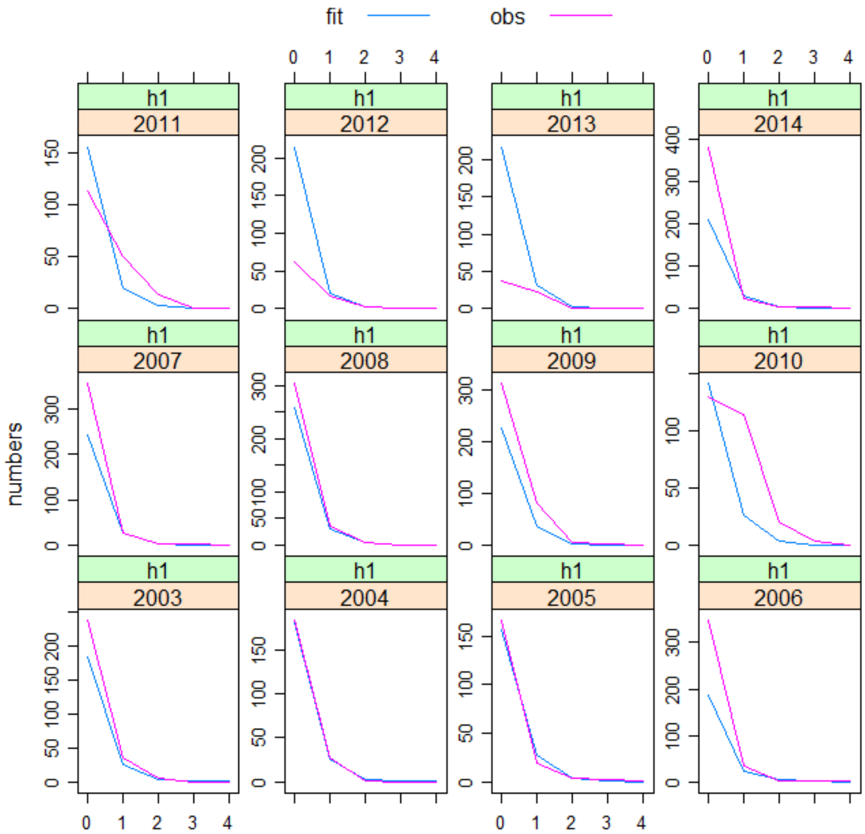


Figure *5.2.9.8.3.5.* Hake in GSA 1-7. Observed vs predicted catch numbers in MEDITS survey performed in Alboran Sea (GSA 1).

The a4a model prediction of the catches in the MEDITS survey in GSA 7 does not fit well the observed catches except in 2005-2007 and 2014 (Figure 5.2.9.8.3.6).

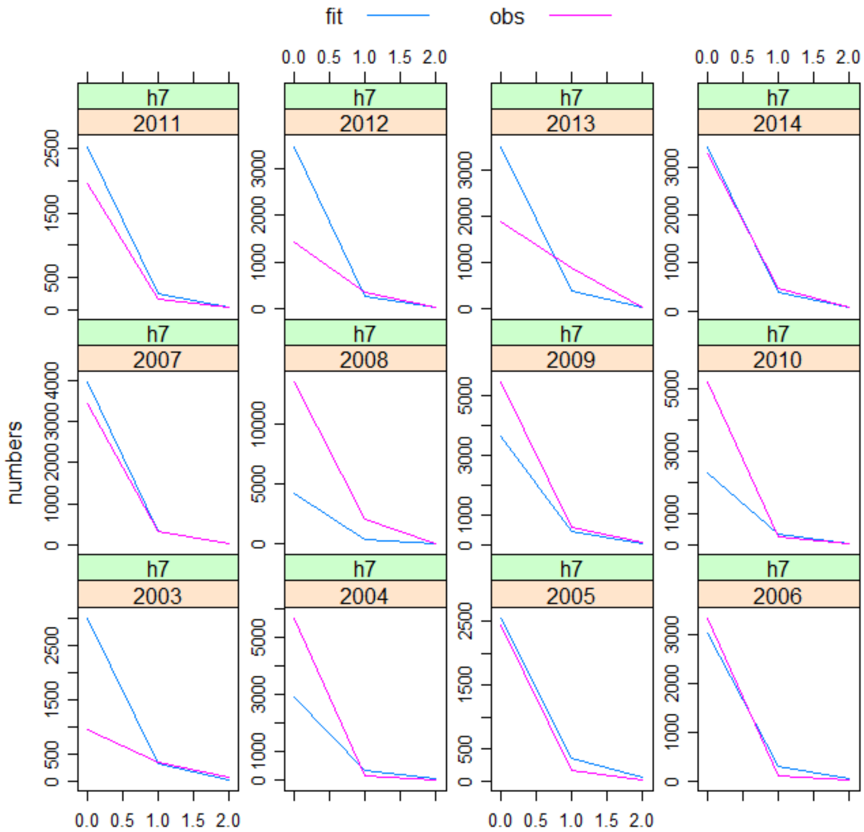


Figure 5.2.9.8.3.6. Hake in GSA 1-7. Observed vs predicted catch numbers in MEDITS survey performed in Gulf of Lions (GSA 7).

The estimated fishing mortality at age (Figure 5.2.9.8.3.7) shows an increase in mortality in age 2-3 in recent years before a general decrease in F.

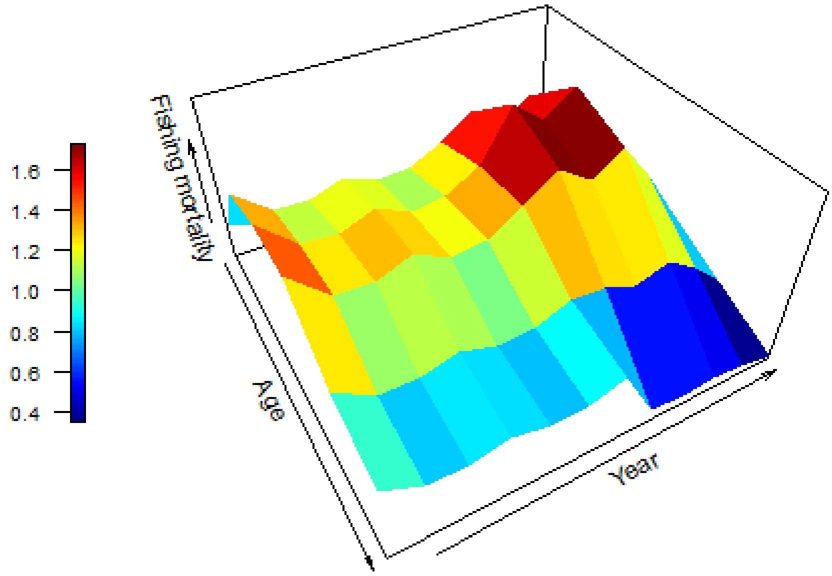


Figure 5.2.9.8.3.7. Hake in GSA 1-7. Fishing mortality at age estimate from the a4a model 41.

The perception of the stock from model 41 (Figure 5.2.9.8.3.8) shows a variable recruitment, with an upward trend in the recent years. SSB varies around 7000 tons and after the lowest point in 2011-2013 is increasing. Catches are steadily declining since 2009. F (harvest) is high throughout the time series but is declining in the most recent years.

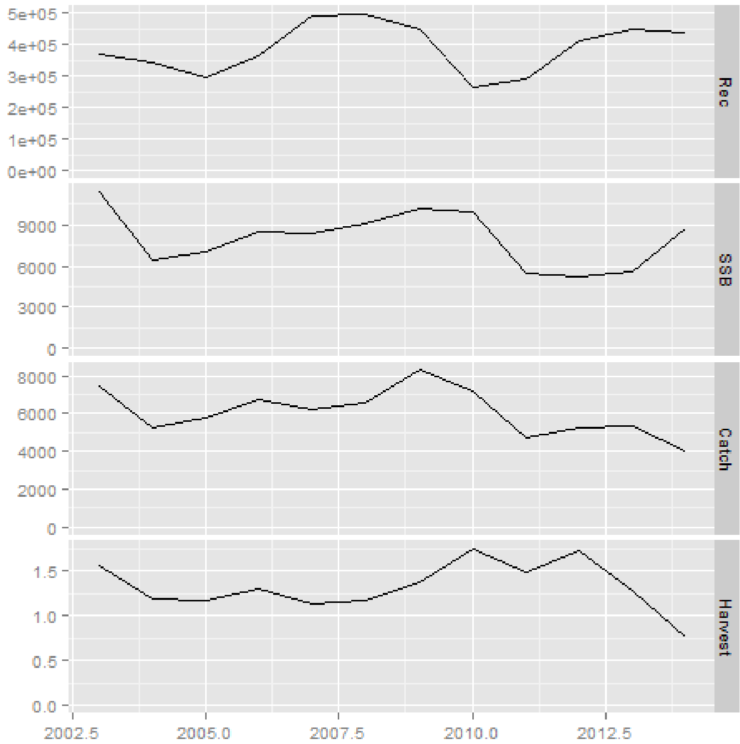


Figure 5.2.9.8.3.8. Hake in GSA 1-7. Summary table of hake stock estimates from Mod 41.

F_{bar} (age 1-3) is 0.76 in 2014, the lowest since 2003 (Table 5.2.9.8.3.1).

Table 5.2.9.8.3.1. Hake in GSA 1-7. Estimated fishing mortality at age and F_{bar} (1-3) from the a4a model run.

	Year											
F @ Age	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
0	0.82	0.81	0.64	1.01	0.62	0.60	0.75	0.47	0.14	0.15	0.18	0.12
1	1.92	1.50	1.50	1.59	1.31	1.71	2.05	1.52	1.82	1.78	1.79	1.23
2	1.63	1.08	1.36	1.55	1.58	1.65	1.94	1.73	2.22	1.87	2.22	1.60
3	2.04	1.28	0.93	1.64	1.61	0.83	1.23	1.86	1.55	2.36	1.47	1.34
4	2.06	1.13	0.75	0.26	1.85	1.50	1.61	1.96	1.86	0.98	1.83	0.28
5	2.06	1.13	0.75	0.26	1.85	1.50	1.61	1.96	1.86	0.98	1.83	0.28

	Year											
Age	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Fbar (1-3)	1.56	1.20	1.17	1.31	1.14	1.17	1.38	1.74	1.49	1.72	1.29	0.76

The a4a assessment was compared with the XSA best model run and the results are comparable in overall stock perception. The main difference is the F in the most recent year, the a4a run giving an F = 0.76 while XSA F= 1.09. All a4a model runs are plotted, along the XSA run in Figure 5.2.9.8.3.10.

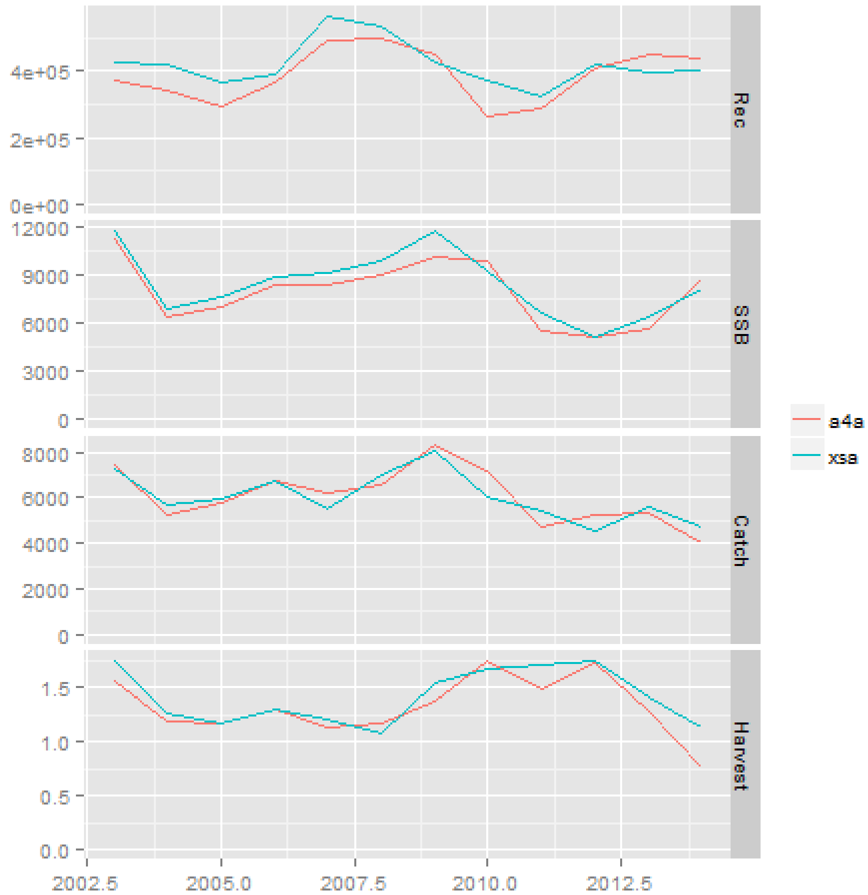


Figure 5.2.9.8.3.9. Hake in GSA 1-7. Comparison of XSA and best model fit in a4a (mod 41).

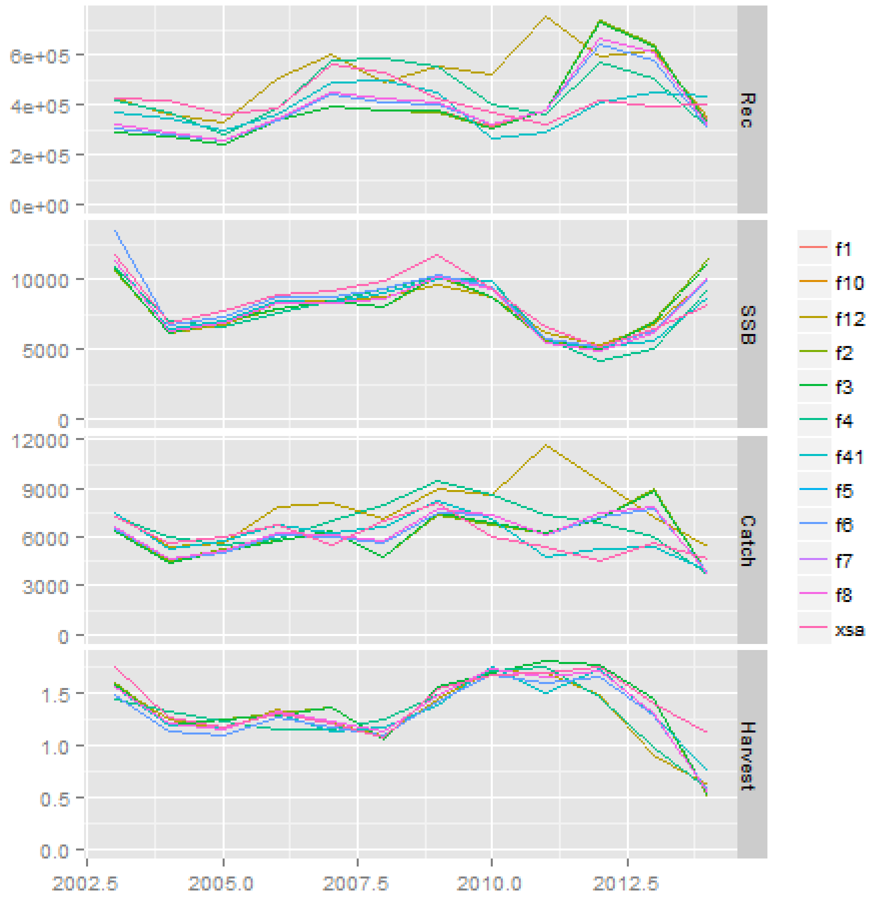


Figure 5.2.9.8.3.10. Hake in GSA 1-7. Comparative parameters estimates from all model runs.

Reference points were derived similarly to the XSA reference points as described in Section *5.2.9.9. The proxy for* F_{mys} *is* $F_{0.1}$ *which is estimated at 0.48* by a4a final model (**Table 5.2.9.8.3.2** and Figure 5.2.9.8.3.10. The XSA estimate is instead $F_{0.1} = 0.39$.

Table 5.2.9.8.3.2. Hake in GSA 1-7. Main reference points defined by the yield per recruit analysis using the a4a model.

refpt	harvest	yield	rec	ssb	biomass
virgin	0.00E+00	0.00E+00	3.80E+05	8.24E+04	6.81E+04
msy	8.86E-01	5.16E+03	3.80E+05	1.18E+04	2.36E+04
crash	NaN	NaN	3.80E+05	NaN	NaN
f0.1	**4.85E-01**	4.82E+03	3.80E+05	2.43E+04	3.18E+04
fmax	8.86E-01	5.16E+03	3.80E+05	1.18E+04	2.36E+04
spr.30	4.77E-01	4.80E+03	3.80E+05	2.47E+04	3.20E+04

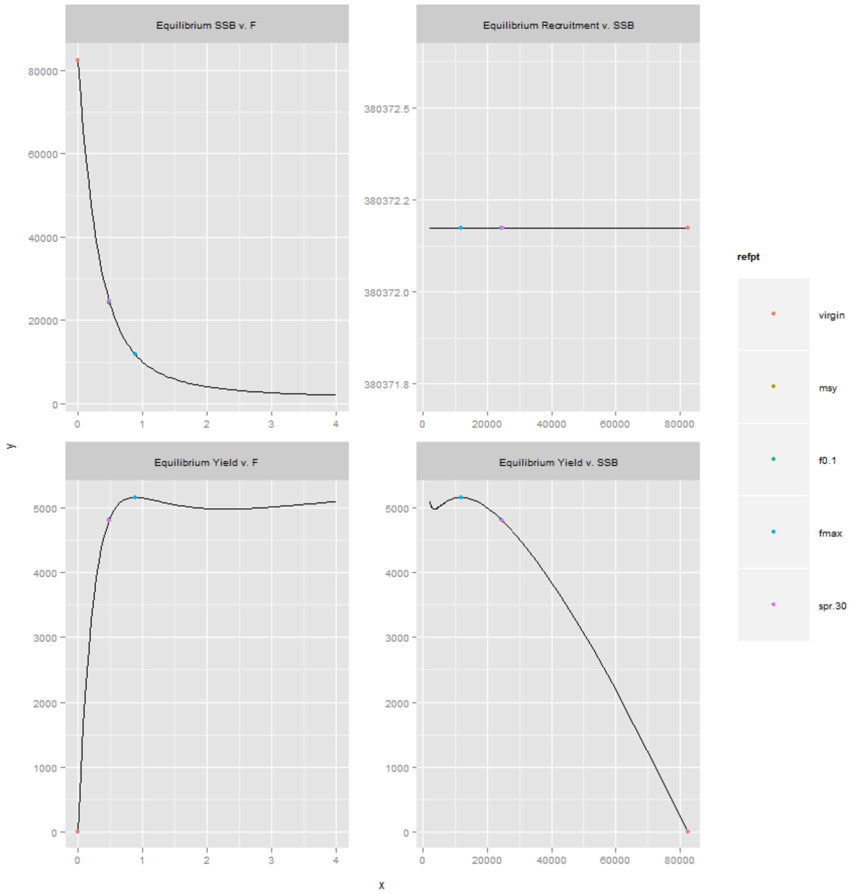


Figure 5.2.9.8.3.11. Hake in GSA 1-7. Yield per recruit reference points derived by the a4a assessment.

Since the outputs of the XSA and a4a were consistent, although slightly different in the stock perception, it was decided to use the XSA run for the short term predictions, the reference points and the MSE since the assessments ran for the individual GSA level were performed with XSA as well.

5.2.9.9 Reference points

5.2.9.9.1 Methods

The FLBRP package allowed a Yield per recruit analysis and an estimate of some F-based Reference Points as F_{max} and $F_{0.1}$. Yield per Recruit computation was made by R project software and the FLR libraries. The fishing mortality rate corresponding to $F_{0.1}$ in the yield per recruit curve is considered here as a proxy of F_{MSY}.

5.2.9.9.2 Input data

The input parameters were the same used in the XSA stock assessment and its results.

5.2.9.9.3 Results

Table 5.2.9.8.3.1. European hake in GSA 1-7. Main reference points defined with the yield per recruit analysis by the XSA assessment.

refpt	harvest	yield	rec	ssb	biomass
virgin	0.00	0.00	1.00	0.22	0.18
msy	0.70	0.01	1.00	0.04	0.07
f0.1	0.39	0.01	1.00	0.08	0.09
fmax	0.70	0.01	1.00	0.04	0.07
spr.30	0.45	0.01	1.00	0.07	0.08

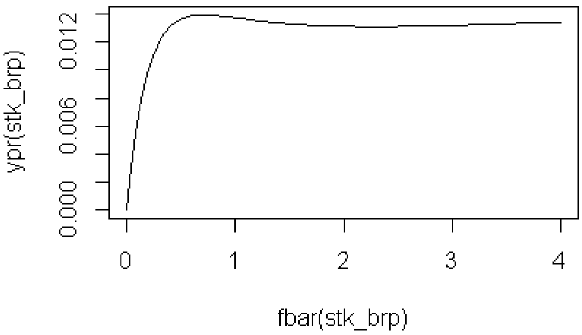


Figure 5.2.9.9.3.1. Hake in GSA 1-7. Yield per recruit curve from the XSA assessment; F01=0.39 and $F_{sq(1-3)=}$ 1.40.

5.2.9.10 Data quality

For details in data quality, see the sections corresponding to the assessments by GSA.

5.2.9.11 Short term predictions 2015-2017

5.2.9.11.1 Method

A deterministic short term prediction for the period 2015 to 2017 was performed using the FLR routines provided by JRC and based on the results of the XSA stock assessments performed during EWG 15-11.

5.2.9.11.2 Input parameters

Input parameters were the same used for the XSA stock assessment and its results. An average of the last three years has been used for weight at age, maturity at age and F at age.

Recruitment (age 0) has been estimated from the population results as the geometric mean of the last 3 years (459070 thousand individuals).

5.2.9.11.3 Results

Table 5.2.9.11.3.1. Hake in GSAs 1-7. Short term forecast in different F scenarios. Basis: F(2015) = mean (F_{bar} 1-3 2012-2014)= 1.40; R(2015) = geometric mean of the recruitment of the last 3 years; R = 459070 thousands; SSB(2014) = 8133 t, Catch (2014)= 4650 t.

Rationale	Ffact or	Fbar	Catch 2014	Catch 2015	Catch 2016	Catch 2017	SSB 2016	SSB 2017	Change SSB 2016-	Change Catch 2014-2016(%)

									2017(%)
Zero catch	0	0.00	6221	0	0	7843	21566	174.99	-100.00
High long term yield (F_{MSY})	0.28	0.39	6221	2416	3901	7843	15746	100.78	-48.04
Status quo	1	1.40	6221	6192	6162	7843	7758	-1.08	33.15
Different scenarios	0.1	0.14	6221	953	1807	7843	19225	145.13	-79.51
	0.2	0.28	6221	1805	3123	7843	17179	119.05	-61.18
	0.3	0.42	6221	2569	4076	7843	15391	96.25	-44.74
	0.4	0.56	6221	3256	4760	7843	13827	76.31	-29.98
	0.5	0.70	6221	3874	5247	7843	12458	58.85	-16.68
	0.6	0.84	6221	4432	5589	7843	11258	43.55	-4.68
	0.7	0.98	6221	4937	5826	7843	10206	30.13	6.18
	0.8	1.12	6221	5395	5987	7843	9282	18.36	16.03
	0.9	1.26	6221	5812	6094	7843	8471	8.01	24.99
	1.1	1.54	6221	6539	6203	7843	7130	-9.09	40.62
	1.2	1.68	6221	6857	6225	7843	6577	-16.14	47.46
	1.3	1.82	6221	7149	6236	7843	6089	-22.36	53.75
	1.4	1.96	6221	7419	6239	7843	5659	-27.84	59.54
	1.5	2.10	6221	7667	6237	7843	5279	-32.69	64.89
	1.6	2.24	6221	7898	6233	7843	4942	-36.98	69.85
	1.7	2.38	6221	8112	6228	7843	4644	-40.79	74.46
	1.8	2.52	6221	8312	6223	7843	4380	-44.16	78.75
	1.9	2.66	6221	8498	6219	7843	4145	-47.15	82.75
	2	2.79	6221	8672	6216	7843	3936	-49.81	86.50

5.2.9.12 Short term predictions 2015-2017 by fleet

5.2.9.12.1 Method
A deterministic short term prediction by fleet for the period 2015 to 2017 was performed using the FLR routines provided by JRC and based on the results of the XSA stock assessments performed during EWG 15-11.

5.2.9.12.2 Input parameters
The same parameters used in the short term by single fleet were used.

5.2.9.12.3 Results

Table 5.2.9.12.3.1. Hake in GSA 1-7. Short term forecast by fleet.

Fleet	Year	Catches	Partial_f
GSA 1 OTB	2015	534.5	0.11
GSA1 GNS	2015	19.2	0.01
GSA 1 LL	2015	17.8	0.00
GSA5 OTB	2015	130.8	0.02
GSA6 OTB	2015	4022.9	0.55
GSA 6 OTHER	2015	135.8	0.04
GSA 7 GNS-FR	2015	173.3	0.06
GSA 7 OTB-FR	2015	1616.5	0.28
GSA7 LL- SP	2015	41.8	0.01
GSA7 OTB-SP	2015	200.0	0.04
GSA 1 OTB	2016	207.8	0.03
GSA1 GNS	2016	8.3	0.00
GSA 1 LL	2016	6.2	0.00
GSA5 OTB	2016	48.9	0.01
GSA6 OTB	2016	1484.6	0.17
GSA 6 OTHER	2016	58.9	0.01
GSA 7 GNS-FR	2016	71.8	0.02
GSA 7 OTB-FR	2016	632.4	0.08
GSA7 LL- SP	2016	15.8	0.00
GSA7 OTB-SP	2016	79.6	0.01
GSA 1 OTB	2017	330.5	0.03
GSA1 GNS	2017	17.3	0.00
GSA 1 LL	2017	12.5	0.00
GSA5 OTB	2017	71.9	0.01
GSA6 OTB	2017	2061.9	0.17
GSA 6 OTHER	2017	119.3	0.01
GSA 7 GNS-FR	2017	143.2	0.02
GSA 7 OTB-FR	2017	934.4	0.08
GSA7 LL- SP	2017	32.3	0.00
GSA7 OTB-SP	2017	123.5	0.01

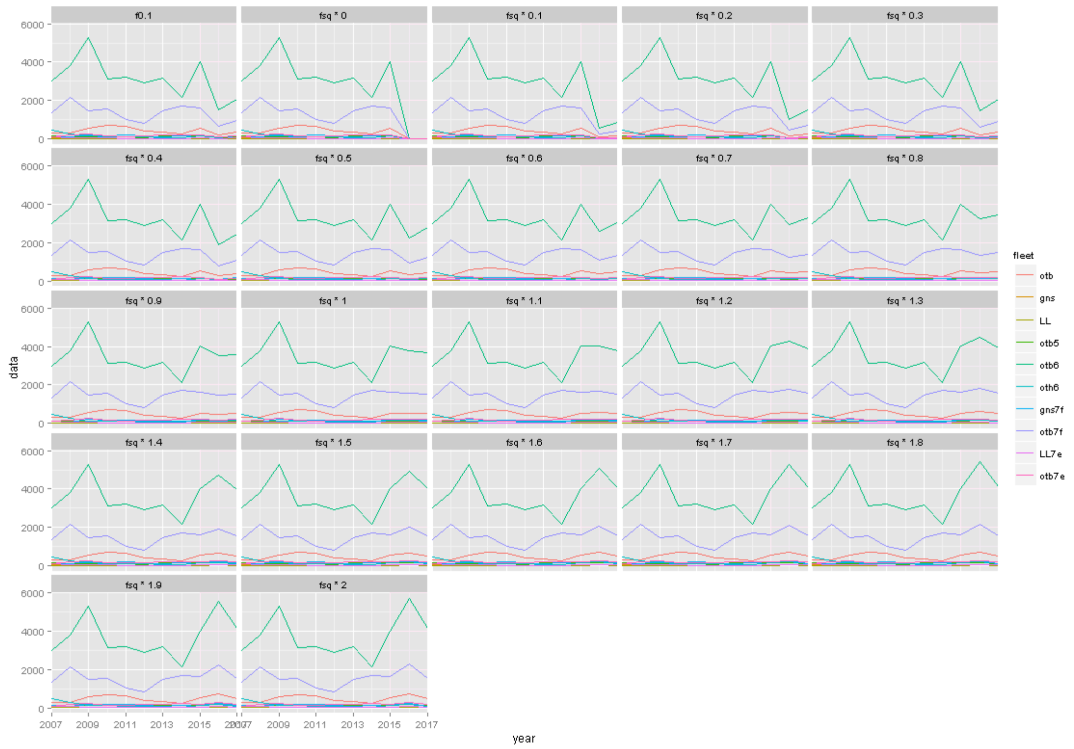


Figure 5.2.9.12.3.1. Hake in GSAs 1-7. Short term forecast by fleet.

5.2.9.13 Stock advice

The current F (1.40) is larger than $F_{0.1}$ (0.39), chosen as proxy of F_{MSY} and as the exploitation reference point consistent with long term yields, which indicates that European hake in GSAs 1-7 is being fished above F_{MSY}. Catches of European hake in 2016 consistent with $F_{0.1}$ (0.23) should not exceed 2416 tonnes.

5.2.9.14 Management strategy evaluation

We ran the Management Strategy Evaluation (MSE) to evaluate if the MSY ranges were precautionary. The F_{MSY} ranges were derived using the formula provided by STECF 15-09. F ranges results were F_{upper} = 0.53 and F_{lower} = 0.26. B_{lim} was estimated as B_{loss} = 5186 (t). The following figure shows the results of the MSE.

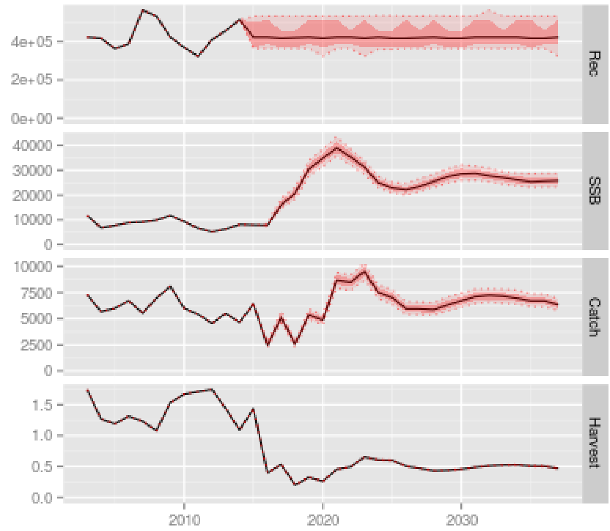


Figure 5.2.9.14.1. Hake in GSAs 1-7. Marine Strategy Evaluation.

The probability of SSB to fall below B_{lim} at F = F_{upper} is equal to 0.

5.2.10 STOCK ASSESSMENT OF HAKE IN GSA 9-11

5.2.10.1 Stock Identification

A study (STOCKMED; Fiorentino et al., 2015) on the European hake (and other commercial species) stock potential distribution in the Mediterranean Sea has been funded by the EU and undertaken under the framework of the MAREA Project. This study suggested that there are two stocks of European hake in the Western Mediterranean Sea: one distributed from the Alboran Sea to the Gulf of Lion and another one from the Gulf of Lion to the Strait of Sicily and beyond. In the view of those findings, STECF EWG 15-11 was asked to assess the state of European hake stocks in the Western Mediterranean Sea following two approaches: by single GSAs and GSAs combined. The present assessment will investigate the state of the hake stock in GSAs 9, 10, and 11.

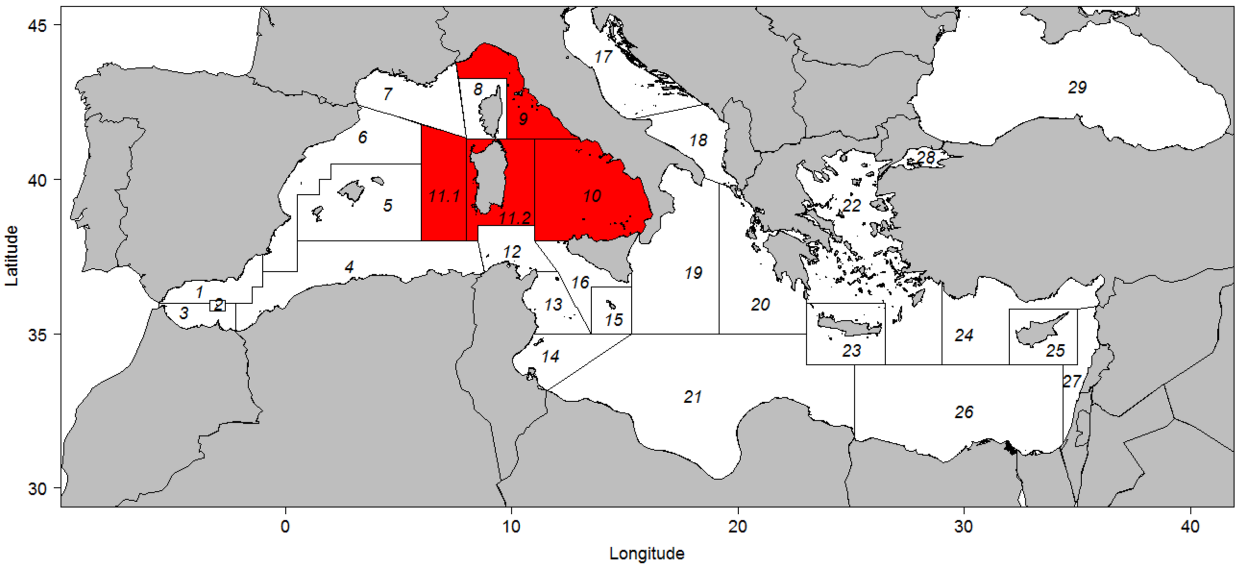


Figure 5.2.10.1.1. Geographical location of GSAs 9, 10, and 11.

5.2.10.2 Growth

Growth parameters are those used in each GSA (see sections of GSA 9, GSA 10 and GSA 11 assessments).

5.2.10.3 Maturity

Maturity ogives were taken from each GSA (see sections of GSA 9, GSA 10 and GSA 11 assessments). Combined maturity at age were calculated as a weighted average using the stock numbers.

5.2.10.4 Natural mortality

Natural mortality was taken from each GSA (see sections of GSA 9, GSA 10 and GSA 11 assessments). Combined natural mortality at age were calculated as a weighted average using the stock numbers.

5.2.10.5 Fisheries

5.2.10.5.1 General description of the fisheries

Hake is one of the main target species of bottom trawlers in terms of landings, incomes and vessels involved. The analysis of available information suggests that about 60% of landings of hake are obtained by bottom trawl vessels, the remaining fraction being provided by artisanal vessels using set nets, i.e. gillnets and trammel net, and long-lines. See Chapters 5.2.6-8 in the Report for further details on hake fisheries in GSAs 9, 10, and 11.

5.2.10.5.2 Management regulations applicable in 2015

See Chapters 5.2.6-5.2.8 in the Report for management regulations on hake fisheries in GSAs 9, 10, and 11.

5.2.10.5.3 Catches

Landing and discards by fleet are described in the following sections 5.2.10.5.4 and 5.2.10.5.5.

5.2.10.5.4 Landings

Landings data were reported to STECF EWG 15-11 through the DCF. In GSAs 9, 10, and 11, the bulk of catches is from otter trawl, while artisanal fisheries (trammel net, gill net, and long-lines) represent the rest of the catches. DCF data on age structure of European hake landings in GSAs 9, 10, and 11 are available for the period 2006-2014. DCF data prior to 2006 were considered inaccurate, therefore they were not included in the stock assessment. For more details on landings and age-structure of landings, please see sections 5.2.6-5.2.8 in this report.

5.2.10.5.5 Discards

Discards data were reported to STECF EWG 15-11 through the DCF. Information on OTB discards was available for 2006 and from 2009 to 2014. The size at which 50% of the specimens caught are discarded is progressively increased in the last years due to the introduction of the EU Regulations on minimum sizes. This phenomenon might be also explained by a reduction of the fishing pressure on the nursery areas. Data and information on length-frequency distributions of discards of hake in GSAs 9, 10, and 11 are available in sections 5.2.6, 5.2.7, and 5.2.8, respectively, of this report.

5.2.10.5.6 Fishing effort

The nominal fishing capacity in the three areas involved in the present assessment has shown a progressive decrease in the last 20 years. Fishing effort (kW*fishing days) performed by trawlers decreased of 25% since 2004. The effort displayed by the artisanal fleet exploiting hake remained constant. For more details on fishing effort exerted on hake in the three GSAs involved in the present assessment, please see sections 5.2.6-5.2.8 in this report.

5.2.10.6 Scientific surveys

5.2.10.6.1 Survey #1 (MEDITS)

5.2.10.6.1.1 Methods

Based on the DCF data call, abundance and biomass indices were re-calculated. The data coming from MEDITS surveys carried out in GSAs 9, 10, and 11 from 1994 to 2014 are presented in sections 5.2.6-5.2.8 of this report.

5.2.10.6.1.2 Geographical distribution

According to recent studies (Orsi Relini *et al.*, 2002; Colloca *et al.*, 2004, 2006), the density of hake recruits in nursery areas in GSA 9 is by far higher than that in the other GSAs of the western Mediterranean and, probably, also of the other Mediterranean GSAs (Figure 5.2.10.6.1.2.1).

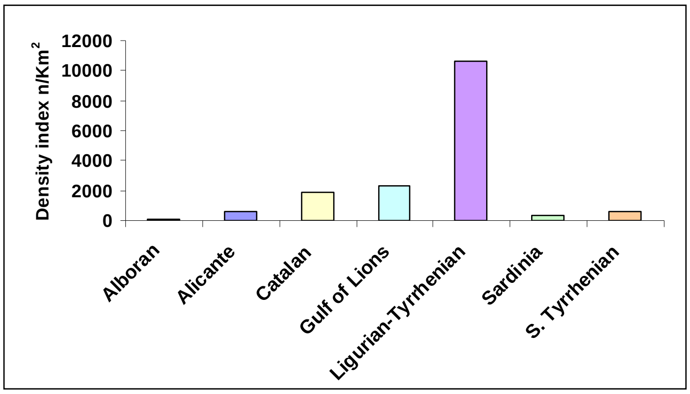


Figure 5.2.10.6.1.2.1. Hake in GSAs 9-11. MEDITS density indices of the hake recruits (<12 cm TL) obtained in different Mediterranean GSAs (from Orsi-Relini et al., 2002, modified).

Further information on the spatial and temporal distribution of hake recruits as well as of adults in GSAs 9, 10, and 11 is presented in sections 5.2.6-5.2.8 of this report.

5.2.10.6.1.3 Trends in abundance and biomass

European hake time series of abundance and biomass indices from MEDITS surveys carried out in GSAs 9, 10, and 11 (1994-2014) are shown and described in sections 5.2.6-5.2.8 of this report.

5.2.10.6.1.4 Trends in abundance by length or age

The stratified abundance indices of European hake in GSAs 9, 10, and 11 are presented in sections 5.2.6, 5.2.7, and 5.2.8, respectively, of this report.

5.2.10.7 Stock Assessment

5.2.10.7.1 Method: XSA

FLR libraries were employed in order to carry out an XSA based assessment. The European hake stock in GSAs 9-11 was assessed for the first time. XSA was carried out using as input data the period 2006-2014 for the catch data and 2006-2014 for the tuning file.

The a4a framework was also used to fit assessment models on the hake stock in GSAs 9-11. However, the results in terms of residuals and retrospective analysis were not satisfactory; therefore, the results of this approach were not presented in the report. The lack of a sufficient time series of data on this stock may have hampered the use of a4a. However, it is recommended to test the use of a4a as a suitable assessment tool on this stock in future years, once a sufficient time series of data will be available.

5.2.10.7.2 Input data

The growth parameters used for VBGF were L_{inf}= 103.9 cm TL; K = 0.212 yr^{-1}; t_0= 0.031 yr. The length-to-weight coefficients used were a= 0.006657, b= 3.028.

Total catches and catch numbers at age from the single GSAs were used as input data. The R script prepared by JRC was used to create a combined stock object to be used in the assessment. Natural mortality and maturity were estimated as weighed mean from the parameters used in the assessments of the single GSAs.

Table 5.2.10.7.2.1 lists the input parameters to the XSA, namely landings, catch number at age, weight at age, maturity at age, natural mortality at age and the tuning series at age.

Table 5.2.10.7.2.1. Hake in GSAs 9-11. Input data to the XSA model.

Catches (t)

2006	2007	2008	2009	2010	2011	2012	2013	2014
4657	3830	3406	3664	3384	3757	2641	2895	3075

Catch numbers-at-age matrix (thousands)

Age	2006	2007	2008	2009	2010	2011
0	82424.000	62020.000	65121.000	91660.000	42494.000	66748.000
1	14603.000	13976.000	12123.000	12360.000	12523.000	12820.000
2	2299.300	1314.100	870.330	812.160	1451.500	1203.900
3	298.580	208.990	251.030	171.530	225.100	285.330
4	102.970	54.785	80.515	85.904	68.254	100.770
5	29.440	12.424	37.507	25.232	36.735	37.943
6+	0.001	2.645	7.758	9.252	11.873	8.372

Age	2012	2013	2014
0	29969.000	26054.000	42564.000
1	10271.000	12899.000	10589.000
2	880.350	744.270	1331.000
3	209.180	134.050	186.980
4	53.596	53.242	39.646
5	14.063	11.699	24.068
6+	2.020	3.865	19.806

Weights-at-age (kg)

Age	2006	2007	2008	2009	2010	2011
0	0.010	0.011	0.010	0.011	0.010	0.009
1	0.139	0.147	0.144	0.146	0.134	0.147
2	0.523	0.526	0.516	0.511	0.513	0.505
3	1.172	1.183	1.135	1.159	1.145	1.167
4	1.916	1.827	1.883	1.876	1.917	1.902
5	2.621	2.822	2.685	2.635	2.766	2.687
6+	3.001	4.924	3.637	3.714	3.983	4.046

Age	2012	2013	2014
0	0.012	0.011	0.009
1	0.140	0.147	0.154
2	0.502	0.547	0.465
3	1.138	1.153	1.147

4	1.929	1.836	1.849
5	2.787	2.603	2.683
6+	3.825	4.383	3.865

Maturity and natural mortality vectors.

Age	**0**	**1**	**2**	**3**	**4**	**5**	**6+**
Maturity	0.00	0.23	0.88	1.00	1.00	1.00	1.00
M	1.18	0.58	0.43	0.36	0.33	0.32	0.30

Hake in GSA 9-11. MEDITS number (n/km^2) at age for GSA 9 only. Age 4+ was used in this assessment, although a Age 3+ was used in the assessment of hake in GSA 9.

Year/age	0	1	2	3	4+
2006	1686.57	58.583	2.502	0.26	0.182
2007	2514.259	38.88	2.24	1.54	0.10
2008	5871.627	57.22	1.24	0.32	0.45
2009	6573.9	52.84	1.09	0.46	0.08
2010	2469.127	37.30	2.57	0.10	0.08
2011	769.899	29.39	1.29	0.33	0.10
2012	1464.35	21.93	0.99	0.48	0.31
2013	1743.236	35.29	1.00	0.10	0.33
2014	1564.17	27.137	1.901	0.218	0.294

Hake in GSA 9-11. MEDITS number (n/km^2) at age for GSA 10.

Year/age	0	1	2	3	4	5	6+
2006	1250.42	99.67	2.32	0.49	0.01	0.01	0.01
2007	1907.19	51.52	0.95	0.97	0.14	0.14	0.01
2008	1544.78	92.69	2.97	1.52	0.01	0.01	0.4
2009	1890.43	78.11	0.38	0.32	0.01	0.32	0.01
2010	813.51	131.46	1.46	0.3	0.17	0.15	0.24
2011	639.35	67.18	2.45	1.2	0.01	0.01	0.01
2012	907.4	56.44	2.37	0.29	0.01	0.16	0.01
2013	1252.29	67.21	4.37	0.29	0.01	0.22	0.01
2014	610.5	64.50	4.00	0.20	0.30	0.01	0.01

Hake in GSA 9-11. Indices from long-line fishery (CPUE at age) from GSA 10. Although Age 1 was used for the assessment of hake in GSA 10, it was removed in the combined assessment of hake in GSAs 9-11.

Year	2	3	4	5	6+
2006	0.012778	0.005738	0.002327	0.000583	0
2007	0.004451	0.012014	0.003051	0.001027	0.000171
2008	0.003799	0.002676	0.00165	0.000871	0.000236
2009	0.010841	0.00422	0.002638	0.000486	0.000574

2010	0.027127	0.003106	0.000952	0.001266	0.000806
2011	0.007395	0.007279	0.003293	0.00049	0.000427
2012	0.010703	0.007996	0.001233	0.000428	0.000107
2013	0.024985	0.012861	0.004887	0.001097	0.001097
2014	0.003283	0.007114	0.002094	0.001818	0.001818

Hake in GSA 9-11. MEDITS number (n/km^2) at age for the GSA 11.

Year/age	0	1	2	3	4	5
2006	670.54	2937.10	318.85	9.71	8.32	0.26
2007	41.52	894.59	52.06	9.41	1.21	0.59
2008	15.63	1789.55	331.40	86.14	4.99	0.11
2009	169.90	1096.91	41.02	2.35	1.04	0.10
2010	425.29	5498.63	325.50	11.09	0.21	0.21
2011	131.21	1448.03	108.27	10.66	2.59	0.10
2012	177.07	932.29	44.40	2.42	0.55	0.33
2013	3.55	1588.47	125.84	9.89	0.92	0.41
2014	33.66	531.75	48.62	4.96	0.71	0.23

5.2.10.7.3 Results

Sensitivity analyses were conducted to assess the effect of the main parameters. Values ranging from 0.5 to 3 (with a 0.5 step increase) for the shrinkage have been tested. Comparison of trends between the settings has been done.

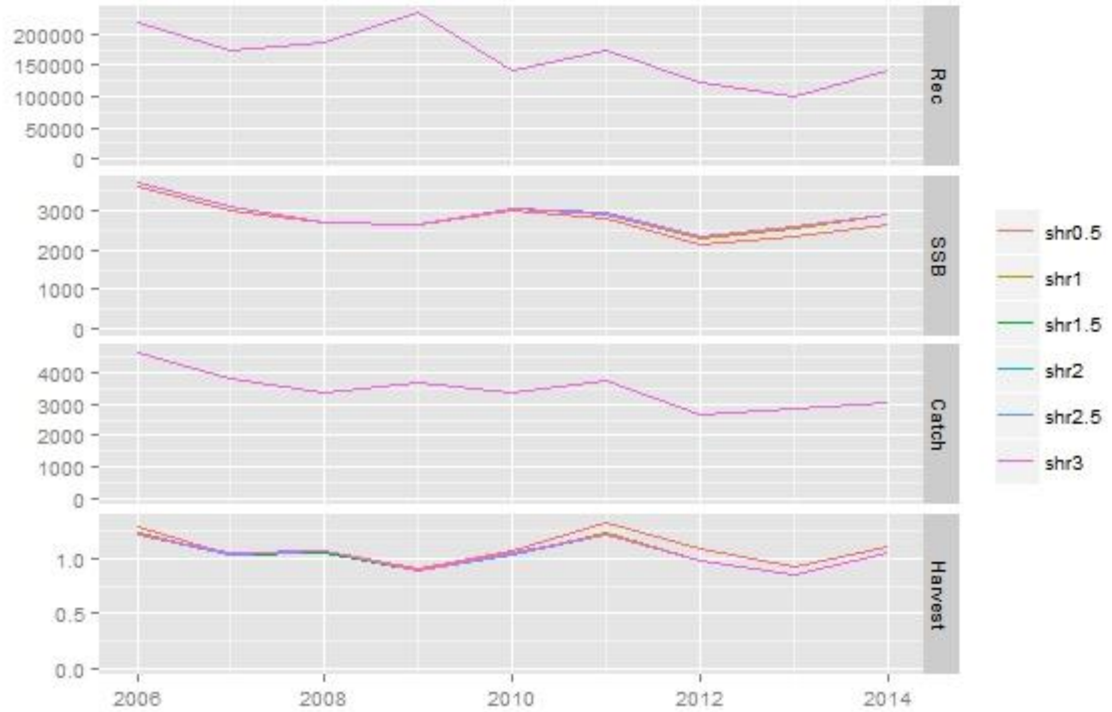


Figure 5.2.10.7.3.1. Hake in GSAs 9-11. Sensitivity on shrinkage weight.

As a result, the settings that minimized the residuals and showed the best diagnostics output were used for the final assessment, and are the following:

Fbar	fse	rage	qage	shk.yrs	shk.age
1-4	2	0	5	3	2

The residuals patterns of the MEDITS trawl surveys in GSAs 9, 10, and 11, and long-line fishery CPUE in GSA 10 are shown in Figure 5.2.10.7.3.2.

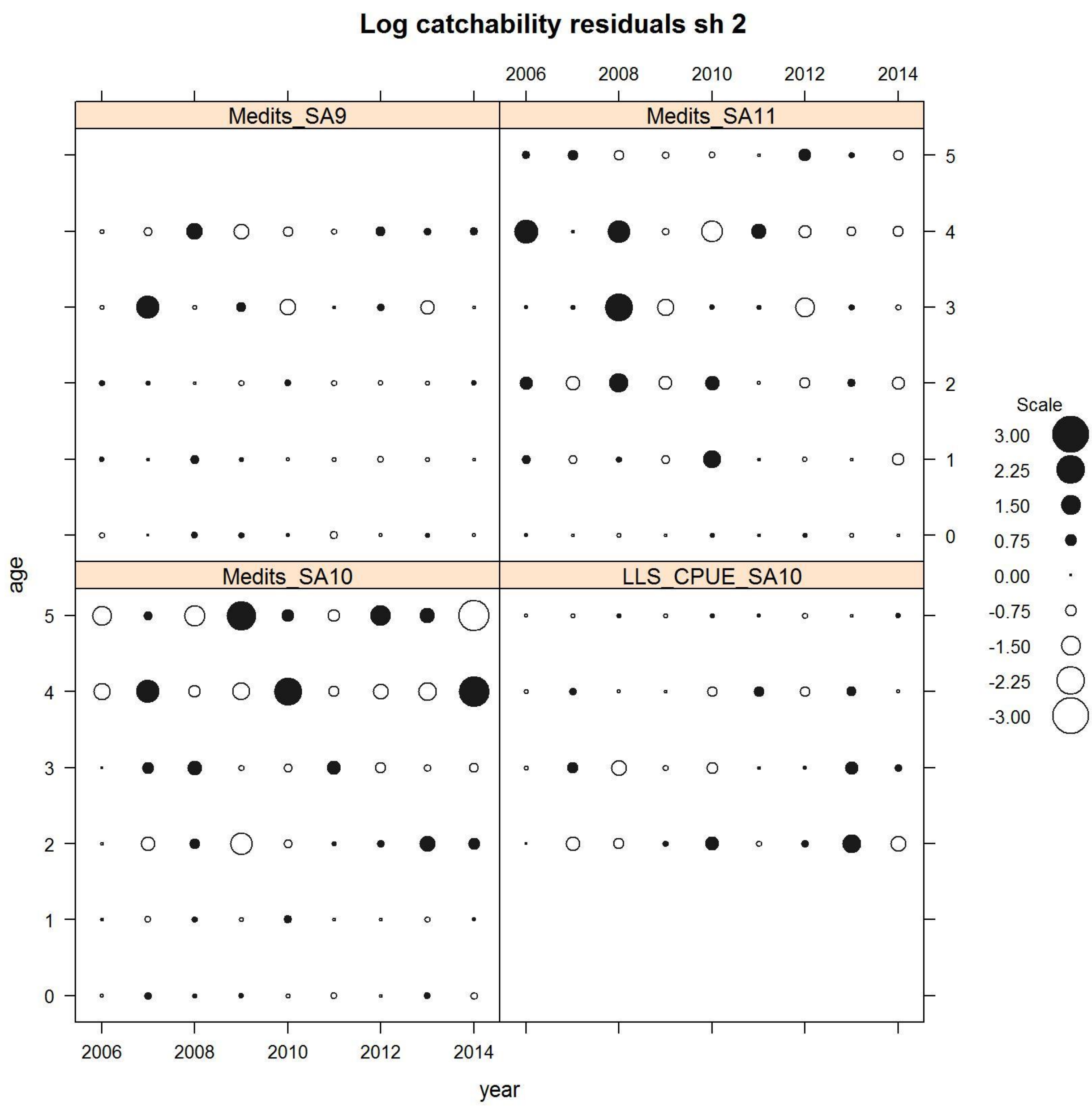


Figure 5.2.10.7.3.2. Hake in GSAs 9-11. XSA residuals for the MEDITS surveys from 2006 to 2014 and long-line fishery CPUE in GSA 10.

The results of the retrospective analysis are shown in Figure 5.2.10.7.3.3.

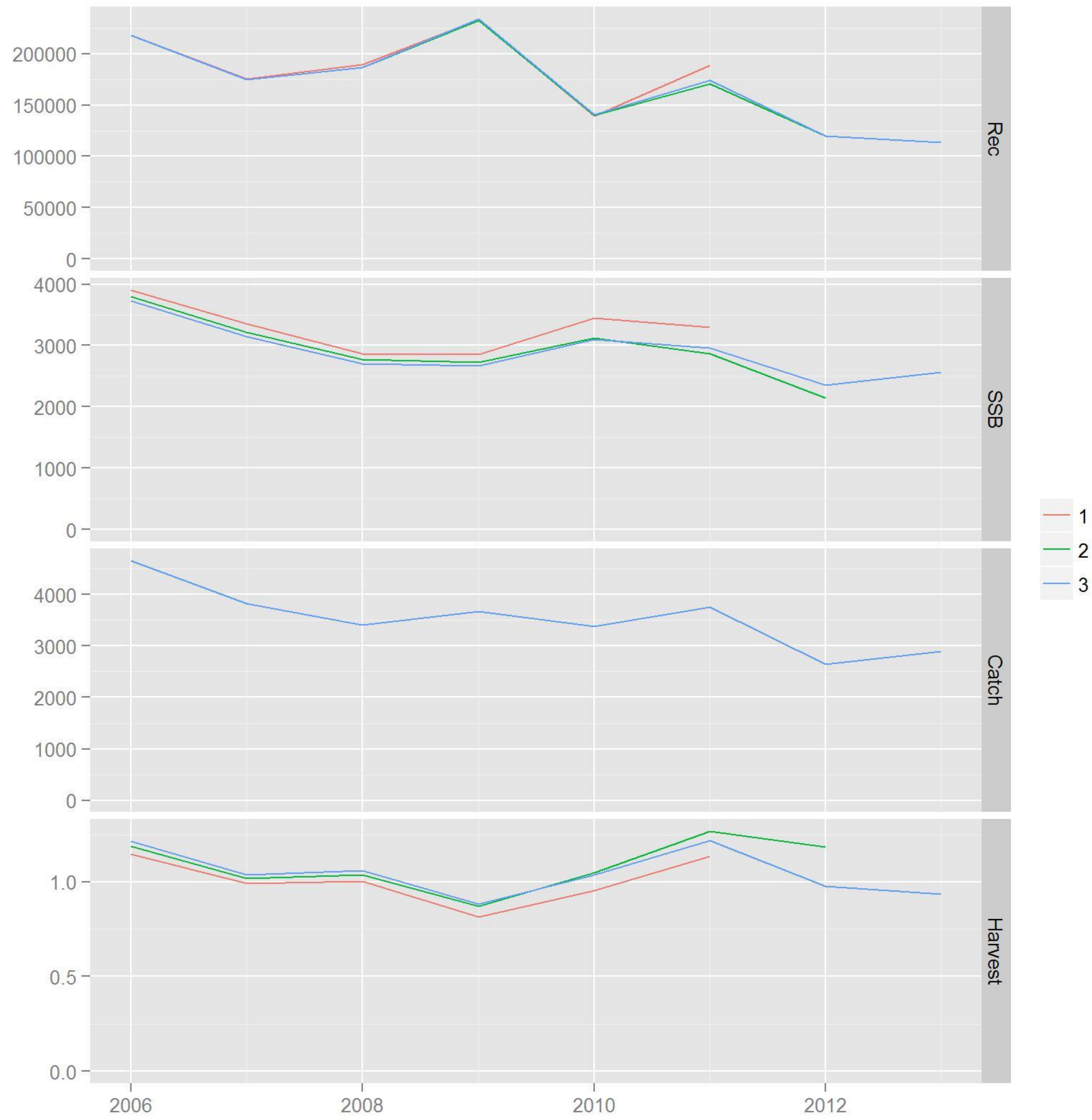


Figure 5.2.10.7.3.3. Hake in GSAs 9-11. XSA retrospective analysis.

The results of the XSA are shown in Fig. 5.2.10.7.3.4. Recruitment, SSB, and catches are showing a slight decreasing trend, with a slight increasing pattern in the last few years. F remains at high levels.

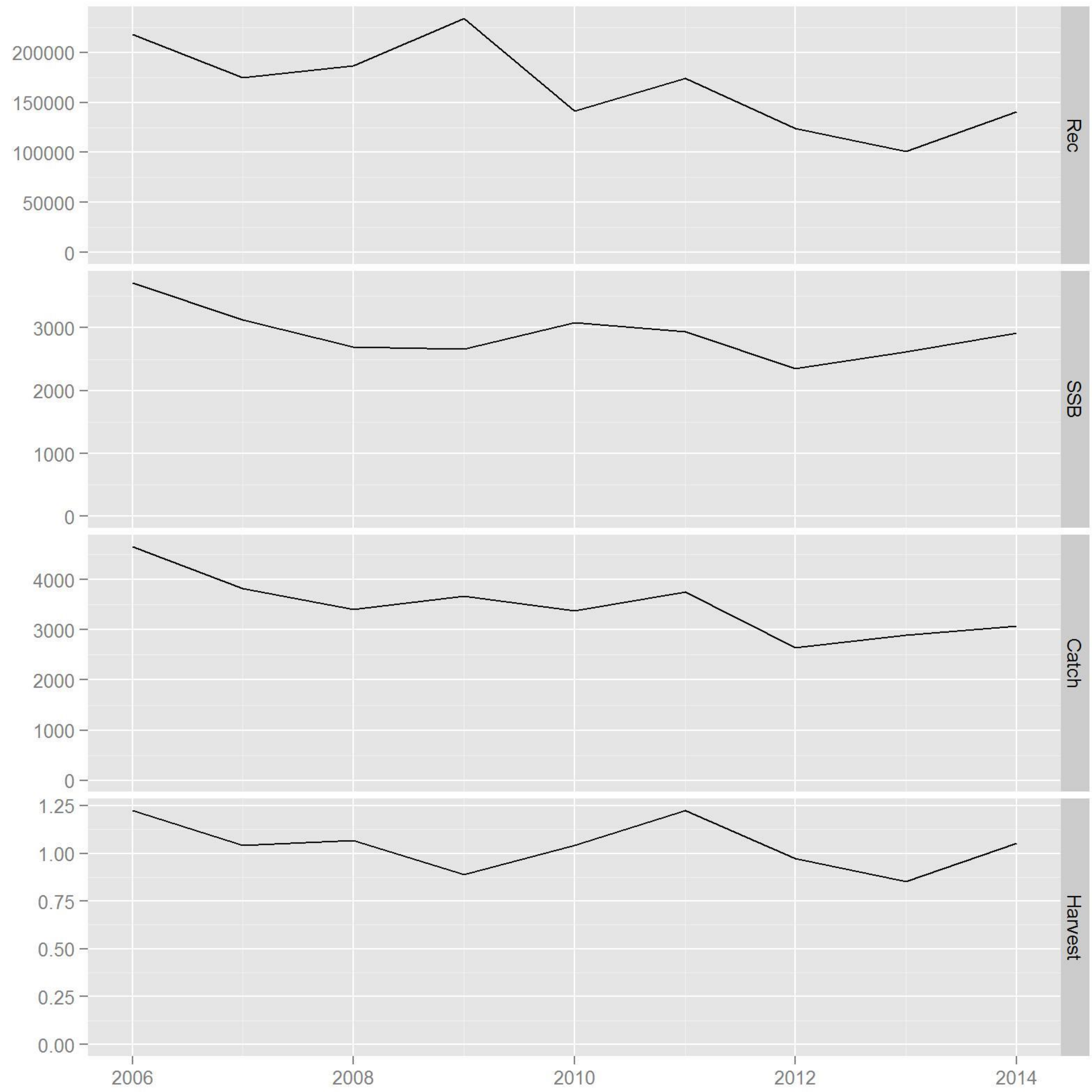


Figure 5.2.10.7.3.4. Hake in GSAs 9-11. XSA summary results. SSB and catch are in tonnes, recruitment in 1000s individuals.

The stock parameters estimates of hake obtained by XSA are provided in Tables 5.2.10.7.3.1-5.2.10.7.3.3.

Table 5.2.10.7.3.1. Hake in GSAs 9-11. Stock numbers at age (thousands) as estimated by XSA.

Age	2006	2007	2008	2009	2010	2011
0	217730	175120	186880	233820	141050	174000
1	24028	21838	19451	21346	20767	20196
2	3612	2583	1736	1813	2688	2326
3	592	490	621	430	527	586
4	233	161	167	223	156	178
5	58	80	70	52	87	54
6+	0	17	14	18	28	11

Age	2012	2013	2014
0	123680	101300	140910
1	16383	21497	16701
2	1705	1531	2360
3	547	405	399
4	171	206	170
5	43	78	103
6+	6	25	84

Table 5.2.10.7.3.2. Hake in GSAs 9-11. XSA summary results.

	Fbar1-4	Recruitment (thousands)	SSB (t)	TB (t)
2006	1.22	217732	3717	8640
2007	1.04	175119	3121	7703
2008	1.07	186877	2696	6810
2009	0.89	233825	2657	7675
2010	1.04	141055	3078	6830
2011	1.22	174001	2941	6931
2012	0.97	123684	2355	5768
2013	0.85	101295	2618	6296
2014	1.05	140914	2911	6346

Table 5.2.10.7.3.3. Hake in GSAs 9-11. F-at-age matrix obtained from XSA.

	F at age						
	0	**1**	**2**	**3**	**4**	**5**	**6+**
2006	1.13	1.66	1.56	0.93	0.74	0.91	0.91
2007	1.02	1.95	1.00	0.72	0.51	0.20	0.20
2008	0.99	1.79	0.97	0.66	0.84	0.99	0.99
2009	1.24	1.49	0.81	0.65	0.61	0.85	0.85
2010	0.78	1.62	1.10	0.72	0.73	0.68	0.68
2011	1.18	1.89	1.02	0.87	1.10	1.74	1.74
2012	0.57	1.80	1.02	0.61	0.46	0.49	0.49
2013	0.62	1.63	0.92	0.51	0.36	0.20	0.20
2014	0.79	1.88	1.18	0.82	0.32	0.32	0.32

5.2.10.8 Reference points

5.2.10.8.1 Methods

The FLBRP package allowed a Yield per recruit analysis and an estimate of some F-based Reference Points as F_{max} and $F_{0.1}$. Yield per Recruit computation was made using R project software and the FLR libraries. The fishing mortality rate corresponding to $F_{0.1}$ in the yield per recruit curve is considered here as a proxy of $F_{MSY.}$

5.2.10.8.2 Input data

The input parameters were the same used for the XSA stock assessment and its results.

5.2.10.8.3 Results

Table 5.2.10.8.3.1. Hake in GSAs 9-11. Main reference points defined with the Yield per recruit analysis.

refpt	harvest	Yield (t)	Recruitment (thousands)	SSB (t)	Biomass (t)
virgin	0.00	0	160880	186670	195760
msy	0.28	7407	160880	48506	55736
crash	28.63	1657	160880	0	1756
f0.1	0.20	7124	160880	69683	77356
fmax	0.28	7407	160880	48506	55736
spr.30	0.25	7368	160880	56002	63404

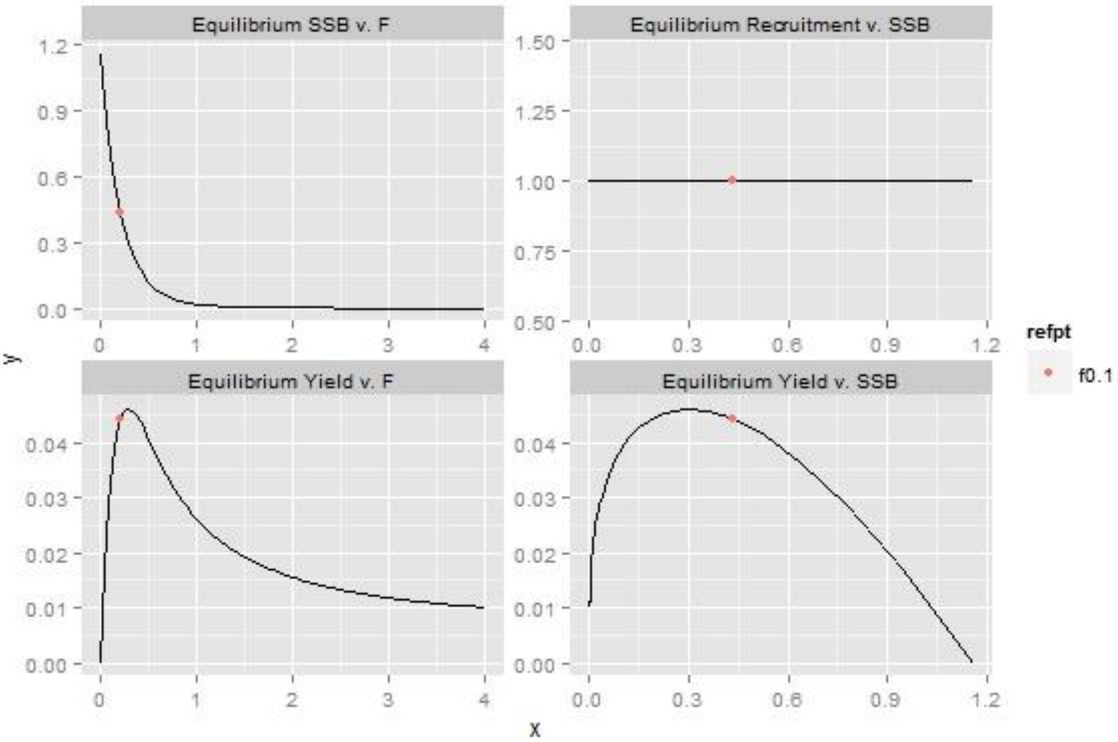


Figure 5.2.10.8.3.1. Hake in GSAs 9-11. Yield per recruit curve.

With the estimated value for $F_{0.1}$ of about 0.20, the current level of F of about 1.05 is higher, and hence, a status of overexploitation can be assumed.

5.2.10.9 Data quality

Data from DCF 2014 as submitted through the Official data call in 2015 were used. Problems in the data were due to the lack of size structure information for some of the fisheries in GSA 9 and GSA 11 (e.g. trammel net).

Discard data were missing for 2007 and 2008.

5.2.10.10 Short term predictions 2015-2017

5.2.10.10.1 Method

A deterministic short term prediction for the period 2015 to 2017 was performed using the FLR routines provided by JRC and based on the results of the XSA stock assessments performed during EWG 15-11.

5.2.10.10.2 Input parameters

The input parameters were the same used for the XSA stock assessment and its results. An average of the last three years has been used for weight at age, maturity at age and F at age.
Recruitment (age 0) has been estimated from the population results as the geometric mean of the last 3 years (120861 thousand individuals).

5.2.10.10.3 Results

Table 5.2.10.10.3.1. Hake in GSAs 9-11. Short term forecast in different F scenarios. Basis: F(2015) = mean (F_{bar} 1-4 2012-2014)= 0.96; R(2015) = geometric mean of the recruitment of the last 3 years; R = 120861 thousands; SSB(2014) = 2911 t, Catch (2014)= 3075 t.

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Rationale	Ffactor	Fbar	Catch 2015	Catch 2016	Catch 2017	SSB 2016	SSB 2017	Change SSB 2016-2017(%)	Change Catch 2014-2016(%)
Zero catch	0.00	0.00	3185	0	0	2739	8656	216.01	-100.00
High long term yield (F0.1)	0.21	0.20	3185	1029	2040	2739	6622	141.76	-66.52
Status quo	1.00	0.96	3185	3218	3233	2739	2755	0.57	4.66
Different Scenarios	0.10	0.10	3185	522	1151	2739	7613	177.94	-83.04
	0.20	0.19	3185	981	1964	2739	6716	145.20	-68.11
	0.30	0.29	3185	1386	2526	2739	5943	116.97	-54.93
	0.40	0.38	3185	1744	2899	2739	5275	92.59	-43.26
	0.50	0.48	3185	2063	3133	2739	4697	71.48	-32.90
	0.60	0.57	3185	2347	3265	2739	4195	53.17	-23.67
	0.70	0.67	3185	2601	3323	2739	3759	37.24	-15.41
	0.80	0.76	3185	2828	3327	2739	3379	23.35	-8.01
	0.90	0.86	3185	3033	3293	2739	3046	11.21	-1.35
	1.10	1.05	3185	3385	3156	2739	2498	-8.79	10.11
	1.20	1.15	3185	3538	3068	2739	2273	-17.03	15.06
	1.30	1.24	3185	3676	2974	2739	2073	-24.32	19.57
	1.40	1.34	3185	3803	2877	2739	1896	-30.78	23.69
	1.50	1.43	3185	3919	2780	2739	1739	-36.53	27.47
	1.60	1.53	3185	4026	2684	2739	1598	-41.65	30.95
	1.70	1.62	3185	4125	2590	2739	1473	-46.23	34.15
	1.80	1.72	3185	4216	2500	2739	1360	-50.33	37.12
	1.90	1.82	3185	4300	2414	2739	1259	-54.03	39.87
	2.00	1.91	3185	4379	2332	2739	1168	-57.36	42.42

5.2.10.11 Short term predictions 2015-2017 by fleet

5.2.10.11.1 Method

A deterministic short term prediction by fleet for the period 2015 to 2017 was performed using the FLR routines provided by JRC and based on the results of the XSA stock assessments performed during EWG 15-11.

5.2.10.11.2 Input parameters

The same parameters used in the short term by single fleet were used.

5.2.10.11.3 Results

Table 5.2.10.11.3.1. Hake in GSAs 9-11. Short term forecast by fleet and GSA.

fleet	year	catches	partial_f	fleet	year	catches	partial_f
trawl9	2015	1089.5	0.31	gtr10	2015	436.8	0.21
trawl9	2016	356.0	0.07	gtr10	2016	150.7	0.04
trawl9	2017	620.0	0.07	gtr10	2017	344.4	0.04
trawl10	2015	552.7	0.12	gtr11	2015	28.4	0.00
trawl10	2016	179.8	0.03	gtr11	2016	9.5	0.00
trawl10	2017	309.3	0.03	gtr11	2017	22.9	0.00
trawl11	2015	483.5	0.07	gns9	2015	297.5	0.10
trawl11	2016	156.0	0.01	gns9	2016	93.4	0.02
trawl11	2017	309.2	0.01	gns9	2017	240.3	0.02
gtr9	2015	79.7	0.03	lls10	2015	217.3	0.11
gtr9	2016	26.4	0.01	lls10	2016	55.4	0.02
gtr9	2017	67.6	0.01	lls10	2017	122.9	0.02

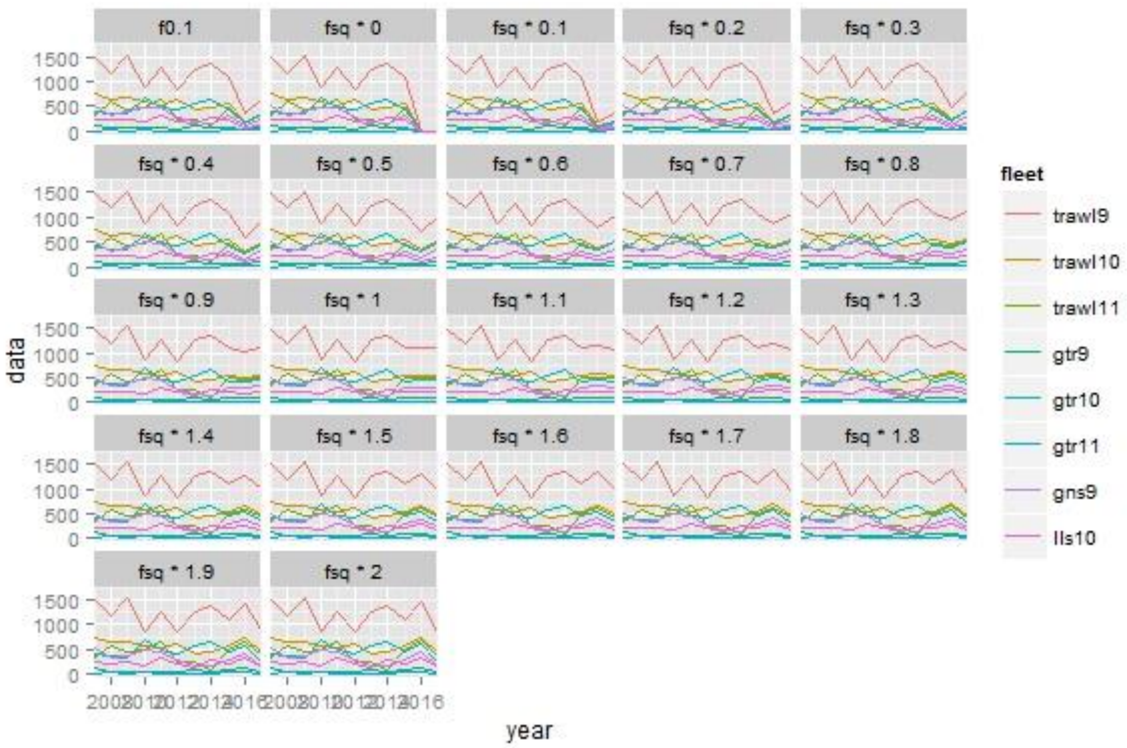


Figure 5.2.10.11.3.1. Hake in GSAs 9-11. Short term forecast by fleet and GSA.

5.2.10.12 Medium term predictions

5.2.10.12.1 Method

Medium term forecasts were not conducted because no meaningful stock-recruitment relationship was estimated.

5.2.10.13 Stock advice

The current F (1.05) is larger than $F_{0.1}$ (0.20), chosen as proxy of F_{MSY} and as the exploitation reference point consistent with high long term yields, which indicates that European hake in GSAs 9-11 is being fished above F_{MSY}. Catches of European hake in 2016 consistent with F_{MSY} should not exceed 1029 tonnes.

5.2.10.14 Management strategy evaluation

A Management Strategy Evaluation was run to evaluate if the MSY ranges were precautionary. The F_{MSY} ranges were derived using the formula provided by STECF EWG 15-09. F ranges results were F_{upper}=0.28 and F_{lower}=0.14. B_{lim} was estimated as B_{loss}=2355 (t). The following figure shows the results of the MSE.

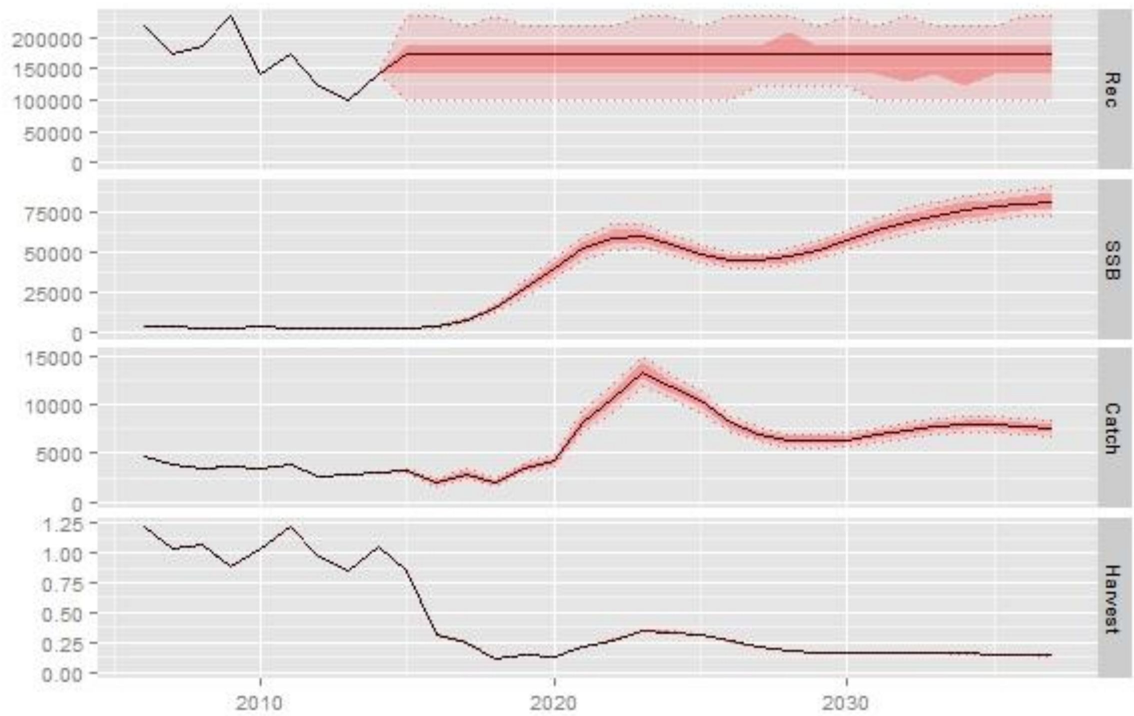


Figure 5.2.10.14.1. Hake in GSAs 9-11. Management Strategy Evaluation.

The probability of SSB to fall below B_{lim} at F = F_{upper} is equal to 0.

5.2.11 STOCK ASSESSMENT OF GIANT RED SHRIMP IN GSA 9

5.2.11.1 Stock Identification

Due to a lack of enough information about the structure of giant red shrimp (Aristaeomorpha foliacea) in the western Mediterranean, this stock was assumed to be confined within the GSA 9 boundaries.

The giant red shrimp is mainly to be found in the epibathyal and mesobathyal waters of the western Mediterranean

In the GSA 9, A. foliacea is more abundant in the Central Tyrrhenian (Ardizzone et al., 1994) while lower concentrations are present in the Northern Tyrrhenian (Anonymous, 2008) and in the Ligurian Sea, where this species considerably decrease over time (Orsi Relini and Relini, 1985).

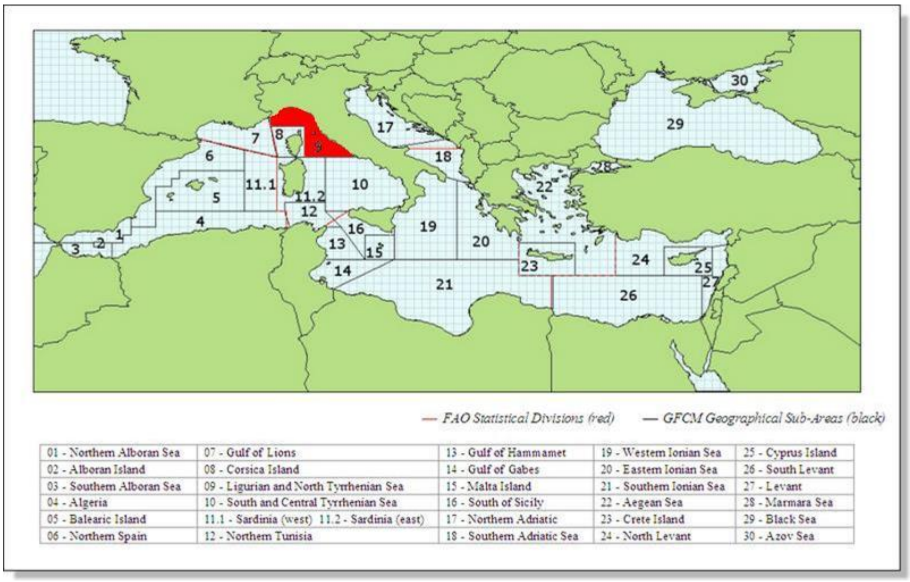


Figure 5.2.11.1.1 Limit of Geographical Sub-Areas (GSAs).

5.2.11.2 Growth

In general the length-frequency distributions have a polymodal pattern, with 4-5 components for females (adult modes of are less defined) and 2 components for males (Leonardi and Ardizzone, 1994).

Analysis on the size structure histograms relating to the central-southern Tyrrhenian shown, particularly in spring, a highly differentiated structure. Both males and females are present in the young classes, with a certain prevalence of the latter. In the range from 32 to 38 mm a mode composed solely of males appears, and over 42 mm distribution is composed solely of females. This characteristic highlights a different mode of growth of the two sexes.

In the last decade different set of growth parameters were estimated for *A. foliacea* in the Tyrrhenian sea (Leonardi and Ardizzone, 1994) but in this analysis were used the set of parameters obtained in the REDS project (FISH/2004/03-32) for the male and from the analysis of size distributions data gathered during GRUND surveys carried out in the GSA9 for female.

The feeding of red shrimps (*A. foliacea, A. antennatus*), studied by Brian (1931) in the Ligurian sea, indicated the euryphagous feeding behaviour of the two species which alternate phases of active hunting with phases in which they consume small benthonic prey (Lagardere, 1972).

Red shrimps obtain food from an area of the sea which extends vertically for several hundred metres (Orsi Relini, 1984). Their diet includes both organisms from the muddy bed and herbivorous organisms which use surface plankton. The former include *Ophiocten abyssicolum*, which is probably useful to the shrimps as a source of calcium with which to build their exoskeleton. The latter include the shrimps of the genuses *Pasiphaea, Sergestes* and the *Eufasiacean Meganyctiphanes norvegica*. In the night these prey move up to the surface waters for feeding needs, while during the day they remain near the sea bed (Orsi Relini and Wurtz, 1977). *A. foliacea* is quite voracious, possibly due to needs imposed by the rapid maturing of the eggs, and is also capable of attacking shrimps of the *Plesionika* genus which can even measure up to 2/3 the size of the aggressor. Food characteristics of this type could entail a greater vulnerability of this species in an altered marine ecosystem (Orsi Relini, 1984).

5.2.11.3 Maturity

The reproduction period of *A. foliacea* lasts from May to September, with a peak in the summer (July-August). Four stages of ovary maturity were described by using a macroscopic colorimetric scale (Levi and Vacchi, 1989) and the mature ovaries can be recognised because initially they are grey coloured, with increasingly dark shades until they become black, due to the presence of carotenoproteins (Orsi Relini and Semeria, 1983).

Mature females are concentrated in the mesobathyal bottoms from spring to autumn. The fertility of *A. foliacea* has been estimated as being equal approximately to 1/3 of the fertility of *A. antennatus* (Orsi Relini and Semeria, 1983). Analyses of the ultrastructure of the ovary indicated cells arranged in a line. *A. foliacea* has a dome-shaped thelycum and characteristics which can be compared to those of decapod crustaceans with a closed thelycum, with coupling coinciding with the moult phases (Orsi Relini L., in Anonymous, 1997). In males the spermatophore originates by passing through the deferent duct, and the spermatic mass is contained in a chamber with "wings" at the edge that serve a protective purpose.

In the Northern Tyrrhenian (Righini and Abella, 1994) the smallest female with spermatophore had a carapace length (CL) of 40 mm. In the Central Tyrrhenian (southern Tuscan Archipelago), the smallest mature female measured 28 mm (CL), and the smallest mature male 29 mm (CL) (Mori et al., 1994). Mature males were observed all year round. In the Central Tyrrhenian (Latium), the size at first maturity is 30-31 mm for males and the smallest female with spermatophore measured 33 mm (Leonardi and Ardizzone, 1994).

Female maturity ogive (Fig. 5.2.11.3.1) was obtained using commercial data gathered during in the 2011 DCF grouping as mature, individuals belonging to the maturity stage 2b (according to the MEDITS maturity scale) onwards. The estimated size at first maturity resulted about 34mm CL.

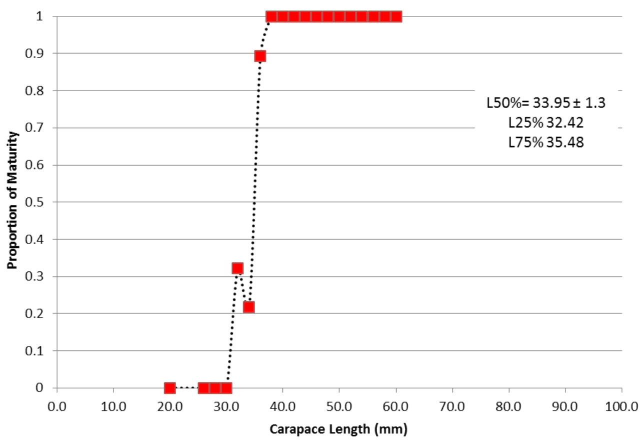


Figure 5.2.11.3.1 Giant red shrimp in the GSA 9. Maturity ogive and proportion of mature female.

Biological data gathered during MEDITS surveys (1994-2012) was used to estimate a sex ratio vector (Fig. 5.2.11.3.2). Smaller sizes were more represented by females, instead between 33 to 39mm CL males become predominant and from 40mm carapace length (CL) the proportion was totally to advantage of female.

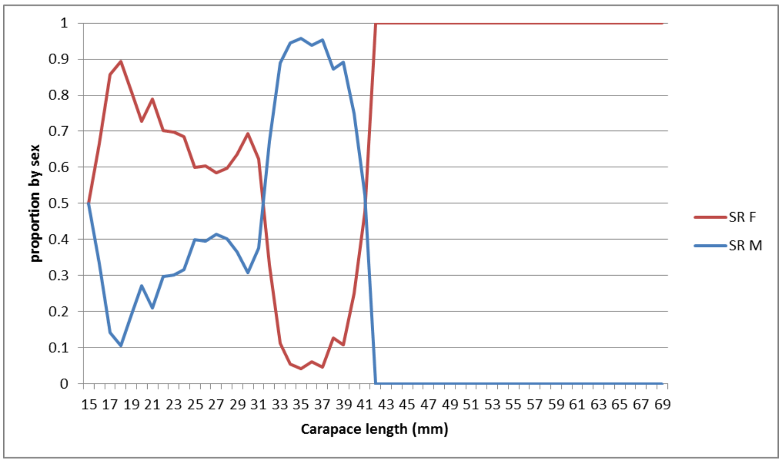


Figure 5.2.11.3.2. Giant red shrimp in the GSA 9. Sex ratio by length.

5.2.11.4 Natural mortality

Natural mortality vector was the same used in the previous assessment and estimated using PRODBIOM (Abella et al., 1997) and it is shown in Table 5.2.11.4.1.

Table 5.2.11.4.1. Giant red shrimp in the GSA 9. Natural mortality.

Age	M
0	1.28
1	0.58
2	0.44
3	0.38
4+	0.34

5.2.11.5 Fisheries

5.2.11.5.1 General description of the fisheries

In the GSA 9 the giant red shrimp, *Aristaeomorpha foliacea*, is one of the most important target species of the otter bottom trawl fishery carried out on the muddy bottoms of the upper and middle slope. The main fishing grounds are located in the central and southern part of the GSA9 (eastern Ligurian Sea, northern and central Tyrrhenian Sea). The species is mainly exploited by the trawl fleets of Porto S. Stefano and Porto Ercole, in Tuscany, and Fiumicino, Anzio, and Terracina, in Latium.

As an example, Fig. 5.2.11.5.1.1 shows the landings per unit of effort (LPUE, kg/vessel/day) by the Porto S. Stefano trawl fleet, which is one of the fleets historically targeting the giant red shrimp in the GSA 09. Seasonality fluctuations are a proper characteristic of the landings of this species, as shown by the LPUE produced by the fleet of Porto S. Stefano in the period 1991-2010. The highest catch rates are observed in late spring-summer; even though peaks due to recruitment and other biological aspects do exist, the main factor affecting this seasonal pattern is the spatial distribution of the fishing effort. In fact, the fishing grounds where the giant red shrimp is targeted are distant from the coast, thus this fishery is strongly influenced by the weather conditions (Sartor et al., 2003; Sbrana et al., 2003).

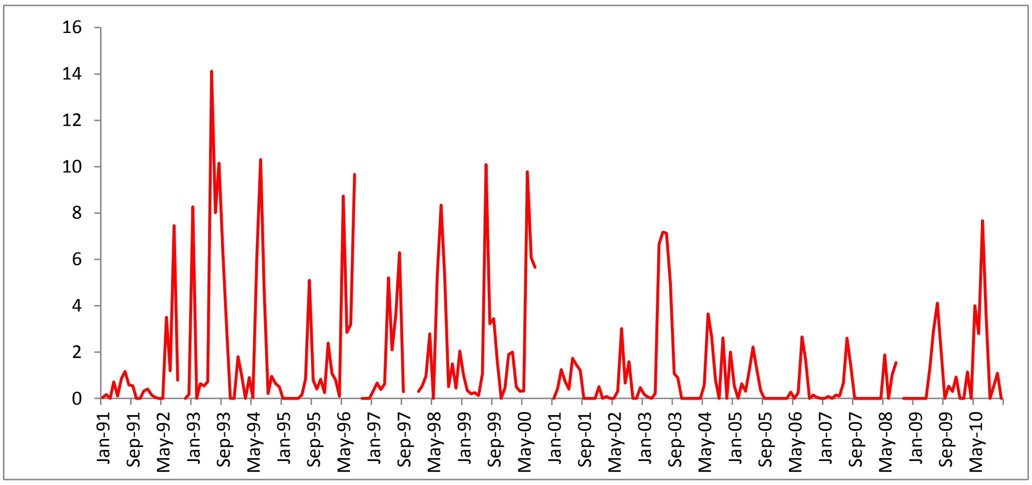


Figure 5.2.11.5.1. Giant red shrimp in the GSA 9. LPUE of Porto Santo Stefano from January 1991 to May 2010.

5.2.11.5.2 Management regulations applicable in 2015

EC regulation 1967/2006 don't provide for a minimum length size for this species. Italian national law provided in the last years a fishing ban of a month which, for the Ligurian fleet, is enforced after the summer fishing season.

5.2.11.5.3 Landings

Total landings of giant red shrimps decreased from about 60 tons in 2006 to 24 tons in 2007, in 2008 and 2009 landings remain quite stable (around 30-40 tons) and then an increasing up to about 70 tons was observed in 2011 followed by a new decrease in the 2012 (Fig. 6.6.2.3.1.1; Tab. 6.6.2.3.1.1). The landings are entirely taken by OTB fleets. Landings data were observed also in 2008 for Gillnet (about 700kg) and in 2012 for trammel (about 1.2 tons). Seasonality fluctuations are a proper characteristic of the landings of this species, as shown by the LPUE produced by the fleet of Santa Stefano in the period 1991-2010 (Fig. 6.6.2.1.1).

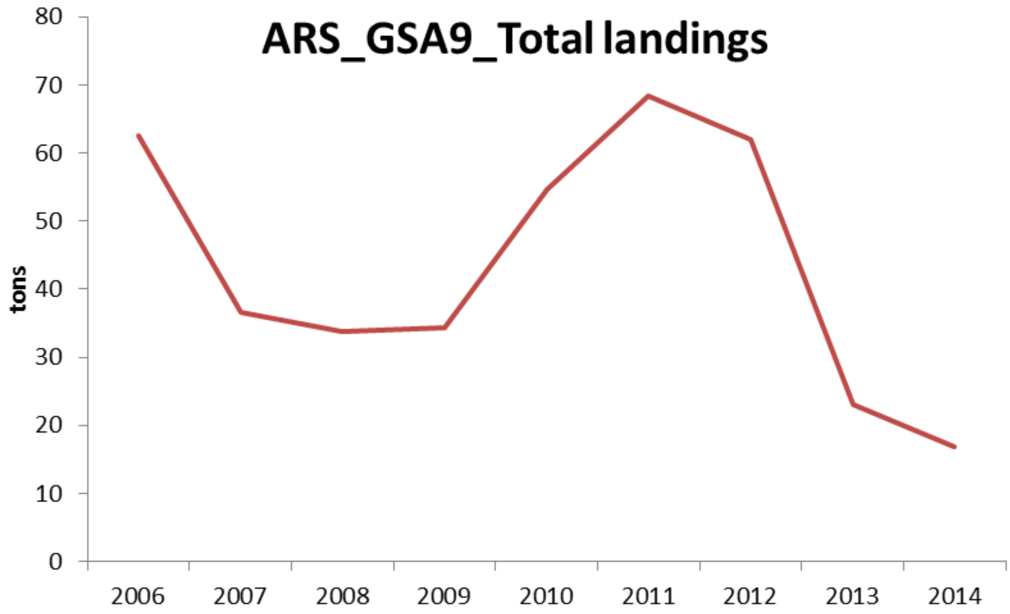


Figure 5.2.11.5.4.1. Giant red shrimp in the GSA 9. Total landings (tons) 2006-2014.

Table 5.2.11.5.4.1. Giant red shrimp in the GSA 9. Annual landings (tons) by fishing technique as provided through the official DCF data call 2015.

YEAR	GEAR	FISHERY	LANDINGS
2006	OTB	MDDWSP	62.60995
2007	OTB	MDDWSP	36.65032
2008	OTB	DWSP	8.73874
2008	OTB	MDDWSP	24.38813
2008	GNS	DEMF	0.69851
2009	OTB	MDDWSP	34.29335
2010	OTB	DWSP	17.70095
2010	OTB	MDDWSP	36.85313
2011	OTB	DWSP	17.62392
2011	OTB	MDDWSP	50.80815
2012	GTR	DEMSP	1.24131
2012	OTB	DWSP	8.34909
2012	OTB	MDDWSP	52.37722
2013	OTB	DWSP	2.5635
2013	OTB	MDDWSP	20.51493
2014	OTB	DWSP	0.6136
2014	OTB	MDDWSP	16.20556

5.2.11.5.4 Discards

Discards data were available only 2012 and resulted almost nil (0.45kg).

5.2.11.5.5 Fishing effort

The trends in fishing effort by fishing technique are listed in Tab.5.2.11.5.6.1 From 2004 until now the effort slightly decreased. (Fig. 5.2.11.5.6.1).

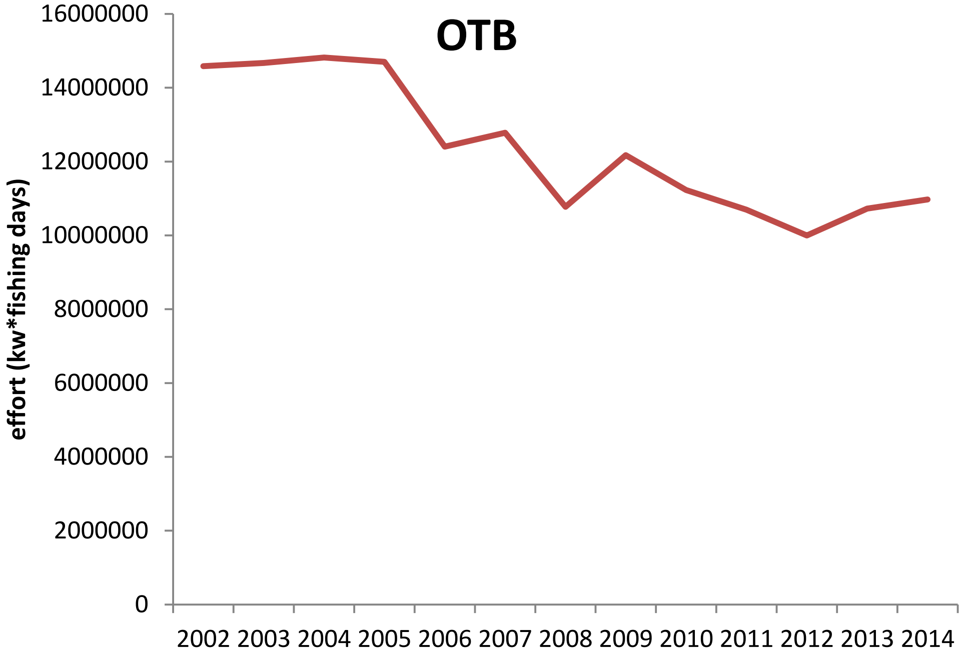


Figure 5.2.11.5.6.1. Giant red shrimp in the GSA 9. Trends in annual trawlers fishing effort as nominal effort (kw*days) deployed in GSA 9 from 2004 to 2014.

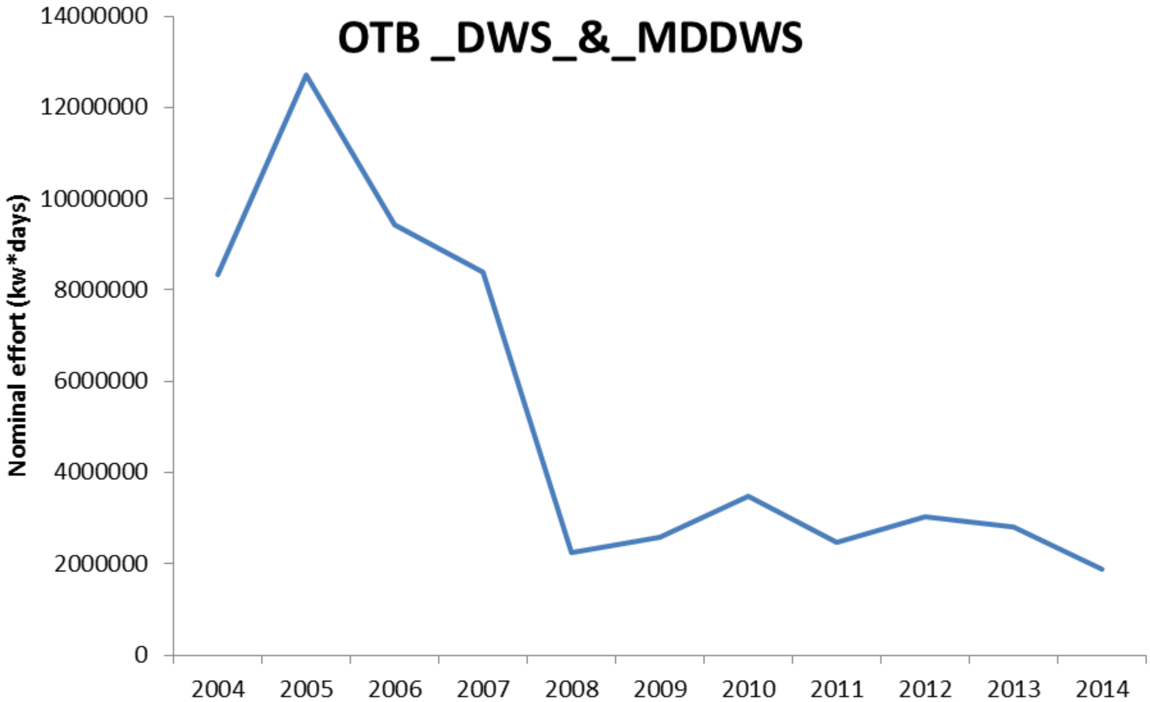


Figure 5.2.11.5.6.2. Giant red shrimp in the GSA 9. Trends in annual deeper trawlers fishing effort as nominal effort (kw*days) deployed in GSA 9 from 2004 to 2014.

Table 5.2.11.5.6.1. Giant red shrimp in the GSA 9. Trends in annual fishing effort as nominal effort (kW*days) deployed in GSA0 9 from 2004 to 2014 as reported through the DCF official data call.

				FISHERY			
Country	Area	Gear	Year	DEMSP	DWSP	MDDWSP	OTB Totale
ITA	9	OTB	2004	6498842	40824	8280673	14820339
ITA	9	OTB	2005	1990472	-	12710127	14700599
ITA	9	OTB	2006	2972712	-	9432075	12404787
ITA	9	OTB	2007	4378056	-	8404088	12782144
ITA	9	OTB	2008	8533729	208500	2033653	10775882
ITA	9	OTB	2009	9585297	504214	2083240	12172751
ITA	9	OTB	2010	7751226	712502	2764273	11228001
ITA	9	OTB	2011	8223517	626629	1846020	10696166
ITA	9	OTB	2012	6956565	725731	2315611	9997907
ITA	9	OTB	2013	7910486	1320396	1493999	10724881
ITA	9	OTB	2014	9088034	658396	1229266	10975696

5.2.11.6 Scientific surveys
5.2.11.6.1 Survey #1 (MEDITS)
5.2.11.6.1.1 Methods

MEDITS surveys were carried out from late spring to mid summer and the sampling design was always random depth-stratified in respect on five depth strata: 10–50, 50–100, 100–200, 200–500 and 500–800 m. GOC 73 trawl net was used during the surveys. The cod-end mesh size was of 20 mm in MEDITS surveys. Hauls duration was of 0.5 h for the hauls carried out on the shelf (10–200m depth) and 1 h for the hauls carried out on the slope (200–800m depth) fishing grounds. Details of sampling protocol can be found in Bertrand *et al*. (2002).
Based on the DCR data call, abundance and biomass indices were recalculated. In GSA9 the following number of hauls was reported per depth stratum (Tab. 5.2.11.6.1.1.1).

Table 5.2.11.6.1.1.1 Number of hauls per year and depth stratum in GSA9, 1994-2014.

Stratum	*GSA09_010-050*	*GSA09_050-100*	*GSA09_100-200*	*GSA09_200-500*	*GSA09_500-800*	Total
1994	21	21	38	40	33	153
1995	20	21	39	40	33	153
1996	20	20	40	40	33	153
1997	20	22	38	41	32	153
1998	21	20	39	40	33	153
1999	20	21	39	41	32	153
2000	20	22	38	42	31	153
2001	20	22	38	42	31	153
2002	15	17	30	33	25	120

2003	15	17	30	31	27	120
2004	15	17	30	34	24	120
2005	16	16	31	34	23	120
2006	15	18	29	35	23	120
2007	15	18	29	35	23	120
2008	16	16	31	34	23	120
2009	16	16	31	34	23	120
2010	15	19	29	34	23	120
2011	15	18	30	33	24	120
2012	15	17	31	35	22	120
2013	16	17	30	35	22	120
2014	15	19	29	36	21	120

Data were assigned to strata based upon the shooting position and average depth (between shooting and hauling depth). Catches by haul were standardized to swept area. The abundance and biomass indices by GSA were calculated through stratified means (Cochran, 1953; Saville, 1977). This implies weighting of the average values of the individual standardized catches and the variation of each stratum by the respective stratum areas in each GSA:

$Yst = \Sigma (Yi*Ai) / A$
$V(Yst) = \Sigma (Ai^2 * si^2 / ni) / A^2$

Where:

A=total survey area
Ai=area of the i-th stratum
si=standard deviation of the i-th stratum
ni=number of valid hauls of the i-th stratum
n=number of hauls in the GSA
Yi=mean of the i-th stratum
Yst=stratified mean abundance
V(Yst)=variance of the stratified mean
The variation of the stratified mean is then expressed as standard deviation:
Confidence interval = Yst ± V(Yst)

Length distributions represented an aggregation (sum) of all standardized length frequencies (subsamples raised to standardized haul abundance per square kilometers) over the stations of each stratum.

5.2.11.6.1.2 Geographical distribution

The stock is more abundant in the southern part of the GSA (Tyrrhenian Sea) as showed in Figure 5.2.11.6.1.2.1.

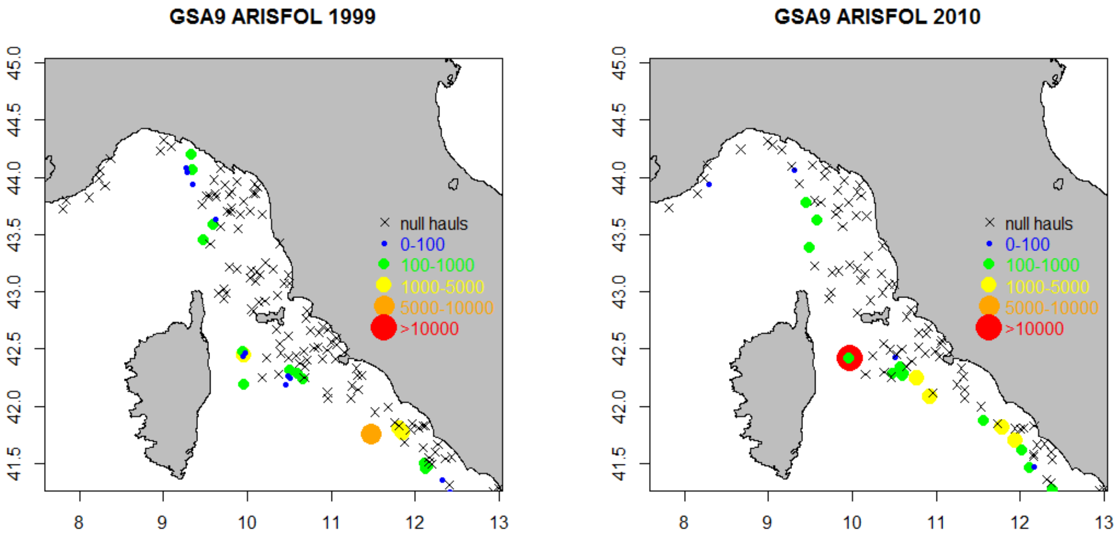


Figure 5.2.11.6.1.2.1. Giant red shrimp in the GSA 9. Abundance by haul obtained in two different years during MEDITS survey.

5.2.11.6.1.3 Trends in abundance and biomass

Fishery independent information regarding the state of the giant red shrimp in GSA 9 was derived from the international survey MEDITS. The estimated abundance and biomass indices do not reveal a clear trend. In the period analyzed (2006-2014) indices showed a remarkable increase in 2010 both in terms of biomass and abundance indices (Fig. 5.2.11.6.1.3).

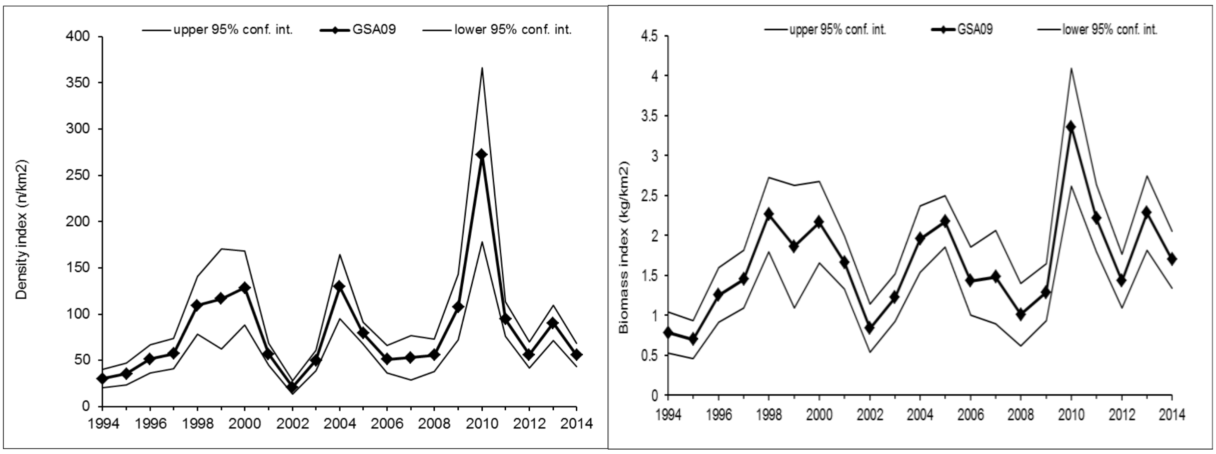


Figure 5.2.11.6.1.3. Giant red shrimp in the GSA 9. MEDITS trends in biomass and density from 1994 to 2014.

5.2.11.6.1.4 Trends in abundance by length or age

The following Figures 5.2.11.6.1.4.1-2 display the stratified abundance indices of GSA 9 in 1994-2014 while the Figures 5.2.11.6.1.4.3-4 the related boxplot.

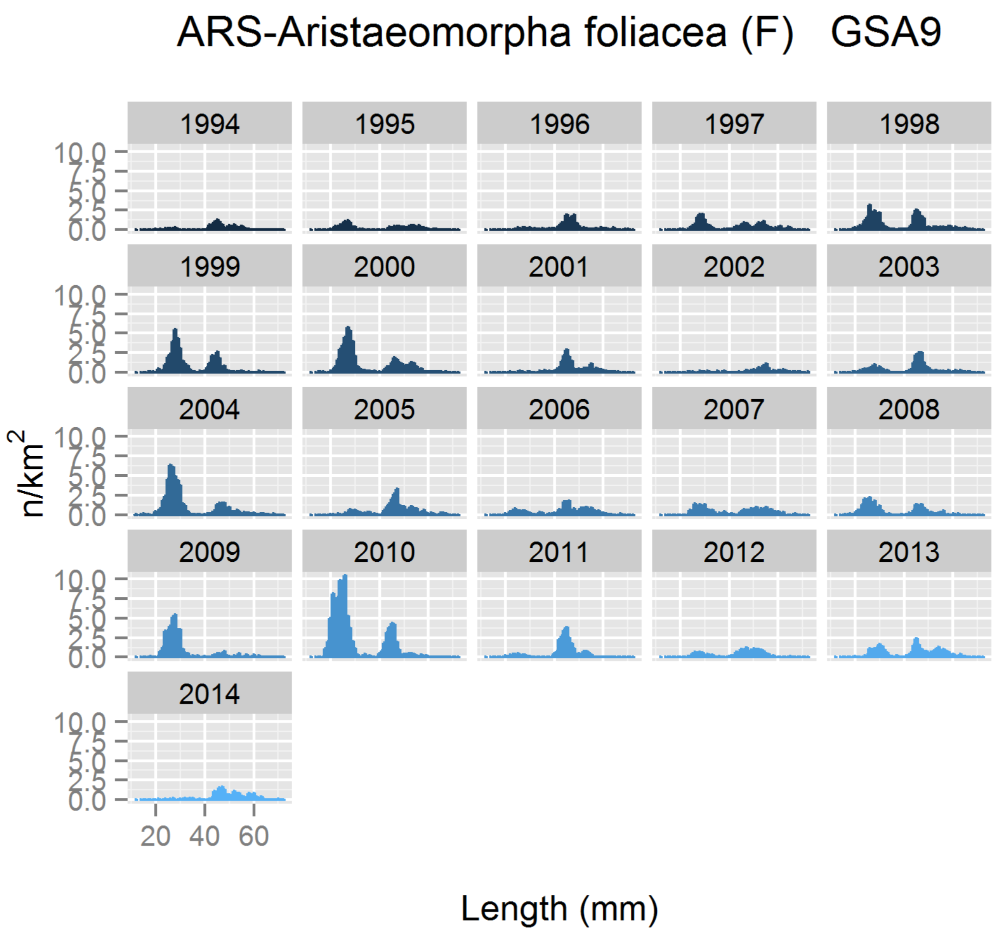


Figure 5.2.11.6.1.4.1. Giant red shrimp in GSA 9. Female stratified abundance indices , 1994-2014.

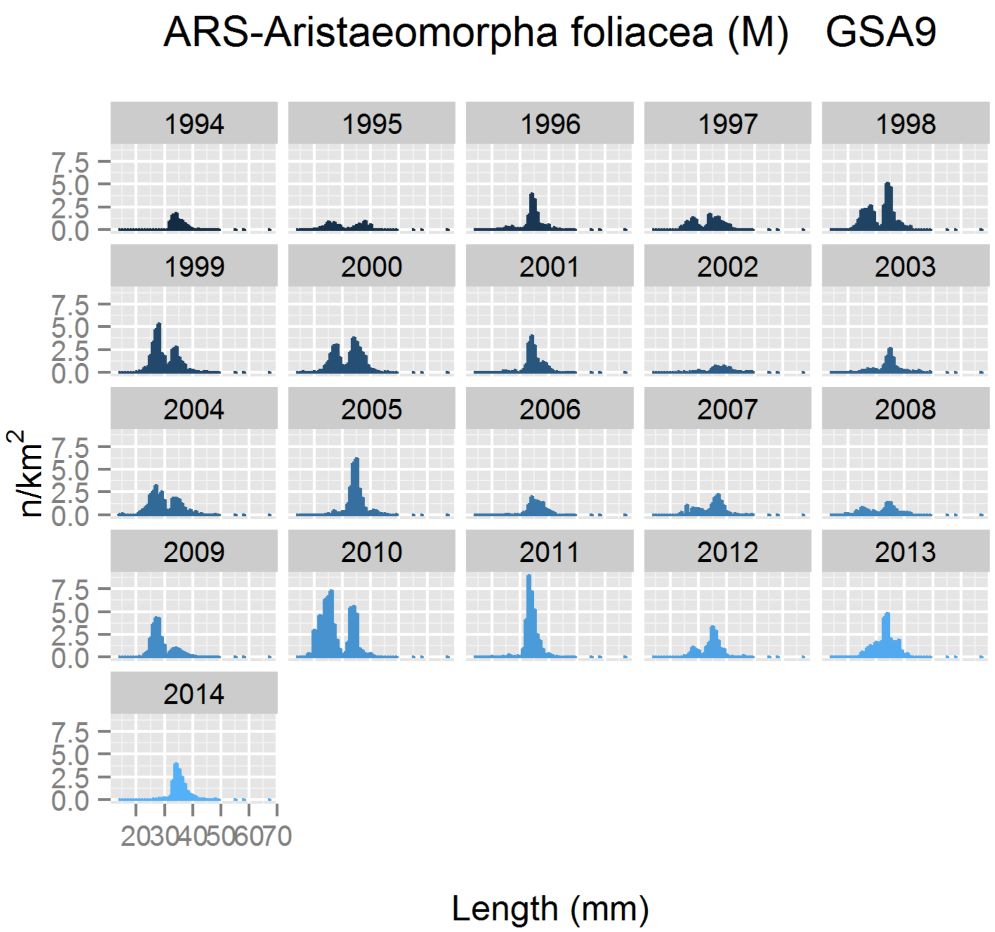


Figure 5.2.11.6.1.4.2. Giant red shrimp in GSA 9. Male stratified abundance indices , 1994-2014.

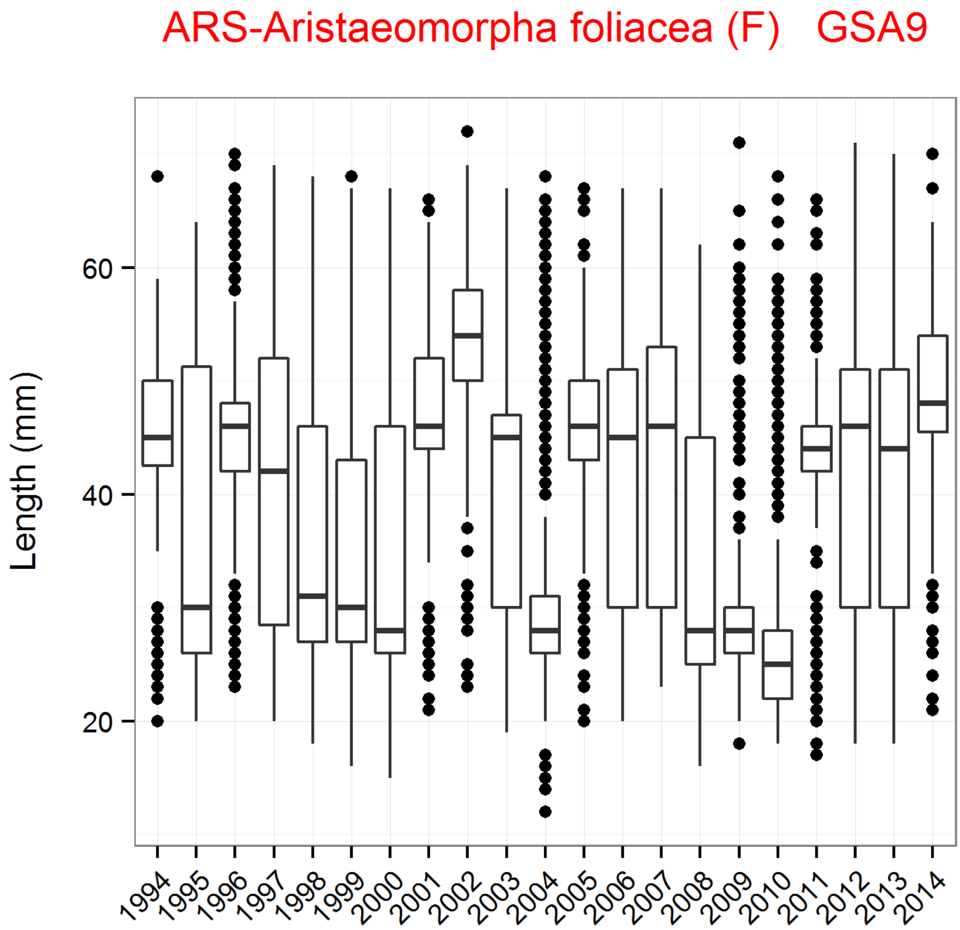


Figure 5.2.11.6.1.4.3. Giant red shrimp in GSA 9. Boxplot of the female stratified abundance indices, 1994-2014.

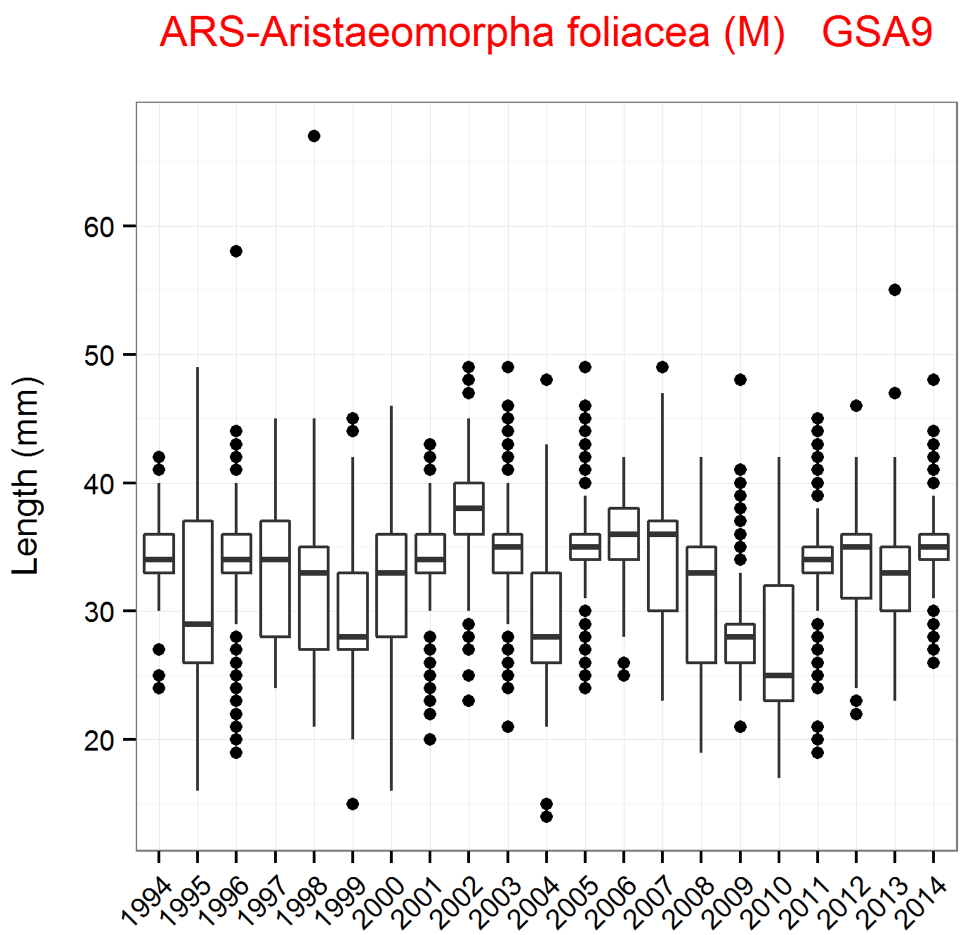


Figure 5.2.11.6.1.4.4. Giant red shrimp in GSA 9. Boxplot of the male stratified abundance indices, 1994-2014.

5.2.11.7 Stock Assessment

5.2.11.7.1 Methods

The assessment of giant red shrimp in the GSA9 has been performed during EWG 11-15 using XSA approach.

5.2.11.7.2 Input data

Data from DCF provided at EWG-11-15 contained information on giant red shrimp landings and the respective age structure for 2006-2014 were used. Since in the 2008 and 2012 were observed landing for GNS and GTR fisheries respectively and since there were no catch at age data, the catch at age data for OTB were raised to the total amount of landings for those years.

A vector of natural mortality value by age was obtained using PRODBIOM (Abella et al., 1997). MEDITS survey indices used for tuning were obtained by sex and then summed up.

Catches in numbers and weight were consistent with total landings and so, no rescaling using Sum Of Product correction (SOP) was carried out.

In figure 5.2.11.7.2.1-2 are showed catches in numbers by age from commercial and survey data.

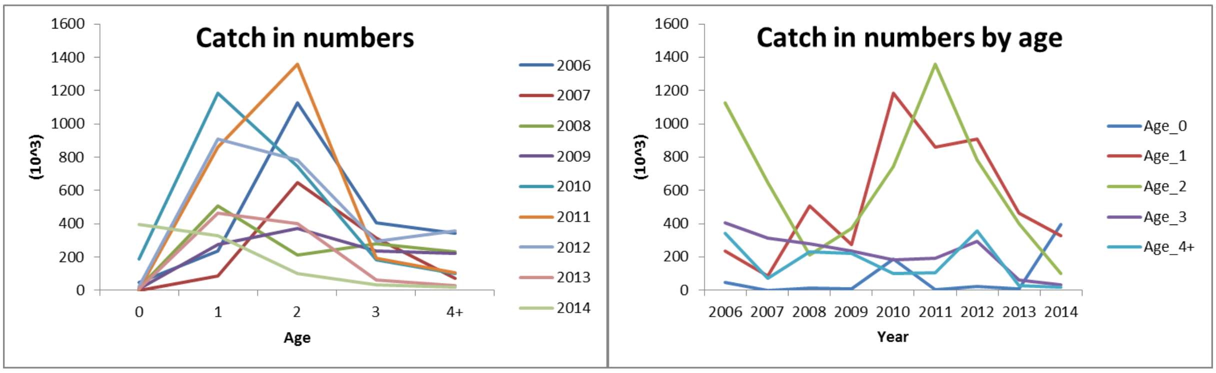


Figure 5.2.11.7.2.1. Giant red shrimp in GSA 9. Catch in numbers by age and year used in the XSA.

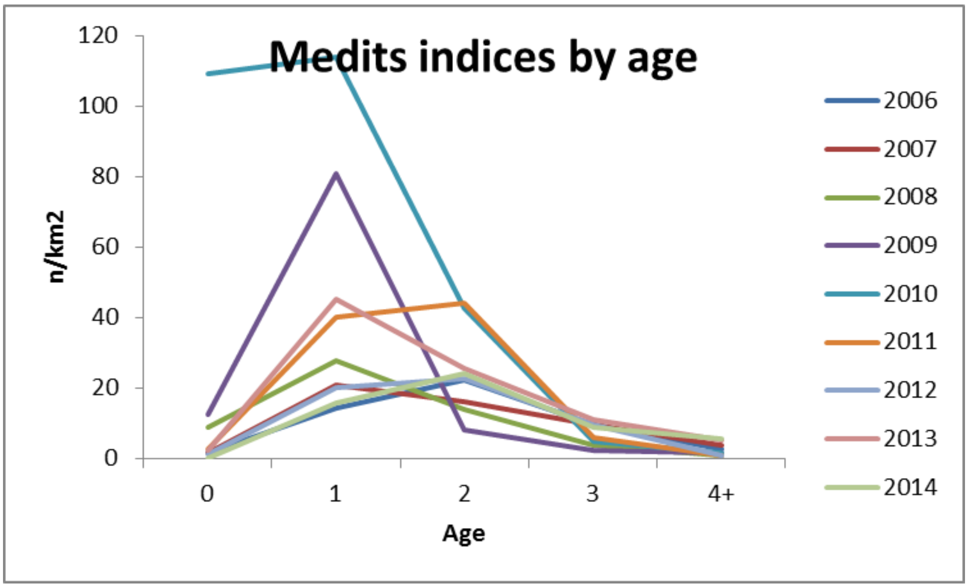


Figure 5.2.11.7.2.2. Giant red shrimp in GSA 9. Catch in numbers by age and year obtained in the Medits survey and used in the XSA as tuning data.

The other inputs are reported in the tables below:

Table 5.2.11.7.2.1. Giant red shrimp in GSA 9. Catch in numbers by age and year used in XSA.

Catch in numbers (thousands)	0	1	2	3	4+
2006	49	235	1128	405	342
2007	0	88	646	313	70
2008	15	507	213	278	228
2009	8	275	373	237	219
2010	185	1186	741	183	102
2011	1	858	1360	190	107
2012	23	909	783	295	355
2013	7	464	400	64	28
2014	397	326	102	32	18

Table 5.2.11.7.2.2. Giant red shrimp in GSA 9. Mean weights at age used in the XSA (both in catch and stock).

Weight at age (kg)	0	1	2	3	4+
2006	0.006	0.020	0.026	0.036	0.039
2007	0.008	0.020	0.029	0.040	0.055
2008	0.010	0.014	0.030	0.042	0.038
2009	0.008	0.014	0.031	0.043	0.039
2010	0.008	0.014	0.031	0.046	0.046
2011	0.007	0.017	0.030	0.044	0.042
2012	0.009	0.016	0.027	0.040	0.040
2013	0.009	0.016	0.028	0.039	0.053
2014	0.015	0.016	0.028	0.047	0.062

Table 5.2.11.7.2.3. Giant red shrimp in GSA 9. Indices from MEDITS survey used in XSA.

Survey indices (n/km^2)	0	1	2	3	4+
2006	1.84	14.51	22.23	9.51	2.76
2007	1.57	21.10	16.12	9.72	3.97
2008	8.89	27.73	14.05	3.76	1.06
2009	12.64	80.73	8.15	2.42	1.55
2010	109.15	113.75	42.55	4.84	1.53
2011	2.78	40.19	44.07	5.99	1.00
2012	1.40	20.27	22.90	9.79	0.92
2013	2.39	45.42	25.77	11.19	5.28
2014	0.36	15.80	24.32	8.90	5.70

Table 5.2.11.7.2.4. Giant red shrimp in GSA 9. Proportion of matures ate age used in XSA.

Maturity				
Age0	Age1	Age2	Age3	Age4+
0	0.6	1	1	1

Table 5.2.11.7.2.5. Giant red shrimp in GSA 9. Natural mortality at age used in XSA.

Natural mortality				
Age0	Age1	Age2	Age3	Age4+
1.28	0.58	0.44	0.38	0.34

Table 5.2.11.7.2.6. Giant red shrimp in GSA 9. Growth and length weight relationships parameters used in PRODBIOM.

	Female	Male
Linf	72	42.7
K	0.4	0.77

t0	0	-0.27
a	0.004	0.003
b	2.357	2.434

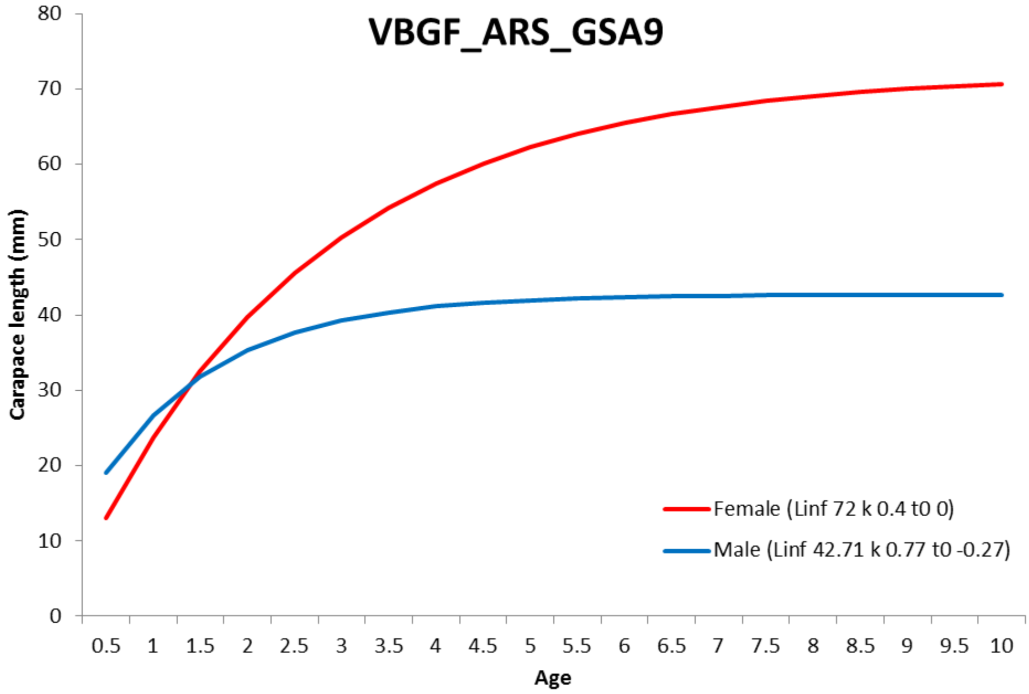


Figure 5.2.11.7.2.3. Giant red shrimp in GSA 9.Growth function for female and male.

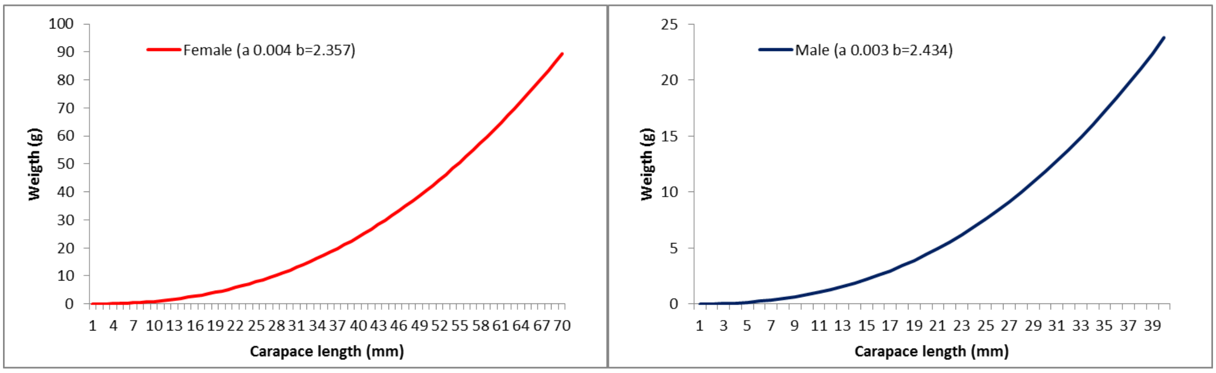


Figure 5.2.11.7.2.4. Giant red shrimp in GSA 9. Length weight relationship for female and male.

5.2.11.7.3 Results

XSA was run using different shrinkage values (Sh1.0, Sh1.5, Sh2.0) and two different qage values (2,3). As showed by Figure 5.2.11.7.3.1, the different settings produced similar estimates of recruitment and SSB.

Comparison of different shrinkage values and relative residuals diagnostics.

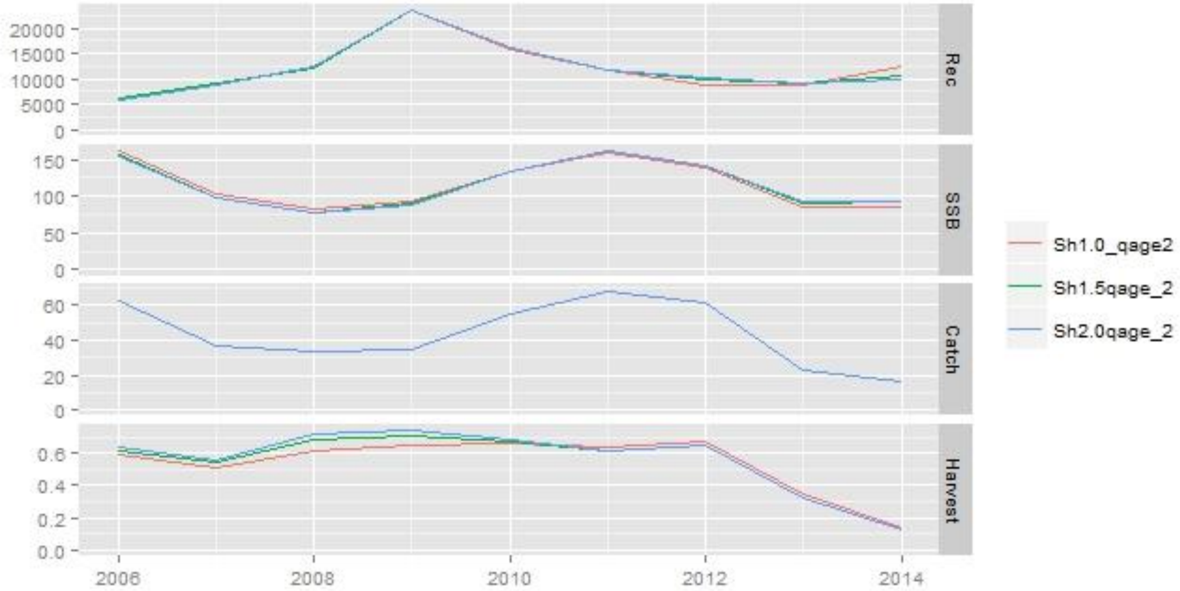
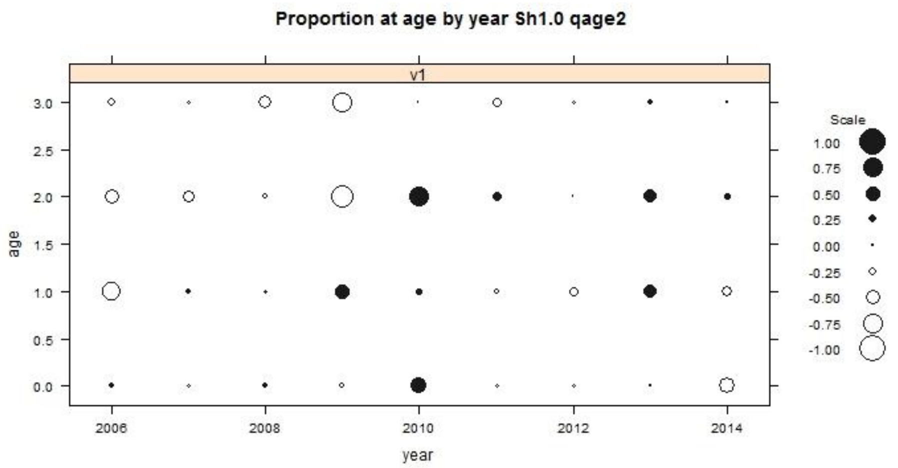


Figure 5.2.11.7.3.1. Giant red shrimp in GSA 9. XSA outputs for different shrinkage scenario.



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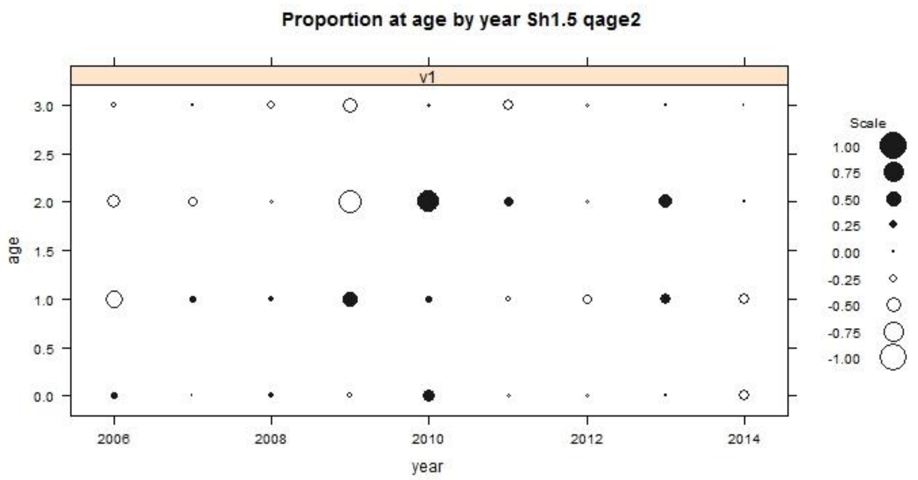


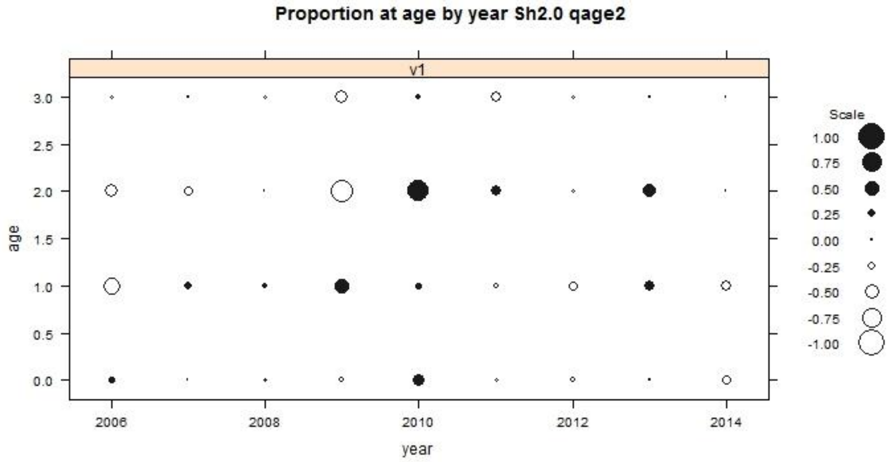


Figure 5.2.11.7.3.2. Giant red shrimp in GSA 9. Log residuals for the tuning fleet.

Model with 1.5 shrinkage was adopted and a new run was made with two different values of qage (2,3).

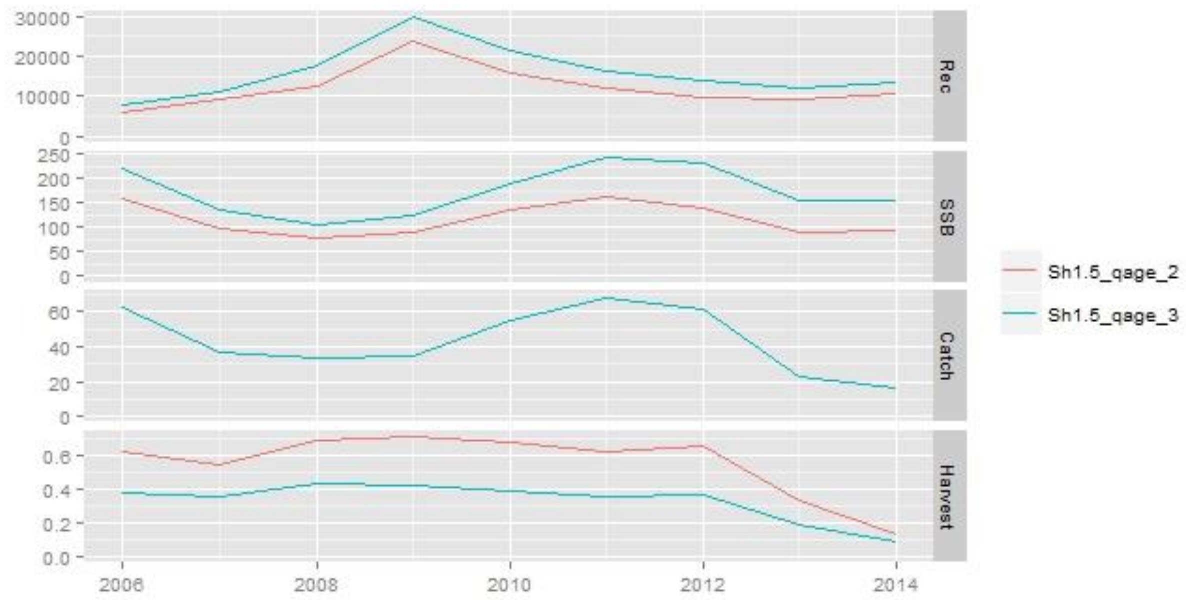


Figure 5.2.11.7.3.3. Giant red shrimp in GSA 9. XSA outputs for different qage scenario.

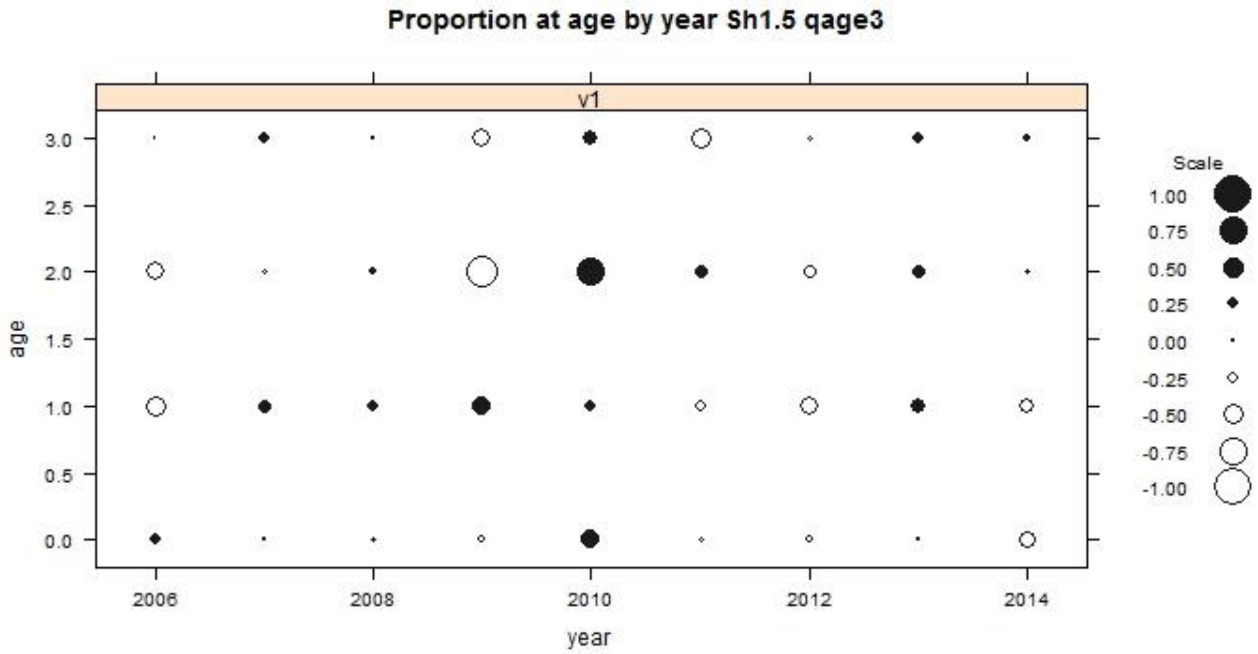


Figure 5.2.11.7.3.4. Giant red shrimp in GSA 9. Log residuals for the tuning fleet with different qage scenario.

Model with 1.5 shrinkage and qage2 was adopted as final model based on the analysis of residual distributions. Residuals from tuning fleets (MEDITS) per age and year were relatively low, ranging from 1 to - 1, and did not show any trend with time.

Moreover a retrospective analysis was conducted on recruitment, mean F and SSB (Figure 5.2.11.7.3.5) to ensure the robustness of the final estimates. The retrospective series indicate good agreement between years in the assessment results, with no systematic bias.

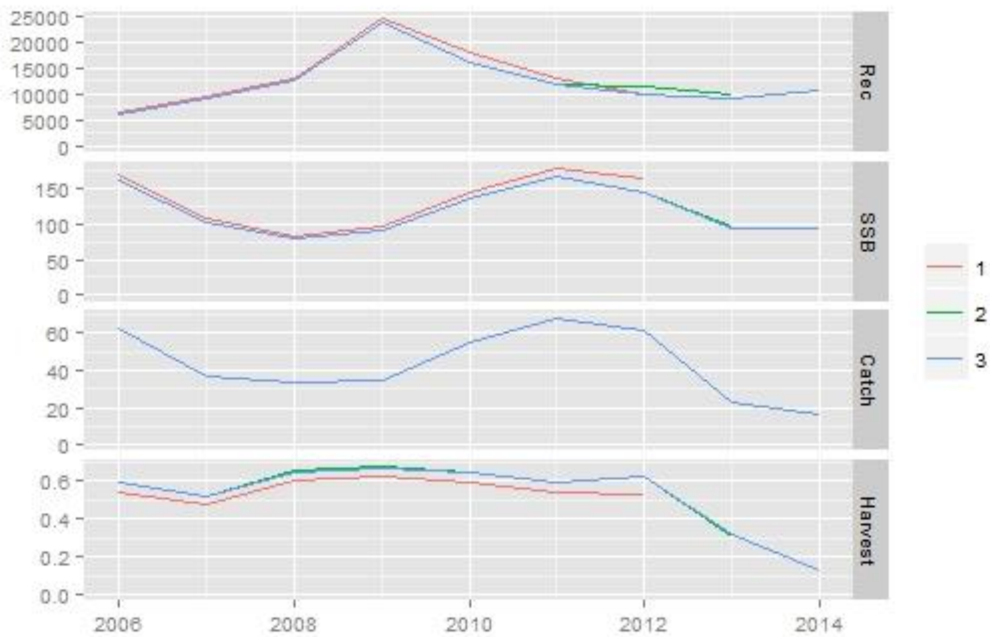


Figure 5.2.11.7.3.5. Retrospective analysis with shrinkage set at 1.5 and qage2.

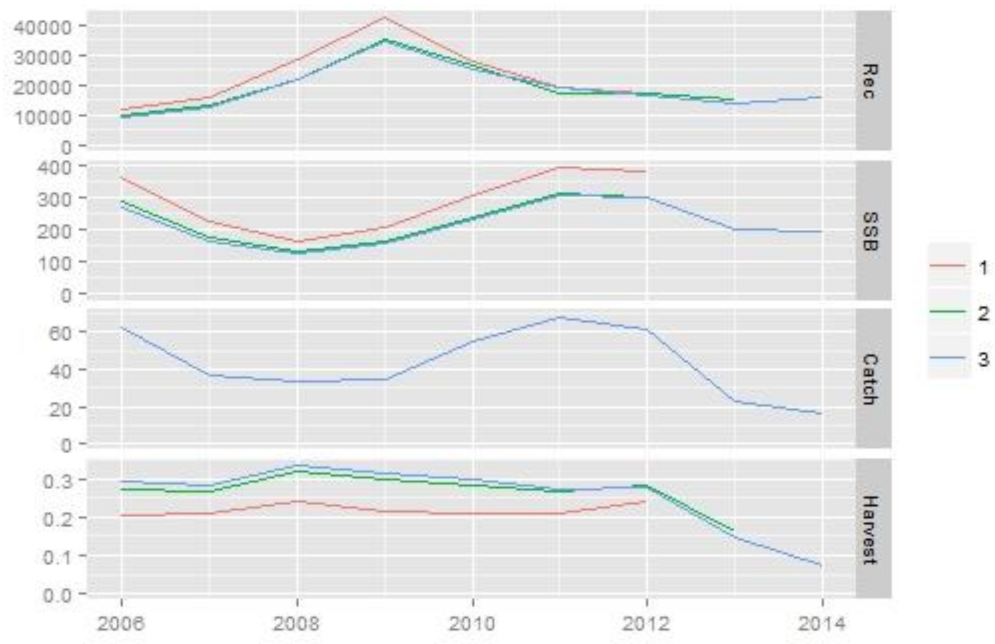


Figure 5.2.11.7.3.6. Retrospective analysis with shrinkage set at 1.5 and qage3.

Based on these simulation analyses, the inputs reported in Table 5.2.11.6.4.1 were selected to run the final XSA.

Table 5.2.11.7.3.1. Giant red shrimp in GSA 9. Inputs selected to run the final XSA.

fse	rage	qage	Shk.n	Shk.f	Shk.yrs	Shk.ages
1.5	1.0	2.0	true	true	5.0	2.0

XSA main outputs (Fig. 5.2.11.7.3.7) showed that F values changing around 0.60 from 2006 to 2012 and then largely decreased. Recruitment varied from a minimum of 6 millions in 2006 to 23 millions in 2009. In the last two years analyzed (2013-2014) the estimated number of recruits was quite stable, around 10 millions of individuals. SSB showed stable values in the last two years around 94 tons. XSA stock summary results are reported in the Tab. 5.2.11.7.3.2.

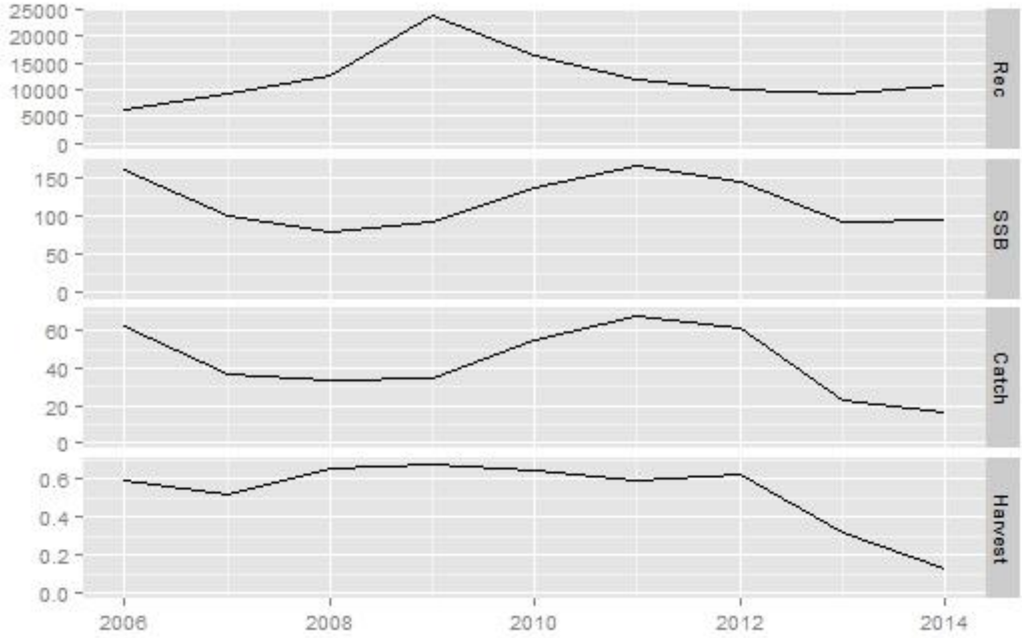


Figure 5.2.11.7.3.7. Giant red shrimp in GSA 9. XSA summary results. SSB and catch are in tons, recruitment in thousands of individuals.

Table 5.2.11.7.3.2. Giant red shrimp in GSA 9. XSA stock summary results.

SSB	2006	2007	2008	2009	2010	2011	2012	2013	2014
Tons	161.176	101.347	80.511	92.16	137.04	166.207	145.643	93.356	94.35
Rec	2006	2007	2008	2009	2010	2011	2012	2013	2014
(x1000)	6141	9116	12526	23960	16247	11969	10055	9273	10785
Stock number	2006	2007	2008	2009	2010	2011	2012	2013	2014
0	6141	9116	12526	23960	16247	11969	10055	9273	10785
1	3041	1682	2534	3475	6658	4420	3327	2784	2574
2	2528	1527	876	1040	1740	2840	1832	1183	1211
3	851	723	465	393	370	526	738	551	441
4+	696	156	365	347	200	289	863	238	242
F by age	2006	2007	2008	2009	2010	2011	2012	2013	2014
0	0.02	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.07
1	0.11	0.07	0.31	0.11	0.27	0.30	0.45	0.25	0.19
2	0.81	0.75	0.36	0.59	0.76	0.91	0.76	0.55	0.11
3	0.86	0.74	1.29	1.31	0.91	0.57	0.66	0.15	0.09
4+	0.86	0.74	1.29	1.31	0.91	0.57	0.66	0.15	0.09
Fbar	2006	2007	2008	2009	2010	2011	2012	2013	2014
(1-3)	0.59	0.52	0.65	0.67	0.65	0.59	0.63	0.32	0.13

The XSA diagnostics are reported below:

```
FLR XSA Diagnostics 2015-09-03 10:47:08

CPUE data from indices

Catch data for 9 years 2006 to 2014. Ages 0 to 4.

fleet first age last age first year last year alpha beta
1 Medits         0        3       2006      2014  <NA> <NA>


Time series weights :

Tapered time weighting applied
Power =   3 over  20 years

Catchability analysis :

Catchability independent of size for ages >   1

Catchability independent of age for ages >   3

Terminal population estimation :

Survivor estimates shrunk towards the mean F
of the final   5 years or the  3 oldest ages.

S.E. of the mean to which the estimates are shrunk =   1.5

Minimum standard error for population
estimates derived from each fleet =  0.3

prior weighting not applied

Regression weights
year
age   2006  2007  2008  2009  2010 2011  2012 2013 2014
all 0.82 0.877 0.921 0.954 0.976 0.99 0.997    1    1


Fishing mortalities
year
age  2006  2007  2008  2009  2010  2011  2012  2013  2014
0 0.010 0.000 0.001 0.000 0.014 0.000 0.003 0.001 0.050
1 0.084 0.047 0.218 0.062 0.179 0.182 0.256 0.145 0.122
2 0.478 0.510 0.219 0.353 0.341 0.469 0.361 0.241 0.059
3 0.323 0.296 0.566 0.527 0.376 0.171 0.218 0.055 0.033
4 0.323 0.296 0.566 0.527 0.376 0.171 0.218 0.055 0.033
```

XSA population number (Thousand)

age					
year	0	1	2	3	4
2006	9200	3909	3701	1775	1475
2007	12469	2532	2013	1478	323
2008	21863	3467	1352	778	623
2009	34778	6071	1562	700	631
2010	25186	9665	3193	706	388
2011	19351	6905	4524	1462	814
2012	16587	5380	3224	1823	2161
2013	13688	4600	2332	1448	626
2014	15492	3802	2228	1181	651

Estimated population abundance at 1st Jan 2015

age					
year	0	1	2	3	4
2015	0	4146	1907	1376	796

Fleet: Medits

Log catchability residuals.

year									
age	2006	2007	2008	2009	2010	2011	2012	2013	2014
0	0.144	0.015	0.036	-0.085	0.307	-0.070	-0.102	0.035	-0.246
1	-0.294	0.196	0.165	0.261	0.141	-0.149	-0.297	0.192	-0.218
2	-0.291	0.017	0.096	-0.509	0.421	0.187	-0.196	0.172	0.046
3	-0.015	0.174	0.033	-0.324	0.264	-0.378	-0.077	0.185	0.147

Regression statistics
Ages with q dependent on year class strength
[1] "0.357803574798871" "0.714375289122282" "9.02527295097246" "5.65372377497984"

Terminal year survivor and F summaries:

,Age 0 Year class =2014

source

scaledWts	survivors	yrcls	
Medits	0.311	2058	2014
fshk	0.046	53430	2014
nshk	0.642	4843	2014

,Age 1 Year class =2013

source

```
scaledWts survivors yrcls
Medits     0.928      1388  2013
fshk       0.072      1331  2013

,Age 2 Year class =2012

source
scaledWts survivors yrcls
Medits     0.959      1417  2012
fshk       0.041       189  2012

,Age 3 Year class =2011

source
scaledWts survivors yrcls
Medits      0.96       905  2011
fshk        0.04       327  2011
```

5.2.11.8 Reference points

5.2.11.8.1 Methods

The yield per recruit (YpR) analysis was run using NOAA software. The analysis was performed to estimate $F_{0.1}$ as target equilibrium YPR reference point for the stock.

5.2.11.8.2 Input data

In the following table are reported the setting inputs for the YpR analysis. The data were the same used in the XSA.

Table 5.2.11.8.2.1. Giant red shrimp in GSA 9. Input data for YpR analysis.

AGE	Selectivity on Fishing Mortality	Selectivity on Natural Mortality	Stock Weights	Catch Weights	Spawning Stock Weights	Fraction Mature
0	0.0029	1.0000	0.0090	0.0090	0.0090	0.0000
1	0.4311	0.4531	0.0163	0.0163	0.0163	0.6000
2	1.0000	0.3438	0.0289	0.0289	0.0289	1.0000
3	0.7117	0.2969	0.0419	0.0419	0.0419	1.0000
4	0.7117	0.2656	0.0460	0.0460	0.0460	1.0000

Proportion of Fishing Mortality Before Spawning 0.5000

Proportion of Natural Mortality Before Spawning 0.5000

Natural Mortality 1.2800

5.2.11.8.3 Results

YpR output curve is illustrated in the Figure 5.2.11.8.3.1. while the main reference points defined with the Yield per recruit analysis are reported in the table 5.2.11.8.3.1. $F_{0.1}$ estimated by the model was 0.51.

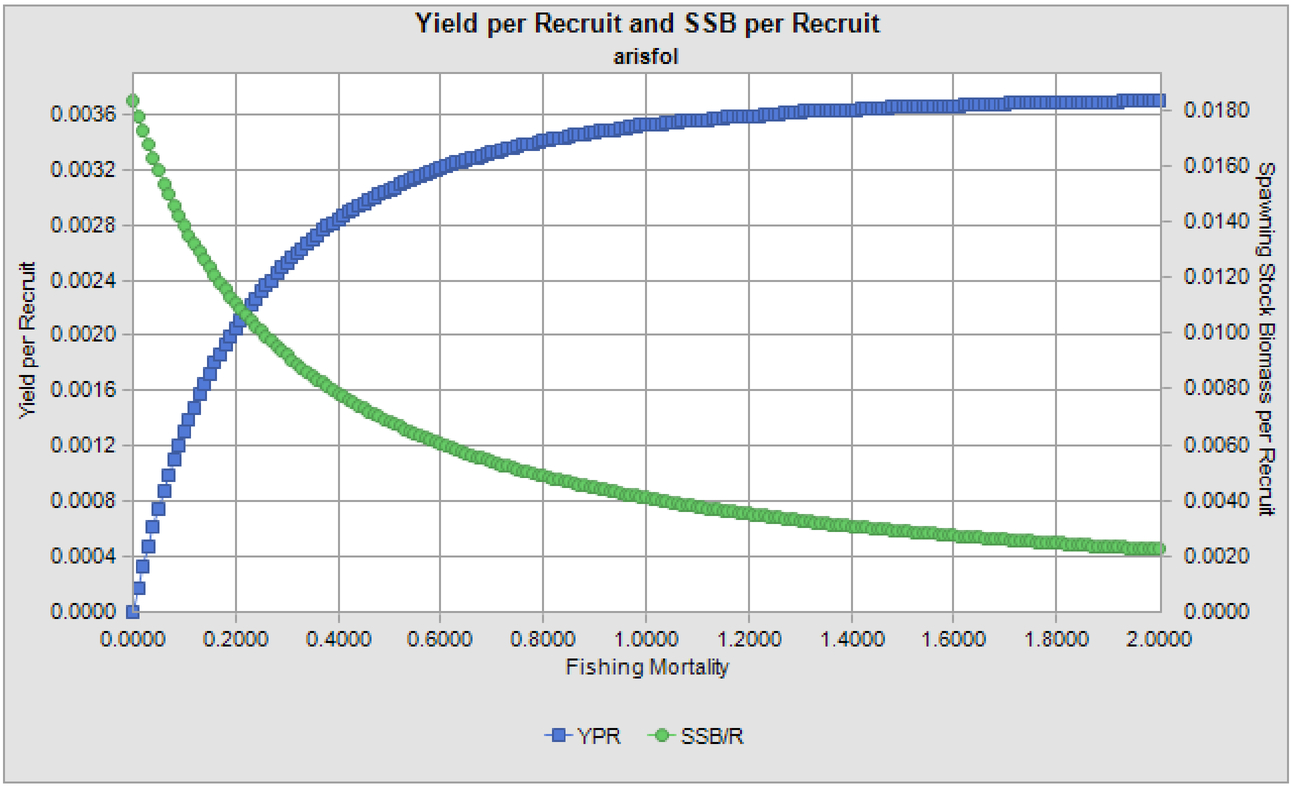


Figure 5.2.11.8.3.1. Giant red shrimp in GSA 9. Yield per Recruit curve.

Table 5.2.11.8.3.1. Giant red shrimp in GSA 9. Main reference points defined with the Yield per recruit analysis.

Reference Point Summary Table

Reference Point	F	Yield per Recruit	SSB per Recruit	Total Biomass per Recruit	Mean Age	Mean Generation Time	Expected Spawnings
F Zero	0.00000	0.00000	0.01835	0.03317	1.37099	4.25349	0.31102
F-01	0.51160	0.00308	0.00673	0.02116	0.58050	2.39736	0.16014
F-Max	N/A						
F at 40 %MSP	0.44690	0.00295	0.00734	0.02181	0.61571	2.50194	0.17197

Since $F_{0.1}$ estimated by XSA (0.51) was coeherent with YpR NoAA estimation, the value was considered as reference point and also used in the short term forecast.

5.2.11.9 Data quality

MEDITS abundance indexes were computed directly by the experts. Although landings data were observed in 2008 for gillnet and in 2012 for trammel any length distribution was available. It is also true that landing values for these two fisheries and years were very low (about 700kg and about 1.2 tons respectively) compare to those of the trawlers.

5.2.11.10 Short term predictions 2015-2017

5.2.11.10.1 Method

A deterministic short term prediction for the period 2015 to 2017 was performed using the FLR routines provided by JRC and based on the results of the XSA stock assessments performed during EWG 15-11 for the years 2006–2014.

5.2.11.10.2 Input parameters

The input parameters were the same used for the XSA stock assessment and its results. Different scenarios, zero catch, harvest at reference point, Fstatusquo and a series of multiplier of Fstq were performed. Fstq=0.294 has been estimated as the geometric mean of the last three years 2012-2014 of Fbar values estimated with FLR.

Recruitment (class 0) has been estimated from the population results from the geometric mean (10018 thousands individuals).

5.2.11.10.3 Results

Table 5.2.11.10.3.1. Giant red shrimp in GSA 9. Short term forecast in different F scenarios. Basis:F(2015) = mean(F_{bar} 1-3 2012-2014)= 0.294; R(2015) = geometric mean of the recuitment of the last 3 years; R = 10018 (thousands); SSB(2015) = 94 t, Catch (2014)= 17 t.

Rationale	Ffactor	Fbar	Catch 2016	Catch 2017	SSB 2017	Change SSB 2016-2017(%)	Change Catch 2014-2016(%)
Zero catch	0.000	0.000	0.00	0.00	142.79	25.96	-100.00
High long term yield F(0.1)	1.744	0.514	43.89	38.07	96.42	-14.94	160.94
Status quo	1.000	0.295	27.53	27.47	113.36	0.00	63.68
Different scenarios	0.100	0.029	3.09	3.71	139.45	23.01	-81.64
	0.200	0.059	6.10	7.16	136.19	20.14	-63.76
	0.300	0.088	9.02	10.38	133.04	17.35	-46.34
	0.400	0.118	11.88	13.38	129.97	14.65	-29.38
	0.500	0.147	14.66	16.18	127.00	12.03	-12.85
	0.600	0.177	17.37	18.78	124.11	9.48	3.26
	0.700	0.206	20.01	21.19	121.30	7.00	18.95
	0.800	0.236	22.58	23.44	118.58	4.60	34.25
	0.900	0.265	25.09	25.53	115.93	2.27	49.15
	1.100	0.324	29.91	29.27	110.87	-2.20	77.85
	1.200	0.354	32.23	30.94	108.44	-4.34	91.66
	1.300	0.383	34.50	32.49	106.09	-6.42	105.12
	1.400	0.412	36.71	33.92	103.80	-8.44	118.25
	1.500	0.442	38.86	35.25	101.58	-10.40	131.05
	1.600	0.471	40.96	36.47	99.42	-12.30	143.54
	1.700	0.501	43.01	37.61	97.32	-14.15	155.73
	1.800	0.530	45.01	38.65	95.28	-15.95	167.61
	1.900	0.560	46.96	39.62	93.30	-17.70	179.20
	2.000	0.589	48.86	40.50	91.38	-19.40	190.52

A short term projection (Table 5.2.11.10.3.1), assuming an F_{stq} of 0.294 in 2015 and a recruitment of 10018 thousands individuals show that:

- Fishing at the F_{stq} (0.294) generates an increase of the catch of about 60% from 2014 to 2016 along with no increase of the spawning stock biomass 2016 to 2017.
- Fishing at $F_{0.1}$ (0.51) generates an increase of the catch of about 161% from 2014 to 2016 and a decrease of the spawning stock biomass of about 15% from 2016 to 2017.

5.2.11.11 Medium term predictions

5.2.11.11.1 Method

Medium term prediction would only be performed if there is a reliable fit of a stock-recruitment relationship obtained from a quite long time series. Since the fit for the giant red shrimp was not considered reliable and the time series cover only nine years, medium term predictions were not carried out.

5.2.11.12 Stock advice

On the basis of the estimated limit management reference point for sustainable exploitation (F_{MSY}=0.51) and considering that this value is higher compare to currently fishing mortality value (0.13) the stock is in underfishing conditions. It is important underling that recently figures obtained in *ad hoc* project promoted by EU (STOCKMED) put in evidence as this stock should be analysed at wider geographical level (e.g. GSA 9,10 and 11 together).

5.2.11.13 Management strategy evaluation

We ran the Management Strategy Evaluation to evaluate if the MSY ranges were precautionary. The F_{MSY} ranges were derived using the formula provided by STECF 15-09. F ranges results were F_{upper}=0.69 and F_{lower}=0.34. B_{lim} was estimated as B_{loss}=80.51 (t). The following figure shows the results of the MSE.

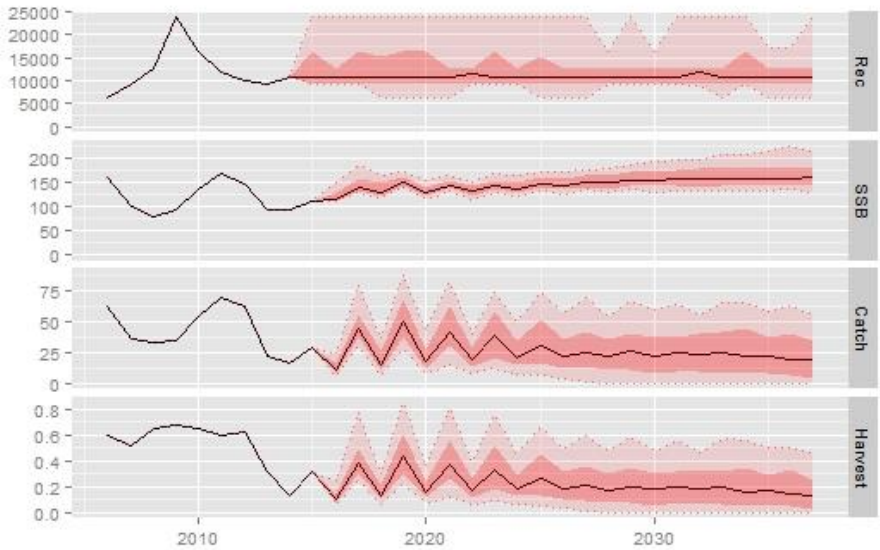


Figure 5.2.11.13.1. Giant red shrimp in GSA 9. Marine Strategy Evaluation.

The probability of SSB to fall below B_{lim} at F = F_{upper} is equal to 0. The dynamics observed for this stock are the result of the stock assessment model (i.e. XSA) settings used inside the MSE becoming less appropriate as the stock status changes in time (i.e. stock assessment settings are often specific to a particular range of stock status). This leads to an increasing difference between the perceived stock and the operating model (i.e. the 'true' stock). To avoid this behaviour in the future, for some of the stocks as it is the case here, a more general stock assessment method should be used in the MSE loop that is less sensitive to the stock status.

5.2.12 STOCK ASSESSMENT OF GIANT RED SHRIMP IN GSA 10

5.2.12.1 Stock Identification

The stock of giant red shrimp, *Aristaeomorpha foliacea*, was assumed in the boundaries of the whole GSA10, lacking specific information on stock identity (Figure 5.2.12.1.1). This species and the blue-red shrimp, *Aristeus antennatus*, are deep-water decapods characterised by seasonal variability and annual fluctuations of abundance (Spedicato *et al*., 1994), as reported for different geographical areas (e.g. Relini and Orsi Relini, 1987). The giant red shrimp *A. foliacea* is distributed beyond 350 m depth, but mainly in water deeper than 500 m. Generally mean length estimated using trawl survey data varies remarkably with depth, for the whole population and the two sexes, increasing at deeper waters.

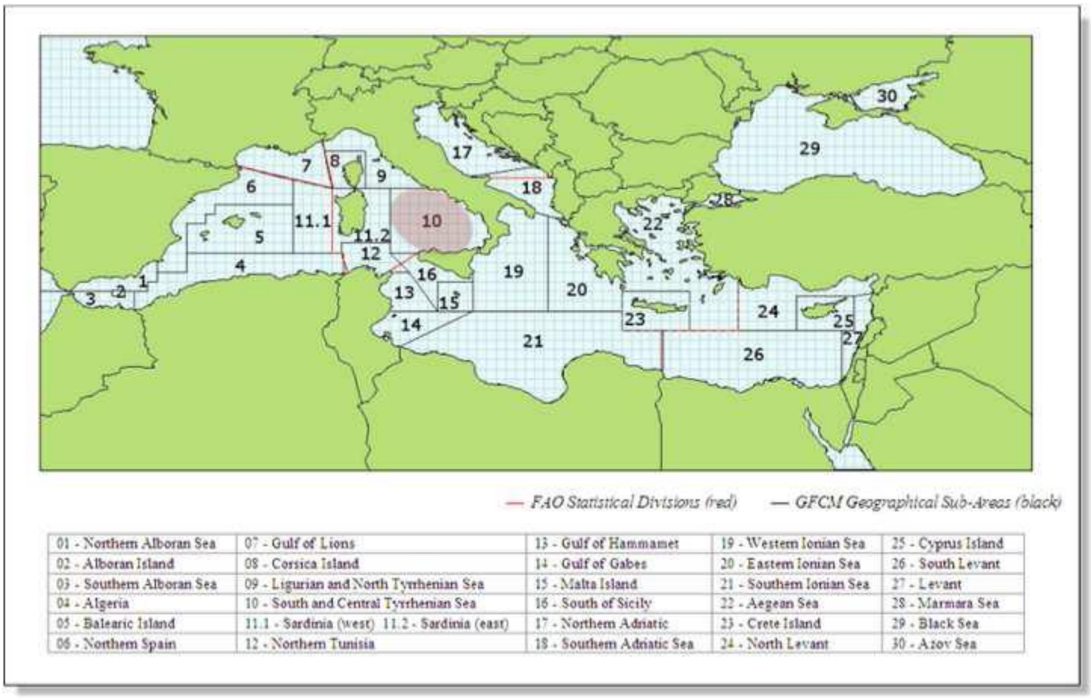


Fig. 5.2.12.1.1. Geographical location of GSA 10.

In the recent years, *A. foliacea* was ranked among the most abundant species (in number and weight) in the trawl survey catches. Higher biomass indices occur particularly southwards the Gulf of Naples (Spedicato *et al*., 1994).

This species has a discrete recruitment pattern and during spring trawl surveys (MEDITS) the recruitment pulse is observed. Since the reproduction takes place in the late spring-summer, recruits could be attributed to the spawning events of the previous year (Spedicato *et al*., 1999). *A. foliacea* is considered fully recruited to grounds at ~24 mm CL (from Samed, AAVV, 2002). Recently a study at Mediterranean scale, using Medits data from 1994 to 2004, has evidenced that the higher abundance indices of recruits were observed in the central-southern Tyrrhenian Sea (AAVV, 2008).

In general, the length frequency distributions of the giant red shrimp have a polymodal pattern, with 4-5 components for females (the modes of adults are less defined) and 2-3 components for the males. For the females a life span of 6-8 years was estimated. The structure of the sizes of *A. foliacea* is characterised by marked differences in growth between the sexes. The larger individuals are females and inhabit deeper waters.

Sex ratio values of ~0.5 show that males and females are not segregated into different bathymetric ranges (Spedicato *et al*., 1994). The reproduction period extends from May to September, with a

peak in the summer (July-August) (Spedicato *et al.*, 1999). Mature males have been observed all year round.
According to the benthic bionomic classification of Pérès and Picard, *P. longirostris*, *N. norvegicus* and red-shrimps typify the populations of slope and bathyal bottoms in the GSA10. Depending on the depth and zone, this fauna is accompanied by characteristic bentic species as *Funiculina quadrangularis*, *Geryon longipes*, *Polycheles typhlops*, *Isidella elongata*, *Griphus vitreus*.
In the central-southern Tyrrhenian Sea, the giant red shrimp represents a specific target of deep-waters trawling fishery given its high economic value (Spedicato *et al.*, 1994).

5.2.12.2 Growth
Estimates of the growth pattern of the giant red shrimp in the GSA 10 were previously obtained using GRUND length frequency distributions from 1991 to 1995 and methods as Elefan and Batthacharya for the analysis of LFDs. Parameters of females were as follows: CL∞=73.24 mm; K=0.483; t0= -0.435 (Spedicato *et al.*, 1998). In the Samed project (AAVV, 2002) and using the Medits data from 1994 to 1999 a new set of parameters was estimated for the Tyrrhenian sea down the Strait of Messina (females: L∞=73 mm; K=0.44; t0= -0.05; males: L∞=48 mm; K=0.59; t0= -0.2). The observed maximum carapace length of females and males were 72 and 46 mm respectively.
Growth has been also studied in the DCF framework and in the Red Shrimps project (AAVV, 2008) through the analysis of the LFDs and the separation of modal components. These estimates have been done using both MEDITS and GRUND average length at putative age, where age was set according to the date of each survey with a birthday on 1st July.
Table 5.2.12.2.1 reports putative ages, mean carapace lengths with relative standard deviations for females.

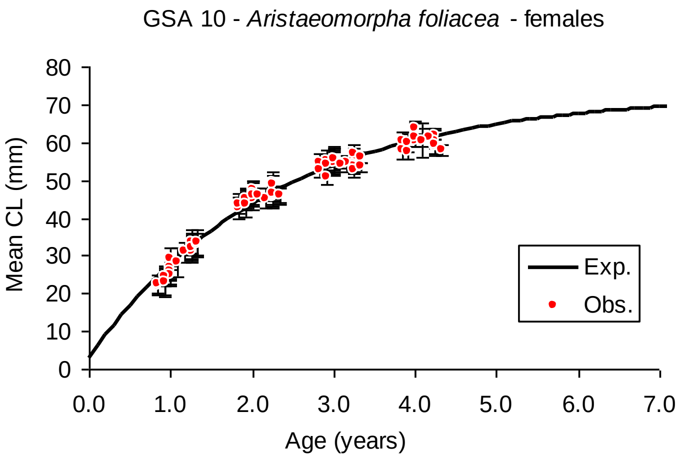
Table 5.2.12.2.1. Giant red shrimp in GSA 10. Putative age, mean length of modal components of the LFD of MEDITS and GRUND survey and relative standard deviations.

putative age	mean CL	st. dev.	putative age	mean CL	st. dev.	putative age	mean CL	st. dev.
0.8	21.9	2.29	2.0	45.5	2.58	3.1	54.3	1.01
0.8	22.5	2.36	2.0	47.5	2.05	3.2	54.5	2.11
0.9	23.0	3.38	2.0	44.9	1.8	3.2	53.5	1.33
0.9	24.6	2.78	2.0	46.7	3.06	3.2	55.3	1.52
0.9	23.0	3.75	2.0	45.9	3.76	3.2	57.0	1.53
1.0	26.6	2.96	2.1	46.2	1.85	3.2	57.2	2.1
1.0	25.0	3.16	2.2	45.1	2.59	3.2	54.3	2.23
1.0	26.0	1.95	2.2	46.6	1.55	3.2	53.5	1.71
1.0	24.8	2.26	2.2	49.2	2.23	3.2	52.9	1.97
1.0	29.1	2.79	2.2	45.6	2.98	3.3	56.0	1.47
1.1	28.2	3.82	2.2	49.1	3.31	3.3	53.6	1.25
1.2	31.0	2.58	2.2	45.8	2.3	3.8	60.3	2.46
1.2	33.3	2.68	2.2	45.9	2.62	3.8	57.9	2.14
1.2	32.8	2.37	2.2	46.6	1.98	3.9	60.0	2.38
1.2	33.4	2.65	2.3	46.1	1.8	3.9	57.6	2.15
1.2	33.7	3.05	2.3	46.2	2.39	4.0	63.1	2.54
1.2	31.1	2.66	2.8	54.7	2.38	4.0	60.3	1.55
1.2	32.1	3.55	2.8	52.6	1.84	4.0	63.8	1.3
1.2	32.0	2.81	2.9	55.0	3.16	4.0	61.1	2.35
1.3	32.9	3.07	2.9	54.0	2.05	4.1	60.5	4.56
1.3	33.5	3.16	2.9	50.9	1.81	4.2	61.3	2.35
1.8	42.6	2.77	3.0	54.8	3.05	4.2	62.0	1.14
1.8	43.8	2.42	3.0	54.9	2.74	4.2	60.4	3.37
1.9	44.4	2.38	3.0	55.7	2.9	4.2	58.8	2.05
1.9	45.2	2.53	3.0	54.8	3.53	4.2	59.6	1.03
1.9	43.8	3.6	3.0	55.6	3.18	4.3	57.8	1.37

putative age	mean CL	st. dev.	putative age	mean CL	st. dev.	putative age	mean CL	st. dev.
0.8	21.9	2.29	2.0	45.5	2.58	3.1	54.3	1.01
0.8	22.5	2.36	2.0	47.5	2.05	3.2	54.5	2.11
0.9	23.0	3.38	2.0	44.9	1.8	3.2	53.5	1.33
0.9	24.6	2.78	2.0	46.7	3.06	3.2	55.3	1.52
0.9	23.0	3.75	2.0	45.9	3.76	3.2	57.0	1.53
1.0	26.6	2.96	2.1	46.2	1.85	3.2	57.2	2.1
1.0	25.0	3.16	2.2	45.1	2.59	3.2	54.3	2.23
1.0	26.0	1.95	2.2	46.6	1.55	3.2	53.5	1.71
1.0	24.8	2.26	2.2	49.2	2.23	3.2	52.9	1.97
1.0	29.1	2.79	2.2	45.6	2.98	3.3	56.0	1.47
1.1	28.2	3.82	2.2	49.1	3.31	3.3	53.6	1.25
1.2	31.0	2.58	2.2	45.8	2.3	3.8	60.3	2.46
1.2	33.3	2.68	2.2	45.9	2.62	3.8	57.9	2.14
1.2	32.8	2.37	2.2	46.6	1.98	3.9	60.0	2.38
1.2	33.4	2.65	2.3	46.1	1.8	3.9	57.6	2.15
1.2	33.7	3.05	2.3	46.2	2.39	4.0	63.1	2.54
1.2	31.1	2.66	2.8	54.7	2.38	4.0	60.3	1.55
1.2	32.1	3.55	2.8	52.6	1.84	4.0	63.8	1.3
1.2	32.0	2.81	2.9	55.0	3.16	4.0	61.1	2.35
1.3	32.9	3.07	2.9	54.0	2.05	4.1	60.5	4.56
1.3	33.5	3.16	2.9	50.9	1.81	4.2	61.3	2.35
1.8	42.6	2.77	3.0	54.8	3.05	4.2	62.0	1.14
1.8	43.8	2.42	3.0	54.9	2.74	4.2	60.4	3.37
1.9	44.4	2.38	3.0	55.7	2.9	4.2	58.8	2.05
1.9	45.2	2.53	3.0	54.8	3.53	4.2	59.6	1.03
1.9	43.8	3.6	3.0	55.6	3.18	4.3	57.8	1.37

The following estimates of von Bertalanffy growth parameters for each sex were obtained from average length at age using an iterative non-liner procedure that minimises the sum of the square differences between observed and expected values and fixing the asymptotic length on the basis of the observed maximum values: females $CL\infty$=72.5 mm, K=0.438, t0= -0.1; males: $CL\infty$=44 cm, K=0. 5, t0= -0.1 (Figure 5.2.12.2.1). These estimates are more accurate, although very close, to those previously obtained.

Average parameters of the length-weight relationship were a=0.0014, b=2.622 for females and a=0.000848, b=2.78 for males, for length expressed in mm.



	females	males
CL_{∞} (mm)=	72.5	44
k/year=	0.438	0.5
t_0(year)=	-0.10	-0.1

Fig. 5.2.12.2.1. Giant red shrimp in GSA 10. Von Bertalanffy growth functions and parameters for females.

5.2.12.3 Maturity

The maturity ogive (Figure 5.2.12.3.1) was obtained from a maximum likelihood procedure applied grouping as mature individuals belonging to the maturity stage 2b (according to the MEDITS maturity scale) onwards. The fitting of the curve was fairly good, however the estimates of the size at first maturity Lm50% (3.5 cm ±0.023 cm) and of the maturity range (0.36 cm ±0.020 cm), reported in the figure below, seem slightly lower if compared with literature values (average of the smallest females in the GSA ~34 mm CL; 39.6 mm carapace length according to Ragonese & Bianchini, 1995).

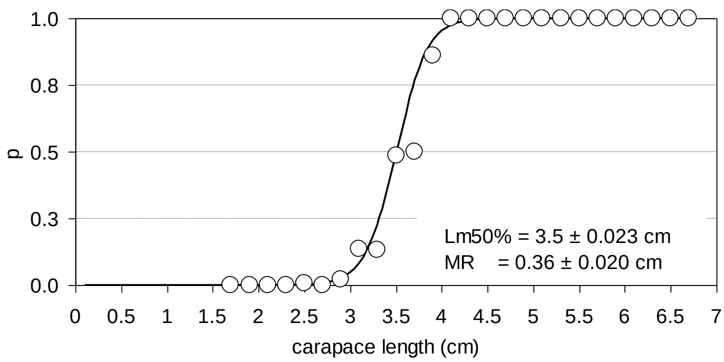


Fig. 5.2.12.3.1. Giant red shrimp in GSA 10. Maturity ogive and proportions of mature female (MR indicates the difference Lm75%-Lm25%).

The sex ratio from DCR evidenced the prevalence of males in the size class from 3.4 to 3.8 cm while from 4 cm onwards the proportion of females was dominant (Figure 5.2.12.3.2).

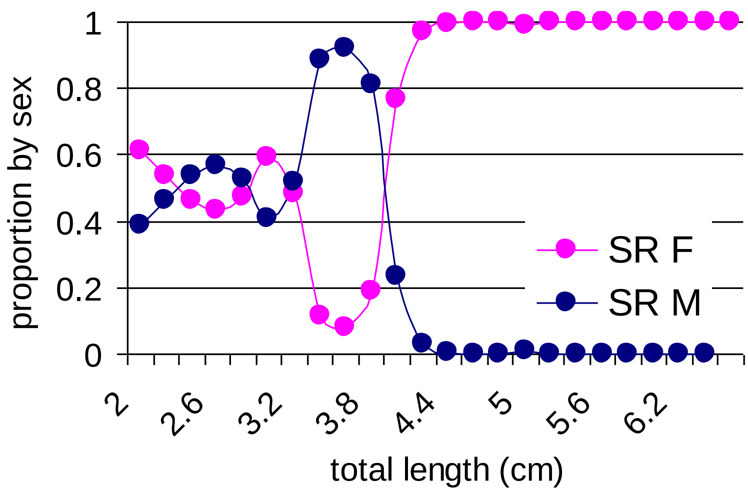


Fig. 5.2.12.3.2. Giant red shrimp in GSA10. Sex ratio.

5.2.12.4 Natural mortality

A vector of natural mortality by age was estimated using PRODBIOM (Abella *et al.*, 1998). The results are shown in Table 5.2.12.4.1. The input parameters used for M estimation were Linf = 73, k = 0.438, t_0 =-0.1, a = 0.0014 and b = 2.62.

Table 5.2.12.4.1. Giant red shrimp in GSA 10. Natural mortality by age.

age 0	age 1	age 2	age 3	Age 4+
1.33	0.73	0.61	0.56	0.53

5.2.12.5 Fisheries

5.2.12.5.1 General description of the fisheries

The Giant red shrimp is only targeted by trawlers and fishing grounds are located offshore 200 m depth, mainly southward Salerno Gulf. Catches from trawlers are from a depth range between 400 and 700 m depth and giant the red shrimp occurs with *A. antennaus*, *P. longirostris* and *N. norvegicus*, *P. blennoides*, *M. merluccius*, depending on operative depth and area.

5.2.12.5.2 Management regulations applicable in 2015

Management regulations are based on technical measures, closed number of fishing licenses for the fleet and area limitation (distance from the coast and depth). In order to limit the over-capacity of fishing fleet, the Italian fishing licenses have been fixed since the late eighties. Other measures on which the management regulations are based regard technical measures (mesh size) and minimum landing sizes (EC 1967/06).

After 2000, in agreement with the European Common Policy of Fisheries, a gradual decreasing of the fleet capacity is implemented. Along northern Sicily coasts two main Gulfs (Patti and Castellammare) have been closed to the trawl fishery up 200 m depth, since 1990. In the GSA10 the fishing ban has not been mandatory along the time, and from one year to the other it was adopted on a voluntary basis by fishers, whilst in the last years it was mandatory.

In 2008 a management plan was adopted, that foresaw the reduction of fleet capacity associated with a reduction of the time at sea. Two biological conservation zone (ZTB) were permanently established in 2009 (Decree of Ministry of Agriculture, Food and Forestry Policy of 22.01.2009; GU n. 37 of 14.02.2009). One is located along the mainland, in front of Sorrento peninsula in the vicinity of the MPA of Punta Campanella (Napoli Gulf, 60 km^2, within 200 m depth) and a second one is along the coasts of Amantea (Calabrian coasts, 75 km^2 up to 250 m depth). In these areas trawling is forbidden and other fishing activities are allowed under permission. Since June 2010 the rules implemented in the EU regulation (EC 1967/06) regarding the cod-end mesh size and the operative distance of fishing from the coasts are enforced.

5.2.12.5.3 Catches (by fleet if possible)

The catch is composed almost esclusively by marketed individuals.

5.2.12.5.4 Landings (by fleet if possible)

Available landing data are from DCF regulations. EWG 15-11 received Italian landings data for GSA10 by fisheries which are listed in Table 5.2.12.5.4.1.

In general, demersal trawlers account for the majority of the total landing. Small amounts are due to some artisanal vessels fishing with gillnet (Figure 5.2.12.5.4.1). This fishery contributes from 0 to 5.8% to the total landing according to the different years. Landings are decreasing from 2006 to 2008 and then slightly increasing from 2008 to 2010. High values are observed in 2013 and 2014.

The size frequency distributions of the trawl landing are comprised between 10 and 67 mm CL and show different modal classes. Gillnetters mainly catch big specimens (Figure 5.2.12.5.4.2).

Table 5.2.12.5.4.1. Giant red shrimp in GSA 10. Annual landings (tons) by fishery, from 2004 to 2014.

YEAR	GEAR	FISHERY	LANDINGS
2004	GNS	DEMF	4
2004	OTB		203
2005	GNS	DEMF	7
2005	OTB		498
2006	GNS	DEMF	8
2006	OTB		412
2007	GNS	DEMF	9
2007	OTB		291
2008	GNS	DEMF	7
2008	OTB		113
2009	GNS	DEMF	5
2009	OTB	DWSP	59
2009	OTB	MDDWSP	148
2010	GNS	DEMF	1
2010	OTB	DWSP	62
2010	OTB	MDDWSP	127
2011	GNS	DEMF	6
2011	OTB		135
2012	GNS	DEMF	8
2012	OTB		152
2013	OTB		399
2014	GNS	DEMF	5
2014	OTB	DWSP	279
2014	OTB	MDDWSP	171

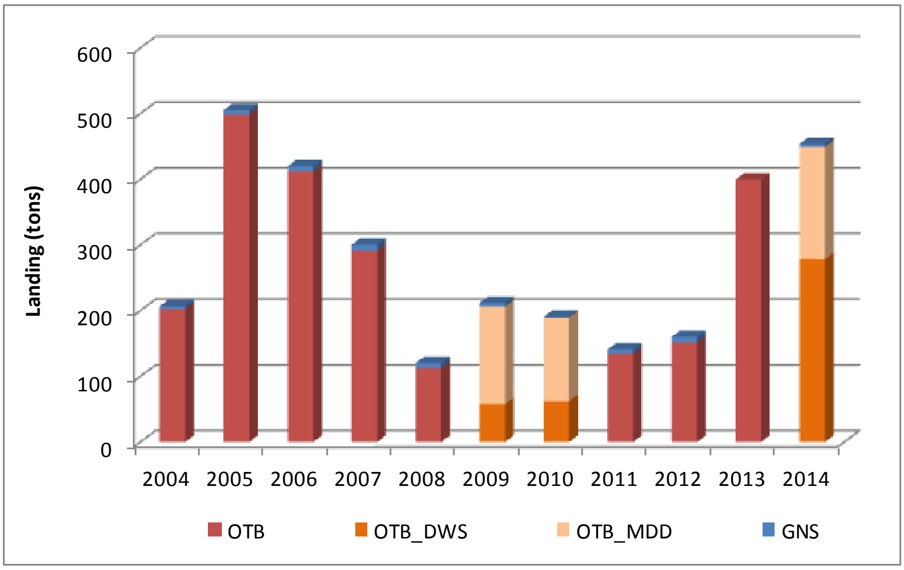


Fig. 5.2.12.5.4.1. Giant red shrimp in GSA 10. Annual landings (tons) from 2004 to 2014.

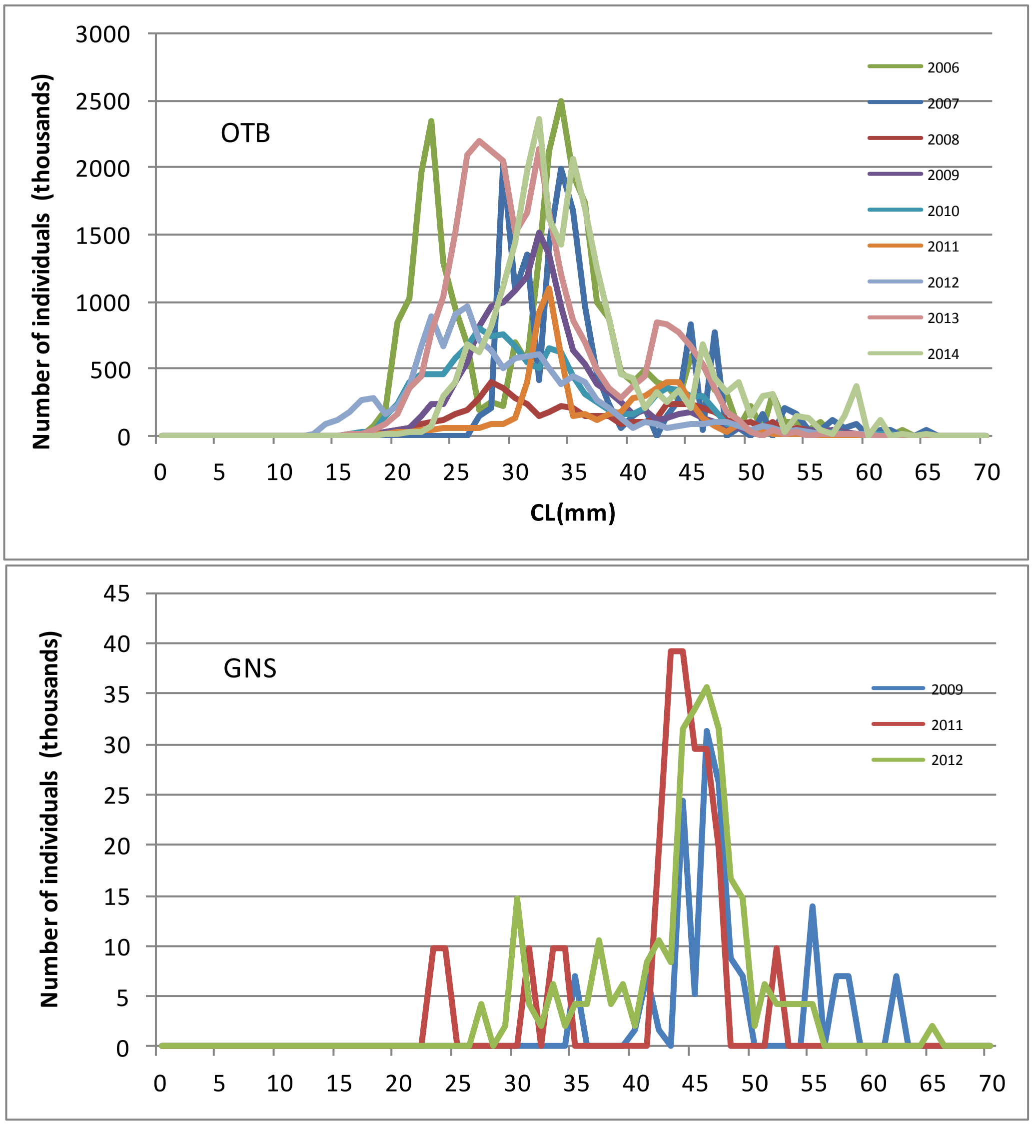


Fig. 5.2.12.5.4.2. Giant red shrimp in GSA 10. Demographic structure of the landing (trawling above and gillnet below) from 2006 to 2014.

5.2.12.5.5 Discards (by fleet if posible)

Discards data from 2009 to 2014 were available. The amount of discards of giant red shrimp in the GSA 10 was generally negligible.

5.2.12.5.6 Fishing effort (by fleet if possible)

The trends in fishing effort by year and major gear type in terms of kW*days are listed in Table 5.2.12.5.6.1 and in Figure 5.2.12.5.6.1.

Table 5.2.12.5.6.1. Effort (kW*days) for GSA10 by gear type, 2004-2014 as reported through the DCF official data call.

Gear	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
DRB	86505	294424	312180	144186	238122	188909	209574	196692	241145	59508	88658
FPO		314508	153589					156	71997	438492	130683
GND	369729	128153	676640	443277	496680	435913	112632	44621	53742	7667	38343

GNS	4362276	5038906	3024622	2226520	2506323	2525668	2782604	2963679	2536182	1904962	2476523
GTR	3671219	1745574	4394209	3883167	3208597	2450304	2689599	2611624	2697356	2919718	2995387
LLD	1823662	1138482	1013389	361358	387768	1471790	2469932	2130245	1643421	1136408	1036683
LLS	7079323	1811552	1493720	1185423	1399622	1010226	1272999	1695680	1051670	1339212	2676577
LTL								6324	893		12334
none	7799360	4540824	3986171	3370493	2539043	3487970	2681538	2106037	1336435	600716	447521
OTB	6970928	8028733	7156787	7112581	5724631	5997764	5603044	5234759	6051158	6154030	8797448
OTM											383607
PS	5807234	2502000	1781508	1783526	1188917	1903718	1652686	1567061	1548326	1721519	1601791
PTM	6995								912		

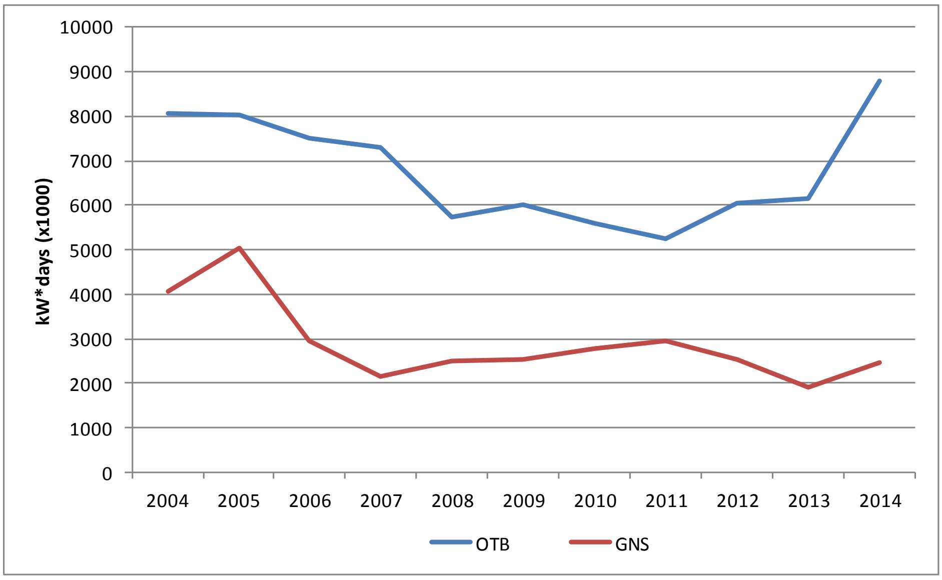


Fig. 5.2.12.5.6.1. Nominal fishing effort of OTB and GNS (KW*days).

The fishing effort of trawlers, that is the major component of fishing in the area, shows a decreasing trend from 2004 to 2011. In the last three years a reversal tendency has been observed, with a particularly high value in 2014. After a decline between 2004 and 2007, gillnet fishery shows a quite constant trend.

5.2.12.6 Scientific surveys

5.2.12.6.1 Survey #1 (MEDITS)

5.2.12.6.1.1 Methods

According to the MEDITS protocol (Bertrand *et al.*, 2002), trawl surveys were yearly (May-July) carried out, applying a random stratified sampling by depth (5 strata with depth limits at: 50, 100, 200, 500 and 800 m; each haul position randomly selected in small sub-areas and maintained fixed throughout the time). Haul allocation was proportional to the stratum area. The same gear (GOC 73, by P.Y. Dremière, IFREMER-Sète), with a 20 mm stretched mesh size in the cod-end, was employed throughout the years. Detailed data on the gear characteristics, operational parameters and performance are reported in Dremière and Fiorentini (1996). Considering the small mesh size a complete retention was assumed. All the abundance data (number of fish and weight per surface unit) were standardised to square kilometre, using the swept area method.

Based on the DCF data call, abundance and biomass indices were recalculated with a standardization to the hour. In GSA 10 the following number of hauls was reported per depth stratum (Table 5.2.12.6.1.1.1).

Table 5.2.12.6.1.1.1. Number of hauls per year and depth stratum in GSA10, 1994-2014.

Stratum	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
10-50	7	8	8	8	8	8	8	8	7	7	7	7	7	7	7	7	7	7	7	7	7
50-100	10	10	10	10	10	10	10	10	8	8	8	8	8	8	8	8	8	8	8	8	8
100-200	17	17	17	17	17	17	17	17	14	14	14	14	14	14	14	14	14	14	14	14	14
200-500	22	23	22	22	22	22	22	24	18	18	18	18	18	18	19	18	18	18	18	18	18
500-800	28	27	28	28	28	27	28	26	23	23	23	23	23	23	22	23	23	23	23	23	23

Data were assigned to strata based upon the shooting position and average depth (between shooting and hauling depth). Catches by haul were standardized to 60 minutes hauling duration. Hauls noted as valid were used only, including stations with no catches (zero catches are included).
The abundance and biomass indices by GSA were calculated through stratified means (Cochran, 1953; Saville, 1977). This implies weighting of the average values of the individual standardized catches and the variation of each stratum by the respective stratum areas in each GSA:

$Yst = \Sigma (Yi*Ai) / A$

$V(Yst) = \Sigma (Ai^2 * si^2 / ni) / A^2$

Where:
A=total survey area
Ai=area of the i-th stratum
si=standard deviation of the i-th stratum
ni=number of valid hauls of the i-th stratum
n=number of hauls in the GSA
Yi=mean of the i-th stratum
Yst=stratified mean abundance
V(Yst)=variance of the stratified mean

The variation of the stratified mean is then expressed as the 95 % confidence interval: Confidence interval = Yst ± t(student distribution) * V(Yst) / n
It was noted that while this is a standard approach, the calculation may be biased due to the assumptions over zero catch stations, and hence assumptions over the distribution of data. A normal distribution is often assumed, whereas data may be better described by a delta-distribution and/or quasi-poisson. Indeed, data may be better modeled using the idea of conditionality and the negative binomial (e.g. O'Brien et al. (2004)).
Length distributions represent the number of individual per km^2 (Cochran, 1977).

5.2.12.6.1.2 Geographical distribution

The geographical distribution pattern of the giant red shrimp has been studied in the area using trawl-survey data, length frequency distribution analyses via modal component separation techniques and geostatistical methods. The abundance of the whole population, as derived from Medits survey, was higher in the southern part of the GSA 10 along the Calabrian coasts as well as the abundance of recruits (Figure 5.2.12.6.1.2.1). The probability of find a nursery area was the highest in the same zone with a high temporal continuity.

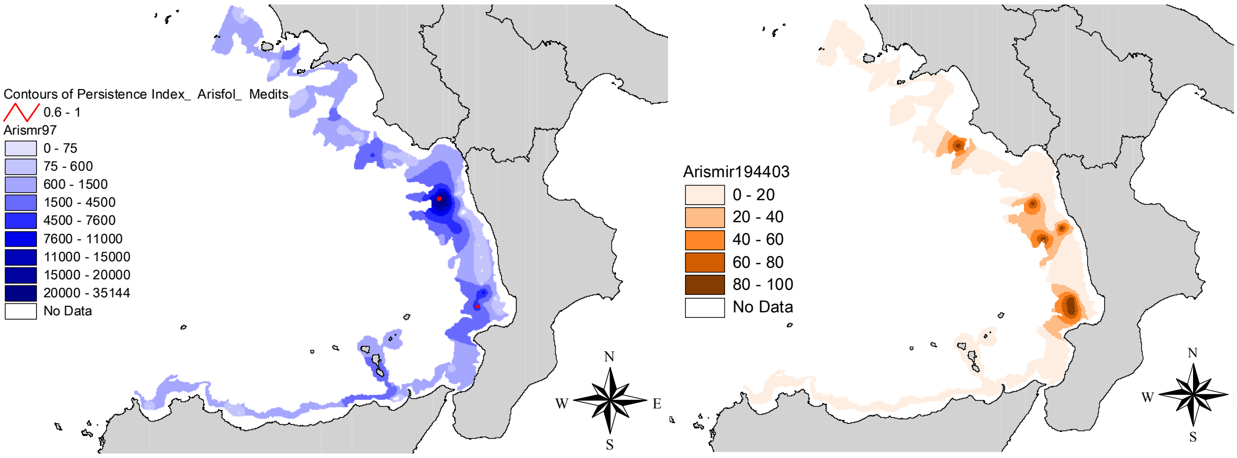
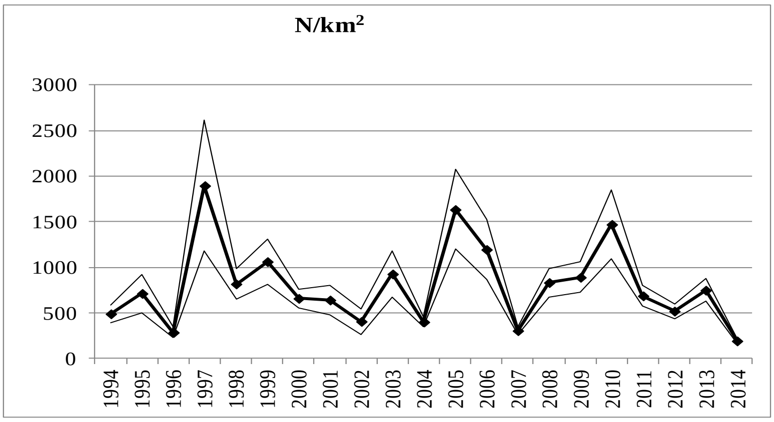


Fig. 5.2.12.6.1.2.1. Giant red shrimp in GSA 10. Maps of abundance (left) and of the probability of nursery localization (right) from MEDITS survey of 1997 and 2003 respectively. The contour of persistence is also evidenced in the map of abundance.

5.2.12.6.1.3 Trends in abundance and biomass

Fishery independent information regarding the state of the giant red shrimp in GSA 10 was obtained from the international survey MEDITS. Figure 5.2.12.6.1.3.1 displays the estimated trend of *A. foliacea* abundance and biomass standardized to the surface unit in GSA 10. Indices from MEDITS trawl-surveys show a fluctuating pattern with two peaks in 1997, 2005 and 2010, but without any trend. The last year shows the lowest value of the whole data series both in density and biomass.



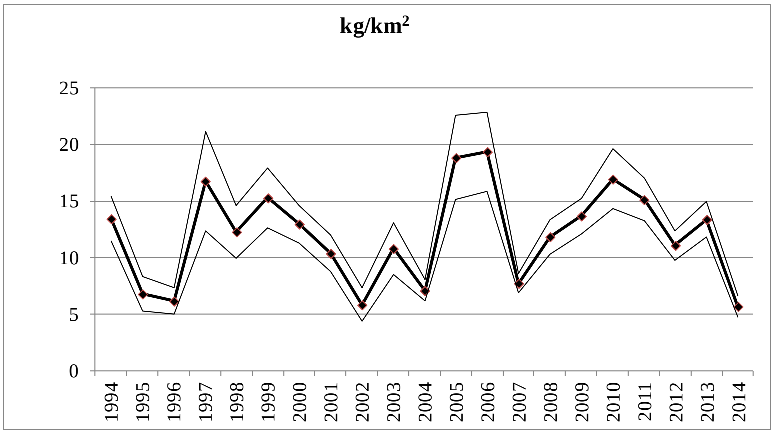


Fig. 5.2.12.6.1.3.1. Giant red shrimp in GSA 10. MEDITS abundance and biomass indices (±95% conf. int.).

5.2.12.6.1.4 Trends in abundance by length or age

The following figures display the stratified abundance indices by length of GSA 10 for the period 1994-2014 (MEDITS data).

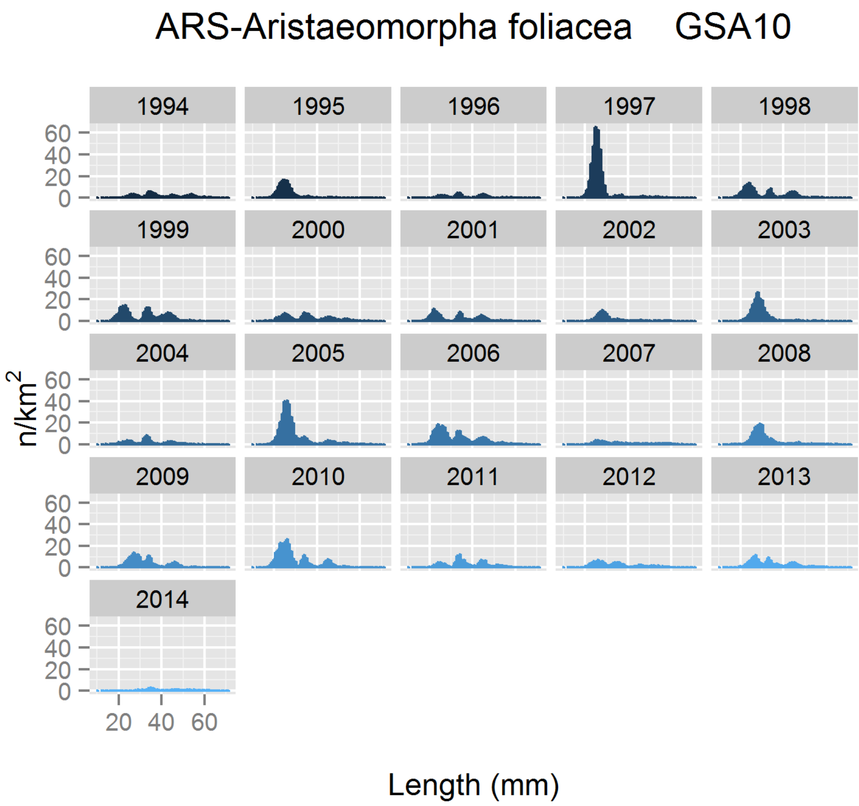


Fig. 5.2.12.6.1.4.1. Giant red shrimp in GSA 10. Stratified abundance indices by size, 1994-2014.

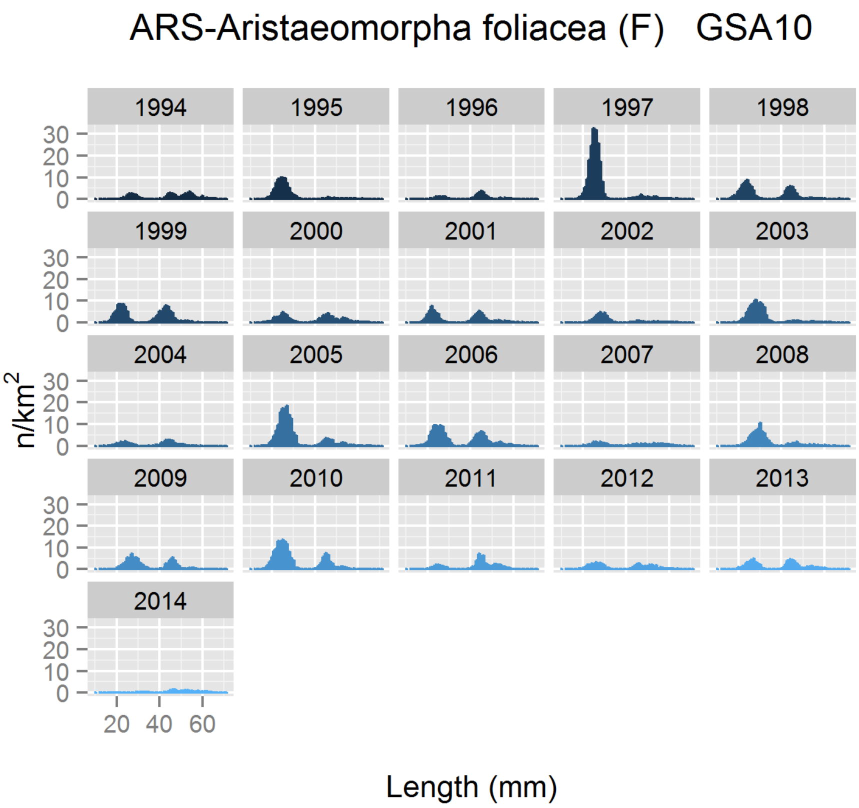


Fig. 5.2.12.6.1.4.2. Giant red shrimp in GSA 10. Stratified abundance indices by size, 1994-2014 (Females).

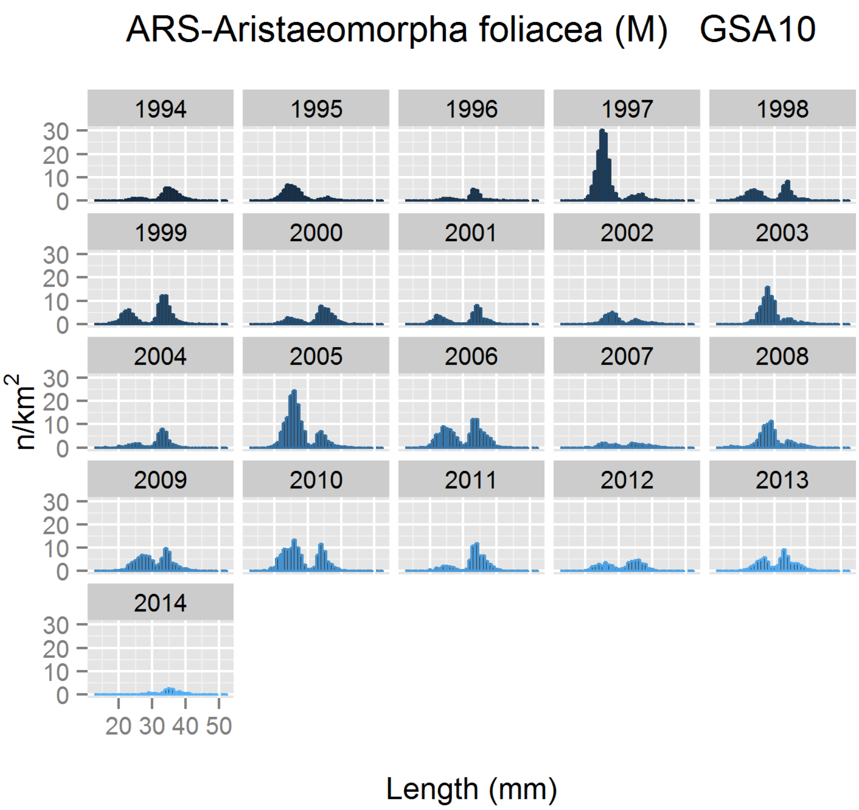


Fig. 5.2.12.6.1.4.3. Giant red shrimp in GSA 10. Stratified abundance indices by size, 1994-2014 (Males).

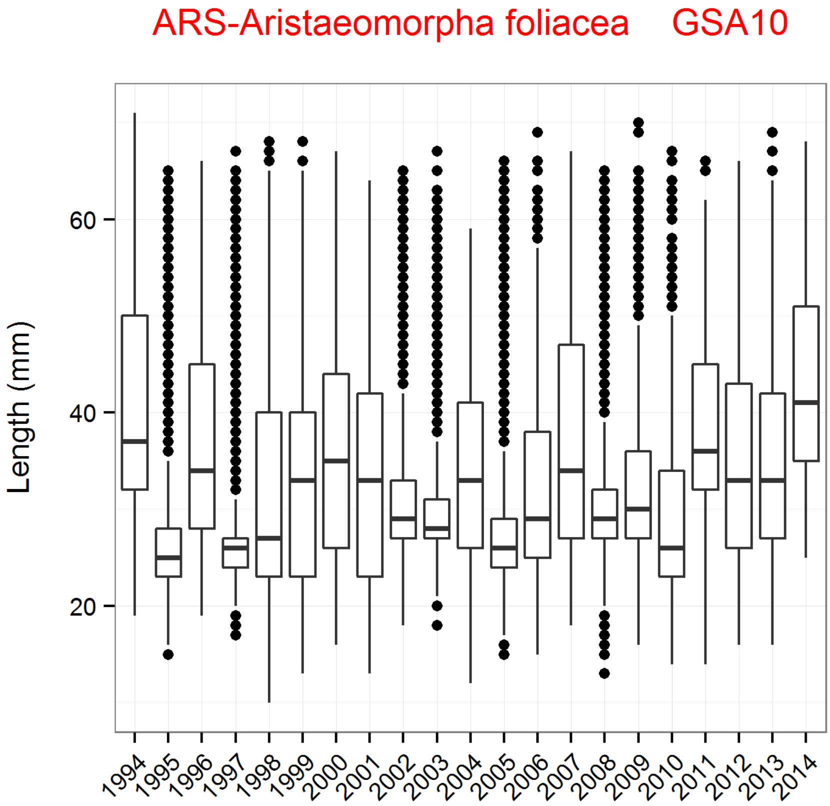


Fig. 5.2.12.6.1.4.4. Giant red shrimp in GSA 10. Demographic characteristics of the population for the period 1994-2014.

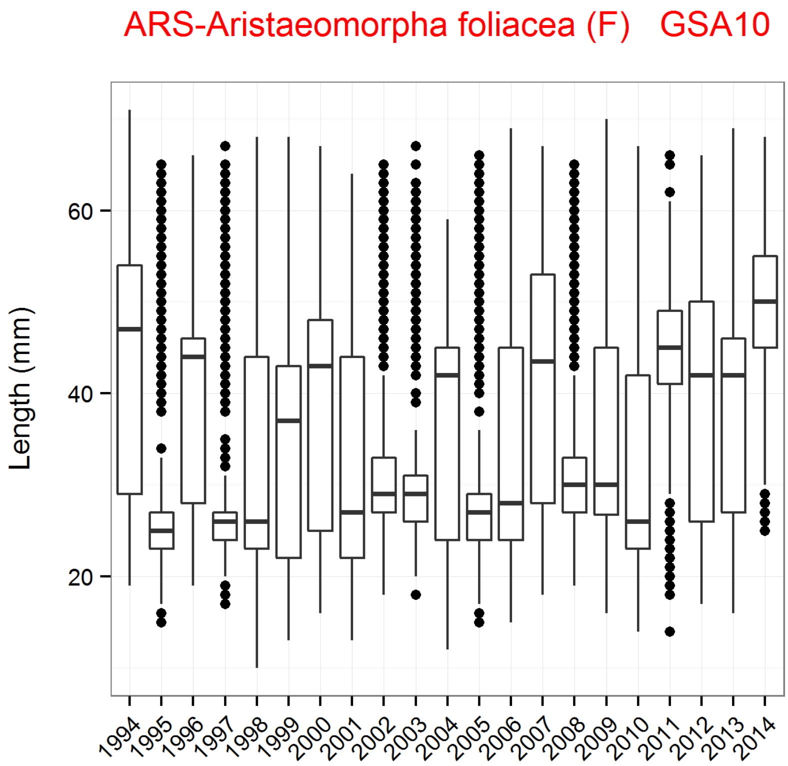


Fig. 5.2.12.6.1.4.5. Giant red shrimp in GSA 10. Demographic characteristics of the females for the period 1994-2014.

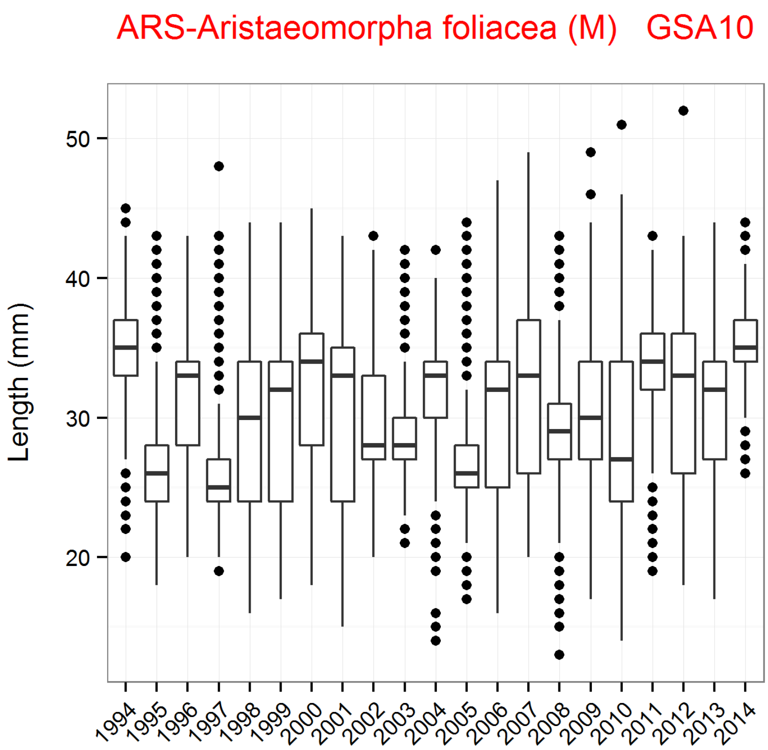


Fig. 5.2.12.6.1.4.6. Giant red shrimp in GSA 10. Demographic characteristics of the males for the period 1994-2014.

5.2.12.7 Stock Assessment

5.2.12.7.1 Methods

The last assessment of giant red shrimp in GSA 10 has been performed during the EWG-12-19. In the last 2015 data call, data from 2006 to 2014 have been provided for the EWG-15-11; the time series from 2006 to 2014 has been considered covering the mean life span of the species, allowing to assess the stock using XSA method. The age distributions from age class 0 to 4+ have been used.

5.2.12.7.2 Input data

For the assessment of giant red shrimp stock in GSA 10 the DCF official data on the length structure has been divided in males and females length structures by means of sex ratio by length; the age distributions by sex have been estimated using the age slicing method and then the resulting distributions were summed up. The DCF official landing data of commercial catch have been used. A sex combined analysis was carried out. The maturity at age has been estimated using the maturity at length transformed to ages by slicing procedure. The natural mortality has been calculated using PRODBIOM (Abella, 1998). The survey indices from MEDITS data from 2006 to 2014 have been used for the tuning. The age distribution is showed in the graph and in the figures and tables below:

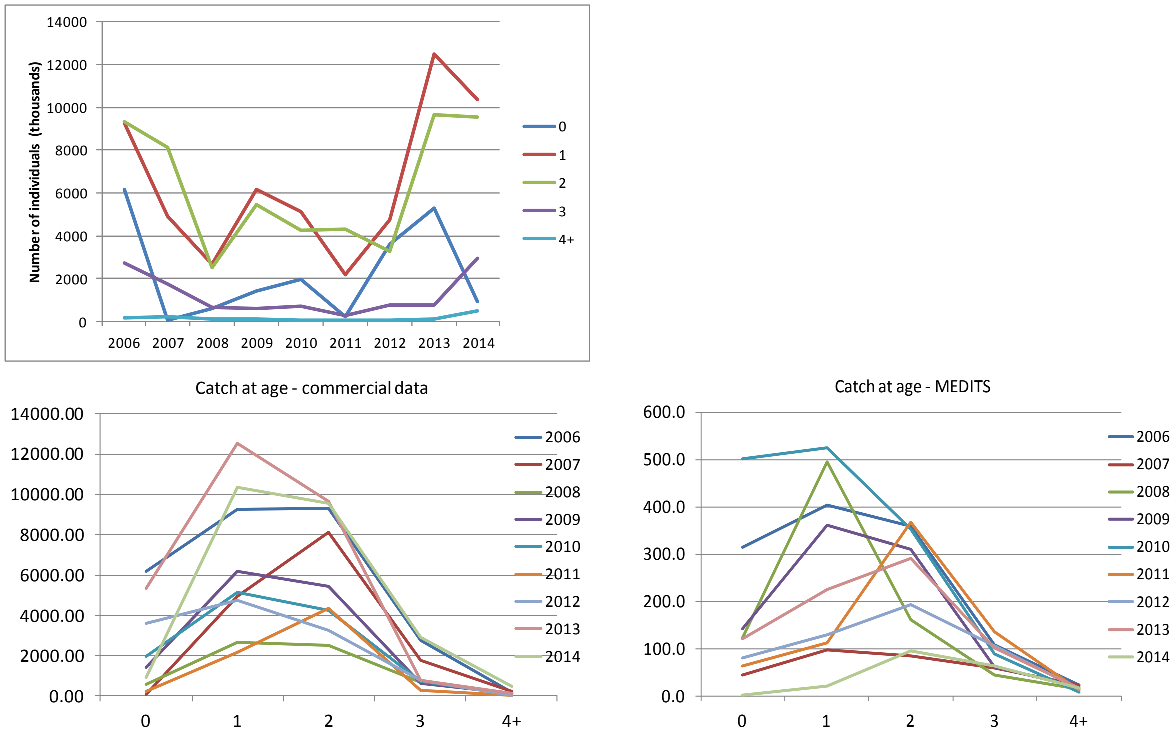


Fig. 5.2.12.7.2.1. Giant red shrimp in GSA 10. Commercial catch in numbers by age and year used in the XSA.

The other inputs are reported in the tables below:

Table 5.2.12.7.2.1. Giant red shrimp in GSA 10. Catch in numbers by age and year used in the XSA.

Catch in numbers (thousands)	age 0	age 1	age 2	age 3	age 4+
2006	6191.53	9249.14	9308.32	2739.20	167.68
2007	83.67	4937.09	8137.44	1775.92	230.49
2008	581.82	2652.89	2498.44	679.19	107.73
2009	1410.77	6174.48	5445.77	601.81	120.38
2010	1983.98	5147.38	4245.29	731.71	66.77
2011	209.76	2164.70	4336.70	281.51	46.74
2012	3581.45	4743.26	3274.08	771.52	36.41
2013	5317.65	12511.43	9634.34	750.89	102.17
2014	933.20	10360.65	9572.44	2923.43	494.99

Table 5.2.12.7.2.2. Giant red shrimp in GSA 10. Weights at age used in the XSA (used for the stock and the catch).

Weight at age (kg)	age 0	age 1	age 2	age 3	age 4+
2006	0.006	0.013	0.021	0.022	0.041
2007	0.009	0.013	0.021	0.029	0.055
2008	0.006	0.012	0.026	0.023	0.038
2009	0.007	0.013	0.018	0.031	0.043
2010	0.006	0.013	0.021	0.026	0.045
2011	0.006	0.021	0.020	0.022	0.029
2012	0.006	0.011	0.020	0.025	0.043
2013	0.006	0.013	0.019	0.024	0.033
2014	0.008	0.015	0.020	0.028	0.036

Table 5.2.12.7.2.3. Giant red shrimp in GSA 10. Indices from MEDITS survey used in the XSA.

Survey indices (n/km^2)	age 0	age 1	age 2	age 3	age 4+
2006	313.8	402.9	357.7	108.3	22.2
2007	43.3	97.7	84.2	59.5	21.8
2008	123.0	493.9	161.6	43.0	13.1
2009	142.5	360.1	310.6	60.7	17.9
2010	501.4	523.6	351.1	88.3	7.6
2011	61.9	112.1	367.4	134.7	12.7
2012	79.1	128.2	193.2	105.9	14.6
2013	119.6	223.8	290.2	100.2	16.9
2014	1.2	19.2	94.5	62.9	16.9

Table 5.2.12.7.2.4. Giant red shrimp in GSA 10. Proportion of matures at age used in the XSA.

Maturity					
Year	age 0	age 1	age 2	Age 3	Age 4+
2006	0.0035	0.424	0.961	0.9990	1
2007	0.0035	0.424	0.961	0.9990	1
2008	0.0035	0.424	0.961	0.9990	1
2009	0.0025	0.382	0.937	0.9995	1
2010	0.0025	0.382	0.937	0.9995	1
2011	0.0025	0.382	0.937	0.9995	1

2012	0.0030	0.3065	0.936	0.9995	1
2013	0.0030	0.3065	0.936	0.9995	1
2014	0.0030	0.3065	0.936	0.9995	1

Table 5.2.12.7.2.5. Giant red shrimp in GSA 10. Natural mortality at age used in the XSA.

Natural mortality				
age 0	age 1	age 2	age 3	Age 4+
1.33	0.73	0.61	0.56	0.53

Table 5.2.12.7.2.6. Giant red shrimp in GSA 10. Growth parameters and length-weight relationship coefficient used in PRODBIOM.

Growth parameters	
CLinf	73
K	0.438
t_0	-0.1
a	0.0014
b	2.62

5.2.12.7.3 Results

XSA was run setting shrinkage at 1.0, 1.5, 2.0 and 2.5. As showed by Fig. 5.2.12.7.3.1, the four different settings produced similar estimates of recruitment and SSB.

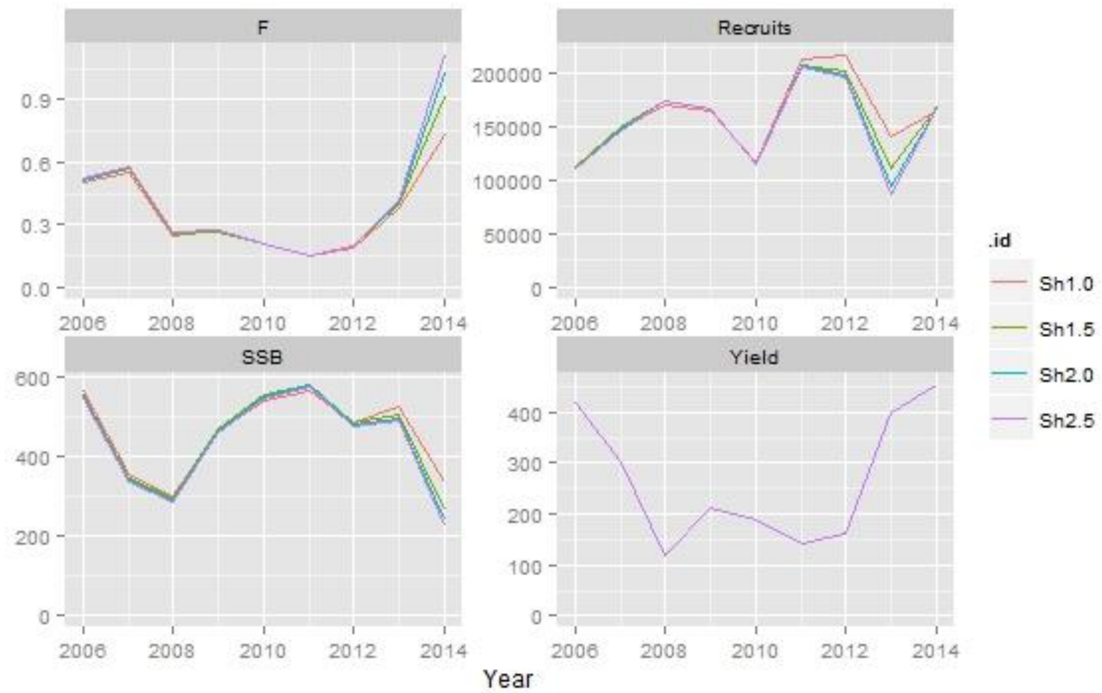


Fig. 5.2.12.7.3.1. Giant red shrimp in GSA 10. XSA outputs for different shrinkage scenario and log residuals for the tuning fleet.

Model with 1.5 shrinkage was adopted as final model based on the analysis of residual distributions (Fig. 5.2.12.7.3.2). Residuals from tuning fleets (MEDITS) per age and year were relatively low, ranging from 2 to - 2, and did not show any trend with time.

Moreover a retrospective analysis was conducted on recruitment, mean F and SSB (Figure 5.2.12.7.3.3) to ensure the robustness of the final estimates. The retrospective series indicate good agreement between years in the assessment results for F, with no systematic bias. More differences are observed for SSB and recruitment.

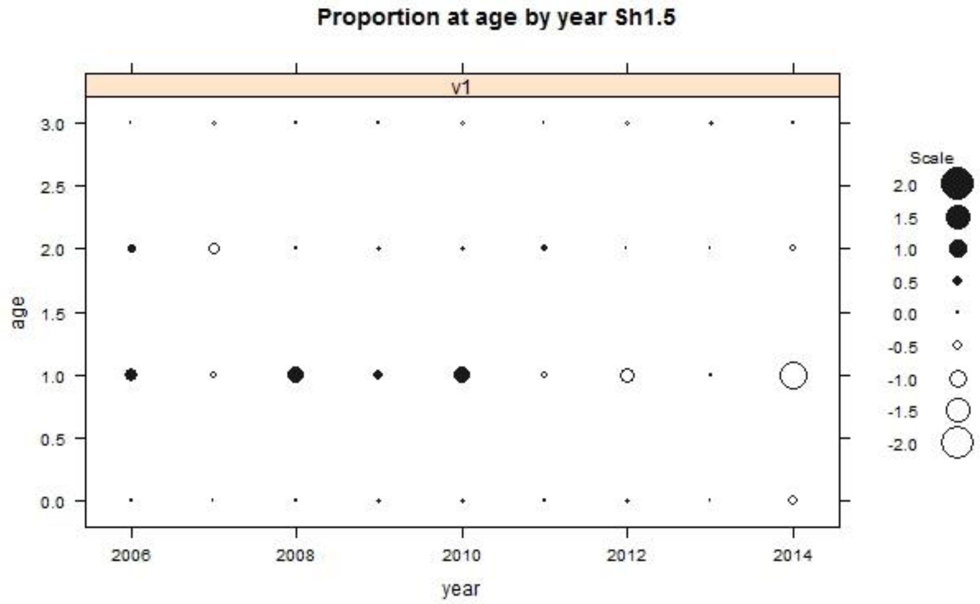


Fig. 5.2.12.7.3.2. Giant red shrimp in GSA 10. Residuals at age obtained with shrinkage set at 1.5.

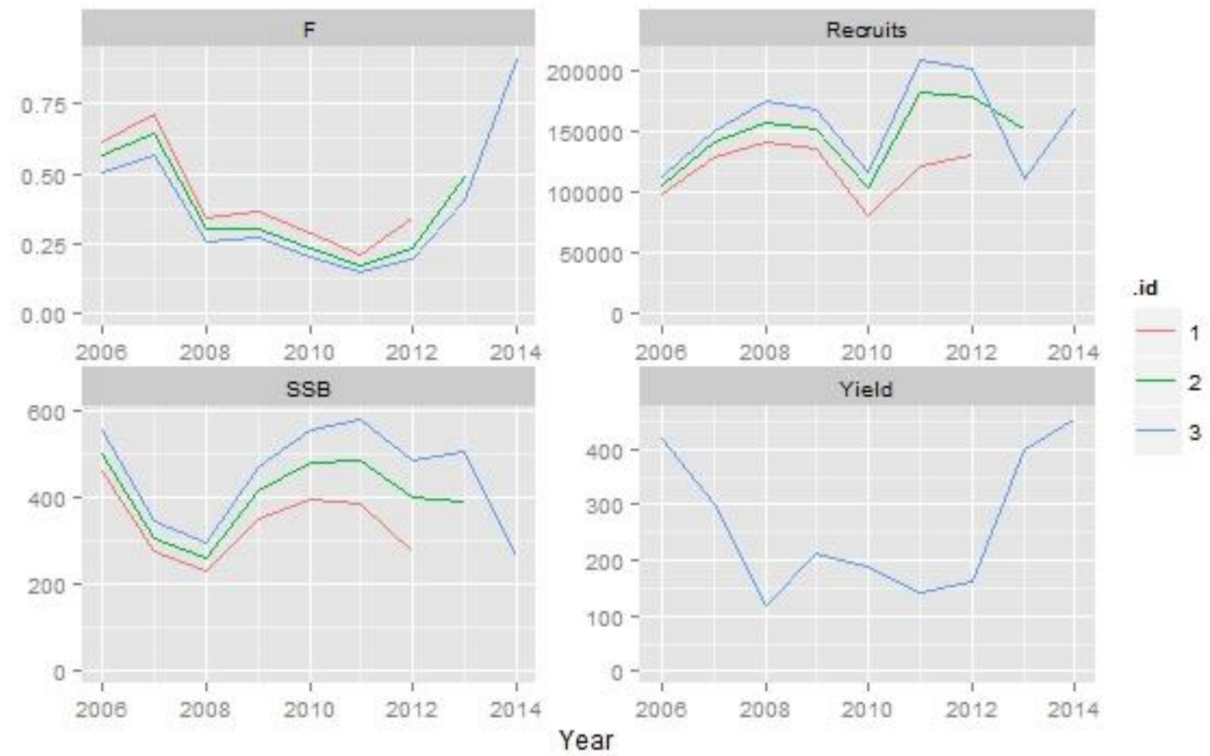


Fig. 5.2.12.7.3.3. Retrospective analysis with shrinkage set at 1.5.

Based on these simulation analyses, the inputs reported in Table 5.2.12.7.3.1. were selected to run the final XSA.

Tab. 5.2.12.7.3.1. Inputs selected to run the final XSA.

fse	rage	qage	Shk.n	Shk.f	Shk.yrs	Shk.ages
1.0	0.0	2.0	true	true	5.0	2.0

XSA main outputs (Fig. 5.2.12.7.3.4) showed a decrease of fishing mortality in the period 2007-2011; then, an evident increase was oserved, reaching a very high value in the last year of the time series. SSB showed an increasing trend up to 2011 followed by a constant decrease up to the minimum in 2014. Recruitment is characterized by a fluctuating trend, varying from a minimum of 113 millions in 2006 to 209 millions in 2011. XSA stock summary results are reported in Table 5.2.12.7.3.2.

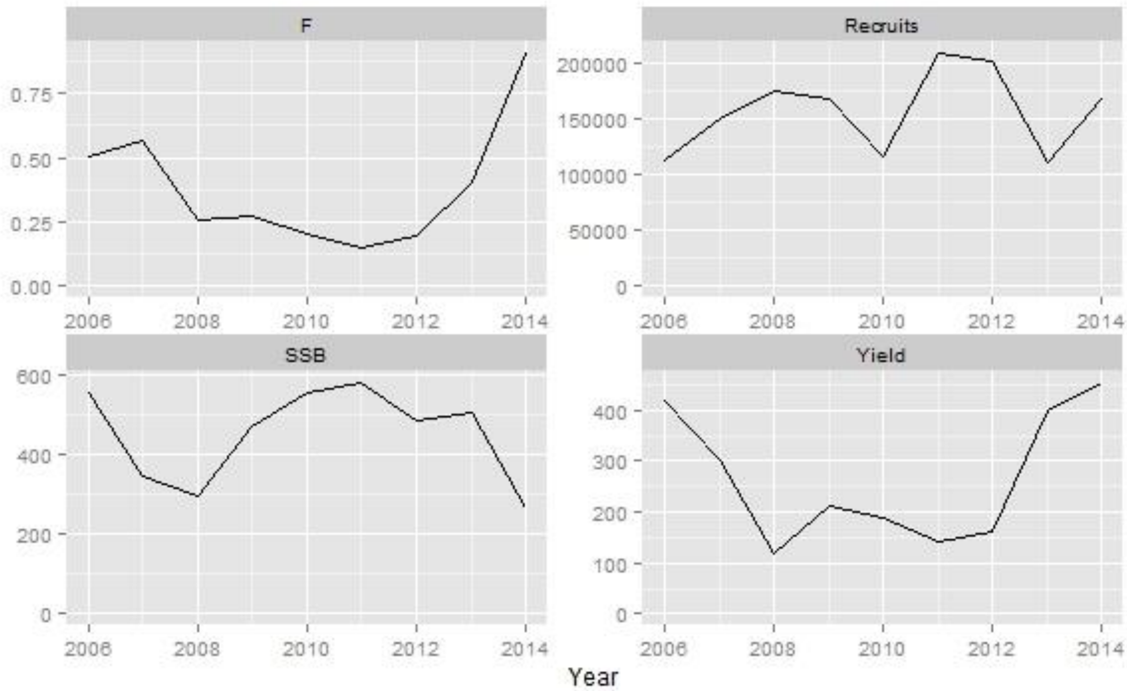


Fig. 5.2.12.7.3.4. Giant red shrimp in GSA 10. XSA summary results. SSB and catch are in tons, recruitment in thousands of individuals.

Tab. 5.2.12.7.3.2. Giant red shrimp in GSA 10. XSA stock summary results.

SSB	2006	2007	2008	2009	2010	2011	2012	2013	2014
Tons	554.91	346.77	294.27	469.81	552.13	579.46	481.92	501.88	265.32

REC	2006	2007	2008	2009	2010	2011	2012	2013	2014
(x1000)	112642	149443	174966	167735	115566	208897	202465	111398	168437

F by age	2006	2007	2008	2009	2010	2011	2012	2013	2014
0	0.113	0.001	0.006	0.016	0.034	0.002	0.035	0.097	0.011
1	0.348	0.311	0.102	0.215	0.186	0.112	0.132	0.429	0.817
2	0.905	1.258	0.448	0.562	0.389	0.411	0.429	0.824	1.610
3	0.664	0.702	0.474	0.280	0.201	0.058	0.177	0.249	1.195

4+	0.664	0.702	0.474	0.280	0.201	0.058	0.177	0.249	1.195

Fbar	2006	2007	2008	2009	2010	2011	2012	2013	2014
(0-3)	0.508	0.568	0.257	0.268	0.202	0.146	0.193	0.400	0.908

The XSA diagnostics are reported below:

XSA Diagnostics 2015-09-03 11:07:14

CPUE data from indices

Catch data for 9 years 2006 to 2014 Ages 0 to 4+

fleet	first age	last age	first year	last year	alpha	beta
Medits	0	3	2006	2014	<NA>	<NA>

Time series weights:

Tapered time weighting applied
Power = 3 over 20 years

Catchability analysis:

Catchability independent of size for ages > 0

Catchability independent of size for ages > 2

Terminal population estimation:

Survivor estimates shrunk towards the mean F
of the final 5 years of the 2 oldest ages.

S.E. of the mean to which the estimates shrunk = 1.5

Minimum standard error for population
estimates derived from each fleet = 0.3

prior weighing not applied

weights
year

age	2006	2007	2008	2009	2010	2011	2012	2013	2014
all	0.82	0.877	0.921	0.954	0.976	0.99	0.997	1	1

Fishing mortalities
year

age	2006	2007	2008	2009	2010	2011	2012	2013	2014
0	0.113	0.001	0.006	0.016	0.034	0.002	0.035	0.097	0.011
1	0.348	0.311	0.102	0.215	0.186	0.112	0.132	0.429	0.817
2	0.905	1.258	0.448	0.562	0.389	0.411	0.429	0.824	1.610
3	0.664	0.702	0.474	0.280	0.201	0.058	0.177	0.249	1.195
4+	0.664	0.702	0.474	0.280	0.201	0.058	0.177	0.249	1.195

XSA population number (Thousand)
Age

year	0	1	2	3	4+

2006	112642	45326	21200	7473	438				
2007	149443	26607	15422	4658	578				
2008	174966	39481	9395	2381	365				
2009	167735	45975	17185	3263	636				
2010	115566	43637	17870	5323	475				
2011	208897	29544	17456	6580	1076				
2012	202465	55141	12735	6288	291				
2013	110826	52637	23651	4523	597				
2014	168437	26727	16232	5548	879				
Estimated population abundance at 1st Jan 2015									
age									
year	0	1	2	3	4+				
2015	0	44069	5688	1764	959				
Fleet: Medits									
Log catchability residuals.									
Year									
age	2006	2007	2008	2009	2010	2011	2012	2013	2014
0	0.066	-0.071	0.101	0.104	0.122	0.082	0.102	-0.048	-0.437
1	0.701	-0.206	0.89	0.492	0.900	-0.297	-0.774	0.031	-1.525
2	0.329	-0.582	0.065	0.186	0.162	0.244	-0.072	-0.024	-0.302
3	-0.003	-0.106	0.099	0.009	-0.155	-0.033	-0.155	0.168	0.079
Regression statistics									
Ages with q dependent on year class strength									
-0.336697942	13.67359336								
Terminal year survivor and F summaries:									
,Age 0 Year class 2014									
	scaledWts	survivors	yrcls						
Medits	0.109	161263	2014						
fshk	0.031	11805	2014						
nshk	0.860	39185	2014						
,Age 1 Year class 2013									
	scaledWts	survivors	yrcls						
Medits	0.563	1238	2013						
fshk	0.437	28994	2013						
,Age 2 Year class 2012									
	scaledWts	survivors	yrcls						
Medits	0.833	1304	2012						
fshk	0.167	9851	2012						
,Age 3 Year class 2011									
	scaledWts	survivors	yrcls						
Medits	0.883	1038	2011						
fshk	0.117	873	2011						

5.2.12.8 Reference points

5.2.12.8.1 Methods

The yield per recruit (YpR) analysis was run using XSA method. The analysis was performed to estimate $F_{0.1}$ as target equilibrium YPR reference point for the stock.

5.2.12.8.2 Input data

The input parameters were the same used for the XSA stock assessment and its results.

5.2.12.8.3 Results

YpR output curve is illustrated in the Figure 5.2.12.8.3.1, while $F_{0.1}$ and F_{bar} are compared in Figure 5.2.12.8.3.2. $F_{0.1}$ estimated by the model was 0.65.

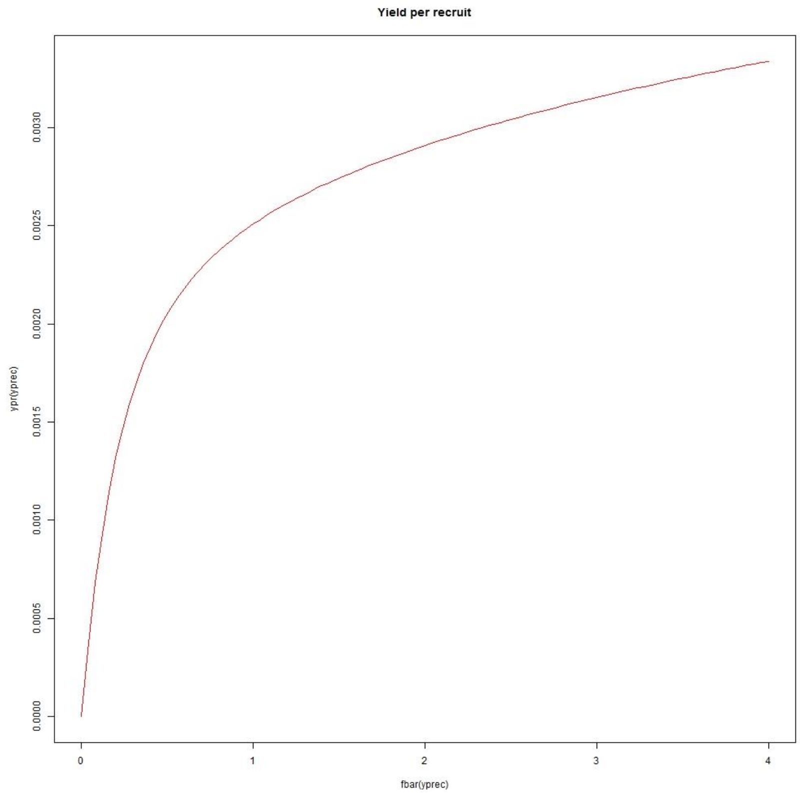


Fig. 5.2.12.8.3.1. Giant red shrimp in GSA 10. Yield per Recruit curve.

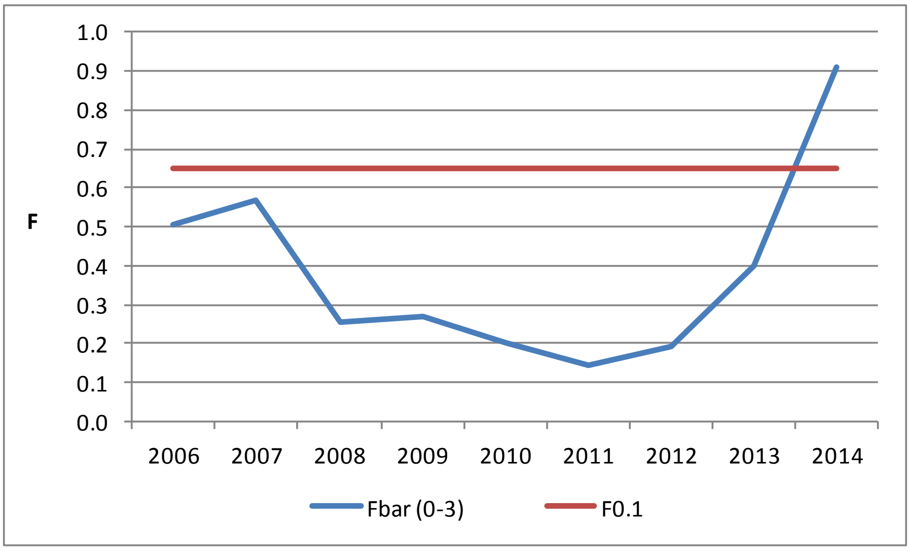


Fig. 5.2.12.8.3.2. Giant red shrimp in GSA 10. Trend of F_{bar} obtained by means of XSA and comparison with $F_{0.1.}$

5.2.12.9 Data quality

Landing and discard data were available for the period 2006-2014. Demographic structures of the gillnet landing were available for three years only. However, this fishery contributes minimally to the total landing of *A. foliacea* in the GSA 10, representing on average 2.4% of the biomass landed per year.

5.2.12.10 Short term predictions 2016-2018

5.2.12.10.1 Method

A deterministic short term prediction for the period 2015 to 2017 was performed using the FLR routines provided by JRC and based on the results of the XSA stock assessments performed during EWG14-19 for the years 2006–2014.

5.2.12.10.2 Input parameters

The input parameters were the same used for the XSA stock assessment and its results.Different scenarios, zero catch, harvest at reference point, Fstatus quo and a series of multiplier of Fstq were performed. Fstq=0.908 has been estimated as the fishing mortality of last year (2014) estimated with FLR.

5.2.12.10.3 Results

A short term projection (Table 5.2.12.10.3.1), assuming an Fstq of 0.908 in 2015 and a recruitment of 168437 thousands individuals show that:

- Fishing at the Fstq (0.908) generates a decrease of the catch of about 13% from 2014 to 2016 and a decrease of about 9% of the spawning stock biomass 2016 to 2017.

- Fishing at $F_{0.1}$ (0.65) generates a decrease of the catch of about 31% from 2014 to 2016 and an increase of the spawning stock biomass of about 10% from 2016 to 2017.

Table 5.2.12.10.3.1. Giant red shrimp GSA 10. Short term forecast in different F scenarios. Basis: F(2015) = mean (F_{bar} 0-3 2012-2014)= 1.40; R(2015) = geometric mean of the recruitment of the last 3 years; R = 156034 thousands; SSB(2014) = 265 t, Catch (2014)= 465 t.

Rationale	Ffactor	Fbar	Catch 2016	Catch 2017	SSB 2017	Change SSB 2016-2017(%)	Change Catch 2014-2016(%)
Zero catch	0.0	0.000	0.000	0.000	579.807	99.265	-100
High long term yield F(0.1)	0.716	0.650	314.867	332.890	200.574	9.981	-30.646
Status quo	1	0.908	395.637	375.903	139.228	-8.707	-12.855
Different scenarios	0.1	0.091	57.523	84.372	494.482	81.661	-87.330
	0.2	0.182	109.693	151.054	423.088	66.075	-75.838
	0.3	0.272	157.148	203.984	363.244	52.277	-65.386
	0.4	0.363	200.438	246.209	312.989	40.0635	-55.851
	0.5	0.454	240.043	280.092	270.702	29.254	-47.127
	0.6	0.545	276.380	307.465	235.044	19.690	-39.123
	0.7	0.636	309.810	329.747	204.909	11.223	-31.760
	0.8	0.726	340.651	348.042	179.378	3.749	-24.967
	0.9	0.817	369.179	363.205	157.695	-2.864	-18.683
	1.1	0.999	420.237	386.653	123.455	-13.867	-7.437
	1.2	1.090	443.166	395.859	109.942	-18.422	-2.386
	1.3	1.180	464.590	403.834	98.329	-22.440	2.333
	1.4	1.271	484.654	410.830	88.313	-25.982	6.752
	1.5	1.362	503.487	417.034	79.646	-29.103	10.900
	1.6	1.453	521.204	422.598	72.117	-31.849	14.803
	1.7	1.544	537.906	427.642	65.553	-34.266	18.482
	1.8	1.634	553.685	432.259	59.807	-36.389	21.957
	1.9	1.725	568.621	436.522	54.757	-38.253	25.247
	2	1.816	582.786	440.490	50.301	-39.889	28.367

5.2.12.11 Short term predictions 2015-2017 by fleet

5.2.12.11.1 Method

A deterministic short term prediction by fleet for the period 2015 to 2017 was performed using the FLR routines provided by JRC and based on the results of the XSA stock assessments performed during EWG 15-11.

5.2.12.11.2 Input parameters

The same parameters used in the short term by single fleet were used.

5.2.12.11.3 Results

Table 5.2.12.11.3.1. Giant red shrimp in GSA 10. Short term forecast by fleet.

Fleet	Year	Catches	Partial F
GNS	2015	2	0.004
OTB	2015	223	0.408
GNS	2016	5	0.006

OTB	2016	376	0.606
GNS	2017	4	0.006
OTB	2017	340	0.606

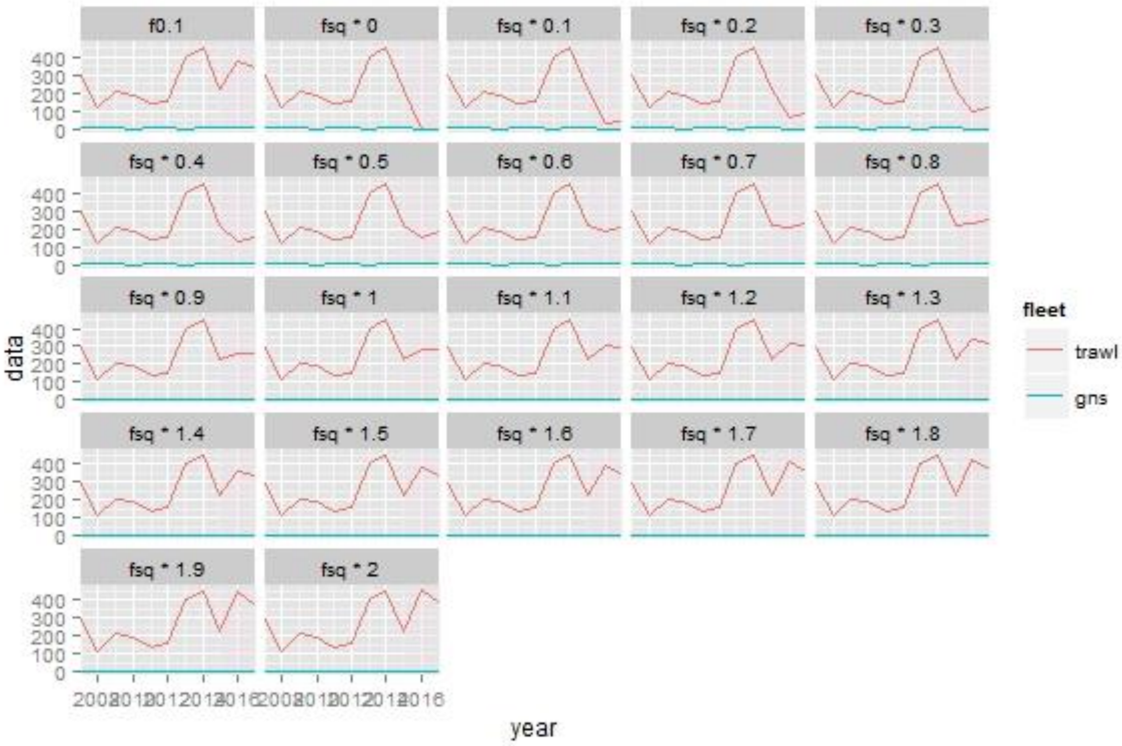


Figure 5.2.12.11.3.1. Giant red shrimp in GSA 10. Short term forecast by fleet.

5.2.12.12 Medium term predictions

5.2.12.12.1 Method

The medium term projections were not conducted because no meaningful stock-recruitment relationship was found.

5.2.12.13 Stock advice

EWG 15-11 proposes $F_{0.1}$=0.65 as limit management reference point consistent with high long term yield and lower risk of stock collapse (proxy of F_{MSY}).

SSB showed a decresing trend in the last years while recruitment fluctuated. As concerns F, an evident increasing trend is observed in the last three years. According to the F estimates obtained using landing and discard data with XSA, in the last year of the time series (2014) F was above the estimated reference value of F_{MSY}=0.65.

STECF-EWG 15-11 advises to reduce the current level of effort and/or catches of the relevant fleets in order to avoid future loss in stock productivity. Catches of giant red shrimp in 2016 consistent with F_{MSY} should not exceed 315 tonnes.

5.2.12.14 Management strategy evaluation

The Management Strategy Evaluation was ran to evaluate if the F_{MSY} ranges were precautionary. The F_{MSY} ranges were derived using the formula provided by STECF 15-09. F ranges results were F_{upper}=0.88 and F_{lower}=0.43. B_{lim} was estimated as B_{loss}=265 t. The following figure shows the results of the MSE. The probability of SSB to fall below B_{lim} is equal to 0.

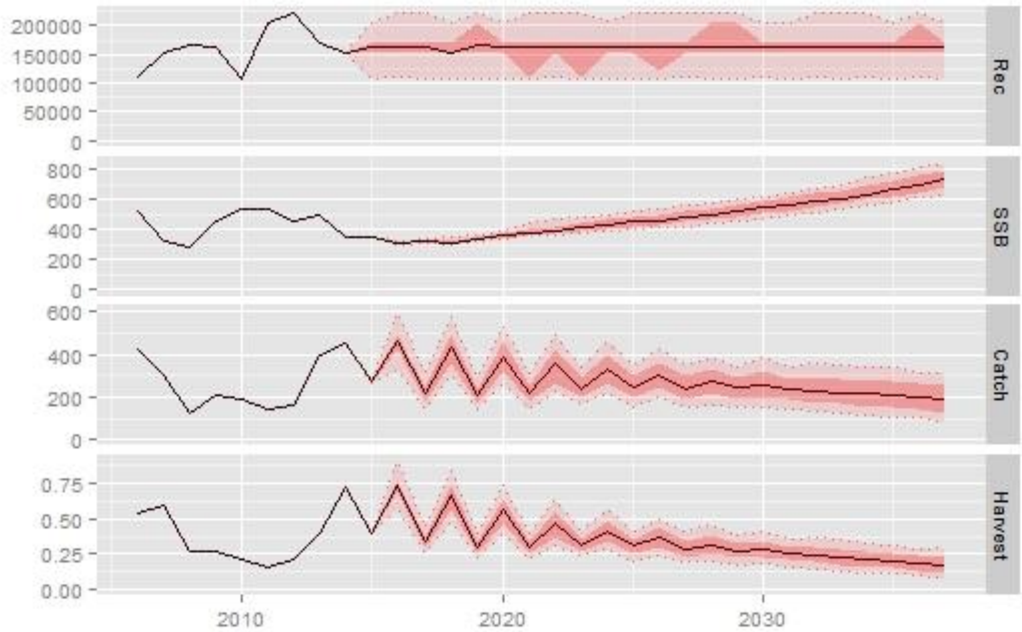


Figure 5.2.3.14.1. Giant red shrimp GSA 10. Marine Strategy Evaluation.

The dynamics observed for this stock are the result of the stock assessment model (i.e. XSA) settings used inside the MSE becoming less appropriate as the stock status changes in time (i.e. stock assessment settings are often specific to a particular range of stock status). This leads to an increasing difference between the perceived stock and the operating model (i.e. the 'true' stock). To avoid this behaviour in the future, for some of the stocks as it is the case here, a more general stock assessment method should be used in the MSE loop that is less sensitive to the stock status.

5.2.13 STOCK ASSESSMENT OF GIANT RED SHRIMP IN GSA 11

5.2.13.1 Stock Identification

According to StockMed project (Fiorentino et al., 2014) the stock configuration with 2 clusters represents the best hypothesis of stock structure in the western Mediterranean. In particular the stock inhabiting GSA 11 seems to be the same in GSA 1, 5, 7, 8 and the northern portion of GSA 9. However due to the lack of more detailed information and analysis, for the present report the assessment have been carried out only in GSA 11 (Fig. 5.2.13.1.1), as it was carried out in the past during STECF EWG 14-19 and STECF EWG 11-14 .

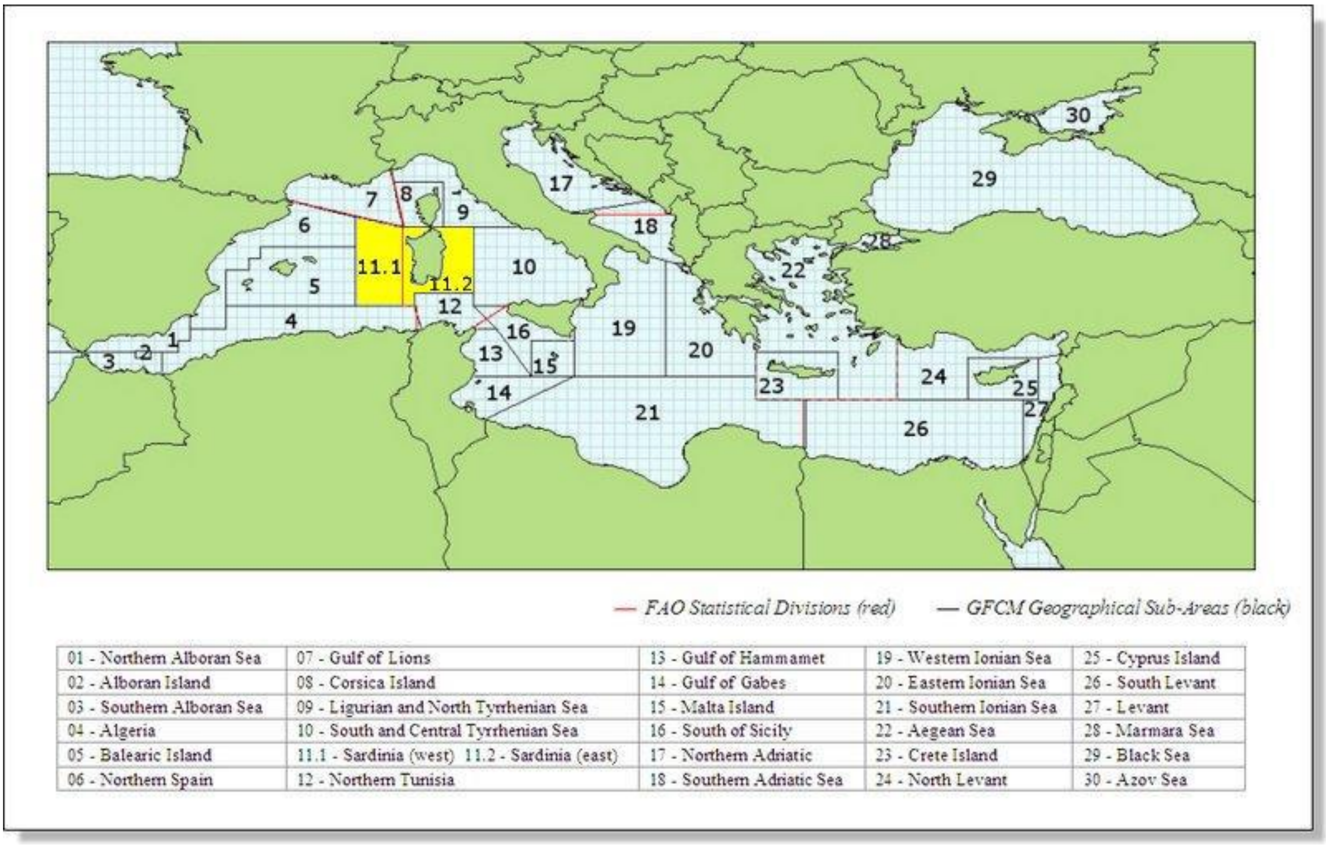


Fig. 5.2.12.1.1. Geographical localization of GSA 11.

Aristaeomorpha foliacea (Risso, 1827) is a dominant species of bathyal megafaunal assemblages and it is sympatric with *Aristeus antennatus* in all the GSA 11. Both species have considerable interest for fisheries.

The giant red shrimp is considered midbathyal occupying mainly the middle slope, between 450 and 600 m of depth, although the range of occurrence is wider (250 and 1300 m) and includes also the epibathyal grounds.

Regarding its trophic ecology, Cartes et al. (2014) found a significant correlation with environmental variables, such us temperature and salinity of intermediate waters, feeding intensity (gut fullness) and prey diversity and stated that the GSA 11 is one of the optimal ecological habitats of *A. foliacea* in the Mediterranean sea. In their preferred (core) habitats, species may reach their greatest densities and best biological condition in terms of size, survivorship and fecundity. In the case of *A. foliacea*, the best trophic conditions coincide with areas with the highest densities, where the species has more structured populations, with peaks of small recruits and larger females.

The giant red shrimp shows high densities and well-structured populations with a clear multimodal size pattern in the GSA 11. Seasonal changes have been reported from southern Sardinia in both the vertical distribution and size-related spatial abundance of *A. foliacea*, with large females (preferentially) tending to move gradually deeper (to 650-740 m) from spring to summer (Mura et al., 1997).

5.2.13.2 Growth

The von Bertalanffy Growth Function parameters of *A. foliacea* by sex in the Sardinian seas found in the scientific literature, are reported in Table 5.2.13.2.1. The species shows a marked difference in growth between sexes, with females reaching bigger length than males: the observed maximum length in the landings was CL = 69 mm for females and CL = 48 mm for males.

Tab. 5.2.13.2.1. Giant red shrimp in GSA 11. Von Bertalanffy Growth function parameters for *Aristaeomorpha foliacea* in GSA 11. Values marked in bold were used in the current assessment.

Females			Males			Reference
Linf.	K	t0	Linf.	K	t0	
75.40	0.46	0.58	49-53	0.6-0.67	0.001-0.3	Cau *et al.* 1994
70.70	0.54	0.27				Cau *et al.* 2002
72.21	0.50	0	**42.71**	**0.77**	**-0.27**	AAVV 2008; Red's Project
70.70	**0.58**	**-0.27**				DCF 2015

5.2.13.3 Maturity

In the western Mediterranean, the spawning season occurs between the end of July and September, with a peak in the summer (July-August) (Mura et al., 1992; Cau et al., 1994; Mori et al., 1994; Spedicato et al., 1994; Ragonese and Bianchini, 1995, Perdichizzi et al., 2012). Before spawning, large females gradually move deeper, to 650–740 m for reproduction (Mura et al., 1997). The size at onset of sexual maturity occurs at about 32.6 mm CL for females (AAVV, 2008).

The maturity vectors for males and females came from the DCF data of year 2014. A weighted maturity vector for males and females combined was produced and used in the current assessment (Table 5.2.13.3.1).

Table 5.2.13.3.1. Giant red shrimp in GSA 11. Sex ratio and maturity vectors for males, females and both sexes combined. Values marked in bold were used in the current assessment.

	Age 0	Age 1	Age 2	Age 3	Age 4+
Sex Ratio (F/F+M)	0.46	0.77	1	1	1
Females	0	0.59	1	1	1
Males	0	0.81	1	1	1
Combined	**0**	**0.64**	**1**	**1**	**1**

5.2.13.4 Natural mortality

The natural mortality vector was calculated using PRODBIOM (Abella et al. 1997) separately for males and females (Table 5.2.13.4.1). A weighted vector for both sexes combined was constructed for the assessment.

Table 5.2.13.4.1. Giant red shrimp in GSA 11. Natural mortality vectors for males, females and both sexes. Values marked in bold were used in the current assessment.

	Age 0	Age 1	Age 2	Age 3	Age 4+
Females	1.12	0.57	0.46	0.41	0.36
Males	1.22	0.61	0.49	0.44	0.38
Combined	**1.17**	**0.58**	**0.46**	**0.41**	**0.36**

5.2.13.5 Fisheries

5.2.13.5.1 General description of the fisheries

As a consequence of government incentives aimed at the fleet modernization, since 1994 up to 2004 the trawl sector showed gradually but remarkable changes, with a general increase in the number of vessels and the replacement of the older ones, low tonnage wooden boats by larger steel boats.

Currently, in GSA 11 operate a total of about 1300 boats, 150 of which are small, medium and big trawlers. Administratively they all belong to the major fishing ports ("compamare"), namely Cagliari, La Maddalena, Olbia, Oristano and Porto Torres (Fig. 5.2.13.5.1.1). Other important ports are Alghero, La Caletta and Sant'Antioco.

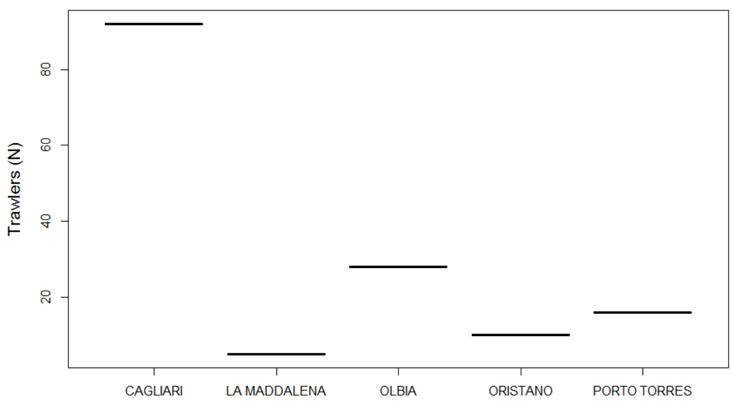


Fig. 5.2.13.5.1.1. Number of trawlers operating in GSA 11 grouped by the main ports.

The giant red shrimp is a high-value species, being a target of a specific deep trawl fishery in the whole GSA 11. The large trawlers of GSA 11 operate all the week from Monday to Friday doing daily or bi-daily fishing trips and delivering products to local markets. Moreover, due to the distance of the fishing grounds to the main harbours of the western cost and the dominant weather conditions, the fleet targeting *A. foliacea* shows some seasonal variations, with more time spent at sea from mid spring to mid-autumn (Murenu et al., 2011). Some large trawlers move seasonally to different fishing grounds far from the usual ports. When the weather permits, small trawlers also perform daily fishing trips to target giant red shrimp.

5.2.13.5.2 Management regulations applicable in 2015

As in other areas of the Mediterranean, management of the stock is based on the control of fishing capacity (licenses), fishing effort (fishing activity) and technical measures (mesh size and area/season closures). EC regulation 1967/2006 does not provide for a minimum length size for this species.
Since 2012, a reduction of the fishing ban period that generally was enforced for 45 days has occured. In 2012 and 2013 the fishing ban was established by the autonomous region of Sardinia from 1st to 30th of September, while in 2014 it was established from the 15th of September until the 15th of October.

5.2.13.5.3 Landings

Giant red shrimp fishery are targeted only by trawlers. According to DCF data uploaded for the purposes of STECF EWG 15-11 the landings of giant red shrimp were at a maximum of 170 tons in 2005 followed by a gradual decline in the successive years (Fig. 5.2.13.5.3.1). The lowest value (38.6 tonnes) was obtained in 2008.

Figure 5.2.13.5.3.1. Giant red shrimp in GSA 11. Annual landings according to DCF data.

The age structure of the landings, according to the DCF data, showed that most of the catch is composed by the age groups 1 and 2, corresponding to a length range between 22 and 37 mm CL (Figs. 5.2.13.5.3.2 and 5.2.13.5.3.3).

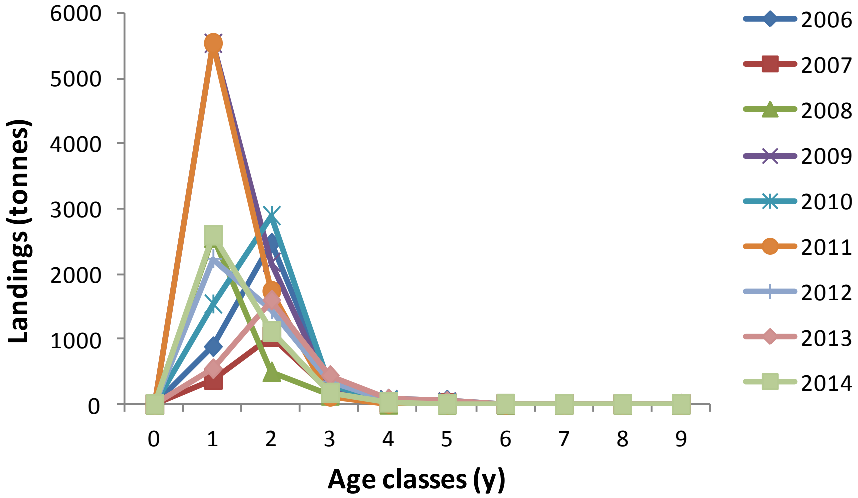


Fig. 5.2.13.5.3.2. Giant red shrimp in GSA 11. Catch composition by age from 2006 to 2013 according to DCF data.

Fig. 5.2.13.5.3.3. Giant red shrimp in GSA 11. Catch composition by length from 2006 to 2013 according to DCF data.

In the DCF data provided to the group also 2005 catch at age data were present. However, the reported catch composition by age was inconsistent with that of years 2006-2014 as it was represented only by ages 0 and 1. Therefore, 2005 catch at age data are not presented in figure 5.2.13.5.3.2.

In figure 5.2.13.5.3.4, the LFDs age-sliced on the basis of the VBGF (Table 5.2.13.2.1) are presented. The age-slicing has been carried out using LFDA (Kirkwood et al., 2001).

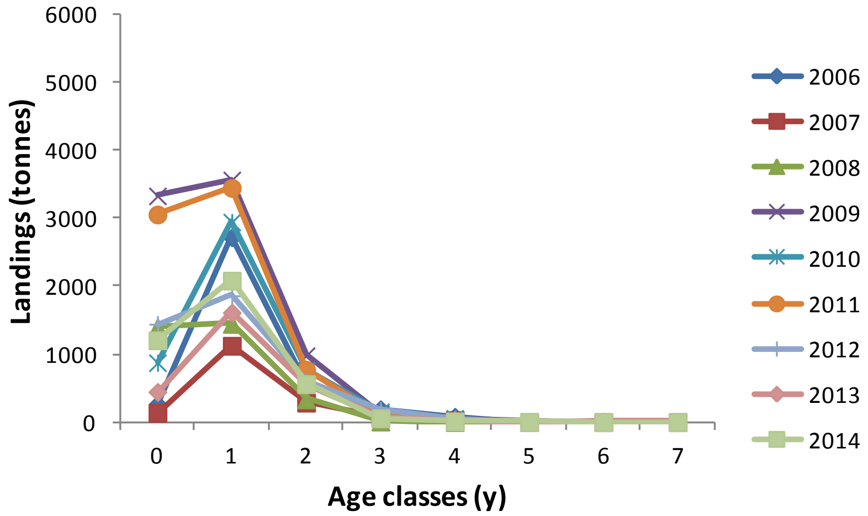


Fig. 5.2.13.5.3.4. Giant red shrimp in GSA 11. Catch composition by age from 2006 to 2013 calculated from age-slicing of LFD data reported in the DCF.

5.2.13.5.4 Discards

No data on discards were present in the 2015 DCF data call for this species in GSA 11. Discards are considered to be neglegible.

5.2.13.5.5 Fishing effort

Fishing effort has been decreasing since 2004 with the lowest values reached in 2013 (Tab. 5.2.13.5.5.1; Fig. 5.2.13.5.5.1).

Table 5.2.13.5.5.1. Fishing effort of the trawl fleet targeting giant red shrimp in GSA 11.

Country	Area	Gear	Year	Nominal Effort	Gt * Days at sea	No Vessels
Italy	GSA 11	OTB	2004	7706431	1721988	167
Italy	GSA 11	OTB	2005	7324728	1785484	146
Italy	GSA 11	OTB	2006	5752588	1358732	194
Italy	GSA 11	OTB	2007	5867826	1414387	241
Italy	GSA 11	OTB	2008	4326313	1095797	146
Italy	GSA 11	OTB	2009	4370758	1045255	149
Italy	GSA 11	OTB	2010	4036734	943795	124
Italy	GSA 11	OTB	2011	3788057	939676	90
Italy	GSA 11	OTB	2012	3824269	922717	78
Italy	GSA 11	OTB	2013	3139044	695331	89
Italy	GSA 11	OTB	2014	3298194	848000	102

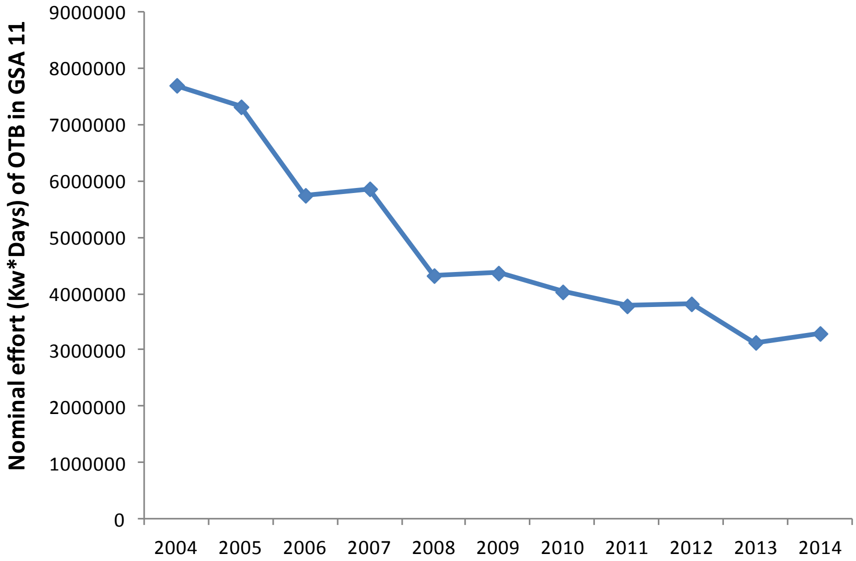


Fig. 5.2.13.5.5.1. Trends in fishing effort (kW*days) for trawl fleet targeting giant red in GSA 11 in the period 2004-2014.

5.2.13.6 Scientific surveys

5.2.13.6.1 Survey #1 (MEDITS)

5.2.13.6.1.1 Methods

Since 1994 the MEDITS trawl surveys have been carried out annually between May and July (except in 2007).

According to the MEDITS protocol (Relini, 2000; Bertand et al., 2002) a stratified random sampling design with allocation of hauls proportional to depth strata extension (depth strata: A: 10–50 m, B: 51–100 m, C: 101–200 m, D: 201–500 m, E: 501–800 m) was adopted. A specific gear (GOC 73, with a 20 mm stretched mesh size in the cod-end) was always used following the specifications reported in Dremière and Fiorentini (1996).

Based on the DCR data call, abundance and biomass indices were recalculated. In GSA 11 the following number of hauls was reported per depth stratum (Tab. 5.2.13.6.1.1).

Tab. 5.2.13.6.1.1 Giant red shrimp in GSA 11. Number of hauls per year and depth stratum in GSA 11, 1994-2013.

Strata	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
A	16	18	20	21	20	19	19	17	20	18	15	17	19	20	17	18	19	20	19	20	21
B	25	20	23	23	22	22	22	25	19	19	20	22	19	19	19	20	19	18	20	19	19
C	20	24	31	31	31	30	31	29	24	24	24	23	24	24	22	24	24	25	23	24	24
D	26	22	24	24	23	23	21	22	20	20	18	20	20	21	21	19	20	20	21	21	21
E	29	23	27	27	27	26	30	29	19	18	18	15	16	16	16	16	17	18	18	17	17

Data were assigned to strata based upon the shooting position and average depth (between shooting and hauling depth). Catches by haul were standardized to square kilometre. Hauls noted as valid were used only, including stations with no catches of hake, red mullet or giant red shrimp (zero catches are included).

The abundance and biomass indices by GSA were calculated through stratified means (Cochran, 1953; Saville, 1977). This implies weighting of the average values of the individual standardized catches and the variation of each stratum by the respective stratum areas in each GSA:

$Yst = \Sigma (Yi*Ai) / A$

$V(Yst) = \Sigma (Ai^2 * si^2 / ni) / A^2$

Where:

A=total survey area

Ai=area of the i-th stratum

si=standard deviation of the i-th stratum

ni=number of valid hauls of the i-th stratum

n=number of hauls in the GSA

Yi=mean of the i-th stratum

Yst=stratified mean abundance

V(Yst)=variance of the stratified mean

Length distributions represented an aggregation (sum) of all standardized length frequencies (subsamples raised to standardized haul abundance per hour) over the stations of each stratum. Aggregated length frequencies were then raised to stratum abundance * 100 (because of low numbers in most strata) and finally aggregated (sum) over the strata to the GSA. Given the sheer number of plots generated, these distributions are not presented in this report.

5.2.13.6.1.2 Geographical distribution

The spatial distribution of *Aristaeomorpha foliacea* has been described by modelling the spatial correlation structure of the abundance indices using geostatistical techniques. The stock is more abundant in the southern part of the GSA (Sardinian Sea) as shown in Figure 5.2.13.6.1.2.1.

The species shows a wide depth distribution over muddy and sandy-muddy bottoms from 450 to 700 m depth. The highest densities are found around the shelf break and deep slope of the south-western coast where are located the most persistent nursery and spawning areas (Fig. 5.2.13.6.1.2.1).

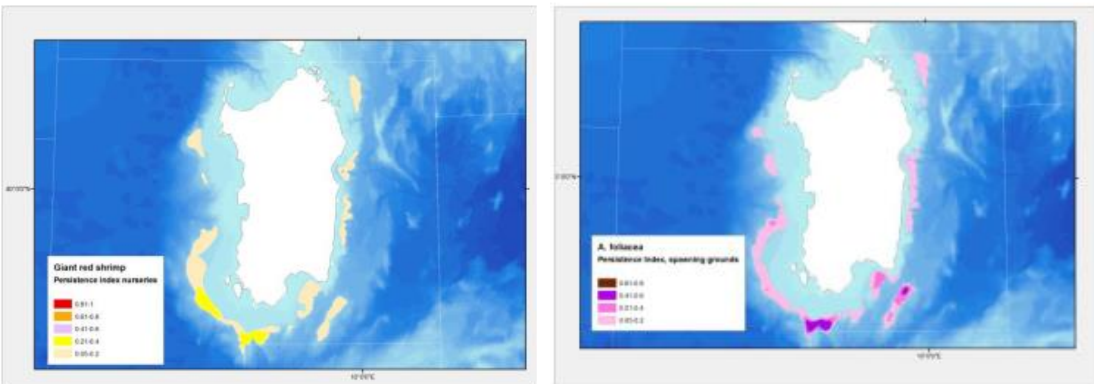


Fig. 5.2.13.6.1.2.1. Giant red shrimp in GSA 11. Temporal persistence of nursery areas (left) and spawning areas (right) based on MEDITS data 1994-2010 (maps from the EU Mediseh-marea project).

5.2.13.6.1.3 Trends in abundance and biomass

Fishery independent information regarding the state of the giant red shrimp in GSA 11 was derived from the international survey MEDITS. Figure 5.2.13.6.1.3.1 displays the estimated trends of giant red

shrimp abundance and biomass in GSA 11 by sex and for both sexes combined. The estimated abundance and biomass indices since the beginning of the time-series show high variation without any trend until 2007, when a significant reduction was observed. In the period from 2008 to 2014 the trend was fluctuating again but showing in general lower values that the previous period. The females are in general more abundant and exhibit bigger fluctuations than males.
From 1994 to 2005 two trawl surveys were regularly carried out each year: MEDITS, in spring, and GRUND, in autumn, although the MEDITS data only are available to the STECF.

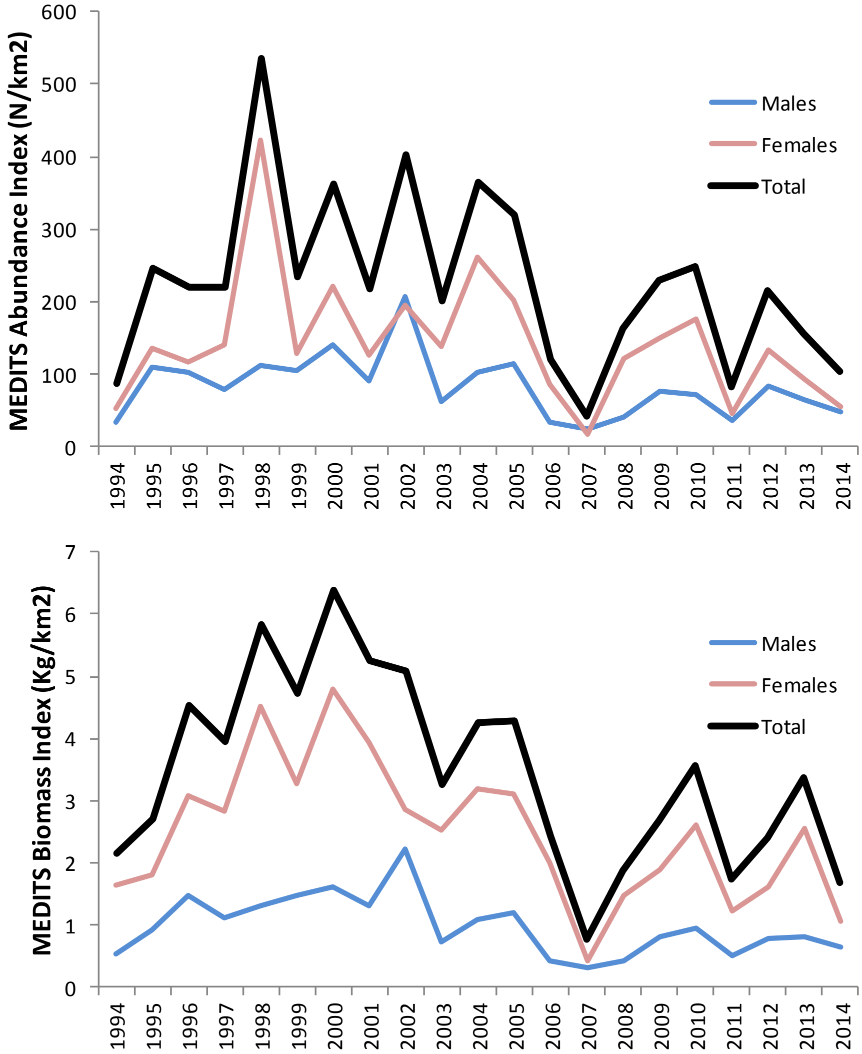


Fig. 5.2.13.6.1.3.1. Giant red shrimp in GSA 11. MEDITS abundance and biomass indices.

5.2.13.6.1.4 Trends in abundance by length or age

Figs 5.2.13.6.1.4.1 and 5.2.13.6.1.4.2 show the standardized length frequency distribution (n/Km^2) of *A. foliacea* females and males in GSA 11 for the period 1994-2013.

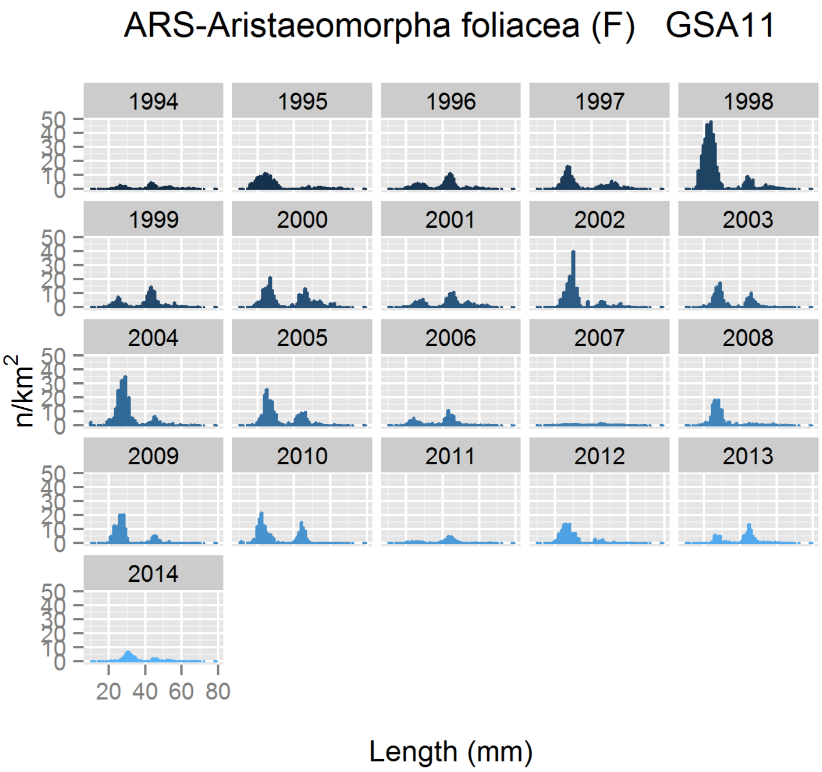


Fig. 5.2.13.6.1.4.1. Giant red shrimp in GSA 11. Stratified abundance indices (n/km^2) of females by size, 1994-2014.

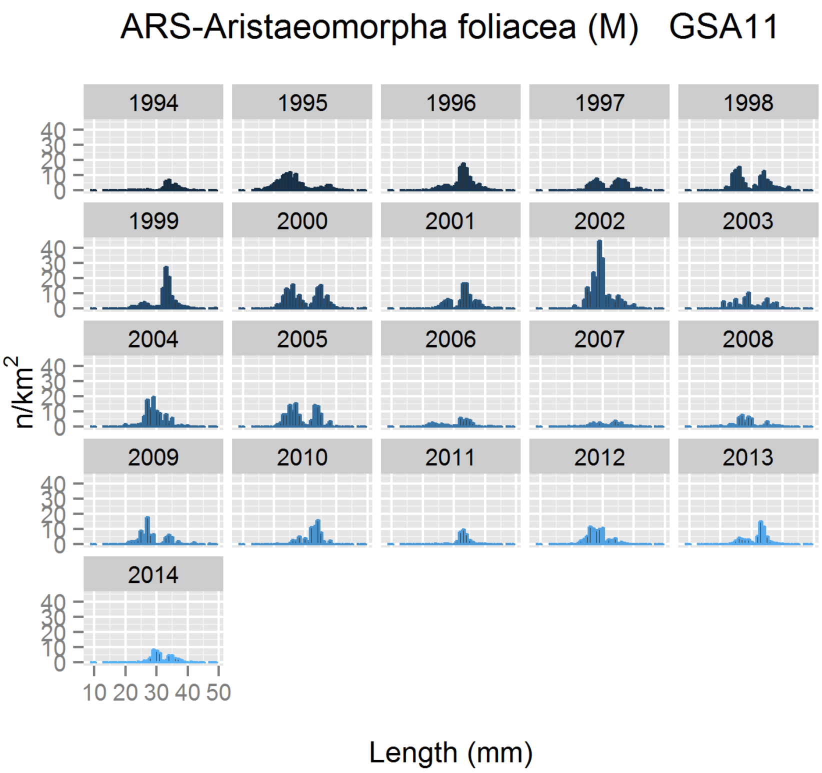


Fig. 5.2.13.6.1.4.1. Giant red shrimp in GSA 11. Stratified abundance indices (n/km^2) of males by size, 1994-2013.

5.2.13.7 Stock Assessment

This stock was assessed for the last time by EWG 15-06. A survey-based (SURBA) model was used back then based on MEDITS data, but the results were not used to draft management advices. The stock was also assessed by STECF EWG 11-14 using a Length Cohort Analysis carried out with ViT software for the years 2006, 2007, 2009 and 2010.

5.2.13.7.1 Methods

The assessment of giant red shrimp in GSA 11 has been performed here using the XSA method because the time series covered more than the life span of the species. FLR libraries were employed in order to carry out the XSA assessment (Darby and Flatman 1994).

5.2.13.7.2 Input data

The catch at age matrix employed in the XSA was calculated from the age-slicing carried out on the size frequency distributions (LFDs) provided by the 2015 DCF data call (Fig. 5.2.13.5.3.4 and Tab. 5.2.1.7.2.1). The original catch at age matrix provides in the framework of the 2015 DCF data call was not used due the inconsistencies found in the age distributions and the VBGF growth parameters reported for the species.

Tab. 5.2.13.7.2.1. Giant red shrimp in GSA 11. Input parameters for XSA, catch at age data.

Catch at age (thousands)	Age 0	Age 1	Age 2	Age 3	Age 4+
2006	262.5	2723.2	543.1	190.0	80.0
2007	135.0	1124.7	286.5	68.3	28.9
2008	1398.9	1447.6	336.3	7.0	0.1
2009	3334.5	3569.8	979.0	122.0	50.0
2010	874.7	2949.1	764.6	152.6	56.2
2011	3060.5	3452.4	770.7	101.3	16.1
2012	1443.1	1862.2	593.8	178.3	38.2
2013	445.1	1614.0	546.3	65.4	39.9
2014	1205.1	2084.9	558.8	54.9	12.7

The mean weight at ages employed in the XSA both for the catch weight at age and stock weight at age matrices were assumed to be constant over the whole period and equal to the series reported for 2014 in the 2015 official data call due to the higher number of samples measured in 2014 (Tab. 5.2.13.7.2.2).

Tab. 5.2.13.7.2.2. Giant red shrimp in GSA 11. Input parameters for XSA, catch and stock weight at age data.

Catch and stock weight (Kg)	Age 0	Age 1	Age 2	Age 3	Age 4+
2006 - 2014	0.009	0.010	0.022	0.044	0.070

The natural mortality (M) and the proportion of mature specimens are reported in tables 5.2.13.3.1. and 5.2.13.4.1. The proportion of F and M before spawning was assumed equal to 0.5.

The tuning fleet matrix was estimated from the age-slicing of MEDITS LFDs and are presented in table 5.2.13.7.2.3.

Tab. 5.2.13.7.2.3. Giant red shrimp in GSA 11. Input parameters for XSA, tuning fleet matrix.

N/km^2	Age 0	Age 1	Age 2	Age 3	Age 4+
2006	38.1	73.5	7.5	0.5	0.4
2007	10.6	24.4	7.4	0.5	0.001
2008	116.9	36.5	8.7	0.7	0.1
2009	145.5	73.1	8.1	0.2	0.001
2010	121.3	113.9	11.4	1.0	0.1
2011	13.8	59.1	6.9	1.2	0.7
2012	135.9	71.2	6.9	0.6	0.4
2013	34.8	106.7	13.2	2.3	0.2
2014	42.2	46.7	13.9	0.8	0.4

The main settings used in the final run of the XSA are reported in Table 5.2.13.7.2.4.

Tab. 5.2.13.7.2.4. Giant red shrimp in GSA 11. Setting parameters for XSA.

	r_age	q_age	shrinkage	N_years	N_ages	Fbar
Final run	0	4	1	4	4	0 - 3

5.2.13.7.3 Results

The final XSA results and diagnostics are reported in figures 5.2.13.7.3.1-3 and table 5.2.13.7.3.1. Several XSA runs were carried out during the meeting using different combinations of setting parameters. Once the r_age, q_age, N_years and N_ages were selected considering the model outputs and diagnostics (not presented in the report) three values of shrinkage (0.5, 1 and 2) were tested (Figs. 5.2.13.7.3.4-6). The model with 1.0 shrinkage was adopted as final model based on the analysis of residual distributions (Fig. 5.2.13.7.3.2). Residuals from tuning fleets (MEDITS) per age and year were relatively low, ranging from 1 to - 1, and did not show any trend with time. Also the retrospective analysis did not show any particular inconsistencies (Fig. 5.2.13.7.3.3).
The results of the assessment (Figure 5.2.13.7.3.1) show an oscillating trend of recruits and an increasing pattern of spawning stock biomass (SSB). The fishing mortality showed a minimum value in 2008 followed by fluctuations in the period 2009-2014. The current F_{bar} 0-3 is equal to 0.50. The F values by age are shown in table 5.2.13.7.3.1 and are in general higher for ages 1 and 2.

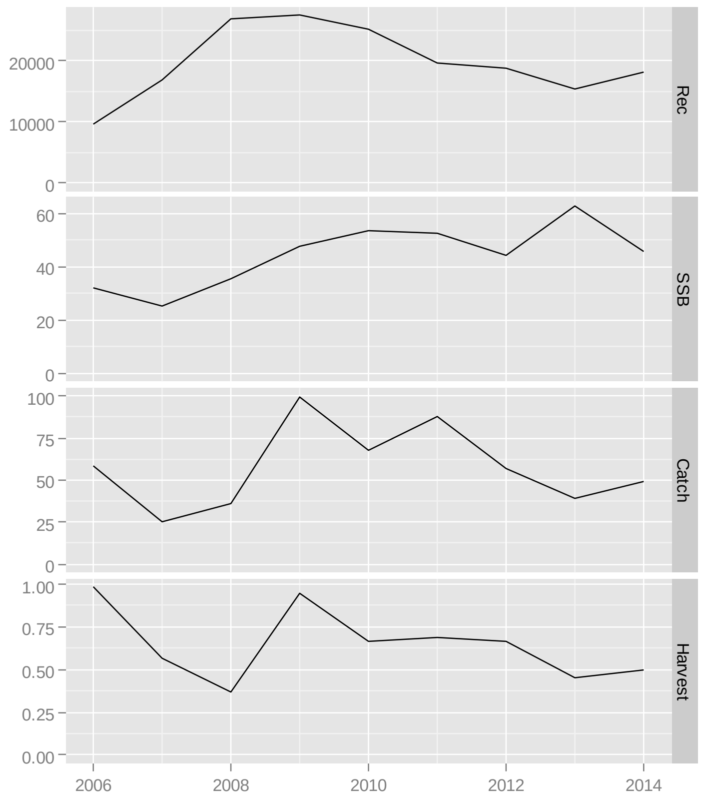


Fig. 5.2.13.7.3.1. Giant red shrimp in GSA 11. XSA summary results. SSB and catch are in tons, recruitment in thousands of individuals.

Table 5.2.13.7.3.1. Giant red shrimp in GSA 11. XSA summary results.

F at age	2006	2007	2008	2009	2010	2011	2012	2013	2014
0	0.05	0.01	0.10	0.25	0.06	0.33	0.15	0.05	0.13
1	1.47	0.76	0.47	1.01	0.90	0.99	0.83	0.56	0.96
2	1.18	0.90	0.85	1.14	0.98	1.02	0.68	1.02	0.58
3	1.23	0.58	0.06	1.39	0.71	0.42	0.99	0.18	0.32
4+	1.23	0.58	0.06	1.39	0.71	0.42	0.99	0.18	0.32
F bar	2006	2007	2008	2009	2010	2011	2012	2013	2014
Ages 0-3	0.98	0.56	0.37	0.95	0.66	0.69	0.66	0.45	0.50
SSB	2006	2007	2008	2009	2010	2011	2012	2013	2014
Tonnes	32.08	25.52	35.41	47.76	53.50	52.82	44.40	62.97	45.97
Recruitment	2006	2007	2008	2009	2010	2011	2012	2013	2014
Thousands	9567	16918	26749	27432	25188	19699	18775	15348	18201

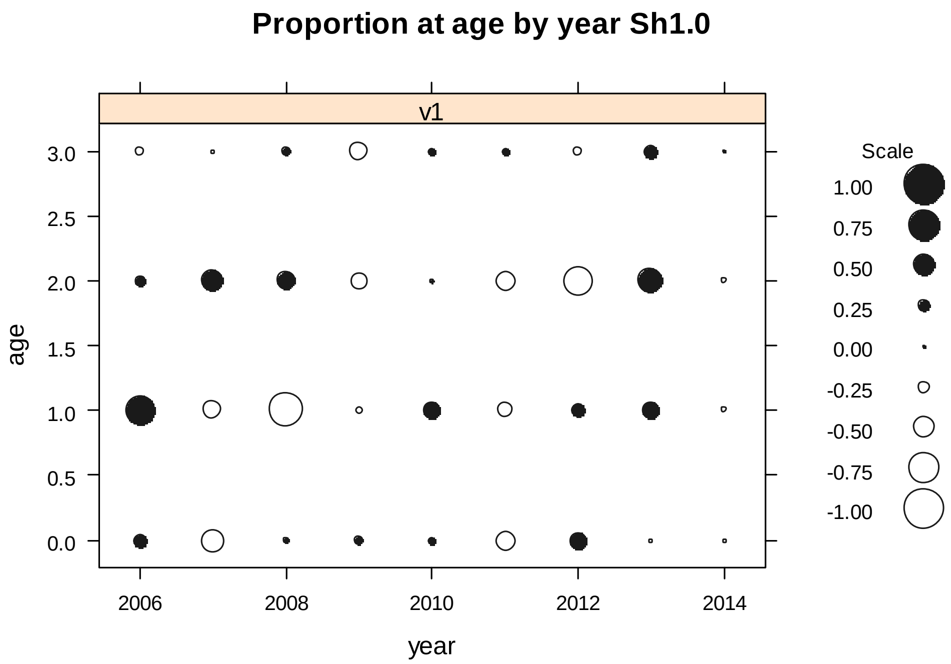


Fig. 5.2.13.7.3.2. Giant red shrimp in GSA 11. Residuals at age obtained with shrinkage set at 1.0.

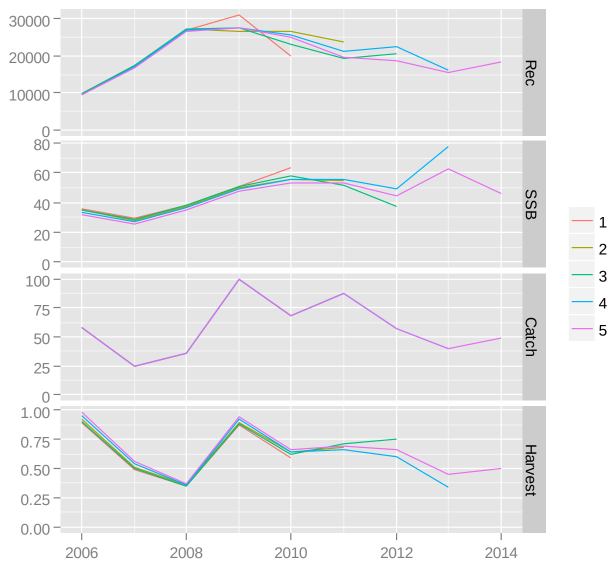


Fig. 5.2.13.7.3.3. Giant red shrimp in GSA 11. Retrospective analysis with shrinkage set at 1.0.

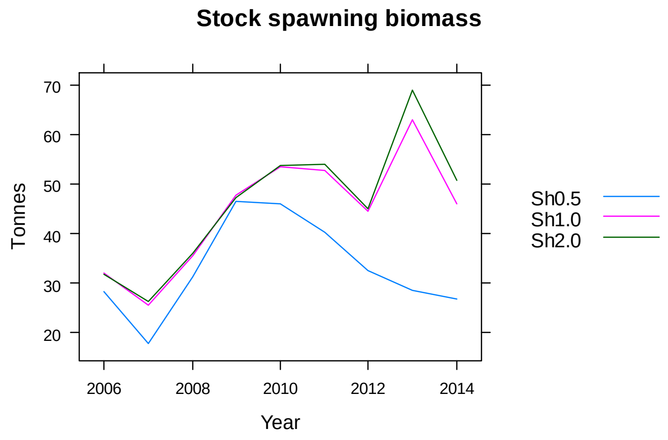


Fig. 5.2.13.7.3.4. Giant red shrimp in GSA 11. Model comparison (SSB).

Fig. 5.2.13.7.3.5. Giant red shrimp in GSA 11. Model comparison (Recruitment).

Fig. 5.2.13.7.3.6. Giant red shrimp in GSA 11. Model comparison (Fishing mortality).

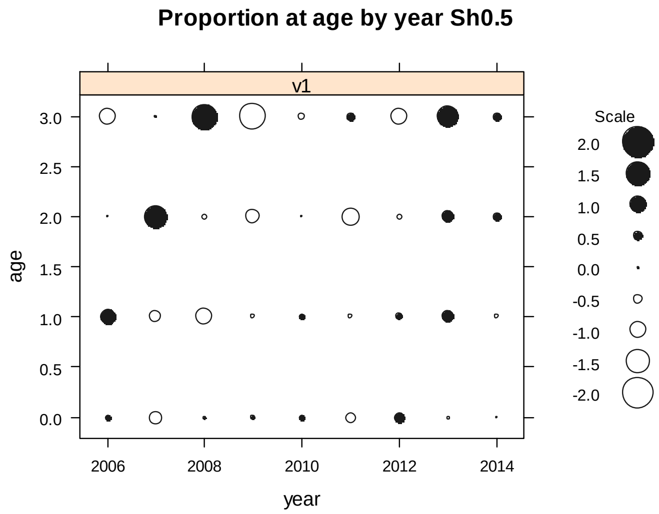


Fig. 5.2.13.7.3.7. Giant red shrimp in GSA 11. Residuals at age obtained with shrinkage set at 0.5.

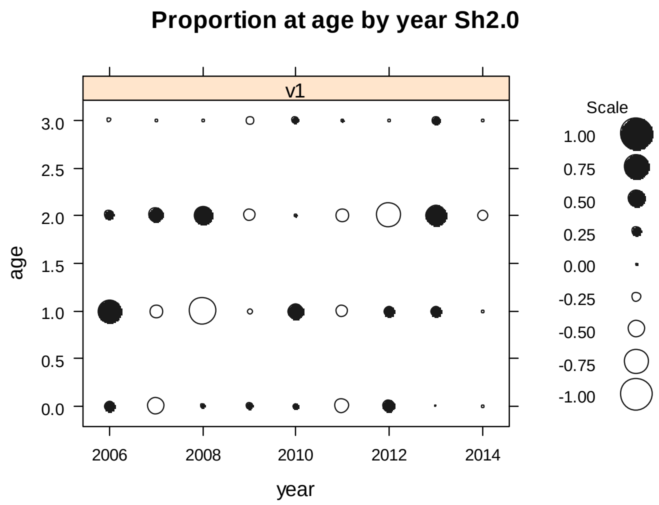


Fig. 5.2.13.7.3.8. Giant red shrimp in GSA 11. Residuals at age obtained with shrinkage set at 2.0.

5.2.13.8 Reference points

5.2.13.8.1 Methods

The reference point has been estimated with yield-per-recruit (YpR) analysis. The analysis was run using FLBRP package in FLR software. The analysis was performed to estimate $F_{0.1}$ as target equilibrium YPR reference point for the stock.

5.2.13.8.2 Input data

The same input data used for the XSA have been employed for the YpR analysis.

5.2.13.8.3 Results

YpR output outputs are illustrated in the Figure 5.2.13.8.3.1. $F_{0.1}$ estimated by the model was 0.31.

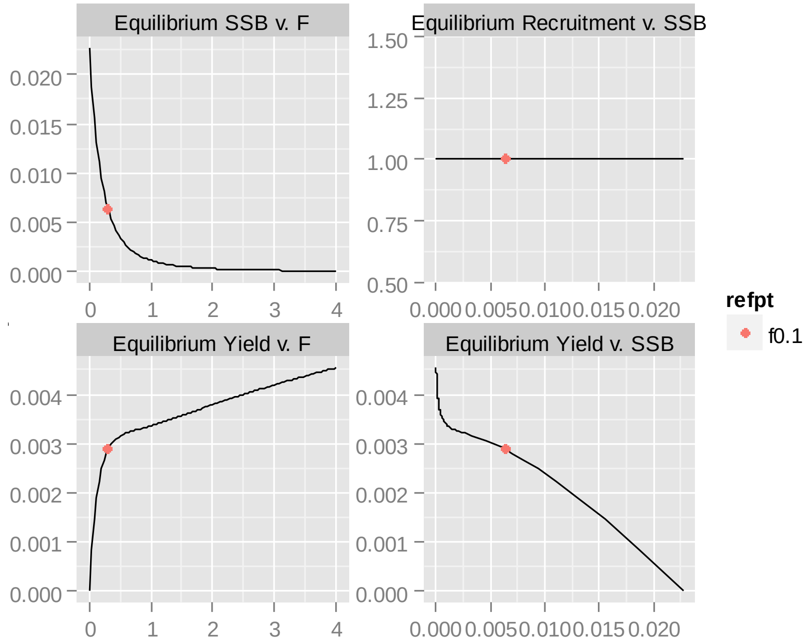


Fig. 5.2.13.8.3.1. Giant red shrimp in GSA 11. Yield per Recruit outputs.

5.2.13.9 Data quality

Data from DCF 2015 official data call were used. An improvement in the data quality of giant red shrimp GSA 11 data has been observed in comparison to the data provided during STECF EWG 14-19.

The sum of products of landings was in general consistent with landing submitted in the 2015 official data call (difference less than 2%).

Catch at age data were available for the period 2005-2014. However due the inconsistencies in age distributions, the experts decided to age-slice the LFDs provided in the framework of 2015 official data call.

Moreover, due to the general low amount of samples analysed in the period 2005-2013 (Fig. 5.2.13.9.1), some of the input data used for the analyses (sex ratio by length, proportion of mature, mean catch weight at age) were selected from 2014 only.

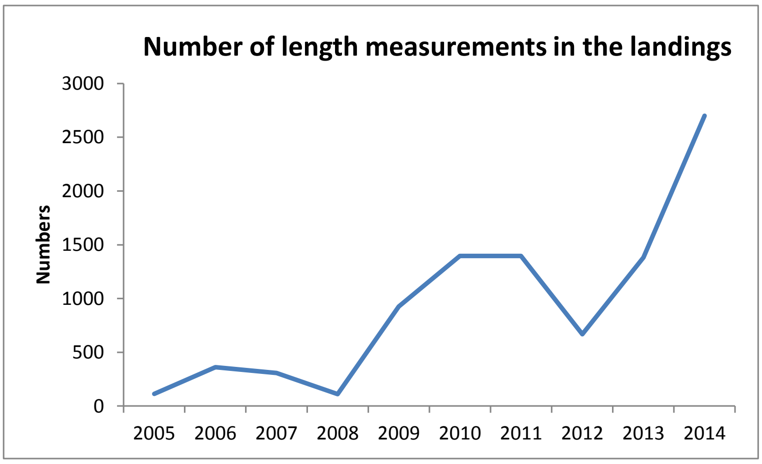


Fig. 5.2.13.9.1. Giant red shrimp in GSA 11. Number of samples measured.

5.2.13.10 Short term predictions 2015-2017

5.2.13.10.1 Method

A deterministic short term prediction for the period 2015 to 2017 was performed using the FLR routines, which takes into account the catch and landings in numbers and weight and the discards.

5.2.13.10.2 Input parameters

The same input parameters used in the XSA analysis shown above were used. Different scenarios of constant harvest strategy with F status quo as an average of F_{bar} from 2012 to 2014 (F_{stq} = 0.53) were performed. Recruitment (class 0) has been estimated from the population results from the geometric mean of the last three years 2012-2014 (17374 thousands individuals) estimated with FLR.

5.2.13.10.3 Results

Short term projection (Table 5.2.13.10.3), assuming an Fstq of 0.53 in 2015 and a recruitment of 17,374 thousands individuals shows that:

Fishing at the F_{stq} (0.53) generates an increase of the catch of 12% from 2014 to 2016 along with an decrease of the spawning stock biomass of 0.15% from 2016 to 2017.
Fishing at $F_{0.1}$ (0.31) generates a decrease of the catch of 27% from 2014 to 2016 and an increase of the spawning stock biomass of 24% from 2016 to 2017.
Catches of giant red shrimp in 2016 consistent with F_{MSY} should not exceed 55.31 tons.

Table 5.2.13.10.3 Giant red shrimp GSA 11. Short term forecast in different F scenarios computed for *Aristeomorpha foliacea* in GSA 11. Basis: F(2014) = mean(Fbar0-3 2012-2014)= 0.53; R(2015) = geometric mean of the recruitment of the last 3 years; R = 17,374 (thousands). SSB 2014 = 46 t; Catch 2014 = 49 t.

Scenarios	Ffactor	Fbar	Catch				SSB		% change in SSB	% change in Catch
			2014	2015	2016	2017	2016	2017	2016-2017	2014-2016
No fishery	0	0	53.49	0	0	75.47	128.05	69.66		-100
F status quo	1	0.53	53.49	55.31	55.15	54.28	54.20	-0.15		12.00
F_{MSY}	0.58	0.31	53.49	35.83	41.51	62.22	76.83	23.48		-27.44
Different scenarios	0.1	0.05	53.49	6.98	9.89	73.01	117.14	60.44		-85.87
	0.2	0.11	53.49	13.58	18.41	70.63	107.23	51.81		-72.50
	0.3	0.16	53.49	19.82	25.76	68.34	98.23	43.74		-59.86
	0.4	0.21	53.49	25.73	32.08	66.12	90.04	36.18		-47.89
	0.5	0.27	53.49	31.33	37.51	63.97	82.59	29.11		-36.55
	0.6	0.32	53.49	36.64	42.19	61.90	75.81	22.48		-25.81
	0.7	0.37	53.49	41.67	46.21	59.90	69.64	16.26		-15.61
	0.8	0.42	53.49	46.45	49.65	57.96	64.01	10.44		-5.93
	0.9	0.48	53.49	50.99	52.61	56.09	58.88	4.98		3.26
	1.1	0.58	53.49	59.41	57.32	52.53	49.93	-4.97		20.32
	1.2	0.64	53.49	63.32	59.18	50.85	46.02	-9.49		28.23
	1.3	0.69	53.49	67.05	60.77	49.21	42.45	-13.74		35.78
	1.4	0.74	53.49	70.60	62.14	47.64	39.19	-17.73		42.97
	1.5	0.80	53.49	73.99	63.31	46.11	36.20	-21.49		49.83
	1.6	0.85	53.49	77.22	64.31	44.64	33.47	-25.02		56.39
	1.7	0.90	53.49	80.32	65.17	43.21	30.96	-28.35		62.65
	1.8	0.95	53.49	83.28	65.91	41.83	28.66	-31.49		68.65
	1.9	1.01	53.49	86.11	66.54	40.50	26.55	-34.45		74.38

	2	1.06	53.49	88.82	67.09	39.21	24.61	-37.24	79.88

5.2.13.11 Medium term predictions

The medium term projections were not conducted because no meaningful stock-recruitment relationship was identified.

5.2.13.12 Stock advice

Current F (0.5) is larger than $F_{0.1}$ (0.31), which was chosen as proxy of F_{MSY} and as the exploitation reference point consistent with high long term yields. This indicates that giant red shrimp in GSA 11 is being fished above F_{MSY}.

STECF EWG 15-11 advises the relevant fleets' effort and/or catches to be reduced until fishing mortality is below or at the proposed F_{MSY} level, in order to avoid future loss in stock productivity and landings. Catches of giant red shrimp in 2016 consistent with F_{MSY} should not exceed 55 tonnes.

5.2.13.13 Management strategy evaluation

A Management Strategy Evaluation (MSE) has been conducted in order to evaluate if the F_{MSY} ranges were precautionary. The F_{MSY} ranges were derived using the formula provided by STECF 15-09. F ranges results were F_{upper}=0.43 and F_{lower}=0.21. B_{lim} was estimated as B_{loss}=25.51 t (B_{pa}= 35.7 t).

The graphs in the figure 5.2.13.13.1 show the results of the MSE.

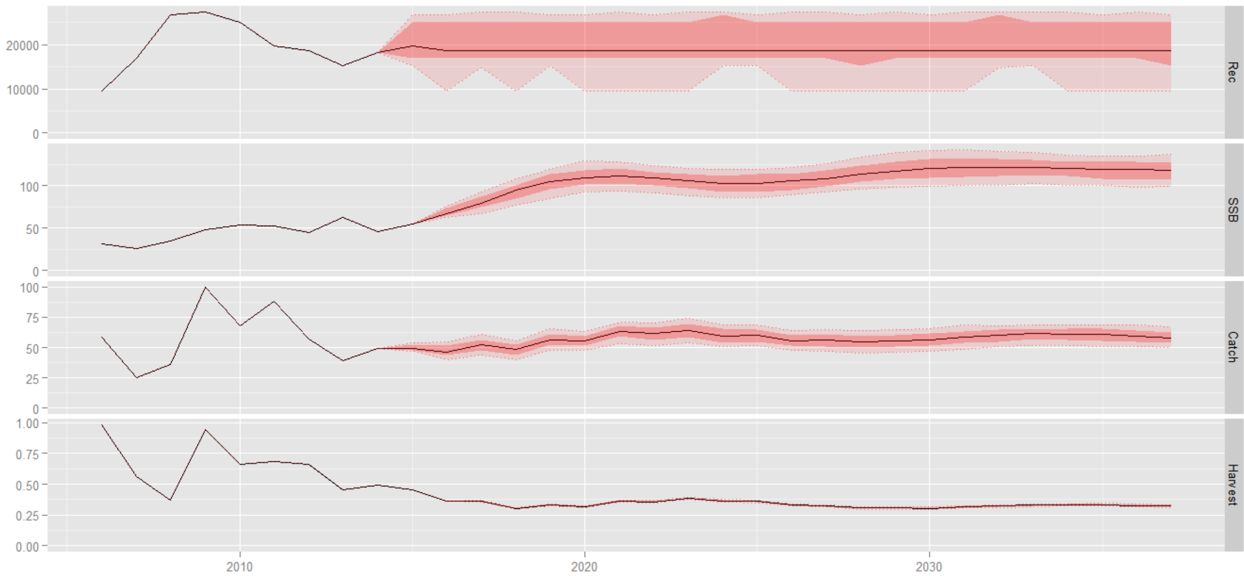


Figure 5.2.6.13.13.1. Giant red shrimp GSA 11. Management Strategy Evaluation.

The probability of SSB to fall below B_{lim} fishing at F equal to F_{MSY} upper level is equal to 0.

5.2.14 STOCK ASSESSMENT OF BLUE AND RED SHRIMP IN GSA 1

5.2.14.1 Stock Identification

No information was documented during regarding stock delimitation of blue and red shrimp, *Aristeus antennatus* (Risso, 1816). It is assumed that the stock geographical distribution corresponds to GSA 1. (Figure 5.2.14.1.1).

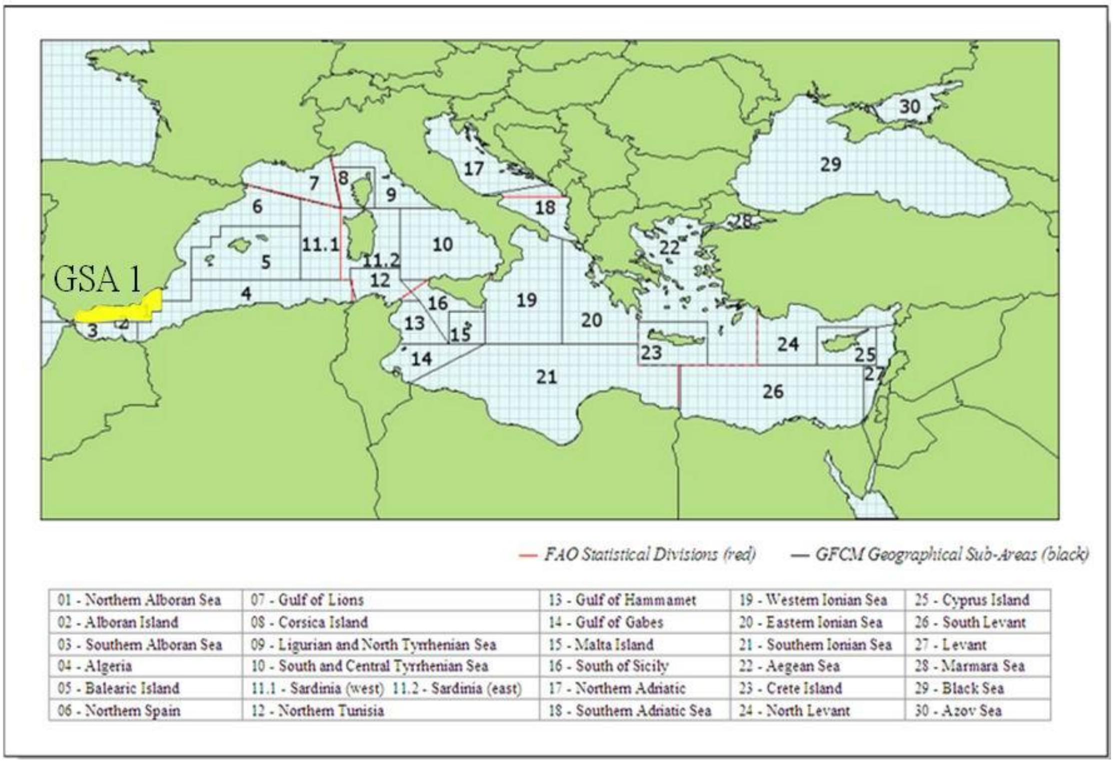


Figure 5.2.14.1.1. Geographical localization of GSA 1

5.2.14.2 Growth

Von Bertalanffy growth parameters (L_{inf} = 80 mm (carapace length), K = 0.37 year^{-1}, t_0 = 0.032 year) were calculated following the modal progression approach, based on monthly length frequency distribution obtained from Data Collection Framework (DCF), 2014.

Length-weight relationshipfor 2014 calculated from DCF 2014 data: a = 0.002038 gr and b = 2.506 (weight = $a \cdot$ length^b).

The weight at age was calculated annually from 2002 and results are presented in Table 5.2.14.2.1

Table 5.2.14.2.1. Blue and red shirmp in GSA 1. Individual weight (kg) by age and year.

	0	1	2	3	4+
2002	0.005	0.01	0.028	0.047	0.069
2003	0.005	0.011	0.03	0.047	0.069
2004	0.005	0.01	0.03	0.047	0.069
2005	0.005	0.01	0.03	0.047	0.069
2006	0.005	0.011	0.028	0.049	0.065
2007	0.005	0.011	0.03	0.05	0.069

2008	0.005	0.012	0.031	0.049	0.065
2009	0.004	0.012	0.031	0.05	0.066
2010	0.005	0.012	0.03	0.048	0.069
2011	0.005	0.012	0.03	0.049	0.064
2012	0.005	0.012	0.03	0.049	0.066
2013	0.005	0.012	0.03	0.047	0.066
2014	0.005	0.012	0.03	0.047	0.069

5.2.14.3 Maturity

Maturity ogive, calculated from DCF 2014, is presented in Table 5.2.14.3.1.

Table 5.2.14.3.1. Blue and red shirmp in GSA 1. Proportion of matures.

Age	0	1	2	3	4+
Prop mat	0.22	0.95	1.0	1.0	1.0

The value of L_{50} is 23.5 mm (carapace length).

5.2.14.4 Natural mortality

Two models for natural mortality *M* where tested.

a) The same value (*M*=0.46 year^{-1}) for all ages. This value has been obtained from the Djabaliet al. (1994) empirical approach calculated for the Vera Gulf (GSA 1).
b) *M* vector according to PRODBIOM (Abella et al., 1997) is presented in Table 5.2.14.4.1.

Table 5.2.14.4.1. Blue and red shirmp in GSA 1. Natural mortality by age estimated by PRODBIOM.

Age	0	1	2	3	4+
M	1.58	0.91	0.158	0.147	0.141

However, after several assessment trials, the option (a) resulted more robust than (b), so the constant *M* value was adopted for the assessment.

5.2.14.5 Fisheries

5.2.14.5.1 General description of the fisheries

Aristeus antennatus, is present in the eastern part of GSA 1 at depths comprised between 400 and 800 m. It is particularly abundant in front of Cape of Gata.

This resource is caught only by depth bottom otter trawl and only by the fleet segment composed by the largest trawlers. The fleet segment is E-trawl (12-24 m) according to GFCM Operational Units code. Around 50 vessels targeting *A. antennatus* (average 2009-2014).

This segment fleet catches about 147 tonnes of blue and red shrimp (average 2011-2014). This fishery can be considered as monospecific with no significant discards, due to the very high price of the species.

5.2.14.5.2 Management regulations applicable in 2015

- Fishing license: fully observed
- Engine power limited to 316 KW or 500 HP: not fully observed
- Mesh size in the codend (40 mm square or 50 mm rhomboidal): fully observed (In force since June 2010)
- Fishing forbidden within upper 50 m depth: fully observed
- Time at sea (12 hours per day and 5 days per week): fully observed
- Minimum landing size (20 mm CL), (EC regulation 1967/2006): mostly fully observed

5.2.14.5.3 Catches

Due to its high economic value, and because is the only target of the fishery, no significant discards are produced. Hence catch and landings are the same figures and are presented in figure 5.2.14.5.3.1.

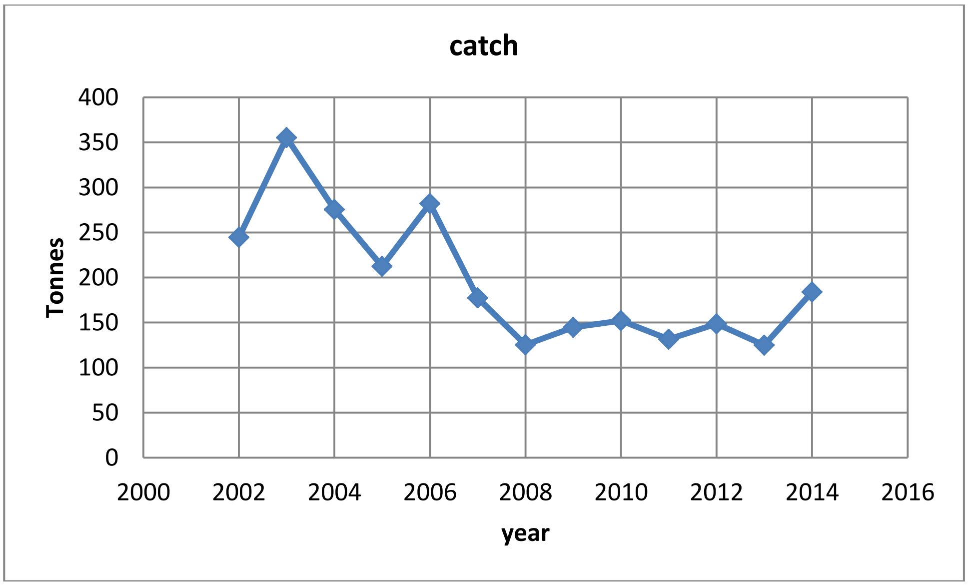


Figure 5.2.14.5.3.1. Blue and red shirmp in GSA 1. Catches by year.

Figure 5.2.14.5.3.2 shows the size structure of landings from 2002 to 2014.

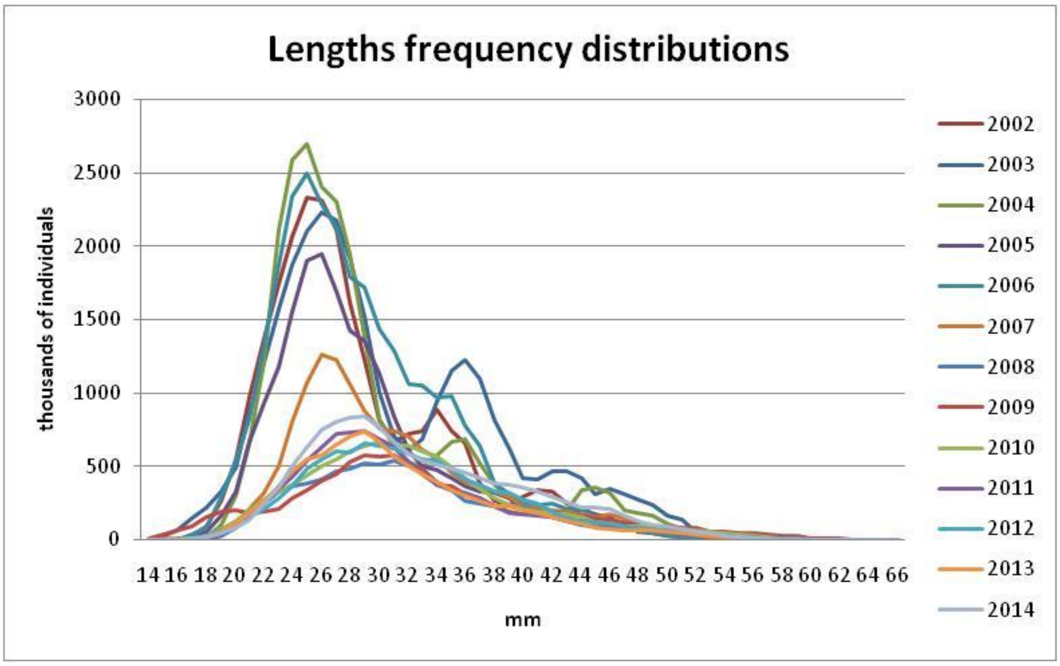


Figure 5.2.14.5.3.2. Blue and red shirmp in GSA 1. Length frequency distributions by year from DCF.

5.2.14.5.4 Landings

See chapter 5.2.14.5.3.

5.2.14.5.5 Discards

Discards are considered negligible.

5.2.14.5.6 Fishing effort

The fishing effort expressed as fishing days by year is presented in Figure 5.2.14.5.6.1.

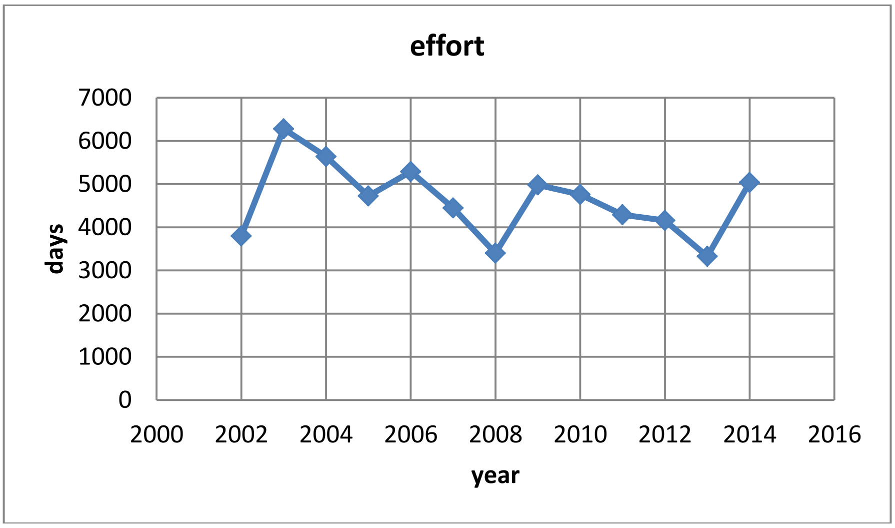


Figure 5.2.14.5.6.1. Effort of the fleet targeting Blue and red shirmp in GSA 1, expressed in days at sea. Source: Spanish Institute of Oceanography (IEO) for the period 2002-2014.

5.2.14.6 Scientific surveys

5.2.14.6.1 Survey #1 (MEDITS)

5.2.14.6.1.1 Methods

The Spanish Institute of Oceanography carries out two scientific surveys under the Data Collection Regulation: MEDITS and MEDIAS. Both are international coordinated surveys.

The IEO is involved in the international bottom trawl survey MEDITS since 1994. The survey takes place in all European Mediterranean countries and the main target species are demersal species. The Spanish MEDITS survey carries out about 170 – 180 hauls in spring. It samples 4 GSAs, including Balearic Islands, and the sampling procedure is based on the common methodology included in the MEDITS instruction manual. The GSAs sampled are: GSA 1, GSA 2, GSA 5 and GSA 6.

Table 5.2.14.6.1.1.1. Number of hauls by year from MEDITS in GSA 1.

year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Hauls	46	47	43	38	51	45	43	39	26	28	31	39	55

5.2.14.6.1.2 Geographical distribution

Aristeus antennatus, is present in the eastern part of GSA 1 at depths comprised between 400 and 800 m. It is particularly abundant in front of Cape of Gata.

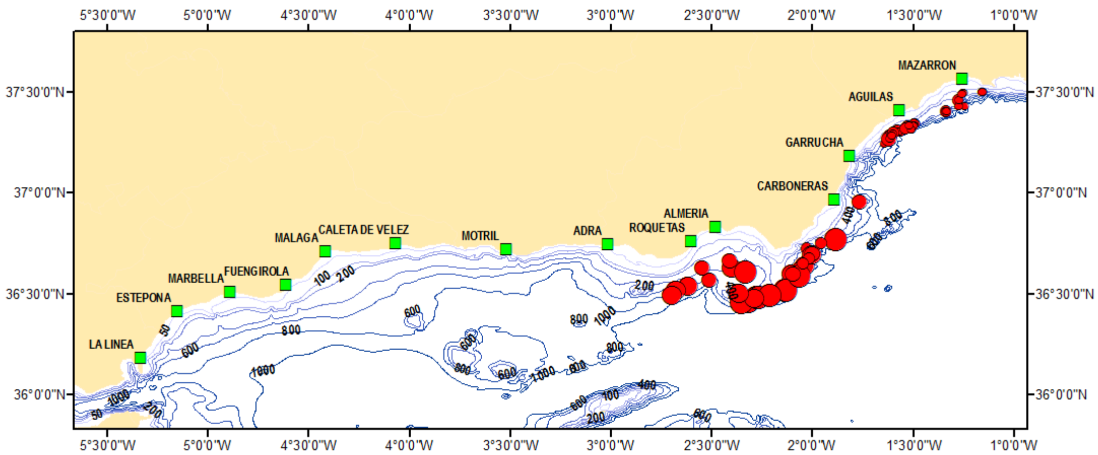
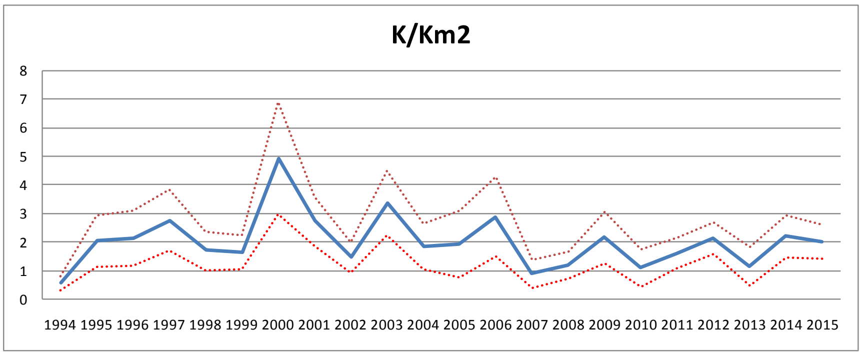


Figure 5.2.14.6.1.2.1. Blue and red shirmp in GSA 1. Geographical distribution according to MEDITS (2009-2014).

5.2.14.6.1.3 Trends in abundance and biomass



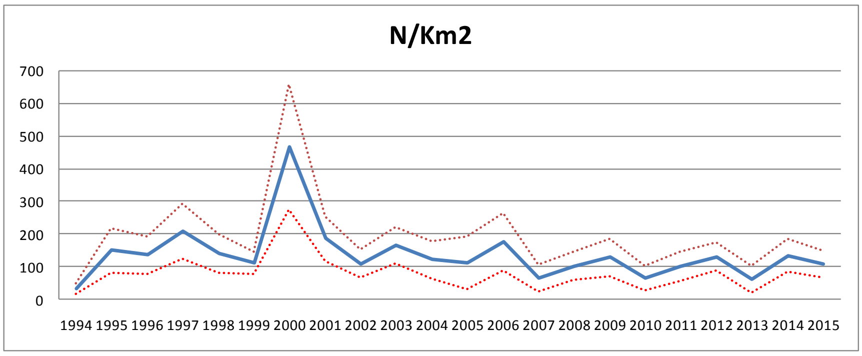


Figure 5.2.14.6.1.3.1. Blue and red shirmp in GSA 1. Series of abundance indices in biomass (kg) and density (number of individuals per km^2) obtained from MEDITS.

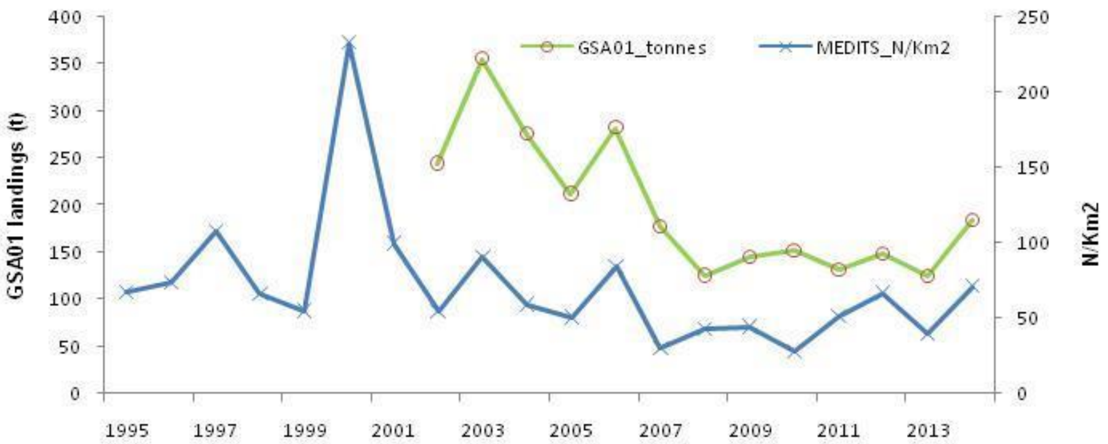


Figure 5.2.14.6.1.3.2. Blue and red shirmp in GSA 1. Series of abundance indices in number of individuals per km^2 compared with the catch in tonnes.

5.2.14.6.1.4 Trends in abundance by length or age

In the table 5.2.14.6.1.4.1 and figure 5.2.14.6.1.4.1 the trends in abundance by age are presented.

Table 5.2.14.6.1.4.1 Number of individuals per km^2 by age and year according to MEDITS surveys.

	0	1	2	3	4+
2002	17.2	38.1	4.8	0.8	0.8
2003	4.7	68.6	16	3.8	2.6
2004	7.9	46.7	5.2	1.7	0.5
2005	8.9	36.5	5.3	0.9	0.8
2006	6.5	56.2	22.3	1.5	1.3
2007	8.8	19.6	4.1	0.9	0.5
2008	10.1	29.6	2.8	0.8	0.5
2009	3	32.7	8.1	1.3	1
2010	5	18.9	5.8	2.6	2.1
2011	9.6	34.2	7.8	1	0.6
2012	6.4	49	12.1	0.8	0.6
2013	7	27.4	7.1	1.4	0.7
2014	14	46.1	12.2	0.5	0.3

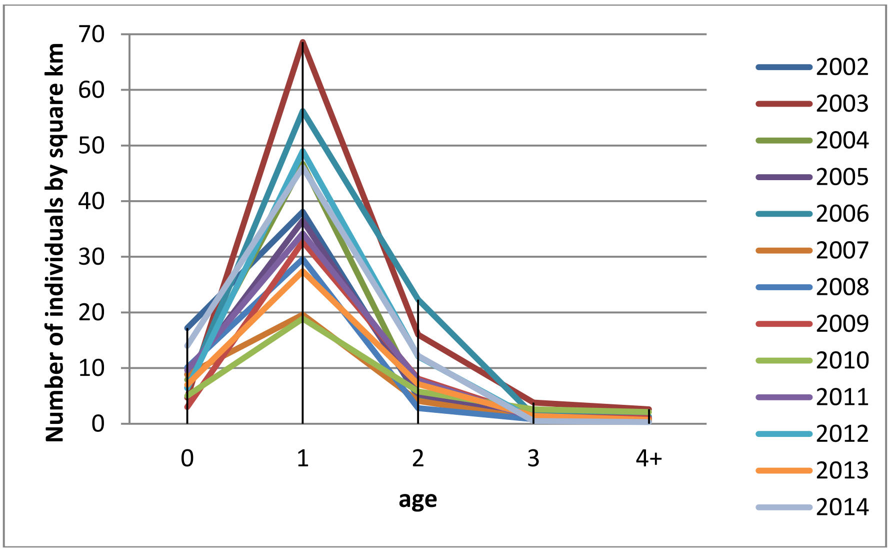


Figure 5.2.14.6.1.4.1. Blue and red shirmp in GSA 1. Age frequency distributions by year according to MEDITS surveys.

5.2.14.7 Stock Assessment

5.2.14.7.1 Methods

The Extended Survivor Analysis (XSA, Darby and Flatman, 1994) using FLR library was used. This stock was assessed for the last time during 2011 (STECF EWG 1105) using LCA with VIT software (Lleonart and Salat, 1997).

5.2.14.7.2 Input data

Weight at age per year in table 5.2.14.2.1
Proportion of matures in table 5.2.14.3.1.
Natural mortality: M = 0.46 year^{-1} for all ages.
Indices from table 5.2.14.6.1.4.1

Catches (in tonnes) in table 5.2.14.7.2.1
Catch at age (in numbers) table 5.2.14.7.2.2

Table 5.2.14.7.2.1. Blue and red shirmp in GSA 1. Catches in tonnes.

2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
244.5	355.4	275.5	212.3	282.1	177.4	125.3	144.6	152.1	131.4	148.6	124.9	184.0

Table 5.2.14.7.2.2. Blue and red shirmp in GSA 1. Catch at age.

Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Age 0	5192	5085	4629	3484	5165	1246	888	1364	1079	984	878	1040	946
1	18014	21063	18976	15345	21773	11781	6581	6717	8309	8013	8422	7878	9975
2	1553	3444	2280	1353	1332	1501	1105	1510	1373	1114	1289	994	2014
3	11	49	90	141	12	49	212	294	179	116	131	68	109
4+	0	0	0	0	4	0	9	14	0	4	3	0	0

XSA settings

- Catchability dependent on stock size for ages < 1
- Catchability independent of age for ages >= 2
- Survivor estimates shrunk towards the mean F of the final 5 years or the 3 oldest ages.
- S.E. of the mean to which the estimates are shrunk = 0.5
- Minimum standard error for population estimates = 0.3

The XSA parameters are:

```
xsa_control<- FLXSA.control(x=NULL, tol=1e-09, maxit=150, min.nse=0.3, fse=0.5,
                  rage=1, qage=2, shk.n=TRUE, shk.f=TRUE, shk.yrs=3, shk.ages=3,
                  window=100, tsrange=20, tspower=0, vpa=FALSE)
```

Catchability analysis :

Catchability independent of size for all ages
Catchability independent of age for ages > 1

Sensitivity analysis

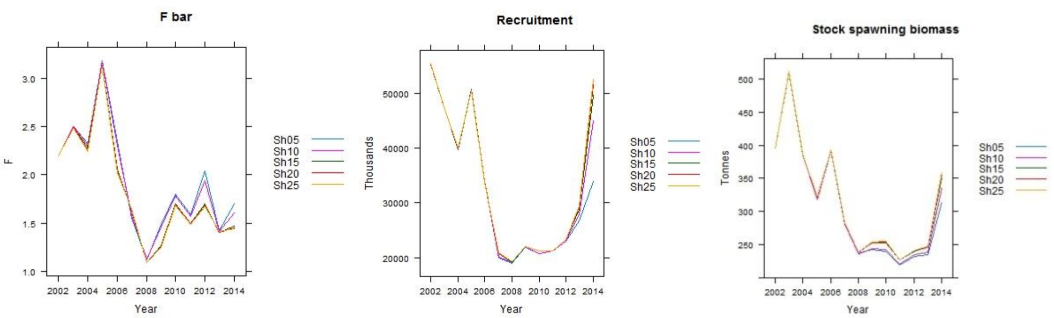


Figure 5.2.14.7.2.1. Blue and red shirmp in GSA 1. Sensitivity on shrinkage weight.

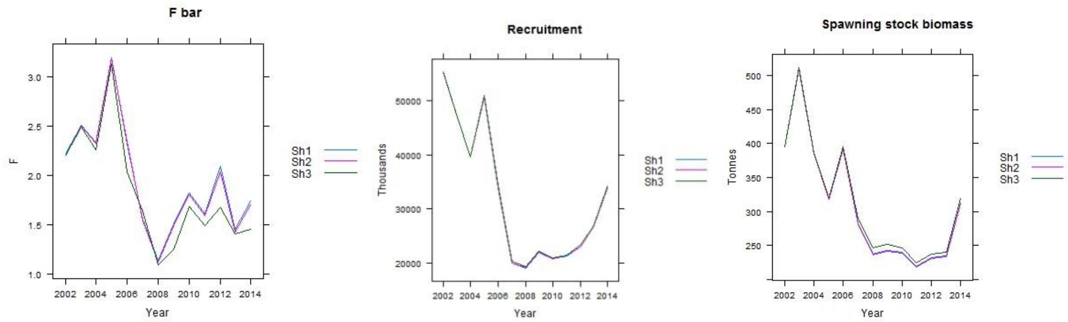


Figure 5.2.14.7.2.2. Blue and red shirmp in GSA 1. Sensitivity for different shrinkage ages with shrinkage weight 0.5.

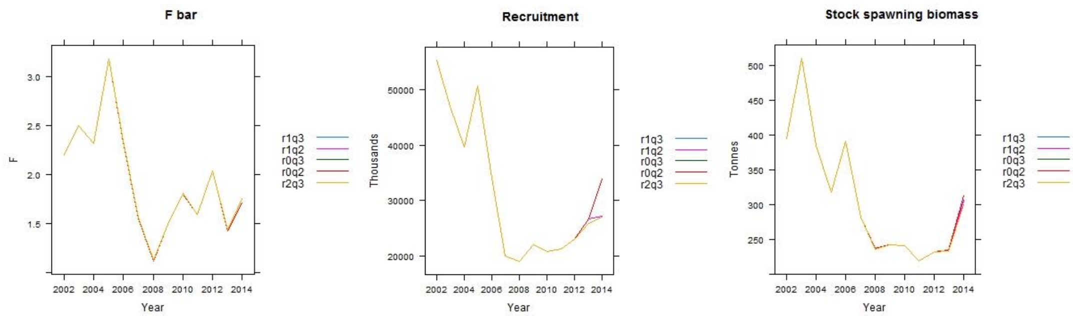


Figure 5.2.14.7.2.3. Blue and red shirmp in GSA 1. Sensitivity for different r age and q age.

5.2.14.7.3 Results

The results of the different XSA runs are presented in the following figures and tables.

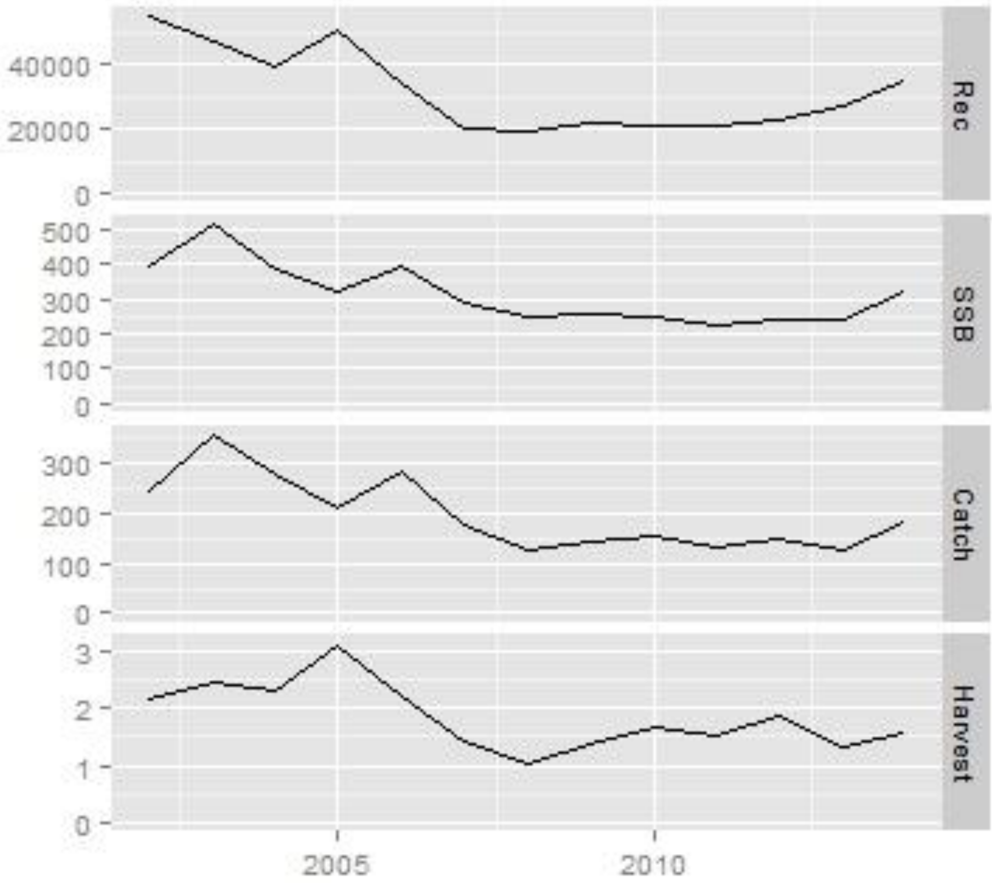


Table 5.2.14.6.1.4.1. Blue and red shirmp in GSA 1. F by age and year.

Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Age 0	0.12	0.14	0.15	0.08	0.2	0.08	0.06	0.08	0.06	0.06	0.05	0.05	0.05
1	1.42	1.83	2.27	2.04	2.01	1.63	1.15	1.27	1.56	1.49	1.66	1.12	1.39
2	2.86	3.01	2.3	4.08	2.47	1.24	0.94	1.54	1.78	1.6	2.1	1.59	1.8
3	1.49	1.69	1.61	2.14	1.56	0.98	0.79	1.07	1.16	1.08	1.32	0.91	1.11
4+	1.49	1.69	1.61	2.14	1.56	0.98	0.79	1.07	1.16	1.08	1.32	0.91	1.11

Table 5.2.14.6.1.4.2. Blue and red shirmp in GSA 1. Stock number at age.

Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Age 0	213813	178645	151418	210105	132290	85046	80612	89666	87808	87310	101853	111865	105016
1	40486	41684	34489	29088	41695	24905	16952	16201	17850	17597	17537	20581	22569
2	2215	4867	3416	1843	1973	2969	2551	2648	2260	1914	2000	1716	3286
3	18	78	148	206	20	108	539	601	353	238	238	155	217
4+	0	0	0	0	7	0	22	26	0	7	4	0	0

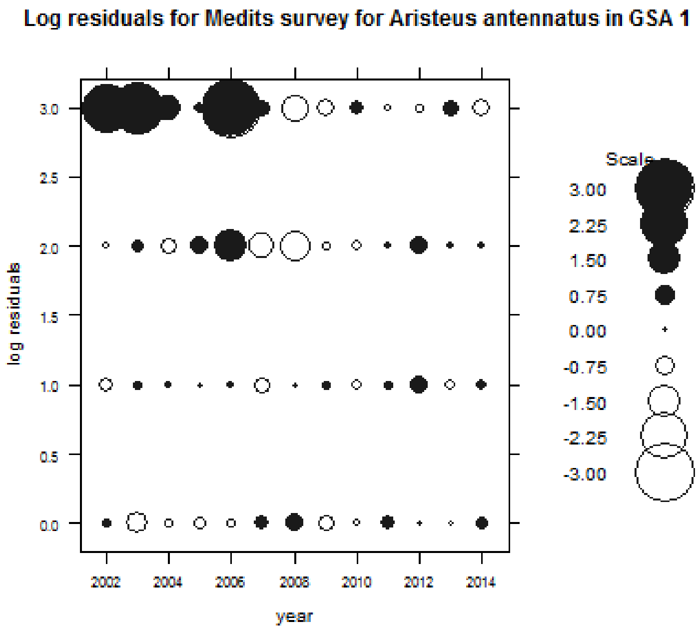


Figure 5.2.14.7.3.4. Blue and red shirmp in GSA 1. XSA residuals for the MEDITS survey.

Table 5.2.14.7.3.1. Blue and red shirmp in GSA 1. XSA summary results (Recruitment, B, SSB, and F).

Year	R	B	SSB	Fbar1-2
2002	55259	626.20	396.07	2.14
2003	46997	711.69	511.43	2.44
2004	39706	554.42	386.71	2.28
2005	51130	530.57	320.40	3.10
2006	34399	546.65	396.22	2.18
2007	20265	381.00	292.12	1.42
2008	19255	332.76	250.56	1.04
2009	22123	329.55	253.64	1.39
2010	20869	336.53	247.40	1.68
2011	21478	316.48	225.31	1.50
2012	23301	336.52	237.95	1.88
2013	27063	355.32	241.36	1.32
2014	34803	468.10	322.58	1.57

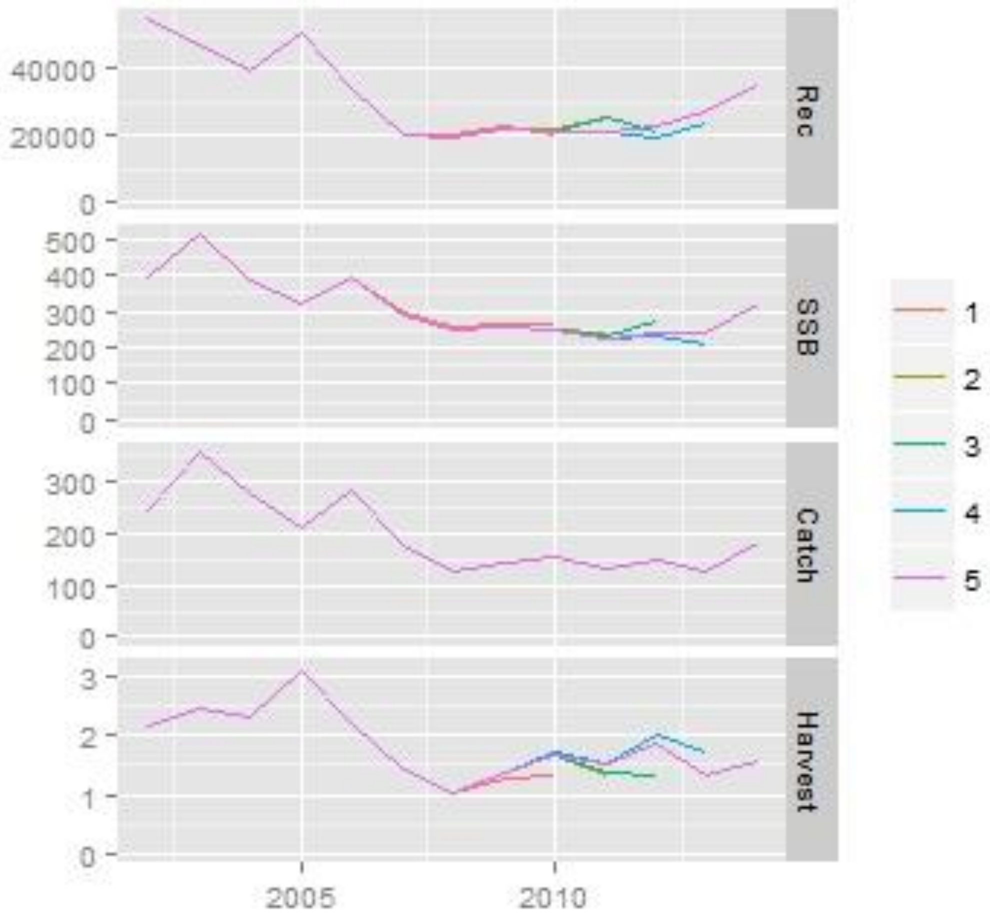


Figure 5.2.14.7.3.5. Blue and red shirmp in GSA 1. XSA retrospective analysis results.

5.2.14.8 Reference points

5.2.14.8.1 Methods

Yield per Recruit computation was made using the NOAA software (results very similar with those of XSA with FLR). The fishing mortality rate corresponding to $F_{0.1}$ in the yield per recruit curve is considered here as a proxy of $F_{MSY.}$

5.2.14.8.2 Input data

The input parameters were the same used for the XSA stock assessment and its results.

5.2.14.8.3 Results

The results are presented in the figure 5.2.14.8.3.1. and the table 5.2.14.8.3.1.

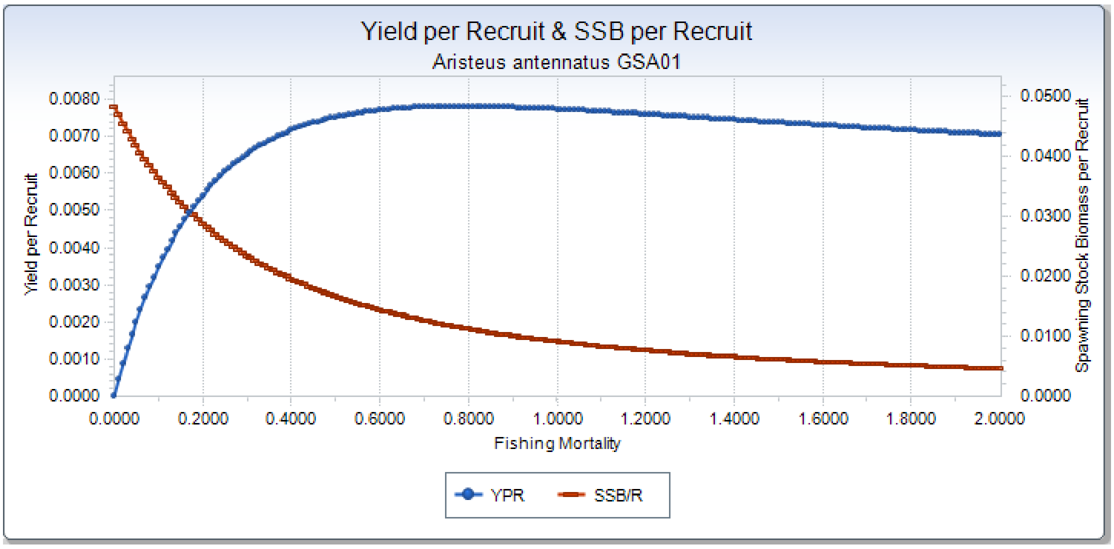


Figure ***5.2.14.8.3.1.*** Blue and red shirmp in GSA 1. Yield per recruit analysis using the software from NOAA and as input parameters the same used for the XSA stock assessment and its results.

Table ***5.2.14.8.3.1.*** Blue and red shirmp in GSA 1. Reference points from the yield per recruit analysis.

F_{MAX}	0.78	NOAA software
$F_{0.1}$ (proxy of F_{MSY})	0.41	NOAA software
$F_{current}$	1.57	

5.2.14.9 Data quality

Data from DCF 2014 as submitted through the Official data call in 2015 were used. Data quality for this stock is appropriate, except for the catch series in the 2002-2008 period, which needed to be reconstructed. For this period, catches for GSA 1 also included GSA 2. Threfore, data time series from regional government sources were used to estimate catches for GSA 1 only during 2002-2008.

5.2.14.10 Short term predictions 2016-2018

5.2.14.10.1 Method

A deterministic short term prediction for the period 2015 to 2017 was performed using the FLR routines provided by JRC and based on the results of the XSA stock assessments performed during EWG 15-11.

5.2.14.10.2 Input parameters

The same input parameters of the XSA were used for running the short term forecast.

5.2.14.10.3 Results

Table ***5.2.14.10.3.1.*** Blue and red shirmp in GSA 1. Short term forecast in different F scenarios. Basis: F(2015) = mean (F_{bar} 1-2 2012-2014)= 1.40; R(2015) = geometric mean of the recruitment of the last 3 years; R = 2838 thousands; SSB(2014) = 322 t, Catch (2014)= 184 t.

Rationale	F scenario	F factor	Catch 2016	Catch 2017	SSB 2017	Change SSB 2016-2017 (%)	Change catch 2014-2016 (%)
zero catch	0	0	0	0	674.26	93.63	-100
High long-term yield (F0.1)	0.4	0.3	96.28	146.14	516.79	48.41	-47.67
Status quo	1.4	0.9	203.87	202.66	348.75	0.15	10.80
Different scenarios	0.15	0.1	36.14	66.15	614.66	76.51	-80.36
	0.31	0.2	67.75	112.79	562.99	61.67	-63.18
	0.62	0.4	119.7	167.5	479.25	37.63	-34.94
	0.77	0.5	141.03	182.36	445.44	27.92	-23.35
	0.93	0.6	159.79	191.97	416.05	19.47	-13.16
	1.08	0.7	176.34	197.86	390.46	12.13	-4.17
	1.24	0.8	190.94	201.15	368.18	5.73	3.77
	1.54	1	215.34	202.96	331.79	-4.72	17.03
	1.7	1.1	225.52	202.48	316.97	-8.98	22.57
	1.85	1.2	234.59	201.51	304.00	-12.7	27.5
	2.01	1.3	242.69	200.26	292.64	-15.96	31.9
	2.16	1.4	249.94	198.88	282.67	-18.83	35.84
	2.32	1.5	256.44	197.45	273.90	-21.34	39.37
	2.47	1.6	262.28	196.06	266.19	-23.56	42.55
	2.63	1.7	267.56	194.73	259.38	-25.52	45.41
	2.78	1.8	272.32	193.5	253.36	-27.24	48
	2.93	1.9	276.65	192.36	248.02	-28.78	50.35
	3.09	2	280.58	191.34	243.28	-30.14	52.49

5.2.14.11 Medium term predictions

Medium term predictions were not carried out as no meaningful stock-recruitment relationship was identified.

5.2.14.12 Stock advice

The current F (1.57) is larger than $F_{0.1}$ (0.41), chosen as proxy of F_{MSY} and as the exploitation reference point consistent with high long term yields, which indicates that Blue and red shirmp in GSA 1 is being fished above F_{MSY}.

STECF EWG 15-11 advises the effort and/or cacthes of Blue and red shirmp in GSA 1 should be reduced until fishing mortality is below or at the proposed F_{MSY} level (0.41), in order to avoid future loss in stock productivity and landings. Catches of Blue and red shirmp in GSA 1 in 2016 consistent with F_{MSY} should not exceed 96 tonnes.

5.2.14.13 Management strategy evaluation

The Management Strategies Evaluation was performed with the R-script provided by JRC. The input data was the output of XSA analysis. After several simulations the final result was run under the a4a option in the loop of 250 iterations. The F_{MSY} ranges were derived using the formula provided by STECF 15-09, being F_{lower}=0.27 and F_{upper}=0.56 and B_{lim} was estimated as B_{loss}=224 tonnes. The probability of SSB falling below B_{lim} fishing at F_{upper} is 0. The dynamics observed for this stock are the result of the stock assessment model (i.e. XSA) settings used inside the MSE becoming less appropriate as the stock status changes in time (i.e. stock assessment settings are often specific to a particular range of stock status). This leads to an increasing difference between the perceived stock and the operating model (i.e. the 'true' stock). To avoid this behaviour in the future, for some of the stocks as it is the case here, a more general stock assessment method should be used in the MSE loop that is less sensitive to the stock status.

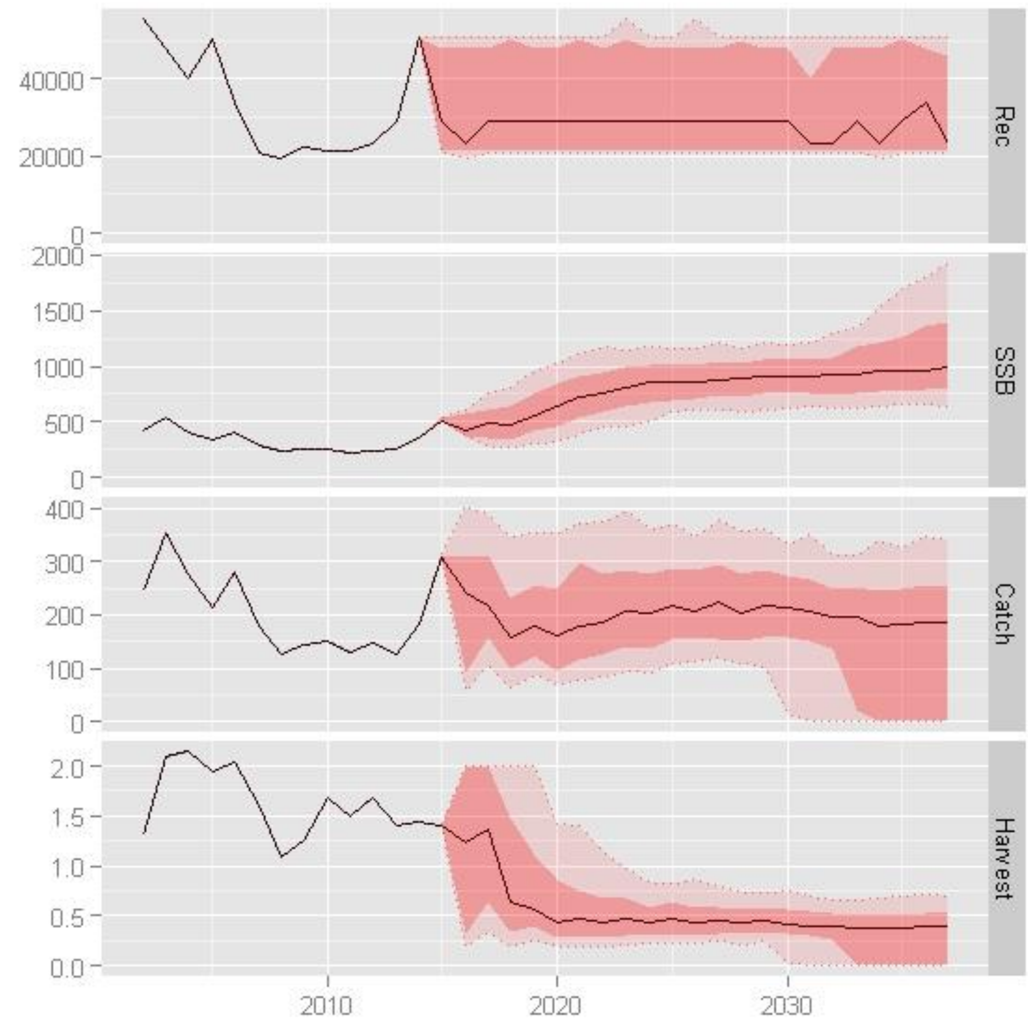


Figure 5.2.14.13.1. Blue and red shirmp in GSA 1. Management Strategy Evaluation (MSE). Predictions of Y_{MSY} strategy with 250 iterations. Using XSA as input and a4a in the iterations loop.

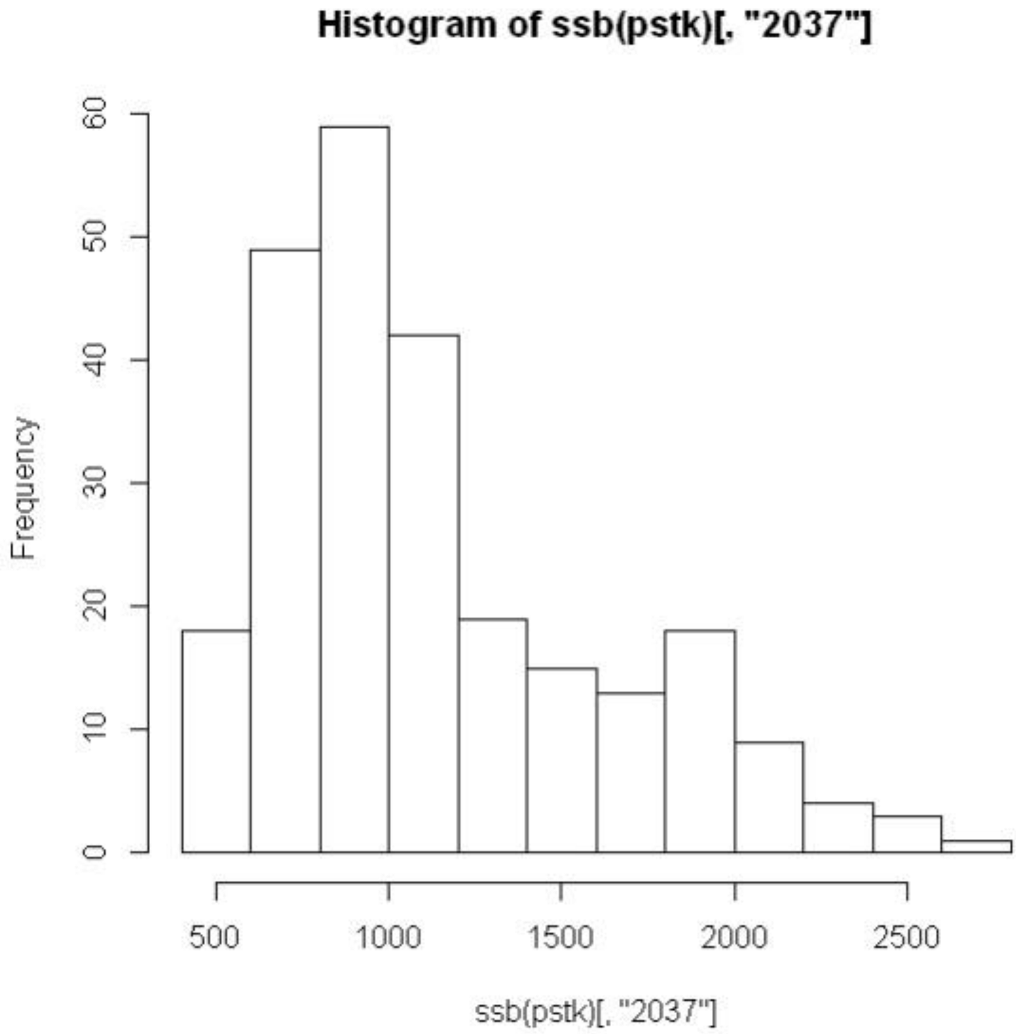


Figure 5.2.14.13.2. Blue and red shirmp in GSA 1 Frequency distribution of SSB in 2037 applying the F_{MSY} strategy (250 iterations) and using XSA as input and a4a in the iterations loop.

5.2.15 STOCK ASSESSMENT OF BLUE AND RED SHRIMP IN GSA 6

5.2.15.1 Stock Identification

Due to insufficient information about the stock structure of blue and red shrimp (*Aristeus antennatus*) in the western Mediterranenan Sea, this stock was assumed to be confined within the boundaries of the GSA 6.

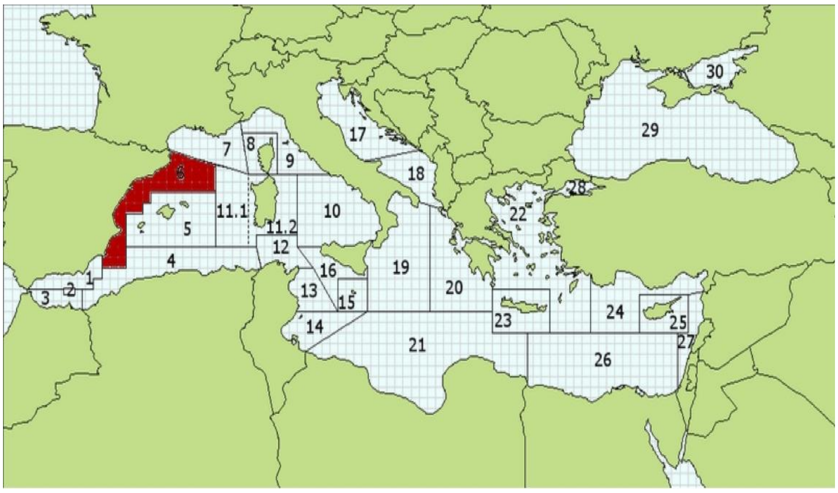


Fig. 5.2.15.1.1. Geographical location of GSA 6.

5.2.15.2 Growth

The growth parameters used were taken from Garcia-Rodriguez (2003), estimated from length frequency distributions analysis (Linf = 77.0; K = 0.38; t0= -0.065), and coincide with the parameters in the Data Collection Framework (DCF) official data call 2015. The parameters of the length-weight relationship were taken from DCF data call 2015 (a= 0.0020; b= 2.5120).

5.2.15.3 Maturity

The maturity ogive was taken from García Rodriguez (2003), with size at first maturity (50 %) estimated at 23.5 mm CL.

Table 5.2.15.3.1. Blue and red shrimp in GSA 6. Maturity at age.

Age class	0	1	2	3	4+
Prop. mature	0.07863	0.7669	0.998	1.0	1.0

5.2.15.4 Natural mortality

A constant value of natural mortality M=0.46 yr^{-1} was used, based on Pauly's (1980) equation and a mean annual temperature of 13 ºC.

5.2.15.5 Fisheries

5.2.15.5.1 General description of the fisheries

Blue and red shrimp is the most important crustacean species in catches and value of GSA 06 (Northern Spain) fisheries. It is a deepwater species caught exclusively by bottom trawl. The blue and red shrimp has a wide bathymetric distribution, between 80 and 3300 m depth (Sardà *et al*., 2004), although commercial fishing grounds are located between 450 and 900 m depth. Deeper areas may act as a refuge for the stock, specially for the juvenile fraction, as they are located far from the main fishing ports and below 1000 m of depth where the trawl fishing is banned (GFCM resolution 2005/1). Females predominate in the landings, representing nearly 80% of the total landings. Discards of the blue and red shrimp are practically nil because of the high commercial value of the species. Other accompanying species of commercial value in the catches are large individuals of hake, greater forkbeard, Nephrops and blue whiting. In GSA 06, the number of harbours with vessels fishing blue and red shrimp is 14. Exploitation is based on young age classes, mainly 1 and 2 year old individuals.

5.2.15.5.2 Management regulations applicable in 2015

Trawl fisheries in GSA 6 are regulated by "Orden AAA/2808/2012" published in the Spanish Official Bulletin (BOE no 313 29 December 2012) containing an Integral Management Plan for Mediterranean fishery resources. To the traditional fisheries regulations already in place (e.g. the daily and weekly fishing effort limited to 12 hours per day five days a week; trawl cod end 40 mm square mesh or 50 mm diamond stretched mesh; engine power of maximum 373 kW [not observed]; license system; minimum landing size of 20 mm CL), this plan adds that fishing mortality for *Aristeus antennatus* in GSA 6 should be kept at or below the reference value F_{01} = 0.24, and that fishing effort be reduced by 20% or more over the period 2013-2017 (based on the effort established on 1 January 2013). This fishing effort reduction will be measured in terms of number of vessels, engine power and tonnage.

5.2.15.5.3 Catches (by fleet if posible)

The catches by the bottom trawl fleet are reported in the following table and figure. Note that catches in the official data call before 2011 are incomplete and correspond only to catches reported in logbooks. This problem was reported in the previous assessment (2012, EWG 12-19). The catches for the period 2002 – 2010 have been corrected using the official data of local Fisheries Directorates of the Autonomous Communities of Catalonia and Valencia, while for 2011 – 2014 the data from the local Fisheries Directorates and the Data Call 2015 coincide.

Table 5.2.15.5.3.1. Blue and red shrimp in GSA 6. Annual catches (t).

2002	2003	2004	2005	2006	2007	2008
723	583	577	308	354	579	730
2009	2010	2011	2012	2013	2014	
743	647	669.5	703.5	678.9	545.6	

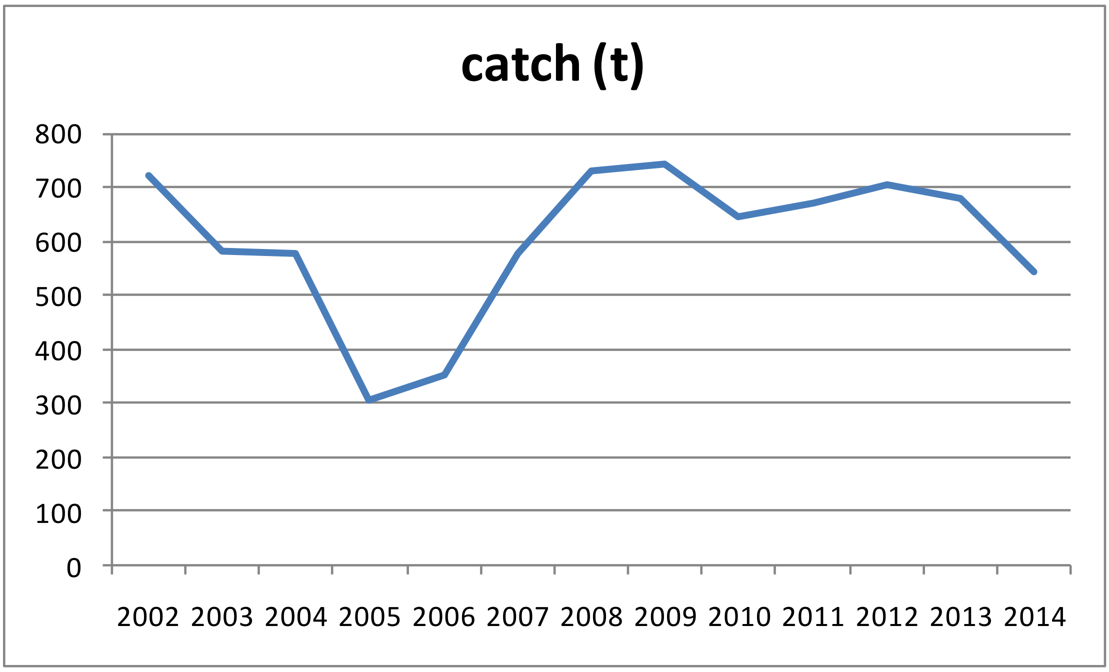


Figure. 5.2.15.5.3.1. Blue and red shrimp in GSA 6. Annual catches (t).

5.2.15.5.4 Landings

Landings are assumed to be equal to catches because discards are negligible (Table 5.2.15.5.3.1).

5.2.15.5.5 Discards

Discards are negligible due to the high commercial value of the species.

5.2.15.5.6 Fishing effort (by fleet if possible)

All indicators of fishing effort have been decreasing over the last 6 years, as well as capacity (number of vessels). The fleet segments involved in the deepwater trawl fishery are in length classes VL1224 and VL2440.

Table 5.2.15.5.6.1. Effort of the bottom trawl fishing fleet (OTB) in GSA 6.

	Effort (kW * days)	Effort (GT * days)
2009	28 339 356	6 063 794.54
2010	26 306 047	5 673 235.42
2011	24 805 884	5 343 285.49
2012	23 553 925	5 109 806.37
2013	22 821 990	5 021 556.13
2014	23 422 870	5 216 516.97

Table 5.2.15.5.6.2. Number of vessels of the bottom trawl fishing fleet (OTB) in GSA 6 active in the first quarter of each year.

2009	**843**
2010	**827**
2011	**756**
2012	**729**
2013	**713**
2014	**700**

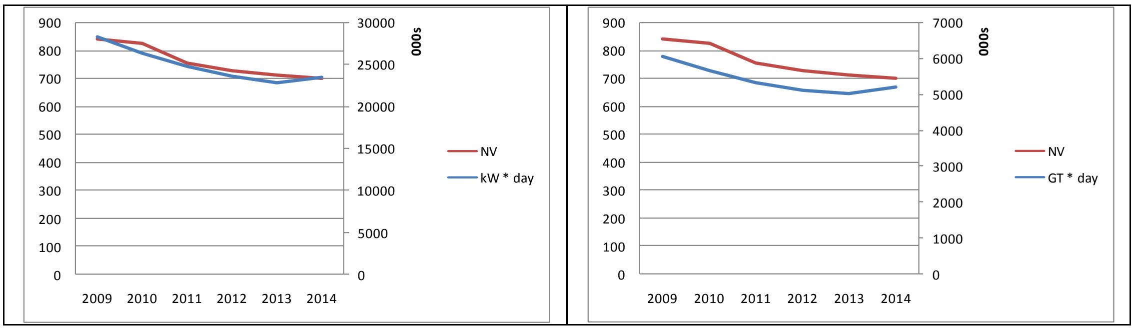


Figure 5.2.15.5.6.1. OTB fishing fleet in GSA 6. Number of vessels, nominal effort (000s of kW*days at sea) and nominal capacity (000s GT*days at sea).

5.2.15.6 Scientific surveys

5.2.15.6.1 Survey #1 (MEDITS)

5.2.15.6.1.1 Methods

The abundance (N/km^2) and biomass (kg/km^2) indices obtained by means of the MEDITS surveys were computed, based on the DCF data call 2015. Blue and red shrimp is present only in the deepest stratum (500 – 800 m) of the MEDITS survey. The number of hauls in that stratum along the 21 year time series is shown in the following table:

stratum	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
500 - 800 m	7	11	10	8	4	10	7	8	7	11	12
stratum	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	
500 - 800 m	8	12	9	9	8	7	7	9	8	10	

Data were assigned to strata based upon the shooting position and average depth (between shooting and hauling depth). Catches by haul were standardized to 60 minutes hauling duration. The abundance and biomass indices by GSA were calculated through stratified means (Cochran, 1953; Saville, 1977). This implies weighting of the average values of the individual standardized catches and the variation of each stratum by the respective stratum areas in each GSA:

Yst = Σ (Yi*Ai) / A
V(Yst) = Σ (Ai2 * si 2 / ni) / A2
Where:
A=total survey area

Ai=area of the i-th stratum
si=standard deviation of the i-th stratum
ni=number of valid hauls of the i-th stratum n=number of hauls in the GSA
Yi=mean of the i-th stratum
Yst=stratified mean abundance V(Yst)=variance of the stratified mean

The variation of the stratified mean is then expressed as the 95 % confidence interval: Confidence interval = Yst ± t(student distribution) * V(Yst) / n
Length distributions represented an aggregation (sum) of all standardized length frequencies (subsamples raised to standardized haul abundance per hour) over the stations of each stratum. Aggregated length frequencies were then raised to stratum abundance * 100 (because of low numbers in most strata) and finally aggregated (sum) over the strata to the GSA.

5.2.15.6.1.2 Geographical distribution

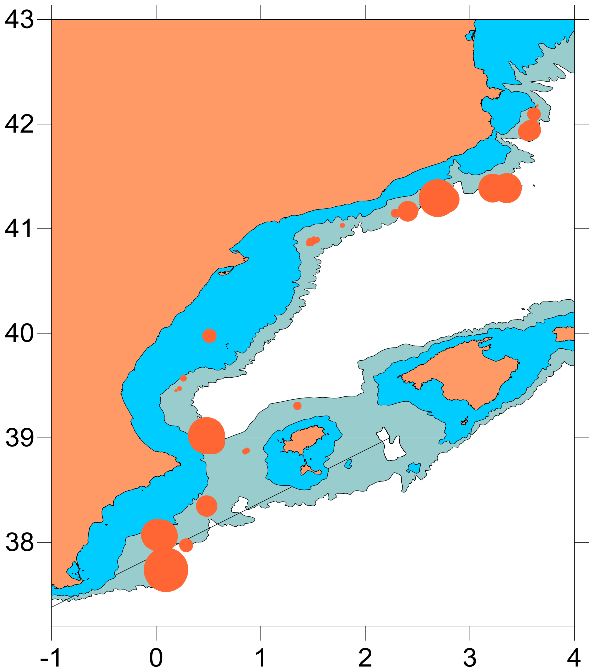


Fig. 5.2.15.6.1.2. Blue and red shrimp in GSA 6. Average density (N/km^2) in MEDITS surveys over the period 1994-2014 (circle diameter proportional to abundance).

5.2.15.6.1.3 Trends in abundance and biomass

The abundance indices derived from the MEDITS surveys show an increasing trend over time, although with high fluctuations, from approximately 75 individuals/km^2 on average in the late 1990s to approximately 100 individuals/km^2 in the last 5 years. In terms of biomass, the increase is from 1 kg/km^2 to 1.5 kg/km^2 approximately over the same period.

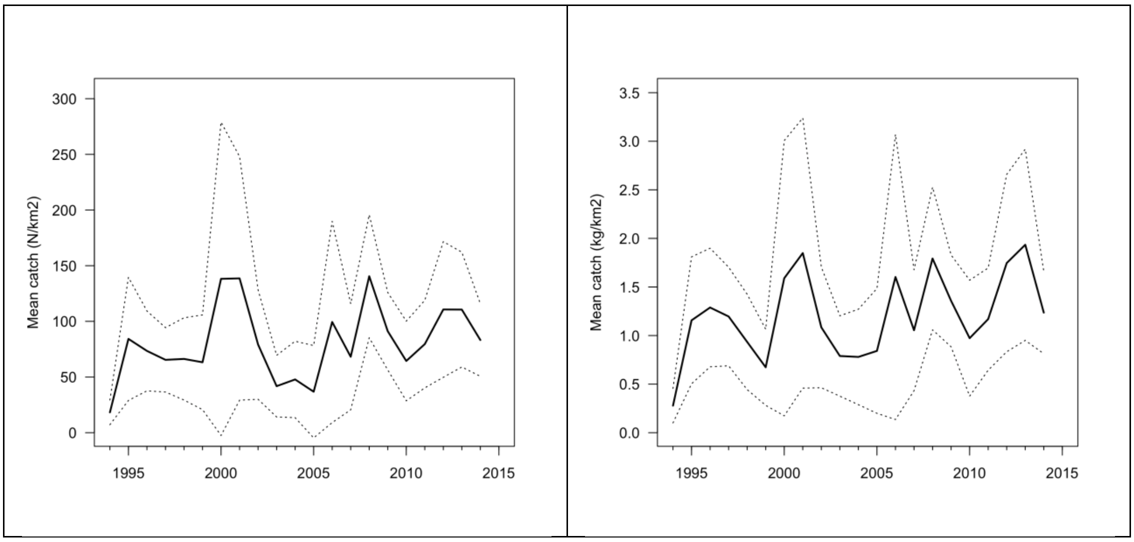


Fig. 5.2.15.6.1.3. Blue and red shrimp in GSA 6. Trends in abundance (left) and biomass (right) indices from 1994 to 2014.

5.2.15.6.1.4 Trends in abundance by length or age

The size distribution of *Aristeus antennatus* sampled during the MEDITS surveys is shown in the following two figures. The average size has fluctuated over the 21 year period of samples, with mean size in the last 5 years being relatively small (25 to 28 mm CL).

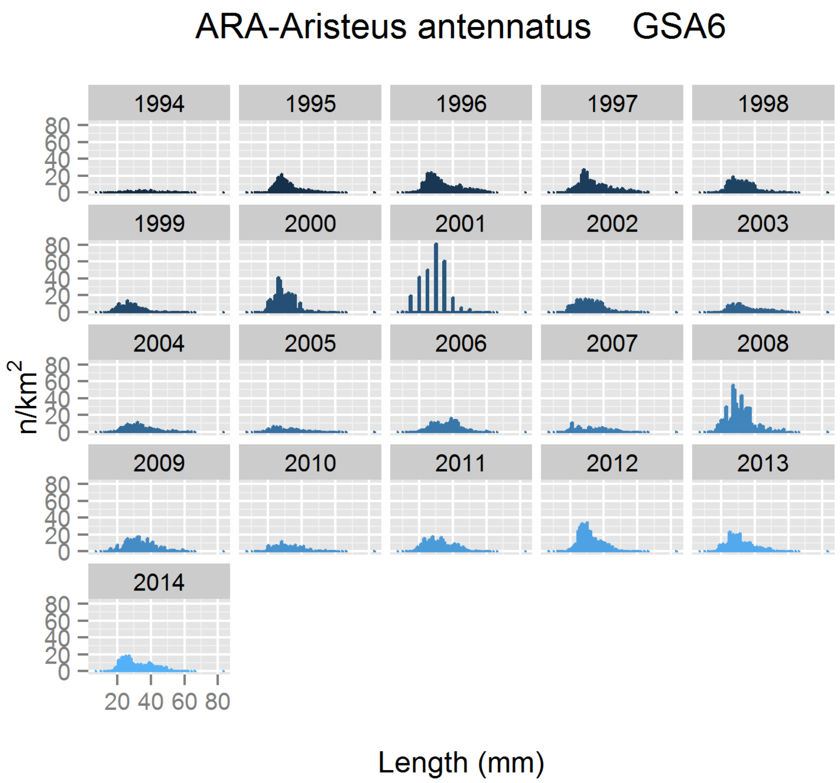


Figure. 5.2.15.6.1.4.1. Blue and red shrimp in GSA 6. Length frequency distributions.

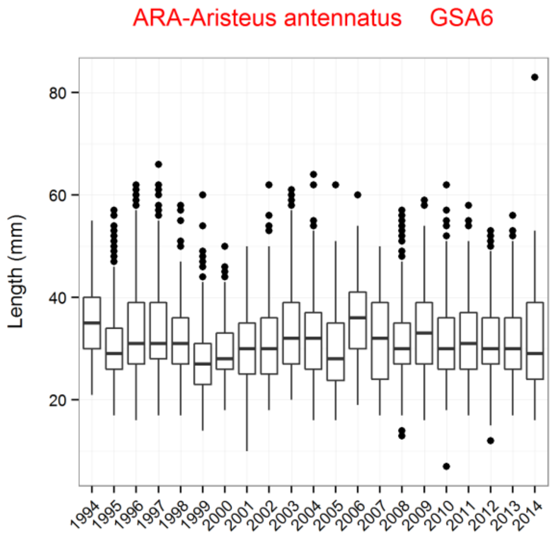


Figure. 5.2.15.6.1.4.2. Blue and red shrimp in GSA 6. Box plots of size frequency histograms, showing the median and 0.25 - 0.75 quantiles (box) and 0.1 – 0.9% quantiles of the distribution (lines). Dots represent outlyers.

5.2.15.7 Stock Assessment

5.2.15.7.1 Methods

The available DCF Data Call 2015 was deemed adequate for the application of an Extended Survivors Analysis (XSA) tuned with fishery independent data (MEDITS abundance indices). A catch-at-age matrix for the period 2002-2014 was constructed, assuming no discarding, and the analysis was carried out in the FLR framework.

5.2.15.7.2 Input data

Table 5.2.15.7.2.1. Blue and red shrimp in GSA 6. Catch-at-age matrix (number of individuals in the commercial catches, in thousands).

Year	age0	age1	age2	age3	age4	age5+
2002	834	65048	13327	1806	541	45
2003	1553	59192	10281	1154	318	38
2004	323	48567	10180	1334	545	54
2005	102	28086	4918	773	266	63
2006	292	28548	8077	633	83	38
2007	123	44272	12577	1528	203	32
2008	254	62949	11536	2259	1027	107
2009	203	63245	13851	1866	669	69
2010	352	50158	14562	1908	345	34
2011	197	37928	15208	2519	577	74
2012	882	56854	17049	2556	414	44
2013	127	69790	11527	2057	319	39

2014	345	65001	12345	2130	288	31

Fig. 5.2.15.7.2.1. Blue and red shrimp in GSA 6. Log-catch curves.

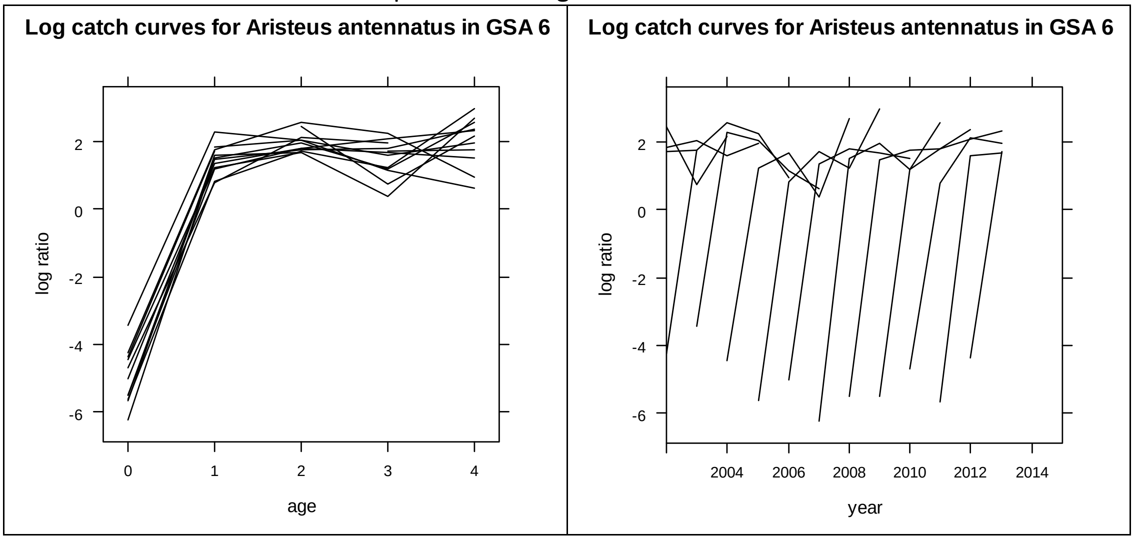


Table 5.2.15.7.2.2. Blue and red shrimp in GSA 6. Catch and stock weights at age (kg).

Age group	age0	age1	age2	age3	age4	age5+
2002	0.0050	0.0120	0.0290	0.0460	0.0600	0.0770
2003	0.0040	0.0120	0.0290	0.0470	0.0600	0.0774
2004	0.0050	0.0100	0.0290	0.0480	0.0620	0.0773
2005	0.0050	0.0100	0.0290	0.0480	0.0630	0.0768
2006	0.0050	0.0110	0.0280	0.0480	0.0000	0.0761
2007	0.0050	0.0110	0.0290	0.0460	0.0600	0.0772
2008	0.0050	0.0100	0.0290	0.0480	0.0640	0.0750
2009	0.0050	0.0110	0.0290	0.0480	0.0630	0.0780
2010	0.0050	0.0110	0.0290	0.0480	0.0640	0.0790
2011	0.0050	0.0130	0.0280	0.0470	0.0630	0.0790
2012	0.0040	0.0110	0.0290	0.0470	0.0640	0.0740
2013	0.0050	0.0100	0.0290	0.0470	0.0600	0.0773
2014	0.0050	0.0110	0.0290	0.0470	0.0640	0.0770

Table. 5.2.15.7.2.3. Blue and red shrimp in GSA 6. Maturity vector and natural mortality.

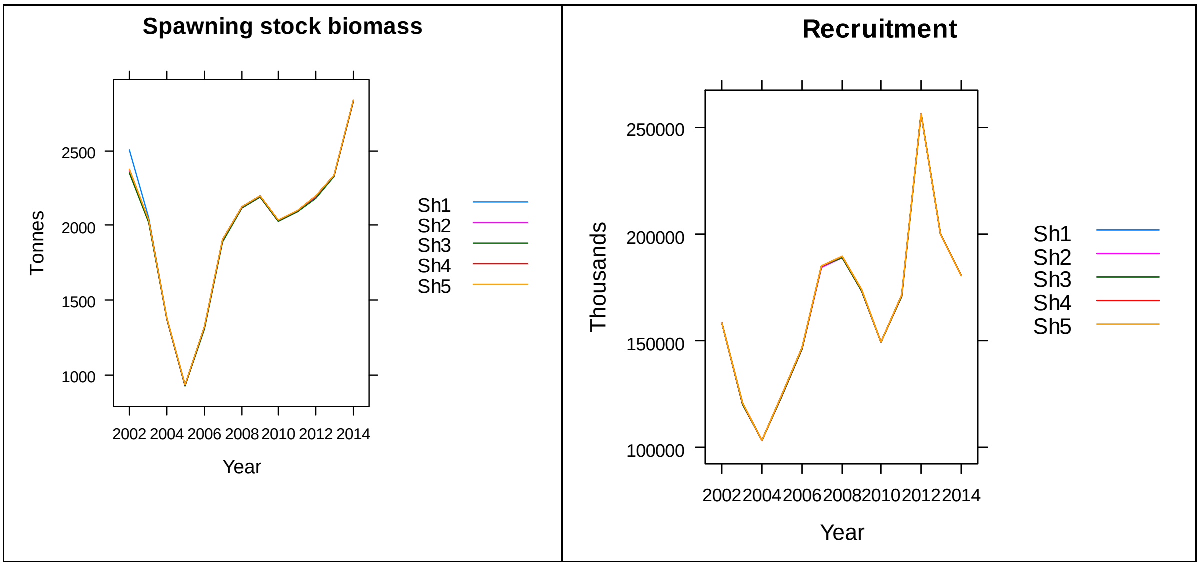
Age group	age0	age1	age2	age3	age4	age5+
maturity	0.07863	0.7669	0.998	1	1	1
M	0.46	0.46	0.46	0.46	0.46	0.46

Table. 5.2.15.7.2.2. Blue and red shrimp in GSA 6. Tuning index (MEDITS), estimated number of individuals per km^2.

	Age 0	Age 1	Age 2	Age 3	Age 4+
2002	34.0	15.4	1.0	0.0	0.0
2003	27.4	15.5	5.0	2.3	1.1
2004	18.5	10.8	1.6	0.6	0.5
2005	8.6	4.0	1.0	0.2	0.1
2006	14.6	24.6	4.3	0.2	0.1
2007	17.5	6.3	2.4	0.0	0.0
2008	50.3	16.1	2.1	0.5	0.3
2009	23.2	16.8	3.3	0.7	0.5
2010	16.4	10.0	1.0	0.5	0.4
2011	26.5	17.7	3.0	0.2	0.1
2012	49.4	23.6	2.1	0.0	0.0
2013	41.1	27.8	14.6	0.5	0.4
2014	36.0	28.0	15.0	0.6	0.3

5.2.15.7.3 Results

The selection of the control parameters for the final XSA run was performed by running sequential sensitivity analysis, testing for a range of suitable parameters in shrinkage weight assumptions (fse range: 0.5 to 2.5), shrinkage on the last ages (shk.age range: 0 to 4), catchability dependent on stock size (r.age range: 0 to 4), age after which catchability is no longer estimated (q.age range: 0 to 4), and shrinkage on the last years (range: 1 to 5). The following figure reproduces the results of the last sensitivity analysis (shrinkage on the last years), for fse= 2.0, shk.age=3, r.age=1, and q.age=2.



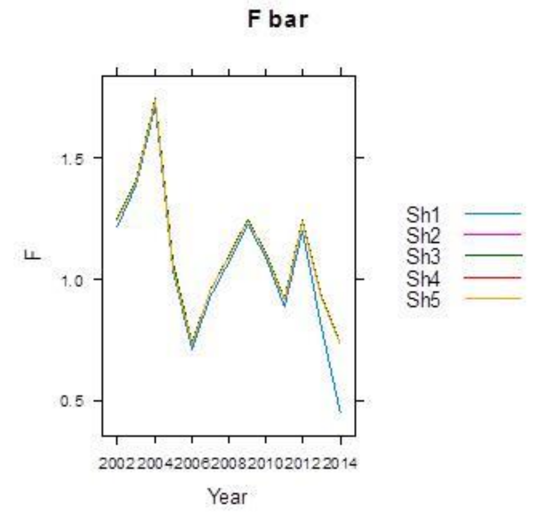


Figure. 5.2.15.7.3.1. Blue and red shrimp in GSA 6. Sensitivity to different shrinkage.

All these analyses were repeated with a natural mortality vector with varying by each class, derived from the application of the PRODBIOM model, but a constant mortality value of M=0.46 produced consistently better results and thus it was used in the final XSA model.

Table 5.2.15.7.3.1. Blue and red shrimp in GSA 6. Natural mortality (M) vector computed with PRODBIOM.

Age group	age0	age1	age2	age3	age4	age5+
M	1.25	0.58	0.44	0.39	0.35	0.31

Settings of XSA final run
Period: 2002-2014
Age 5+ group was used as input.
Catchability analysis:
Catchability dependent on stock size for ages < 1
Catchability independent of age for ages >= 2
M constant at 0.46 yr^{-1}.
Survivor estimates shrunk towards the mean F of the final 3 years or the 3 oldest ages. S.E. of the mean to which the estimates are shrunk = 2.0

Table. 5.2.15.7.3.2. Blue and red shrimp in GSA 6. Log-catchability of the residuals for the tuning fleet MEDITS.

	age0	age1	age2	age3	age4
2002	0.419	0.172	-1.249	-0.023	0.006
2003	0.482	0.277	0.892	0.779	0.128
2004	0.239	0.308	-0.03	0.456	0.003
2005	-0.708	-0.876	-0.052	-0.26	-0.023
2006	-0.350	0.689	0.447	-0.118	0.074
2007	-0.403	-0.72	-0.439	0.067	-0.023
2008	0.629	0.062	-0.403	-0.776	0.006
2009	-0.059	0.068	0.151	-0.209	0.188

2010	-0.256	-0.457	-1.112	-0.070	0.135
2011	0.086	0.203	-0.263	-0.919	-0.051
2012	0.137	0.499	-0.528	-0.023	0.006
2013	0.032	-0.093	1.527	-0.405	0.067
2014	0.004	-0.007	0.219	-0.337	0.091

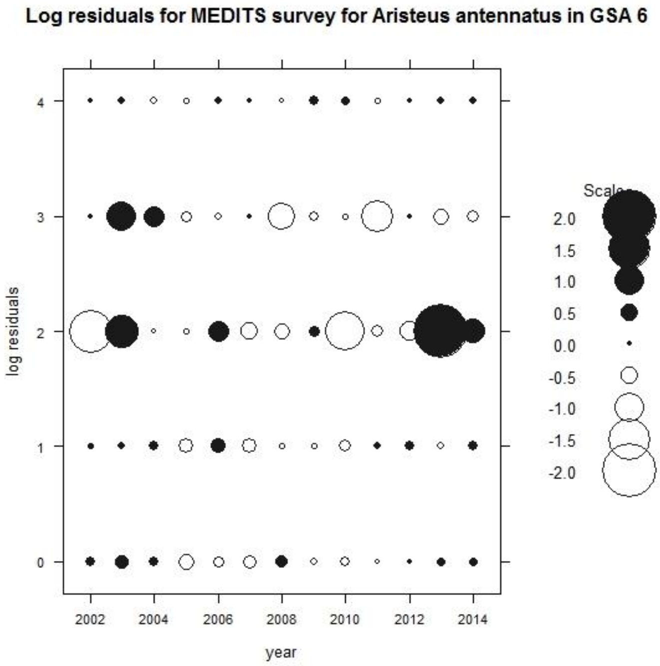


Fig. 5.2.15.7.3.2. Blue and red shrimp in GSA 6. Log-catchability of the residuals for the tuning fleet MEDITS.

The annual vectors of fishing mortality estimated by the selected XSA model are shown in table 5.2.15.7.3.3. Fishing mortality has fluctuated around 1.0 yr^{-1} in the study period, with the notable exception of the 2 most recent years, when it decreased to 0.52 yr^{-1} in 2014. The average F over the period 2012-2014 is 0.78 yr^{-1}.

Table. 5.2.15.7.3.3. Blue and red shrimp in GSA 6. Fishing mortality estimates.

age	0	1	2	3	4	5+		Fbar(1-3)
2002	0.0067	1.3846	1.0421	0.2601	0.9208	0.9208		0.8956
2003	0.0164	1.3901	1.3837	0.2900	0.0865	0.0865		1.0213
2004	0.0040	1.7060	1.7228	0.9532	0.2899	0.2899		1.4607
2005	0.0010	0.7898	1.2834	0.8059	0.7002	0.7002		0.9597
2006	0.0025	0.6206	0.7940	0.7592	0.2366	0.2366		0.7246
2007	0.0008	0.9286	0.9168	0.4515	0.8612	0.8612		0.7656
2008	0.0017	1.1385	0.9996	0.5572	0.9352	0.9352		0.8984
2009	0.0015	1.1013	1.3457	0.5798	0.4305	0.4305		1.0089
2010	0.0030	0.8602	1.3182	0.9673	0.2615	0.2615		1.0485
2011	0.0014	0.7073	1.0640	1.3859	1.5196	1.5196		1.0524
2012	0.0037	1.0838	1.3182	0.7038	1.5168	1.5168		1.0352

2013	0.0006	0.6144	0.9893	0.7403	0.2255	0.2255		0.7813
2014	0.0017	0.6191	0.2715	0.6822	0.2787	0.2787		0.5243

Table. 5.2.15.7.3.4. Blue and red shrimp in GSA 6. XSA summary table.

	RECRUITS	TOTALBIO	TOTSPBIO	LANDINGS	YIELD/SSB	FBAR 1-3
	Age 0					
2002	158201	3377.6	2341.8	723	0.31	0.8956
2003	120269	2733.3	2011.6	583	0.29	1.0213
2004	102952	2014.1	1364.8	577	0.42	1.4607
2005	123222	1638.1	919.0	308	0.34	0.9597
2006	146284	2177.5	1303.3	354	0.27	0.7246
2007	184800	2972.1	1883.1	579	0.31	0.7656
2008	189207	3249.5	2104.8	730	0.35	0.8984
2009	173593	3289.9	2183.0	743	0.34	1.0089
2010	149580	2998.4	2027.3	647	0.32	1.0485
2011	171553	3166.1	2088.9	670	0.32	1.0524
2012	304224	3603.0	2202.8	704	0.32	1.0353
2013	280926	4339.9	2598.3	679	0.26	0.7813
2014	253111	5472.6	3848.3	546	0.14	0.5243
Arith.						
mean	181378.6	3156.32	2067.46	603.19	0.31	0.9366
units	(Thousands)	(tonnes)	(tonnes)	(tonnes)		

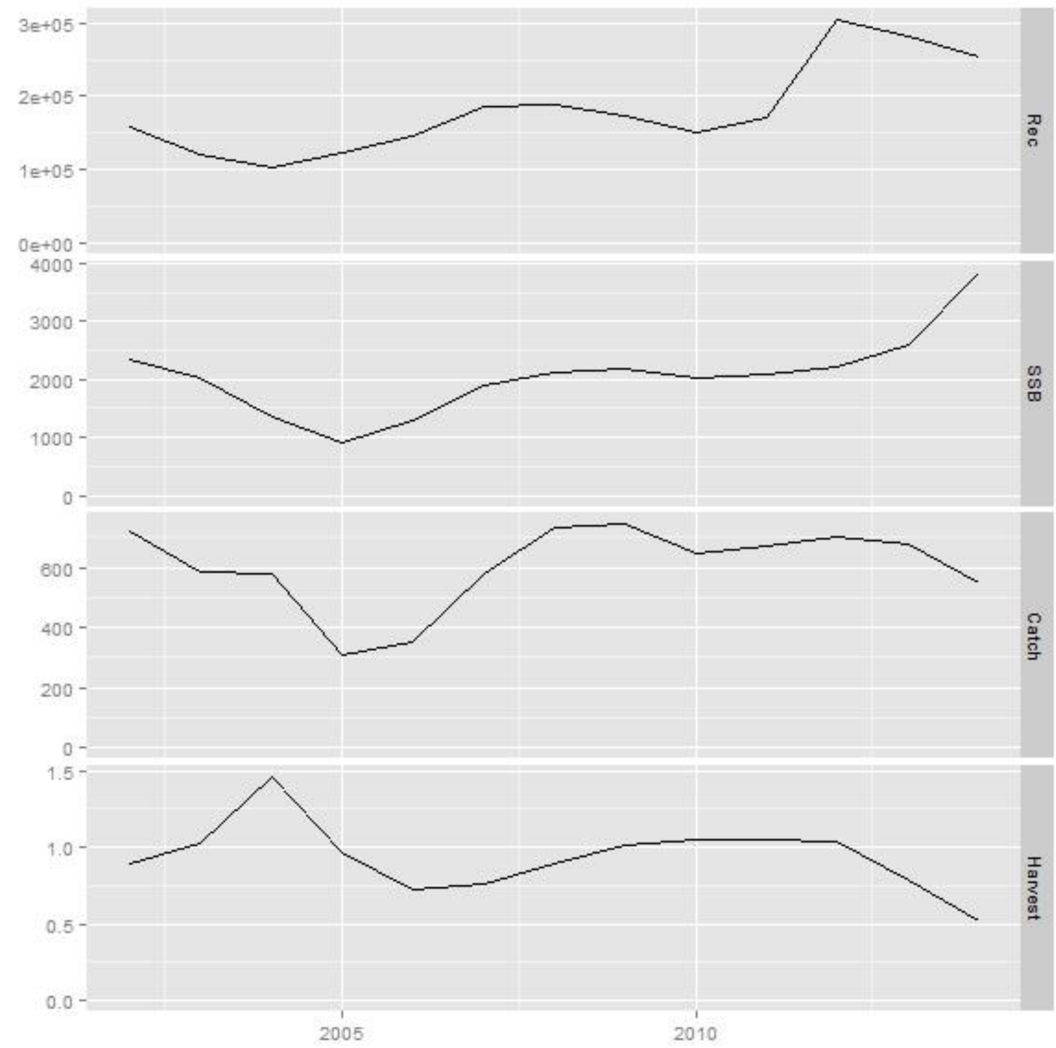


Figure 5.2.15.7.3.3. Blue and red shrimp in GSA 6. SSB and catch are in tonnes, recruitment in 1000s individuals.

A retrospective analysis conducted on SSB, F and recruitment shows that the results of the final XSA estimates are rather robust (Fig. 5.2.15.7.3.4).

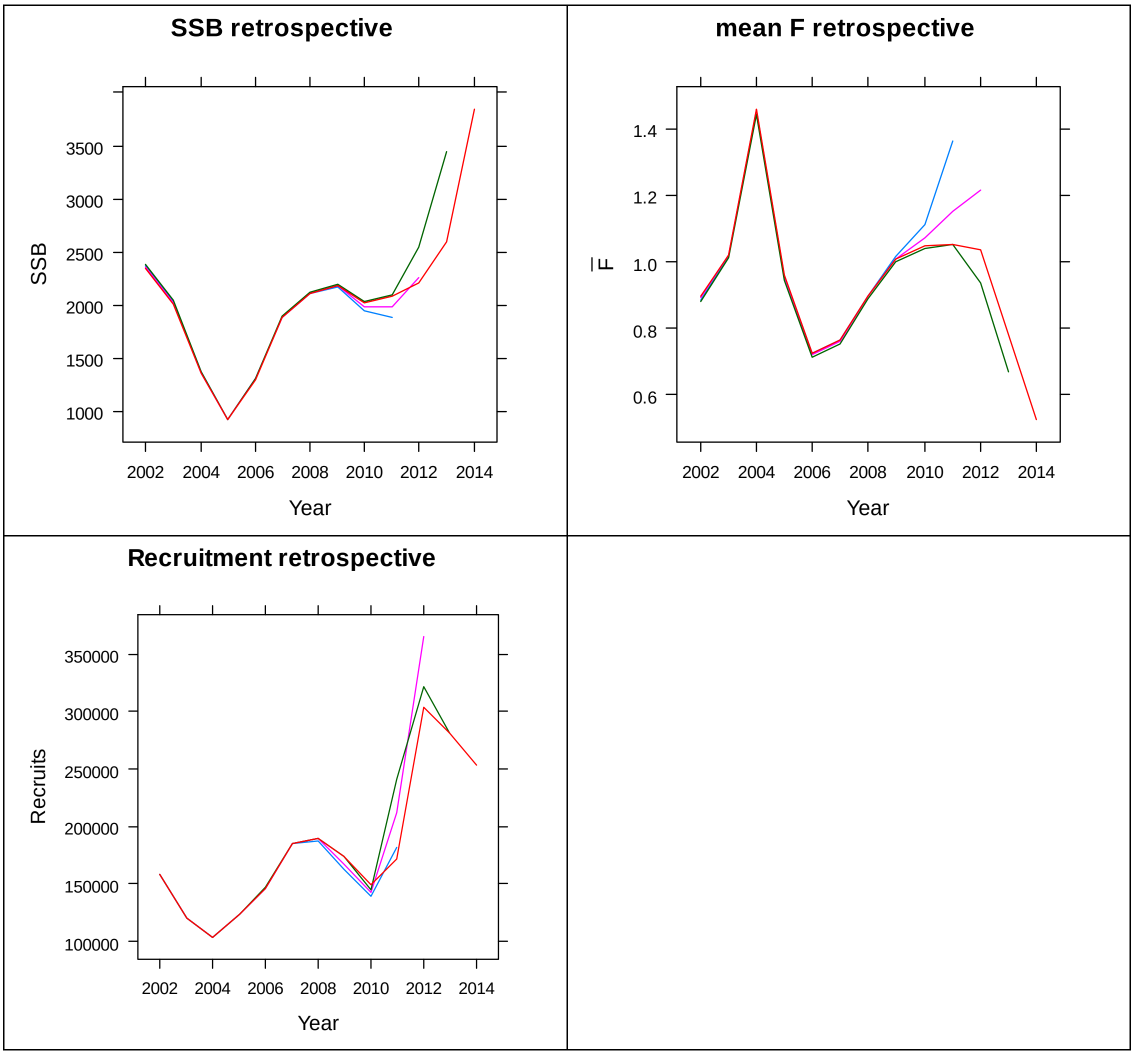


Fig. 5.2.15.7.3.4. Blue and red shrimp in GSA 6. Results of the retrospective analysis.

Figure 5.2.15.7.3.5 shows that the trends estimated between total biomass and recruits closely match (top left panel), but a meaningful SSB/R relationship could not be established. The top right panel shows that landings are not strongly correlated with F, but with the exception of years 2009-2010, landings follow the same trend of abundance detected for age 1 shrimp by the MEDITS indices (bottom left panel).

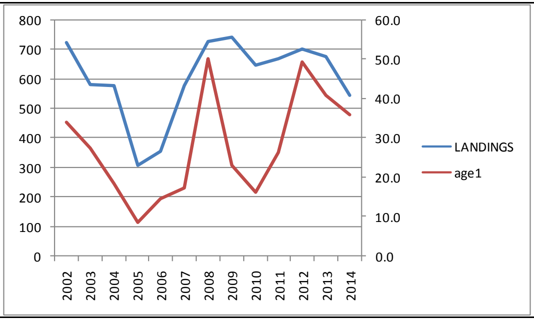


Fig. 5.2.15.7.3.5. Blue and red shrimp in GSA 6. Relationships between selected pairs of indicators: recruits, total biomass, landings, Fbar and Age 1 individuals from MEDITS surveys.

5.2.15.8 Reference points

5.2.15.8.1 Methods

Yield per recruit analysis (YPR) was conducted assuming equilibrium conditions, based on the exploitation pattern resulting from the XSA analysis. YPR was used for the estimation of $F_{0.1}$ (i.e. proxy of F_{MSY}) and F_{max}.

5.2.15.8.2 Input data

Table 5.2.15.8.2.1. Blue and red shrimp in GSA 6. Input parameters used in the YPR analysis.

Age group	Stock weight (kg)	Catch weight (kg)	maturity	F 2014	M
0	0.005	0.005	0.079	0.0024	0.46
1	0.011	0.011	0.777	1.0553	0.46
2	0.029	0.029	0.998	0.3972	0.46
3	0.047	0.047	1	0.6931	0.46
4	0.064	0.064	1	0.2707	0.46
5+	0.077	0.077	1	0.2707	0.46

5.2.15.8.3 Results

Table 5.2.15.8.3.1. Blue and red shrimp in GSA 6. Results of the YPR analysis.

	F	Y/R (kg)	SSB/R (kg)	Bio/R (kg)	mean age
	0	0	0.0503	0.0664	1.7121
F0.1	0.36	0.0067	0.0188	0.0325	0.9470
Fmax	0.66	0.0073	0.0107	0.0233	0.7174
F at SSB 0.3	0.46	0.0071	0.0153	0.0285	0.8509

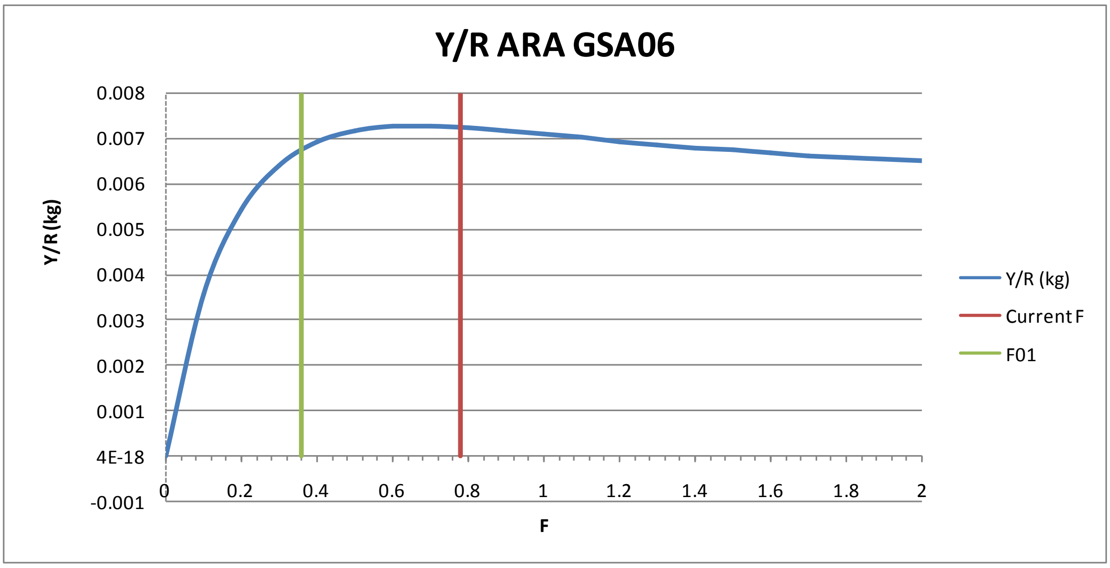


Figure 5.2.15.8.3.1. Blue and red shrimp in GSA 6. Results of the YPR analysis.

5.2.15.9 Data quality

Data quality for this stock is adequate, except for the catch series in the 2002-2010 period, which needed to be reconstructed from local fisheries statistical data. This problem had been noted earlier in the previous assessment carried out in STECF 12-19.

5.2.15.10 Short term predictions 2015-2017

5.2.15.10.1 Method

A short term forecats was produced using the FLR script provided by JRC.

5.2.15.10.2 Input parameters

Input parameters are the output of the XSA stock assessment, with F_{MSY} set as 0.36 from the yield-per recruit analysis in section 5.2.15.8.

5.2.15.10.3 Results

Table 5.2.15.10.3.1. Blue and red shrimp in GSA 6. Short term forecast in different F scenarios. Basis: F(2015) = mean (F_{bar} 1-3 2012-2014)= 0.78; R(2015) = geometric mean of the recruitment of the last 3 years; R = 278633 thousands; SSB(2014) = 3848 t, Catch (2014)= 547 t.

	Ffactor	Fbar	Catch_2015	Catch_2016	Catch_2017	SSB_2016	SSB_2017	Change_SSB_2016-2017(%)	Change_Catch_2014-2016(%)
	0.00	0.00	0	0	0	4375	7172	63.91	-100.00
	0.10	0.08	93	124	190	4375	6764	54.58	-77.25
	0.20	0.15	182	240	347	4375	6385	45.93	-56.02
	0.30	0.23	266	349	477	4375	6034	37.91	-36.20
	0.40	0.30	346	450	584	4375	5709	30.48	-17.69

	0.50	0.38	422	544	671	4375	5407	23.58	-0.40
	0.60	0.45	494	633	741	4375	5127	17.18	15.75
	0.70	0.53	563	715	797	4375	4868	11.25	30.85
	0.80	0.60	628	792	842	4375	4627	5.75	44.96
	0.90	0.68	690	864	877	4375	4404	0.65	58.15
status quo	1.00	0.78	749	932	903	4375	4197	-4.09	70.49
	1.10	0.83	805	995	923	4375	4004	-8.48	82.03
	1.20	0.90	858	1054	938	4375	3826	-12.55	92.84
	1.30	0.98	909	1109	947	4375	3661	-16.33	102.95
	1.40	1.05	957	1161	953	4375	3508	-19.84	112.43
	1.50	1.13	1003	1210	956	4375	3365	-23.09	121.30
	1.60	1.20	1047	1255	956	4375	3233	-26.10	129.62
	1.70	1.28	1089	1298	954	4375	3111	-28.90	137.42
	1.80	1.35	1130	1338	951	4375	2997	-31.50	144.73
	1.90	1.43	1168	1375	946	4375	2892	-33.91	151.59
	2.00	1.50	1204	1410	941	4375	2794	-36.14	158.03
F_{MSY}	0.48	0.36	407	525	654	4375	5468	24.97	-3.90

5.2.15.11 Medium term predictions

Not conducted as a meanigful stock recruitment relationship was not identified.

5.2.15.12 Stock advice

EWG 15-11 proposed $F_{0.1}$ = 0.36 as proxy of F_{MSY} and as the exploitation reference point consistent with high long term yields. Taking into account the results obtained by the XSA analysis presented here (current F is estimated at 0.52), the stock is considered to be being fished above F_{MSY}.

5.2.15.13 Management strategy evaluation

The application of the empirical formula derived in the EWG 15-06 meeting (Ispra, June 2015) produced a range of F_{MSY} from 0.24 to 0.49.

A management strategy for F_{MSY} at the upper range achieved by 2020 was evaluated using FLR script provided by JRC. The management strategy evaluation included uncertainty in: a) recruitment around a mean level resulting from the geometric mean of the last 3 years of data, b) uncertainty in the MEDITS tuning fleet indices, and c) uncertainty in the perceived stock status. The stock was assessed by a statistical catch at age (SCA in a4a library) at each iteration, with a total of 250 iterations. The following figure shows the evolution of the main four stock indicators. The probability of SSB falling below B_{lim} fishing at F_{upper} was estimated at 0. The dynamics observed for this stock are the result of the stock assessment model (i.e. XSA) settings used inside the MSE becoming less appropriate as the stock status changes in time (i.e. stock assessment settings are often specific to a particular range of stock status). This leads to an increasing difference between the perceived stock and the operating model (i.e. the 'true' stock). To avoid this behaviour in the future, for some of the stocks as it is the case here, a more general stock assessment method should be used in the MSE loop that is less sensitive to the stock status.

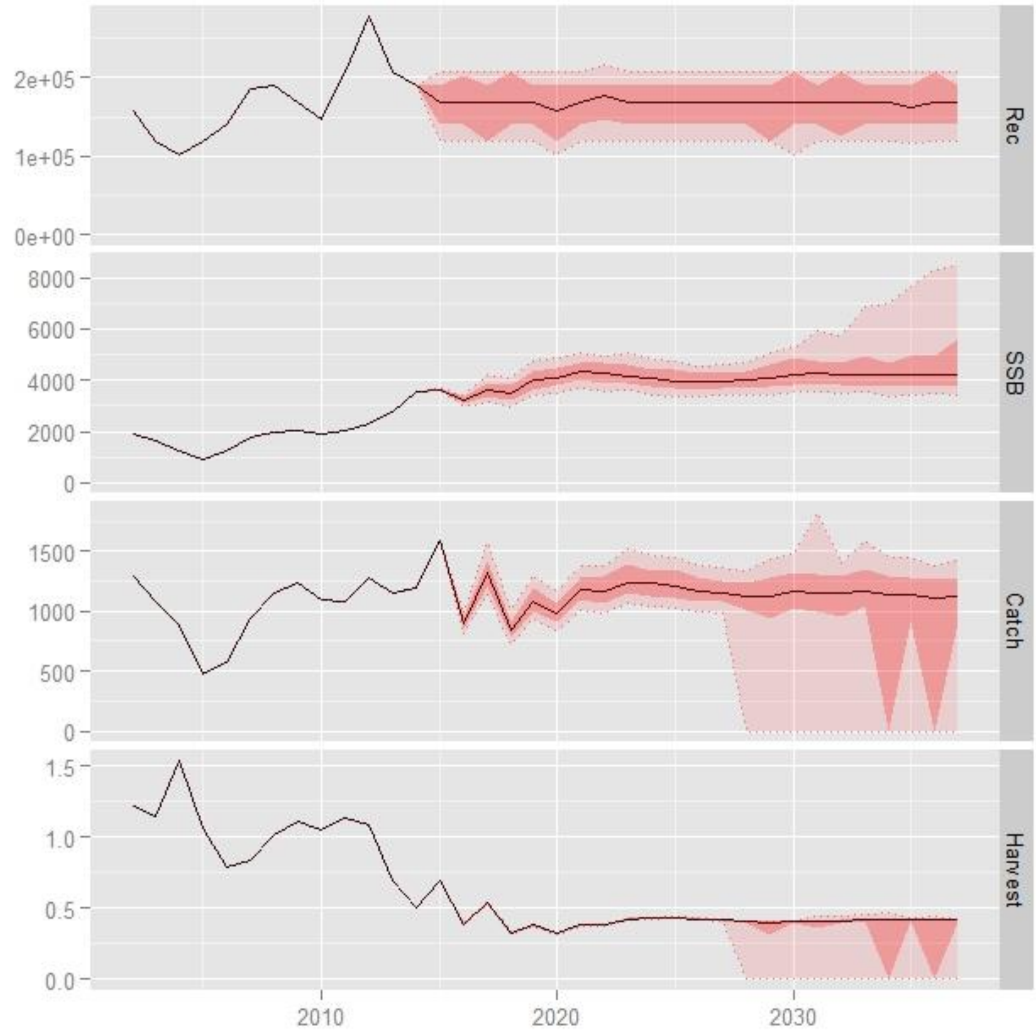


Fig. 5.2.15.13.1. Blue and red shrimp in GSA 6. Projection of recruitment, spawning stock biomass, landings and fishing mortality for the period 2015 – 2037 based on a management strategy achieving F_{MSY} upper (0.49) by 2020.

6 SPATIO-TEMPORAL MAPS OF HIGH OCCURRENCE OF JUVENILES AND/OR SPAWNERS OF HAKE, GIANT RED SHRIMP AND BLUE AND RED SHRIMP

The spatial distribution of juveniles and spawners of three important commercial species: hake (*Merluccius merluccius*), giant red shrimp (*Aristaeomorpha foliacea*), and blue and red shrimp (*Aristeus antennatus*) was examined in the western Mediterranean (GSAs 1 and 5-11). Stratified CPUE data (n/km^2) coming from the MEDITS survey were analysed for this purpose. For years 1994-2014, when MEDITS data were available, yearly CPUEs were standardised by dividing with the maximum CPUE value of the year and bubble plots were created (Figs. 6.1 - 6.12).

The size thresholds applied to identify juveniles and spawners of each species were extracted from the final report of the MEDISEH project (Colloca et al. 2013). Juveniles are generally considered to be the 0-age recruits, while spawners are considered to be adult specimens that have reached a size suggesting that they can reproduce. Within each species, often different threshold sizes for juveniles and/or spawners were reported in the MEDISEH report in different GSAs. Therefore, the threshold sizes for each species used here were calculated by averaging the available threshold sizes in the MEDISEH report across the GSAs (Table 6.1). This approach allows for a uniform representation of nurseries and spawner concentrations across the whole western Mediterranean basin, but it does not account for the different growth and maturation rates that are known to occur in different GSAs.

Table 6.1 Size thresholds used to group juveniles and spawners of *Merluccius merluccius*, *Aristaeomorpha foliacea* and *Aristeus antennatus*.

Species	Upper size threshold for juveniles (mm)	Lower size threshold for spawners (mm)
Merluccius merluccius	114	336
Aristaeomorpha foliacea	26	36
Aristeus antennatus	23	26

It should be noted that the construction of the maps of high occurrence of juveniles and spawners of the three species was based on data from a single seasonal survey, the MEDITS, which is carried out in May-July. Therefore, identified areas of high occurrence correspond to nurseries and aggregation areas of spawners/adults during this specific period of the year. Supplementary nurseries/spawning grounds could be used in other seasons by these species (Colloca et al. 2013).

For *M. merluccius*, the timing of the MEDITS survey allowed for a good depiction of the juvenile occurrence. Areas with persistently high concentrations of hake juveniles include parts of the Catalan coast (GSA 6), the gulf of Lions (GSA 7), and the Ligurian sea (GSA 9) (Fig. 6.1, 6.2). Around the Balearic Islands (GSA 5) and Sardinia (GSA 11), occurrence of hake juveniles showed high variability from year to year. Interestingly, the Balearic Islands exhibited substantial occurrence of hake juveniles only from 2007 onwards. The nursery areas identified here are in general agreement with previous findings (Colloca et al. 2013; Colloca et al. 2015; Druon et al. 2015). Regarding *M. merluccius* spawners, there was a mismatch between the MEDITS survey period (late spring-early summer) and the main spawning period (winter-spring) of the species, which resulted into low catch of big hake during MEDITS in most GSAs. Sardinia (GSA 11) and the gulf of Lions (GSA 7) exhibited the highest concentrations of spawners (Fig. 6.2, 6.3). The persistent occurrence of hake spawners around Sardinia is probably due to the fact that unlike most other areas in the western Mediterranean, the reproductive period of *M. merluccius* in Sardinia is long, with two peaks of activity that fall in winter and summer (Colloca et al. 2013), the latter coinciding with the timing of the MEDITS survey.

A. foliacea was rarely caught during MEDITS in the N-W Mediterranean (GSAs 1, 5, 6 7), while in GSA 9 the smallest specimens caught were age 1+ (Colloca et al. 2013). That explains why the only areas with relatively high concentrations of juveniles in every year were found to be Sardinia (GSA 11) and the Tyrrhenian sea (GSA 10) (Fig. 6.5, 6.6). The spawning period of *A. foliacea* in the western Mediterranean (summer months) coincides with the MEDITS survey period, meaning that the survey data provide good approximations of the spawning aggregations (Colloca et al. 2013). GSAs 10 and 11 appear to be the main areas of occurrence of *A. foliacea* spawners, while there have been a few years when spawning aggregations occurred in GSA 9 as well, especially after 2004 (Fig. 6.7, 6.8). These findings for *A. foliacea* are in general agreement with previous studies (Colloca et al. 2013; 2015).

For *A. antennatus* juveniles, the timing of the MEDITS survey is not considered suitable; a more accurate depiction of nursery areas would require sampling in late autumn-winter (Guijarro et al., 2008). Also, recruitment for this species takes place mostly at depths beyond 900m, which are not accessed by MEDITS (Sarda and Company, 2012). Therefore, the maps produced here (Fig. 6.9, 6.10) are not considered truly representative of the actual nursery areas and reflect the occurrence of bigger juveniles. Annual maps of spatial occurrence of *A. antennatus* juveniles exhibit great variability from year to year, with Sardinia (GSA 11) exhibiting the most persistent occurrence of juveniles (Fig. 6.9). The peak of the spawning period of *A. antennatus* in the western Mediterranean (summer months) coincides with the MEDITS survey period; hence, the occurrence of spawning aggregations can be identified (Colloca et al. 2013) (Fig. 6.11, 6.12). Spawning aggregations occurred in almost every year in Sardinia (GSA 11), gulf of Lions (GSA 7) and Ligurian Sea (GSA 9), while in the Spanish GSAs (1, 5, 6) there was a greater interannual variability (Fig. 6.11).

It should be noted that the MEDITS data that were made available to STECF 15-11 contained some obvious errors regarding the coordinates of some hauls in GSA 6 in years 2010 and 2013. In these years, some coordinates in GSA 6 corresponded to areas in continental Spain (Fig. 6.1, 6.3, 6.9, 6.11) Therefore, years 2010 and 2013 were excluded for the construction of the figures with the pooled data (Fig. 6.2, 6.4, 6.10, 6.12).

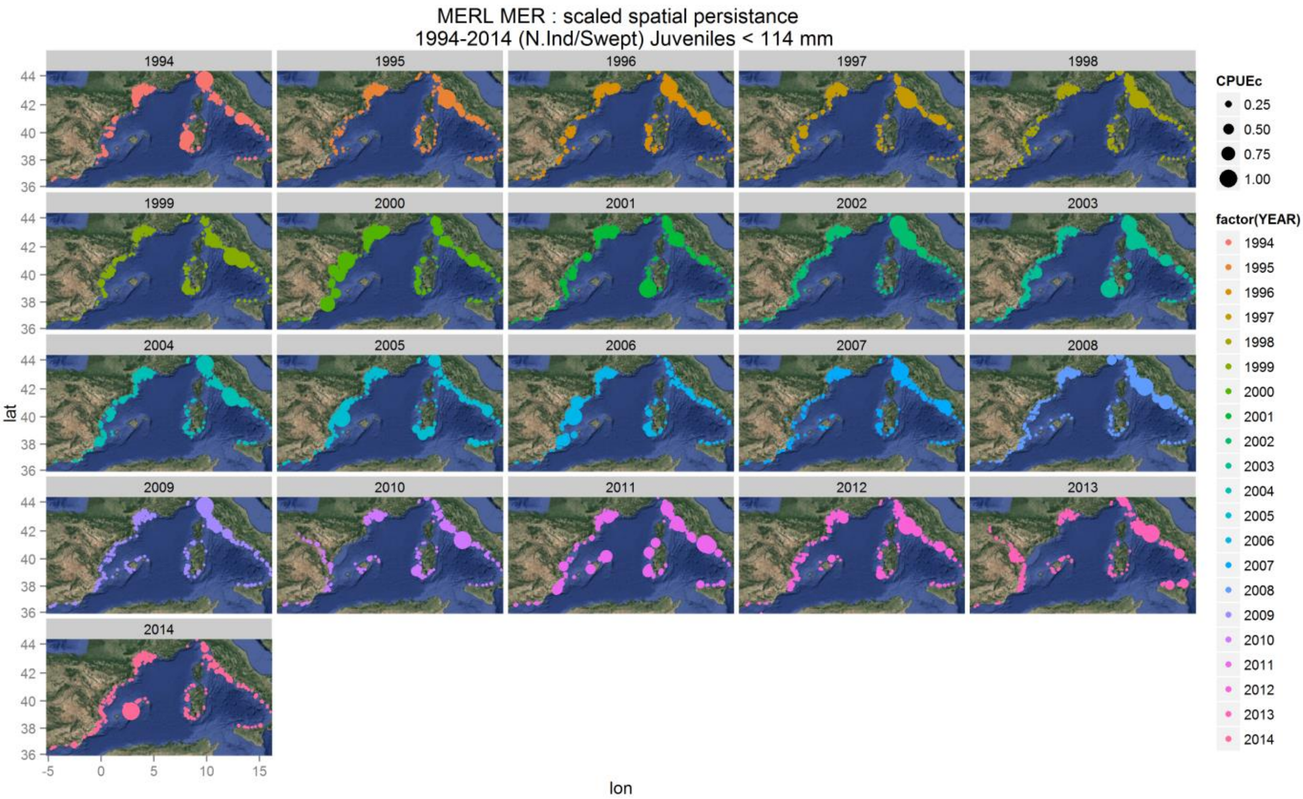


Figure 6.1. Annual spatial occurrence of *Merluccius merluccius* juveniles in the western Mediterranean in 1994-2014, based on data from the MEDITS survey.

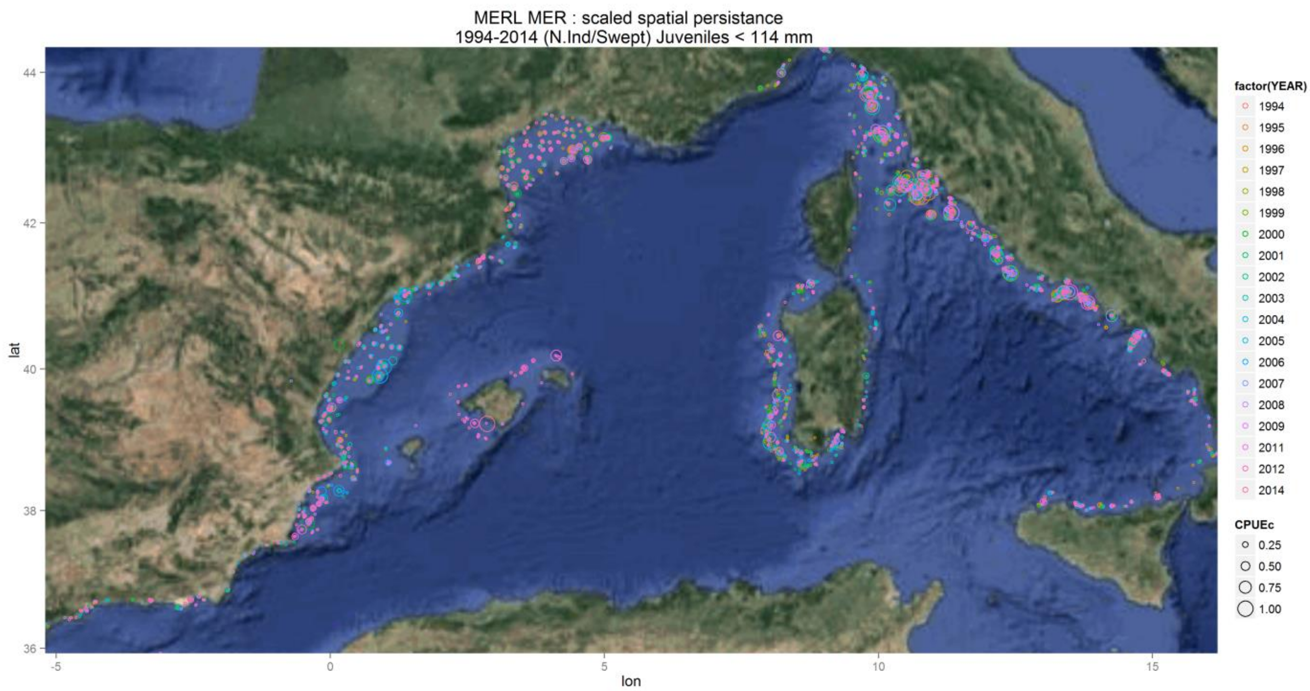


Figure 6.2. Pooled spatial occurrence of *Merluccius merluccius* juveniles in the western Mediterranean in 1994-2014, based on data from the MEDITS survey.

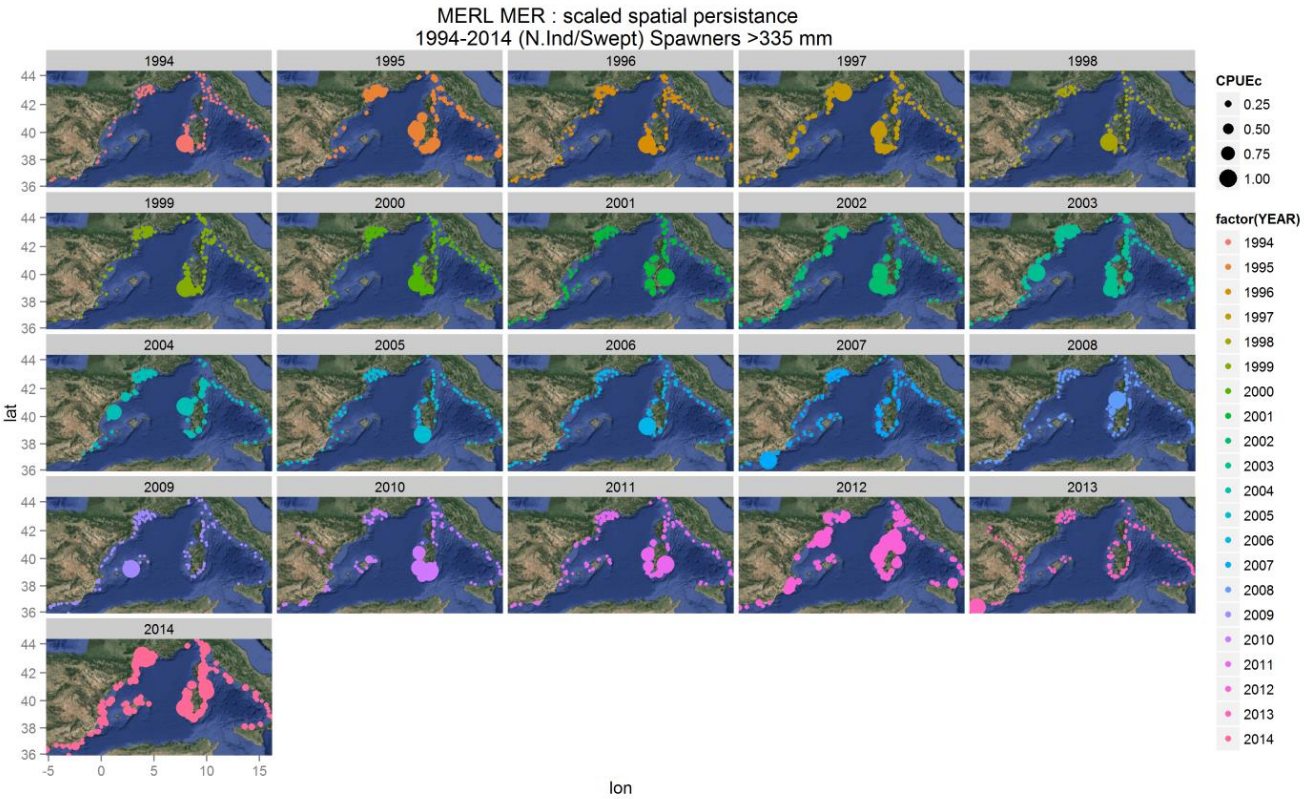


Figure 6.3. Annual spatial occurrence of *Merluccius merluccius* spawners in the western Mediterranean in 1994-2014, based on data from the MEDITS survey.

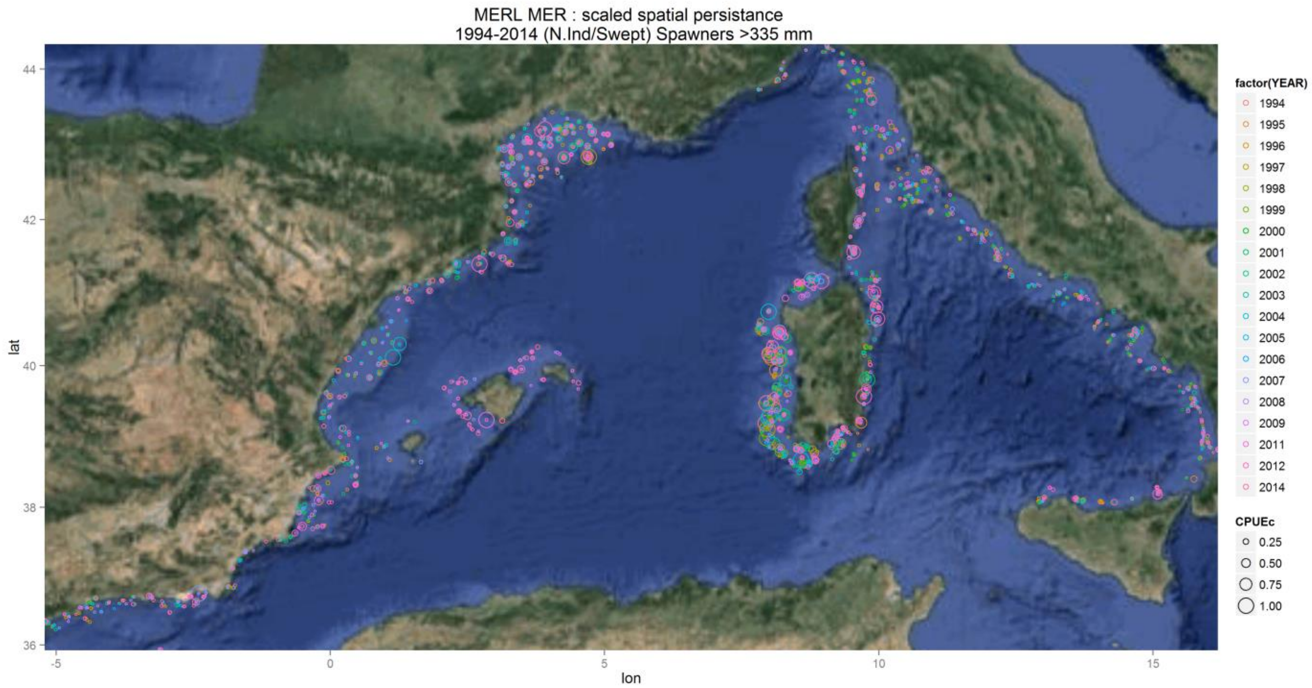


Figure 6.4. Pooled spatial occurrence of *Merluccius merluccius* spawners in the western Mediterranean in 1994-2014, based on data from the MEDITS survey.

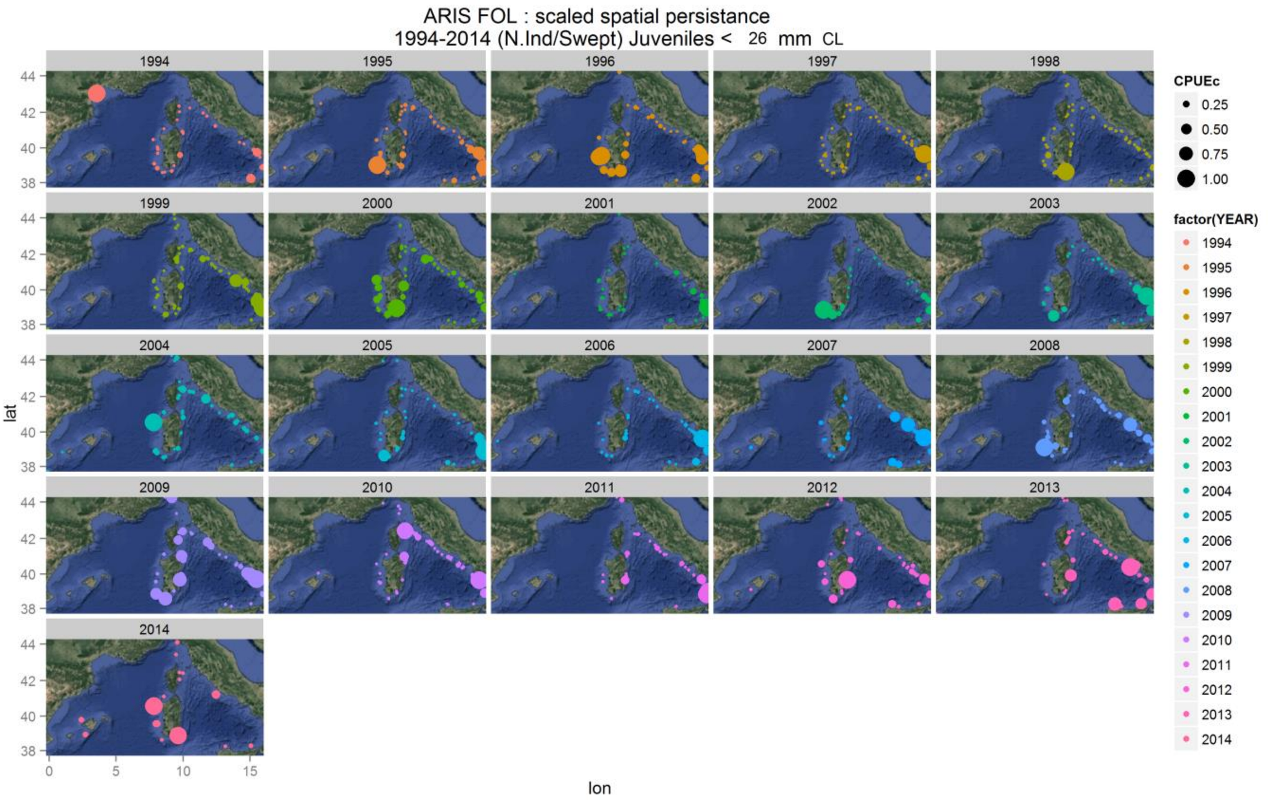


Figure 6.5. Annual spatial occurrence of *Aristaeomorpha foliacea* juveniles in the western Mediterranean in 1994-2014, based on data from the MEDITS survey.

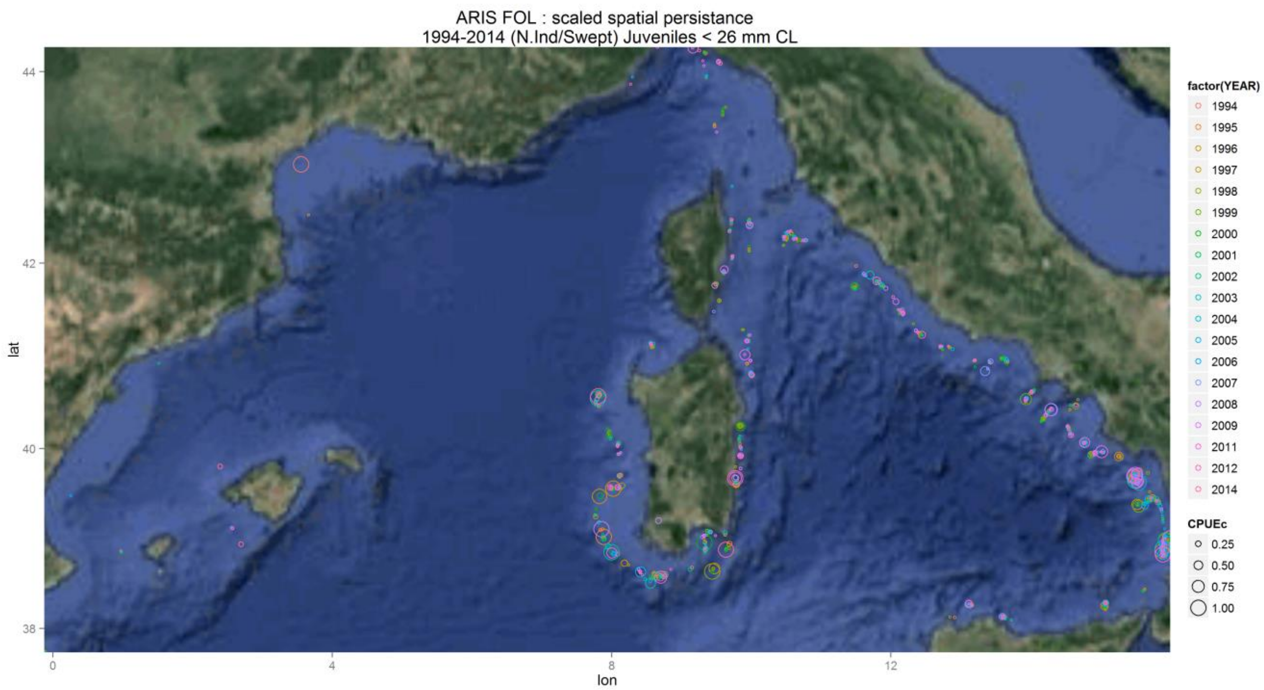


Figure 6.6. Pooled spatial occurrence of *Aristaeomorpha foliacea* juveniles in the western Mediterranean in 1994-2014, based on data from the MEDITS survey.

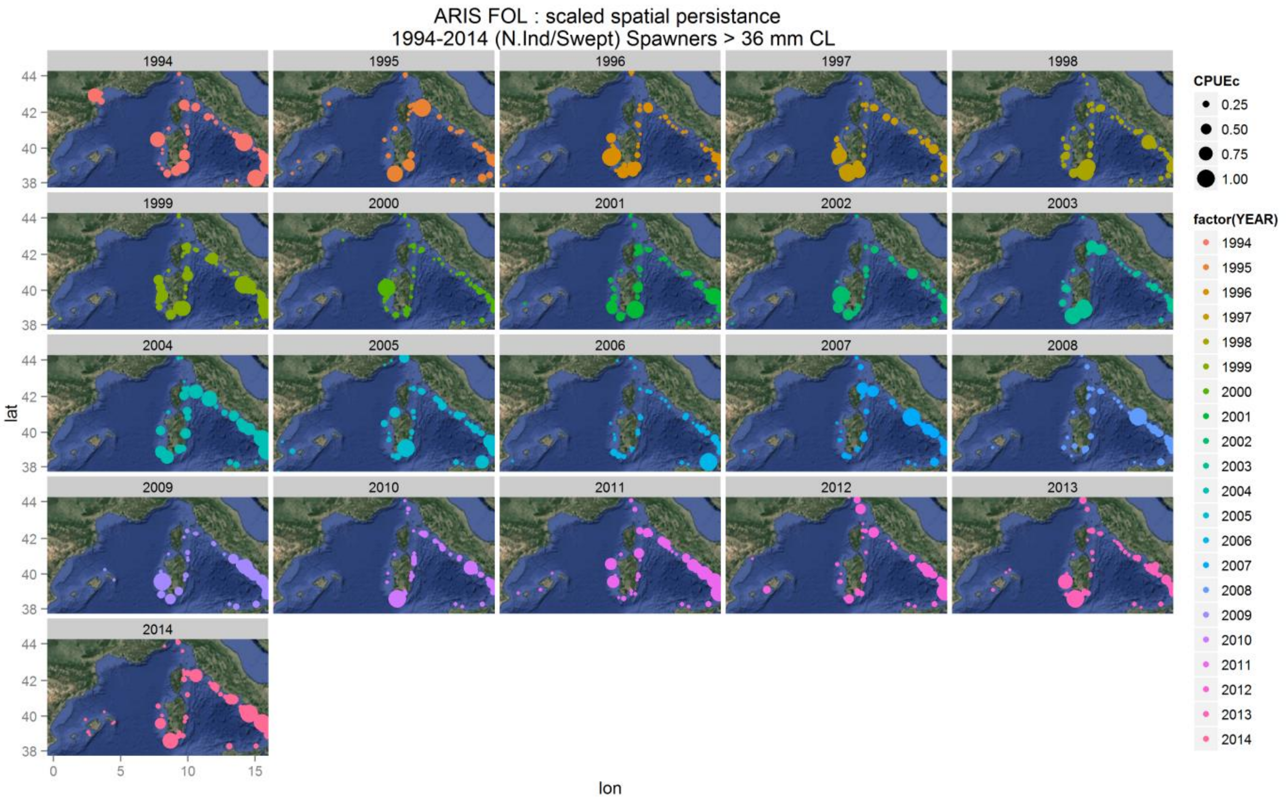


Figure 6.7. Annual spatial occurrence of *Aristaeomorpha foliacea* spawners in the western Mediterranean in 1994-2014, based on data from the MEDITS survey.

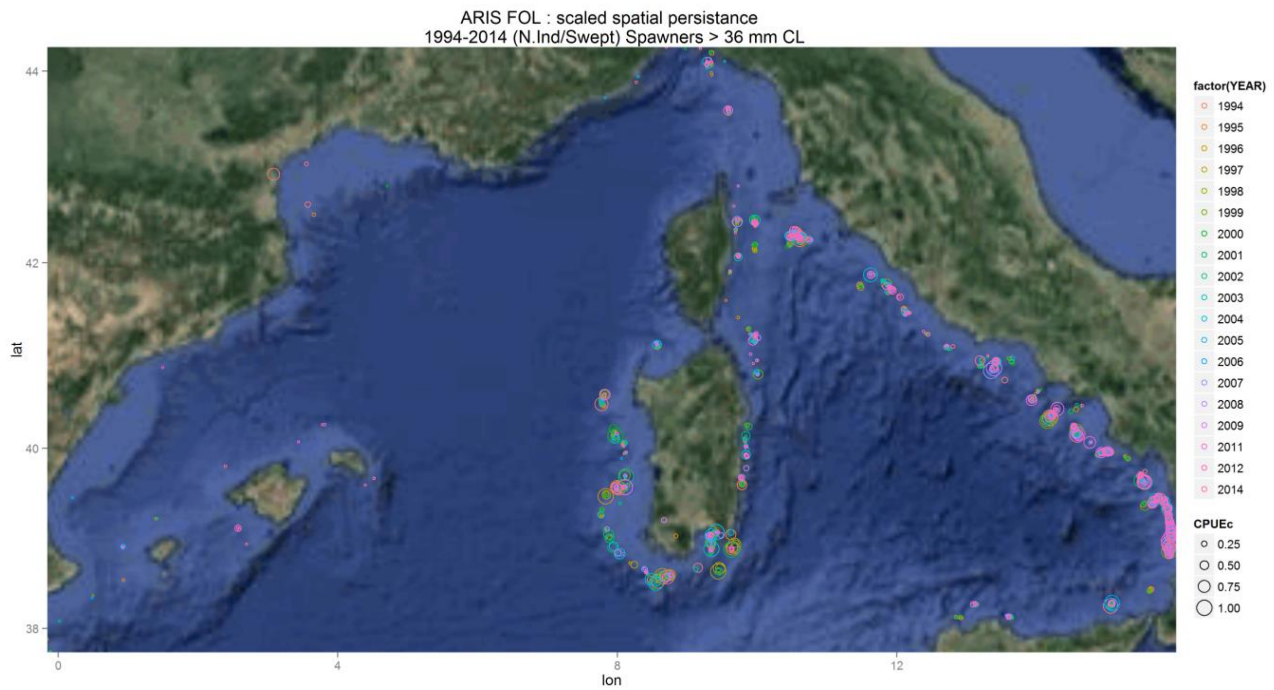


Figure 6.8. Pooled spatial occurrence of *Aristaeomorpha foliacea* spawners in the western Mediterranean in 1994-2014, based on data from the MEDITS survey.

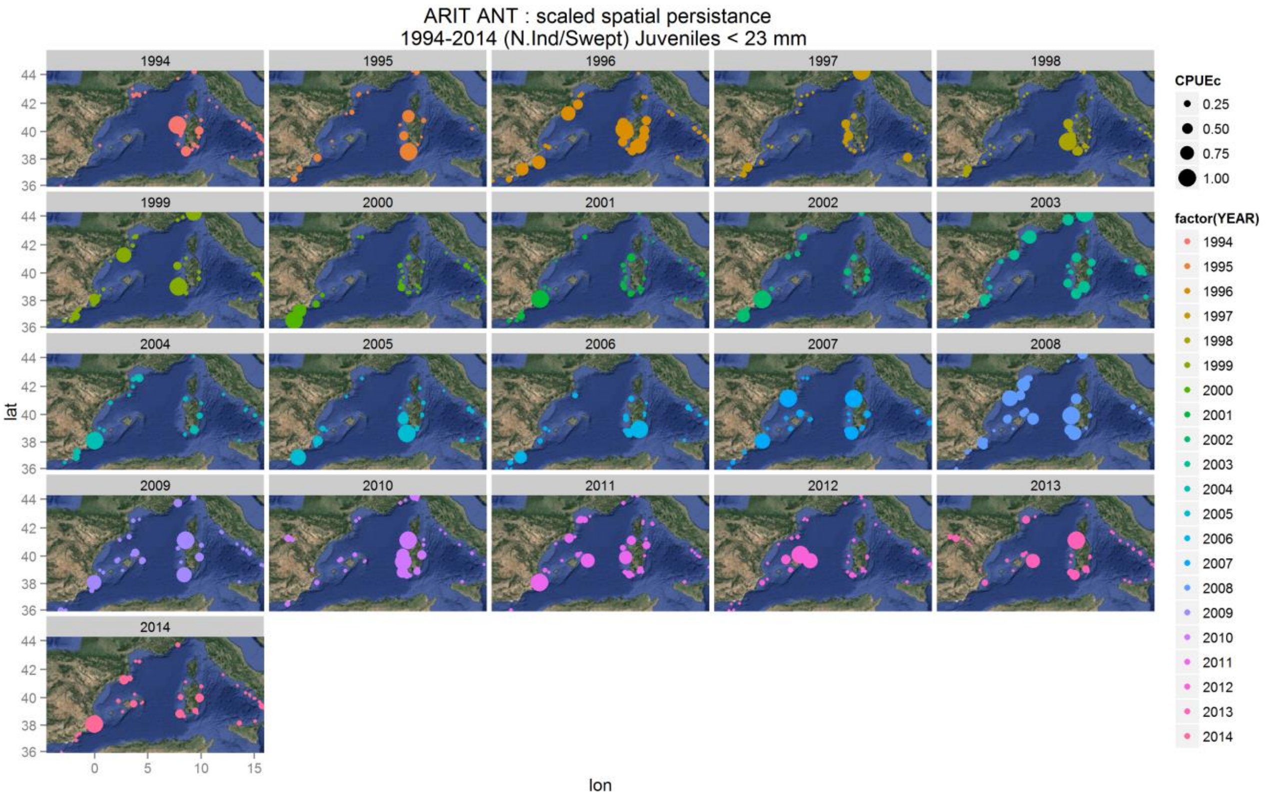


Figure 6.9. Annual spatial occurrence of *Aristeus antennatus* juveniles in the western Mediterranean in 1994-2014, based on data from the MEDITS survey.

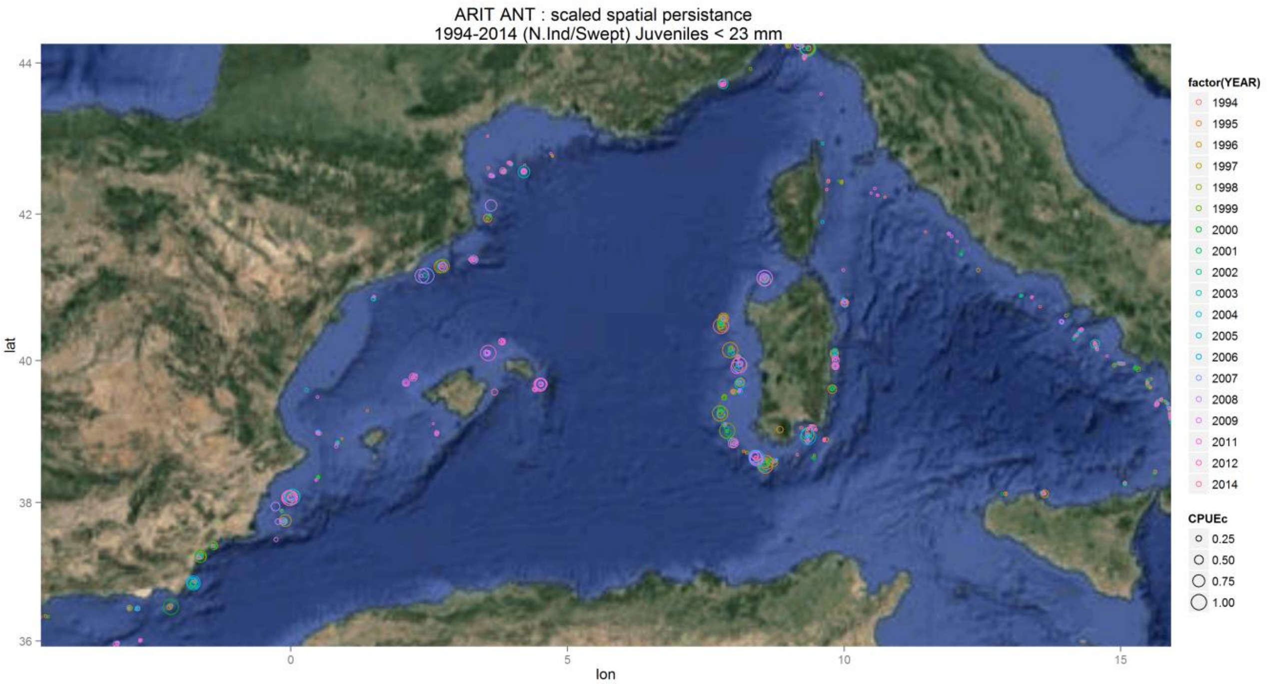


Figure 6.10. Pooled spatial occurrence of *Aristeus antennatus* juveniles in the western Mediterranean in 1994-2014, based on data from the MEDITS survey.

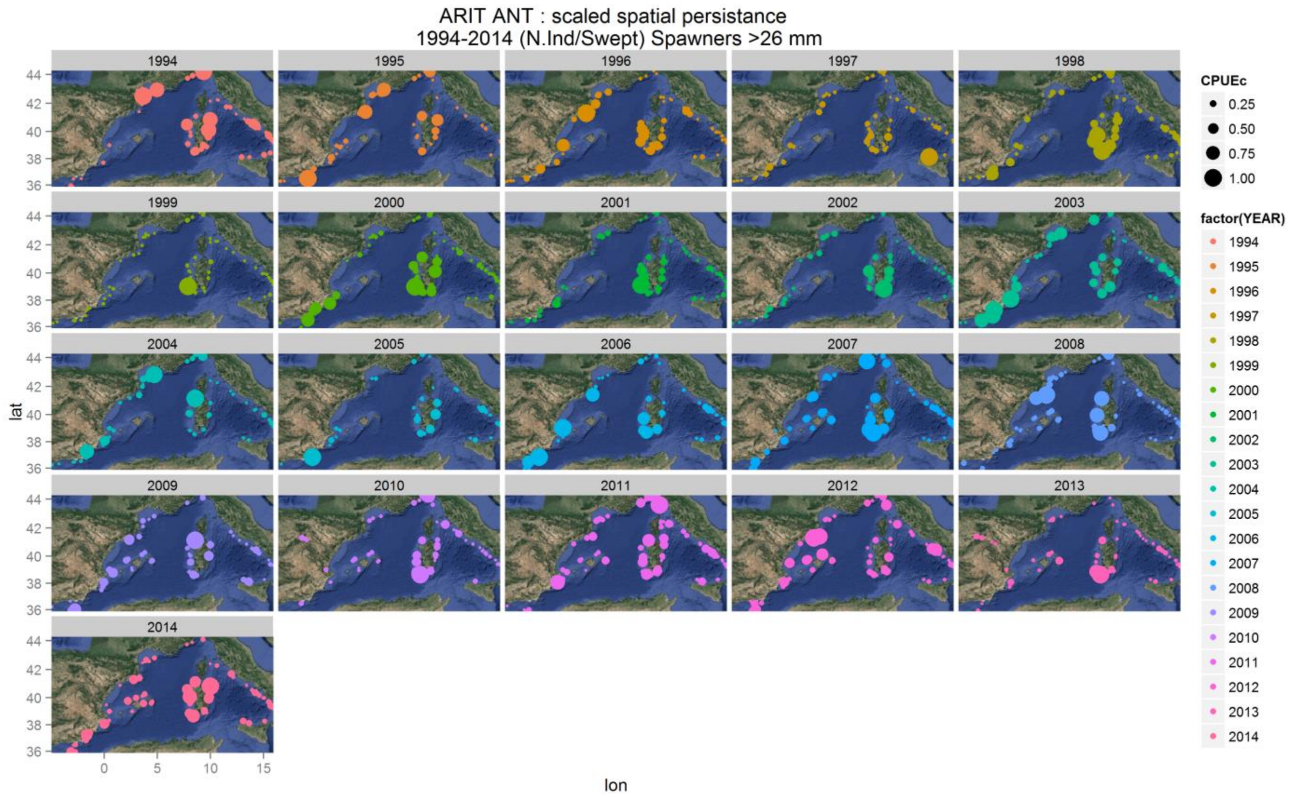


Figure 6.11. Annual spatial occurrence of *Aristeus antennatus* spawners in the western Mediterranean in 1994-2014, based on data from the MEDITS survey.

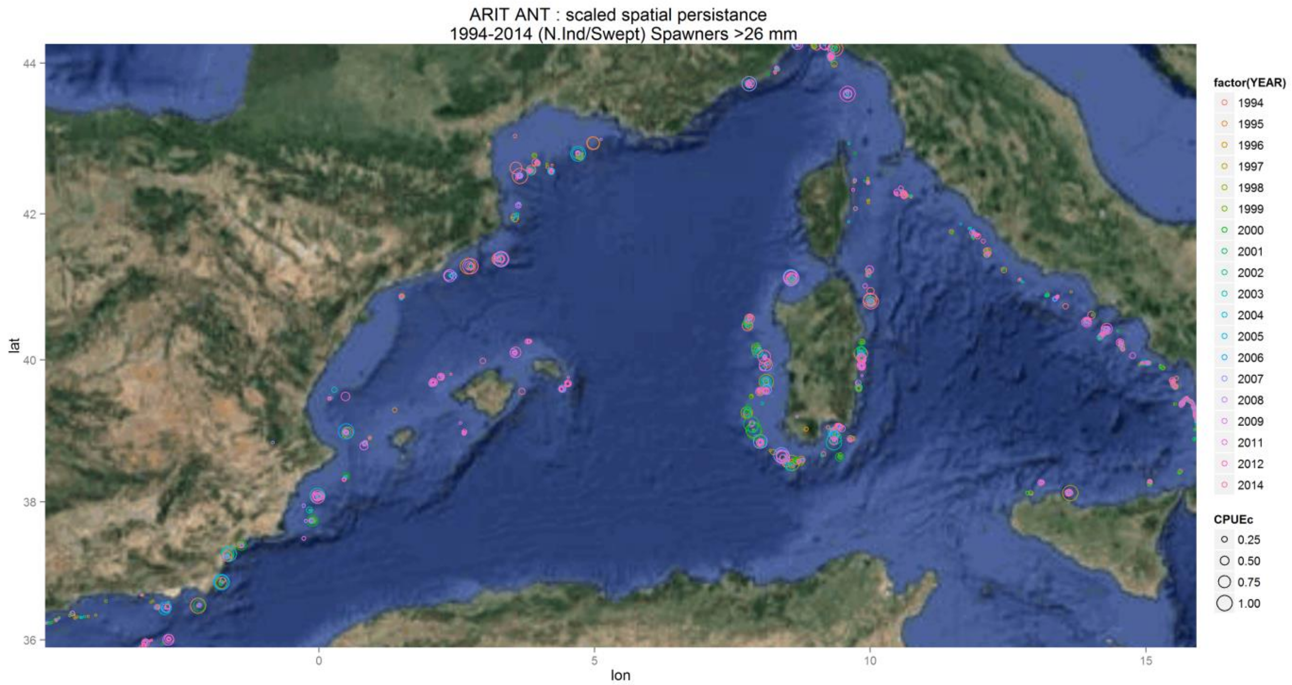


Figure 6.12. Pooled spatial occurrence of *Aristeus antennatus* spawners in the western Mediterranean in 1994-2014, based on data from the MEDITS survey.

7 DATA QUALITY AND COMPLETENESS

7.1 Data Overview

The data call was issued on April 2015. The 'legal' deadline for submissions was the 2nd of July 2015. Upon communication with the member states some data tables were corrected and re-uploaded in relation to the 'operational' deadline of the 17th August 2015.
Data was uploaded by each country according to the following table:

Table 7.1.1. Timeline of data upload from Mediterranean Member States, data call '**legal' deadline of the 2h of July 2015; 'operational' deadline 17 August 2015**.

COUNTRY	First Upload	Last Upload
ITA	29 June 2015	12 August 2015
ESP	01 July 2015	05 August 2015
FRA	19 June 2015	02 July 2015
SVN	05 June 2015	23 July 2015
MLT	02 July 2015	02 July 2015
CYP	01 July 2015	06 August 2015
GRC	02 July 2015	31 Aug 2015
HRV	27 June 2015	31 July 2015*

*: *additional submissions on 4 Sep 2015 upon a request by the EWG*

The overall 2015 Data Call performance of data coverage, timeliness and progress of submissions by member state and main table/variable will be made available by the end of the year and after the completion of the EWG 15-16 Mediterranean stock assessments part 2, on the dedicated weblink: http://datacollection.jrc.ec.europa.eu/coverage

MEDITS Specific data problems

It should be noted that the MEDITS data that were made available to STECF 15-11 contained some obvious errors regarding the majority of hauls coordinates in GSA 6 in years 2010 and 2013 and the entire years can‘t be used in the context of any spatial analysis. The error clearly is related with the incorrect specification of the Hauling Quadrant and should be fixed.

7.2 Stock Specific Data Issues

Hake in GSA 1

A number of errors were detected in the MEDITS database (e.g. an error in the 2013 size frequencies abundances in length class 38 cm/age class 3, not considered in the analysis; 2013-2014 data submitted twice). Because of this, MEDITS data used in the assessment were provided by EWG15-11 invited experts.
No data on OTB discarded sizes of European hake in GSA 1 available.
No data on LLS landings sizes available.

Concerning GNS+GTR, size data were available for 2009, 2010 and 2014.

Hake in GSA 5

Discarded biomass for 2014 showed values unusually low and should be further checked.
Effort information was available for 2009-2014.
A comparison of the abundance indices by size from the surveys covering the period 2007-2014 between the Data Call and the national database was performed. They showed high agreement for the last years, but inconsistent values for 2007-2008, which should also be checked.

Hake in GSA 6

No apparent issues.

Hake in GSA 7

Effort data were missing before 2009.
Stock structure data submitted through the data call were in length and were converted in age using the length-to-age slicing functions. The growth of European Hake (*Merluccius merluccius*) in the Gulf of Lions was recently re-estimated through tagging experiments carried out by IFREMER (Mellon-Duval et al., 2010). The new parameters have not been yet compared to a re-analysis of otoliths readings, because of the uncertainty on otoliths readings. Therefore the age -growth parameters submitted through the Data call were not used since they were not derived from the recent estimates.

Hake in GSA 8

DCF data quality was deficient for this particular species.
Catch data, proceeding from the limited number of trawlers cover only the period 2010-2014. Landings are too low in all the years where data are available.
Age structure of the catch is not available and probably not collected due to the scarce commercial interest of this species in the area.
Survey data suffered a gap in the time series, due to a technical problem that made impossible the utilization of the research vessel to carry out the cruise in 2002, and likely had a negative effect in the quality of the analysis.

Hake in GSA 9

Length frequencies distributions for several years were missing.
Discard data were absent for years 2007-2008.

Hake in GSA 10

Raw upload data were used, because those stored in the databases supplied by JRC showed some inconsistency (fishery data).
Discards data of 2007, 2008 were absent.

Hake in GSA 11

Catch information for the artisanal fleets (GTR and LSS) are represented only in some years and sometimes there is no relation in time with the data on lengths of catches. In particular, although the DCR/DCF database has values for total landings of hake in GSA11, data at length are missing for some years and gears (OTB in 2005 and for GTR in 2005, 2006 and 2008). Similarly a gap of information for total values of discards (GTR 2010) was detected while some data of discard at length were present.

It is also true that the size distribution of both GTR landings (2010) and GTR discard (2005, 2010) seems to be unrealistic for this species.
The last problem identified were some unusual value for total discards and numbers of discards at age in some years (OTB, 2006; GTR, 2005). To overcome these data quality problems of GSA 11, a deep check of information was made in the first days of the meeting and it was decided to fill gaps and correct records in order to be able to successfully perform the assessment.

Hake in GSA 9-11
Lack of size structure information for some of the fisheries in GSA9 and GSA11 (e.g. trammel-net)

Giant Red Shrimp in GSA 9
Although landings data were observed in 2008 for Gillnet and in 2012 for trammel, no length distribution was available.
It is also true that landing values for these two fisheries and years were very low (about 700kg and about 1.2 tons respectively) compared to the trawlers ones.

Giant Red Shrimp in GSA 10
Demographic structures of the gillnet landings were available for only three years.

Giant Red Shrimp in GSA 11
An improvement in the data quality of giant red shrimp GSA 11 data has been observed in comparison to the data provided during STECF EWG 14-19.
Due the inconsistencies in age distributions, the experts decided to age-slice the LFDs provided in the framework of 2015 official data call.
Due to the general low amount of samples analysed in the period 2005-2013 some of the input data used for the analyses (sex ratio by length, proportion of mature, mean catch weight at age) were selected from 2014 only.

Blue and Red Shrimp in GSA 1
No issues identified.

Blue and Red Shrimp in GSA 6
Catch series for the 2002-2010 period, needed to be reconstructed from local fisheries statistical data. This problem had been noted earlier in the previous assessment carried out in STECF 12-19.

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

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10 List of Background Documents

Background documents are published on the meeting's web site on: http://stecf.jrc.ec.europa.eu/web/stecf/ewg1511

List of background documents:

1. EWG-15-11 – Doc 1 - Declarations of invited and JRC experts (see also section 10 of this report – List of participants)

European Commission

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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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