Stock Assessment Form

Small Pelagics

Reference Year: 2017

Reporting Year:2018

Results of the XSA stock assessment method for the sardine stock in the GSA16.

Stock Assessment Form version 1.0 (January 2014)

Uploader: Barra Marco

Stock assessment form

1 Basic Identification Data

Scientific name:	Common name:	ISCAAP Group:
Sardina pilchardus	European sardine	[Small gregarious pelagic - 35]
1st Geographical sub-area:	**2nd Geographical sub-area:**	**3rd Geographical sub-area:**
[GSA_16]		
4th Geographical sub-area:	**5th Geographical sub-area:**	**6th Geographical sub-area:**
1st Country	**2nd Country**	**3rd Country**
[Italy]	[Country_2]	[Country_3]
4th Country	**5th Country**	**6th Country**
Stock assessment method: (direct, indirect, combined, none)		
Indirect: XSA		
Authors:		
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The ISSCAAP code is assigned according to the FAO 'International Standard Statistical Classification for Aquatic Animals and Plants' (ISSCAAP) which divides commercial species into 50 groups on the basis of their taxonomic, ecological and economic characteristics. This can be provided by the GFCM secretariat if needed. A list of groups can be found here:

http://www.fao.org/fishery/collection/asfis/en

2 Stock identification and biological information

Due to the lack of specific information about the geographical boundary of the stock, the stock is assumed to be confined in GSA 16 for stock assessment purposes.

2.1 Stock unit

2.2 Growth and maturity

Incorporate different tables if there are different maturity ogives (e.g. catch and survey). Also incorporate figures with the ogives if appropriate. Modify the table caption to identify the origin of the data (catches, survey). Incorporate names of spawning and nursery areas and maps if available.

Table 2.2-1: Maximum size, size at first maturity and size at recruitment.

Somatic magnitude measured (LT, LC, etc)				**Units**	
Sex	**Fem**	**Mal**	**Combined**	**Reproduction season**	Late autumn - winter
Maximum size observed			203	**Recruitment season**	Spring - summer
Size at first maturity				**Spawning area**	Continental shelf
Recruitment size to the fishery			11 cm	**Nursery area**	Continental shelf

*Maximum size observed corresponds to the maximum size ever observed in the MEDIAS acoustic campaign

*Size at first maturity was calculated based on samplings in July of the last few years.

Von Bertalanffy growth parameters were initially estimated using biological information obtained from the commercial samples. Anyway, the obtained fit was quite poor and estimated parameters lead to inconsistent values in natural mortality estimates compared to other GSAs. A similar situation was observed for maturity at age estimates. The WGSASP thus agreed to use growth parameters and maturity from GSA 1.

Table 2-2.2: M vector and proportion of matures by size or age.

Size/Age	Natural mortality (Unsexed)	Proportion of matures (Females)
0	**1.24**	**0.46**
1	**0.78**	**0.94**
2	**0.61**	**0.99**
3	**0.52**	**1**

Table 2-3: Growth and length weight model parameters

			Sex			
		Units	**female**	**male**	**Combined**	**Years**
Growth model	**L_∞**	cm			22.6	
	K				0.39	
	t_0				-1.75	
	Data source					
Length weight relationship	**a**				0.0053	
	b				3.12	
	M (scalar)					
	sex ratio (% females/total)					

3 Fisheries information

3.1 Description of the fleet

In GSA 16, sardine (*Sardina pilchardus*) is mainly targeted by purse seiners (PS) and pelagic pair trawlers (PTM). Along the Southern coast of Sicily, the Sciacca harbour represent the main port for fleets targeting small pelagics with PTM exclusively located in such port. Moreover, it is worth to note that PTM actually operate through a special permission issued annually. The bulk of landings for both anchovy and sardine is from PS, representing on average about the 72% of the landings for both species. Due to a lower market price of sardine with respect to anchovy, most of the fleet effort insists on anchovy rather than on sardine. Considering the average annual landings of both species, sardine landings represents about 34% of the catches.

Table 3-1: Operational units exploiting the stock

	Country	GSA	Fleet Segment	Fishing Gear Class	Group of Target Species	Species
Operational Unit 1*	[Italy]	[GSA16]	[Fleet Segment1]	PS	[Small gregarious pelagic - 35]	PIL
Operational Unit 2*	[Italy]	[GSA16]	[Fleet Segment2]	PTM	[Small gregarious pelagic - 35]	PIL

Table 3.1-2: Catch, bycatch, discards and effort by operational unit in the reference year for GSA16.

Operational Units*	Fleet (n° of boats)*	Catch (T or kg of the species assessed)	Other species caught (names and weight)	Discards (species assessed)	Discards (other species caught)	Effort (units)
[Operational Unit 1-GSA16]		220.7	ANE - 1398.5	0		
[Operational Unit 2-GSA16]		123.4	ANE - 1339.4	0		
Total		344.2	2737.9			

3.2 Historical trends

Landing data in the period 2002 - 2010 showed temporally consistent fluctuation; in the first 3 years of the time series (2002 - 2004), landings decreased from 2264 tons (the highest value recorded in the time series) to 884 tons. Such decreasing trend was followed by an increase in landings that in 2006 reached a value (2216 tons) similar to the one observed in 2002. Landing values decreased again from 2007 to 2010. In 2011, sardine landings increased again and slowly decreased till 2016 from 1786 tons (2011) to 1261 tons (2016). In the last year of the time series landings abruptly dropped to 344 tons representing the lowest value recorded in the time series.

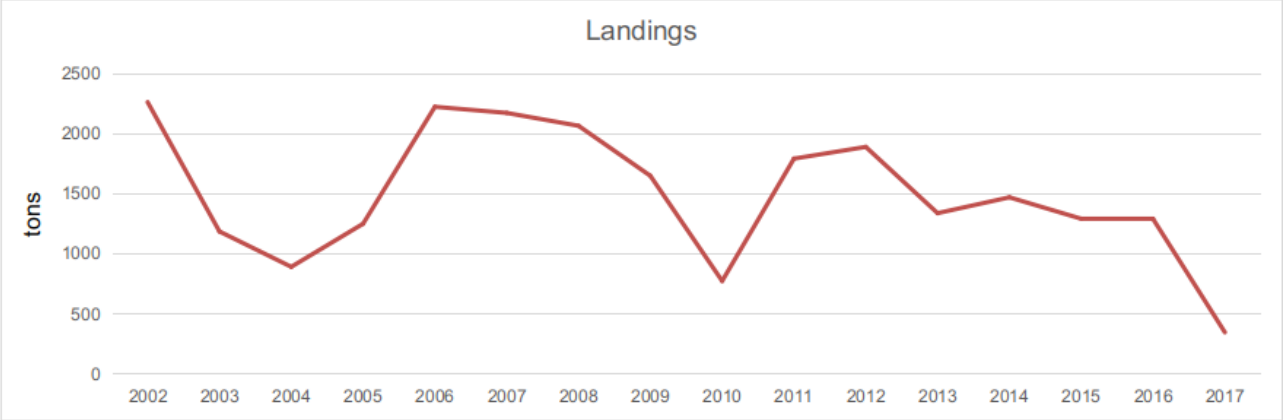

Fig 3.1. European sardine landings in GSA 16 (2002 - 2017).

3.3 Management regulations

Small pelagics fishery in GSA 16 is operated by two Operational Units namely PS and PTM, the latter operating through a special permission issued annually. The following measures actually impact sardine fishery:

Minimum landing size: 11 cm

Mesh size regulation:

PS: 14 mm;

PTM: 20 mm

In addition, towed fishing gears are not allowed in the coastal area below the 50 m isobath, or within a distance of 3 nautical miles from the coastline.

3.4 Reference points

4 Fisheries independent information

4.1 Direct method: Acoustics

4.1.1 Brief description of the chosen method and assumptions used

Acoustic surveys are routinely carried out in GSA 16 from 1998, and from 2009 acoustic surveys are carried out under DCF umbrella (MEDIAS program). Acoustic survey in GSA 16 cover the whole continental shelf (30 - 250m depth). Acoustic echoes are recorded by means of Simrad EK60 split-beam scientific echosounder along predefined transect perpendicular to the coastline (intertransect distance: 5 NM), while a zig-zag sampling scheme is adopted in a small sector of the study area (east of Capo Passero) due to the very narrow continental shelf. During the survey, experimental trawls hauls are carried out to characterize the observed echoes. Acustic data are processed by means of Ecoview Software, according to the MEDIAS protocol, in order to estimate the NASC (Nautical Area Scattering Coefficient; m^2nmi^{-2}) due to pelagic fishes and considering an Elementary Distance Sampling Unit (EDSU) of 1 nmi. In each EDSU, the fish NASC is partitioned by considering the nearest trawl haul composition (Simmonds & MacLennan, 2005).

Table 4.1-1: Acoustic cruise information.

Date	Late July - early August 2017		
Cruise	Ancheva 17	**R/V**	G. Dallaporta
Target species	ANCHOVY, SARDINE		
Sampling strategy	Parallel transect spaced 5 nm, zig zag east of Capo Passero		
Sampling season	Summer		
Investigated depth range (m)	30-250 m		
Echo-sounder	SIMRAD EK 60, 38 kHz (for biomass estimation) 120 kHz and 200 kHz (used as complementary frequency)		
Fish sampler	Pelagic trawl		
Cod –end mesh size as opening (mm)	18 mm		
ESDU (i.e. 1 nautical mile)	1 nautical mile		
TS (Target Strength)/species	-72.6		
Software used in the post-processing	Echoview		
Samples (gear used)	Pelagic trawl		
Biological data obtained	Length-Weight relationship, Age, Sex, Maturity		
Age slicing method	Otolith		
Maturity ogive used	L50		

Table 4.1-2: Acoustic results by age class

	Biomass in metric tons	fish numbers	Nautical Area Scattering Coefficient	Indicator …	Indicator …
Age 0	11711.7	1392313076			
Age 1	2566.1	165903774			
Age 2	772.9	31957712			
Age 3					
Age 4					

4.1.2 Spatial distribution of the resources

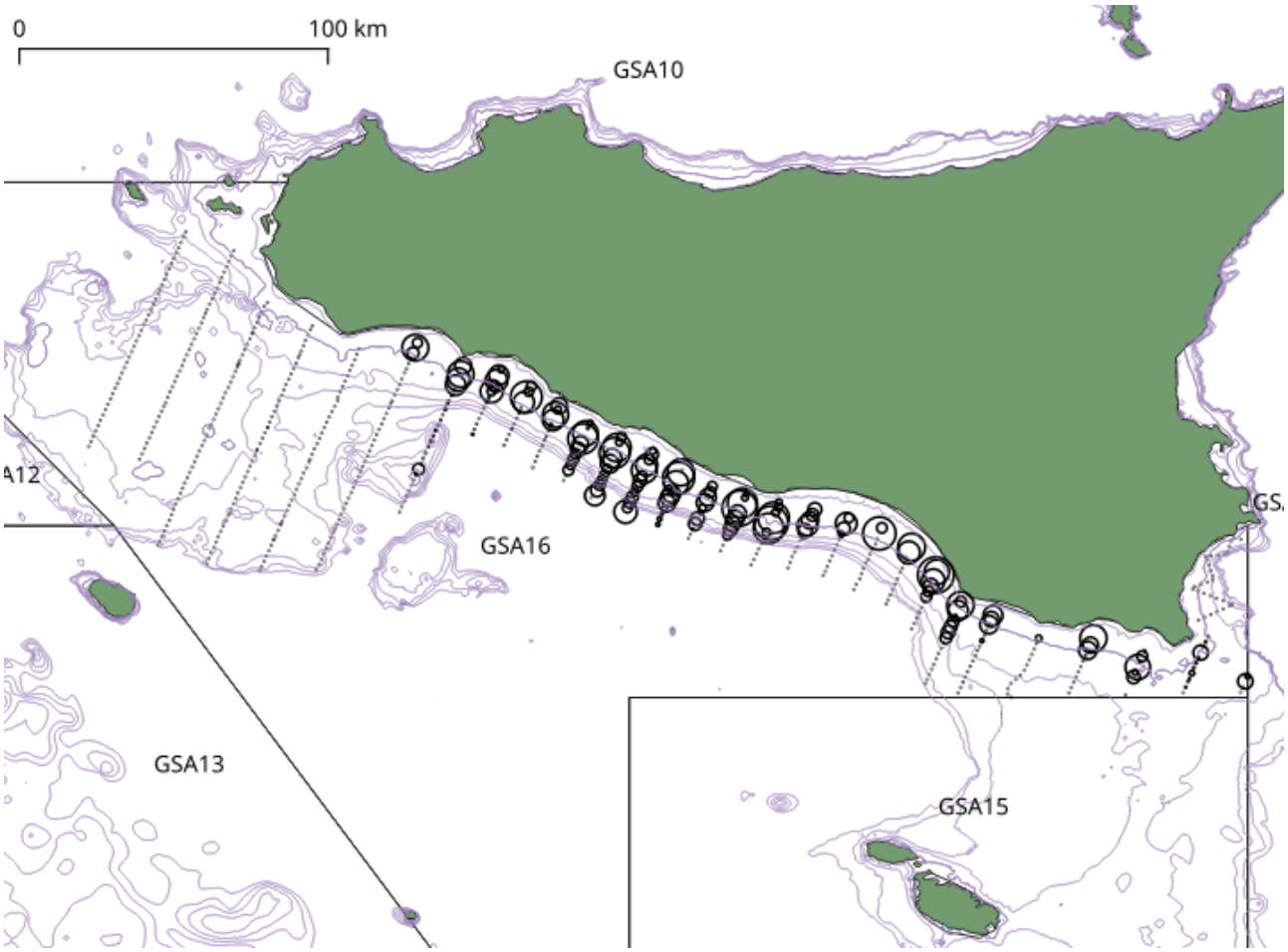

Figure 4.1.2.1. Proportional representation of sardine biomass per EDSU in GSA16 (2017).

4.1.3 Historical trends

The area covered during the acoustic surveys slightly changed over the considered period (2002 - 2017). Thus, for stock assessment purposes the acoustic estimates were standardized according to a common area of about 2200 nmi^2. Acoustic data highly varied in the considered time period, ranging between ~8000 and ~35000 tons. The lowest biomass values observed in the acoustic time series were 8054 and 9053 tons observed respectively in 2009 and 2017.

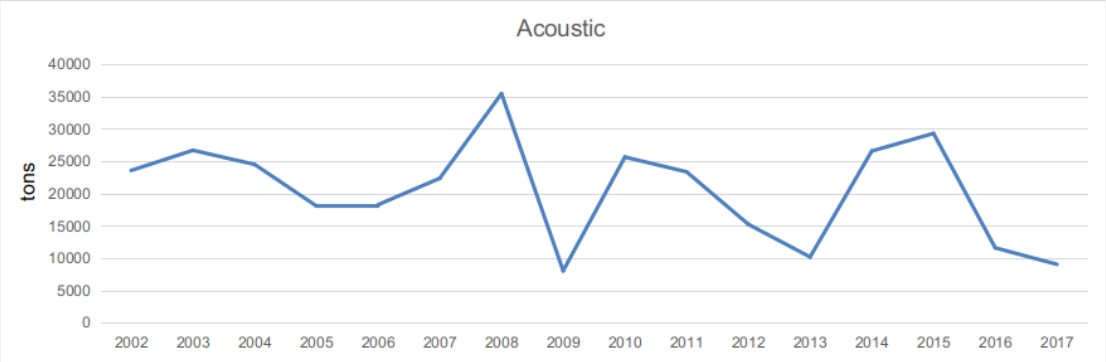

Figure 4.1.3.1 Acoustic survey abundance index of sardine in GSA16.

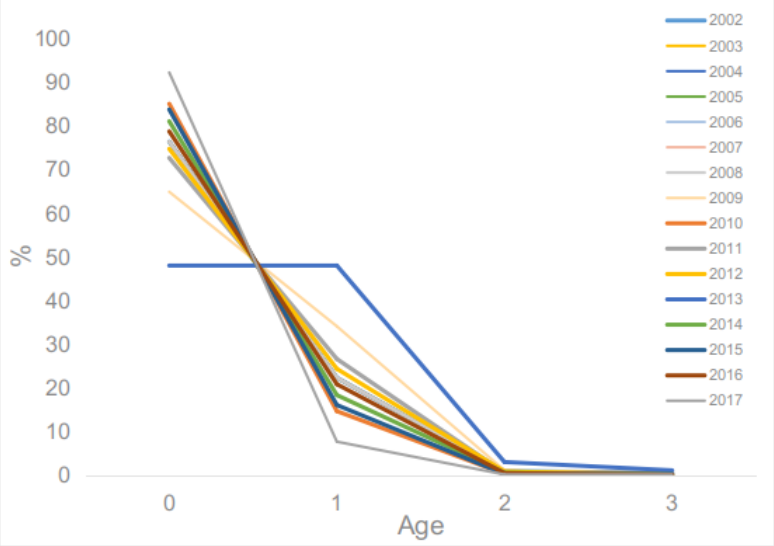

Figure 4.1.3.2 Proportion at age of sardine in GSA16.

5 Ecological information

5.1 Protected species potentially affected by the fisheries

6 Stock Assessment

Extended survivors analysis was used for sardine stock in GSA 16.

6.1.1 Extended survivors analysis (XSA)

6.1.2 Model assumptions

The main model assumption is that the number of individuals at age in the catches is measured without error.

6.1.3 Scripts

XSA was carried out in R environment (version 3.4.4) by using FLXSA package (version 2.6.2)

6.1.4 Input data and Parameters

Catch at age data (Tab 6.1) were estimated from PS and PTM landings by using an average ALK (2009-2017) estimated using age readings of sardine samples from landings.

Table 3.1: Numbers at age (Thousands) in landings (Sardine, GSA16)

AGE 0	AGE 1	AGE 2	AGE 3	Year
10269.3	76070.3	19498.8	818.7	2002
4923.5	38689.7	11116.1	516.3	2003
4934.3	31964.8	5714.5	137.5	2004
5138.2	40376.9	11600.9	538.8	2005
9214.2	72406.5	20803.4	966.2	2006
8998.3	70709.6	20315.9	943.6	2007
9210.1	68969.7	18081.5	775.9	2008
3604.8	45662.1	16936.4	1176.8	2009
4737.1	30329.1	6998.8	294.2	2010
3126.3	51346.8	21368.3	1074.4	2011
13077.0	73388.6	14761.8	437.6	2012
6181.6	45028.7	11130.3	450.3	2013
4727.6	48802.9	14970.8	475.3	2014
9273.6	50224.8	9724.5	212.8	2015
10618.8	49101.5	9860.7	201.1	2016
2089.4	14269.7	2038.5	4.8	2017

Natural mortality (Tab. 6.2) was computed according to Gislason and using the following parameters for the von Bertalanffy growth curve:

***Linf**: 22.6 (cm)*

***K**: 0.39*

***t_0**: -1.75*

Table 6.2: Natural mortality and maturity vector used in the XSA.

	Age 0	***Age 1***	***Age 2***	***Age 3***
Natural Mortality	1.24	0.78	0.61	0.52
Maturity	0.46	0.94	0.99	1

XSA was carried out by using the settings reported in Table 6.3. A sensitivity analysis was also carried out using different combinations of "rage", "qage" and "fse" values and the final model was selected by looking at residuals both in terms of magnitude and distribution (i.e. normality).

Table 6.3: XSA parameters used for sardine in GSA 16

Min - Max fbar	Plus group	shk.yrs	shk.ages	rage	qage	fse
1 - 2	3	1	1	-1, 0	1 to 3 by 1	0.5 to 3 by 0.5

6.1.5 Tuning data

Numbers-at-age from acoustic surveys (Tab. 6.4) were computed by using an average ALK (2009-2017) estimated from age readings of sardine sampled during the acoustic surveys.

Table 6.4:Numbers at age (Thousands) in acoustic surveys (Sardine, GSA16)

AGE 0	AGE 1	AGE 2	AGE 3	Year
1516499.1	442656.8	17873.7	8470.9	2002
1717098.8	501210.7	20238.0	9591.4	2003
1576881.4	460282.1	18585.3	8808.2	2004
1163142.0	339514.1	13708.9	6497.1	2005
1175541.9	343133.5	13855.1	6566.4	2006
1438581.8	419913.3	16955.3	8035.6	2007
2280721.2	665728.6	26880.9	12739.7	2008
307452.0	161423.3	4996.5	6.3	2009
1508200.4	259349.0	4433.9	1053.3	2010
1289474.8	471743.8	9293.0	4312.7	2011
769308.7	250390.4	8227.2	1371.7	2012
235874.5	235897.0	14591.9	5199.1	2013
2152070.6	485961.2	13842.7	3257.2	2014
2428794.3	465084.1	6031.4	376.2	2015
990585.8	261692.8	5313.2	585.9	2016
1466479.3	121292.3	1750.2	652.8	2017

6.1.6 Results

A preliminary analysis was done to check the cohort consistency. The consistency plot showed a general lack of consistency for both acoustic and landings dataset (Fig. 6.1).

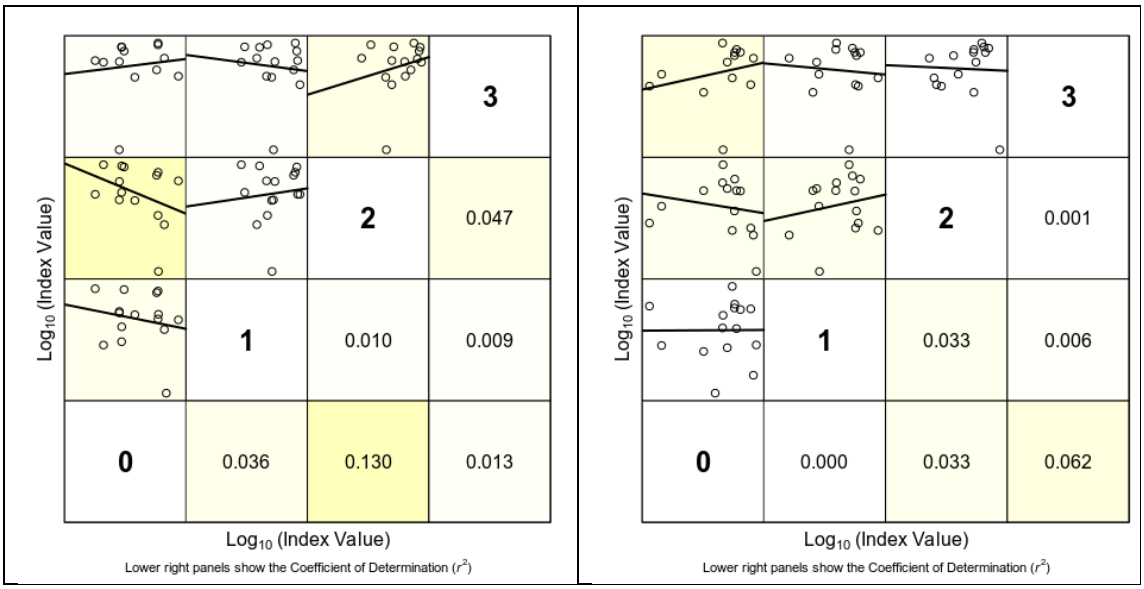

Figure 6.1: Cohort consistency plot for landings (left panel) and acoustic (right panel) dataset (sardine GSA 16)

Sensitivity analysis carried out on qage, rage and fse values highlighted quite stable fitting (i.e. absence of distinct pattern), even if a certain degree of variability was observed in the estimates related to the terminal year (Fig. 6.2).

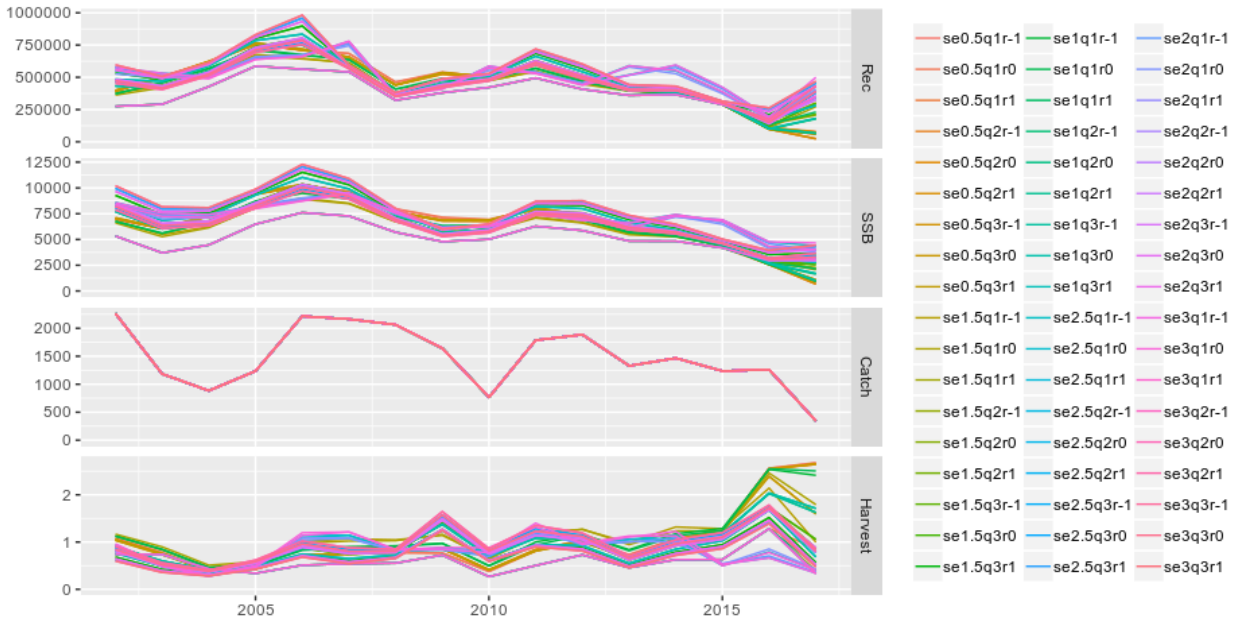

Figure 6.2: Sensitivity analysis carried out using different “rage”, “qage” and “fse” values (see table 2).

According to residuals summary statistics, the “best” model was the one using fse=2, qage=2 and rage= -1. Residuals plot for the final model (Fig. 6.3) highlighted acceptable residuals values.

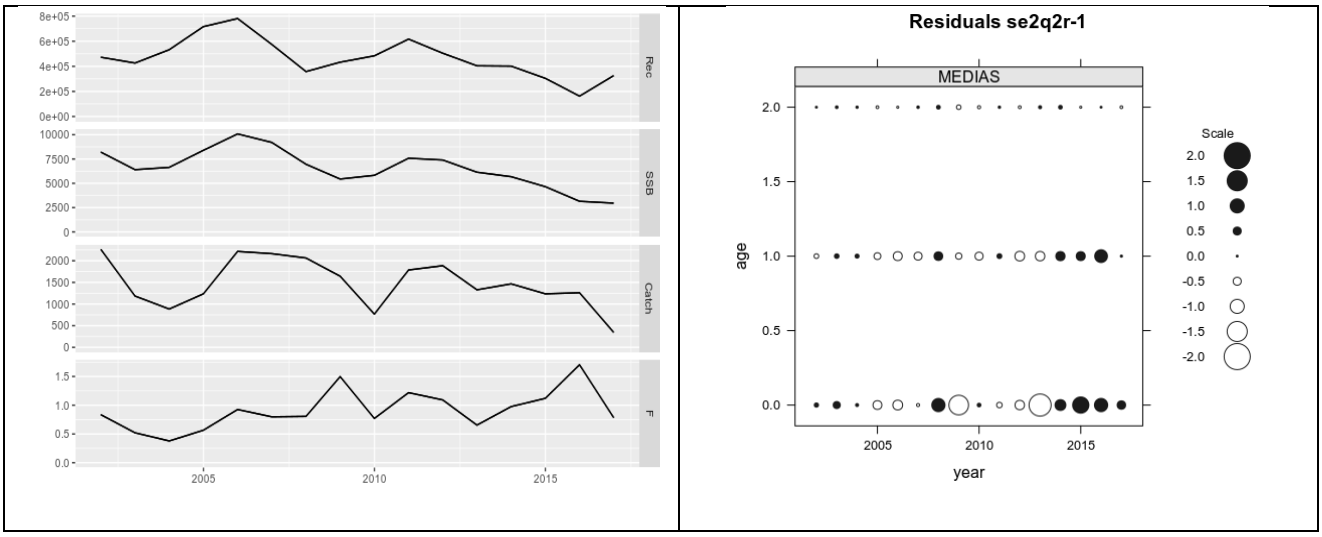

Figure 6.3: Final model (left panel) and obtained residuals (right panel).

6.1.7 Robustness analysis

6.1.8 Retrospective analysis, comparison between model runs, sensitivity analysis, etc.

Retrospective analysis was also carried out to verify the model stability. The obtained results (Fig. 6.4) highlighted a certain degree of stability leading the WGSASP to consider the model reliable and suitable to provide an advise about the sardine stock status.

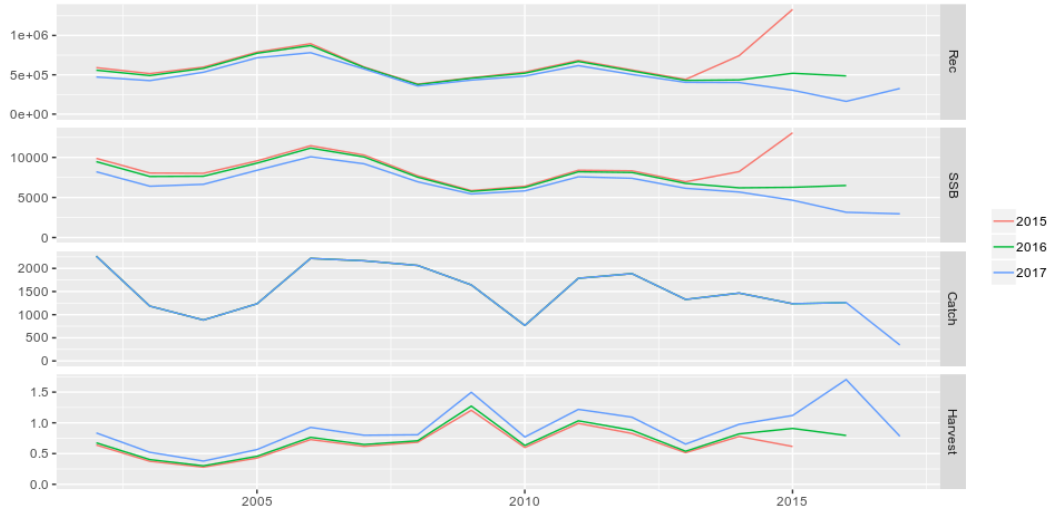

Figure 6.4: Retrospective analysis results.

6.1.9 Assessment quality

The model was considered suitable to provide an advice.

7 Stock predictions

8 Draft scientific advice

F values estimates (Tab. 8.1) ranged between 0.38 and 1.5, and in particular in the reference year the estimated values was 0.78 leading to an F_{curr}/FMSY of 1.69 (FMSY estimated as the F at E=0.4; STECF 2017). The stock is thus considered overexploited.

Year	Biomass	Catch	SSB	Recruits	Fbar
2002	11901	2304	8207	472319	0.84
2003	9674	1206	6404	426059	0.52
2004	10669	898	6641	532355	0.38
2005	13799	1258	8395	716520	0.57
2006	16021	2257	10080	780982	0.93
2007	13665	2204	9203	574474	0.80
2008	9780	2100	6962	358131	0.81
2009	8715	1523	5439	432936	1.50
2010	9495	904	5823	483792	0.77
2011	12244	1759	7580	616959	1.22
2012	11290	2136	7397	504413	1.09
2013	9260	1352	6143	404004	0.65
2014	8749	1523	5680	401600	0.98
2015	7010	1453	4653	304254	1.12
2016	4438	1451	3151	162318	1.70
2017	5383	383	2960	326149	0.78

Table 8.1: Final model estimates

Based on	Indicator	Analytic al reference point (name and value)	Current value from the analysis (name and value)	Empirical reference value (name and value)	Trend (time period)	Status
Fishing mortality	Fishing mortality		0.78	F at E=0.4, estimated as 0.46	D	IO
	Fishing effort					
	Catch				D	
Stock abundance	Biomass					
	SSB		2960			
Recruitment						
Final Diagnosis		Overexploited				

8.1 Explanation of codes

Trend categories

1) N - No trend
2) I - Increasing
3) D – Decreasing
4) C - Cyclic

Stock Status

Based on Fishing mortality related indicators

1) **N - Not known or uncertain** – Not much information is available to make a judgment;
2) **U - undeveloped or new fishery** - Believed to have a significant potential for expansion in total production;
3) **S - Sustainable exploitation**- fishing mortality or effort below an agreed fishing mortality or effort based Reference Point;
4) **IO –In Overfishing status**– fishing mortality or effort above the value of the agreed fishing mortality or effort based Reference Point. An agreed range of overfishing levels is provided;

    Range of Overfishing levels based on fishery reference points

    In order to assess the level of overfishing status when $F_{0.1}$ from a Y/R model is used as LRP, the following operational approach is proposed:

    - If $Fc^*/F_{0.1}$ is below or equal to 1.33 the stock is in **(O_L): Low overfishing**
    - If the $Fc/F_{0.1}$ is between 1.33 and 1.66 the stock is in **(O_I): Intermediate overfishing**
    - If the $Fc/F_{0.1}$ is equal or above to 1.66 the stock is in **(O_H): High overfishing**

    *Fc is current level of F

5) **C- Collapsed**- no or very few catches;

Based on Stock related indicators

1) **N - Not known or uncertain:** Not much information is available to make a judgment
2) **S - Sustainably exploited:** Standing stock above an agreed biomass based Reference Point;
3) **O - Overexploited**: Standing stock below the value of the agreed biomass based Reference Point. An agreed range of overexploited status is provided;

    Empirical Reference framework for the relative level of stock biomass index

    - **Relative low biomass:** Values lower than or equal to 33rd percentile of biomass index in the time series **(O_L)**

- **Relative intermediate biomass:** Values falling within this limit and 66th percentile **(O_I)**
- **Relative high biomass:** Values higher than the 66th percentile **(O_H)**

4) **D – Depleted**: Standing stock is at lowest historical levels, irrespective of the amount of fishing effort exerted;
5) **R –Recovering:** Biomass are increasing after having been depleted from a previous period;

Agreed definitions as per SAC Glossary

Overfished (or overexploited) *- A stock is considered to be overfished when its abundance is below an agreed biomass based reference target point, like B0.1 or BMSY. To apply this denomination, it should be assumed that the current state of the stock (in biomass) arises from the application of excessive fishing pressure in previous years. This classification is independent of the current level of fishing mortality.*

Stock subjected to overfishing (or overexploitation) *- A stock is subjected to overfishing if the fishing mortality applied to it exceeds the one it can sustainably stand, for a longer period. In other words, the current fishing mortality exceeds the fishing mortality that, if applied during a long period, under stable conditions, would lead the stock abundance to the reference point of the target abundance (either in terms of biomass or numbers)*