Food and Agriculture Organization of the United Nations

General Fisheries Commission for the Mediterranean
Commission générale des pêches pour la Méditerranée

Scientific Advisory Committee on Fisheries (SAC)

Working Group on Stock Assessment of Small Pelagic species (WGSASP)

Online, 18–23 January 2021

REPORT

EXECUTIVE SUMMARY

The Working Group on Stock Assessment of Small Pelagic Species (WGSASP)[1] was carried out online on 18–23 January 2021. The main objectives of this meeting were to: i) review the consistency of procedures to provide advice; ii) review the assessment of small pelagic stocks; and iii) run a hands-on data session to deal with methodological issues.

The WGSASP reviewed 20 stock assessments including the geographical subareas (GSAs) 6 and 7 anchovy (*Engraulis encrasicolus*) and sardine (*Sardina pilchardus*) benchmark session.Validated advice was provided for 18 of these stocks, nine of which with quantitative advice and the remaining nine with qualitative precautionary advice; two assessments were considered preliminary: Atlantic mackerel (*Scomber scombrus*) in GSA 27 and common dolphinfish (*Coryphaena hippurus*) in western and central Mediterranean.

[1] This meeting was supported by the European Union under grant agreement SI2.795396.

OPENING OF THE WORKING GROUPS ON STOCK ASSESSMENT

1. The meetings of the Working Group on Stock Assessment of Demersal Species (WGSAD) and the Working Group on Stock Assessment of Small Pelagic Species (WGSASP) were held online from 18 to 23 January 2021.

JOINT SESSION

2. Elisabetta Betulla Morello, General Fisheries Commission for the Mediterranean (GFCM) of the Food and Agriculture Organization of the United Nations (FAO) Fishery Resources Officer, opened the joint session of the Working Groups on Stock Assessment (WGSAs) presenting the recap on relevant conclusions and decisions from the twenty-first session of the Scientific Advisory Committee on Fisheries (SAC) (Egypt, June 2019) and forty-third session of the Commission (Greece, November 2019), including the request for the revision of the framework for the provision of advice and COVID-19 pandemic related consequences on the WGSA work plan.

3. Mr Arni Magnusson, GFCM Senior Consultant in Biostatistics, introduced the STock Assessment Results (STAR) framework: a new tool developed by the Secretariat to organize GFCM stock assessment results, and streamline and automate the information flow from stock assessments to scientific advice, strengthening quality assurance and data dissemination. He underlined that the central part of the framework would be the STAR database, scheduled to be launched in 2021, which would serve as a foundation to provide a variety of quality-controlled data products related to the management of fisheries in the Mediterranean and Black Sea. The core STAR files will be made available regularly on the GFCM website once validated by the SAC.

WORKING GROUP ON STOCK ASSESSMENT OF SMALL PELAGICS

4. The meeting of the WGSASP was attended by 47 participants from GFCM member countries, representatives of the FAO regional projects and the European Union Directorate-General for Maritime Affairs and Fisheries (DGMARE), as well as the GFCM Secretariat (list of participants included as Appendix 2). The WGSASP was chaired by Ms Marianna Giannoulaki.

5. The agenda was introduced by the chairperson and adopted by the working group (WG) (agenda available in Appendix 1).

6. All stock assessment forms presented and finalized during the WG meeting as well as the respective STAR Excel templates are available on the GFCM SharePoint page of the expert groups (https://gfcm.sharepoint.com/EG). Following the recommendations made at the seventeenth session of the SAC (FAO headquarters, Rome, Italy, March 2015), these will be made public on the GFCM webpage once validated by the SAC at its twenty-second session.

PROGRESS REGARDING RECOMMENDATIONS FROM THE PREVIOUS YEAR

7. The chairperson summarized the conclusions and recommendations emanating from the previous session of the WGSASP (FAO headquarters, Rome, Italy, December 2019), as well as the assessments presented on that occasion. The main points raised related to the need to i) increase the number of stocks assessed in the southern and eastern Mediterranean; ii) organize preparatory meetings for the revision and harmonization of input data; iii) pursue the work on defining a common methodology to harmonize otolith reading across the Mediterranean Sea; and iv) increase the historical perspective for each assessed stock as much as possible. She also presented the terms of reference of the WGSASP, including requirements as formulated by the twenty-first session of the SAC and the forty-third session of the Commission.

JUSTIFICATION OF WGSASP 2021 PROCEDURES

8. The WG based its advice on the framework for describing stock status and providing management advice, approved by the SAC at its sixteenth session (Malta, March 2014). In addition, it used the approach agreed at the WGSASP (FAO headquarters, Rome, Italy, November 2018) to maintain consistency in advice across the different stocks evaluated.

9. For those stocks for which reference points were not available, and following the precautionary approach which requires that advice be provided with available data, the WG followed through with the approach used in previous years:

- When long time series of estimates were available, the status of the biomass and the evaluation of current fishing mortality levels were established in relation to the abundance and fishing mortality levels observed in the time series. The main criteria to assess the status of both stocks and fishing mortality using the time series were: i) the stability of stock biomass levels; ii) signals of change in growth and/or age/length composition; iii) signals of recruitment impairment; and iv) changes in fishing mortality levels.

- In the case that the assessment method, for example two-stage biomass model in combination with a direct estimate of biomass from acoustic surveys, does not allow for a reference point, the WG reevaluated the use of Patterson E for assessing the status of the stock and investigated the possibility of adopting an approach based on resampling of spawning stock biomass (SSB) and harvest rate (HR) to produce the joint probability of SSB being above the precautionary spawning stock biomass (SSBpa) and harvest rate below the precautionary harvest rate (HRpa).

Assessment models to-do list and potential alternative assessment models

10. The WG agreed and strongly encouraged all participants to use the most complete dataset (including the longest time series) available to run the assessment, and invited all WGSASP members to come to the sessions with all information available for the assessed stock in the area. The WG recommended that the experts participating in the WGSASP provide all information required to perform advice using the stock assessment forms. In addition, all biological data related to the stocks need to be provided in a standardized input form, that is, the Excel template provided in the GFCM online system. Participants using scripts to perform analysis (e.g. R scripts) were encouraged to share their scripts using the software library incorporated in the WG SharePoint workspace.

STOCK ASSESSMENTS BY AREA AND SPECIES

11. The WGSASP critically analysed each stock assessment presented, also reviewing input data and basic assumptions. The rationale behind every new model was requested, and a scrupulous inspection of the results and the diagnoses was carried out. The individual stock summaries are included below.

12. Information on a total of 20 stocks was presented to the WGSASP (see Appendix 4). Including the GSAs 6 and 7 anchovy (*Engraulis encrasicolus*) and sardine (*Sardina pilchardus*) benchmark session, a total of 20 stocks were analysed. Validated advice was provided for 18 of these stocks, nine of which with quantitative advice and the remaining nine with qualitative precautionary advice; two assessments were considered preliminary (Atlantic mackerel (*Scomber colias*) in GSA 27 and common dolphinfish (*Coryphaena hippurus*) in western and central Mediterranean). A detailed table of advice on the status of the stocks analysed, including WGSASP comments, are included in Appendix 4.

INDIVIDUAL STOCK SUMMARIES

GSA 1 – Northern Alboran Sea

Anchovy (*Engraulis encrasicolus*) in GSA 1

Authors: Giráldez, A., Torres, P. Ramírez, J.G.[1], Garriga, M.[2], Iglesias, M. González, M. & Ventero, A.

Fishery: Anchovy in GSA 1 is the main target species of the purse seine fleet in northern Alboran Sea, due to its high economic value, although its abundance is rather low and very confined. The current fleet in GSA 1 the northern Alboran Sea is composed by 81 units (15 landing ports), characterised by small vessels, average TJB 25.8. Fourteen percent of them are smaller than 12 m (86 percent being bigger than 12 m) and none of them is bigger than 24m. The purse seine fleet has been continuously decreasing in the last two decades, from more than 230 vessels in 1980 to 81 in 2019. A strong reduction of larger vessels occurred from 1985 onwards, possibly linked to a decrease in anchovy catches in northern Morocco, where a part of that fleet fished under agreement between the countries. Subsequently the fleet continued to decline but more slowly. Landings in the period 1990–2019 have been highly variable, with a minimum of 165 tonnes in 1993 and a maximum 3 140 tonnes in 2019. Higher catches occurred in 1996, 2001, 2002 and 2013, and in 2019 between 2 000 and 3 200 tonnes were caught.

Data and parameters: Official landings time series 1979–2019, length distribution data from commercial catches 2003–2019, landing weights by age, growth parameters from age reading, and body condition.

Assessment method: Surplus production in continuous time (SPiCT), trends, length-based spawning potential ratio (LB-SPR).

Results: Catches are highly variable. The acoustic survey exhibits catchability problems that did not allow its use as a biomass index for the stock assessment model. No stock assessment could be validated. Fish size by age and body condition have decreased since last year. While showing a decreasing trend over the long-term since 1973, an increase in catches is observed since 2009. The age structure of the landings shows that age 3 is missing since 2014. The WG suggests to adopt the assessment as precautionary and, according to this, to not increase fishing mortality (F).

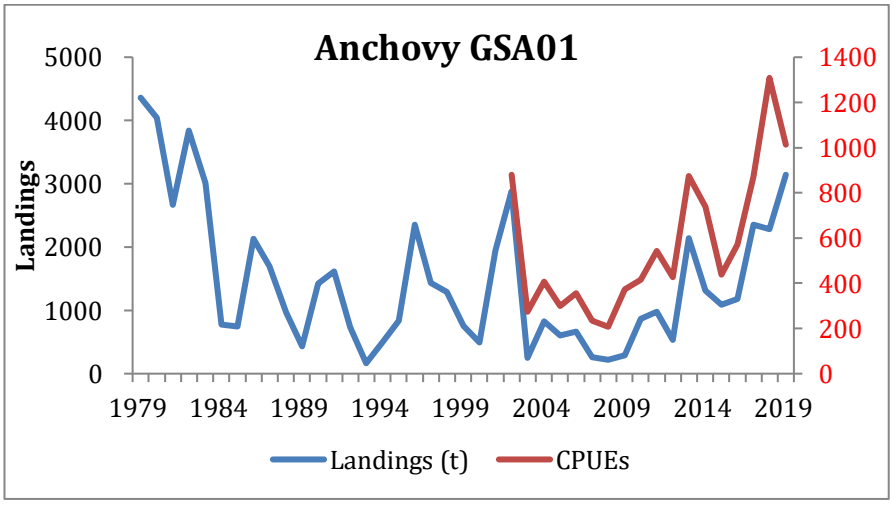

Figure 1.1. Trends in anchovy landings and CPUE in GSA 1 (1979–2019)

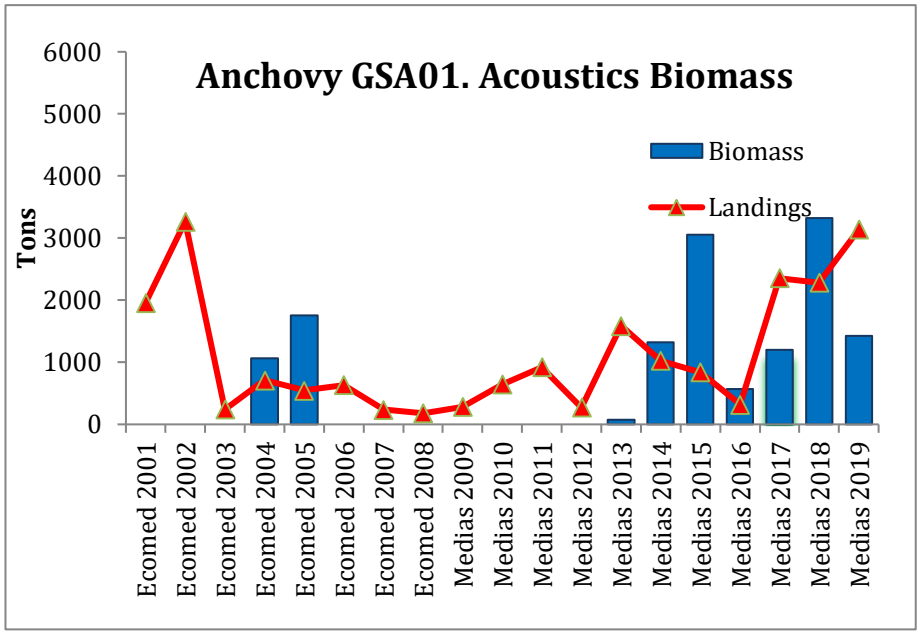

Figure 1.2. Trends in anchovy landings and biomass assessed by acoustic surveys (2001–2019)

Data issues: The runs performed with SPiCT model suggested that there is not enough contrast in the catch data to allow F to vary in the time series. The two-stage biomass model also resulted to be not appropriate, as the survey is not designed to capture the recruitment of this stock. An additional run was performed by LB-SPR using length structure by year. This assessment however produced unrealistic high values for the ratio of fishing mortality to natural mortality (F/M). This result was mainly driven by the increase in the catch of adult individuals during the last years, denoting somehow a bimodal length structure.

Diagnose of stock status: Stock status was considered uncertain. The SPiCT model was able to meet most of criteria to be accepted. However, the sensitivity analysis on the priors used produced both overfishing and no overfishing stock status as estimates were too close to reference point. Based on the long-term decreasing trend in catches (1979–2019 time series), the WG suggested to adopt a precautionary approach and not to increase fishing mortality. The assessment was considered qualitative and the advice not to increase fishing mortality is given on a precautionary basis.

Advice and recommendations: Not to increase fishing mortality.

GSA 1 – Northern Alboran Sea

Sardine (*Sardina pilchardus*) in GSA 1

Authors: Torres, P., Giráldez, A., Ramírez, J.G., Garriga, M., Iglesias, M., González, M. & Ventero, A.

Fishery: Sardine landings have been highly variable over time. It is a highly appreciated species at this moment presenting low catches in recent years. The current fleet in GSA 1 (northern Alboran Sea) is composed by 81 units (15 landing ports), characterised by small vessels, average TJB 25.8. Fourteen percent of them are smaller than 12 m (86 percent of them being bigger than 12 m) and none of them is bigger than 24 m. The purse seine fleet has been continuously decreasing in the last two decades, from more than 230 vessels in 1980 to 81 in 2019. Sardine landings in the period 1990–2019 have been highly variable. Higher catches occurred in 1992 (11 000 tonnes). In 2019 landings were 2 400 tonnes, the lowest value in the historical series.

Data and parameters: Official landings time series 1957–2019, length distribution data from commercial catches (2003–2019), landing weights by age, growth parameters from age reading, and body condition.

Assessment method: The model used was the assessment for all (a4a), a statistical-catch-at-age (SCAA) model.

Model performance: After different runs and sensitivity analysis (12 different scenarios), the best model was selected according to the best fitting (catches and survey index), good residuals and retrospective analysis.

fmod1 = ~s(age, k = 3)+s(year,k = 4)

qmod1 = list(~s(age,k = 4),~1,~1)

index.var(index2[[1]]) = 0.5

srmod1 = ~s(year,k = 8)

Results: Catches are highly variable, with no clear trend. There is a decrease in length and weight in size classes 0 and 1 in the last year. Since 2016, the oldest ages are disappearing; in 2019 there are no longer ages greater than five years. Body condition has also decreased in the last year.

The assessment was an update of the benchmark model in 2019. Different runs were also performed, changing the Fbar range (0–3 instead of 1–4), in order to include age 0, which is present in the catches. The decision of the WG was to maintain the same Fbar range as in the benchmarked assessment. The assessment was considered validated providing qualitative advice. Based on the results, the stock is considered in overexploitation with very low SSB and recruitment in the final year. The advice is to reduce fishing mortality.

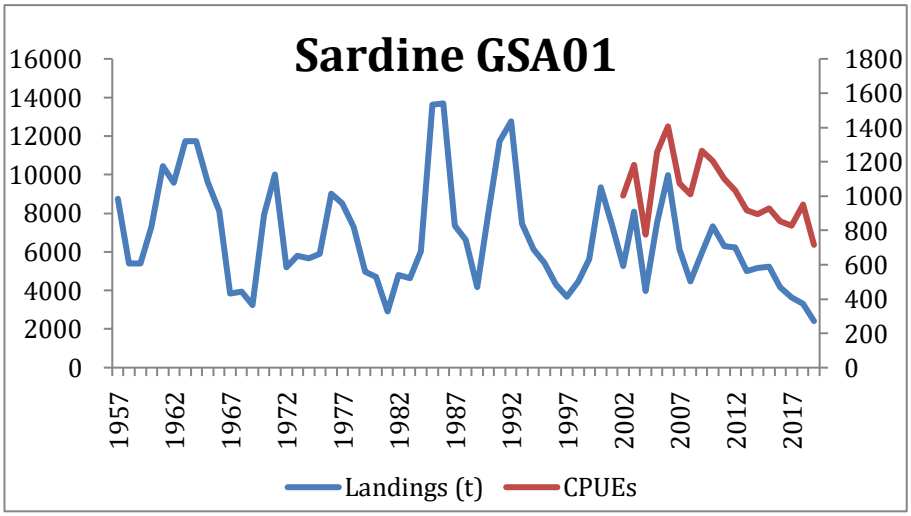

Figure 2.1. Trends in sardine landings and CPUE in GSA 1 (1957–2019)

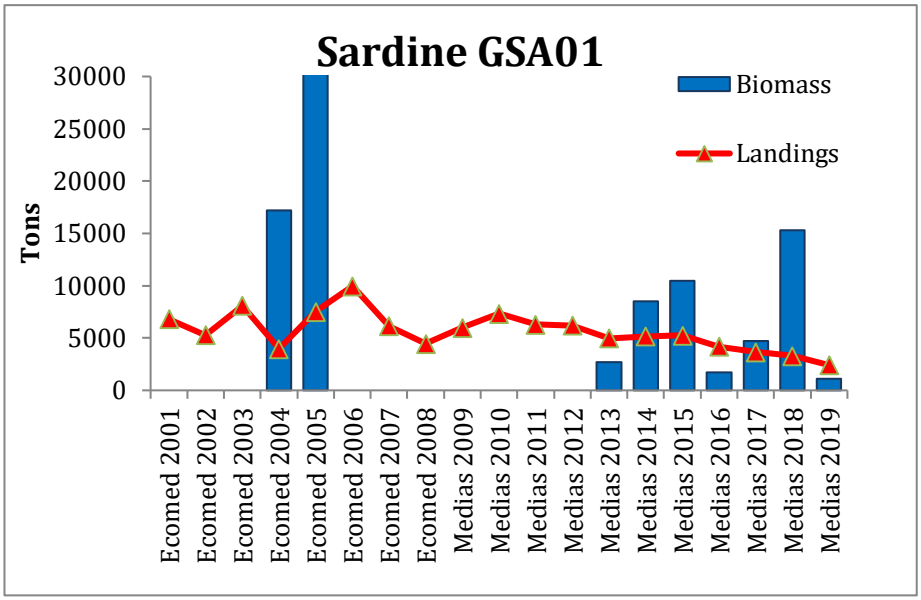

Figure 2.2. Trends in sardine landings and biomass assessed by acoustic surveys (2001–2019)

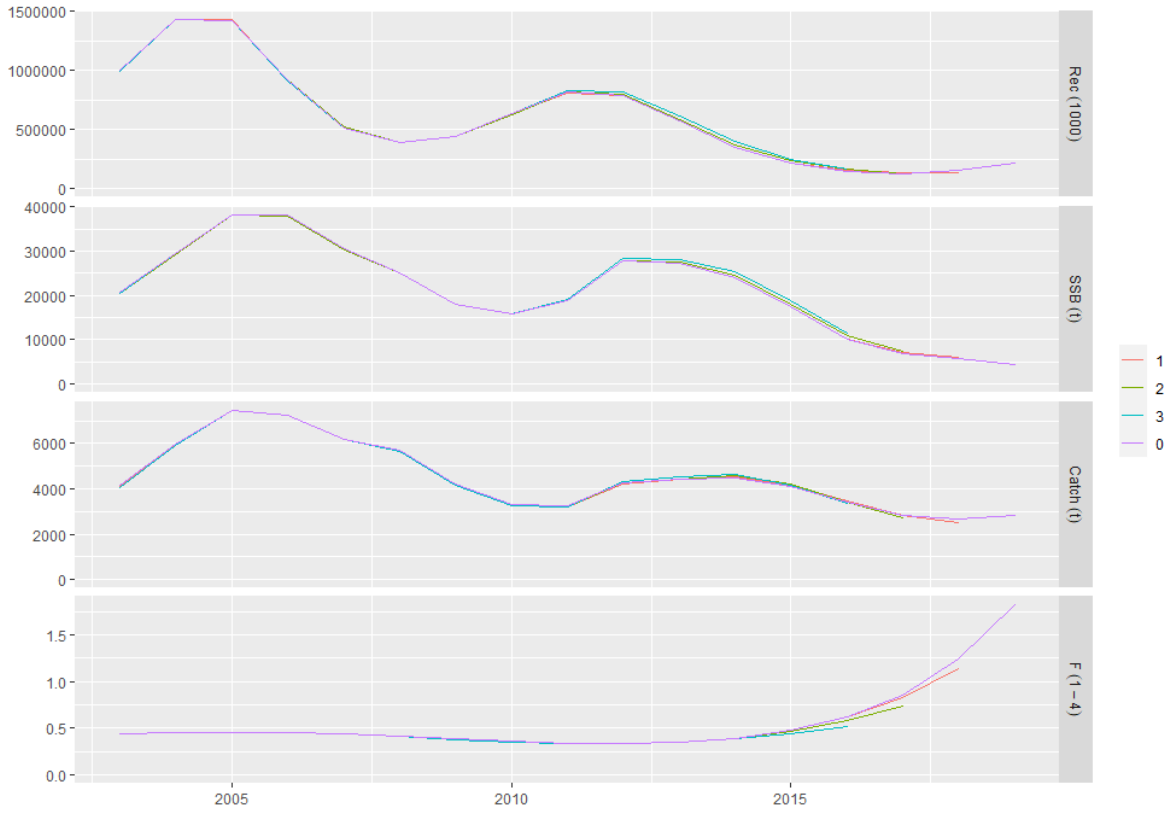

Figure 2.3. Retrospective analysis output for three years back for the a4a assessment model regarding sardine stock in GSA 1 using age 5 as a plus group

Data issues: There was high uncertainty in the acoustic survey index. The practical difficulties in the specific area were recognized, however the need that appropriate actions be taken towards adjusting the survey appropriately was stressed.

Diagnose of stock status: The assessment was considered validated providing qualitative advice. Based on the results, the stock is considered in overexploitation with very low SSB and recruitment in the final year. The advice is to reduce fishing mortality.

Table 2.1. Comparative table with last year assessment

$F_{current}$ ($F_{bar\ 1–4}$ in 2019)	1.82
F_{msy} (2019)	0.42
$E_{current}$	0.74
$E_{current}$/E0.4	1.76
$B_{current}$ (SSB)	4 525
Bloss	4 525
33rd percentile SSB (tonnes)	
66th percentile SSB (tonnes)	

Advice and recommendations: Reduce fishing mortality. It is recommended to further explore the stock results when Fbar is based on ages 0–3.

GSA 3 – Southern Alboran Sea

Sardine (*Sardina pilchardus*) in GSA 3

Authors: Idrissi, M.H., Yassir, A., EL Arraf, S., Ramirez, J.G., Garriga, M. & Hernandez, P.

Fishery: Sardine is the main species caught by purse seiners fishery in the southern Alboran Sea (GSA 3). This fishery is mainly conducted in the coastal zone of Moroccan Mediterranean sea by costal purse seiners.The number of vessels accounted for and targeting sardine last year (2019) in GSA 3 was 97 units. This fleet is based mainly in four important ports M'diq, Nador, Al Hoceima and Ras Kebdana with high mobility of purse seiners between ports following the abundance of resources. During the assessed time series (2008–2019), the total production of sardine fluctuates between 4 441 and 13 853 tonnes/year with an annual average about 8 824 tonnes. The annual landings fluctuate with a decreasing trend.

Data and parameters: Official landings time series 2008–2019, catch-at-length data from commercial catches, landing weights by age, growth parameters from age reading, ogive maturity, M vector using Gislason spreadsheet and abundance index at length were used to run a statistical catch at age model (a4a).

Assessment method: The model used was a statistical-catch-at-age (a4a). Catch-at-age data and survey index-at-age are constructed using l2a (slicing) included in the a4a script. The model structure is defined by three submodels: fishing mortality (fmod), survey catchability (qmod) and stock-recruitment (srmod).

Model performance: The sensitivity of the model was tested using different values of knots in the three submodels. The best model is chosen according to the best fitting of catches, survey index, good residuals and best retrospective analysis.

Results: Current F is higher than F_{msy} and exploitation ratio $E_{current}/E_{0.4}$ is above 1 , which indicates that the stock is subject to overfishing. $SSB_{current}$ is below 33rd percentile, so the stock is in relatively low biomass.

Table 3.1. Comparative table with last year assessment

$F_{current}$ ($F_{bar\ 0–3}$ in 2019)	1.1
F_{msy} (2019)	0.44
$E_{current}$	0.63
$E_{current}/E0.4$	1.57
$B_{current}$ (SSB)	8831
Bloss	8831
33rd percentile SSB (tonnes)	14647
66th percentile SSB (tonnes)	22379

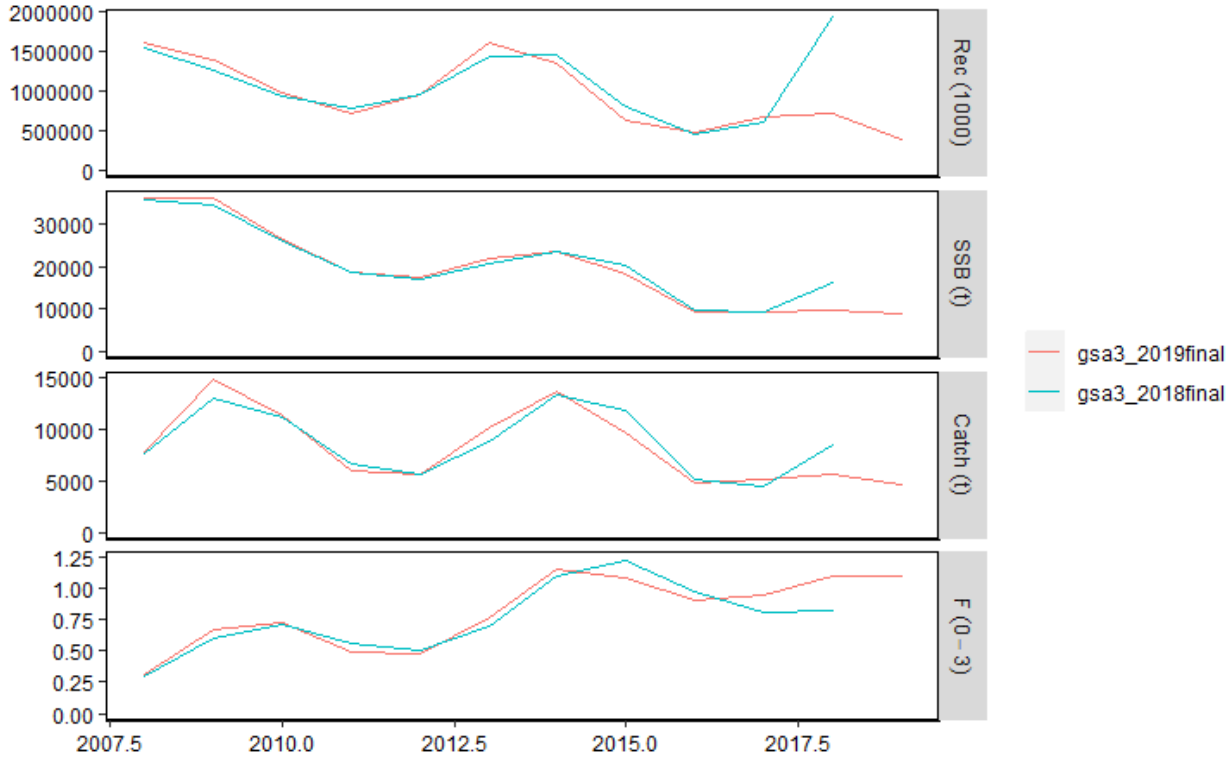

Figure 3.1. Comaparative plot of stock assessment outputs from 2018 and 2019

Diagnosis of stock status: The assessment was considered validated providing quantitative advice. Based on the results, the stock was considered in overexploitation and with relative low biomass.

Advice and recommendations: Reduce fishing mortality towards Fmsy.

GSA 4 – Algeria

Sardine (*Sardina pilchardus*) in GSA 4

Authors: Ben Smail, S., Guechaoui, M., Bennoui, A., Ferhani, K., Ramirez, J.G., Garriga, M. & Hernandez, P.

Fishery: Sardine is one of the main small pelagic species targeted by purse seiners operating in the ports of Ghazaouet and Beni-Saf with an average of 70 percent of small pelagic landings from 2015 to 2019 followed by round sardinella (*Sardinella aurita*) (20 percent).

The sardine landings increased from 2005 to 2007, decreased in 2008, then recovered in 2009. From this year to 2012, a decreasing trend was observed following by an increasing trend until 2018. A decrease in sardine catches in 2019 (3 761 tonnes) was noticed compared to the previous year (2018, 13 900 tonnes) with a lost rate of 73 percent. The average value of sardine landings for the studied period (2005–2019) is 6 386 tonnes, which represent 66 percent of landings of small pelagic.

The fishery takes place all year around. There is no monthly or seasonal closure period for seine fishing along the Algerian coast.

Data and parameters: Official annual landings time series (2005, 2007, 2012, 2016, 2017, 2018 and 2019), catch number at length per study period (2005 and 2007, 2012 and 2016, 2017–2019) converted into catch number at age per study period by slicing by R programme, growth parameters estimated from age reading, ogive maturity, M vector using Gislason estimator, 22 different values of terminal fishing mortality (Fterm values from 0.01 and 0.05 then from 0.1 to 2 with class interval 0.1), and total catches by period (tonnes).

Assessment method: The sardine stock in the Algerian Alboran Sea was assessed by using the virtual population analysis model (VPA), interaction and transition (VIT) based on VIT software (Jordi Lleonart and Jordi Salat, 1992). The model was applied using two different analyses with growth parameters estimated from age reading and growth parameters estimated by including data larvae. The LBSPR model was also applied separately for three periods in GSA 4. An analysis of bias related to the length frequency distributions (LFDs) was performed, taking into account length data coming from different ports separately.

Model performance: VIT: twenty-two different values of terminal fishing mortality (Fterm values from 0.01 and 0.05 then from 0.1 to 2 with class interval 0.1) were taken to assess a stock of sardine in the Algerian Alboran Sea. LBSPR: a stochastic approach was implemented in order to estimate Fmax and SPR_fmax acknowledging the uncertainty in life-history parameters (Linf and M/k).

Results:

VIT model results

The level of exploitation of the sardine stock was carried out by estimating the ratio of current mortality in terms of the F0.1 (Fcur/ F0.1). For the first analysis, the obtained value of the ratio Fcur/F0.1 of the three periods is less than 1.33 indicating that the stock is in low overfishing. In the second analysis, the values of

the ratio of the two last periods are between 1.33 and 1.66 which indicates an intermediate overfishing of the sardine stock in GSA 4.

Table 4.1. Summary of VIT results

	First analysis (VPA using growth based on reading)		Second analysis (VPA using growth including larvae)	
	$Fcur/F_{0.1}$	**$SSBcur/SSB_{0.1}$**	**$Fcur/F_{0.1}$**	**$SSBcur/SSB_{0.1}$**
Period: 2005 and 2007	0.54	1.60	0.92	1.22
Period: 2012 and 2016	0.75	1.58	1.46	0.90
Period: 2017–2018–2019	0.75	1.55	1.44	0.90

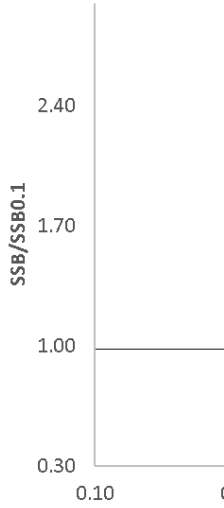

Figure 4.1. First analysis (VPA growth based on otolith readings): diagnosis of stock status (low overfishing)

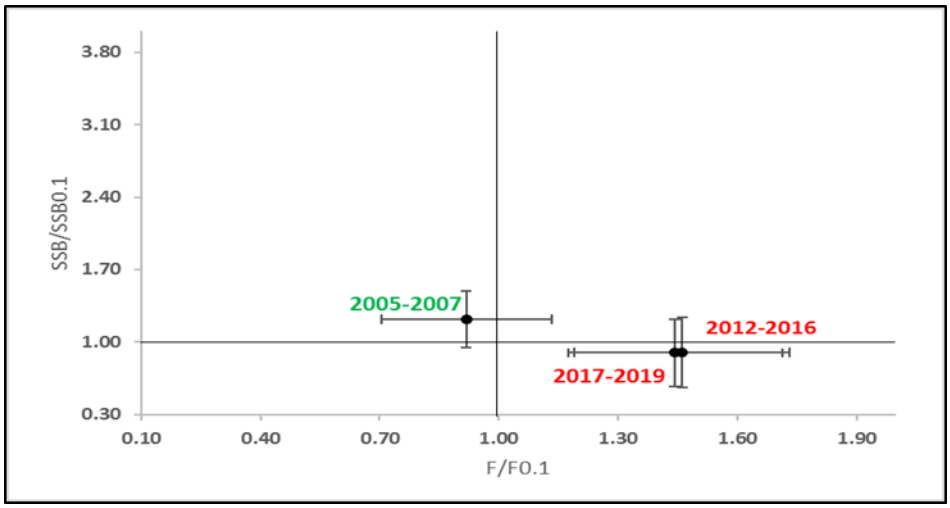

Figure 4.2. Second analysis (VPA growth including larvae): diagnosis of stock status (Intermediate overfishing)

LBSPR model results

Table 4.2. Summary of LBSPR results

	SPR			SL50		
	2005&2007	2012&2016	2017–2019	2005&2007	2012&2016	2017–2019
2.50%	0.169	0.050	0.054	11.11	11.08	11.07
50%	0.547	0.193	0.198	11.49	11.44	11.41
97.50%	0.957	0.368	0.380	11.68	11.62	11.58

	SL95			F		
	2005&2007	2012&2016	2017–2019	2005&2007	2012&2016	2017–2019
2.50%	12.59	12.52	12.47	0.37	0.41	0.43
50%	13.14	13.04	12.97	0.67	0.71	0.73
97.50%	13.45	13.33	13.23	1.16	1.20	1.22

	Fmax	SPR_Fmax
2.50%	0.3	0.121
50%	0.5	0.208
97.50%	0.9	0.299

SPR/SPR_fmax			F/Fmax		
2005&2007	2012&2016	2017–2019	2005&2007	2012&2016	2017–2019

2.50%	1.396	0.417	0.444	1.25	1.37	1.42
50%	2.624	0.924	0.952	1.34	1.43	1.46
97.50%	3.203	1.232	1.273	1.29	1.34	1.35

Data issues: No data issues were identified.

Diagnosis of stock status: The stock assessment was accepted as qualitative advice. fishing mortality is increasing and the stock is probably subject to overfishing.

Advice and recommendations: The WG recommends to reduce fishing mortality. The stock assessment would benefit from an analysis of the data collection protocol whose improvement could also significantly improve the quality of the assessment outputs.

GSA 9 – Ligurian Sea and northern Tyrrhenian Sea

Anchovy (*Engraulis encrasicolus*) in GSA 9

Authors: Musumeci, C., De Carlo, F., Lanteri, L., Ligas, A., Massaro, A., Panciroli, H., Petrillo, M., Rossetti, I., Sartini, M., Sbrana, M., Viva, C. & Sartor, P.

Fishery: In GSA 9, anchovy is exploited by purse seiners, especially along Ligurian and Tuscan coasts. The fishery takes place all year round, but most of the fishing activity is concentrated in the second and third quarter. In GSA 9, anchovy is also a bycatch of bottom trawling, though landings by bottom trawling are usually less than 10 percent of total landings of anchovy in GSA 9.

Data and parameters: No biological parameters were used for this assessment. However, age data, LFDs of catches, survey data, and so on, are available and can be used to perform analytical assessment (i.e. SCAA) in the future.

A sensitivity analysis was performed focusing on the impact of priors (log r). All trials provided consistent perception of the stock, as well as quite stable retrospective analyses. The run with log r=1.7 was considered the best.

Assessment method: SPiCT was run for the landings in GSA 9 for the period 1972–2019, using the biomass estimated by acoustic survey (MEDIAS) and relative biomass (kg/km^2) from the bottom trawl survey (MEDITS) as tuning indices.

Model performance: The stability of the model was tested by running a retrospective analysis, which gave consistent results. All the points listed in the checklist for the acceptance of a SPiCT assessment (ICES, 2019) were checked and obtained positive results.

Results: Based on the SPiCT assessment, an increasing trend in the biomass has been estimated since 2014. A strong decrease in F has been observed since 2013 (Figure 5.1).

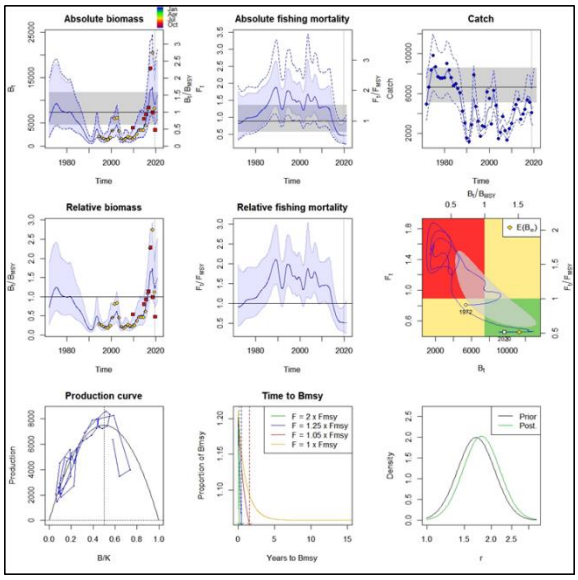

Figure 5.1. Anchovy results from SPiCT model: biomass, F and catch estimates

Table 5.1. Comparative table with last year assessment

$F_{current}$ ($F_{bar\ 1–3}$ in 2019)	0.46
F_{msy} (2019)	0.89
$F_{current}/F_{msy}$	0.52
Current B (tonnes)	9 037.23
$B_{current}/B_{msy}$	1.21

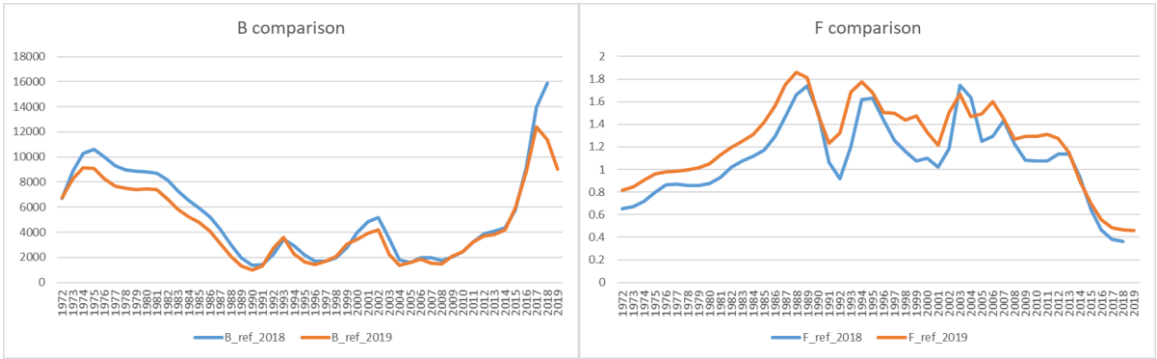

Figure 5.2. Comparison with the results of last year's assessment

Data issues: No data issues were identified

Diagnosis of stock status: The assessment was considered validated with quantitative advice. The stock is sustainably exploited (F/Fmsy = 0.52, B/Bmsy = 1.21).

Advice and recommendations: The advice is to evaluate potential fishing opportunities.

GSA 9 – Ligurian Sea and northern Tyrrhenian Sea

Sardine (*Sardina pilchardus*) in GSA 9

Authors: Musumeci, C., De Carlo, F., Lanteri, L., Ligas, A., Massaro, A., Panciroli, H., Petrillo, M., Rossetti, I., Sartini, M., Sbrana, M., Viva, C. & Sartor, P.

Fishery: In GSA 9, more than 95 percent of sardine landings come from purse seiners, especially along the Ligurian and Tuscan coasts. The fishery takes place all year round, but most of the fishing activity is concentrated in the second and third quarter. In GSA 9, sardine is also a bycatch of bottom trawling, though landings by this fleet are usually less than 5 percent of the total.

Data and parameters: No biological parameters were used for the assessment. However, age data, LFDs of catches, survey data, and so on, are available and can be used to perform analytical assessments in the future.

A sensitivity analysis focused on the impact of priors (log r) was performed. All trials provided consistent perception of the stock, as well as quite stable retrospective analyses. The run with log r=1 was considered the best.

A run was carried out using quarterly data, but the results were noisy, due to the seasonality of this fishery in the area.

Assessment method: SPiCT was run for the landings in GSA 9 for the period 1972–2019, using the biomass estimated by acoustic survey (MEDIAS) and relative biomass (kg/km^2) from the bottom trawl survey (MEDITS) as tuning indices.

Model performance: The stability of the model was tested running a retrospective analysis, which gave consistent results. All the points listed in the checklist for the acceptance of a SPiCT assessment (ICES, 2019) were checked and obtained positive results.

Results: Based on the SPiCT assessment, an increasing trend in the biomass has been estimated since 2010. A strong decrease in F has been observed since 2010 (Figure 6.1).

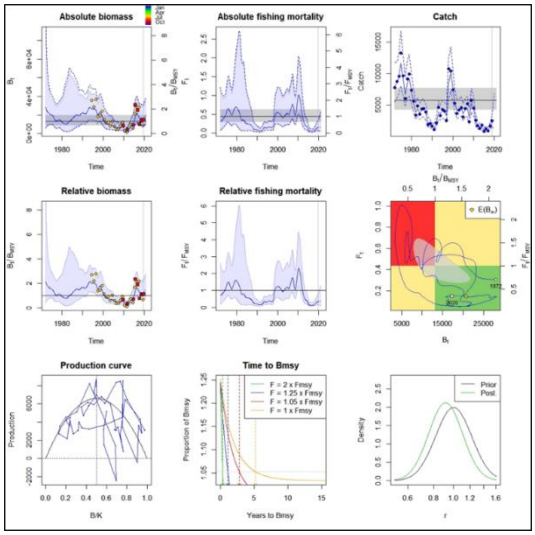

Figure 6.1. Sardine results from SPiCT model: biomass, f and catch estimates

Table 6.1. Summary of assessment results

$F_{current}$ ($F_{bar\ 1–3}$ in 2019)	0.15
F_{msy} (2019)	0.44
$F_{current}/F_{msy}$	0.34
Current B (tonnes)	16 457.36
$B_{current}/B_{msy}$	1.25

Figure 6.2. Comparison with the results of last year's assessment

Data issues: No issues were highlighted in the data. As mentioned before, data suitable for running analytical assessment are available, and will be used in the future.

Diagnosis of stock status: The assessment was considered validated with quantitative advice. The stock is sustainably exploited (F/Fmsy = 0.34, B/Bmsy = 1.25).

Advice and recommendations: The advice is to evaluate potential fishing opportunities.

GSA 16 – Southern Sicily

Sardine (*Sardina pilchardus*) in GSA 16

Authors: Barra, M., Basilone, G., Bonanno, A., Genovese, S., Pulizzi, M. & Mazzola, S.

Fishery: Sardine in GSA 16 is mainly targeted by purse seines and midwater pair trawls. Sardine landings (Figure 7.1) at the beginning of the time series were around 1 900 tonnes and increased up to 10 000 tonnes in 1998. From 2001 landings start to decrease, and 1 200 tonnes only were landed in 2003. Sardine landings in the period 2003–2011 were relatively stable while in the period 2012–2019 a consistent decrease was observed. The lowest landing value (~345 tonnes) was recorded in 2017.

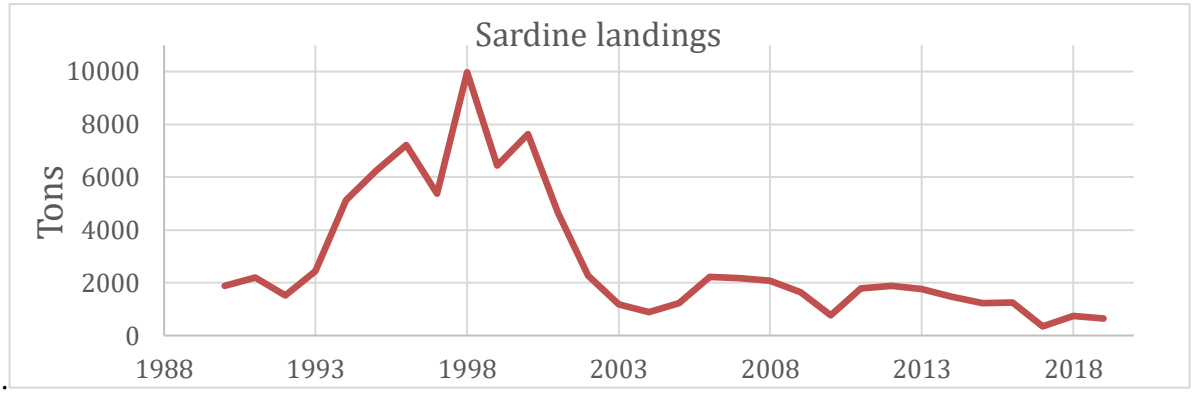

Figure 7.*1*. Sardine landings in GSA 16

Data and parameters: For both landings and acoustic surveys, numbers at age were available in the period 2002–2019 only. Due to changes in the area covered during the survey, acoustic biomass estimates were standardized according to a minimum common area of 2 200 nm^2. Acoustic biomass estimates in the period 2002–2019 ranged between 3 300 and 35 500 tonnes (Figure 7.2). Although the observed high variability in acoustic biomass estimates, in the period 2015–2019 a clear decreasing trend was observed. In particular, even if in 2019 the estimated total biomass was higher than in the previous year (Figure 7.2, blue line), most of the recorded biomass was age 0 and the remaining biomass was age 1 only (Figure 7.2, red line).

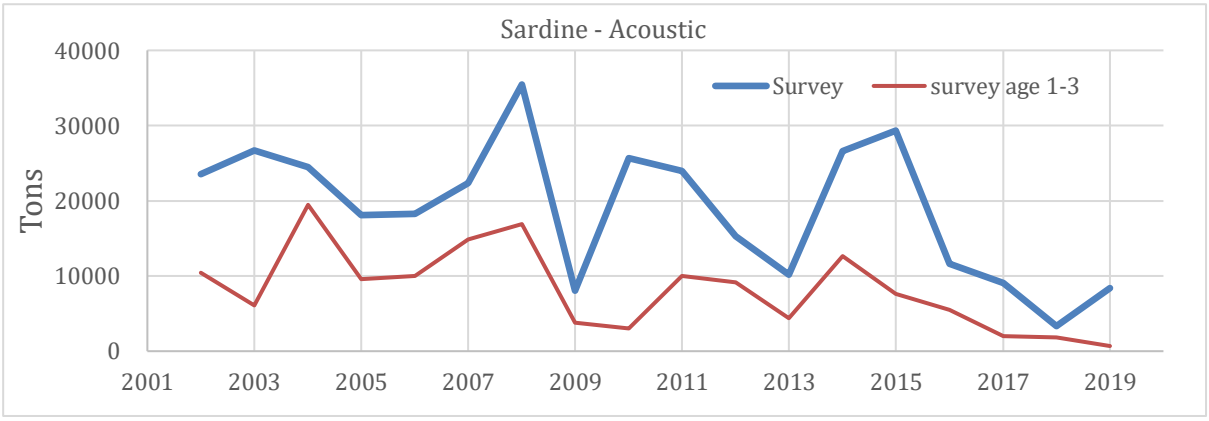

Figure 7.*2*. Acoustic biomass estimates with the blue line representing the total estimated biomass and the red line representing the estimated biomass in the age range 1–3

Furthermore, yearly ALKs for sardine recorded during the survey showed a consistent temporal shrinkage of ages.

Average ALKs were used for both acoustic biomass estimates and landings.

Von Bertalanffy growth parameters were: L_{inf} = 17.27; t_0 = -1.91; K = 0.49.

Maturity ogives and natural mortality vectors are reported in Table 7.1.

Table 7.*1*. Natural mortality and maturity vectors

Ages	Maturity	Mortality
0	0.56	1.11

1	0.81	0.78
2	1	0.63
3	1	0.54

Assessment method: According to the previous assessment, two age-based models, namely extended survivor analysis (XSA) and a4a, were used.

Model performance:

XSA

A sensitivity analysis was carried out on fse, rage and qage parameters. According to residuals summary statistics, the best model was the one using fse = 2, qage = 2 and rage = -1. The retrospective analysis (Figure 7.3), applied up to three years back, evidenced quite a stable model.

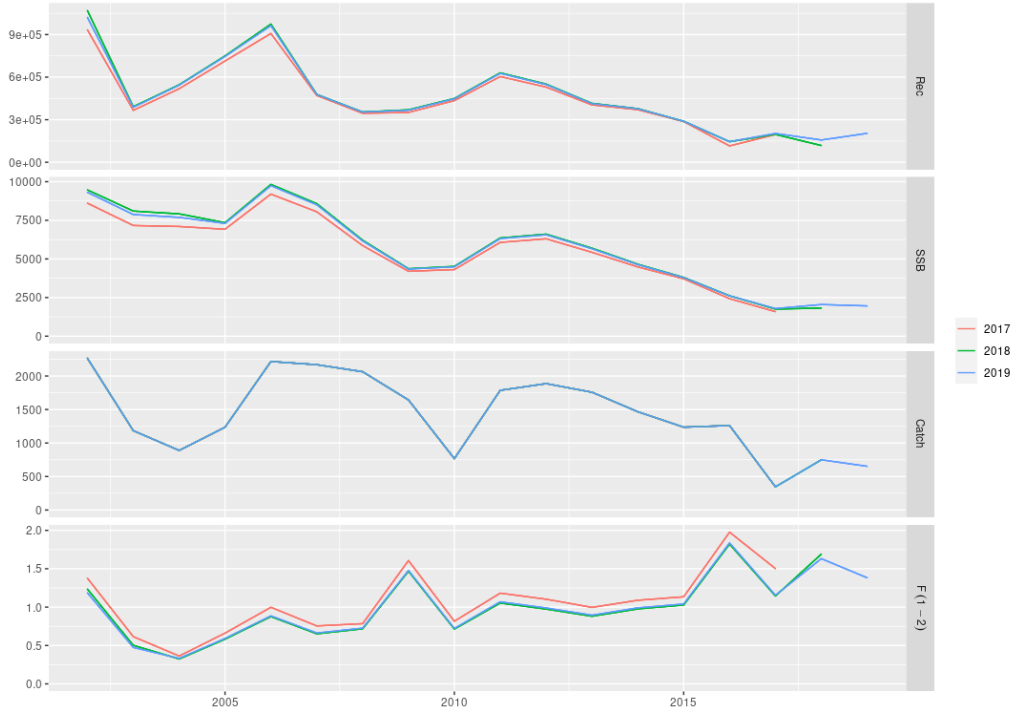

Figure 7.3. XSA retrospective analysis

A4a

Different s-r, q and f sub-models were considered, but in most cases the model failed to converge. The best model was the one considering the following sub-models:

- Fmod = ~s(replace(age, age>2,2), k = 2)+s(year, k = 10)
- Qmod = list(~factor(age))
- srmod = ~s(year,bs = "cr",k = 10)

The retrospective analysis (Figure 7.3), applied up to three years back, evidenced quite high model instability.

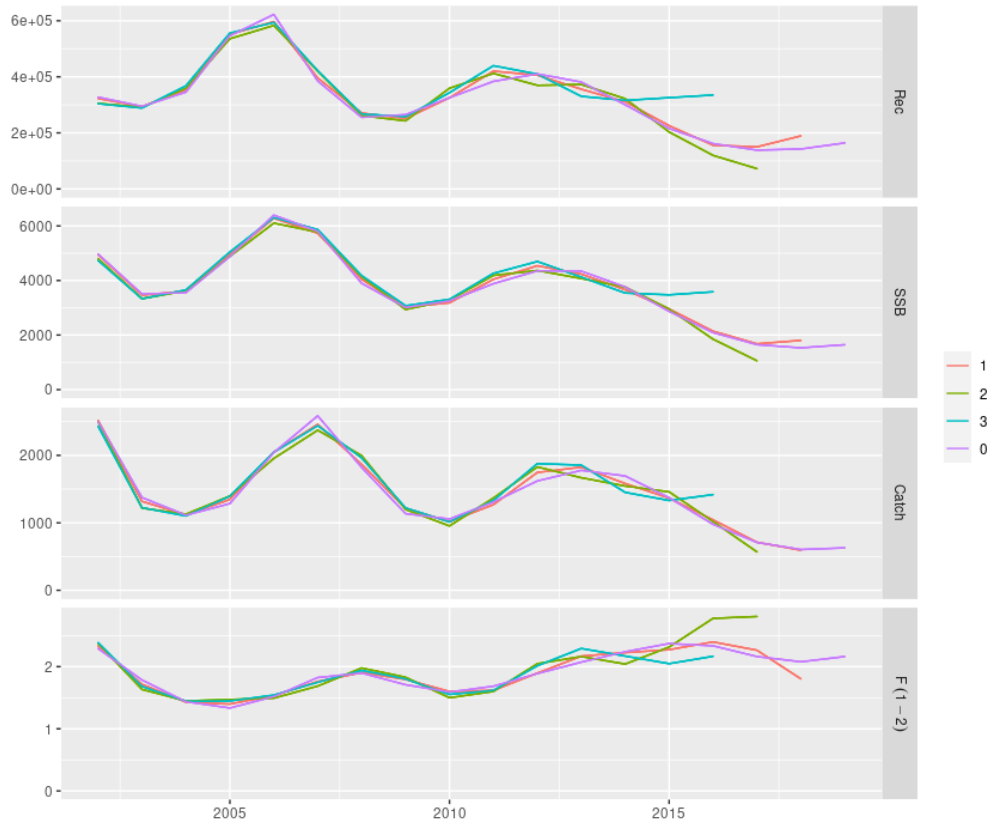

Figure 7.4. A4a retrospective analysis

Results: The estimates obtained by means of XSA and a4a showed quite similar trend and values for recruitment, SSB and catch. On the contrary, F values estimated by a4a were higher compared to XSA (Figure 7.5).

The a4a model was considered suitable to provide a qualitative advice due to the instability observed in the retrospective analysis, as well as the lack of convergence while testing for different submodels.

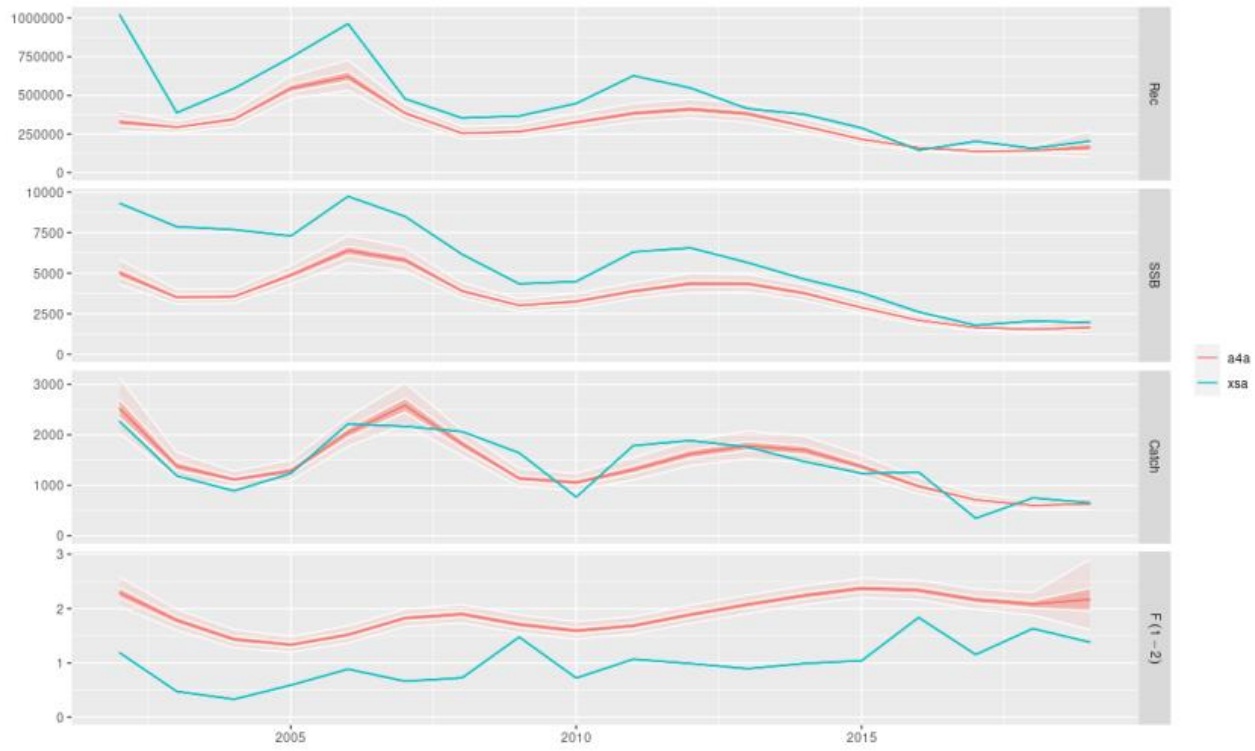

Figure 7.5. Comparison between the final a4a and XSA models

Data issues: The catch weight and age readings were not available for the period 2002–2008 thus the LFD expansion was made by considering the average LFD in the period 2009–2014.

Diagnosis of stock status: Considering the output of the model as well as the shrinkage of age structure and the low biomass levels of the adult population observed in acoustic surveys, the stock should be considered as unsustainably exploited but the assessment is considered validated for qualitative advice.

Advice and recommendations: Considering the output of the model as well as the shrinkage of age structure and the low biomass levels of the adult population observed in acoustic surveys, the management advice is to reduce fishing mortality.

GSA 16 – Southern Sicily

Anchovy (*Engraulis encrasicolus*) in GSA 16

Authors: Barra, M., Basilone, G., Bonanno, A., Genovese, S., Pulizzi, M. & Mazzola, S.

Fishery: Anchovy in GSA 16 is mainly targeted by purse seines and midwater pair trawls. Landings at the beginning of the time series (Figure 8.1) were around 2 000 tonnes and increased up to 15 000 tonnes in 1998. From 2001, landings start to decrease and only about 3 000 tonnes were landed in 2003. Anchovy landings in the period 2003–2009 were relatively stable ranging between 3 091 and 5 486 tonnes, while in the period 2010–2013 they consistently decreased to 1 163 tonnes. Since 2014, anchovy landings showed a positive trend increasing up to 3 556 tonnes in 2019.

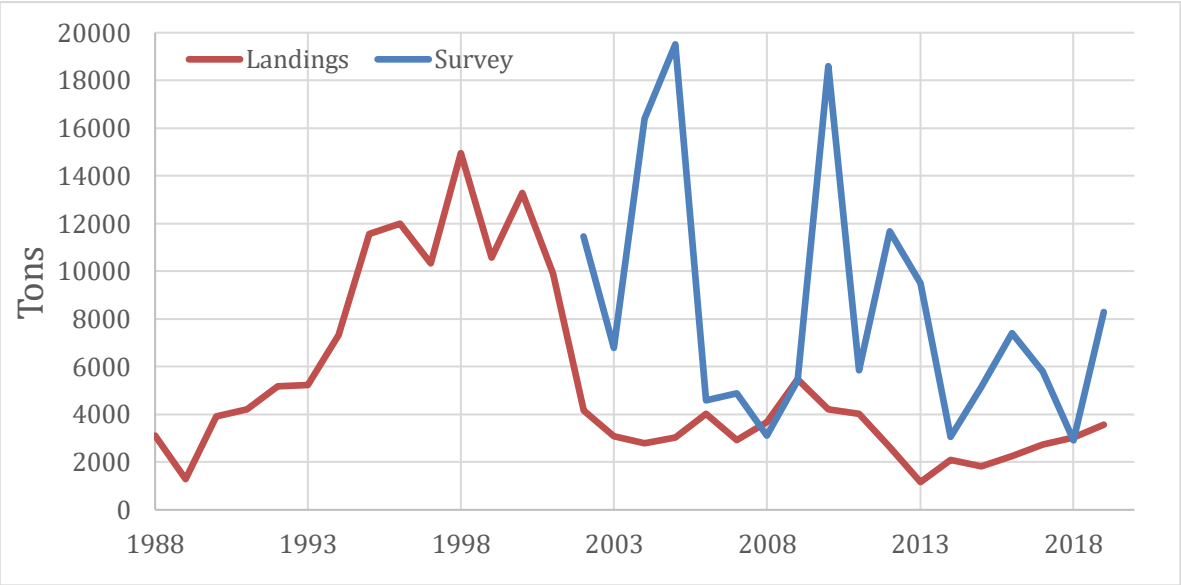

Figure 8.1. Anchovy landings (red line) and acoustic biomass estimates (blue line) in GSA 16

Data and parameters: Numbers-at-age were available only in the period 2002–2019 for both landings and acoustic surveys. Due to changes in the area covered during the survey, acoustic biomass estimates were standardized according to a minimum common area of 2 200 nm^2. Acoustic biomass estimates in the period 2002–2019 ranged between 3 000 and 20 000 tonnes. Despite the high temporal variability of acoustic biomass estimates, in the period 2010–2018 an overall decreasing trend was observed, while in 2019 the estimated biomass was the highest in the last five years.

Average ALKs were used for both acoustic biomass estimates and landings. Considering the yearly ALKs, the age structure observed in landings and acoustic surveys was quite stable in the considered period. In particular, most of the adult population was age 1 and 2, while only in some years few age 3 individuals were observed.

Von Bertalanffy growth parameters were (Basilone *et al.*, 2004): L_{inf} = 18.6; t_0 = -1.81; K = 0.3

Maturity ogive and natural mortality vectors are reported in Table 8.1.

Table 8.2. Natural mortality and maturity vectors

Ages	Maturity	Mortality
0	0.6	1.05
1	0.9	0.64
2	1	0.48
3	1	0.4

Assessment method: According to the previous assessment, two age-based models (XSA and a4a) and a surplus production model (SPiCT) were used. For the two age-based models, numbers-at-age in landings and acoustic surveys were based on the average ALK.

Different runs were carried out for both XSA and a4a working on the whole time series (2002–2019 for age-based models) or on a subset of years. The magnitude and distribution of residuals for each run were evaluated. In the case of XSA, the best performances were obtained by working on data from 2008 to 2019, while for a4a the whole time series was considered.

SPiCT was run considering landings from 1990 to 2019 and acoustic biomass estimates from 2002 to 2019 (ages 1:3).

Model performance:

XSA

A sensitivity analysis was carried out on fse, rage and qage parameters. The best model, based on the residuals, was the one considering fse = 2, qage = 2 and rage = -1. The retrospective analysis (Figure 8.2), applied up to three years back, evidenced instability in recruitment and SSB, while the trend in F was quite coherent.

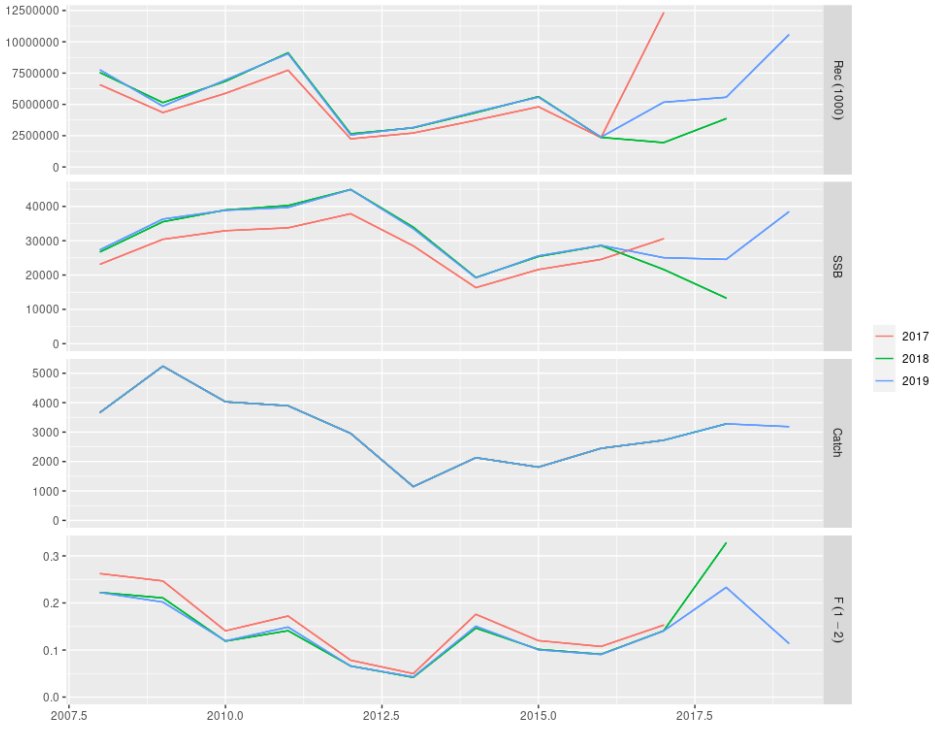

Figure 8.2. XSA retrospective analysis

A4a

Different s-r, q and f sub-models were considered, but in most cases the model failed to converge. The best model was the one considering the following sub-models:

- Fmod = ~s(replace(age, age>2,2), k=2)+s(year, k=10)
- Qmod = list(~factor(age))
- srmod = ~s(year,bs="cr",k=10)

The retrospective analysis (Figure 8.3), applied up to three years back, evidenced quite high model instability.

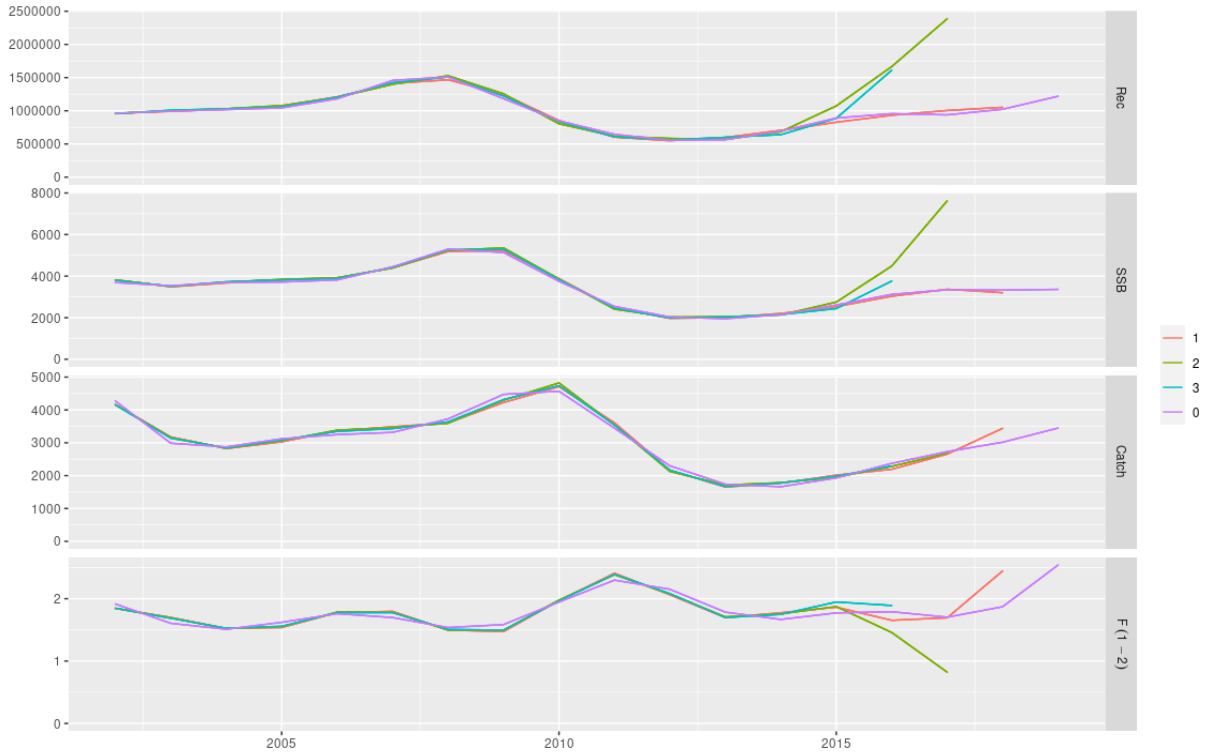

Figure 8.3. A4a retrospective analysis

SPiCT

In a first step, preliminary runs were carried out on the whole time series, by using hard or soft eulertype and keeping the default settings for priors. Under these settings, the model was not able to converge or showed wide confidence intervals for estimated parameters.

In order to obtain a proper convergence, Logn and Logr priors were defined as follows:

- Logr: c(log(1.2), 0.1, 1)
- Logn: log(2)

The best obtained model (Figure 8.4) evidenced acceptable fit performances and diagnostic plots did not evidence assumptions violation except for the catch autocorrelation (ACF). Retrospective analysis (Figure 8.5) showed similar trends among the different runs.

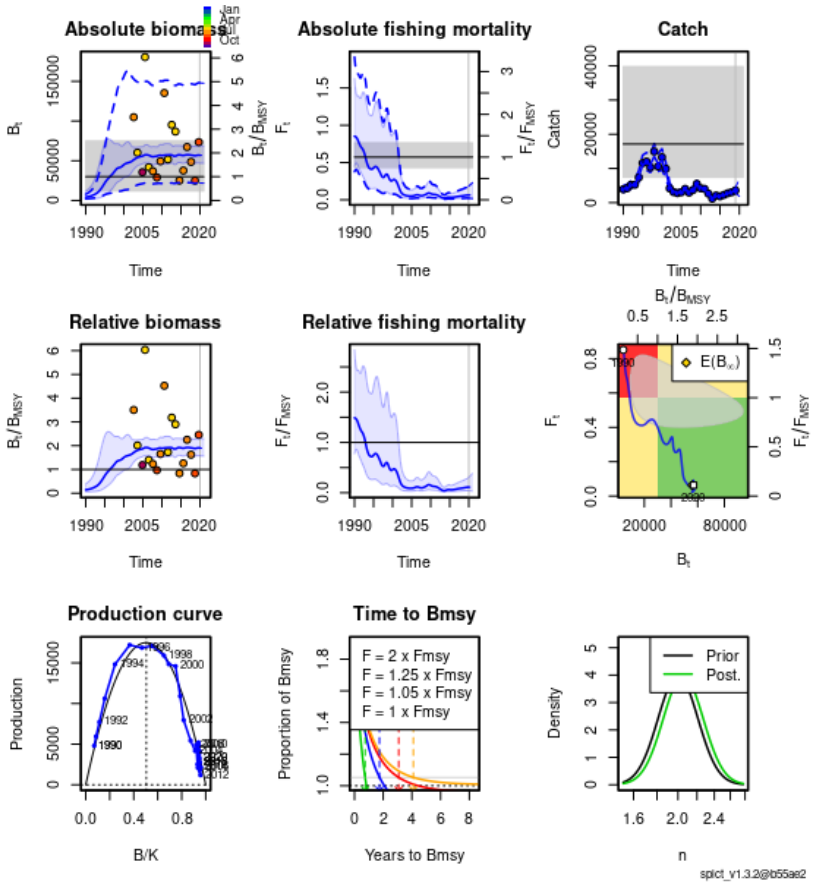

Figure 8.4. SPiCT results

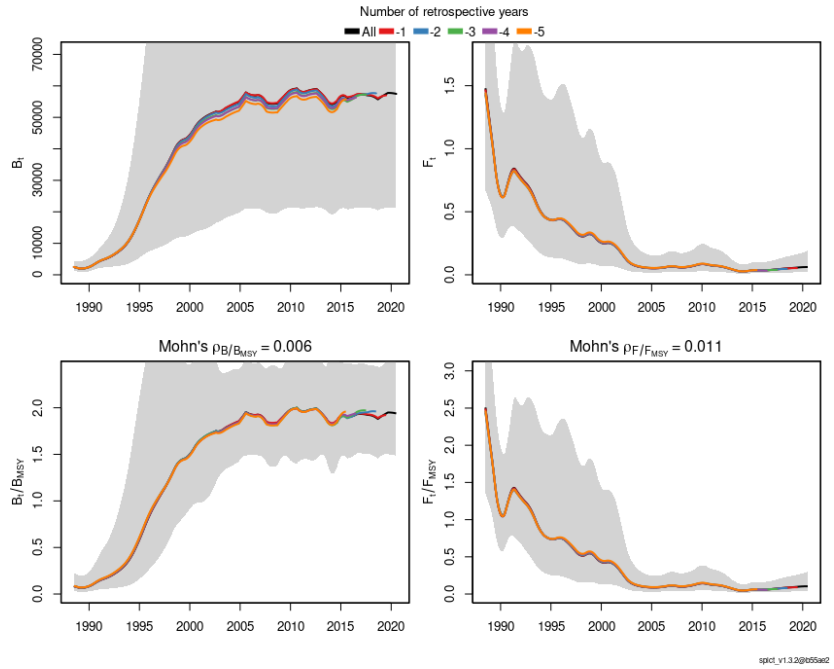

Figure 8.5. SPiCT retrospective analysis

The SPiCT model was evaluated according to the *Guidelines for the stochastic production model in continuous time (SPiCT)*. Even if most of the guidelines were met, changes in initial values led to different parameter estimates.

Data issues: The catch weight and age readings were not available for the period 2002–2008 thus the LFD expansion was made by considering the average LFD in the period 2009–2014. For few catches, the reported fishing area was Lampedusa that is outside GSA 16.

Results: The two-age based model showed quite high variability in the retrospective analysis, and strong differences in the SSB and F values. The SpiCT model (Figure 8.5) was considered suitable to provide qualitative advice.

Diagnosis of stock status: The assessment is considered validated for qualitative advice. The stock is sustainably exploited but the advice is that on precautionary basis fishing effort should not be increased.

Advice and recommendations: Do not increase fishing mortality.

GSAs 17–18 – Adriatic Sea

Anchovy (*Engraulis encrasicolus*) in GSAs 17–18

Authors: Angelini, S., Arneri, E., Belardinelli, A., Biagiotti, I., Boscolo Palo, G., Bratina, P., Brunel, T., Canduci, G., Cacciamani, R., Calì, F., Cikes-Kec, V., Colella, S., Costantini, I., De Felice, A., Domenichetti, F., Donato, F., Gašparević, D., Hintzen, N., Ibaibarraga, L., Juretic, T., Kule, M., Leonori, I., Malavolti, S., Martinelli, M., Milone, N., Modic, T., Panfili, M., Pesic, A., Santojanni, A., Tesauro, C., Ticina, V. & Palluqi, A.

Fishery: Anchovy are fished by purse seiners and pelagic trawlers belonging to Italy, Croatia and, to a much smaller extent, Slovenia, Albania and Montenegro. The Italian fleet authorized to fish small pelagics in the Adriatic Sea is composed of about 62 midwater pelagic trawlers and about 81 purse seiners with quite different tonnage. Most of the Italian boats whose port of registry is located in GSA 18 actually fish and land in GSA 17. Croatia has 152 authorized purse seiners fishing small pelagics, particularly sardine. Albania, Montenegro and Slovenia have respectively 26, 23 and 25 fishing vessels authorized to fish small pelagic in GSAs 17 and 18. Exploitation is based on all the age classes from 0 to 3+. The Italian catches of anchovy represent the majority of the catches, however since 2000, catch from the eastern side, mainly Croatia and Albania, have significantly increased.

Data and parameters: Catch-at-age from the different countries are lumped together; the considered time series goes from 2000 to 2019. Survey information are divided in four acoustic surveys (Echo East, EchoWest 17, L survey, Echo East and West 18) covering different periods from 2004 to 2019. Growth parameters are summarised in Table 9.1, while natural mortality vector and proportion of mature by ages are showed in Table 9.2.

Table 9.*3*. Biological parameters used in the assessment (combined sex) for anchovy

Growth model	L_{inf}	18.61
	k	0.622
	t_0	-0.849

Length-weight relationship	a	0.0032
	b	3.2339

Table 9.*4.* Natural mortality by Gislason and proportion of matures by ages

Size/Age	Natural mortality	Proportion of matures
0	2.75	0
1	1.21	1
2	0.89	1
3	0.76	1

Assessment method: State-space assessment program (SAM) has been performed to assess the stock status of anchovy in GSAs 17 and 18 from 2000 to 2019. Acoustic surveys data were available and used as tuning indices of abundance-at-age from 2004 to 2014 for the western side of GSA 17 (Italy), from 2004 to 2014 from GSA 18, from 2015 to 2019 from the western side of GSAs 17 and 18, and from 2013 to 2016 for the eastern side of the Adriatic Sea (Croatia). The SAM model allows selectivity to evolve gradually over time. It has fewer model parameters than full parametric statistical assessment models, with quantities such as recruitment and fishing mortality modelled as random effects. SAM assessment was run using the FLSAM package in the R framework.

Model performance: The stability of the model was tested running a retrospective analysis, which gave consistent results, notwithstanding the different time series of the four surveys that could have affected the stability of this analysis.

Results: The average fishing mortality for age 1 (Figure 9.1, middle) shows an increasing trend over the considered time series reaching the highest value in 2016 (F = 1.388); the 2019 value corresponds to 1.22. The spawning stock biomass (Figure 9.1, top) shows an increasing trend up to 2006 (58 720 tonnes) that then decreases continuously reaching the value of 17 089 tonnes in 2019, close to the lowest value registered in 2016 (16 547 tonnes). Recruitment (Figure 9.1, bottom) follows a similar trend, being stable at the beginning of the time series, registering the highest value in 2007 (130 867 767 number of individuals), then presenting a continuous decreasing trend reaching the value of 79 422 479 number of individuals in 2019.

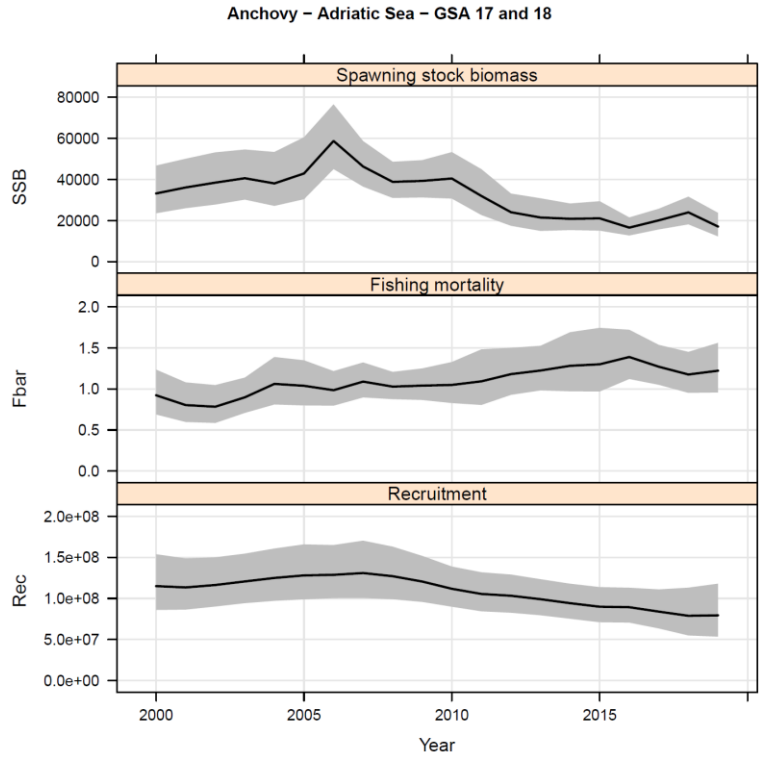

Figure 9.*3.* Anchovy results from SAM model: SSB, F and recruitment estimates

Data issues: Relevant standard operating procesdure (SOP) correction was applied to the catch-at-age data. These discrepancies should be addressed in the next benchmark.

Diagnosis of stock status: The assessment was considered validated with quantitative advice. The stock is in overfishing status and overexploited (F/F_{msy} = 1.51, B/B_{pa} = 0.80).

Table 9.5. Stock assessment results and advice

Based on	**Indicator**	**Analytical 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	F_{msy} = 0.81 (corresponding to E = 0.4)	F_{cur} = 1.22		I	IO_I
Stock abundance	Biomass	B_{lim} = 16 200 B_{pa} = 21 400	B_{cur} = 17 089		D	O_L
Final diagnosis	In overfishing status and overexploited					

Advice and recommendations: The advice is to reduce fishing mortality.

GSAs 17–18 – Adriatic Sea

Sardine (*Sardina pilchardus*) in GSAs 17–18

Authors: Cikes-Kec, V., Angelini, S., Arneri, E., Belardinelli, A., Biagiotti, I., Boscolo Palo, G., Bratina, P., Brunel, T., Canduci, G., Cacciamani, R., Calì, F., Colella, S., Costantini, I., De Felice, A., Domenichetti, F., Donato, F., Gašparević, D., Hintzen, N., Ibaibarraga, L., Juretic, T., Kule, M., Leonori, I., Malavolti, S., Martinelli, M., Milone, N., Modic, T., Panfili, M., Pesic, A., Palluqi, A., Santojanni, A., Tesauro, C. & Ticina, V.

Fishery: Sardines are fished by purse seiners and pelagic trawlers belonging to Croatia, Italy and, to a much smaller extent, Albania, Montenegro and Slovenia.

Albanian sardine catches are mostly from purse seiners, nine of them are active ones. Croatia has about 152 active purse seiners targeting small pelagic (mainly sardine). The Italian fleet is composed of about 62 pairs of midwater trawlers and about 81 purse seiners (with quite different tonnage), with the former being more predominant than the latter ones. Most of the Italian boats whose port of registry is located in GSA 18 actually fish and land in GSA 17. In Montenegro, most of the catches are originated from small-scale beach seine fisheries and from small purse seiners fisheries in coastal waters (< 70 m depth) where are operating 12 active fishing vessels, while in Slovenia only 13 purse seiners are currently active.

Data and parameters: Catch-at-age from the different countries are lumped together; the considered time series goes from 2000 to 2019. Survey information are divided in five acoustic surveys (Pelmon GSA 17E; European Union MEDIAS – Italy (western part GSA 18); European Union MEDIAS – Italy and Slovenia (western and northern part of GSA 17); L-survey European Union MEDIAS – Italy, Slovenia and acoustic survey Montenegro, Albania (west GSA 17 and whole GSA 18); and European Union MEDIAS – Croatia (eastern part of GSA 17)) covering different periods from 2004 to 2019. Growth parameters are summarised in Table 10.1, while natural mortality vector and proportion of mature by ages are showed in Table 10.2.

Table 10.*6*. Biological parameters used in the assessment (combined sex) for sardine in GSAs 17–18

Growth model	L_{inf}	19.8
	k	0.38
	t_0	-1.785
Length-weight relationship	a	0.0062
	b	3.094

Table 10.7. Natural mortality by Gislason and proportion of matures by ages, used in assessment for sardine in GSAs 17–18

Size/age	Natural mortality	Proportion of matures
0	1.06	0
1	0.83	1
2	0.69	1
3	0.61	1
4	0.48	1

Assessment method: A4a has been performed to assess the stock status of sardine in GSAs 17 and 18 from 2000 to 2019. This is a statistical catch-at-age model implemented in R that makes use of the FLR platform and uses automatic differentiation model builder (ADMB) for optimization (Jardim *et al*., 2014). One of the most important features of this model is that the structure of each of its components is given using R's syntax for model equations. This provides a very flexible but still accessible approach for stock assessment. Acoustic surveys data were available and used as tuning indices as biomass index from 2003 to 2010, and as abundance-at-age from 2004 to 2014 for the western side of GSA 17 (Italy), from 2004 to 2014 for the western side of GSA 18, from 2015 to 2019 for the western side of GSA 17 and the whole GSA 18, and from 2013 to 2019 for the eastern side of GSA 17 (Croatia). Fishing mortality was modelled as a bivariate smooth depending on age and year with three and ten knots respectively; initial numbers-at-age were a smooth function on age with three knots, recruitment was an annual fixed factor and observation variance of catch-at-age and indices were constant along ages. The catchability of the GSA 17 west and GSA 18 west accounted for the 2008 change in survey design, and were bound for ages 2 and older, whereas the catchability of the L survey was bound for ages 1 and older and the catchability of the Echo East GSA 17 survey was bound for ages 2 and older.

Model performance: The residual pattern did not show any major deviation and the difference between the modelled and the observed total catch was small. The observation variances were assumed constant along age, indicating the largest observation uncertainty for the GSA 18 west index and the smallest for the catch-at-age. Uncertainty estimates of the a4a model results were obtained using the function simulate, that samples randomly from a multivariate normal distribution centered at the fitted parameters with variance-covariance matrix computed from the Hessian returned by ADMB. The coefficients of variation of recruitment, SSB and fishing mortality were below 0.15 for most of the time series, but increased sharply in the last two years for SSB and recruitment (up to 0.3 for SSB and above 1 for recruitment).

The retrospective analysis could only be conducted for two years backwards due to convergence issues with the a4a model, but no systematic bias was detected. The Mohn's rho for recruitment was -0.0228, for SSB 0.4754 and for fishing mortality -0.1678. However, these results should be taken with caution as they are limited by the number of years removed. In addition, it should be taken into account that in the current analysis the number of knots of the smoothing functions depending on year were not adjusted as the number of years were reduced. This might deserve further consideration in the future. The high uncertainty in the estimates and the problems in model run convinced the WG not to accept the assessment as benchmarked.

Results: The final summary plots indicate that recruitment and SSB have been decreasing since 2012, but have increased slightly in the last two years. Fishing mortality has been increasing continuously since the beginning of the time series. In general, uncertainty is very high in the last years.

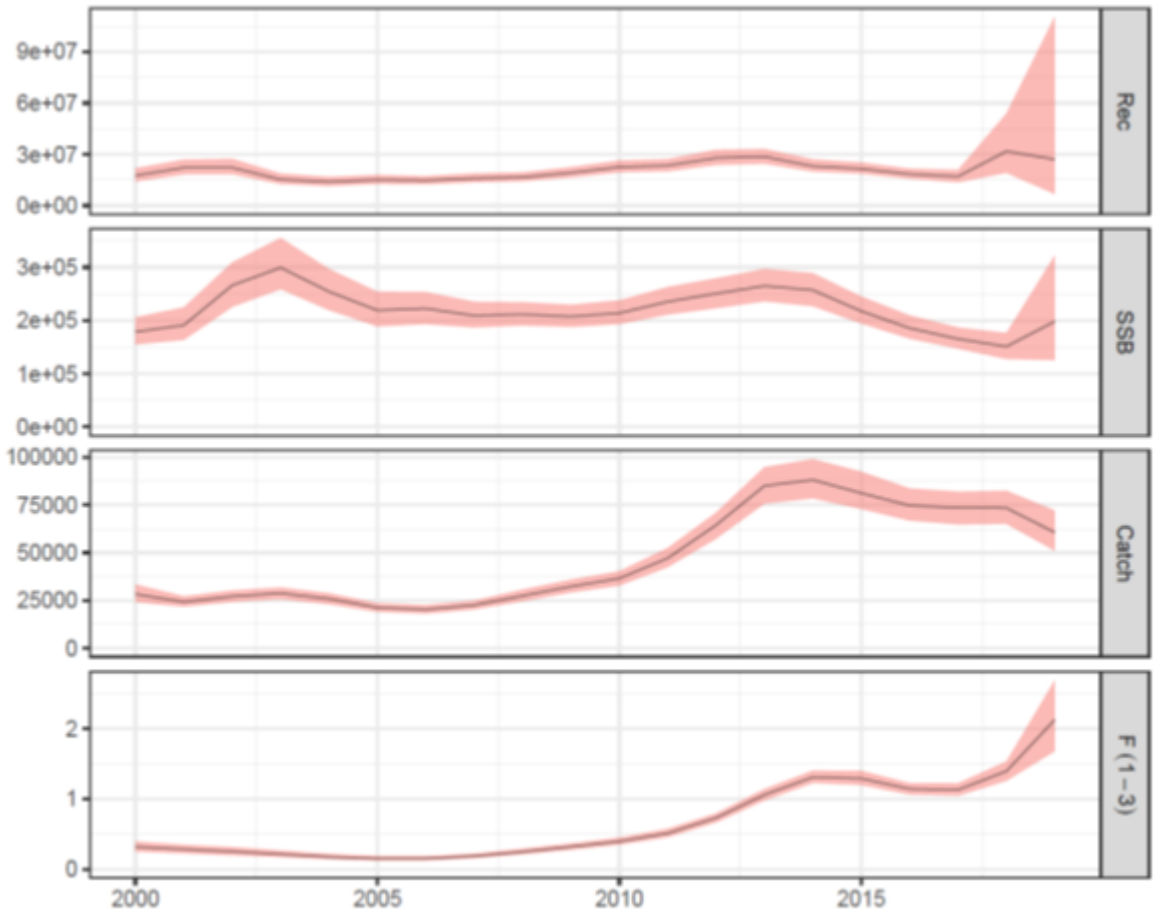

Figure 10.1. Time series of recruitment, SSB, catch and fishing mortality for sardine in GSAs 17–18

Data issues:

In general, the sardine age-structured data were noisy and showed little internal cohort consistency both in the catches and in the surveys. Although the underlying reasons could not be understood, the following potential issues were discussed:

- In 2014, a workshop on intercalibration of sardine otolith reading was carried out within the framework of AdriaMed. The age structure of the sardine input data used in the current assessment are based on the results and agreements of that workshop. Given that the workshop was relatively recent, the sardine otolith ageing was not anticipated to be an issue and the age structured data were considered adequate in the initial data preparation meetings. However, a later in-depth analysis showed big differences between the age structure of catch-at-age data and some of the acoustic indices. In particular, the European Union MEDIAS in GSA 17 east, following otolith reading criteria in accordance with the 2016 Workshop on age estimation of European anchovy of the International Council for the Exploration of the Sea (ICES), and in line with the common standardized MEDIAS protocol, showed individuals up to age 2, while the catch-at age matrix in the same area had individuals of age 4. This raised doubts on the consistency of the sardine age readings. For the time being, it was decided not to use the age readings from the acoustic survey in GSA 17 east. But this issue needs to be further studied.

- A constant ALK has been applied for the catch-at-age data before 2015. This might introduce bias in the age-structured data, especially if there has been a change in growth along years.

- Older ages have disappeared in the last years, resulting in a downward trend in the average age in the catches and in some surveys. Although some exploratory analysis on length data was initiated during the benchmark, a more detailed analysis is still pending.

- The catch-at-age data by country in some years had big SOPs. It is still necessary to explore the reasons for these big SOPs, and correct them.

- Past assessments of this stock had been based on the so-called "long time series". The use of long time series was extensively discussed during the data preparation meetings and the benchmark. The group considered that data before 2000 were too uncertain to be used for the assessment due to changes in the catch statistics of some countries, data gaps and unreliable assumptions to reconstruct past data. Therefore, the group decided to use only data from 2000 onwards.

Issues to be addressed in the future should include:

- reviewing the sardine otolith ageing criteria and repeating intercalibration exercises between age readers;
- using annual ALKs to transform length distributions in the catch and in the surveys into ages and avoiding, as much as possible, the use of an ALK from other year/region/survey;
- analysing if there is any change in growth along the years;
- analysing the differences between the total catch and the SOP of catch-at-age data by country and applying the SOP correction for each of the countries, if needed;
- standardising and consolidating the survey methodology used for assessment across the area (GSAs 17 and 18);
- exploring potential assessment models; and
- if a4a is used, studying how the number of knots of the smoothing functions depending on year will be adjusted as additional years are added in the stock assessment, and adjusting the number of knots of the smoothing functions depending on year in the retrospective analysis.

Diagnosis of stock status: The assessment was considered validated for quantitative advice but not benchmarked. The stock is in overfishing status and overexploited ($F/F_{msy} = 4.43$, $B/B_{pa} = 0.67$).

Table 10.*8*. Stock assessment results and advice

Based on	**Indicator**	**Analytical 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	$F_{msy} = 0.47$ (corresponding to E = 0.4)	Fbar = 2.11		I	IO
Stock abundance	Biomass	$B_{lim} = 178\ 200$ $B_{pa} = 294\ 300$	$B_{cur} = 198\ 600$		N	IO

Final diagnosis	In overfishing status and overexploited

Advice and recommendations: The advice is to reduce fishing mortality.

GSA 20 – Eastern Ionian Sea

Sardine (*Sardina pilchardus*) in GSA 20

Authors: Giannoulaki, M., Tsoukali, S., Machias, A., Tsagarakis, K., Pyrounaki, M.M. & Somarakis, S.

Fisheries: The fishery in the area consists of 35 purse seines vessels that target anchovy and sardine and to a lesser percentage Atlantic chub mackerel (*Scomber colias*) and bogue (*boops boops*). Data concerning the fishery in the area are the ones officially reported by the Hellenic Statistical Service (HelStat) and the data collection regulation. Sardine landings' time series (1985 to 2019) ranged from 215 tonnes (in 1987) to 2 943 tonnes (in 2004) and exhibited high fluctuations throughout this period.

Assessment method: A surplus production model SPiCT was run for the Greek sardine landings in GSA 20 for the period 1985–2019 using the biomass estimated by acoustics as a tuning index, ranging from 2013 to 2019. SPiCT was run successfully with the use of priors.

Model performance: SPiCT run converged successfully with the combination of two priors: logFFmsy (relative fishing mortality, (log(1.138), 0.1, 1, 2008, based on a past assessment estimate) and logr (population intrinsic growth rate, (log(0.8), 0.1, 1)), providing acceptable retrospective and meeting all seven criteria mentioned in the checklist suggested for SPiCT. Other priors were also tested (e.g. virgin biomass, initial depletion level), but with no successful convergence or acceptable model results.

Results: The results showed an increase in the relative and absolute biomass in the beginning of the time series until the mid-1990s, and a moderate decrease thereafter. The fishing mortality appears quite similar throughout the time series with no particular fluctuations (Figure 11.1). The stock is considered overexploited for the reference year.

Table 11.1. SPiCT model results regarding biomass and fishing mortality for 2019

	SPiCT 2019
B (2019)	**2 481 tonnes**
B/Bmsy	**0.897**
$F_{current}$	**0.427**
F_c/F_{MSY}	**1.082**

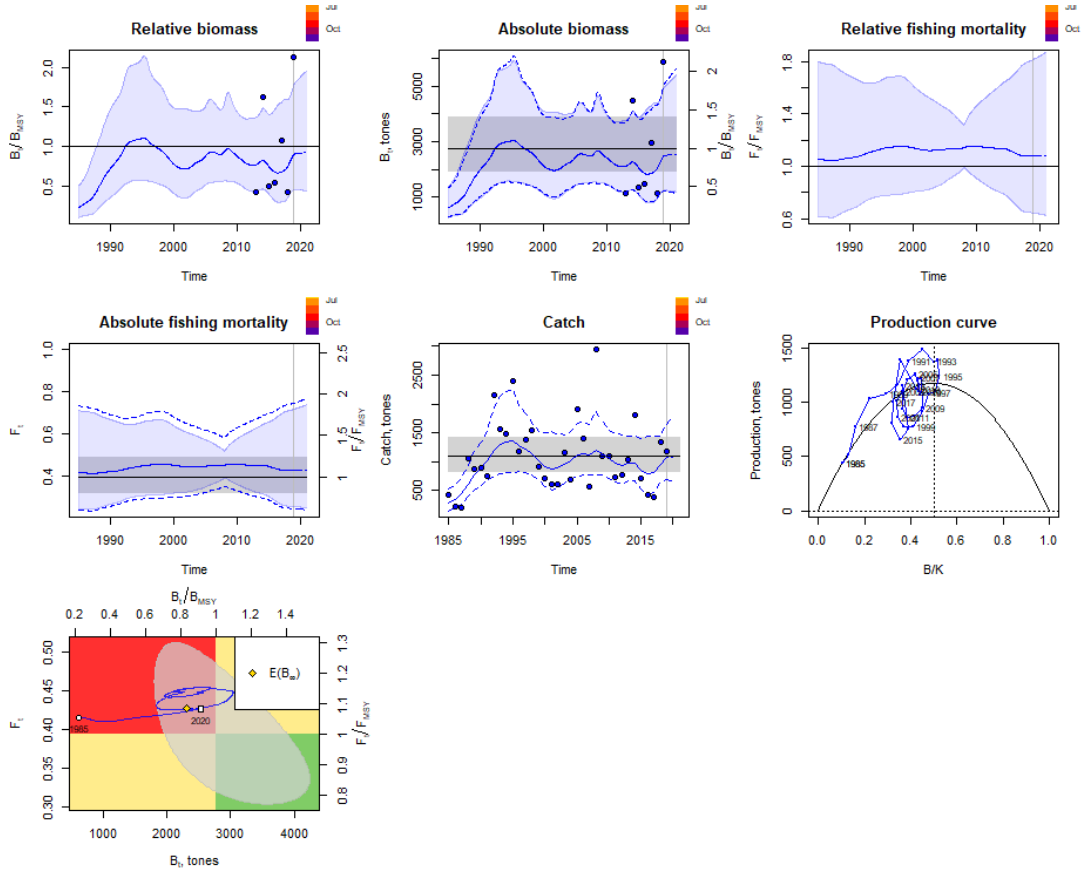

Figure 11.1. SPiCT model results showing the biomass (relative and absolute) and fishing mortality (relative and absolute) estimated, as well as the kobe plot indicating stock status

List of data issues: No issues were highlighted in the data.

Diagnosis of stock status: The successful run of the SPiCT model indicated an unsustainable level of exploitation but with high uncertainty. For this reason, the assessment was considered validated providing qualitative advice. The stock is considered overexploited.

Advice and recommendations: The assessment was considered qualitative. The WG further recommended carrying out the acoustic surveys on a regular basis in order to increase the length of the time series for the survey index. They also suggested to explore the application of other assessment methods such as age structure models.

GSA 20 – Eastern Ionian Sea

Anchovy (*Engraulis encrasicolus*) in GSA 20

Authors: Giannoulaki, M., Tsoukali, S., Machias, A., Tsagarakis, K., Pyrounaki, M.M. & Somarakis, S.

Fisheries: The fishery in the area consists of 35 purse seines vessels that target anchovy and sardine and to a lesser percentage Atlantic chub mackerel and bogue. Data concerning the fishery in the area are the ones officially reported by HelStat and the data collection regulation. Anchovy landings' time series (1981 to 2019) ranged from 50 tonnes (in 1988) to 2 452 tonnes (in 1984) and exhibited high fluctuations throughout this period. A decrease in landings has been observed since 2012.

Assessment method: A surplus production model SPiCT was run for the Greek anchovy landings in GSA 20 for the period 1981–2019 using the biomass estimated by acoustic surveys as a tuning index, ranging from 2013 to 2019. SPiCT was run successfully with the use of priors.

Model performance: SPiCT run converged successfully with the combination of two priors: logFFmsy (relative fishing mortality, (log(1.86), 0.2, 1, 2008, based on a past assessment) and logr (population intrinsic growth rate, (log(0.9), 0.1, 1)), providing acceptable retrospective and meeting all seven criteria mentioned in the checklist suggested for SPiCT. Additional priors were tested (e.g. virgin biomass, initial depletion level), but with no successful convergence or acceptable model results.

Results: The results showed an increase in the relative and absolute biomass since 2000 and a decreasing trend in the absolute and relative fishing mortality since 2008, indicating sustainable exploitation of the stock for the reference year (Figure 12.1).

Table 12.1. Estimates of the SPiCT model regarding biomass and fishing mortality in 2019

	SPiCT 2019
B (2019)	**4 340 tonnes**
B/Bmsy	**1.713**
$F_{current}$	**0.094**
F_{c}/F_{MSY}	**0.203**

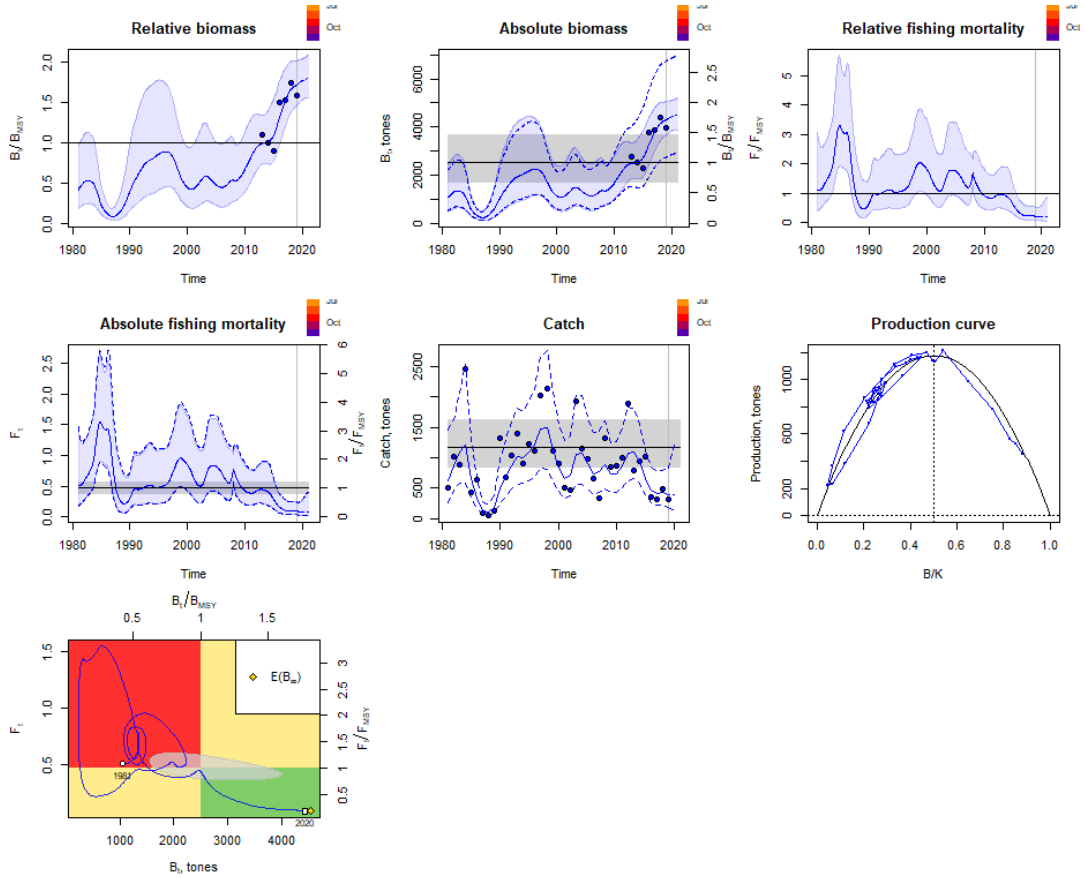

Figure 12.1. SPiCT model results showing the biomass (relative and absolute) and fishing mortality (relative and absolute) estimated, as well as the kobe plot indicating stock status

List of data issues: No issues were highlighted in the data.

Diagnosis of stock status: The successful run of the SPiCT indicated a sustainable level of exploitation, but the uncertainty produced was high. For this reason, the assessment was considered validated for providing qualitative advice. Based on this, the stock is sustainably exploited.

Advice and recommendations: The assessment was considered qualitative. The WG further recommended carrying out the acoustic surveys on a regular basis in order to increase the length of the time series for the survey index. It also suggested the application of other assessment methods such as age structure models.

GSA 22 – Aegean Sea (Greece)

Anchovy (*Engraulis encrasicolus*) in GSA 22

Authors: Giannoulaki, M., Tsoukali, S., Machias, A., Tsagarakis, K., Pyrounaki, M.M. & Somarakis, S.

Fishery: Anchovy in the Greek part of GSA 22 is mainly fished by the purse seine fleet (~200 vessels) and it is generally considered a mixed fishery with sardine. Discards, although very low, they were taken into account for the assessment as 2 percent of the reported landings. Age structure of the discards is missing for all the years and gear. Anchovy landings showed an increase since 1970 (~5 000 tonnes) peaking in the late 1980s (~25 000 tonnes) and decreasing again in the early 1990s. Since then, the landings range between 8 500 to 16 451 tonnes with the lowest values observed in early 2000s and 2011. The Turkish landings were

lower than 5 000 reported tonnes till 1997, steadily increasing thereafter and reaching similar values to the Greek landings since 2011.

Assessment method: A surplus production model SPiCT and two analytical age structure models: a4a, and FLR wrapper for the state-space assessment model (FLSAM) were run.

SPiCT was run with the priors regarding the logFFmsy (relative fishing mortality) and logr (population intrinsic growth rate), with input data the catch time series (1980–2018) and the survey biomass index for the years 1995–1996, 2003–2006, 2008, 2013–2014, 2016 and 2019.

For the analytical models: data regarding catch, abundance index, age composition of catch and abundance index were used. A single tuning fleet was used based on the abundance-at-age estimates from summer acoustic surveys conducted in the Greek part of GSA 22 (2003 to 2019 with gaps in 2007, 2009–2013, 2015, 2017, 2018). For the years 2007, 2009–2012, where no European Union data collection framework (DCF) was carried out in Greece, catch numbers-at-age were set at "NA" for the a4a model and reconstructed for the missing years.

Model performance: The SPiCT run converged successfully. Both a4a and FLSAM models resulted in high uncertainty in the estimates, especially towards the last years of the time series. The retrospective was also very poor. This was mainly due to the fragmented information on the surveys (lack of survey in 2009–2012, 2015, 2017 and 2018) in the last years and the lack of catch-at-age data for the period 2009–2012 that amplified uncertainties. The survey residuals and model fit in respect to the survey was not very good, regarding both models.

Results: Based on the a4a results in accordance to last year's assessment, anchovy SSB fluctuated over the time period examined (2000–2019) from 27 455 tonnes (in 2017) to 93 212 tonnes in 2003. A drop in SSB was observed in the years 2007 to 2013 followed by an increase, apart from the low SSB value in 2017. The assessment shows an increase in the number of recruits during the last two years. Fbar (1–3) shows a decrease since 2010 followed by an increase since 2017. The two models (a4a and FLSAM) showed similar trends in terms of catch but different trends for fishing mortality and recruitment. They both estimated similar high Fbar values in the last year (2019). Both models runs had fitting issues, giving unstable results, but all indicating high exploitation of the stock in the last year (Figure 13.1). SPiCT results also agree with the estimated high exploitation of the stock in the last year but are also in agreement with last year sustainable status (Figure 13.2).

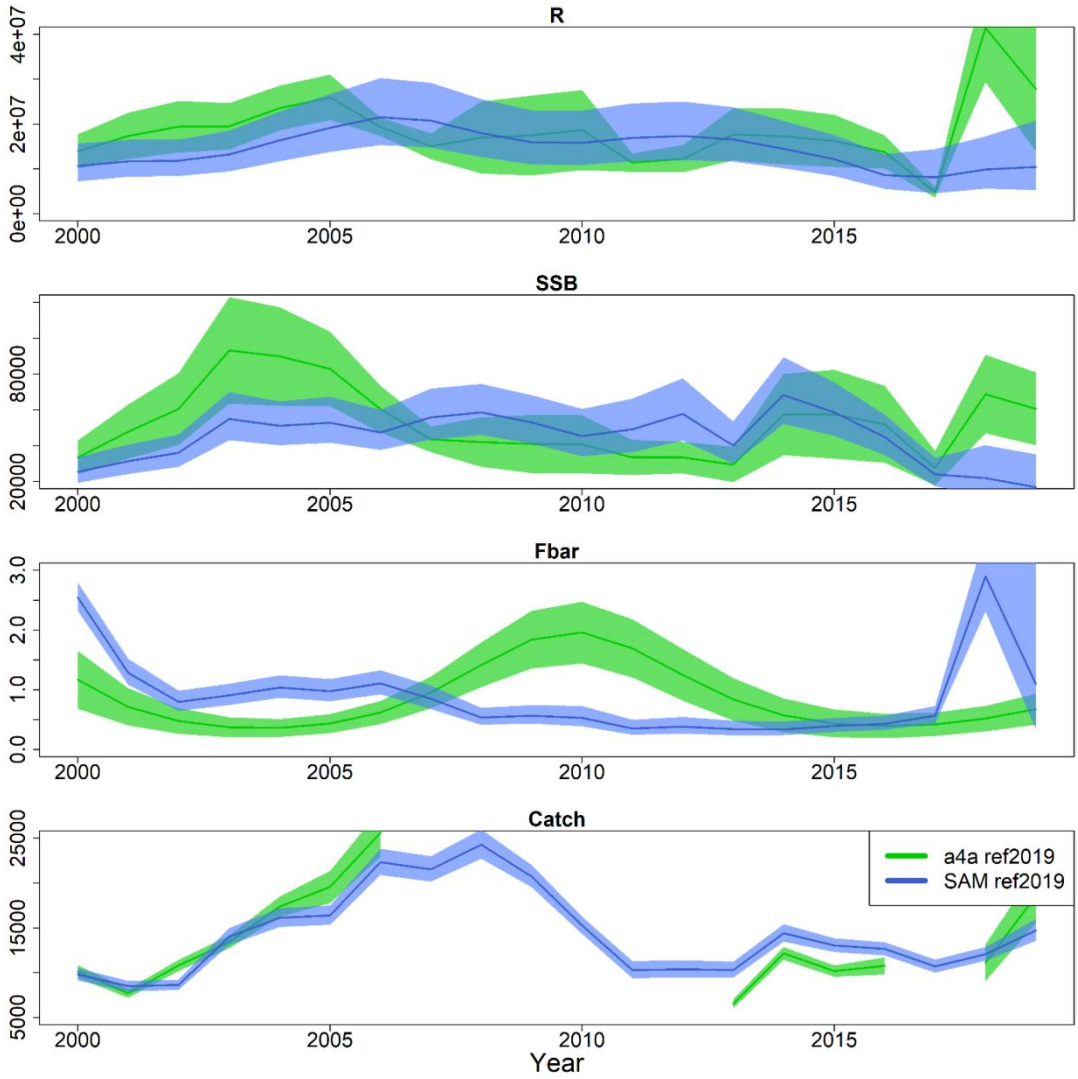

Figure 13.1. Comparison of model output of the SAM and the a4a model (reference year 2019) for anchovy in the Greek part of GSA 22

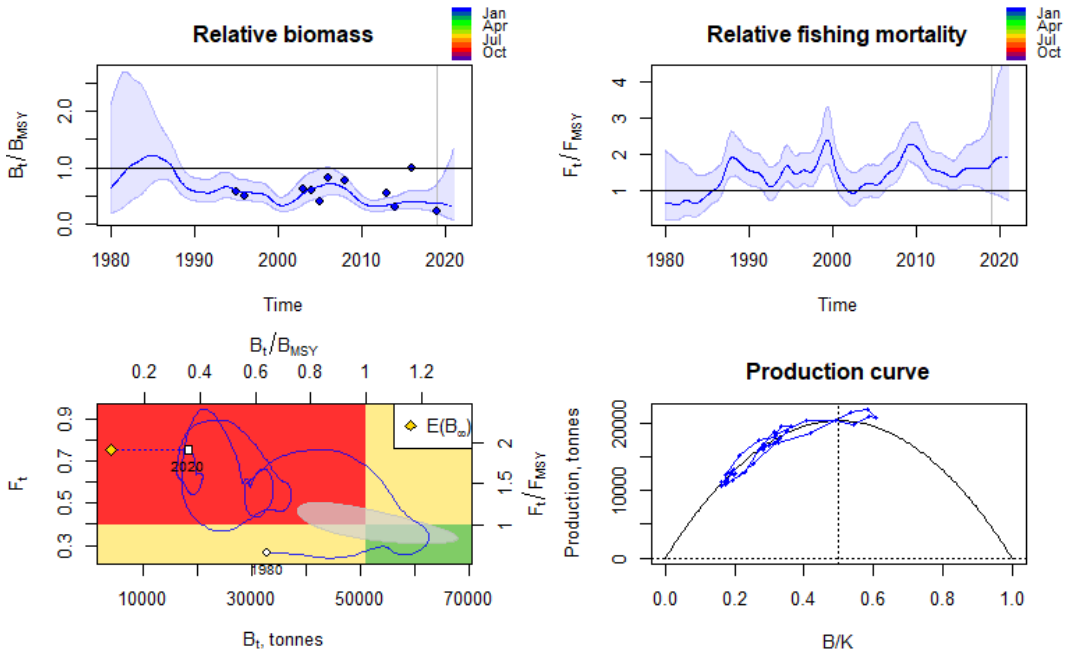

Figure 13.2. SPiCT model results showing the relative biomass and relative fishing mortality estimated, as well as the kobe plot indicating stock status as overexploited

Table 13.1. Comparative results of the a4a, FLSAM and SPiCT regarding SSB and fishing mortality in 2019.

	A4a 2019	FLSAM 2019	SPiCT 2019	A4a 2018
SSB (2019)	**60530**	**16872**	**19538**	**76344**
$F_{current}$	**0.729**	**1.096**	**0.679**	**0.222**
F_c/F_{MSY}	**1.56**	**2.35**	**1.721**	**0.475**

Results of the a4a with reference year 2018 are also given for comparative reasons. Note that Fmsy in the case of a4a and FLSAM is the F corresponding the empirical reference point of E=0.4 (Patterson, 1992).

Data issues: Due to logistics problems, there are gaps in the DCF data (in terms of survey for 2007, 2009–2012, 2015, 2017 and 2018, but also in terms of the catch-at-age for 2007, 2009–2012 and 2017) and assumptions had to be made to fill them for the SAM model. Moreover, uncertainty is high in the a4a model as shown by confidence intervals in the plot. The retrospective of the a4a model is unstable due to data gaps concerning the surveys. It is important to stress the need that surveys and landings sampling needs to take place on an annual basis in order for the assessment model to capture adequately the temporal dynamics of the species.

Diagnosis of stock status: The lack of continuous surveys in the recent period largely influences the assessment and causes uncertainties in the estimated parameters, driving a poor retrospective. The lack of

catch-at-age data in a given period of years amplifies the effect of the lack of surveys in the a4a model. All models indicated high exploitation of the stock in the last year.

Advice and recommendations: The assessment was considered validated as qualitative. The stock is in overexploitation and the advice is to reduce fishing mortality. The working group recommended exploring the potential to apply data-limited models in the stock assessment.

GSA 22 – Aegean Sea (Greece)

European sardine (*Sardina pilchardus*) in GSA 22

Authors: Giannoulaki, M., Tsoukali, S., Machias, A., Tsagarakis, K., Pyrounaki, M.M. & Somarakis, S.

Fishery: Sardine in the Greek part of GSA 22 is mainly fished by the purse seine fleet (~200 vessels) and it is generally considered a mixed fishery with anchovy. Discards although very low, were taken into account for the assessment as 2 percent of the reported landings. Age structure of the discards is missing for all the years and gear. Sardine landings for the period 1970–1989 ranged between 8 330 to 16 031 tonnes, followed by an increase during 1990–2001 of 17 171–24 500 tonnes and dropping again afterwards to 7 000–14 500 tonnes. The Turkish landings followed a similar pattern during those periods although at lower absolute numbers, except in the last ten years where the absolute reported landings were a bit higher than the Greek landings.

Assessment method: A surplus production model SPiCT and two analytical age structure models: a4a and FLSAM were run. SPiCT was run with different combinations of priors (relative fishing mortality, recruitment, initial depletion level) with input data the catch time series (1980–2018) and survey abundance index time series 1995–1996, 2003–2006, 2008, 2013–2014, 2016 and 2019.

For the analytical models, data regarding catch, abundance index, age composition of catch and abundance index were used. A single tuning fleet was used based on the abundance-at-age estimates from summer acoustic surveys conducted in the Greek part of GSA 22 (2003 to 2019 with gaps in 2007, 2009–2013, 2015, 2017 and 2018). For the years 2007 and 2009–2012, where no European Union DCF was carried out in Greece, catch numbers-at-age were set at "NA" for the a4a model and reconstructed for the missing years.

Model performance: The SPiCT run converged successfully with the priors regarding the logFFmsy (relative fishing mortality) and logr (population intrinsic growth rate). Both a4a and FLSAM models resulted in high uncertainty in the estimates, especially towards the last years of the time series. The retrospective was also very poor. This was mainly due to the fragmented information on the surveys (lack of survey in 2009–2012, 2015, 2017, 2018) in the last years and the lack of catch-at-age data for the period 2009–2012 that amplified uncertainties. The survey residuals and model fit in respect to the survey was not very good, regarding both models.

Results: Based on the a4a results (Figure 14.1), the sardine SSB fluctuated between 11 250 (in 2012) and 24 582 tonnes (in 2006), with 19 005 tonnes estimated for 2019. Furthermore, an increasing trend in recruitment and fishing mortality was estimated for the recent years. The FLSAM results (Figure 14.1) show a similar trend in the time series of SSB and catches, as well as similar values, but a higher fluctuation in Fbar and smoother fluctuation in the recruitment compared to a4a model. Both models indicate high exploitation of the stock, but with different estimated Fbar values. SPiCT results also agree with the estimated high exploitation of the stock (Figure 14.2).

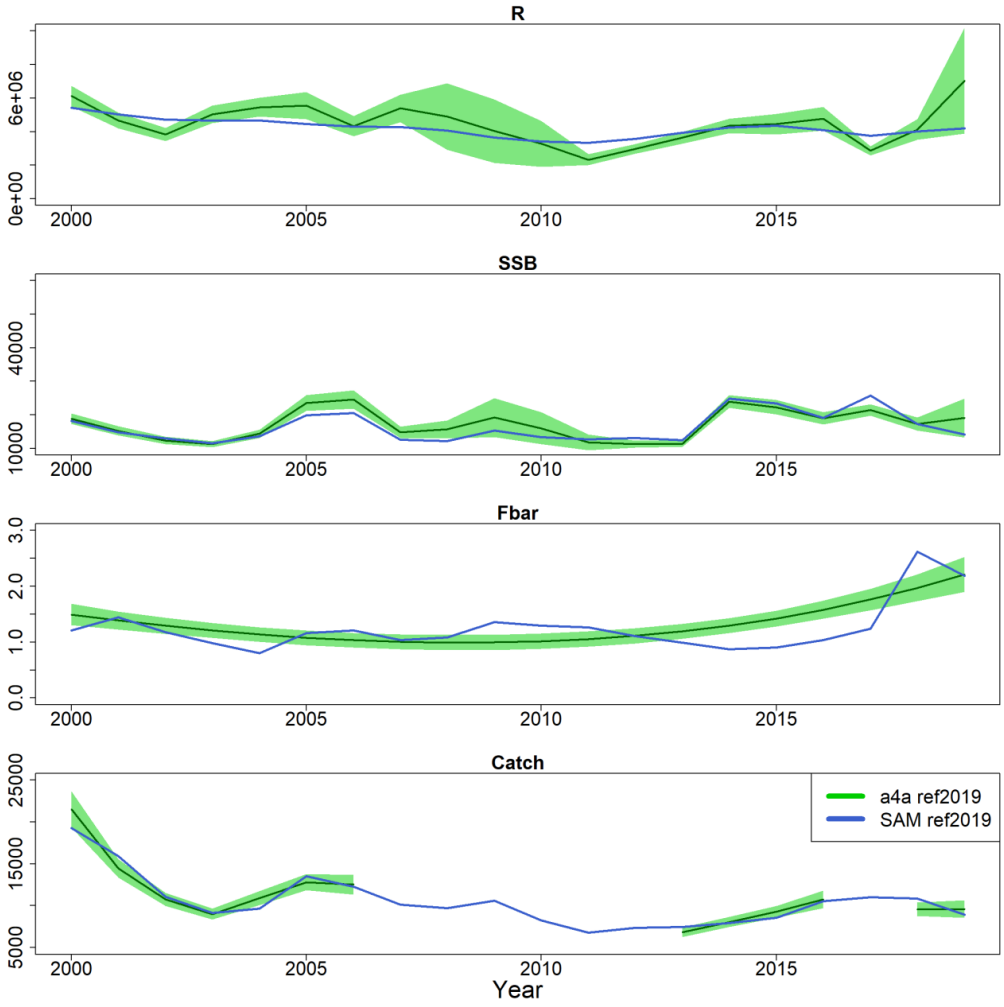

Figure 14.1. Comparison of model output of the SAM and the a4a model (reference year 2019) for sardine in the Greek part of GSA 22

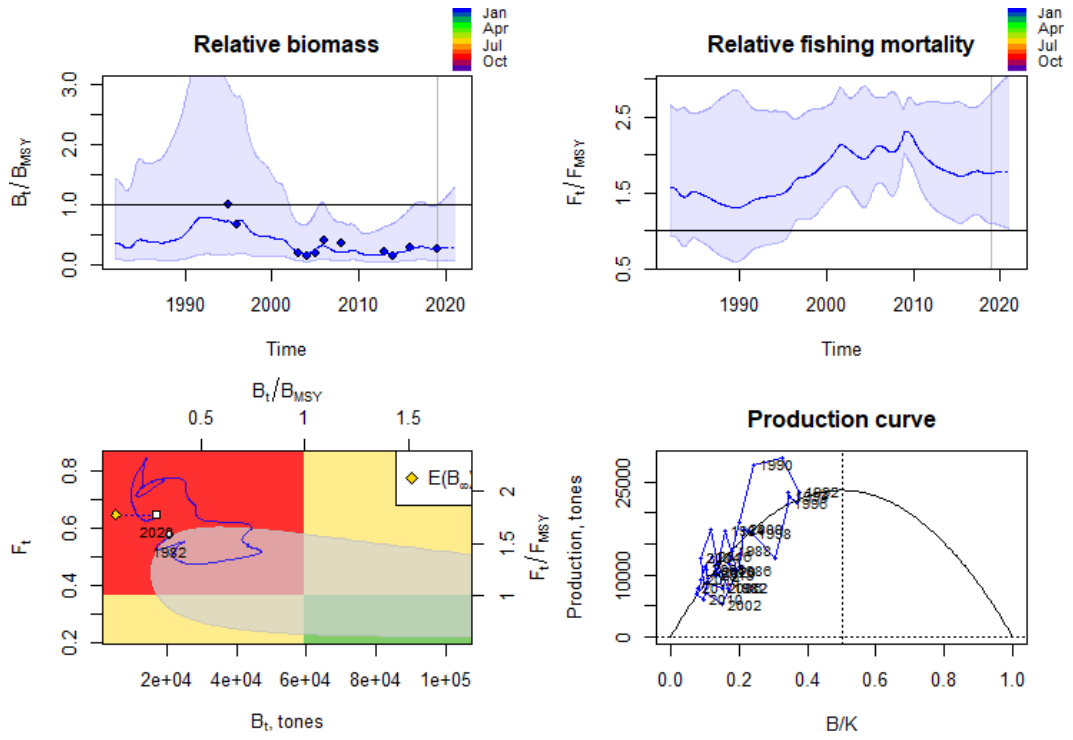

Figure 14.2. SPiCT model results showing the relative biomass and relative fishing mortality estimated, as well as the kobe plot indicating stock status (overexploited)

Table 14.1. Estimates of the model results of a4a, SAM and SPiCT regarding SSB and fishing mortality in 2019, with results of the a4a with reference year 2018 given for comparative reasons

	A4a 2019	FLSAM 2019	SPiCT 2019	A4a 2018
SSB (2019)	**19 005**	**14 168**	**16 133**	**37 326**
$F_{current}$	**2.208**	**2.183**	**0.64**	**0.518**
F_c/F_{MSY}	**4.39**	**4.35**	**1.756**	**1.01**

Data issues: Due to logistics problems, there are gaps in the DCF data (in terms of surveys for 2007, 2009–2012, 2015, 2017 and 2018, but also of the catch at age for 2007, 2009–2012 and 2017) and assumptions had to be made to fill them in the SAM model. Moreover, uncertainty is high in the a4a model as shown by confidence intervals in the plot. The retrospective of the a4a model is unstable due to data gaps concerning the surveys. It is important to stress the need that surveys and landings sampling take place on an annual basis in order that the assessment model captures adequately the temporal dynamics of the species.

Diagnosis of stock status: The lack of continuous surveys in the recent period largely influences the assessment and causes uncertainties in the estimated parameters. The lack of catch-at-age data in a given period of years in the a4a model amplifies the effect of the lack of surveys. The stock is considered overexploited.

Advice and recommendations: The assessment was considered qualitative. The stock is in overexploitation and the advice is to reduce fishing mortality. The WG recommended exploring the potential to apply data-limited models in the stock assessment.

The following assessments were held during the parallel benchmark session and a separate detailed benchmark report will be written for this purpose.

GSA 6 – Northern Spain

Anchovy (*Engraulis encrasicolus*) in GSA 6

Authors: Giráldez A., Torres, P. Ramírez, J.G., Garriga, , M., Iglesias, M., González, M. & Ventero, A.

Fishery: The current fleet in GSA 6 (northern Spain) is composed of 100 units (average gross tonnage 40.4), 1 percent of them are smaller than 12 m (operational unit 1), 81 percent are between 12–24 m (operational unit 2) and 18 percent are over 24 m (operational unit 3). The purse seine fleet has been continuously decreasing in the last two decades, from 222 vessels in 1990 to 100 in 2019. The smallest units have been lost.

Anchovy is the main target species of the purse seine fleet in northern Spain due to its high economic value. Catches in the period 1990–2019 have been highly variable, with a minimum of 2 800 tonnes in 2007 and an average of 11 000 tonnes. Higher catches occurred in the period 1990–1994, 17 000 to 22 000 tonnes were caught. Thereafter it has been continuously decreasing with three recoveries in 2002, 2009 and it has been increasing since 2012. In 2019 the catches were 13 900 tonnes, 35 percent less than the previous year. Years with higher landings are usually correlated with a successful and high recruitment period, while unsuccessful recruitment in a given year is correlated with a low level of landings.

The catches evolution is consistent with the result of acoustic assessment.

Data used in the assessment correspond to DCF.

Data and parameters: Official landings time series 1945–2019, length distribution data from commercial catches 2004–2019, landing weights by age, growth parameters from age reading, and body condition.

Assessment method: a4a (accepted), SPiCT

Model performance:

Ages 0–2+

fmod1 = ~s(age, k = 3)+s(year,k = 9, by = as.numeric(age= 1))

qmod1 = list(~s(age,k = 3))

srmod1 = ~s(year,k = 7)

index.var(index2[[1]]) = 0.5

Ages 0–3+

fmod1 = ~s(age,k = 3)+s(year,k = 4)

qmod1 = list(~s(age,k = 3))

srmod1 = ~s(year,k = 3)

Results: SPiCT and a4a models were explored during the benchmark session but instability in the models prevented the assessment from being benchmarked. A full report on the assessments trialed will be available and the benchmark suggested to keep on working in the next year towards exploring new modeling approaches. Various sources of information provide contrasting messages (the two a4a models providing a consistent perception of overexploitation, the shrinking of age ranges in catches, the decrease in body condition and a general increase in acoustic estimates) which prompted the WG to agree on validating the assessment as qualitative with a stock in overexploitation and the advice to reduce fishing mortality.

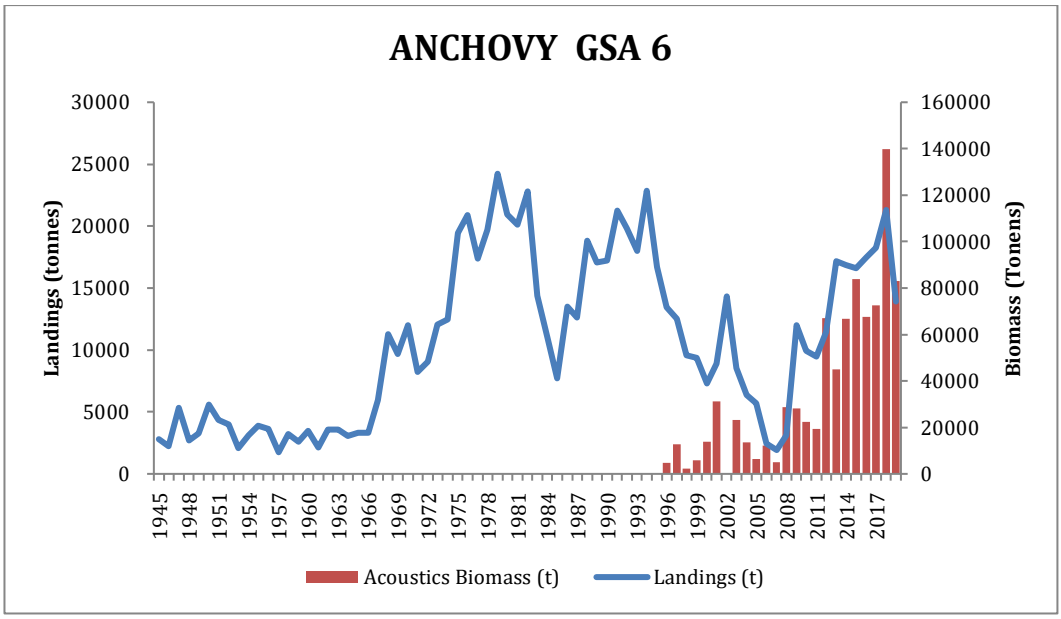

Figure 15.1. Trends in anchovy landings and biomass assessed by acoustic surveys (2001–2019)

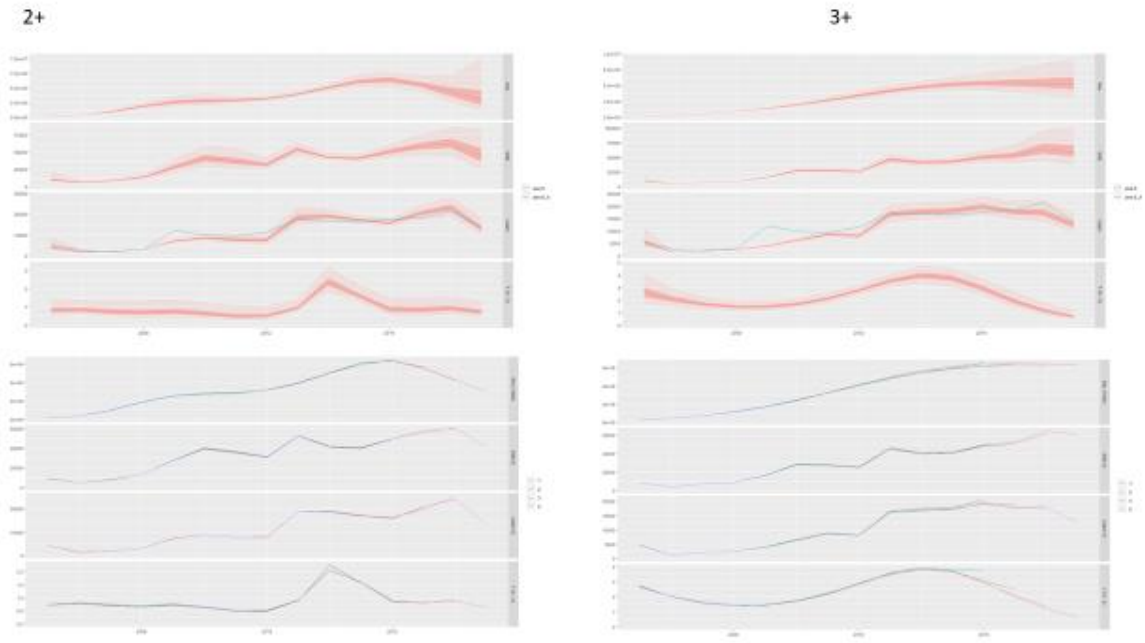

Figure 15.2. Model results and retrospective analysis output for three years back for the a4a assessment model regarding the anchovy stock in GSA 6 using age 2 and greater and age 3 and greater

Data issues: No data issues were reported.

Diagnosis of stock status: Assessed as qualitative with a stock in overexploitation and the advice to reduce fishing mortality.

Table 15.1. Comparative table with last year assessment

	Age 2 +	Age 3 +
$F_{current}$ ($F_{bar\ 0–2}$ in 2019)	0.64	0.65
F_{msy} (2019)	0.54	0.51
$E_{current}$	0.44	0.46
$E_{current}$/E0.4	1.10	1.15
$B_{current}$ (SSB)	41 306	60 472
Bloss	4 704	4 083
33rd percentile SSB (tonnes)		
66th percentile SSB (tonnes)		

Advice and recommendations: Reduce fishing mortality. The stock assessment was quite sensitive to both knots value for submodels and different models. Therefore, the absolute values are not fully reliable. However, given that both final model parametrizations provide comparable message of overfishing for most recent period, the advice is provided in qualitative terms.

GSA 6 – Northern Spain

Sardine (*Sardina plichardus*) in GSA 6

Authors: Torres, P., Giráldez, A., Ramírez, J.G., Garriga, M., Iglesias, M., González M. & Ventero, A.

Fishery: The current fleet in GSA 6 (northern Spain) is composed by 100 units (average gross tonnage 40.4), 1 percent of them are smaller than 12 m (operational unit 1), 81 percent are between 12–24 m (operational unit 2) and 18 percent are over 24m (operational unit 3). The purse seine fleet has been continuously decreasing in the last two decades, from 222 vessels in 1990 to 100 in 2019. The smallest units have been lost.

Sardine, although with a lower price than anchovy, was an important support to the fishery until 2009 as it was the most fished species. Although in the last few years their prices become rather close. In the period 1990–2019 sardine landings show a negative trend, between 53 000 tonnes in 1994 to 6 300 tonnes in 2015, the lowest value in the whole series. The whole period average is 24 543 tonnes. In 2019, landings are very low (6 711 tonnes). The landing evolution is consistent with result of acoustic assessments.

Data and parameters: Official landings time series 1945–2019, length distribution data from commercial catches 2004–2019, landing weights by age, growth parameters from age reading, and body condition.

Assessment method: a4a

Model performance:

fmod1 = ~s(replace(age, age>2,2), k = 3)+s(year,k = 9)

qmod1 <- list(~s(age,k = 4), ~1, ~1)

srmod1 = ~s(year,k = 5)

Results: Assessments were attempted using a4a and SPiCT. The SPiCT model was able to meet most diagnostic criteria but three different priors were required to achieve convergence. The fact that good a4a models were available prompted the benchmark to focus on them. Following significant efforts in model selection, an a4a model using yearly ALKs, age 4 plus group, no breakpoint in the F model and a scalar natural mortality based on an average of several M estimators (M = 0.7, derived according to the details given by the barefootecologist.com and described in the report) was benchmarked and used to provide quantitative advice. The main issue identified by the benchmark was the need to improve the growth curve also taking into account larval growth.

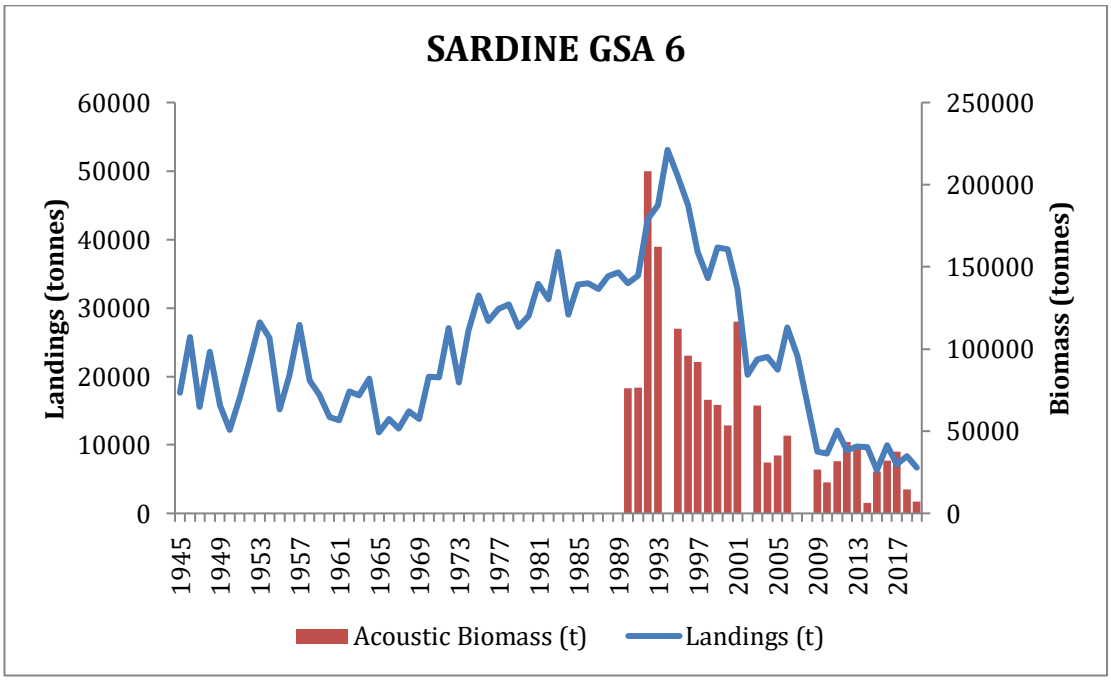

Figure 16.1. Trends in sardine landings and acoustic biomass in GSA 6 (1945–2019)

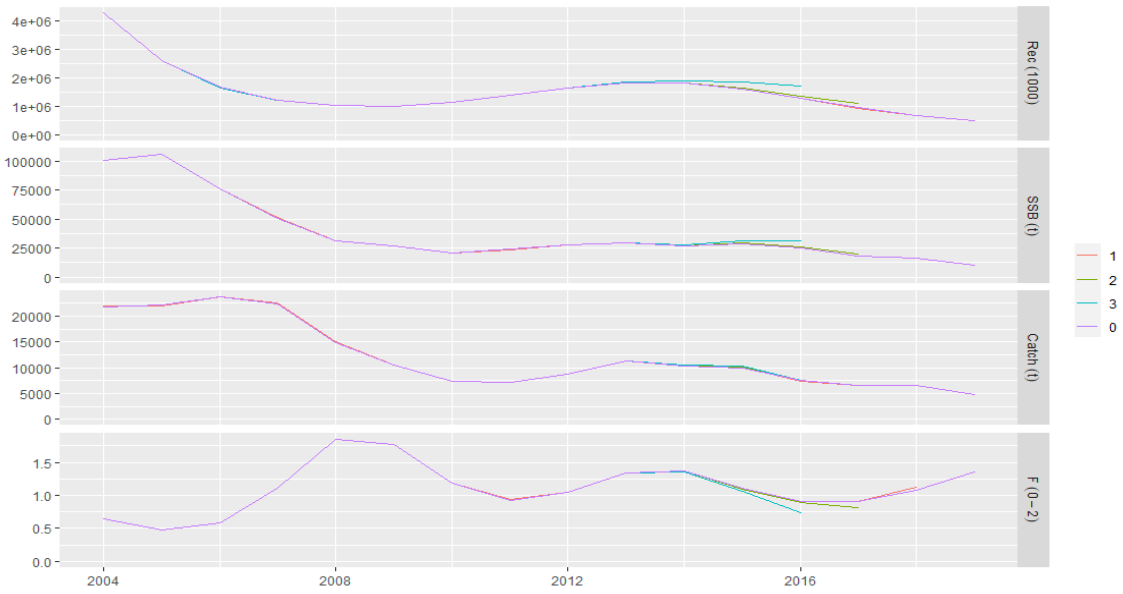

Figure 16.2 Retrospective analysis output for three years back for the a4a assessment model regarding the sardine stock in GSA 6 using age 4 as a plus group

Data issues: The issue identified was the need to improve the growth curve also taking into account larval growth.

Diagnosis of stock status: The assessment was considered benchmarked, validated and quantitative, in overexploitation and the advice was to reduce fishing mortality.

Table 16.1. Comparative table with last year assessment

$F_{current}$ ($F_{bar\ 0–3}$ in 2019)	1.19
F_{msy} (2019)	0.47
$E_{current}$	0.63
$E_{current}$/E0.4	1.56
$B_{current}$ (SSB)	9 644.1
Bloss	9 644.1
33rd percentile SSB (tonnes)	
66th percentile SSB (tonnes)	

Advice and recommendations: Reduce fishing mortality.

GSA 7 – Gulf of Lion

Anchovy (*Engraulis encrasicolus*) in GSA 7

Authors: Hattab, T. & Bourdeix, J.H.

Fisheries: The number of trawlers targeting small pelagic fish strongly decreased in recent years. As a consequence, the total catch has been low for the last ten years fluctuating around 1 600 tonnes. Since 2015, it even decreased further (around 1 000 tonnes, i.e. the lowest values since the 1980s). Most regulations (no fishing activity during the week-end, length of trawlers, etc.) are fully respected, the limitation of engine power for trawlers being the only one not.

Biological parameters: Morphometric parameters were obtained directly onboard during the 2019 scientific survey to achieve age determination and reproductive parameter analysis. Length-weight relationships were thus obtained. Further samples from the fisheries are collected all year round to assess the health of the stock. The size distribution in the survey was unimodal and very similar to that of the last six years. Finally, the condition index decreased in 2019 after the increase that was observed in 2018 (the highest observed in the past 25 years).

Assessment method: Indirect using a4a model plus the use of acoustic survey as a direct estimate of biomass. A statistical catch-at-age model (a4a) was fitted for this stock using the FLa4a R package. Numbers-at-age were available only in the period 2002–2019 for both landings and acoustic surveys. The DCF reported landings were used for the assessment including catch (in tonnes), catch-at-age (in thousands) and weight-at-age in the catch. Numbers-at-age (thousands) based on acoustics were used for tuning. Annual ALKs were used for age slicing in both acoustic biomass estimates and landings. To take into account the observed changes in growth patterns, two natural mortality vectors were used for the two time periods identified by the break point analysis (2002–2008 and 2009–2019). The analysis was carried out for the ages 0 to 3.

Model performance: Sensitivity analysis was carried out on s-r, q and f sub-models. According to residuals summary statistics, and the results of retrospective analysis (applied up to three years back), the selected model was the one considering the following sub-models:

fmod = ~s(age, k = 3) + s(year, k = 6)

qmod = ~s(age, k = 3) + s(year, k = 6)

Srmod = ~bevholt(CV = 0.1)

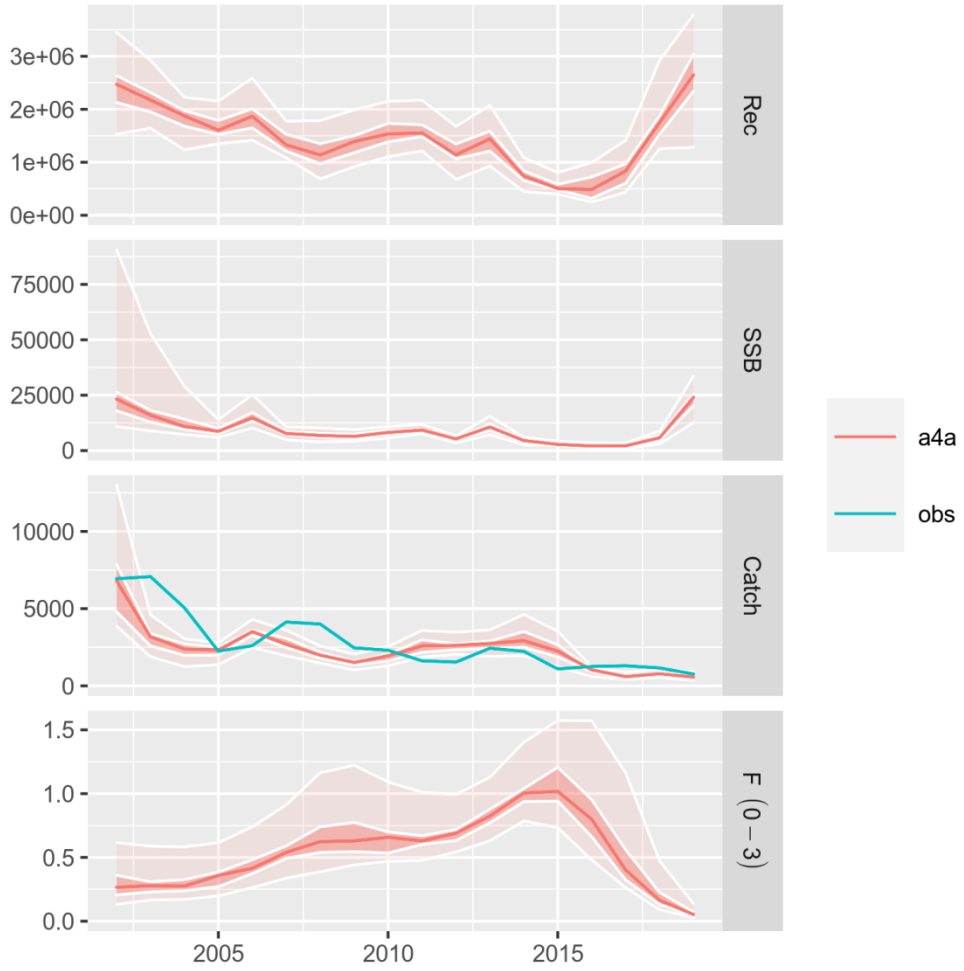

Figure 17.1. a4a model output for anchovy in GSA 7

The retrospective analysis of the selected model evidenced quite high model stability, the Mohn's rho of F, SSB and recruitment are respectively 0.26, 0.34 and 0.21.

Results: As in 2018, landings in 2019 were extremely low (768 tonnes). The fishing effort is both lower and more opportunistic than before. The total number of boats landing anchovies is not negligible. However, all but one of them target small pelagic fish only at given restricted periods depending on the market.

F_{curr} is lower than Fmsy and exploitation ratio Ecurrent/E0.4 is below 1, which indicates that the stock is sustainably exploited. The results of the a4a model were used to define a reference point for F only and not for SSB. This choice is justified by the shortness of the time series used in the a4a model which started in 2002. Direct estimates of total biomass are available from 1993 onwards and show that highest and lowest levels of biomass were observed before 2002. In this case, the use of direct estimates of biomass by acoustic will allow for more precautionary estimates of biomass-related reference points.

Table 17.1. Compariative table with last year assessment

a4a model	F_{cur} ($F_{bar\ 0–3}$ in 2019)	0.22
a4a model	$F_{cur}/F_{0.4}$	0.48
a4a model	$E_{cur}/0.4$	0.61
Direct estimate	B_{2019}	36 470 tonnes
Direct estimate	B_{lim}	22 889 tonnes
Direct estimate	B_{pa}	45 778 tonnes
Direct estimate	B_{ratio}	0.79

Biomass slightly increased in 2019 in comparison to 2018, but it is still below the B_{pa} (B_{2019}/B_{pa} = 0.79). Further, biological parameters showed no improvement of the stock in terms of ecological state.

Diagnosis of Stock status: The assessment was considered **benchmarked**, **validated** and **quantitative. The** stock is judged **sustainably exploited** given the exploitation rate and in low biomass, given that the estimated biomass is below Bpa. The exploitation level is low and the current situation of the stock is supposed to be driven mainly by exogenous environmental factors. As the low fishing effort is mostly linked to the low commercial value of small and lean fish, management measures need to ensure that if size and condition increase again the fishing activity would not increase too much to allow the stock for a recovery.

Advice and recommendation: The WG precautionarily recommends not to increase fishing mortality.

GSA 7 – Gulf of Lion

Sardine (*Sardina pilchardus*) in GSA 7

Authors: Hattab, T. & Bourdeix, J.H.

Fisheries: The fishing pressure is still very low due to the absence of market for small and lean sardines. Since 2010, landings (370 tonnes in 2019) have been stable but at their lowest since 1865, while they used to be between 10 and 14 000 tonnes between 1993 and 2008. Also, while pelagic trawlers represented the main float targeting sardines (over three-quarters until 2010), it is now purse seines that land the most sardines (around three-quarters in 2011–2019). However, the activity of purse-seiners is very opportunistic and none of these boats are focusing on sardines all throughout the year. Sardine landings of purse seines are very seasonal, one season offshore Marseille from January to April and one season off Port-Vendres in July–September.

Assessment method: two-stage biomass model.

As last year, a two-stage biomass model was performed. This requires a series of catch as well as two independent tuning series (an index of recruitment and an index of adult biomass). Both tuning indices were obtained from the PELMED acoustic survey (see below). In order to separate between juvenile and adult sardines, we used a cutting length that came from previous analyses on age slicing. However, as growth has changed quite substantially during the 20-year period of the survey, this length was not constant. The cutting length was taken as 12.5cm until 2008 and 11cm afterwards. As the series need to be concomitant and without missing data, the model was run from 1995 to 2019.

Model performance: Sensitivity analyses were conducted on model parameters, and the results were shown mostly insensitive to the initial estimates of recruits and adults. 0.4 was chosen for the growth parameter according to a trade-off between minimizing the sum of squared residuals and the fitting to the adult biomass. Indeed, preference was given to adult fitting rather than recruitment, which is highly variable**.**

Results: The exploitation rate assessed by the two-stage biomass model confirmed the extremely low fishing mortality in 2019 (harvest rate = 0.01).The joint probability of SSB being higher than SSB_{pa} and HR lower than HR_{pa} is 0.8. The SSB/SSB_{pa} and HR/HR_{pa} are respectively 1.55 (stdev = 0.02) and 0.08 (stdev = 0.005).

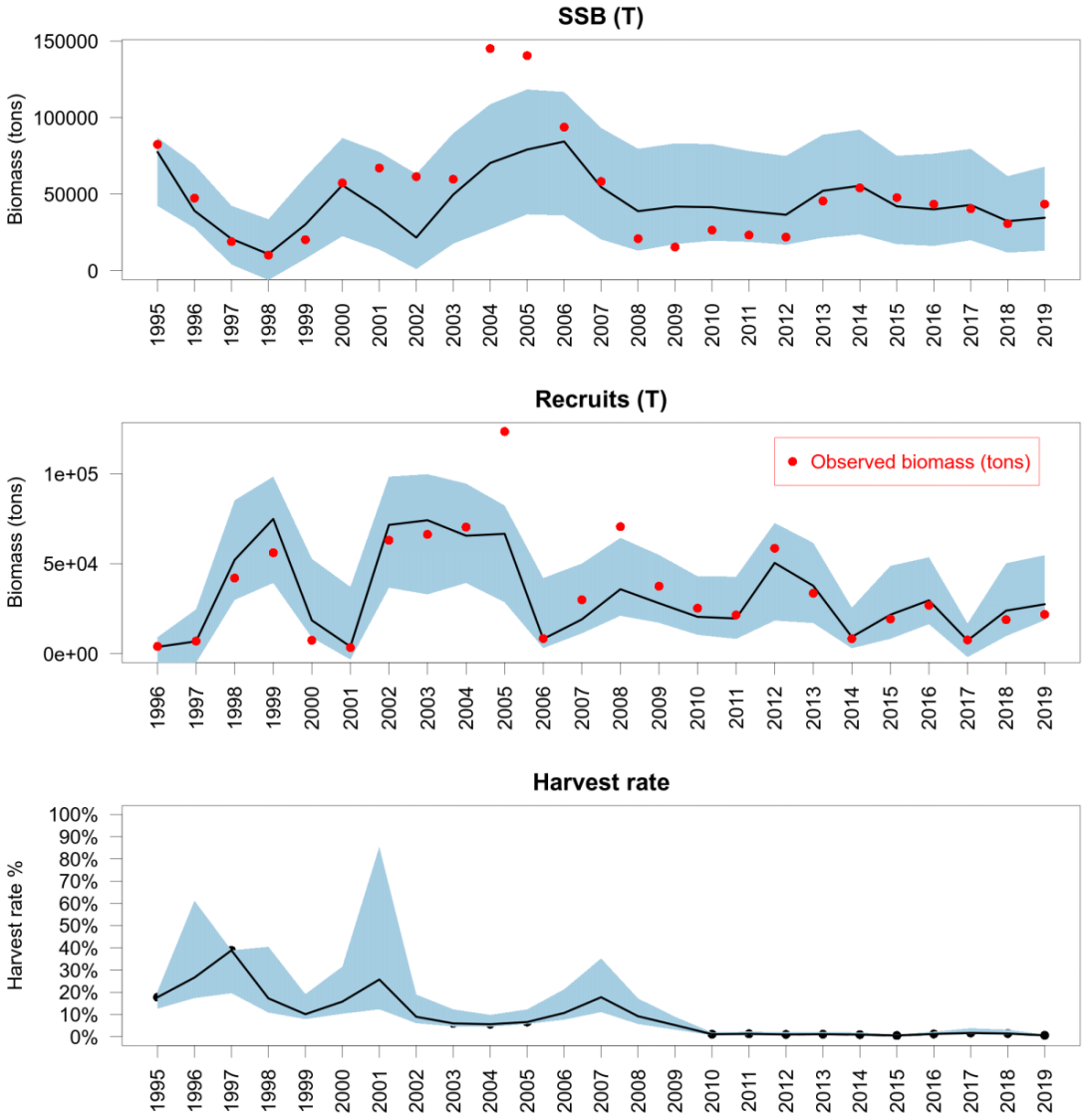

Figure 18.1. Two-stage biomass model output for sardine in GSA 7

Furthermore, 2019 biomass and abundance estimates showed a slight increase due mainly to a good recruitment in 2018. Still, the age and size composition of the stock confirmed the domination of small and young fish as in previous years (mainly age 1).

In summary, the stock is in a similar state to that of last years and this does not result from overexploitation.

Table 18.1. Comparative table with last year assessment

HR/HR_{pa}	0.08 (stdev = 0.005)
SBB/SBB_{pa}	1.55 (stdev = 0.02)
SSB 2019	47 659
$P[SSB>SSB_{pa}$ and $HR<HR_{pa}]$	0.8

Diagnosis of stock status: The assessment was considered benchmarked, validated and quantitative. The stock is judged ecologically unbalanced due to its lack of old individuals and problems of growth. The exploitation level was extremely low in 2019 (HR = 0.08), and the biomass in 2019 is still low despite a slight increase. As the low fishing effort is mostly linked to the low commercial value of small and lean fish, management measures need to ensure that if size and condition increase again the fishing activity would not increase too much to allow the stock for a recovery.

Advice and recommendation: The WG recommends not to increase fishing mortality.

The following assessments were considered preliminary and only a short summary is provided.

GSA 27 – Palestinian waters

Atlantic chub mackerel (*Scomber colias*) in GSA 27

Authors: Fahim, R.M.[1], Mahmoud, H.H.[1], Madi, A.[3], Aboutair, M., Lelli, S.[3] & Vasconcellos, M.[3]

[1] College of Fisheries Technology and Aquaculture, Arab Academy for Science, Technology and Maritime transport, Alexandria, Egypt.

[2] Ministry of Agriculture, Palestine.

[3] FAO-EastMed Project. Rome, Italy.

Fishery: Atlantic mackerel is a species belonging to the Scombridae family. It is a species of mackerel found in the temperate waters of the Mediterranean Sea, the Black Sea, and the northern Atlantic Ocean, where it is extremely common and occurs in huge shoals in the pelagic zone down to about 200 m (660 ft). It spends the warmer months close to shore and near the ocean surface, appearing along the coast in spring and departing with the arrival of colder weather in the fall and winter months. During the fall and winter, it migrates out into deeper and more southern water, seeking warmer temperatures.

Data and parameters: Data have been collected within a fisheries data collection system supported by the FAO EastMed project, along the coast of the Gaza Strip in four landing sites (Gaza City, Dar al Balah, Khan Yunes and Rafah). The first pilot study was completed at the end of 2013, with a second, third and fourth routine sampling which covered the years 2014–2015 and 2016. The monthly LFDs

were raised to the monthly landings and analyzed by the Electronic LEngth Frequency ANalysis for estimating growth parameter (ELEFAN) program incorporated in length frequency distribution analysis (LFDA) software for the estimation of growth parameters for the sexes combined. The length-weight relationship, the length at first maturity (L_{m50}) and the sex ratio were also studied. ProdBiom method was applied to estimate natural mortality.

Assessment method: VIT software was used for pseudo cohort analysis (Lleonart and Salat, 1992). Y/R analysis which implemented in VIT was applied for the calculation of the reference point F0.1 R analyses for the assessment LBPARS, LIME and plot.

Results: Sex ratio (percent females / total) was 20 percent during study period. The stock was assessed for the three years together. The Y/R analysis indicated a current level of fishing mortality 0.451. The target reference points $F_{0.1}$ was 0.29766.

Diagnosis of stock status: The assessment was considered preliminary. The stock seems to be in moderate exploitation in Palestine in GSA 27.

Advice and recommendations: It is recommended to maintain the fishing mortality in line with the agreed reference point.

GSAs 5-12-13-14-15-16 (Italy, Malta, Spain and Tunisia)

Common dolphinfish (*Coryphaena hippurus*) in GSAs 5, 12, 13, 14, 15 and 16

Authors: Roa-Ureta, R.[1], Moltó, V.[2], Ospina-Alvarez, A.[3], Besbés-Benseddik, A.[4], Besbés, R.[4], Mariani, A.[5], Gambin, M.[6], Grau, A.M.[7], García, S.[2], Macías, D.[2], Catalán, I.A.[3], Vaconcellos, M.[8], Hernández, P.[8] & Ceriola, L.[9]

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[5]Unimar, Roma, Italy

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Fishery: Common dolphinfish is a pelagic species with worldwide distribution, characterized by migratory behavior and fast-growing rates. Recent genetic studies have revealed: i) differentiation between Mediterranean and Atlantic dolphinfish populations; and ii) no significant genetic differentiation within the Mediterranean basin. This suggests a unique stock in the entire Mediterranean basin. Spain, Malta, Italy and Tunisia target this species seasonally (August–December) through a small-scale fishery based on fishing aggregation devices (FADs). Dolphinfish is also captured as bycatch of the longliners targeting large pelagic species. The small-scale boats exploit the juvenile phases, recruits less than one year of

age, of this rapidly growing fish, while longline fisheries capture juveniles and adults year-round although their capture is just 10 percent of the total in the latest decade. The stock has not been assessed until now due to scarcity of data, including no time series of the age composition or scientific surveys and deficient records of fishing effort. Previous trials for assessment were attempted in 1999 and 2001 by VPA, and more recently in 2016 by a depletion model based on catch per unit effort (CPUE). However, effort data were available only in two countries and the index was not considered reliable. With the support of the CopeMed and MedSudMed projects on convening expert-meetings of the so called CORY-working group since 2011 onwards, including data preparation meetings in 2016, 2019 and 2020, data finally acquired from Spain, Italy, Malta and Tunisia allowed for the application of another depletion model that uses catches and effort in an independent way and accepts more than one fleet.

Data and parameters: Four fleets were considered for the FAD fishery. Monthly catches from the four countries, covering the 2008–2019 period and fishing effort in number of fishing days per month from Malta, Spain and Italy were provided. In the case of Tunisia, effort data were not available, and it was estimated using the Italian fleet as the fleet with the most similar characteristics through predicting mean matching techniques (using the Mice R package). The longline fleet was considered unique for the three countries for which monthly catches and number of hooks were available: Italy, Malta and Spain. The average individual weight month^{-1} was extracted from the length weight relationship: $W = 0.0097 L^{2.9837}$. Individual length data were available from Malta regularly, while from the other countries only punctual years were available from previous CopeMed studies. For the missing years, an average length per month from country-based data was estimated. Seventy-seven parameters were estimated simultaneously in the model, including the natural mortality rate, initial abundance, 12 annual recruitment pulses per fleet, and three fishing operational parameters per fleet.

Assessment method: Multifleet multiannual generalized depletion model (MMAGD). This is a data-poor stock assessment method based on generalized depletion models (Roa-Ureta *et al*., 2012)[2]. In this case, it was adapted to the special conditions of this fishery with five fleets (four FADs small-scale and one common longline fleet). It was implemented in a customized version of the R package CatDyn written in a separate R script, named "CatDynCoryMed", made available to the CORY-WG.

Results: The instantaneous exploitation rate estimated according to Patterson formula: F/Z, shows that the fishery stays close to sustainable exploitation, and reaches 40 percent only shortly during any given season, usually just in one month, while in the remaining months of the season, the exploitation rate is much lower. Recruitment showed a decreasing trend from 2008 to 2012 and then it stabilized around ten million recruits per year up to the last season (2019). It has to be noted that the stock experiences high natural mortality rates (0.25 per month or three per year), which leads to large variations in biomass within the span of a season.

Diagnosis of stock status: The assessment was presented to the 2021 WGSASP meeting, stock status at the moment lookS sustainable based on the Patterson empirical reference point but the assessment was considered preliminary so no advice was provided.

Advice and recommendations: The assessment was considered preliminary so no advice was provided. The WG noted the need to improve the information available in certain datasets, the need to peer review the modeling approach followed and the need to evaluate a suitable reference point that captures the variability of stock status.

[2] **Roa-Ureta, R.H.** 2012.Modeling in-season pulses of recruitment and hyperstability-hyperdepletion in the *loligo gahi* fishery of the Falkland islands with generalized depletion models. *ICES Journal of Marine Science*, 69: 1403–1415.

CONCLUSIONS AND RECOMMENDATIONS

Joint WGSAs session

13. The WGSAs agreed on using the new STAR Excel templates proposed by the GFCM Secretariat to contain detailed summaries of validated stock assessments including metadata, results and information required to produce the table of advice. The data submitted with STAR templates will be imported in a database and will comprise the basis for future quality-controlled products. The STAR templates have been devised in such a manner as to allow for the streamlined automation of tasks (including the automated production of the table of advice and data analysis), reduce the risk of errors and promote transparency.

WGSASP

The WGSASP, in response to its 2019 terms of reference and based on scientific evidence and discussions undertaken, reached the following conclusions and recommendations:

14. The WG included a benchmark session on anchovy and sardine in GSAs 6 and 7 which will be covered by a separate report. The WG was a mixture of parallel hands-on sessions and plenary discussions.

15. Including GSAs 6 and 7 anchovy and sardine benchmark session, a total of 20 stocks was analysed. Validated advice was provided for 17 of these stocks, eight of which with quantitative advice and the remaining nine with qualitative precautionary advice; two assessments were considered preliminary (Atlantic mackerel in GSA 27 and common dolphinfish in western and central Mediterranean) and the benchmark of anchovy in GSA 7 is pending completion. A detailed table of advice on the status of the stocks analysed, including WGSASP comments, is included in Appendix 1.

16. The WG was informed of the outcomes of the benchmark session on anchovy and sardine in the Adriatic Sea which finished in November 2020. The WG acknowledged and supported the work done, in particular:

- Anchovy in GSAs 17–18 was benchmarked using a SAM model. New ages as estimated from revised otolith readings and agreed ALKs were used in the assessment, and a careful revision of input data, paying particular attention to the aggregation and time series of survey indexes was carried out. Reference points were updated following the previous conceptual framework proposed by the WGSASP (i.e. empirical analysis of time series as a basis for B_{lim} and B_{PA} estimated on probabilistic terms; F_{MSY} as fishing mortality at exploitation rate = 0.4). Short-term forecasts were carried out for a number of F multipliers, including for F_{MSY}. The stock was found to be overexploited and in overexploitation.

- Sardine in GSAs 17–18 was not benchmarked but advice was provided based on an a4a model. The main issues encountered were that the two modelling approaches trialled – a4a and SAM – provided similar perspectives, but SAM did not converge. Uncertainties and low contrast in the catch-at-age matrix, which were believed to affect statistical catch-at-age model fitting, prevented the group from accepting this advice as a benchmark. Reference points were estimated following the same approach as for anchovy, but no short-term forecasts were performed due to the uncertainties mentioned above. The stock was found to be overexploited and in overexploitation.

The WG acknowledged the important input of Leire Ibaibarriaga and Andres Uriarte (AZTI) as well as Niels Hintzen and Thomas Brunel (Wageningen Marine Research [WMR]) towards the finalization of the work.

17. The WG underlined common issues regarding the shrinkage of age structure in various stocks (e.g. GSA 7, GSA 9, GSA 16 and GSA 22) towards ages 0–2, mostly detected in survey data. This resulted in problematic fitting of statistical catch-at-age models; the WGSASP suggested alternative modelling/methodological solutions be sought in these cases.

18. The WG noted the fact that in some cases growth of sardine was reported to have increased significantly over the years (e.g. GSA 16) while in others it had slowed down significantly (e.g. GSA 7) so that the same size was found to be zero years or four years, respectively. This stimulated a discussion on growth and age-reading of sardine across the Mediterranean Sea and prompted the WG to suggest an intercalibration exercise be carried out at a regional level.

19. In the context of SPiCT, the WG underlined the importance of thoroughly understanding the implications and biological meaning of any priors used and suggested thorough investigation of their impacts on the model outcomes through sensitivity testing. The WG further noted that the selection of priors should be well justified, including through the presentation of comparative tables and the application of the checklist for the acceptance of SPiCT assessments (Mildenberger, Kokkalis and Berg, 2019). In addition, the WG suggested to perform a review and compilation of priors commonly used for each species across the Mediterranean.

20. The WG noticed that on several occasions (e.g. GSAs 9 and 16) attempts had been made to include quarterly data in the assessments but this had resulted in more uncertain results owing to the high variability associated with certain quarters. The WG recommended care be taken to appropriately and consistently sample catches over the whole period of the year covered by the fishery and/or take due consideration of seasonal fisheries.

21. A4a models were used to assess many stocks. The WG noted the need for closer inspection of underlying models through GAM plots and summary outputs; a4a developers should be contacted in this regard. This would allow users to evaluate and optimize model fit.

22. The WG acknowledged with great pleasure the preliminary length-based assessments presented for Atlantic mackerel in GSA 27 (Palestine), with particular reference to the meticulous work done to collect and collate available data as well as the efforts made to take into account any biases stemming from data collection. Owing to the fact that Atlantic mackerel is a migratory species and Palestinian fishing grounds cover a small area, and supported by the evidence provided by FAO official catch data that Scomber species are landed, at times in significant quantities, across the eastern Mediterranean (Cyprus, Egypt, Lebanon, Syria and Turkey), the WG suggested this assessment should be tackled over a wider area, preferably at the level of the entire eastern Mediterranean subregion.

23. The WG was impressed by the preliminary assessment presented for common dolphinfish in the western and central Mediterranean and commended the efforts made towards data collection, collation, analysis and modelling for this species using a multiannual general depletion model. In view of GFCM Recommendation GFCM/43/2019/1 on a set of management measures for the use of anchored fish aggregating devices in common dolphinfish fisheries in the Mediterranean Sea and the possibility of a future benchmark assessment, the WG discussed the data requirements necessary for an improvement of the current approach as emerging from the presentation (e.g. biological data from Italy, effort data from Tunisia) and acknowledged that the establishment of a research programme, as suggested in the recommendation, would help in this respect. Furthermore, the WG supported the need for a peer review of the methodology used, as it is new to the GFCM, and underlined the importance of selecting a reference point that best captured the variability in this peculiar stock.

24. The WG suggested that in data-poor/limited/uncertain situations more than one methodology be run and evaluated in terms of consistent output.

25. The WG considered the evaluation and improvement of the growth parameters and life-history characteristics necessary for all stocks and in particular towards the application of certain data-poor methods. This is a field that should be further explored in order to make data-poor and data-rich stock assessments more comparable.

26. The WG recommended to continue the effort of increasing the number of stocks assessed (particularly in the eastern and southern Mediterranean) and encouraged the presentation of existing information on the status of small pelagic stocks collected in different GSAs throughout the Mediterranean during the intersession.

27. The WG stressed the need for surveys used as tuning indices in assessment models to be adjusted in order to adequately capture the spatial and temporal dynamics of small pelagic populations. Moreover, the WG stressed the need to avoid gaps in the time series of surveys as in certain areas, such as GSA 22, the gaps in surveys result into high uncertainties in assessment models.

28. The WG noted the fact that, for most assessments, time series were still not long enough to calculate biomass reference points based on Bloss.

29. The WG underlined the importance of maintaining the same assumptions than the previous year when performing update assessments to make years comparable. With the exception of benchmarked assessments, should the assumptions need to be changed, justification should be provided; in the case of a benchmarked assessment desirable changes in assumptions should be included in a list of issues to be tackled in the next benchmark session.

30. The WG agreed on the need to perform a benchmark assessment for sardine and anchovy in GSA 16 in the 2021–2022 intersession.

Sardine and anchovy benchmark in GSAs 6 and 7

31. A benchmark session was carried out for sardine and anchovy in GSAs 6 and 7. To this end data were provided by all countries up to 2019. A detailed account of the benchmark is provided in a separate report.

32. The benchmark acknowledged the useful input of the external reviewer, Alexandra Silva.

33. A data preparation meeting was held in advance of the benchmark session and this proved crucial in analysing the information at hand towards exploring some of the main assumptions of the assessments, including:

- whether to perform assessment on separate or joint GSAs;
- how to account for differences in the growth pattern over the time series, such as by splitting the time series in two and introducing a breakpoint; and
- how to estimate natural mortality.

The benchmark commended the important work done by all experts towards this assessment.

34. The benchmark agreed on the fact that, owing to the combined effect of differences in growth, exploitation and oceanographic drivers, the two GSAs should be assessed separately for both species; it also agreed on trialling different assumptions on growth by foreseeing a breakpoint in the time series.

35. Assessments were carried out using various methodologies according to the availability of data as summarised in Appendix 1/B. One benchmark, the one for anchovy in GSA 7, is still pending finalization. A summary of results is provided below:

- Anchovy in GSA 6: assessments were attempted using a4a and SPiCT. The SPiCT model was able to meet most diagnostic criteria but three different priors were required to achieve convergence. A number of a4a models were explored but proved to be very unstable depending on the submodels chosen; the benchmark agreed on the fact that the assessment would require more work in order to be benchmarked. The reasons for this were that the data proved difficult to fit with catch-at-age models. The suggestion is to go back to the data and explore them further towards applying additional methods (e.g. including length-based ones). Nevertheless, the group agreed on providing qualitative advice (stock in overexploitation). The benchmark underlined the importance of having otolith readings from survey data in GSA 6 for a future benchmark.
- Sardine in GSA 6: assessments were attempted using a4a and SPiCT. The SPiCT model was able to meet most diagnostic criteria but three different priors were required to achieve convergence. The fact that good a4a models were available prompted the benchmark to focus on them. Following significant efforts in model selection, an a4a model using yearly ALKs, 4+ plus group, no breakpoint in the F model and a scalar natural mortality based on an average of several M estimators (M = 0.7, derived according to the details given by the barefootecologist.com and described in the report) was benchmarked and used to provide quantitative advice. The main issue identified by the benchmark was the need to improve the growth curve also taking into account larval growth.
- Anchovy in GSA 7: assessment trials are being carried out with SPiCT and a4a. More time is required to finalise the work which is foreseen to be completed on the week of 8–12 February 2021.
- Sardine in GSA 7: assessment was done based on a two-stage biomass model. The assessment was considered benchmarked. The situation is very similar to previous years: individual size is still small and the age composition unbalanced. A two-stage biomass model plus the use of the 2019 acoustic biomass as a direct estimate to get as updated information on the stock as possible, confirmed the very low fishing mortality. Based on this and the estimated reference point, the sardine stock is sustainable although fish are still very small and deemed ecologically unbalanced.

36. The benchmark recommended the formulation of summary tables to help the final selection of the most appropriate model to provide advice on stock status. Information that could be contained in such summary tables include stability, retrospective (Mohn's rho), model fit (residuals, etc.), number of observations, number of parameters estimated, likelihood, Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC).

37. The external reviewer, Alexandra Silva, suggested that parallels be made with the ICES stock annex to expand and improve the information contained in the stock assessment forms in the case of benchmarked assessments. This expanded document would then be regarded as a reference document for future replication of the assessments involved.

WORK PLAN

38. The WG agreed on the following preliminary work plan:

General

- Perform a benchmark assessment for sardine and anchovy in GSA 16 in the 2021–2022 intersession.
- Keep working on the possibility to benchmark sardine stock in the Adriatic Sea.
- Work towards improving growth parameters and life-history characteristics for all stocks.
- Work towards identifying/exploring the effect of priors in stock assessment models.
- Work towards the intercalibration of age reading among the Mediterranean sardine stocks.
- Compile tables of priors by species.

GSA 1 anchovy

- There could be a benefit in improving the growth curve considering that if more ages emerged then a statistical catch-at-age model could be used.
- Efforts should be made to explore length-based models that do not assume equilibrium conditions in the future as a two-stage biomass model was not deemed the best option as the survey is catching the recruitment of sardine not anchovy.

GSA 1 sardine

The stock was benchmarked in 2019 but it is advisable for a future benchmark to:

- explore the results by applying different Fbar ranges, notably 0–3; and
- provide different weights at age by year in the future.

GSA 3 sardine

The stock was benchmarked in 2019 but it is advisable for a future benchmark to:

- improve life-history parameters;
- improve LFDs through the investigation of possible biases; and
- further explore the high abundance estimated by the survey through the time series, which is in contrast with the low survey abundance observed in GSA 1, towards facilitating the performance of joint GSAs 1 and 3 assessments.

GSA 4 sardine

- Work towards improving life history parameters.
- Perform a thorough analysis of the data collection protocol and improve LFDs through the investigation of possible biases.
- Continue applying data-limited models.
- Explore the use of acoustic surveys as an age structure index.

GSA 9 sardine and anchovy

- Apply an age-structured model.
- The inclusion of GSA 10 in future assessments is encouraged.

GSA 16 anchovy

- Analyse data collection efforts to investigate uncertainty in quarterly data.
- Re-evaluate the time series of the catches determining the proportion of catch coming from outside GSA 16 in the current time-series by using a proportion of effort in GSA 13.
- Efforts should be made to improve the fit of age-structured models.

GSA 16 sardine

- Analyse data collection efforts to investigate uncertainty in quarterly data.
- Efforts should be made to improve the fit of age-structured models.

GSA 20 snchovy and sardine

- Carry out the survey in order to increase the length of the survey index series.
- Explore the possibility of applying other model besides SPiCT, for example, age structure model.

GSA 22 anchovy and sardine

- Stress the need to carry out surveys every year in order to reduce the uncertainty in the assessments especially in age-structured models.
- Explore the potential to apply data-limited models.

ADOPTION OF THE REPORT AND OF THE RECOMMENDATIONS FROM THE WORKING GROUP

39. The WGSASP proposed to hold the next session of the WGSAs in November/December 2021 in Rome, with the proposed terms of reference as included in Appendix 3.

40. The conclusions and recommendations were adopted by the WGSASP on 23 January 2021. The whole report will be adopted after revisions and amendments by electronic correspondence.

Appendix 1

Agenda

1. **Joint opening and arrangements of the WGSAs (WGSASP and WGSAD-Western)**
2. **Introductory session for the WGSASP**
3. **Sub-group A: WGSASP**
    i. **Assessment of priority stocks (Table 1)**
    ii. **Assessment of non-priority stocks (Table 2)**
4. **Sub-group B: Benchmark session for *Engraulis encrasicolus* (ANE) and *Sardina pilchardus* (PIL) in GSAs 6&7**
5. **Closing session (in plenary)**

Table 1. Priority stocks

#	Subregion	Species	GSA	Type of assessment
1	WM	*Engraulis encrasicolus*	1	Dev. of 2019 assessment
2	WM		9	Dev. of 2019 assessment
3	CM		16	Updated assessment
4	CM		20	Update assessment
5	EM		22	Update assessment
6	WM	*Sardina pilchardus*	1	Updated benchmark
7	WM		3	Updated benchmark
8	WM		4	Updated assessment
9	WM		9	Updated assessment
10	CM		16	Update assessment
11	CM		20	Update assessment
12	EM		22	Update assessment
13	Western and central	*Coryphaena hippurus*	5-12-13-14-15-16	New

Table 2. Non-priority stocks

#	Subregion	Species	GSA	Type of assessment
14	EM	*Scomber colias*	27	New

Appendix 2

List of participants

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Appendix 3

Proposed terms of reference for the revision of the framework for the provision of advice

The revision of the framework of advice will entail consultation with scientists and managers/administrations, including through meetings (a first one proposed by the first semester 2020), as well as a rethinking of the functioning of the Working Groups on Stock Assessments (WGSAs). This process will be linked to the GFCM 2030 Strategy.

The revision should take into account the peculiarities of stocks/fisheries assessed (e.g. pelagics vs. demersals), with particular focus on priority species, and the following proposed Terms of reference are suggested:

1. Review existing practice (methods, measures taken – indicators and reference points) for advice and management within the GFCM.
2. Review frameworks for the provision of advice in other regional fisheries management organisations and advisory bodies, with particular attention to be paid to those bodies providing advice for many species.
3. Revise the calendar for the provision of advice.
4. Address the provision of advice for data limited situations and the formulation of precautionary advice, including a framework for providing advice when direct methods and/or harvest rates are used as well as in data poor/limited situations, including precautionary catch or effort advice.
5. Specify procedures for the estimation of reference points in different data availability situations, including:
    a. Review reference points in adopted GFCM decisions and discuss technical approaches in relation their estimation.
    b. Address biomass reference points (percentiles, trends and other): guidelines on their use (especially with respect to short time series).
    c. Address reference points for data limited and new situations (e.g. spawning potential ratio).
6. Formulate a procedure for the performance of forecasts
    a. Provide guidelines on how to translate outcomes of scientific assessments into catch or effort advice towards monitoring the fishery vs the advice given.
7. Formulate a procedure for the performance of management strategy evaluation when needed, including the investigation of a range of possible measures, including temporal/spatial measures and technical measures such as gear selectivity and exploitation patterns.
8. Review aspects related to the transmission of information on status of stocks, including:
    a. How to report data issues in terms of their use and problems, with particular reference to differences with official data on catch and effort, as well as the use of surveys in the assessment.
    b. How to report stock status (summary sheets).
    c. How to report the outcome of benchmarking process.
9. Review the format and content of the elements for management plans.

Appendix 4/A

Advice on the status of the stocks analyzed, including WGSASP comments and recommendations

(Advice on the ratio between current and target indicators are only provided for stocks for which the output of the assessment is considered a quantitative indicator of the status of the stocks, otherwise when the assessment is considered indicative of trends a qualitative advice is provided)

GSA	Species	Methodology used	F/F_{MSY} *(E)	B/B_{MSY} *B/B_{pa} **B/B_{lim}	Stock status	Management advice	WG comments
1	Anchovy	SPiCT; trends*	--	--	Uncertain	Not to increase fishing mortality	The runs performed with the SPiCT model suggested that there is not enough contrast in the catch data to allow F to vary in the time series. The two-stage biomass model also resulted to be not appropriate as the survey is not designed to capture the recruitment of this stock. The assessment was considered **qualitative** and the advice not to increase fishing mortality is given on a precautionary basis.
1	Sardine	a4a*, SpiCT,	--	--	In overexploitation	Reduce fishing mortality	The assessment was an update of the benchmark model. Different runs were performed, changing the Fbar range (0:3 instead of 1-4), in order to include age 0, which is present in the catches. The decision of the group was to maintain the same Fbar range as in the benchmarked assessment. The assessment was considered **validated** providing **qualitative advice**. Based on the results, the stock is considered in overexploitation with very low SSB and recruitment in the final year. The advice is to reduce fishing mortality
3	Sardine	a4a*	Ecur/E0.4=1.57	--	In overexploitation	Reduce fishing mortality	The assessment was an update of the benchmark model. Several a4a runs were performed, testing different k values for the f submodel. Most of them gave consistent results and no particular issues were raised. The assessment was considered **validated** providing **quantitative advice**. Based on the

GSA	Species	Methodology used	F/F_{MSY} *(E)	B/B_{MSY} *B/B_{pa} **B/B_{lim}	Stock status	Management advice	WG comments
							results, the stock is considered **in overexploitation** with relative low biomass. The advice is to reduce fishing mortality.
4	Sardine	LBSPR, VIT	--	--	In overexploitation	Reduce fishing mortality	Data limited methodologies (VIT and LBSPR models) were applied separately for three periods in GSA 4 (western Algeria). An analysis of bias related to the LFDs was performed, taking into account length data coming from different ports separately. The stock assessment was accepted as **qualitative** advice. The stock is **in overexploitation** and the advice is to reduce fishing mortality. The stock assessment would benefit from an analysis of the data collection protocol whose improvement could also significantly improve the quality of the assessment outputs.
9	Anchovy	SPICT	0.52	1.21	Sustainably exploited	Evaluate potential fishing opportunities	The SPICT model was used for the assessment. The sensitivity regarding the impact of priors (logr) used was examined. Sensitivity analysis showed stable results and the run with logr=1.7 was chosen. This value reflects the recruitment pattern in the area, that relies on river input, narrow continental shelf and specific water circulation. The assessment was considered validated with **quantitative** advice. The stock is **sustainably exploited** (F/Fmsy=0.52, B/Bmsy=1.21) and the advice is to evaluate potential fishing opportunities
9	Sardine	SPICT	0.34	1.25	Sustainably exploited	Evaluate potential fishing opportunities	The SPICT model was used for the assessment. The sensitivity regarding the impact of priors (logr) used was examined. All trials provided consistent perception of the stock. A run was carried out using quarterly data, but the results were noisy, due to the seasonality of this fishery in the area. The assessment was considered

GSA	Species	Methodology used	F/F_{MSY} *(E)	B/B_{MSY} *B/B_{pa} **B/B_{lim}	Stock status	Management advice	WG comments
							validated with **quantitative** advice. The stock is **sustainably exploited** (F/Fmsy=0.34, B/Bmsy=1.25) and the advice is to evaluate potential fishing opportunities.
16	Anchovy	SPICT, a4a, XSA	--	--	Uncertain	Not to increase the fishing mortality	A SPICT model as well as an a4a and an XSA were run. The XSA model appears to be more driven by the survey. The a4a model provided uncertain results and most of the runs did not converge. The a4a model revealed a stock in overexploitation while the XSA and SPiCT models revealed a sustainably exploited stock. Owing to this uncertainty and to the fact that the survey did not reveal a dramatic situation, the assessment was validated with **qualitative** advice**.** The stock status is **uncertain** and the advice is to not increase the fishing mortality
16	Sardine	a4a*, XSA, SPiCT	--	--	In overexploitation	Reduce fishing mortality	Two age structured models were run, a4a and XSA. The results of the two models gave the same message, but very different F ratios. The a4a model reflects the low biomass state and the shrinking of age range inferred by the acoustic survey. Also a SPiCT model was performed, giving an F ratio value in-between the other two runs. Due to this uncertainty in the estimates but in accordance with the acoustic survey signal and the trends estimated by the assessment, the stock assessment was validated with **qualitative** advice. The stock is **in overexploitation** and the advice is to reduce fishing mortality.
17-18	Anchovy	FLSAM	F/FMSY = 1.51	SSB/SSBlim = 1.05 SSB/SSBpa = 0.80	Overexploited and in overexploitation	Reduce fishing mortality	Assessment is considered benchmarked. The stock assessment was validated with **quantitative** advice. The stock is **overexploited and in overexploitation** and the advice is to reduce fishing mortality
17-18	Sardine	a4a*, FLSAM	F/FMSY = 4.43	SSB/SSBlim	Overexploited and	Reduce fishing	A4a and SAM provided similar perspectives, but

GSA	Species	Methodology used	F/F_{MSY} *(E)	B/B_{MSY} *B/B_{pa} **B/B_{lim}	Stock status	Management advice	WG comments
				=1.11 SSB/SSBpa = 0.67	in overexploitation	mortality	SAM did not converge, so a4a was used as the basis for advice. Uncertainties and low contrast in the catch at age matrix, which were believed to affect statistical catch at age model fitting, prevented the group from accepting this assessment as a benchmark. No short-term forecast were provided. The stock is **overexploited and in overexploitation** and the advice is to reduce fishing mortality.
20	Anchovy	SPiCT	--	--	Sustainably exploited	Not to increase the fishing mortality	The assessment was carried out using a SPiCT model. Several runs were performed, testing different priors, and the assumption of an overexploitation of the stock in the past was taken. The message resulting from the converging runs agreed on a sustainable level of exploitation, but the uncertainty produced was high. For this reason, the assessment was considered **validated** providing **qualitative** advice**.** The stock is **sustainably exploited**.
20	Sardine	SPiCT	--	--	In overexploitation	Reduce fishing mortality	The assessment was carried out using a SPiCT model. Several runs were performed, testing different priors. All of them indicated a situation of overexploitation, however the lack of information in the early part of the time series suggested to validate the assessment providing **qualitative** advice. The stock was deemed **in overexploitation** and the advice is to reduce fishing mortality. The suggestion for future work is to explore other types of models or try to identify some data for the past that can help setting the priors.
22	Anchovy	a4a*, SPICT, FLSAM	--	--	In overexploitation	Reduce fishing mortality	A4a, FLSAM and SPiCT models were run. In all cases, the lack of continuous surveys in the recent period largely influences the assessment and cause uncertainties in the estimated parameters.

GSA	Species	Methodology used	F/F_{MSY} *(E)	B/B_{MSY} *B/B_{pa} **B/B_{lim}	Stock status	Management advice	WG comments
							The lack of catch-at-age data for a period of years in the a4a model amplifies the effect of the lack of surveys in the recent period. All the model runs had fitting issues and gave unstable results, but the sign was always of high exploitation in the last year. Taking this into consideration, the group conveyed to validate the assessment with **qualitative** advice. The stock is **in overexploitation** and the advice is to reduce fishing mortality.
22	Sardine	a4a*, SPICT, FLSAM	--	--	In overexploitation	Reduce fishing mortality	A4a, FLSAM and SPiCT models were run. The comparison between a4a and FLSAM results is consistent in terms of message given, but not in terms of values. In all the runs, the lack of continuous surveys in the recent period largely influences the assessment and cause uncertainties in the estimated parameters. The lack of catch at age data in a given period of years in the a4a model amplifies the effect of the lack of surveys. The assessment was considered **qualitative**. The stock is **in overexploitation** and the advice is to reduce fishing mortality.

Appendix 4/B

Advice on the status of the stocks analyzed in the benchmark session for the assessment of anchovy and sardine in GSAs 6 and 7, including comments and recommendations

(Advice on the ratio between current and target indicators are only provided for stocks for which the output of the assessment is considered a quantitative indicator of the status of the stocks, otherwise when the assessment is considered indicative of trends a qualitative advice is provided)

GSA	Species	Methodology used	F/F_{MSY} *(E)	B/B_{MSY} *B/B_{pa} **B/B_{lim}	Stock status	Management advice	WG comments
6	Sardine	a4a*, SpiCT	-0.63-	--	In overexploitation	Reduce fishing mortality	The stock was assessed using two approaches. SPiCT provides a more optimistic view than a4a because the acoustic biomass has recently increased. Some diagnostics failed to be met. Accordingly, addvice was provided based on the a4a model. The assessment was considered **benchmarked and validated providing quantitative advice**. Based on the results, the stock is considered in overexploitation (Fcur= 1.19, SSB cur= 9641 tonnes) with very low SSB and recruitment in the final year. The advice is to reduce fishing mortality. Future work should concentrate on improving estimates of life-history parameters from fishery-independent data.
7	Sardine	2-stage biomass model*, SPICT	HR/HR_{pa}=0.08		Sustainably exploited	Keep current fishing mortality	Advice was provided based on the two-stage biomass model. The assessment was considered **benchmarked and validated providing quantitative advice**. Based on the results, the stock is sustainably exploited (SSB cur= 44103 tonnes) and ecologically unbalanced. The advice is to keep current fishing pattern. Future work should concentrate on assessing this stock with a statistical cach at age and/or integrated model
6	Anchovy	a4a*, SpiCT			In overexploitation	Reduce fishing mortality	The stock was assessed using two approaches. Estimates of both absolute and relative fishing mortality and biomass hold large uncertainty, presenting values above and below reference points. The assessment by SPiCT is considered

GSA	Species	Methodology used	F/F_{MSY} *(E)	B/B_{MSY} *B/B_{pa} **B/B_{lim}	Stock status	Management advice	WG comments
							preliminar and further analyses are required. Accordingly, advice was provided based on the a4a model. The assessment was considered **validated** providing **qualitative advice** but was **not considered benchmarked**. Based on the results, the stock is considered in overexploitation (Fcur= 1.19, SSB cur= 9 641 tonnes). The advice is to reduce fishing mortality. Future work should concentrate on applying alternative methods to assess this stock (e.g. improving SPiCT assessment and using methods based on biomass and limited data).
7	Anchovy	a4a	F/Fmsy =0.48	B/B_{pa} = 0.79	Sustainably exploited	Keep current fishing mortality	The stock was assessed using two approaches: a4a and SPiCT. The assessment by SPiCT is considered preliminary and further analysis is required. The assessment based on the a4a model was considered **benchmarked and validated providing quantitative advice.** Based on the results, the stock is considered sustainably exploited (SSB cur= 36 470 tonnes) but in low biomass. The advice is to keep the current fishing mortality. Future work should concentrate on improving the a4a diagnostics.

Appendix 5

Draft work plan for the intersession 2019–2020 towards the benchmark assessment of sardine and anchovy in the Strait of Sicily (GSA 16)

1. Construct a table of metadata available: put everything even if not continuous in time and retrieve raw data and check them all.
2. Address all issues of the data, in particular:

- Total catch: check the longest time series
- Survey:
    - GSA 16: Use the MEDIAS survey index
- LFD in catch:
    - GSA 16: analyze the changes in the length-at-age relationship along the time series
- Ageing: Use the ALK estimated per year and compare years
- Slicing of LFD: if needed consider to compare slicing from growth curve and from ALK. See the consistency or difference and think where they come from.
- Any other thing that come up while exploring the raw data.
- Life-history parameters
    - vBGP: Thinking how to satisfactorily use larvae data to improve the growth curve or explore other biologically acceptable ways.
    - M: Depends on the vBGP and/or ageing accepted hypothesis.

Appendix 6

Proposed terms of reference of the Working Groups on stock assessment for demersal and small pelagic species (WGSAs)

The main objective of the annual meetings of the WGSAs is to provide advice on the main commercial stocks, as prioritized by the Scientific Advisory Committee on Fisheries (SAC) and the Commission. Specifically, the WGSAs will, on a stock-by-stock basis:

1. Analyse the datasets provided by the participants, check model parameters, evaluate model performance through sensitivity tests and residuals analysis, run stock assessments on a practical session and agree on final stock assessment models.

2. When possible, estimate biological reference points (biomass and fishing mortality).

3. In cases where analytical BRP cannot be obtained, attempt to use an empirical approach based on standing stock as stock status indicator, the harvest ratio (catch/biomass from survey) as fishing impact, and some indicators (SST, chlorophyll, condition factor, etc.) of environmental stress.

4. Provide diagnosis and advice on the status of stocks as assessed by the WGSAs, and suggest management advice to the SAC.

5. Complete a stock assessment form detailing the input data, preliminary analysis and stock assessment model, including all assumptions, model runs and analysis of model uncertainty used for the provision of advice, on a stock-by-stock basis.

6. Present and discuss related scientific/technical information useful for the assessment of stock status in the GFCM area of application.