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Scientific, Technical and Economic Committee for Fisheries (STECF)

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Small pelagic stocks in the Adriatic Sea

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Mediterranean assessments part 1 (STECF 15-14)

Edited by Massimiliano Cardinale, Dimitrios Damalas and Giacomo Chato Osio

This report was reviewed by the STECF by written procedure during September 2015

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Abstract
The Expert Working Group meeting of the Scientific, Technical and Economic Committee for Fisheries EWG 15-11 was held from 31 Aug - 04 Sep 2015 in Palma de Mallorca, Spain to assess the status of small pelagic stocks in the Adriatic Sea.
The report was reviewed by written procedure during September 2015.

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Small pelagic stocks in the Adriatic Sea

Mediterranean assessments part 1 (STECF-15-14)

THIS REPORT WAS REVIEWED BY THE STECF BY WRITTEN PROCEDURE DURING SEPTEMEBER 2015

Request to the STECF

STECF is requested to review the report on Small Pelagic Stocks in the Adriatic (ToRs 6-11) of the STECF Expert Working Group meeting 15-11, evaluate the findings and make any appropriate comments and recommendations.

Observations of the STECF

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

STECF notes that the age reading protocol for sardine was revised in 2015, but it is unclear how these revisions were applied in practice i.e. to the entire time series or only applied to the 2014 data. For this reason, the EWG 15-11 were unable to use the data obtained from the 2015 data call and instead reverted to using the data used previously (i.e. EWG 14-14), meaning that no estimates of fishing mortality, spawning stock biomass or recruitment are available for the most recent year. STECF endorses the approach taken.

The main data issue identified was the lack of Croatian data prior to 2013. Croatia has been a member of the EU since 2013 so there is no legal obligation for submitting data before this year. Catch at age data for anchovy or sardine are not fully available. This is due to the fact that discard data are available only sporadically for a limited proportion of Italian and Slovenian fleets, and completely absent for the Croatian fleet.

ToR 7. *Taking the outcomes of an ad-hoc contract*[1] *into account, re-evaluate the timing of spawning, recruitment and maturation with respect to the fishery and the assessment for the stocks of anchovy and sardine in GSAs 17-18.*

STECF notes the considerable recent advances made in the assessment and derivation of reference points of anchovy and sardine stocks in the Adriatic. The EWG 15-11 presents updated assessments for both stocks where the FLSAM model setting were revised so as to better reflect the ecology of the species. Given that anchovy spawn in summer and the data is provided by split year, the proportion of mortality occurring prior to spawning was set at zero whereas previously this had been set at 0.5. Sardine spawn during the winter and given that the data are provided by calendar year, the proportion of mortality occurring before spawning was set at zero, whereas previously this had been set at 0.5. STECF endorses this approach. STECF notes that this has resulted in revisions in to the estimates of SSB. For anchovy, the assumption that zero individuals are mature at the time of spawning has resulted in a substantial downward revision in SSB. For Sardine, setting the proportion of mortality occurring prior to spawning to zero for 0-gp individuals results in a considerable increase in SSB compared to the previous assessment.

ToR 9. *Assess trends in historic and recent stock parameters for the longest time series possible available up to and including 2014, for the stocks of anchovy and sardine across GSA 17 and 18. This shall cover the evaluation of the level of fishing mortality exerted by different fleet segments, fishing*

[1] Commitment No. SI2.699950 – Multiannual plan on the small pelagic stocks in the Adriatic Sea: necessary elements from the STECF (24 July 2015).

mortality at age, spawning stock biomass, stock biomass, and recruits at age. Different assessment models should be applied as appropriate, including analyses of retrospective effects.

STECF notes that a number of alternative assessments were tested during EWG-15-11, particularly alternative fits using a4a (Jardim et al., 2015).

For anchovy, strong retrospective patterns persisted in all assessment models fit with fishing mortality consistently underestimated and SSB overestimated year-on-year.

It remains difficult to replicate the sardine assessment outside the FLSAM fit. In contrast to the difficulty replicating elsewhere, good retrospective patterns were observed for the FLSAM sardine assessment.

ToR 8. Review the catch-at-age data of the acoustic survey for sardine and anchovy with a view to improve their low internal consistency.

ToR 8 was not addressed owing to there was no MEDIAS Survey expert present at EWG-15-11.

ToR 10. *Propose and evaluate candidate MSY value or range of values and safeguard points in terms of fishing mortality and stock biomass. The proposed values shall be related to long-term high yields and low risk of stock/fishery collapse and ensure that the exploitation levels restore and maintain marine biological resources at least at levels which can produce the maximum sustainable yield.*

For anchovy, STECF notes that the changes in assessment timing settings has also altered the stock-recruit estimates, moving from a strongly linear relationship to one that has a greater spread. Lack of density-dependence in the stock-recruit relationship necessitated the use of using mean SSB to define the breakpoint of a hockey-stick fit to the stock-recruit relationship following the approach recommended by FMSYREF3 (ICES, 2015).

Eqsim (ICES 2015) was used to estimate anchovy F_{MSY} reference point on the basis of an Hockey-stick recruitment model with fixed breakpoint at the mean SSB (139,000 tonnes). On the basis of median simulated catches the estimated reference points were: F_{MSY} = 0.30; F_{lower} = 0.23, F_{upper} = 0.36. The estimated F_{MSY} is close to the centre of the range of estimates of F_{MSY} from EWG-14-19 (0.225-0.429).

Eqsim (ICES 2015) was used to estimate sardine reference F_{MSY} point on the basis of an Hockey-stick recruitment model with fixed breakpoint at the mean SSB (446,000 tonnes). On the basis of median simulated catches the estimated reference points were: F_{MSY} = 0.08; F_{lower} = 0.065, F_{upper} = 0.11. The estimated F_{MSY} is close to the centre of the range of estimates of F_{MSY} from EWG-14-19 (0.057-0.198). The same approach used for defining biological for anchovy was applied to sardine resulting in candidate B_{lim} = 223,000 and B_{pa} = 446,000 tonnes. These were used in subsequent management strategy evaluations.

ToR 11. *Update the available simulations with more recent data from 2014 and test further management strategy evaluations to safeguard SSB of falling below B_{lim} with 5% probabilities (e.g., shorter advice to implementation cycles, escapement strategies with a capped F).*

Given the data issues identified above (ToR 6), it was not possible to include data collected during 2014 for the purpose of the MSE.

Two management strategies were evaluated by EWG 15-11 (a) A harvest control rule defined by the points in (SSB,F) of (0,0) (B_{lim},0), (B_{pa},F_{target}), (inf, F_{target}). F_{target} was given by F_{MSY} and the F_{MSY} lower and upper bounds given above (ToR 10). The target was set for the first year of the simulation, 2018 and 2020 and (b); a fixed escapement strategy with fishing mortality capped at F_{MSY}.

Conclusions of the STECF

STECF endorses the findings presented in the report of the EWG 15-11 and draws the following conclusions.

- With regard to the estimation of single point F_{msy} and F_{msy} ranges:

For sardine the single point and F_{msy} ranges were estimated as follows: F_{msy} = 0.08; F_{lower} = 0.065, F_{upper} = 0.11

For anchovy, the single point F_{msy} and ranges were estimated as follows: F_{msy} = 0.3; F_{lower} = 0.23, F_{upper} = 0.364

- With regard to the Management Strategy Evaluation:

For sardine:

1. Moving to MSY will result in considerable decrease in catches.
2. The catches are variable (high CVs) throughout reflecting the variable, autocorrelated nature of recruitment in the stock.
3. The probability of being below B_{lim} is relatively high throughout.
4. Similar to anchovy, the escapement strategy does not appear to offer more benefit over the HCR in terms of the probability of SSB < B_{lim}. This reflects the choice of $B_{escapement}$ = B_{lim}, as the HCR adjusts up to B_{pa} but the escapement strategy implemented sets fishing mortality at the target when SSB > B_{lim}.

For anchovy:

1. Moving to MSY will result in considerable decrease in catches in the short-term though they increase and stabilise over the longer-term.
2. The catches are variable (high CVs) throughout reflecting the variable, autocorrelated nature of recruitment in the stock.
3. The probability of being below B_{lim} is initially very high but decreases over the time of management.
4. The escapement strategy does not appear to offer more benefit over the HCR in terms of the probability of SSB < Blim. This reflects the choice of $B_{escapement}$ = B_{lim}, as the HCR adjusts up to B_{pa} but the escapement strategy implemented sets fishing mortality at the target when SSB > B_{lim}.

Report to the STECF

EXPERT WORKING GROUP ON

Small pelagic stocks in the Adriatic Sea

Mediterranean assessments part 1 (EWG-15-11)

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

1. Executive summary

In response to the ToRs 7 to 11, the STECF EWG 15-11 on Mediterranean Sea stock assessments part 1 has endeavoured to assess the status of sardine and anchovy in the Adriatic Sea. Relevant data were compiled and reviewed, including those called officially by DG Mare through the 2015 DCF data call for the Mediterranean and Black Sea, serviced by JRC . Expert knowledge completed the data, which were analyzed using a variety of stock assessment approaches. The data and methods applied are documented in section 5 of the present report. As requested by the TORs, STECF EWG 15-11 has conducted an assessment of anchovy and sardine in GSA 17 and 18, the estimation of MSY reference points and a management strategy evaluation (MSE) for both stocks.

Anchovy

STECF EWG 15-11 was aware that the age-reading protocol for anchovy in the Adriatic Sea (GSA 17 and 18) was revised in 2015, but there was no information provided by the countries on how the revised age-reading was applied (e.g. only to 2014 data or to the whole DCF series). Thus, it was concluded that a reliable stock assessment for anchovy in GSA 17 – 18 was not possible on a limited dataset from DCF 2015, so alternatives have been sought for. Since data from the STECF EWG 14-14 were available, a comparison with the latest DCF (2015) data was made. On the basis of this analysis it was decided to use the STECF EWG 14-14 data (which includes merged catch-at-age data up to 2013 compiled from both the DCF and national experts).

Although the data used were the same as for the assessment conducted during EWG 14-14, changes were made to the assessment model settings in order to account for the ecology of the species. The changes made were:

1. Given that anchovy spawns in summer and the data are provided by split year (starting in the summer), the proportion of mortality (natural and fishing) occurring prior to spawning was changed from 0.5 to 0;

2. Given the split year and summer spawning, the proportion mature at age zero was changed from 0.75 to 0, as the age zero fish are immature at spawning.

All other assessment settings (FLSAM settings) remained the same as those used in EWG-14-14.

The revision of the stock assessment model settings provided a very similar trend of the anchovy stock in GSA 17 compared to previous assessments, although the assumption that 0 fish individuals are immature at spawning lowered the level of the SSB substantially. Moreover, the changes in the assessment timing settings altered the stock-recruit estimates, moving from a strongly linear relationship to one with a more spread pattern.

To address the possibility of changes in productivity and decide which time series of stock and recruitment to use for the MSY simulations, Peterman's productivity method (Peterman et al., 2003) was applied to the anchovy data to estimate time-varying recruitment productivity (slope at the origin of the stock-recruit curve). A Kalman filter was used to estimate the AR(1) time-varying slope at the origin of a linearised Ricker formulation (Peterman et al., 2003, Minto et al., 2015). While it is clear that the productivity of the estimated stock has varied over time, the current level is close to the average of the entire time series and justifies the use of the entire time period to estimate the

MSY reference points. On these basis, a Hockey-stick with a fixed breakpoint at the mean SSB was used to estimate F_{MSY} using the entire time series of stock and recruitment data.

Eqsim (ICES 2015) was used to estimate anchovy F_{MSY} reference point on the basis of an Hockey-stick recruitment model with fixed breakpoint at the mean SSB (139,000 tonnes) and first-order autocorrelated recruitment residuals to account for the observed variations in recruitment productivity. Assigning B_{pa} = 1.4 x B_{lim}, results in a B_{pa} lower than the breakpoint, the breakpoint is therefore used as a candidate B_{pa} (139,000 tonnes) in the MSE simulation section. ICES (2015) recommends that where the catches are skewed, the median provides a more robust estimate of the reference points compared to the mean. Thus, on the basis of median simulated catches the estimated reference points were: F_{MSY} = 0.30; F_{lower} = 0.23, F_{upper} = 0.36. The estimated F_{MSY} is close to the centre of the range of estimates of F_{MSY} from EWG-14-19 (0.225-0.429).

The main results of the MSE were:

1. Moving to MSY will result in a considerable decrease in catches in the short-term though catches increase and stabilise over the longer-term.
2. The catches are variable (i.e. high CVs) throughout reflecting the variable, autocorrelated nature of recruitment in the stock.
3. The probability of the SSB being below B_{lim} is initially very high but decreases over the time of management period.
4. The escapement strategy does not appear to offer more benefit over the HCR in terms of the probability of SSB < B_{lim}. This reflects the choice of $B_{escapement}$ = B_{lim}, as the HCR adjusts up to B_{pa} but the escapement strategy implemented sets fishing mortality at the target when SSB > B_{lim}.

Sardine

For sardine, given the issues with the updated catch at age data, it was concluded by the EWG that a reliable stock assessment for sardine in GSA 17 – 18 was not possible on a limited dataset from DCF 2015, so alternatives have been sought for. Since data from the STECF EWG 14-14 were available, a comparison with the latest DCF (2015) data was made. On the basis of this analysis it was decided to use the STECF EWG 14-14 data (which includes merged catch-at-age data to 2013 compiled from both the DCF and national experts).

Although the data used were the same as for the assessment conducted during EWG 14-14, changes were made to the assessment model settings in order to account for the ecology of the species. The changes made were:

- Given that sardine spawns in the winter and the data are provided in calendar year (starting in January 1st), the proportion of mortality (natural and fishing) occurring prior to spawning was changed from 0.5 to 0.

All other assessment settings (FLSAM settings) remained the same as those used in EWG-14-14.

The revision of the stock assessment model settings provided a very similar trend of the sardine stock compared to previous assessments. However, setting the proportion of mortality occurring prior to

spawning to zero of age 0 individuals shows a considerably increase in SSB compared to previous assessments (as they are not discounted by a portion of the year's mortality).

To address the possibility of changes in productivity and decide which time series of stock and recruitment data to use for the MSY simulations, Peterman's productivity method was applied to the sardine data to estimate time-varying recruitment productivity (slope at the origin of the stock-recruit curve). A Kalman filter was used to estimate a random walk (heavily autocorrelated) time-varying slope at the origin. While it is clear that the productivity of the estimated stock has varied over time with a marked dip in productivity in the late 1990s, the current level is close to the average of the entire time series and justifies the use of the entire time period to estimate the MSY reference points.

On that basis, a Hockey-stick with a fixed breakpoint of the mean SSB (446,000 tonnes) was used to estimate F_{MSY} from the entire time series, similar to anchovy.

Eqsim (ICES 2015) was used to estimate sardine reference F_{MSY} point on the basis of an Hockey-stick recruitment model with fixed breakpoint at the mean SSB (446,000 tonnes), first-order autocorrelated recruitment residuals to account for the observed variations in recruitment productivity. ICES (2015) recommends that where the catches are skewed, the median provides a more robust estimate of the reference points than the mean. On the basis of median simulated catches the estimated reference points were: F_{MSY} = 0.08; F_{lower} = 0.065, F_{upper} = 0.11. The estimated F_{MSY} is close to the centre of the range of estimates of F_{MSY} from EWG-14-19 (0.057-0.198). The same approach used for defining biological for anchovy was applied to sardine resulting in candidate B_{lim} = 223,000 and B_{pa} = 446,000 tonnes. These were used in subsequent management strategy evaluations.

The main results of the MSE were:

1. Moving to MSY will result in considerable decrease in catches.
2. The catches are variable (high CVs) throughout reflecting the variable, autocorrelated nature of recruitment in the stock.
3. The probability of the SSB being below B_{lim} is relatively high throughout the management period.
4. Similar to anchovy, the escapement strategy does not appear to offer more benefit over the HCR in terms of the probability of SSB < B_{lim}. This reflects the choice of $B_{escapement} = B_{lim}$, as the HCR adjusts up to B_{pa} but the escapement strategy implemented sets fishing mortality at the target when SSB > B_{lim}.

2. Introduction

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

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

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

3. TERMS OF REFERENCE FOR EWG 15-11: SMALL PELAGIC STOCKS IN THE ADRIATIC SEA

The STECF-EWG 15-11 was requested to:

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

ToR 7. Taking the outcomes of an ad-hoc contract[2] into account, re-evaluate the timing of spawning, recruitment and maturation with respect to the fishery and the assessment for the stocks of anchovy and sardine in GSAs 17-18.

ToR 8. Review the catch-at-age data of the acoustic survey for sardine and anchovy with a view to improve their low internal consistency.

- **ToR 8** was not addressed owing to the no MEDIAS Survey expert being present at EWG-15-11.

ToR 9. Assess trends in historic and recent stock parameters for the longest time series possible available up to and including 2014, for the stocks of anchovy and sardine across GSA 17 and 18. This shall cover the evaluation of the level of fishing mortality exerted by different fleet segments, fishing mortality at age, spawning stock biomass, stock biomass, and recruits at age. Different assessment models should be applied as appropriate, including analyses of retrospective effects.

ToR 10. Propose and evaluate candidate MSY value or range of values and safeguard points in terms of fishing mortality and stock biomass. The proposed values shall be related to long-term high yields and low risk of stock/fishery collapse and ensure that the exploitation levels restore and maintain marine biological resources at least at levels which can produce the maximum sustainable yield.

[2] Commitment No. SI2.699950 – Multiannual plan on the small pelagic stocks in the Adriatic Sea: necessary elements from the STECF (24 July 2015).

ToR 11. Update the available simulations with more recent data from 2014 and test further management strategy evaluations to safeguard SSB of falling below B_{lim} with 5% probabilities (e.g., shorter advice to implementation cycles, escapement strategies with a capped F).

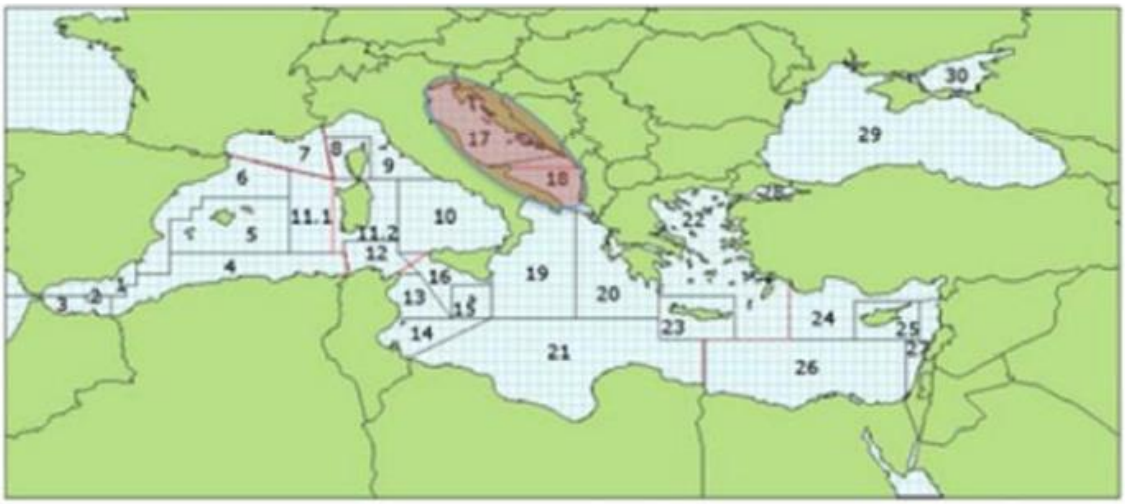
The **ToRs** were addressed by species.

4 SMALL PELAGIC STOCKS IN THE ADRIATIC SEA

4.1 ANCHOVY IN GSA 17-18

4.1.1 Stock Identification

Many studies have been carried out regarding the presence of a unique stock or the presence of different sub populations of anchovy in the Adriatic Sea (GSA 17 and GSA 18). This has several implications for the management, i.e. differences in the growth features between subpopulations imply the necessity of *ad hoc* strategies in the management. The hypothesis of two distinct populations claims the evidence of morphometric differences between northern and southern Adriatic anchovy, such as colour and length, and some variability in their genetic structure (Bembo *et al.*, 1996). Nevertheless, many authors warn against the use of morphological data in studies on population structure (Tudela, 1999) and, recent study from Magoulas *et al.* (2006), revealed the presence of two different clades in the Mediterranean, one of those is characterized by a high frequency in the Adriatic Sea (higher than 85%) with a low nucleotide diversity (around 1%). Therefore, in this year assessment, and according to the fact that most of the registered vessels in GSA 18 fish anchovy in GSA 17 but land in GSA 18, it was decided to merge the two GSAs and thus carry out an assessment for anchovy in GSA 17-18. (Figure 1).



01 - Northern Alboran Sea	07 - Gulf of Lions	13 - Gulf of Hammamet	19 - Western Ionian Sea	25 - Cyprus Island
02 - Alboran Island	08 - Corsica Island	14 - Gulf of Gabes	20 - Eastern Ionian Sea	26 - South Levant
03 - Southern Alboran Sea	09 - Ligurian and North Tyrrhenian Sea	15 - Malta Island	21 - Southern Ionian Sea	27 - Levant
04 - Algeria	10 - South and Central Tyrrhenian Sea	16 - South of Sicily	22 - Aegean Sea	28 - Marmara Sea
05 - Balearic Island	11.1 - Sardinia (west) 11.2 - Sardinia (east)	17 - Northern Adriatic	23 - Crete Island	29 - Black Sea
06 - Northern Spain	12 - Northern Tunisia	18 - Southern Adriatic Sea	24 - North Levant	30 - Azov Sea

Figure 1: Geographical location of GSAs 17 and 18.

4.1.2 Data revision to 2014

The DCF 2015 data revision for anchovy in GSA 17 – 18 revealed a series of gaps and inconsistencies (Table 1).

Table 1: GSA 17 – 18 anchovy: an overview of DCF 2015 data and the gaps identified.

	Source	Year reported	Data available for years	GSA
MEDIAS	DCF	2015	2004 – 2014	Separate 17 & 18
landings@age HRV	DCF	2015	2013 – 2014/per year	Only 17
landings@age SVN	DCF	2015	2006 – 2008 and 2010 – 2014/per quarter	Only 17
landings@age ITA	DCF	2015	2005 – 2014 for GSA 17; 2006 – 2014 for GSA 18 / per year	Separate 17 & 18
length freq HRV	DCF	2015	2013 – 2014	Only 17
length freq ITA	DCF	2015	2006-2009 and 2011-2014 for GSA 18; 2005 – 2014 for GSA 17 /per year	Separate 17 & 18
length freq SVN	DCF	2015	2007 - 2014	17

First, there is no catch at age data for anchovy available. The landings at age data is available, but the discards data necessary to reliably estimate catch at age are only available sporadically and for a limited proportion of Italian fleet (**Figure 2**). There is no discards at age data available for Croatian or Slovenian fleet (**Figure 2**).

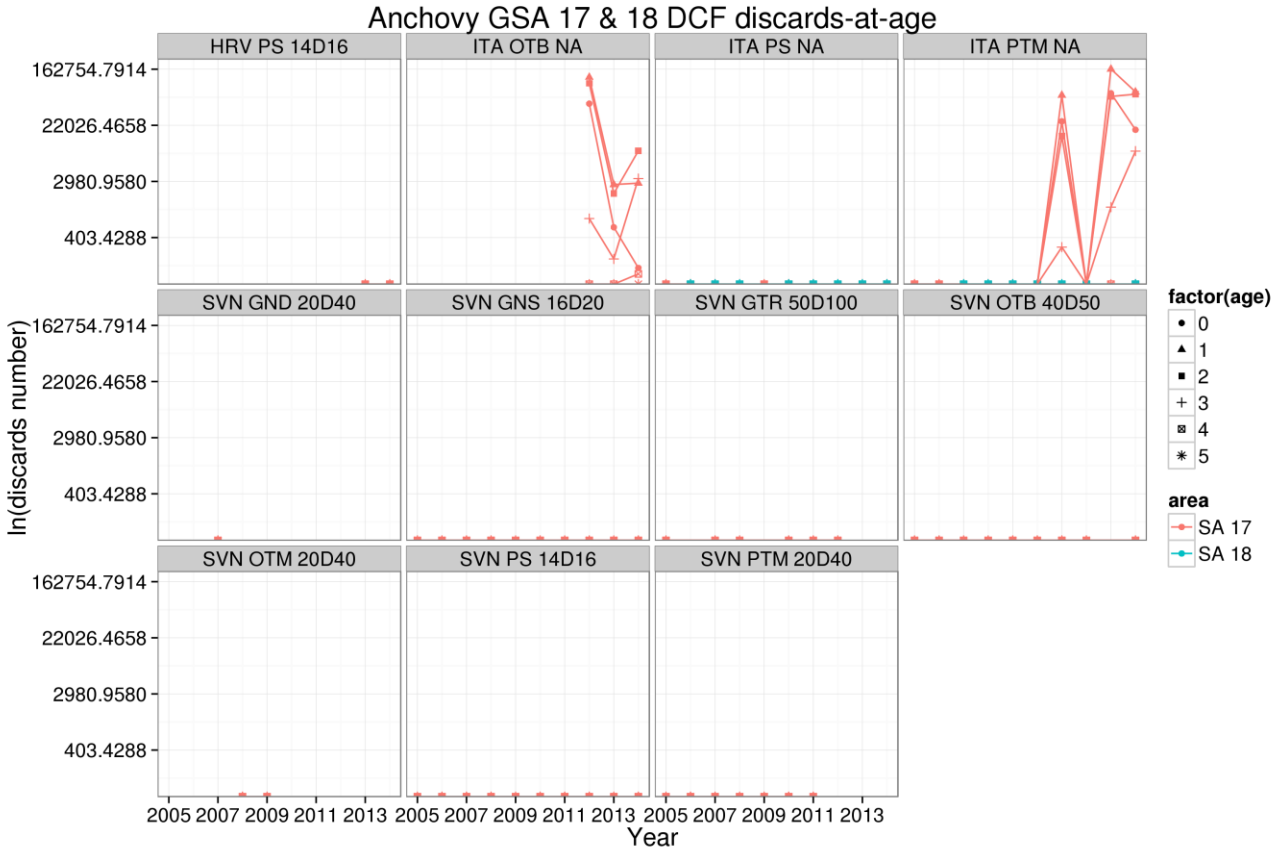


Figure 2: GSA 17 – 18 anchovy: available DCFf 2015 data on discards at age for anchovy in gsa 17 (red line) and 18 (blue line) by country and fleet.

Second, based on the DCF 2015 data there is only a short time series of landings at age data for anchovy available from all countries (**Figure 3**). The Croatian landings at age data is available only for GSA 17 for the years 2013 and 2014. The longest time series of landings at age data for Italian fleet goes back to 2005 for GSA 17 and to 2006 for GSA 18. The low absolute values of landings at age data for Slovenian fleet suggest an unidentified error in the data submitted. The 2009 landings at age data is also missing for the Slovenian fleet. There is no historical (pre 2005) data available from the DCF for any of the countries.

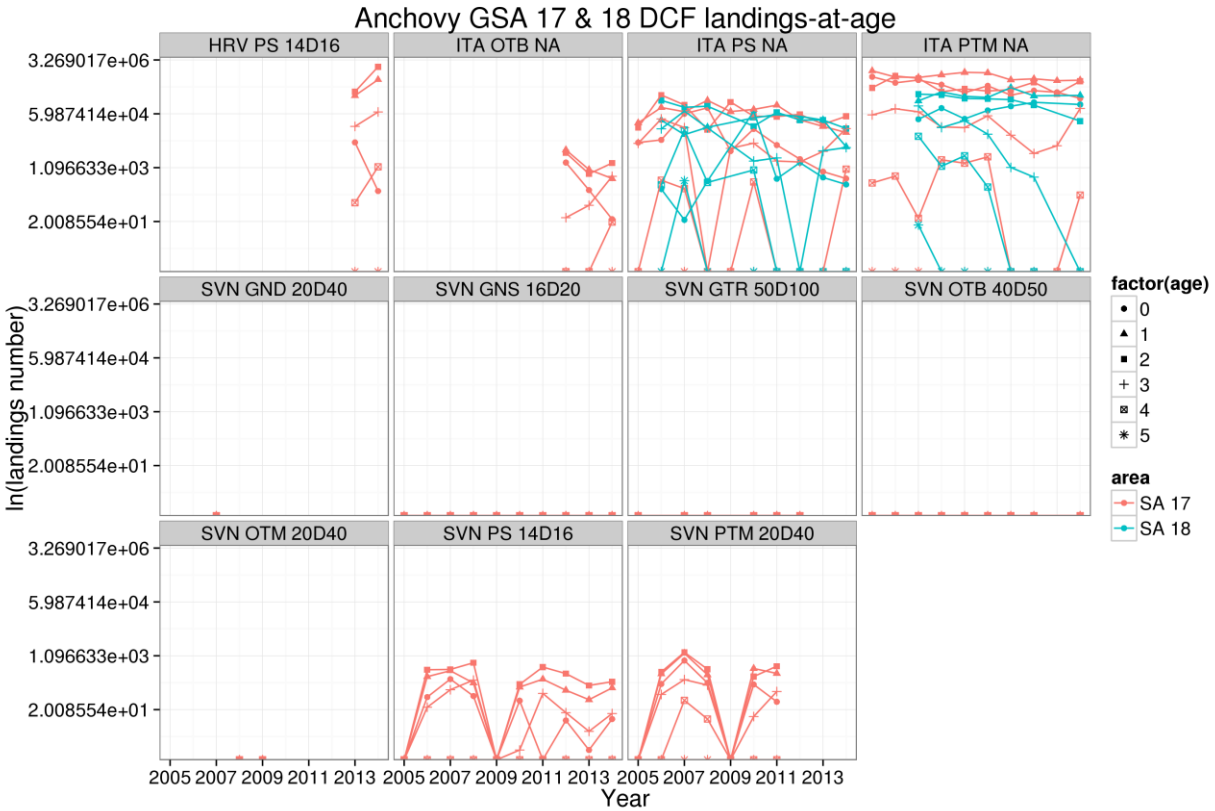


Figure 3: GSA 17 – 18 anchovy: available DCF 2015 landings at age data for anchovy in GSA 17 (red line) and 18 (blue line) by fleet and country.

Finally, the EWG was aware that the age-reading protocol for anchovy in the Adriatic (GSA 17 and 18) was revised in 2015, but there was no information provided by the countries on how the revised age-reading was applied (e.g. only to 2014 data or to the whole DCF series). Given the issues with the updated data, it was concluded that a reliable stock assessment for anchovy in GSA 17 – 18 was not possible on a limited dataset from DCF 2015, so alternatives have been sought for. Since data from the STECF EWG 14-14 were available, a comparison with the latest DCF (2015) data was made (**Figure 4**). On the basis of this analysis it was decided to use the STECF EWG 14-14 data (which includes merged catch-at-age data up to 2013 compiled from both the DCF and national experts).

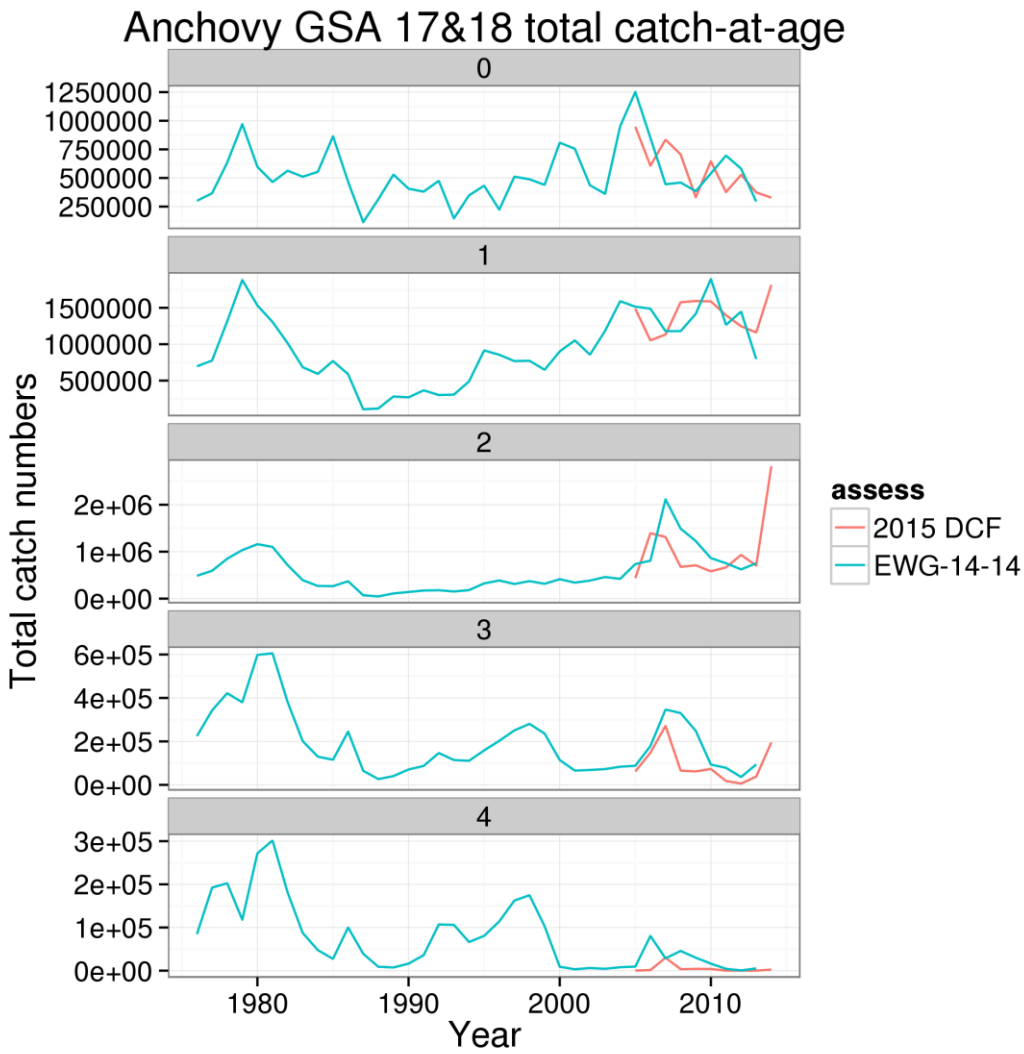


Figure 4: GSA 17 – 18 anchovy: a comparison of merged total catch at age data available from DCF 2015 and EWG 14-14.

The historical growth parameters of anchovy from Sinovčić (2000) based on Von Bertalanffy analysis have been used in the stock assessments preformed thus far in the Adriatic Sea (GSA 17 and 18). A more recent natural mortality vector by age for anchovy has been used from Gislason et al. (2010).

4.1.3 Stock assessment

Although the data used were the same as for the assessment conducted during EWG 14-14, changes were made to the assessment settings in order to account for the ecology of the species. The changes made were:

1. Given that anchovy spawns in summer and the data are provided by split year (starting in the summer), the proportion of mortality (natural and fishing) occurring prior to spawning was changed from 0.5 to 0;
2. Given the split year and summer spawning, the proportion mature at age zero was changed from 0.75 to 0, as the fish are immature at spawning.

All other baseline assessment settings (FLSAM settings) remained the same as those used in EWG-14-14.

4.1.3.1 Growth

The growth of anchovy in Adriatic Sea was assessed using the historical growth parameters (Sinovčić, 2000). Age-length and age-weight keys were produced using the otolith reading and actual length-weight parameters. The growth parameters used during the EWG 15-11 were:

Table 2: Von Bertalanffy growth parameters for anchovy in GSA 17-18.

Growth parameters	Linf	k	t0
Both sexes	19.4	0.57	-0.5

Note that given the absence of historical length-frequency data, and the issues identified with the recent data above, no attempt was made to slice the length frequencies to produce catch-at-age.

4.1.3.2 Maturity

The updated maturity at age sets the age 0 maturity to 0 (Table 3).

Table 3: Proportion of mature specimens at age for anchovy in GSA 17-18.

Period	**Age**	**0**	**1**	**2**	**3**	**4**	**5+**
1975-2013	Prop.Matures	0.00	1.00	1.00	1.00	1.00	1.00

4.1.3.3 Natural mortality

Table 4: Natural mortality vector by age from Gislason et al. (2010) for anchovy in GSA 17-18.

Period	**Age**	**0**	**1**	**2**	**3**	**4**	**5+**
1975-2013	M	2.36	1.10	0.81	0.69	0.64	0.61

The changes to this year's assessment settings only reflect in the SSB time series, the rest of the estimated parameters remain the same (Figure 5). The exclusion of age 0 (zero) individuals shows a considerably reduced (caused by the omittence of age 0 fish from the SSB) and smoother SSB time series than seen in previous assessments (Figure 5).

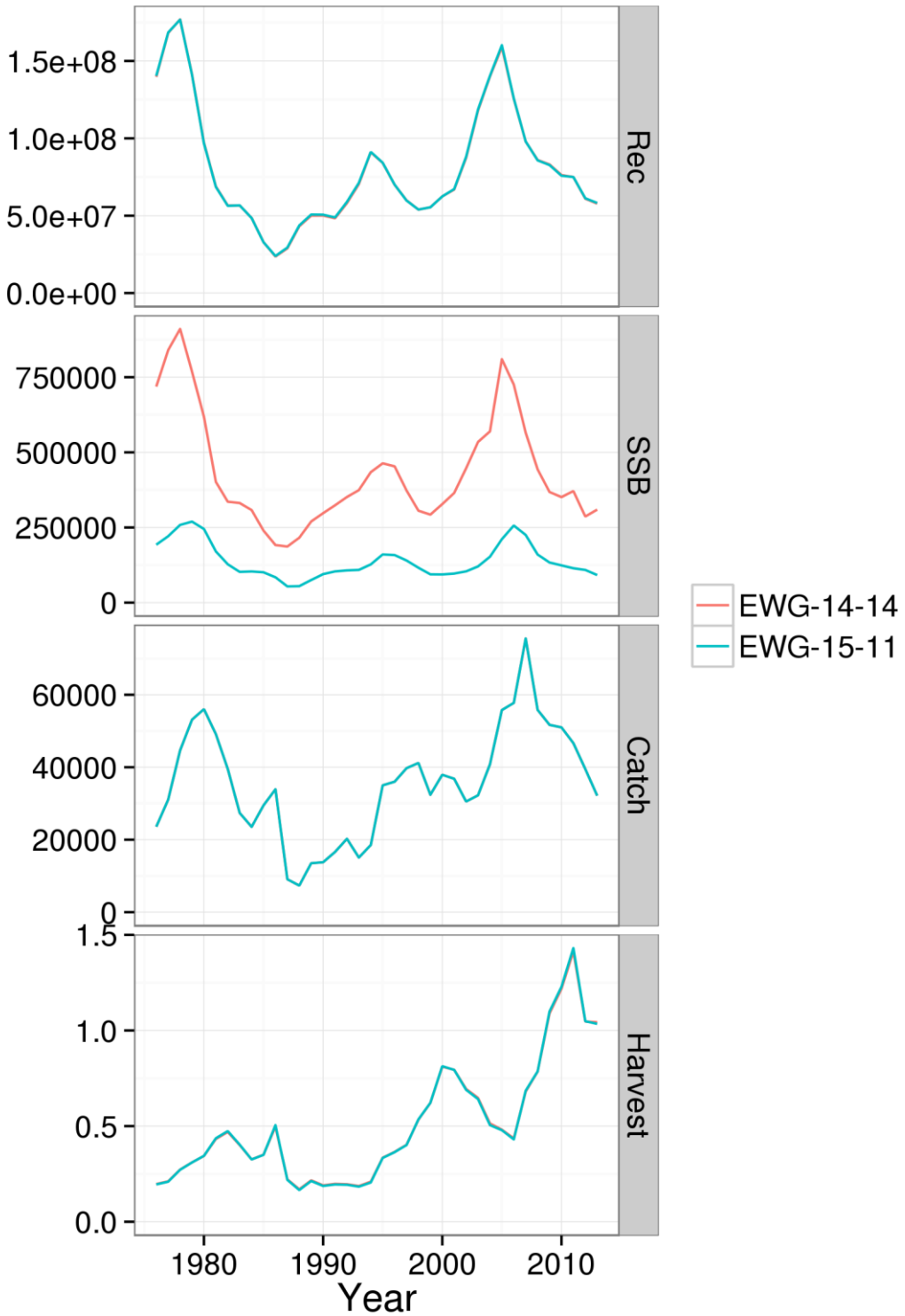


Figure 5: GSA 17 – 18 anchovy: a comparison of SAM results from EWG 15-11 and 14-14.

4.1.3.4 Alternative assessment settings

A number of alternative assessments were tested during EWG-15-11, particularly alternative fits using a4a (Jardim et al., 2015). Given the lack of internal consistency (cohort tracking) in the survey, the FLSAM fit downweights the survey indices considerably, relying mostly on the catch-at-age data. a4a assessments with catchability models that effectively ignore much of the survey structure (e.g., *qmodel = list(~1, ~1, ~1)* - single non-age-specific catchability per survey) easily replicated the FLSAM fit (Figure 6). Strong retrospective patterns persisted in all assessment models fit with fishing

mortality consistently underestimated and SSB overestimated year-on-year, as discussed in the ad-hoc contract[3]. The most recent year dropped had, however, a smaller retrospective effect than the previous 4 years dropped.

4.1.4 Updated stock-recruit estimates

The changes in the assessment timing settings altered the stock-recruit estimates, moving from a strongly linear relationship to one with more spread (Figure 7).

There are two key present issues with the estimation of Fmsy reference points for anchovy:

1. As identified in EWG-14-19 (2015), anchovy recruitment appears to continually increase with increasing SSB (Figure 7). The diffculty, as identified in ICES (2015), is that with ever-increasing recruitment the resultant F_{MSY} reference points can often be very low. The reason is that allowing the stock to continually increase by low fishing pressure, results in continually increasing recruitment and large yields at those low fishing mortalities. Essentially, if the population grows continually so will the yields. This relates to a lack of density dependence in observed stock-recruit data. Though density-dependence may not be apparent given the range of historical SSBs, a recommended practical approach in such cases is to use the mean SSB to define the breakpoint of a hockey-stick fit to the stock-recruit data (ICES, 2015). This was the solution taken during EWG-15-11.

2. EWG-14-19 noted the possibility of alternative environmental regimes affecting the recruitment of anchovy and addressed this via a sensitivity of the reference points to a suitably chosen subset or the entire time period. To address the possibility of changes in productivity, *Peterman's productivity method* (Peterman et al., 2003) was applied to the anchovy data to estimate time-varying recruitment productivity (slope at the origin of the stock-recruit curve). A Kalman filter was used to estimate the AR(1) time-varying slope at the origin of a linearised Ricker formulation (Peterman et al., 2003, Minto et al., 2015). While it is clear that the productivity of the estimated stock has varied over time(Figure 8), the current level is close to the average of the entire time series and justifies the use of the entire time period to estimate the Fmsy reference point.

On the basis of (1) and (2) above, a Hockey-stick with a fixed breakpoint of the mean SSB was used to estimate Fmsy from the entire time series.

[3] Commitment No. SI2.699950 – Multiannual plan on the small pelagic stocks in the Adriatic Sea: necessary elements from the STECF (24 July 2015).

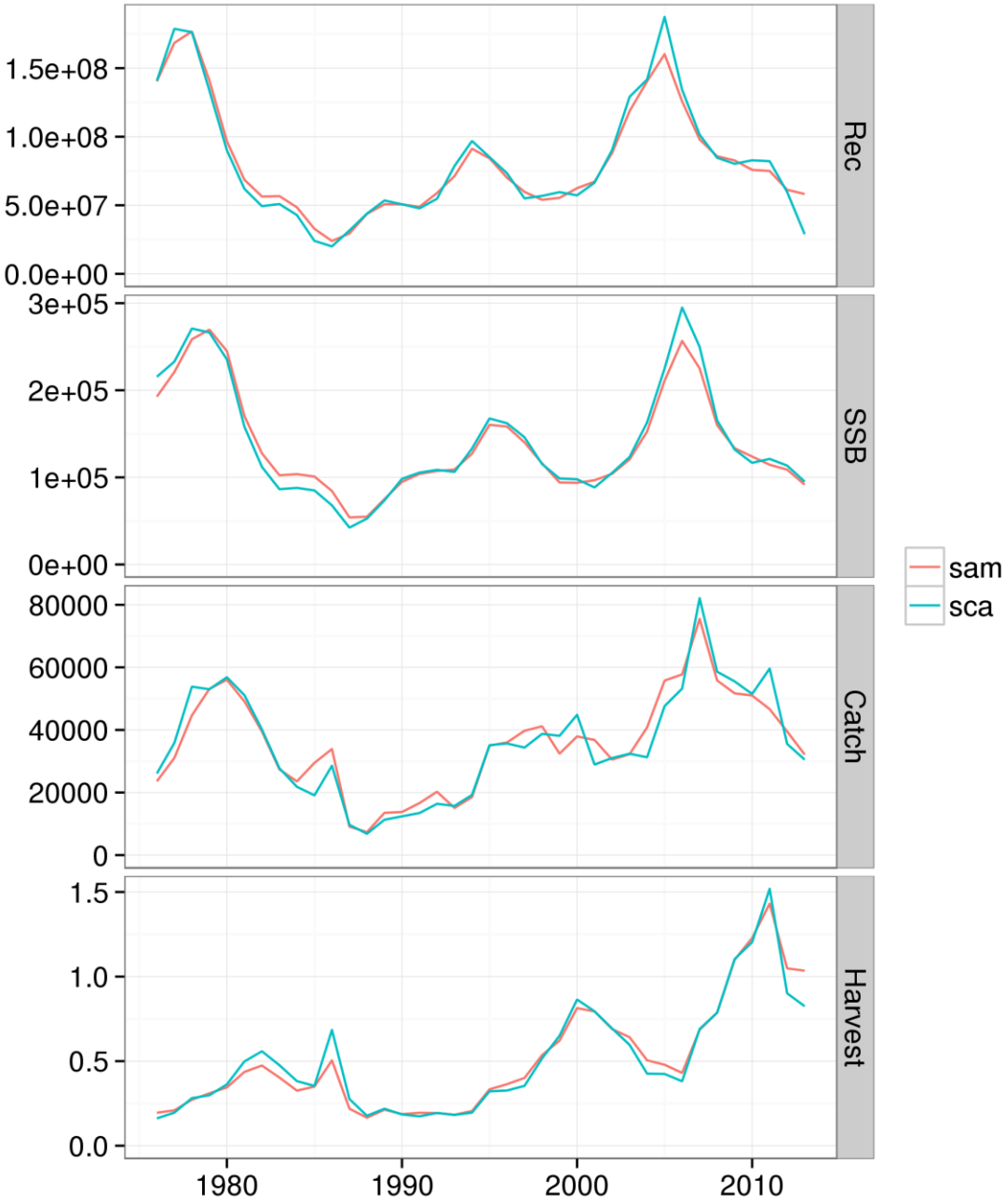


Figure 6: GSA 17 – 18 anchovy: A comparison of stock assessment results using FLSAM and SCA (in a4a).

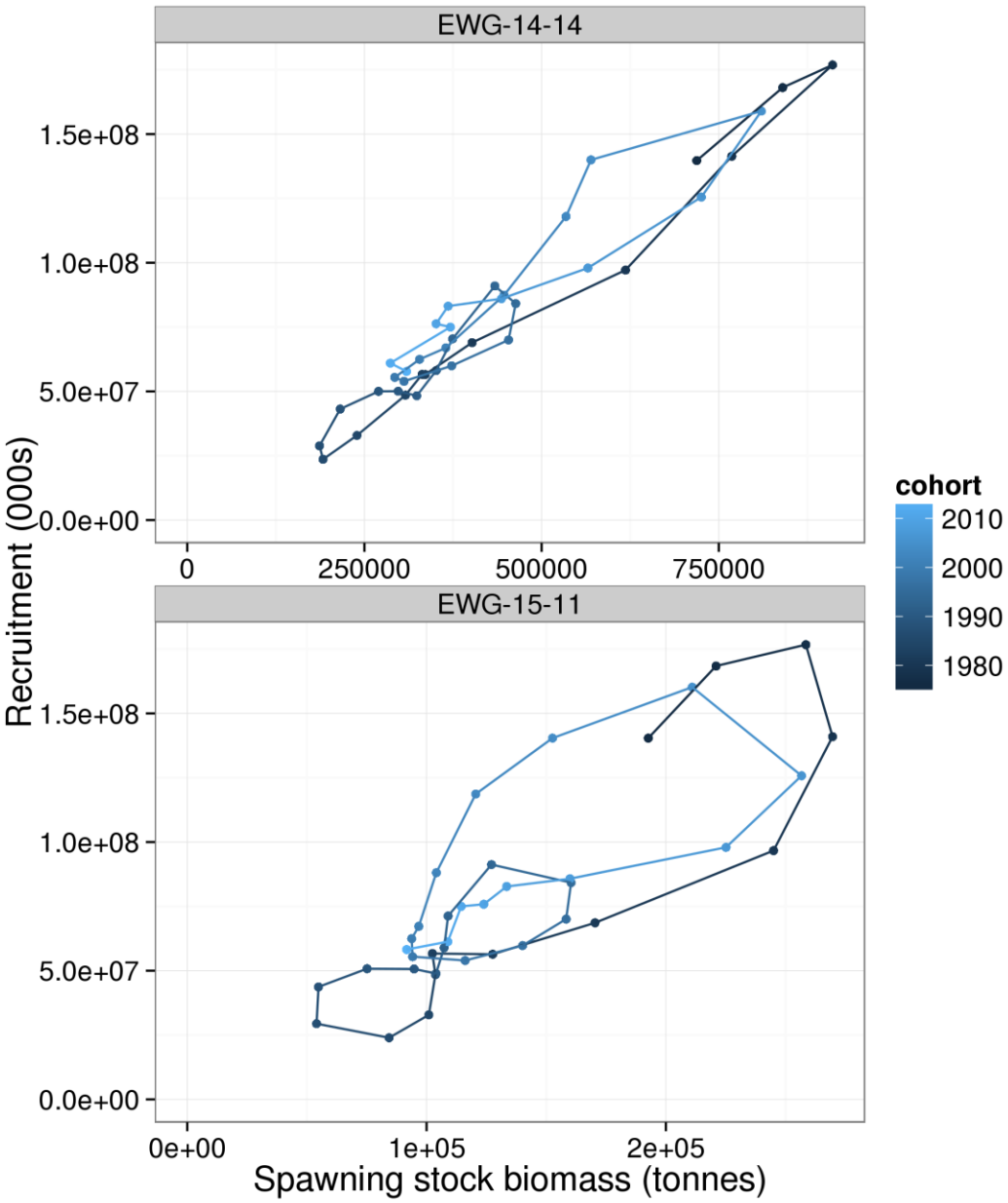


Figure 7: GSA 17 – 18 anchovy: a comparison of stock recruitment relationship of anchovy in GSA 17-18 estimated during EWG 14-14 and EWG 15-11.

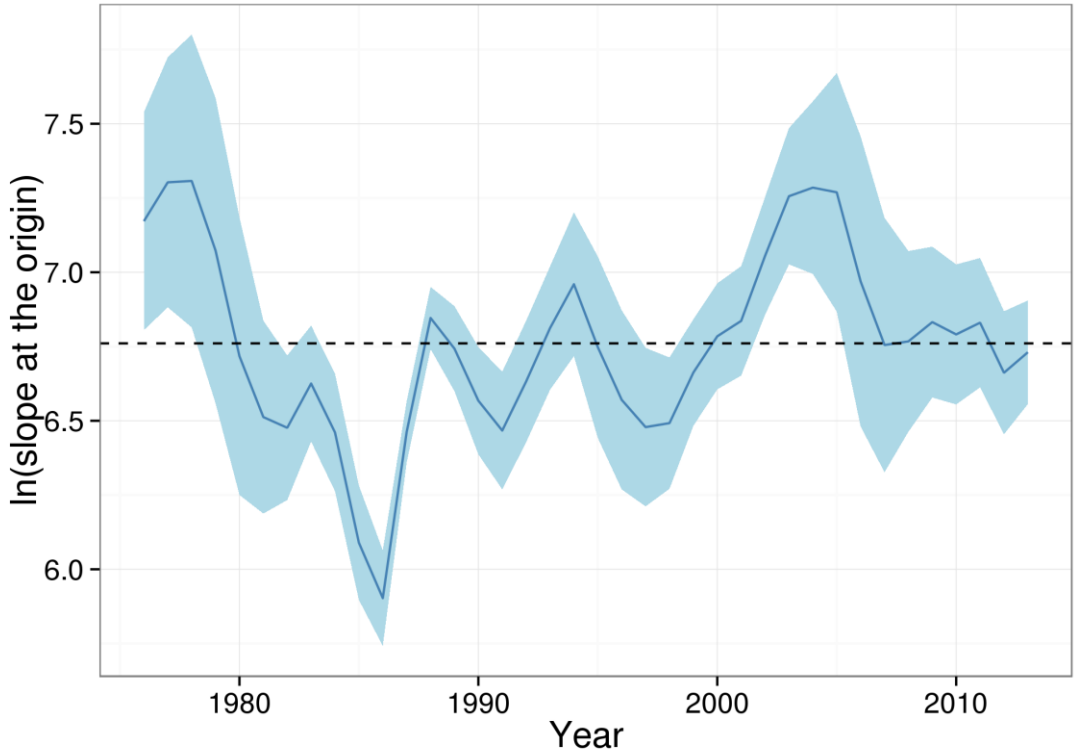


Figure 8: GSA 17 – 18 anchovy: productivity time series estimated using a Kalman filter.

4.1.5 Estimated anchovy reference points

Eqsim (ICES 2015) was used to estimate anchovy reference F_{msy} point on the basis of:

- Hockey-stick recruitment model with fixed breakpoint at the mean SSB (approximately 139,000 tonnes) (Figure 9);
- First-order autocorrelated recruitment residuals to account for the observed variations in recruitment productivity (Figure 8).
-

The observed catches fall above the simulated median yield curve (Figure 10), however, it is important to note that the observed catches are not equilibrium points that can be sustained indefinitely at the fishing mortality rates observed. This is borne out in the simulations where the estimated long-term sustainable yields are considerably lower for higher fishing mortality (Figure 10). Different values of the reference points (and ranges based on 5% reduction in MSY, estimated using the *eqsim_range* function in the *msy* package) are simulated depending on whether the mean or median catches are used:

- On the basis of mean simulated catches: F_{msy} = 0.34; F_{lower} = 0.23, F_{upper} = 0.45;
- On the basis of median simulated catches: **F_{msy} = 0.3; F_{lower} = 0.23, F_{upper} = 0.364**;

ICES (2015) recommends that where the catches are skewed the median provides a more robust estimate of the reference points. From a practical perspective it can be taken that half the catches will be above and half below this point, whereas the mean can be driven by occasional large catches but the typical annual expectation could be considerably lower than the mean expectation. For these reasons, the median-catch based MSY reference points are proposed for anchovy (highlighted in bold

above). The estimated Fmsy is close to the centre of the range of estimates of Fmsy from EWG-14-19 (0.225-0.429).

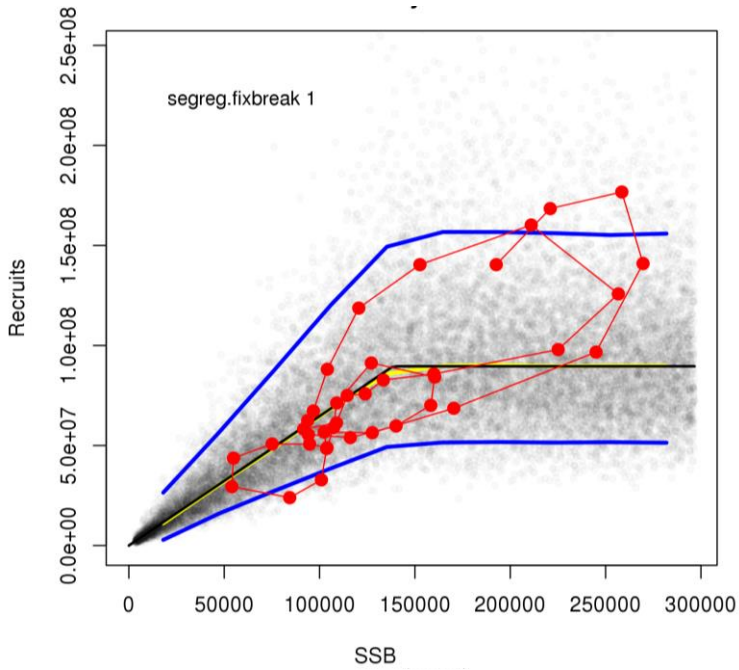


Figure 9: GSA 17 – 18 anchovy: segmented hockey-stick with a fixed breakpoint at the average SSB (tonnes).

The current biological safeguard B_{lim} value for anchovy is set to B_{loss}, the lowest observed SSB from which a recovery has been observed. By definition, the area to the left of the breakpoint is where recruitment is impaired and therefore the breakpoint can be considered a natural choice for B_{lim}. However, given that the breakpoint is fixed as opposed to estimated, alternatives for B_{lim} are presented. Mace (1994) highlights the use of the SR curve to define a threshold SSB as the point at which recruitment is half that of the maximum (Rmax/2). For the fixed segmented fit, this corresponds to half of the breakpoint SSB (69,500 tonnes). This is higher than the previously suggested B_{loss} (which is not suitable based on the continuously decreasing recruitments observed on the left limb of the SR data (Figure 9)). It is important to note, however, that only low recruitments have been observed historically at this level.

Assigning B_{pa} = 1.4 x B_{lim}, results in a B_{pa} lower than the breakpoint, the breakpoint is therefore used as a candidate B_{pa} (139,000 tonnes) in the MSE simulation sections. Note that were these or other values for B_{pa} and B_{lim} adopted for the basis of a multi-annual plan it would be essential to fix them in time, as the reference point is dependent on the definition of the breakpoint.

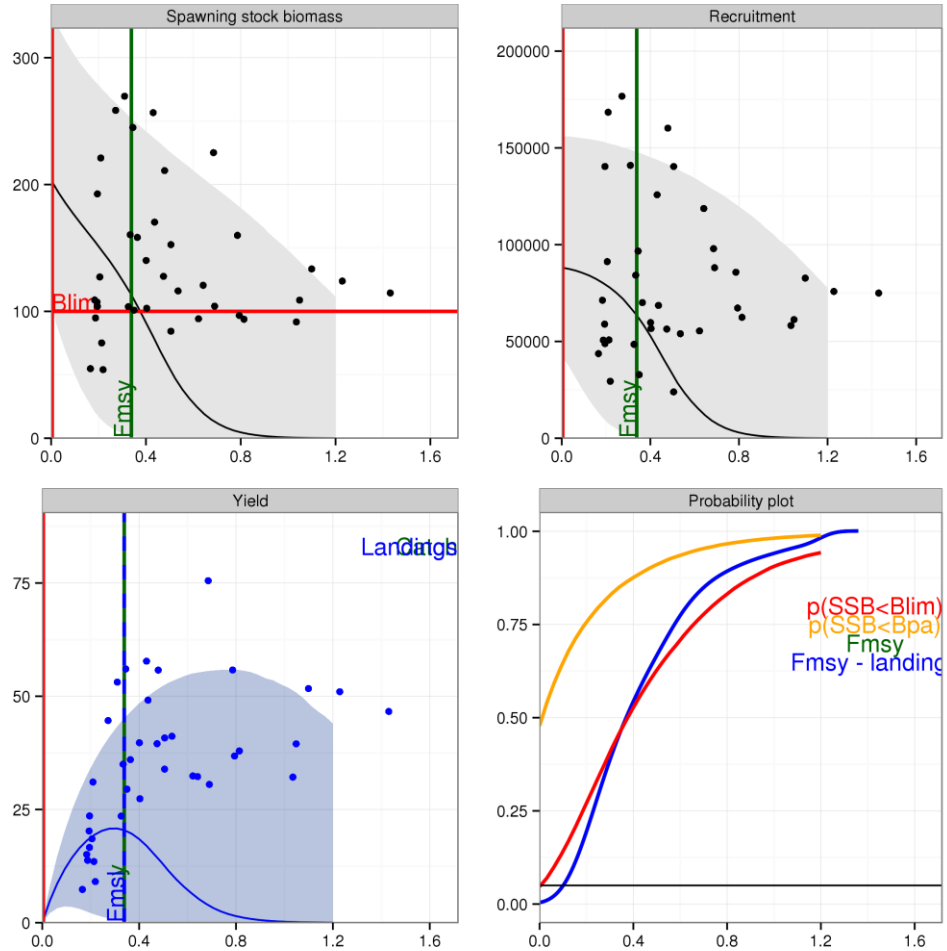


Figure 10. GSA 17 – 18 anchovy: EqSim simulations using a fixed breakpoint (mean SSB) hockey-stick model and autocorrelated recruitment. Note that arbitrary B_{lim} values were used to allow the plotting routines to work and hence the probabilities associated with SSB (bottom-right plot) should not be interpreted.

4.1.6 Management strategy evaluations

The management strategy evaluations explored for EWG-15-11 differed from previous attempts at MSEs for these stocks[4] by:

1. Being based on GSA 17-18 instead of GSA 17 alone;
2. Using the Hockey stick with autocorrelated residuals stock-recruit function in the operating model instead of the Kalman filter;
3. Attempts at implementing an escapement approach.

The operating model for the anchovy stock was the closest fitting statistical-catch-at-age model fit using a4a. The operating model recruitment function was the fixed breakpoint Hockey stick with autocorrelated residuals. Two main harvest strategies were tested:

1. A harvest control rule defined by the points in (SSB,F) of (0,0) (B_{lim},0), (B_{pa},F_{target}), (inf, F_{target}). F_{target} was given by F_{MSY} and the F_{MSY} lower and upper bounds estimated previously. The target

[4] Commitment No. SI2.699950 – Multiannual plan on the small pelagic stocks in the Adriatic Sea: necessary elements from the STECF (24 July 2015).

was set for the first year of the simulation, 2018 and 2020. Note that the harvest rate between B_{pa} and B_{lim} is altered (Figure 11).

2. A fixed escapement strategy with fishing mortality capped at F_{MSY} (Figure 11). The choice of $B_{escapement}$ is a critically important feature of escapement strategies. Given that trial simulations with $B_{escapement}$=B_{pa} resulted in close to zero catch throughout, $B_{escapement}$ was set equal to B_{lim}. $B_{escapement}$ pertains to the projected biomass at the end of the advice/TAC year. Note that for SSB > B_{lim} the rate is set to the target in constrast with the HCR that uses B_{pa} also. Again, the target was set for next year, 2018 and 2020.

Each scenario required a substantial amount of computing time to run (assessments run per each year and iteration and scenario), which restricted the amount of iterations possible to 100. For each scenario summary statistics were collected in terms of SSB relative to reference points, catch, etc. (Table 5). Given the limited time available to set up involved simulations, the results must be treated as indicative of the effects rather than in absolute terms at present. Overall, the findings of the MSE are:

5. Moving to MSY will result in considerable decrease in catches in the short-term though they increase and stabilise over the longer-term.
6. The catches are variable (high CVs) throughout reflecting the variable, autocorrelated nature of recruitment in the stock.
7. The probability of being below B_{lim} is initially very high but decreases over the time of management.
8. The escapement strategy does not appear to offer more benefit over the HCR in terms of the probability of SSB < Blim. This reflects the choice of $B_{escapement}$ = B_{lim}, as the HCR adjusts up to B_{pa} but the escapement strategy implemented sets fishing mortality at the target when SSB > B_{lim}.

A comparative illustration of the immediate move to F_{MSY} is shown in Figure 12 .

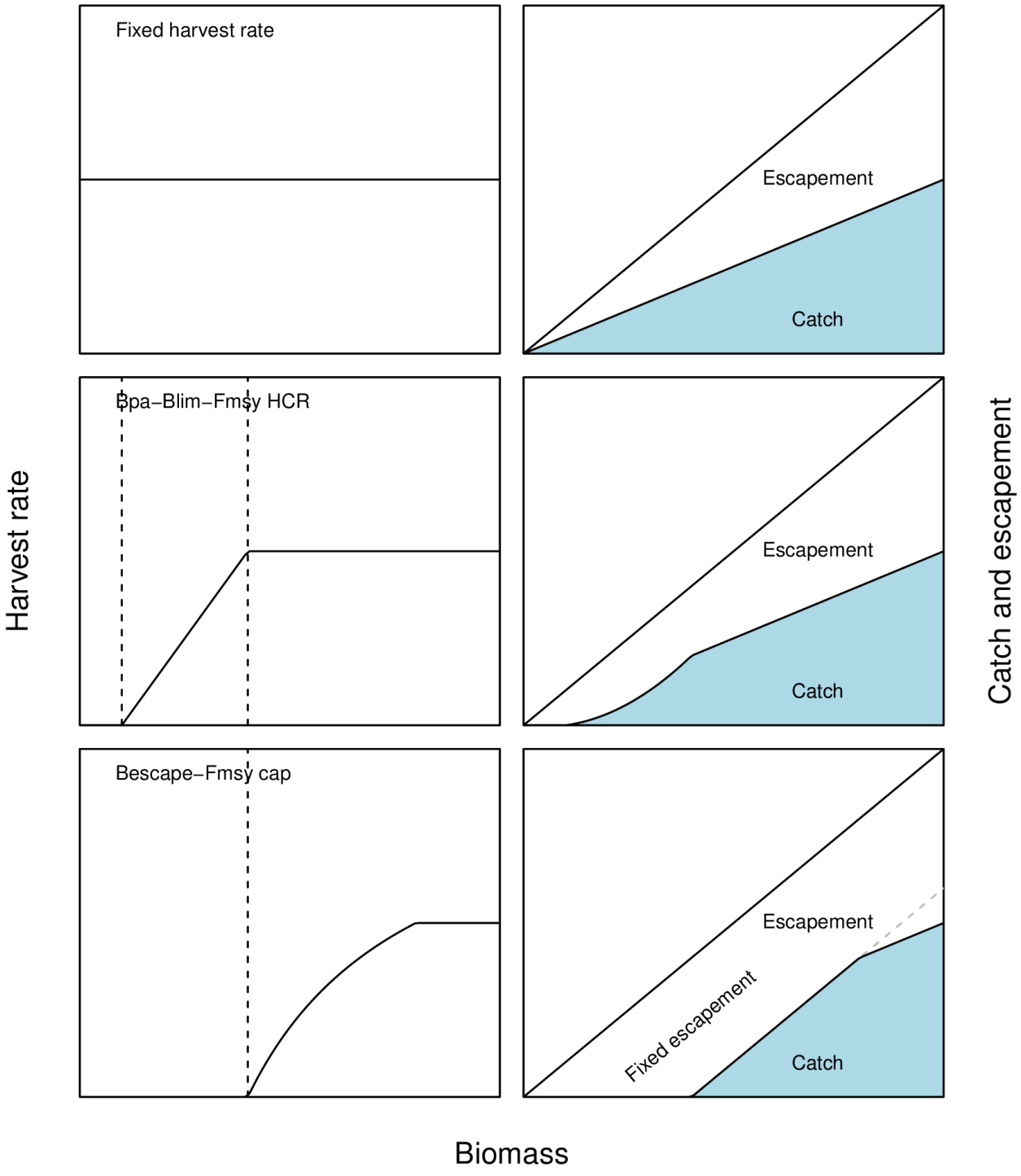


Figure 11. Illustration (adapted from FAO manual) of some harvest strategies of relevance to anchovy and sardine MSE simulations.

Table 5. GSA 17-18 anchovy: management strategy evaluation results. Scenarios are given per column where "Now" refers to an immediate move to the target F, 2018: a move to the target by 2018, etc.

		Fmsy	Flow	Fupp	Bescape	Fmsy	Flow	Fupp	Bescape	Fmsy	Flow	Fupp	Bescape
Metric	**Year**	**Now**	**Now**	**Now**	**Now**	**2018**	**2018**	**2018**	**2018**	**2020**	**2020**	**2020**	**2020**
SSB	2015	75405	76331	74655	75083	67581	67701	67478	68751	67245	67333	67170	62602
P(SSB < Blim)	2015	0.56	0.54	0.56	0.51	0.62	0.62	0.62	0.53	0.6	0.6	0.6	0.64
P(SSB < Bpa)	2015	0.93	0.92	0.93	0.93	0.96	0.96	0.96	0.98	0.97	0.97	0.97	0.98
Catch	2015	4384	3569	5009	10100	8235	8108	8343	14703	10937	10880	10985	14015
CV(Catch)	2015	1.451	1.472	1.436	0.796	1.245	1.253	1.239	0.972	1.382	1.388	1.377	0.99
SSB	2018	133029	135298	130869	113616	120273	120157	120247	101317	119300	119769	118391	105360
P(SSB < Blim)	2018	0.23	0.23	0.24	0.25	0.3	0.3	0.29	0.25	0.31	0.31	0.31	0.42
P(SSB < Bpa)	2018	0.56	0.52	0.58	0.71	0.67	0.67	0.67	0.81	0.64	0.64	0.64	0.7
Catch	2018	7523	6380	8665	16027	7459	5812	8420	12965	4744	3929	5629	7609
CV(Catch)	2018	1.858	1.795	1.796	0.811	1.813	1.797	1.88	0.84	2.734	2.652	2.704	2.792
SSB	2020	152574	156327	149669	130589	144398	146622	141854	123702	145939	147304	144057	131340
P(SSB < Blim)	2020	0.16	0.16	0.18	0.22	0.24	0.24	0.25	0.25	0.24	0.24	0.25	0.32
P(SSB < Bpa)	2020	0.48	0.47	0.48	0.61	0.53	0.5	0.55	0.63	0.52	0.52	0.53	0.57
Catch	2020	17915	14741	18988	19966	14821	12151	15801	18275	17505	13678	19553	8481
CV(Catch)	2020	1	1.009	1.012	0.756	1.213	1.199	1.236	0.807	1.146	1.155	1.084	1.865
SSB	2025	158613	165672	153223	140393	155779	161737	151985	139739	157246	163878	151548	154896
P(SSB < Blim)	2025	0.12	0.13	0.16	0.17	0.15	0.15	0.18	0.16	0.18	0.17	0.19	0.2
P(SSB < Bpa)	2025	0.43	0.36	0.44	0.52	0.42	0.36	0.43	0.55	0.41	0.37	0.45	0.43
Catch	2025	20581	18626	21733	22984	20112	17033	20953	22709	18916	16023	20921	16892
CV(Catch)	2025	0.914	0.793	0.883	0.634	0.916	0.939	0.963	0.649	1.02	1.055	0.949	1.203

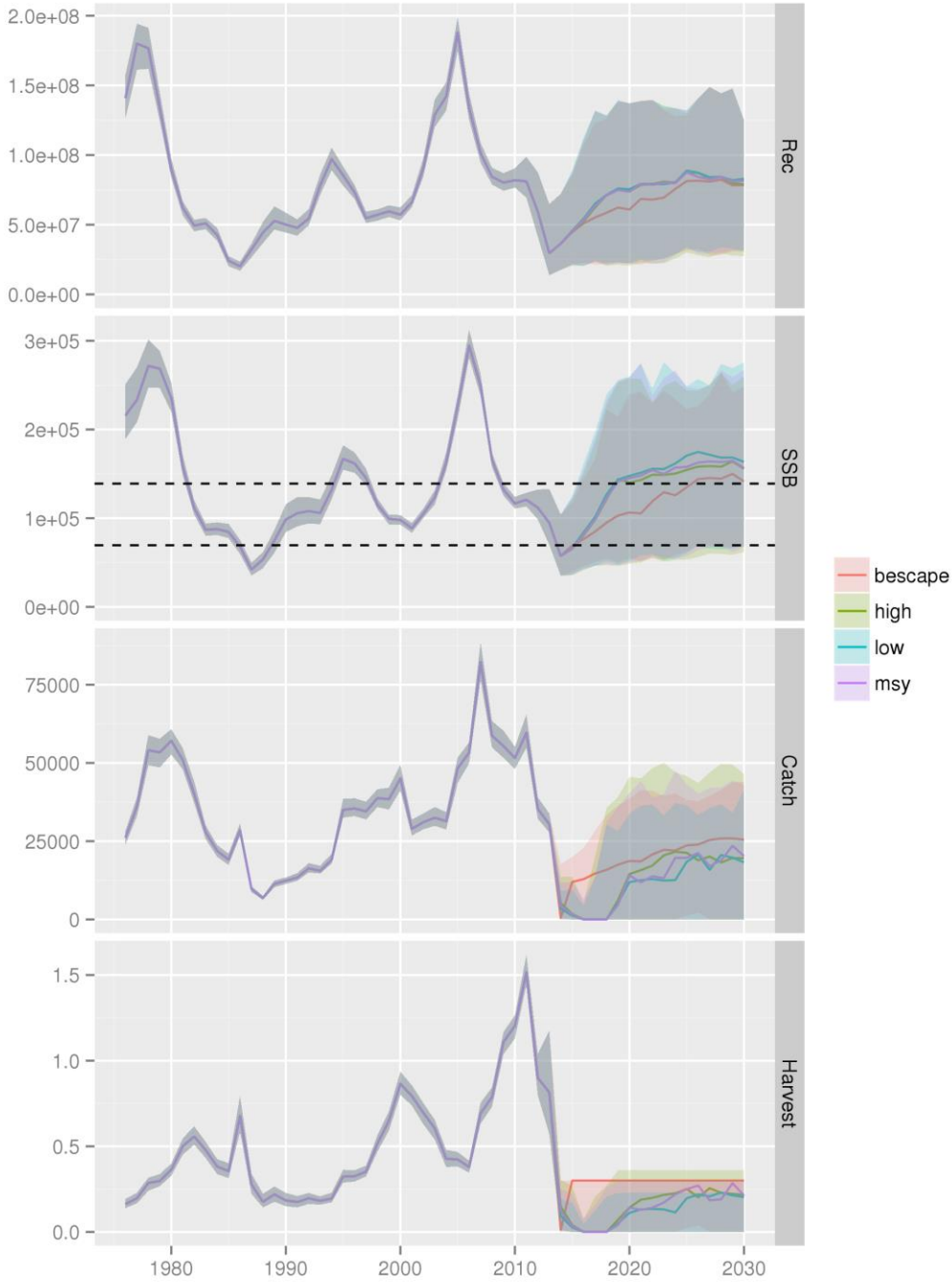


Figure 12. GSA 17-18 anchovy: illustration of the immediate move to management "Now" scenarios.

4.2 SARDINE IN GSA 17-18

4.2.1 Stock Identification

Although there is some evidence of differences on a series of morphometric, meristic, serological and ecological characteristics, the lack of genetic heterogeneity in the Adriatic stock has been demonstrated through allozymic and mitochondrial DNA (mtDNA) surveys (Carvalho *et al.*, 1994) and through sequence variation analysis of a 307-bp cytochrome b gene (Tinti *et al.*, 2002). Also, Ruggeri *et al.* (2013) supports the hypothesis of one stock on the basis of microsatellites DNA, even if suggests that some of the genetic homogeneity observed could be apparent and the identification of a subtle structuring in sardine population could be limited by technical difficulties and by the incomplete knowledge of molecular mechanisms. Therefore, in this year assessment, and according to the fact that most of the registered vessels in GSA 18 fish sardine in GSA 17 but land in GSA 18, it was decided to merge the two GSAs and thus carry out an assessment for sardine in GSA 17-18. (Figure 13).

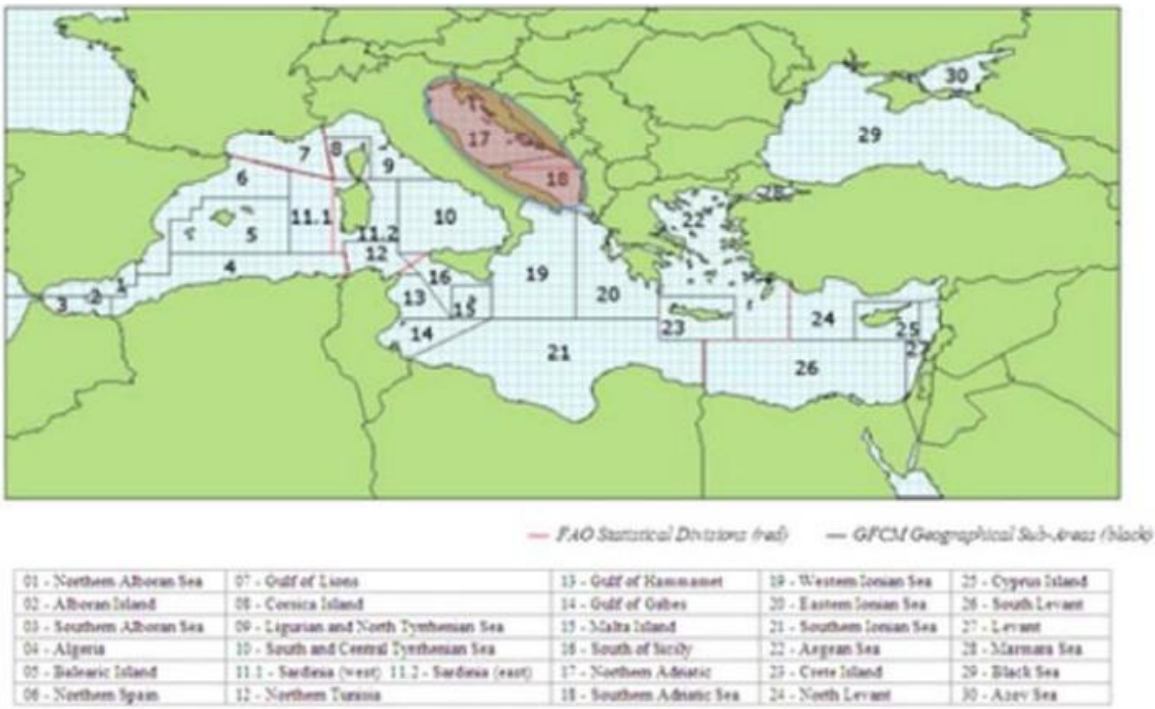


Figure 13: Geographical location of GSAs 17 and 18.

4.2.2 Data revision to 2014

The DCF 2015 data revision for sardine in GSA 17 – 18 revealed a series of gaps and inconsistencies presented below (Table 6).

Table 6: GSA 17 – 18 sardine: an overview of DCF 2015 data and the gaps identified.

	Source	Year reported	Data availability	GSA
MEDIAS	DCF	2015	2004 – 2014	Separate 17 & 18
landings@age HRV	DCF	2015	2013 – 2014/per year	Only 17
landings@age SVN	DCF	2015	2007 – 2008; 2010 – 2012 and 2014	Only 17
landings@age ITA	DCF	2015	2006-2009 and 2011-2014/per year for GSA 18 2005 – 2014 for GSA 17	Separate 17 & 18
length freq HRV	DCF	2015	2013 – 2014 /per year	only 17
length freq ITA	DCF	2015	2005 – 2014 for GSA 17 and 2005 – 2014 (-2010) for GSA 18 /per year	separate 17 & 18
length freq SVN	DCF	2015	2007 - 2014	17

First, there is no catch at age data available. The landings at age data is available, but the discards data necessary to reliably estimate catch at age are only available for Italian PTM fleet for 2011 and 2013 (**Figure 14**). There is no discards at age data available for Croatian or Slovenian fleet.

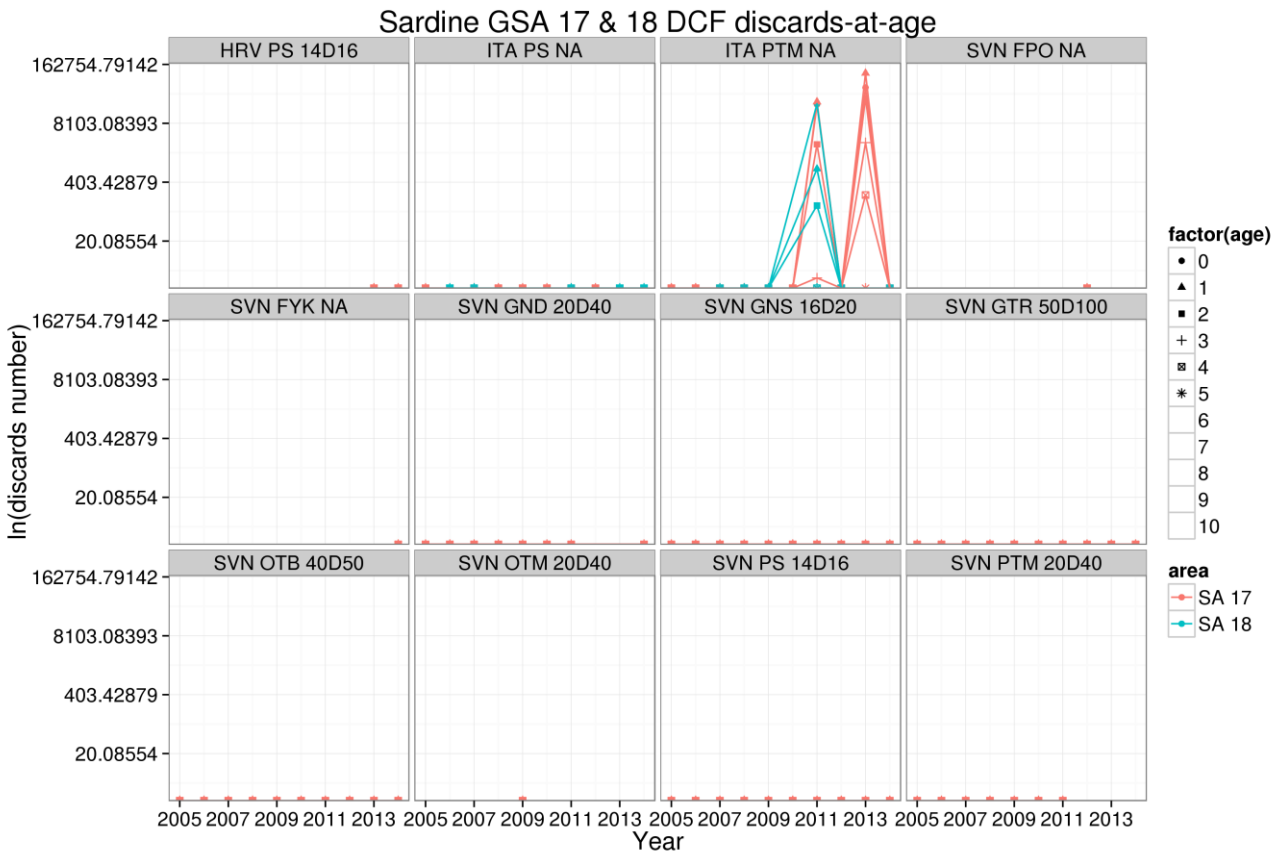


Figure 14: Available DCF 2015 data on discards at age for sardine in GSA 17 (red line) and 18 (blue line) by country and fleet.

Second, based on the DCF 2015 data there is only a short time series of landings at age data for sardine available from all countries (**Figure 15**). The Croatian landings at age data is available only for GSA 17 for the years 2013 and 2014. The longest time series of landings at age data for Italian fleet goes back to 2005 for GSA 17 and to 2006 for GSA 18. The low absolute values of landings at age data for Slovenian fleet suggest an unidentified error in the data submitted. The 2009 landings at age data

is also missing for Slovenian fleet. There is no historical (pre 2005) data available from the DCF for any of the countries. The 2014 data also appear to be in error with very large catches from Croatia. These data were updated late in the meeting and it was therefore not possible to include them.

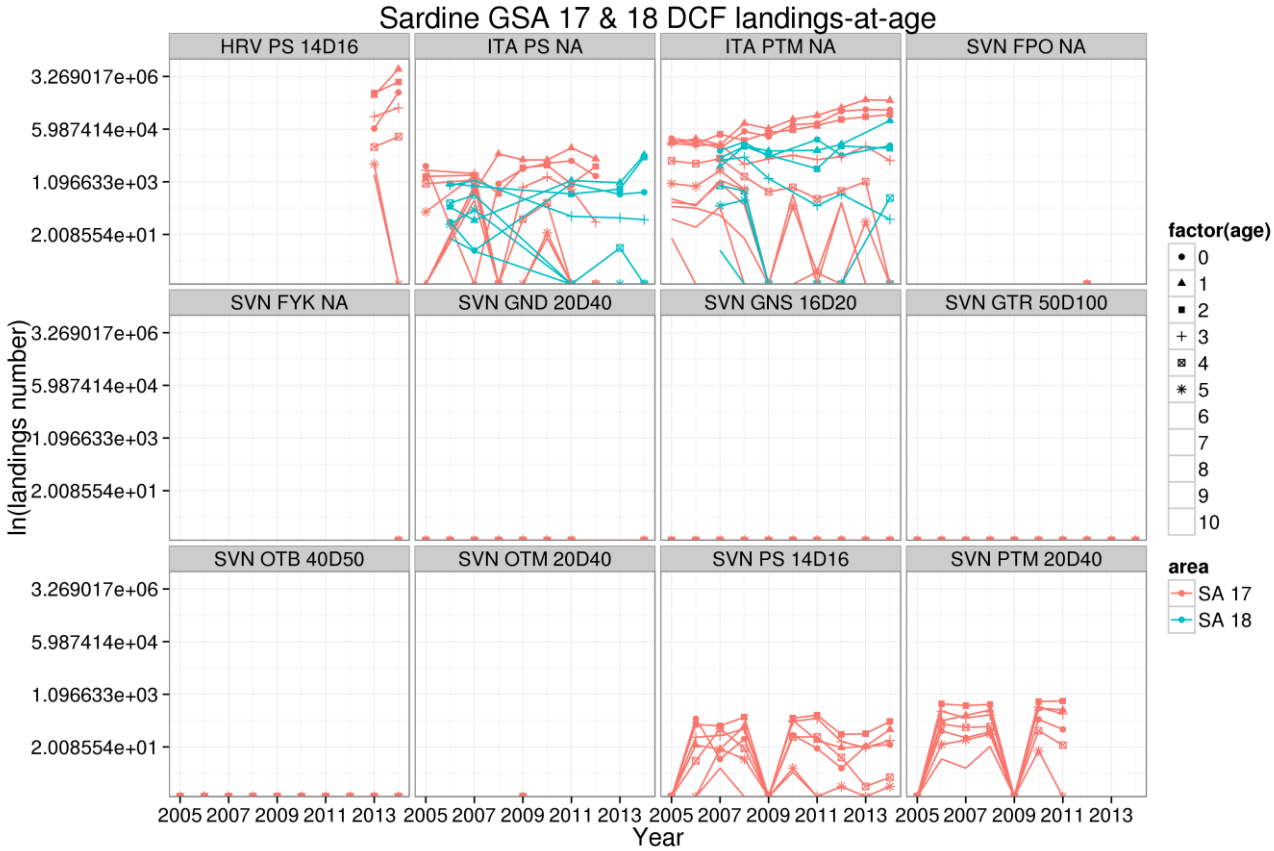


Figure 15: Available DCF 2015 data on landings at age for sardine in GSA 17 (red line) and 18 (blue line) by fleet and country.

Given the issues with the updated data, it was concluded by the EWG that a reliable stock assessment for sardine in GSA 17 – 18 was not possible on a limited dataset from DCF 2015, so alternatives have been sought for. Since data from the STECF EWG 14-14 were available, a comparison with the latest DCF (2015) data was made (**Figure 16**). On the basis of this analysis it was decided to use the STECF EWG 14-14 data (which includes merged catch-at-age data to 2013 compiled from both the DCF and national experts).

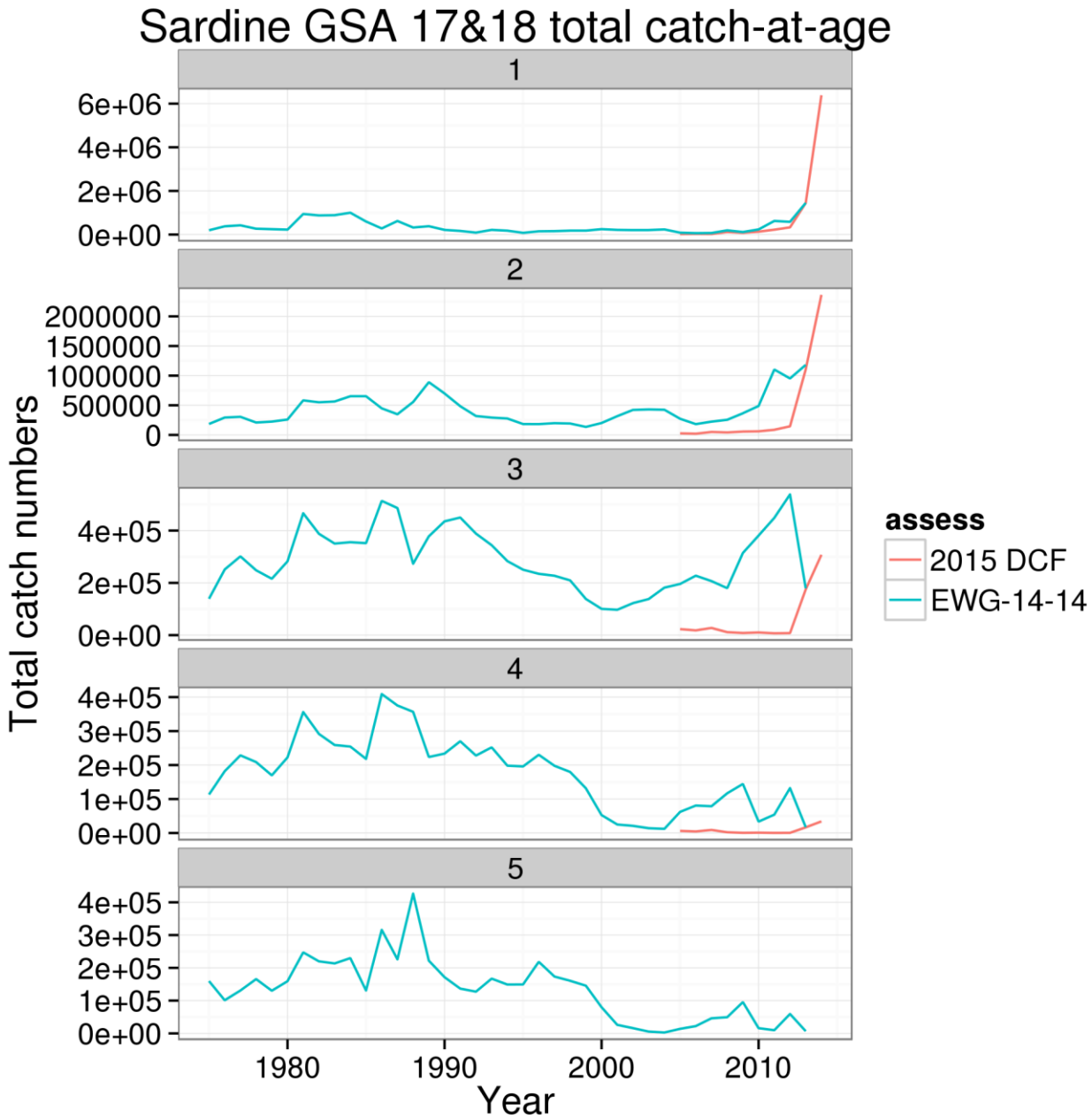


Figure 16: A comparison of merged GSA 17 – 18 sardine total catch at age data available from DCF 2015 and EWG 14-14.

The historical growth parameters of sardine from Sinovčić (1984) based on Von Bertalanffy analysis have been used in the stock assessments done thus far in the Adriatic Sea (GSA 17 and 18). A more recent natural mortality vector by age for sardine has been used from Gislason et al. (2010).

4.2.3 Stock assessment

Although the data used were the same as for the assessment ran at EWG 14-14, changes were made to the assessment settings in order to account for the ecology of the species. The changes made were:

- Given that sardine spawns in the winter and the data are provided in calendar year (starting in January 1st), the proportion of mortality (natural and fishing) occurring prior to spawning was changed from 0.5 to 0.

All other baseline assessment settings (FLSAM settings) remained the same as those used in EWG-14-14.

4.2.3.1 Maturity

The growth of sardine in the Adriatic Sea was assessed using historical growth parameters (Sinovčić, 1984). Age-length and age-weight keys were produced using otolith readings and actual length-weight parameters. The growth parameters used during the EWG 14-09 were:

Table 7: Von Bertalanffy growth parameters for sardine in GSA 17-18.

Growth parameters	L_{inf}	k	t_0
Both sexes	20.5	0.46	-0.5

4.2.3.2 Maturity

Table 8: Proportion of mature specimens at age for sardine in GSA 17-18.

PERIOD	Age	1	2	3	4	5
1975-2013	Prop.Matures	1.00	1.00	1.00	1.00	1.00

4.2.3.3 Natural mortality

Table 9: Natural mortality vector by age from Gislason et al. (2010) for sardine in GSA 17-18.

PERIOD	Age	1	2	3	4	5	6
1975-2013	M	1.10	0.76	0.62	0.56	0.52	0.50

The changes to this year's assessment settings only reflect in the SSB time series, the rest of the estimated parameters remain the same (Figure 17). Setting the proportion of mortality occurring prior to spawning to zero of age 0 (zero) individuals shows a considerably increased SSB time series than seen in previous assessments (as they are not discounted by a portion of the year's mortality).

4.2.3.4 Alternative assessment settings

A large number of alternative assessments were tested for sardine. Again, given the lack of internal consistency (cohort tracking) in the survey, the FLSAM fit downweights the survey indices considerably, relying mostly on the catch-at-age data. An a4a assessments with catchability models that effectively ignore much of the survey structure (e.g., *qmodel = list(~1, ~1, ~1)* - single non-age-specific catchability per survey) and tensor splines allowing for the exploitation pattern to vary in time was the only assessment of those trialled to come relatively close to the historical estimates (though not the recent estimates of fishing mortality) from FLSAM. It remains difficult to replicate the sardine assessment outside the FLSAM fit. In contrast to the difficulty replicating elsewhere, good retrospective patterns were observed for the FLSAM sardine assessment.

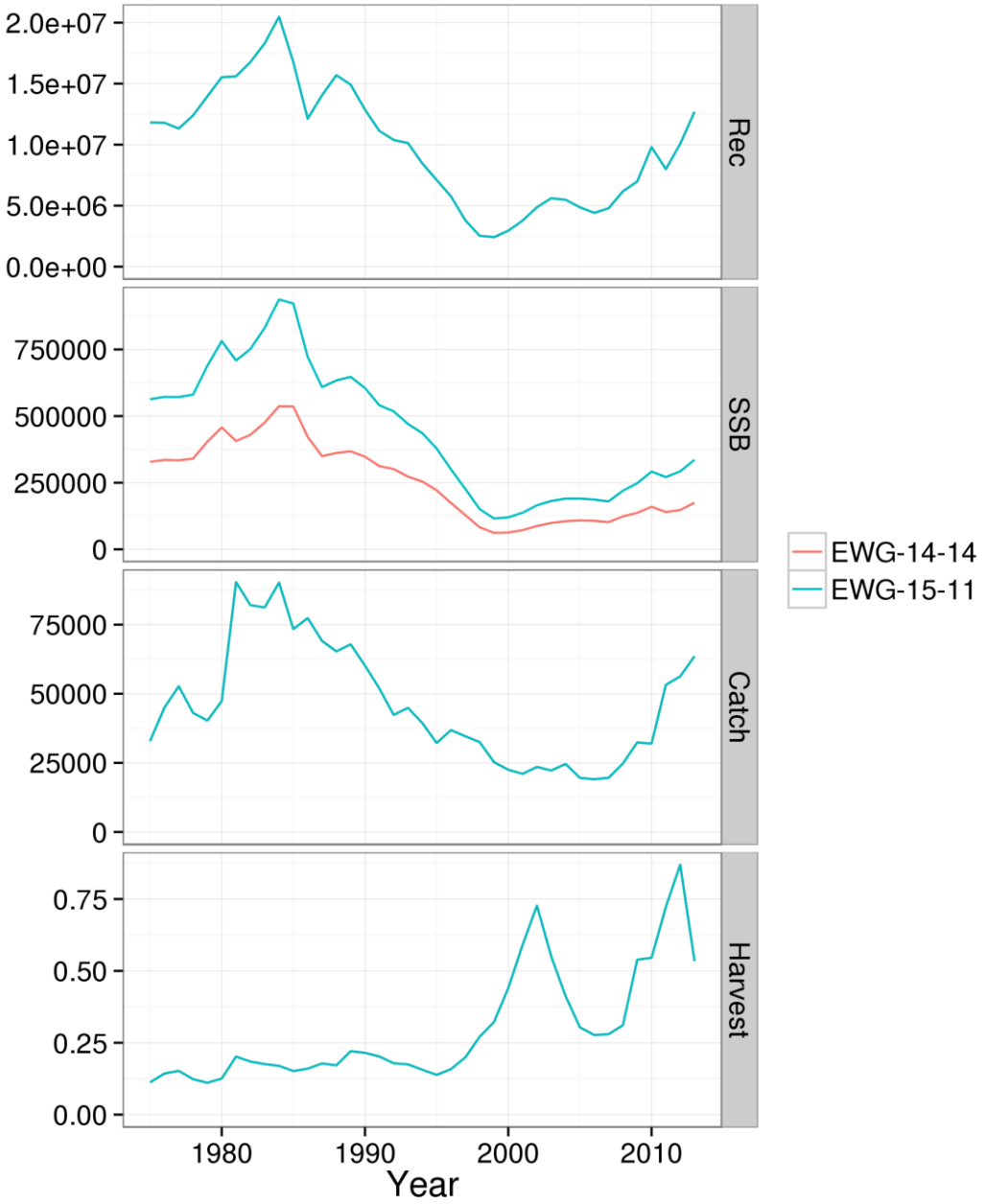


Figure 17: GSA 17 – 18 sardine: a comparison of SAM results performed at EWG 15-11 and 14-14.

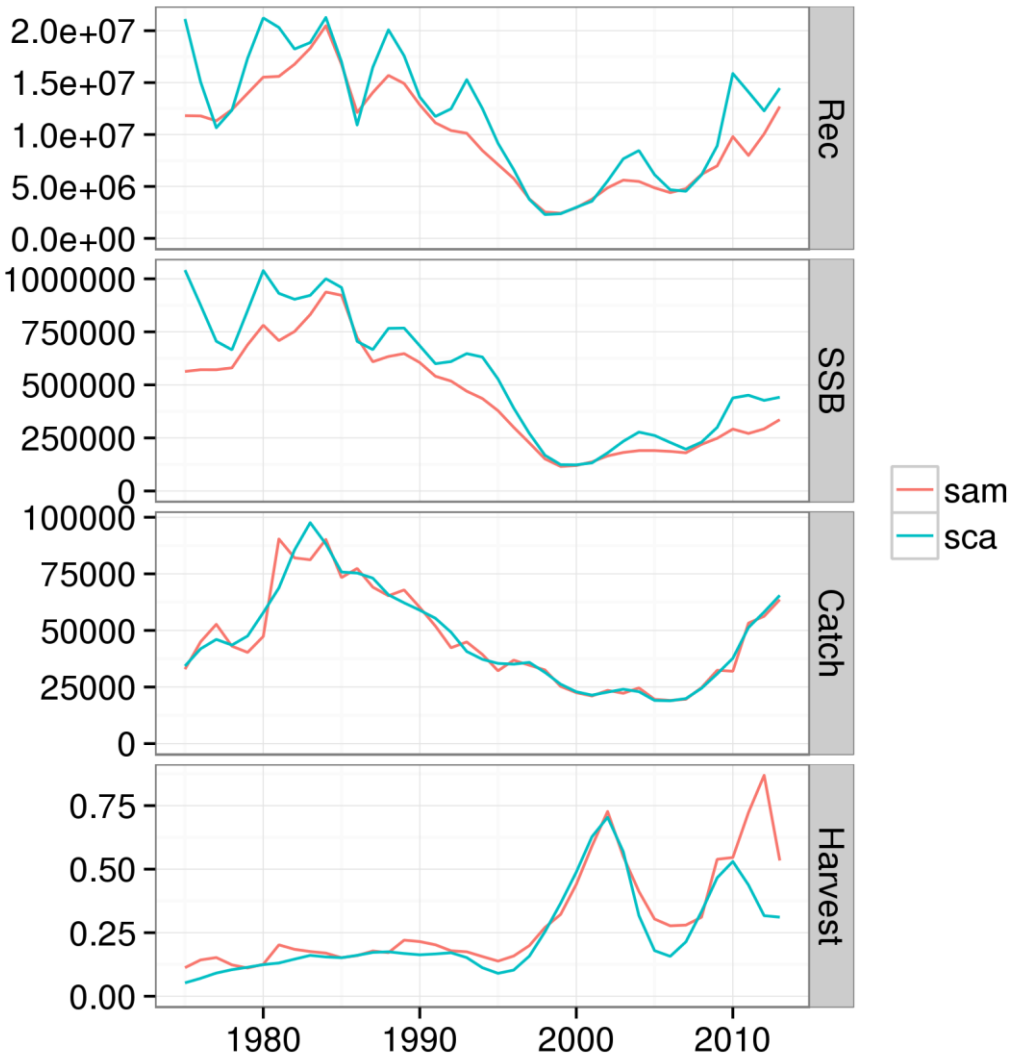


Figure 18: GSA 17 – 18 sardine: a comparison of stock assessment results for sardine using SAM and SCA (in a4a).

4.2.4 Updated stock-recruit estimates

The changes in the assessment timing settings altered the stock-recruit estimates only in the scale of the SSB (Figure 19).

The two key issues identified for reference point estimation of anchovy are exemplified for sardine, namely:

(1) Sardine recruitment appears to continually increase with increasing SSB (Figure 19). As a result, high fishing mortalities very quickly impact recruitment in contrast to other stocks where recruitment may not be impaired considerably at low SSB.

(2) EWG-14-19 noted the possibility of alternative environmental regimes affecting the recruitment of sardine and addressed this via a sensitivity of the reference points to a suitably chosen subset or the entire time period. To address the possibility of changes in productivity, *Peterman's productivity method* was applied to the sardine data to estimate time-varying recruitment productivity (slope at the origin of the stock-

recruit curve). A Kalman filter was used to estimate a random walk (heavily autocorrelated) time-varying slope at the origin.
While it is clear that the productivity of the estimated stock has varied over time with a marked dip in productivity in the late 1990s (Figure 20) , the current level is close to the average of the entire time series and justifies the use of the entire time period to estimate the Fmsy reference point.

On the basis of (1) and (2) above, a hockey-stick with a fixed breakpoint of the mean SSB was used to estimate Fmsy from the entire time series, similar to anchovy.

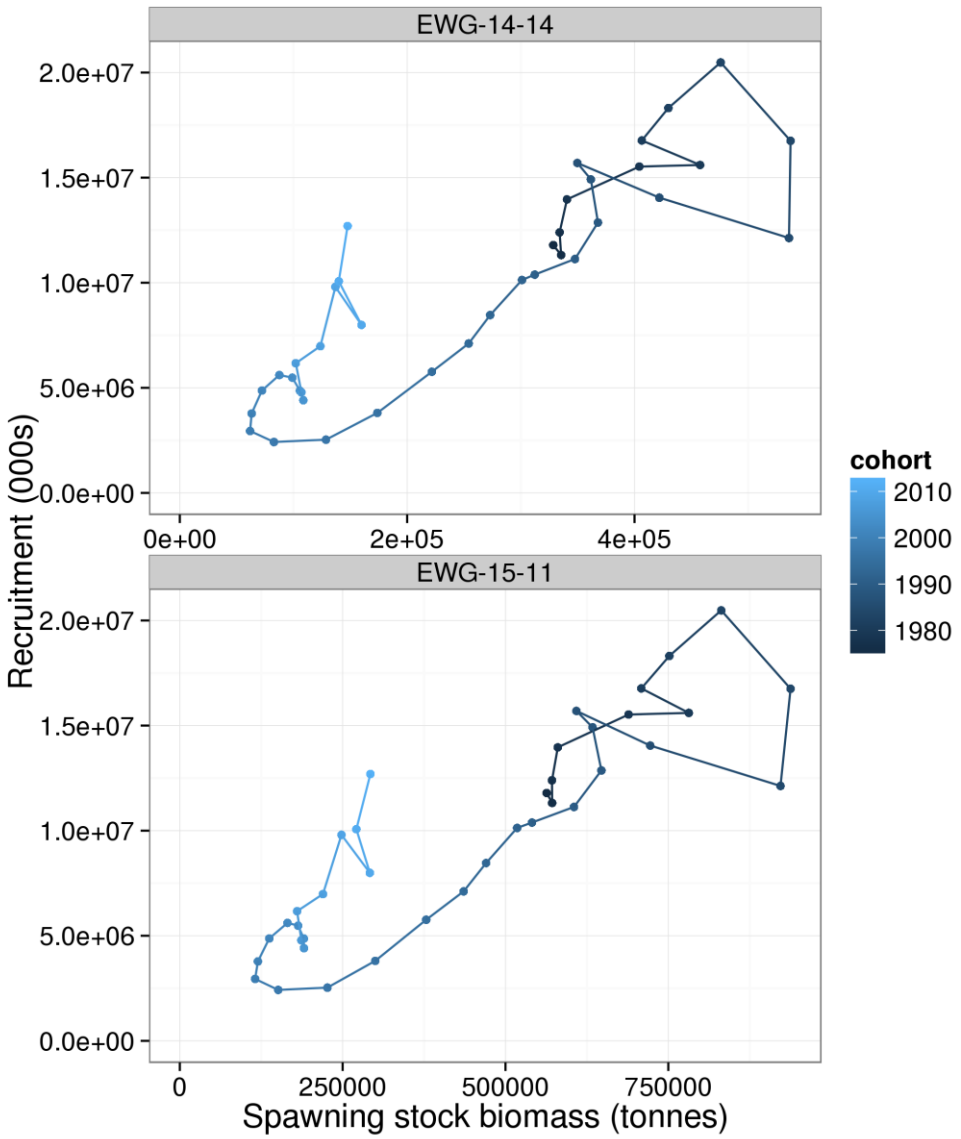


Figure 19: GSA 17-18 sardine: a comparison of stock recruitment relationship estimated during EWG 14-14 and EWG 15-11.

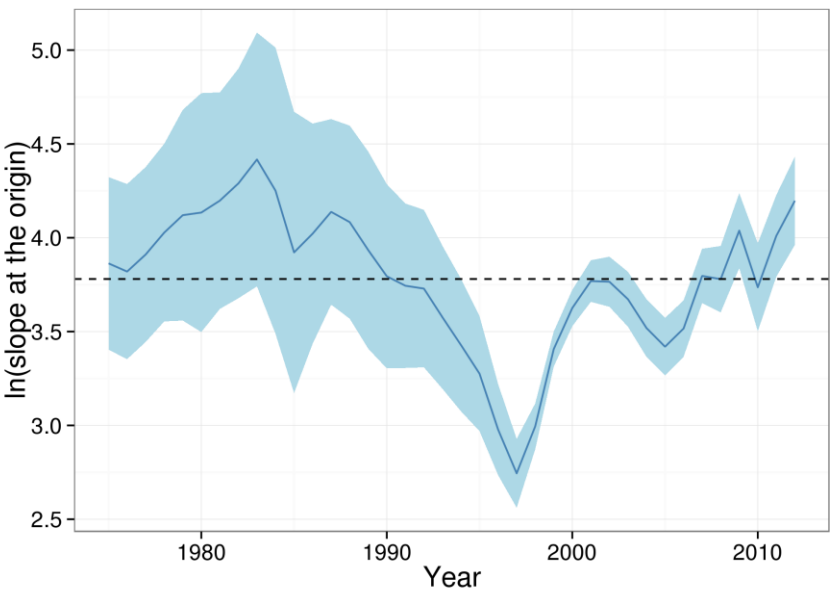


Figure 20: Sardine GSA 17-18 productivity time series estimate using Kalman filter.

4.2.5 Estimated sardine reference points

Many attempts were made to simulate the sardine populations using specifically developed code but many of these populations crashed. Finally, EqSim was settled upon to be used to estimate sardine reference F_{msy} point on the basis of:

- Hockey-stick recruitment model with fixed breakpoint at the mean SSB (approximately 446,000 tonnes) (Figure 9);
- First-order autocorrelated recruitment residuals to account for the strongly autocorrelated nature of the SR estimates (Figure 21). The recruitment time series consists of an elongated loop in the SR plane.

The observed catches fall above the simulated median yield curve (Figure 22), however, it is again important to note that the observed catches are not equilibrium points that can be sustained indefinitely at the fishing mortality rates observed. Indeed, the strength of the autocorrelation in the residuals (over the time-span observed) demonstrates that higher yields may only be available during periods of good environmental conditions and may not be expected typically.
Different values of the reference points (and ranges based on 5% reduction in MSY, estimated using the *eqsim_range* function in the *msy* package) are simulated depending on whether the mean or median catches are used:

- On the basis of mean simulated catches: F_{msy} = 0.16; F_{lower} =0.1, F_{upper} =0.25;
- On the basis of median simulated catches: **F_{msy} = 0.08; F_{lower} = 0.065, F_{upper} = 0.11**;

ICES (2015) recommends that where the catches are skewed the median provides a more robust estimate of the reference points. Therefore, the median-catch based MSY reference points are proposed for sardine (highlighted in bold above). The estimated F_{msy} is close to the centre of the range of estimates of Fmsy from EWG-14-19 (0.057-0.198).

The same approach (and associated limitations) used for defining biological reference points for anchovy was applied to sardine resulting in candidate B_{lim} = 223,000 and B_{pa} = 446,000 tonnes. These were used in subsequent management strategy evaluations.

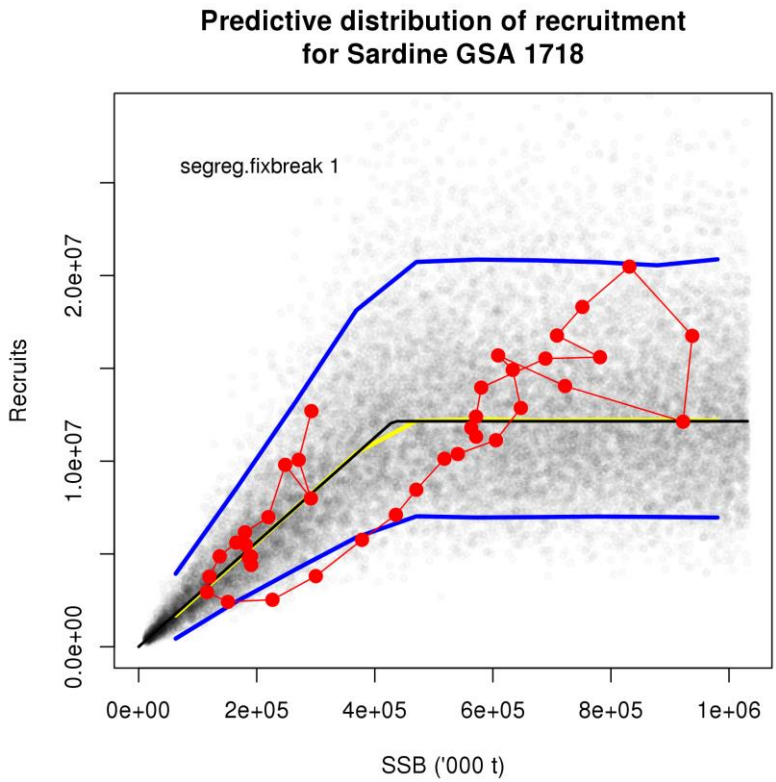


Figure 21: GSA 17-18 sardine: segmented hockey-stick with a fixed breakpoint at mean SSB. Note the x-axis units are in tonnes, not thousand tonnes.

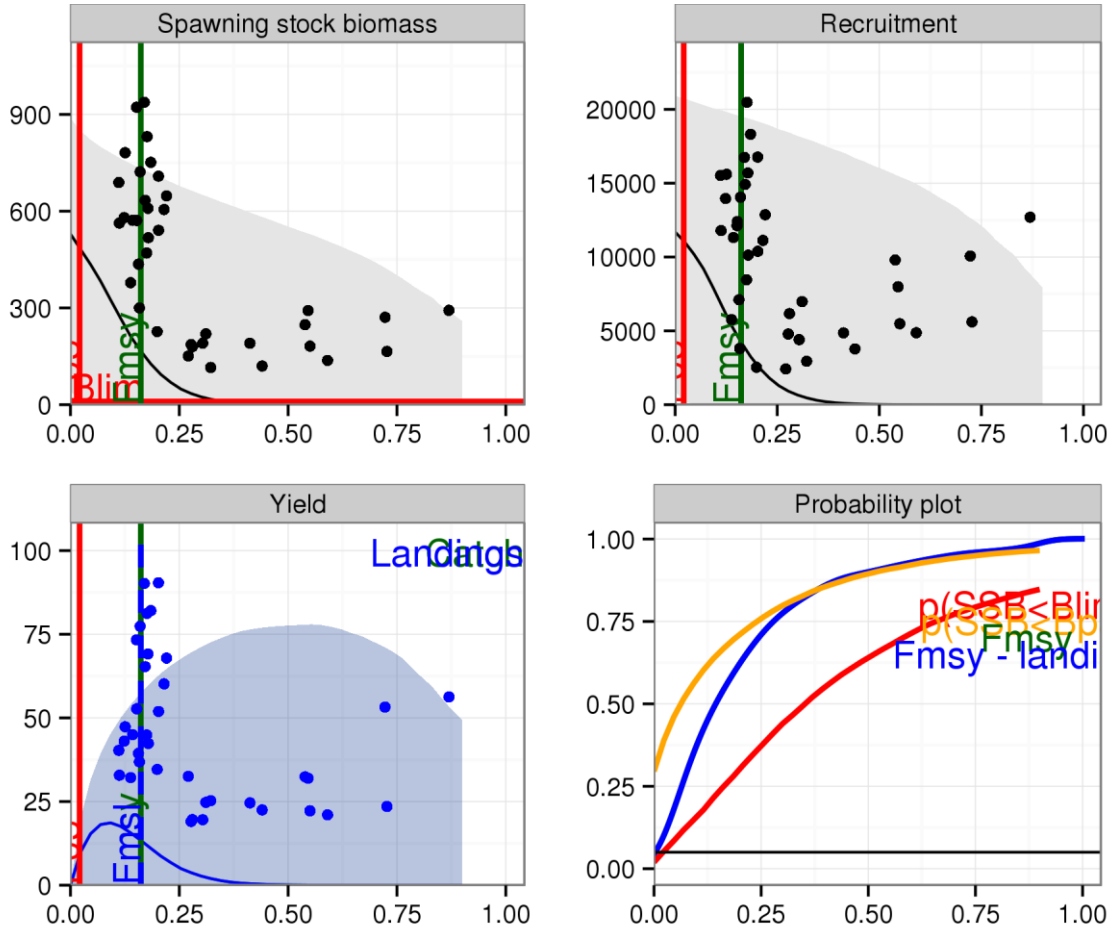


Figure 22: GSA 17 – 18 sardine: EqSim simulations using a fixed breakpoint (mean SSB) hockey-stick model and autocorrelated recruitment. Note that arbitrary B_{lim} values were used to allow the plotting routines to work and hence the probabilities associated with SSB (bottom-right plot) should not be interpreted.

4.2.6 Management strategy evaluations

The management strategy evaluations explored for sardine had the same structure as anchovy with the sardine assessment (closest fitting statistical catch-at-age model). Importantly, it was possible to simulate the sardine population forward here, which previously proved very difficult.

Overall, the findings of the sardine MSE are:

9. Moving to MSY will result in considerable decrease in catches.
10. The catches are variable (high CVs) throughout reflecting the variable, autocorrelated nature of recruitment in the stock.
11. The probability of being below B_{lim} is relatively high throughout.
12. Similar to anchovy, the escapement strategy does not appear to offer more benefit over the HCR in terms of the probability of SSB < B_{lim}. This reflects the choice of $B_{escapement} = B_{lim}$, as the HCR adjusts up to B_{pa} but the escapement strategy implemented sets fishing mortality at the target when SSB > B_{lim}.

A comparative illustration of the immediate move to Fmsy is shown in Figure 12.
No further time was available to investigate the MSE output but broadly the suggested F_{msy} reference points offer relatively stable population projections compared to previous attempts. Choice of

biological safeguards will be key to the performance of given startegies in safeguarding stock replenishment and future yields.

Table 10. GSA 17-18 sardine: management strategy evaluation results. Scenarios are given per column where "Now" refers to an immediate move to the target F, 2018: a move to the target by 2018, etc.

		Scenario											
		Fmsy	**Flow**	**Fupp**	**Bescape**	**Fmsy**	**Flow**	**Fupp**	**Bescape**	**Fmsy**	**Flow**	**Fupp**	**Bescape**
Metric	**Year**	**Now**	**Now**	**Now**	**Now**	**2018**	**2018**	**2018**	**2018**	**2020**	**2020**	**2020**	**2020**
SSB	2015	423324	425478	419783	418082	402108	402388	401629	378993	399690	399900	399330	377491
P(SSB < Blim)	2015	0.11	0.11	0.11	0.11	0.13	0.13	0.13	0.19	0.14	0.14	0.14	0.22
P(SSB < Bpa)	2015	0.56	0.56	0.58	0.57	0.61	0.61	0.61	0.7	0.66	0.66	0.66	0.72
Catch	2015	18527	15052	23957	20634	27328	26622	28523	27447	27389	26959	28121	31952
CV(Catch)	2015	0.647	0.654	0.636	0.5	0.867	0.888	0.835	0.912	1.041	1.059	1.013	1.133
SSB	2018	439178	446251	426824	427949	409986	410323	406145	381087	409639	413676	409407	379840
P(SSB < Blim)	2018	0.14	0.13	0.16	0.19	0.2	0.19	0.2	0.26	0.19	0.17	0.19	0.29
P(SSB < Bpa)	2018	0.5	0.49	0.51	0.5	0.56	0.56	0.58	0.59	0.58	0.57	0.57	0.6
Catch	2018	18040	14857	21550	21975	14676	12123	20120	16198	22326	20058	20720	28263
CV(Catch)	2018	0.767	0.792	0.798	0.511	0.891	0.882	0.844	0.696	1.485	1.351	1.073	0.933
SSB	2020	434392	443707	421397	418537	414849	418767	405899	387982	409263	413638	408303	378199
P(SSB < Blim)	2020	0.13	0.11	0.15	0.17	0.2	0.2	0.21	0.29	0.16	0.13	0.15	0.26
P(SSB < Bpa)	2020	0.47	0.47	0.5	0.52	0.51	0.49	0.53	0.58	0.54	0.51	0.52	0.59
Catch	2020	17995	15676	22177	21367	16233	13782	20119	18550	15335	12462	20449	17080
CV(Catch)	2020	0.788	0.737	0.776	0.566	0.886	0.855	0.862	0.675	0.91	0.907	0.848	0.685
SSB	2025	467895	477632	454190	446333	457320	464122	445618	430592	457102	465652	447465	431890
P(SSB < Blim)	2025	0.18	0.18	0.18	0.23	0.18	0.18	0.19	0.25	0.19	0.19	0.19	0.25
P(SSB < Bpa)	2025	0.44	0.44	0.47	0.48	0.45	0.45	0.47	0.51	0.46	0.44	0.47	0.48
Catch	2025	19118	16382	23621	21674	17901	15092	22376	20424	18647	15335	22908	20324
CV(Catch)	2025	0.747	0.74	0.775	0.6	0.799	0.795	0.809	0.658	0.793	0.8	0.79	0.667

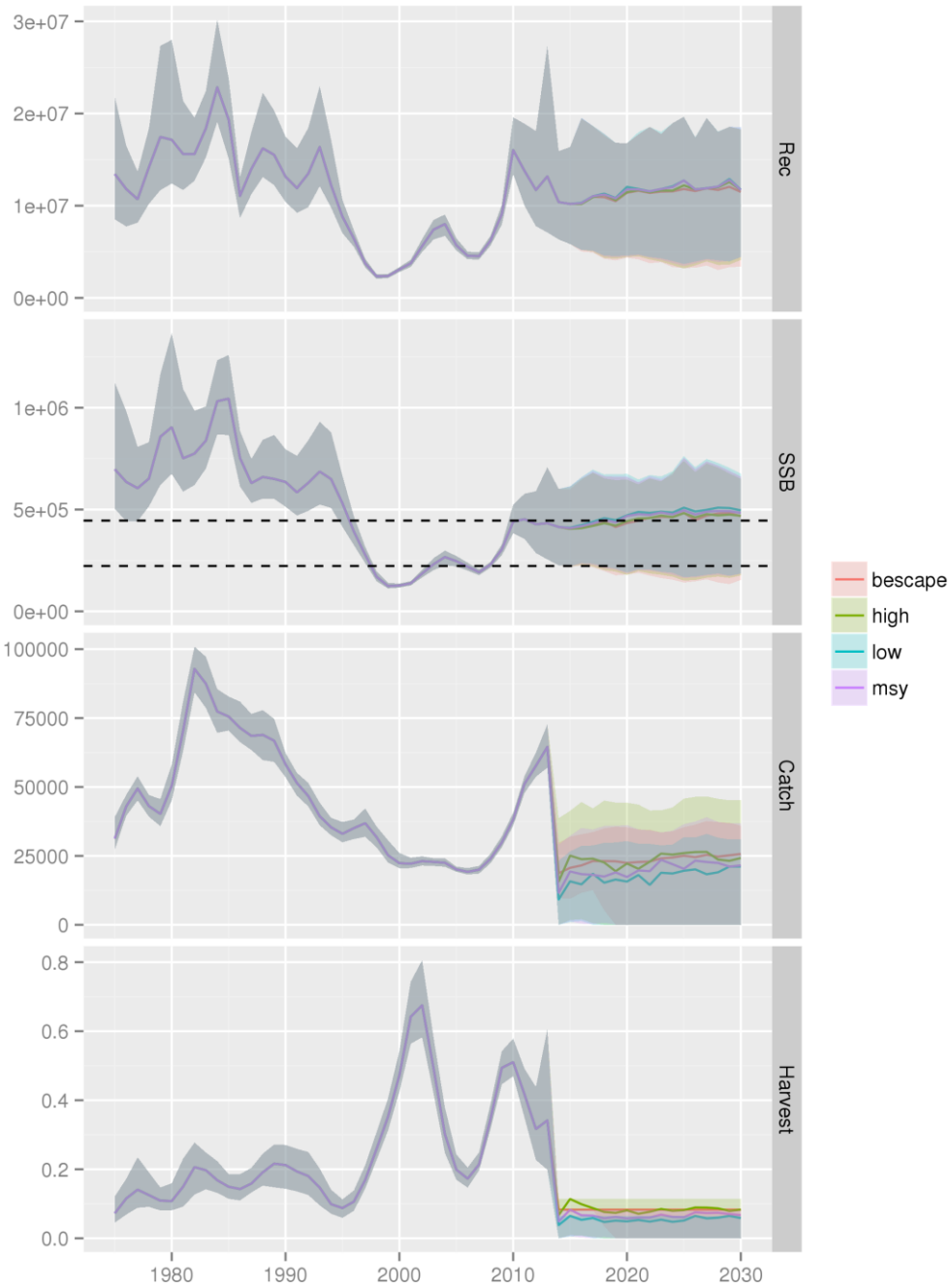


Figure 23. GSA 17-18 sardine: illustration of the immediate move to management "Now" scenarios.

5 DATA QUALITY AND COMPLETENESS

Anchovy in GSA 17-18

The main issue identified was the lack of Croatian data prior to 2013. Croatia has been a member of the EU since 2013 so there is no legal obligation for submitting data before this year. A future specific data call for historical Croatian data prior to 2013 may solve this issue. Secondly, catch at age data for anchovy are not fully available. This is due to the fact that discard data are available only sporadically for a limited proportion of Italian and Slovenian fleets, and completely absent for the Croatian fleet. Finally, the age-reading protocol for anchovy in the Adriatic (GSA 17 and 18) was revised in 2015, but there was no information provided by the member states on how the revised age-reading was applied (e.g. only to 2014 data or to the whole DCF series).

Sardine in GSA 17-18

The main issue identified was the lack of Croatian data prior to 2013. Croatia has been a member of the EU since 2013 so there is no legal obligation for submitting data before this year. A future specific data call for historical Croatian data prior to 2013 may solve this issue. Secondly, catch at age data for anchovy are not fully available. This is due to the fact that discard data are available only sporadically for a limited proportion of Italian and Slovenian fleets, and completely absent for the Croatian fleet. The 2014 data also appear to be in error with very large catches from Croatia. Upon a request to the Croatian authorities, these data were corrected on the last day of the meeting and it was therefore not possible to include them in the analyses.

6 REFERENCES

Jardim, E., Millar, C. P., Mosqueira, I., Scott, F., Osio, G. C., Ferretti, M., Alzorriz, N., and Orio, A. (2015). What if stock assessment is as simple as a linear model? The a4a initiative. – ICES Journal of Marine Science, 72 (1): 232-236.

ICES (2015). Report of the joint ICES -MyFISH workshop to consider the basis for fmsy ranges for all stocks (WKMSYREF3), 17-21 november 2014, charlottenlund, denmark. ICES CM 2014/ACOM:64 2(4): 156pp.

Minto, C., Flemming, J.M., Britten, G.L., and Worm, B. 2014. Productivity dynamics of atlantic cod. Canadian Journal of Fisheries and Aquatic Sciences 71 (2): 203-216.

Peterman, R.M., Pyper, B.J., and MacGregor, B.W. 2003. Use of the kalman filter to reconstruct historical trends in productivity of Bristol Bay sockeye salmon (Oncorhynchus nerka). Canadian Journal of Fisheries and Aquatic Sciences 60(7): 809-824.

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8 List of Background Documents

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