ICES IBPBass REPORT 2018

ICES Advisory Committee

ICES CM 2018/ACOM:54

Report of the Inter-benchmark Protocol on Sea Bass (*Dicentrarchus labrax*) in divisions 8.ab (Bay of Biscay North and Central) (IBPBass 2018)

July–September 2018

By correspondence

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Executive summary

The ICES Inter-benchmark protocol for sea bass in ICES subareas 8.a and b (IBPBass) was held by correspondence between July and 15 September 2018. The meeting was chaired by Höskuldur Björnsson, Iceland, reviewed by Niels Hintzen, Netherlands, and attended by three participants from two nations (France and UK).

The ICES Inter-benchmark was conducted to set the reference points, if possible, for this recently benchmarked stock (WKBass; ICES, 2018). This report is structured around the terms of reference covering this point.

The Inter-benchmark concluded that the stock–recruitment relationship is type 6 (ICES, 2017a). Due to a lack of contrast in the data and the narrow range in landings and estimated recruitment, biomass reference points are very constraining.

Table 1. Sea bass in divisions 8.a–b. Reference points. All weights are in tonnes.

Framework	Reference point	Value	Technical basis
MSY approach	MSY $B_{trigger}$	16 688	B_{pa}
	F_{MSY}	0.123	F that maximizes median long-term yield in stochastic simulations under constant F exploitation; constrained by the requirement that $F_{MSY} \le F_{pa}$
	$F_{MSY\ lower}$	0.123	F that maximizes 5% long-term yield in stochastic simulations under constant F exploitation
Precautionary approach	B_{lim}	11 920	B_{pa} / exp(CV * 1.645)
	B_{pa}	16 888	Lowest observed SSB
	F_{lim}	0.172	F that, In equilibrium gives a 50% probability of SSB>B_{lim}
	F_{pa}	0.123	F_{pa} = F_{lim} / exp(CV * 1.645)
Management plan	SSB_{mgt}	Not defined	
	F_{mgt}	Not defined	

1 Terms of reference

IBPBass–Inter-Benchmark Protocol on Sea bass in 8.ab

2018/x/ACOMxx An **Inter-Benchmark of Sea Bass in Divisions 8.a and b** (IBPBass), chaired by Höskuldur Björnsson, Iceland and attended by one invited external expert, Niels Hintzen, Netherlands will be established and work by correspondence to:

a) Re-examine and update, if appropriate, MSY and PA reference points according to ICES guidelines (*see* Technical document on reference points);

Stocks	Stock leader	Stock assessor
Sea bass (*Dicentrarchus labrax*) in Divisions 8.a,b (Bay of Biscay North and Central)	Mickael Drogou	Mathieu WOILLEZ

The Inter-Benchmark Workshop will report by 15 September 2018 for the attention of ACOM.

2 Sea bass (*Dicentrarchus labrax*) in divisions 8.a–b (Bay of Biscay north and central) biological reference points (bss.27.8ab)

2.1 Current reference points

There are no current Biological Reference Points for the Sea bass (*Dicentrarchus labrax*) in divisions 8.a–b (Bay of Biscay North and Central).

2.2 Source of data

The sea bass in divisions 8.a–b stock is intending to be a category 1 stock with an analytical assessment based on a Stock Synthesis 3 (SS3) modelling approach. Data used in the analysis were taken from the final assessment model obtained during (ICES, 2018).

2.3 Methods

All analyses were conducted with EQSIM in R. To do so, the SS3 model output was converted to an FLStock object in order to run EQSIM. All model and data selection setting are presented in Table 1.

Table 2. Sea bass in divisions 8.a–b; IBPBass 2018. Model and data selection settings.

DATA AND PARAMETERS	SETTING	COMMENTS
SSB-recruitment data	Full dataseries (year classes 1985–2016)	
Exclusion of extreme values (option extreme.trim)	No	
Trimming of R values	Yes	-3,+3 Standard deviations
Mean weights and proportion mature; natural mortality	2007–2016	
Exploitation pattern	2007–2016	
Assessment error in the advisory year. CV of F	0.212	Set ICES default value
Autocorrelation in assessment error in the advisory year	0.423	Set ICES default value

2.4 Results

2.4.1 Stock–recruitment relationship

The S–R relationship was explored using age 0 as age of recruitment. As no fishing mortality occurs for most fish below or equal to age 3, we assumed that considering age 3 as age of recruitment, rather than age 0, would not provide any better information. Several models were fitted to the S–R relationship (Figure 1). The most statistically appropriate model seems to be a Ricker model, which model some density-dependence at high SSB. However, a segmented regression was considered as an appropriate S–R model given the lack of biologically understandable trends in S–R that would justify a density-dependent process occurring at current stock state.

Based on the S–R relationship classification proposed by ICES (2017a), the sea bass stock can be categorised as a type 6 S–R plot. This is a stock with a narrow dynamic range of SSB and showing no evidence of past or present impaired recruitment. Thus, it is justified to consider B_{pa} at the breakpoint of a segmented regression (Figure 1).

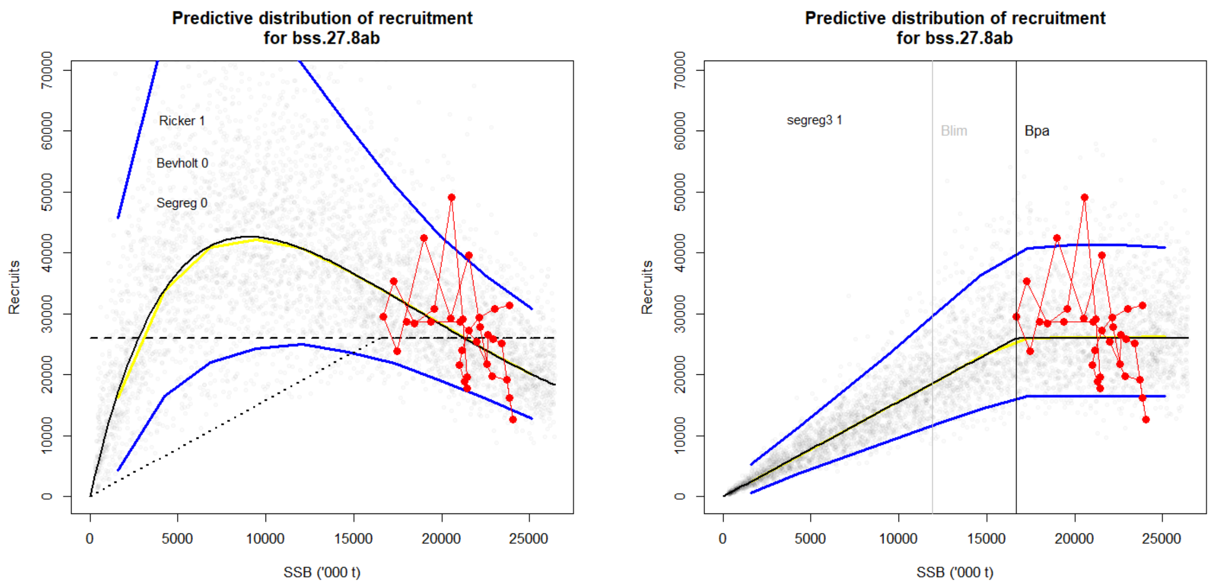

Figure 1. Sea bass in divisions 8.a–b; IBPBass 2018. Stock–recruitment relationship.

B_{pa} is estimated to be equal to B_{loss}. This implies a B_{pa} of 16 688 tonnes with a $B_{lim} = B_{pa}$ / exp(CV * 1.645) = B_{pa} / 1.4 = 11 920 tonnes, with CV taken equal to 0.2045 (default value recommended by ICES, (2017a).

2.4.2 Yield and SSB

F_{MSY} is estimated from the base run and taken as the peak of the median landings equilibrium yield curve. The F_{MSY} range is calculated as those F values associated with median yield that is 95% of the peak of the median yield curve.

2.5 Eqsim analysis

2.5.1 Segmented regression method, full SR time-series, without $B_{trigger}$

F_{lim} and F_{pa} was estimated using the EqSim software to run the simulation with $B_{trigger}$ set to 0 (i.e. no $B_{trigger}$ used), $F_{cv} = F_{phi} = 0$ (i.e. no assessment/advice error set for this first run) and the segmented regression as the only SR method. F_{lim} is estimated as the fishing mortality that, at equilibrium from a long-term stochastic projection, leads to a 50% probability of having SSB above B_{lim}. F_{lim} was estimated to be 0.172, and F_{pa} is estimated to be 0.123 based on the following equation [$F_{pa} = F_{lim}$/exp(CV * 1.645)].

Initially, F_{MSY} is calculated as the fishing mortality that maximises median long-term yield in stochastic simulations under constant F exploitation (i.e. without MSY $B_{trigger}$). Using the same simulation method with the inclusion of assessment/advice error default values: F_{cv}=0.212, F_{phi}=0.423 from WKMSYREF4 (ICES, 2016). F_{MSY} = 0.138 and is thus above F_{pa} = 0.123, see Figure 2 and Figure 3. In such a case, F_{MSY} is reduced to F_{pa} (i.e. F_{MSY} cannot exceed F_{pa}).

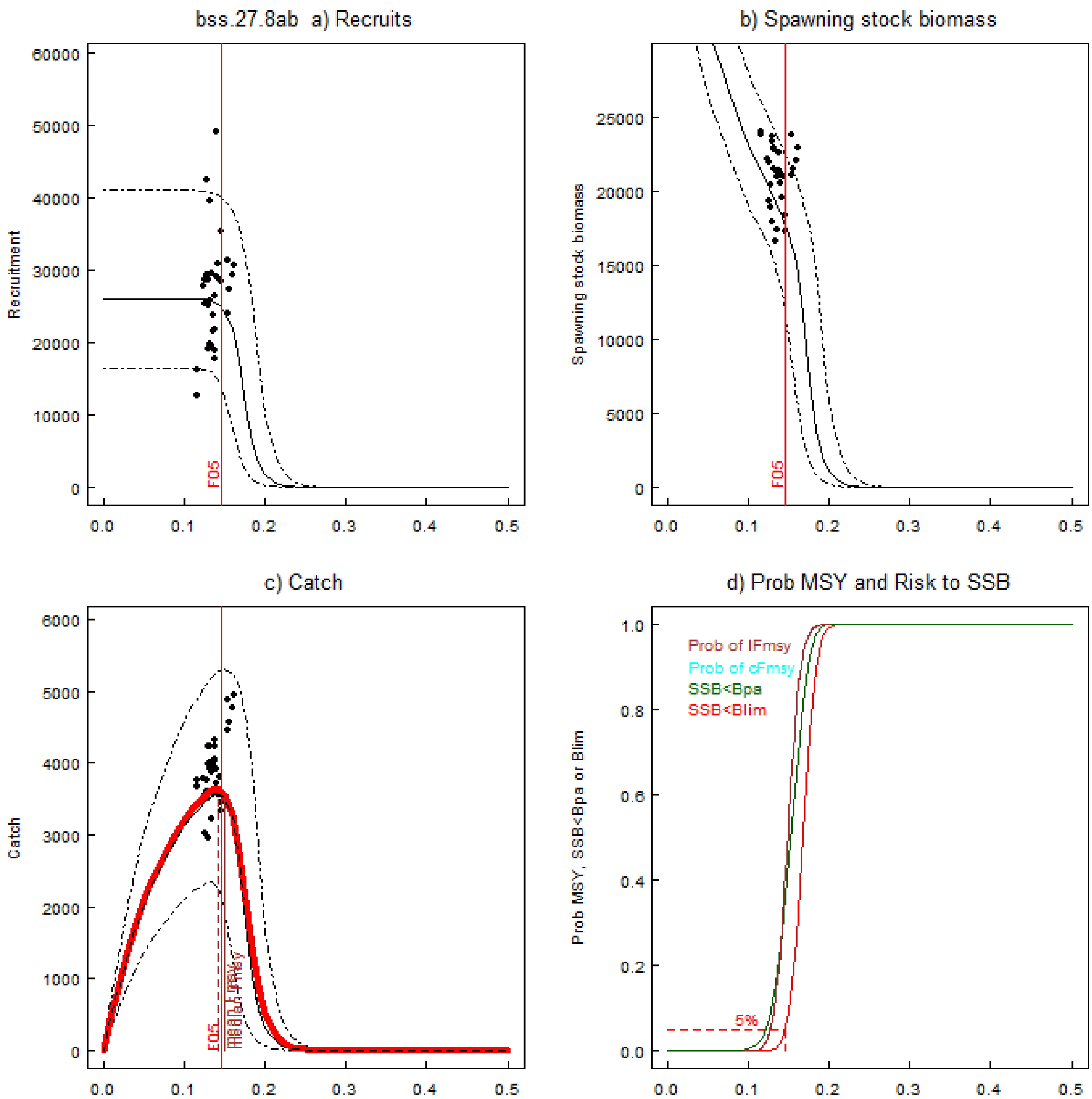

Figure 2. Sea bass in divisions 8.a–b; IBPBass 2018. Eqsim summary plot without $B_{trigger}$. Panels a to c: historic values (dots) median (solid black) and 90% intervals (dotted black) recruitment, SSB and landings for exploitation at fixed values of F. Panel c also shows mean landings (red solid line). Panel d shows the probability of SSB<B_{lim} (red), SSB<B_{pa} (green) and the cumulative distribution of F_{MSY} based on yield as landings (brown).

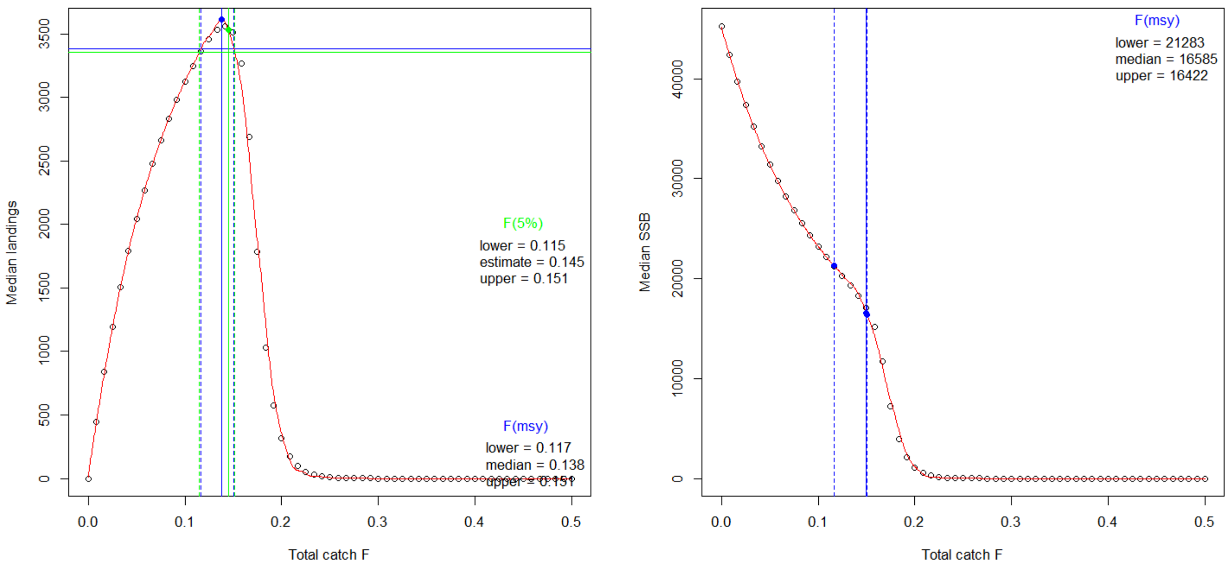

Figure 3. Sea bass in divisions 8.a–b; IBPBass 2018. Left plot is Eqsim median landings yield curve with estimated reference points without $B_{trigger}$. Blue lines: F_{MSY} estimate (solid) and range at 95% of maximum yield (dotted). Green lines: F (5%) estimate (solid) and range at 95% of yield implied by F (5%) (Dotted). Right plot is Eqsim median SSB curve with estimated reference points without $B_{trigger}$. Blue dots: lower and upper SSB corresponding to lower and upper F_{MSY}.

2.5.2 Segmented regression method, full SR time-series, with $B_{trigger}$

ICES defines MSY $B_{trigger}$ as the 5th percentile of the distribution of SSB when fishing at F_{MSY}. However if the stock has not been fished at F_{MSY}, as in this case, then MSY $B_{trigger}$ is set to B_{pa}.

For this final run, assessment/advice error were included using the same default values and MSY $B_{trigger}$ was set to 16 688 tonnes. As shown in Figure 4, EqSim output $F_{p.05}$ (fishing mortality that gives 5% probability of SSB below B_{lim}) equals 0.186. As F_{MSY} estimated in the first run is below $F_{p.05}$, then F_{MSY} is kept to 0.123.

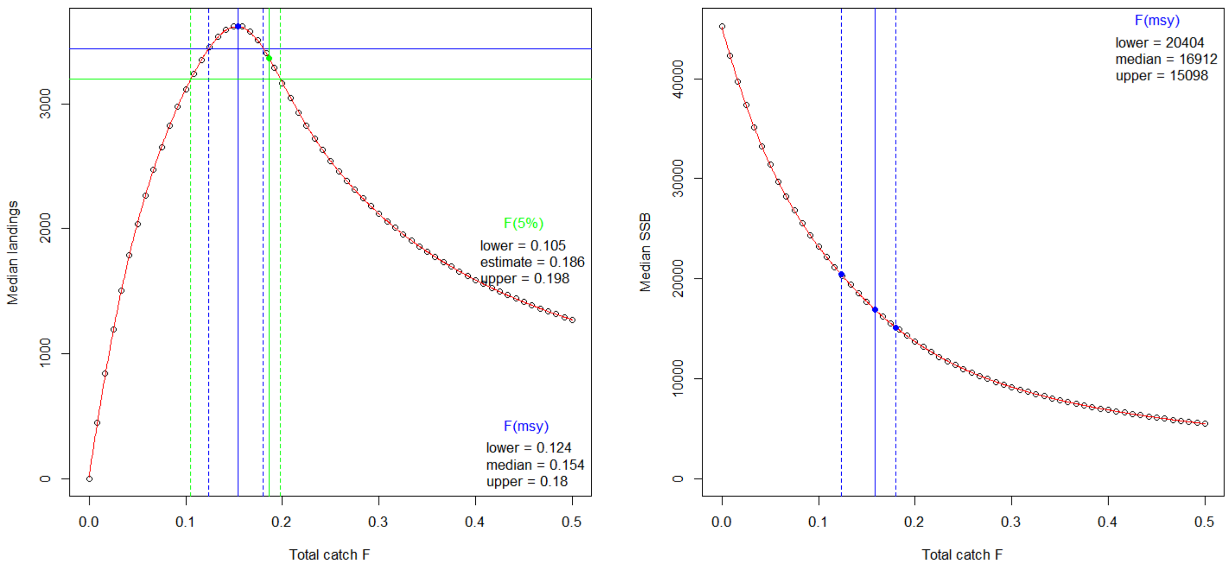

Figure 4. Sea bass in divisions 8.a–b; IBPBass 2018. Eqsim median landings yield curve with estimated reference points with $B_{trigger}$. Blue lines: F_{MSY} estimate (solid) and range at 95% of maximum yield (dotted). Green lines: F (5%) estimate (solid) and range at 95% of yield implied by F (5%) (Dotted).

2.6 Proposed reference points

For the sea bass in division 8.ab stock, the proposed reference points are reported in Table 3. Those proposed reference points are then displayed on the diagnostic plots of the final assessment (Figure 5), i.e. the recruitment, the SSB and the F_{bar} (computed from ages 4–15) time-series.

Table 3. Sea bass in divisions 8.a–b; IBPBass 2018. Summary table of proposed stock reference points for method Eqsim.

STOCK		Sea bass divisions 8ab	
PA Reference points	Value	Rational	
B_{lim}	11 920 t	B_{pa} / 1.4	
B_{pa}	16 688 t	Lowest observed SSB	
F_{lim}	0.172	In equilibrium gives a 50% probability of SSB>B_{lim}	
F_{pa}	0.123	F_{pa} = F_{lim} / 1.4	
MSY Reference point	Value		
F_{MSY} without $B_{trigger}$	0.138		
F_{MSY} lower without $B_{trigger}$	0.117		
F_{MSY} upper without $B_{trigger}$	0.150		
$F_{P.05}$ (5% risk to B_{lim} without $B_{trigger}$)	0.145		
F_{MSY} upper precautionary without $B_{trigger}$	0.151		
MSY $B_{trigger}$	16 688 t	Value reduced to B_{pa}. Never fished at F_{MSY} before. (originally equals to 17 715 t)	
$F_{P.05}$ (5% risk to B_{lim} with $B_{trigger}$)	0.186		With WKMSYREF4 default values for assessment/advice error
F_{MSY} with $B_{trigger}$	0.123	Reduced value (originally equals to 0.154)	
F_{MSY} lower with $B_{trigger}$	0.123		
F_{MSY} upper with $B_{trigger}$	0.180		
F_{MSY} upper precautionary with $B_{trigger}$	0.180		
Median SSB at F_{MSY}	20 528 t		
Median SSB lower precautionary (median at F_{MSY} upper precautionary)	15 123 t		
Median SSB upper (median at F_{MSY} lower)	20 528 t		

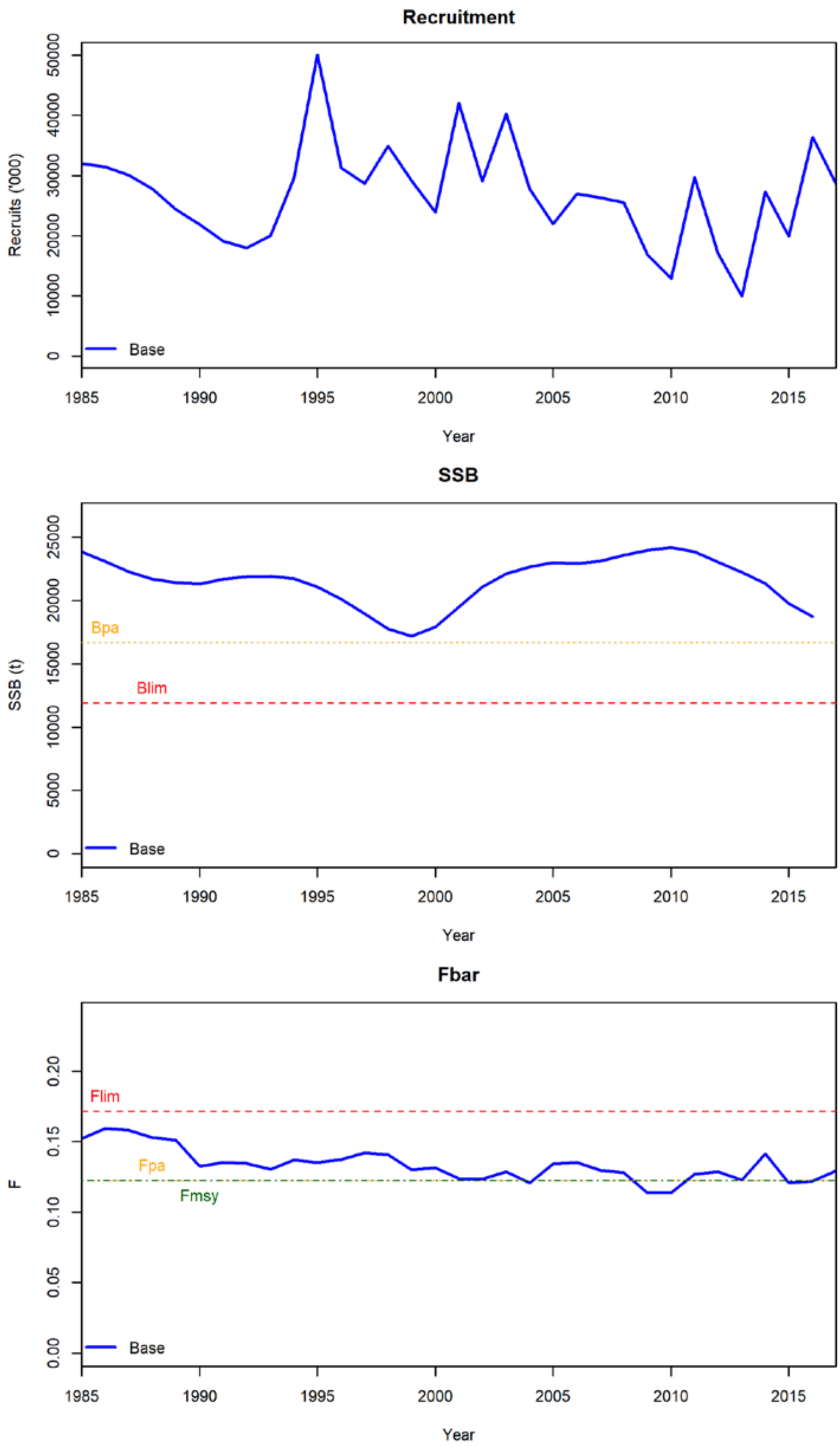

Figure 5. Sea bass in divisions 8.a–b; IBPBass 2018. Recruitment, SSB and F_{bar} time-series with IBPBass 2018 biological reference points.

3 Reviewer's report

3.1 Review from Höskuldur Björnsson

The work is based on the SS3 assessment that is not supposed to be reviewed here. How review on reference points can be done in this case without reviewing the assessment, is not clear. Trends in fishing mortality and stock size shown from different reports are quite different. In the 2017 assessment (WGBIE 2017 Report) the F from 1985–2000 is considerably lower than from 2001–2015 and SSB has been decreasing with time while in the IPB2018 F has been reducing with time and SSB increasing. All changes are though small in both versions.

One question that arises is why the SS3 model was not used for the HCR simulations, using results from an assessment model in simulation model based on very different premises is always questionable. The SS3 is of course age-based and the M by age is hopefully identical with what is used in the simulations. M by size is not the same, and using fixed M by age would therefore have been more sensible also giving same M by size. Most likely this approach should not give a major problem, F by age from SS3 might be an underestimate, but the advice would also be similar underestimate. This conversion from a length to age-based would still need some checking; therefore, some of the review done, is based on looking directly at development of the indices and catches rather than the results of the EQSIM model. Looking at the settings of the EQSIM model, the choice of SSB model, i.e. hockey-stick with breakpoint at B_{loss} seems sensible.

The assessment indicates relatively even landings, but the recreational landings are only known for one year and the same proportion used for other years. Lpue (used in the assessment) is stable, and if used in the assessment, should lead to stable stock if catches are not very variable as other data used in the assessment model are not "strong enough" to override.

Commercial length distributions are quite similar from year to year. The left part seems nearly identical between years, indicating relatively stable recruitment or that the selection is very sharp and not changing much.

Fit of the model to the lpue index is not good, but the contrast in data is so small that a good fit is not expected, whatever good fit means. The modelled lpue is as expected more stable than the observed one.

Looking at development of SSB, Recruitment and F since 1985 from SS3 there are indications that the fisheries have been sustainable. Range of SSB is between 18 and 25 thousand tonnes, F seems to be between 0.12 and 0.15 and no trend is seen in recruitment. Recruitment is though difficult to estimate, except in the last few years where age data are available.

Looking at things in a different way that can be justified as fishing mortality is very stable, B_{loss} is the lowest value in a 30 year time-series with reasonably stable F and therefore a candidate for B_{lim}. ($P(SSB < B_{lim}) < 0.05$.) The average F in the period would then be a candidate for F_{MSY} associated with $B_{trigger}=B_{lim}=B_{loss}$.

Setting B_{loss} as B_{pa} as done here is according to ICES procedures due to narrow dynamic range of the stock. As B_{lim} is $B_{loss}/1.4$, it would be expected that F leading to 5 percent probability of SSB < B_{lim} was higher than the average F over the simulation period. Why that is not the case is not clear but that result would fail on the commons sense test.

Following ICES procedures B_{lim}=B_{loss} is not acceptable as $B_{trigger}$=B_{pa} would then be ≈B_{loss}x1.4 and the stock most of time below $B_{trigger}$.

Then we come to the main problem, how could this assessment be considered as type 1?. 30–40% of the catches are unknown (perhaps not worse than discard problems elsewhere), and the tuning data based on lpue index from commercial catch. Age data are very limited not allowing check of the lpue index against "converged" assessment independent of the lpue index. Part of the problem with the assessment is that the range of stock size and fishing mortality is small, leading to little contrast in aggregated data and it is only recently that age disaggregated data are available.

Looking at the data from the perspective of index based assessment (type 3), it could be argued that F_{proxy} should be 20% lower than average F_{proxy} of last three decades, the 20% is some kind of precautionary buffer. The SS3 model can in this context be looked at as a filter on the lpue Index and is, like direct use of the lpue index dependent on the index being reasonably free of time-trends. Additionally, the recreational catches should reasonably constant proportion of total catches or at least without trend.

In recent decades, the average F has been around 0.13 or approximately 0.55*M. This might look like a rather low value, but M is assumed, and lowering M would lead to higher F but not change advice much.

Summary

1) Nothing is seriously wrong with the EQSIM analysis, except that it is based on uncertain assessment. Assessment bias or very high autocorrelation of the assessment error should be included.

2) The resulting F_{MSY} in the lower range of recent fishing mortality looks like a sensible result.

3) The main problems are unknown recreational catches, and possible trends in the tuning index.

3.2 Review from Niels Hintzen

3.2.1 General comments

There are hardly any data on age 0, so why would you consider a stock–recruitment relationship between age 0 and SSB? Why not age 3 and SSB?

Justification should be given why an age-based tool can be used for a length-based assessment. Age data were not part of the likelihood when fitting the model, why would we be able to trust the outcomes in age data?

Model fits seem to indicate an underestimation of young fish and overestimation of old fish. So, in a way, your productivity based on just observations, seems to be higher than estimated in the EQsim software.

Only a segmented regression relationship seems to have been fitted. Is there any reason to exclude e.g. Beverton and Holt, and Ricker? This is especially odd since in the assessment model itself, a Beverton–Holt relationship has been assumed with steepness of 0.999, which clearly is unrealistic.

You’ve taken a CV on SSB and F directly from the assessment model. Given the substantial retrospective in runs, I don’t think a CV ~0.1 is appropriate. Better to take default value of 1.4 as a multiplication factor.

3.2.2 Answers

In answer to your question specifically on the age-based tool being used. SS3 is an age-based assessment using length data and a growth model, which in this case is informed by age–length keys. The length data are converted to age data using the growth model and the output from the model is both age and length. The age–length data are part of the likelihood function. Only the age data from the output are formatted into the FLR structure, as is done with other models, so that it can be run with in the EqSim framework.

The assumed Beverton and Holt with steepness of 0.999 gives a model that shows no relationship, it's just a straight line through the cloud of points, similar to what would be given by the segmented regression after the breakpoint. This stock is very much environmentally driven, which masks any stock and recruit relationship, there are developments to include the environmental drivers in future assessments, but this is not available to the group yet.

I would agree with you that the CV on SSB and F are unrealistic and underestimate the full uncertainty in the model therefore the default values should be used.

3.2.3 Comments

There obviously is a difference between converting length data to age through a growth model and age data by itself. I presume ageing error is part of the reason why this approach it taken.

It's a bit tricky though, to fully understand how this impacts the estimation of reference points, given that younger ages seem to be underestimated and older ages overestimated (other than through a conservative approximation of productivity right now).

More than happy to assume environment is a large driver of recruitments; however, I'd still like to see a fit of the three main curves through the SR-pairs as I thought there could be some density-dependence at larger SSB sizes. You know best if that is realistic or not of course.

3.2.4 Answers

Figure 6. Sea bass in divisions 8.a–b; IBPBass 2018. Fits.

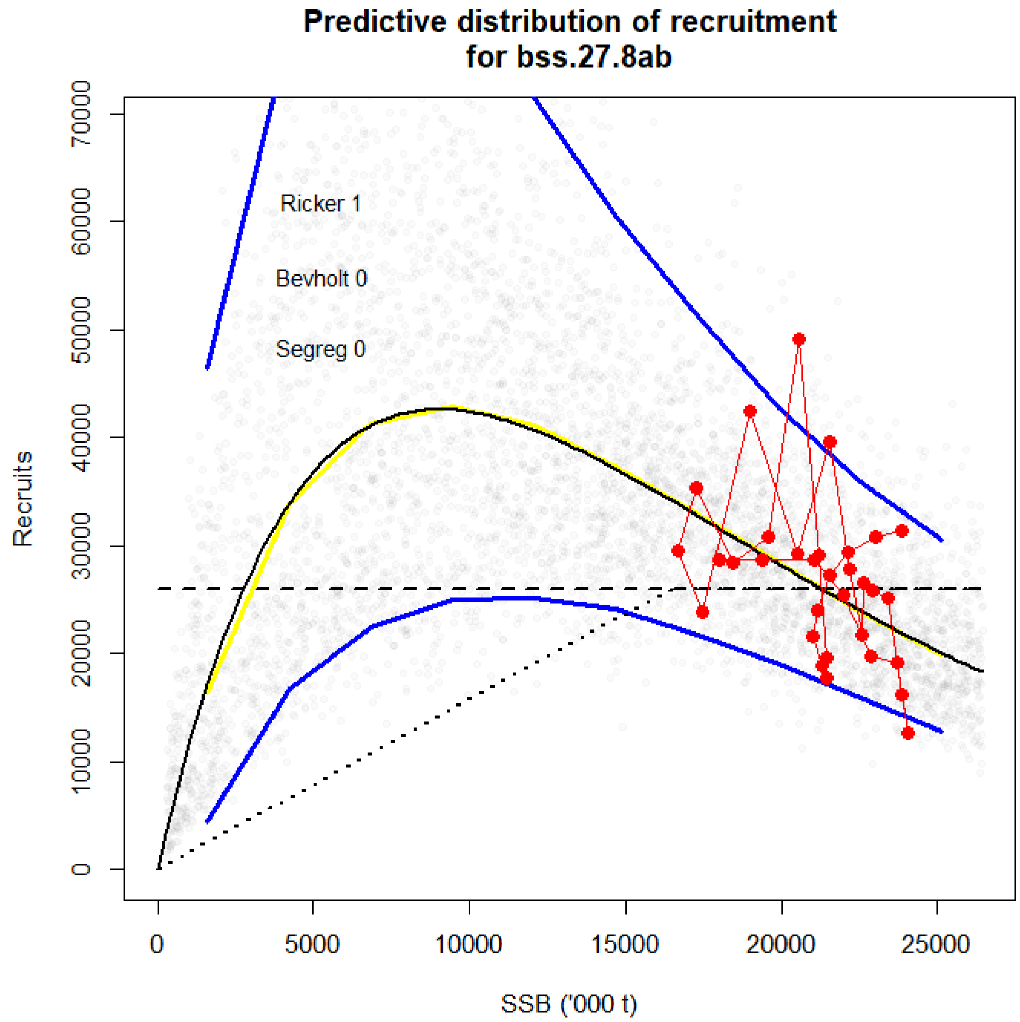

Figure 7. Sea bass in divisions 8.a–b; IBPBass 2018. Predictive distribution of recruitment.

As the model has weighted them so that the Ricker SR is the only one contributing, Fit1 and Fit2 are exactly the same. In other examples, the model can weight them, so that all three could contribute giving something quite different.

3.3 Final review from Niels Hintzen

Sea bass is assessed using predominantly length data using SS3. Age data are part of the modelling framework, but are not used in estimating parameters (excluded from the likelihood function, stated in the WGBIE report / benchmark report). As such, the age data that are obtained from the model fit, are only a verification tool rather than a true model fit. For this reason, EQsim, which is age-based, may not be the perfect candidate for reference point estimation. From a practical sense, it is the only one readily and reliably available.

I note that younger ages tend to get underestimated, and older ages get overestimated in the SS3 fit, which automatically leads to underestimation of productivity in any S–R relationship, driving the EQsim analyses. I consider this a precautionary approach.

The SS3 fits recruitment assuming a Beverton–Holt relationship with steepness of 0.999 (flat horizontal line). This affects recruitment estimation, but may not provide problems if the weight on this likelihood contribution aspect is minimal.

Fitting Ricker, B&H and segmented regression curves through the S–R pairs, show that statistically only a Ricker can be fitted through the dataset, suggesting high density-dependence. This relationship suggests that sea bass should be caught at much higher F_{MSY} values than currently is the case, and that equilibrium biomass is much lower than currently is the case. Current knowledge of the state of the stock from experts should weigh more heavily than the statistical characteristics.

Although assessment uncertainty estimated in the model is small, the uncertainty in the input data (especially catch data reflecting unreliably estimated recreational catches), the CVs to use in reference point estimation should be set according to default values by ICES WKMSYREF IV (ICES, 2017b).

3.3.1 Wrap-up

- Assuming that recruitment estimation affects the outcome of S–R pairs to a minimum in the SS3 assessment;
- Assuming that considering age 3 as age of recruitment rather than age 0 would not provide any better information;
- Concluding that B_{pa} at the breakpoint of a segmented regression is justified given the small range in SSB values;
- Concluding that a segmented regression is an appropriate S–R model given the lack of biologically understandable trends in S–R that would justify a density-dependent process occurring at current stock state;
- Concluding that B_{lim} should be derived taking a cv of 0.2045 from B_{pa} (B_{pa} /1.4);
- Concluding that CV of F and phi of F should be set to default values of 0.212 and 0.423.

3.3.2 Answers

Age 3 as age of recruitment do not provide any better information, because only natural mortality apply which is constant across ages and years. So age 3 is strongly correlated to age 0. The shape of the SR plot is the same.

Biological reference points updated accordingly (see Annex 2: Working Document).

4 References

ICES. 2017a. ICES fisheries management reference points for category 1 and 2 stocks. *In* ICES Advice Technical Guidelines. Published 20 January 2017. DOI: 10.17895/ices.pub.3036. http://ices.dk/sites/pub/Publication%20Reports/Advice/2017/2017/12.04.03.01_Reference_points_for_category_1_and_2.pdf

ICES. 2017b. Report of the Workshop to consider F_{MSY} ranges for stocks in ICES categories 1 and 2 in Western Waters (WKMSYREF4), 13–16 October 2015, Brest, France. ICES CM 2015/ACOM:58. 187 pp. http://ices.dk/sites/pub/Publication%20Reports/Expert%20Group%20Report/acom/2015/WKMSYREF4/01%20WKMSYREF4%20Report.pdf

ICES. 2018. Report of the Benchmark Workshop on Seabass (WKBASS), 20–24 February 2017 and 21–23 February 2018, Copenhagen, Denmark. ICES CM 2018/ACOM:44. 283 pp.

Annex 1: Participants list

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Annex 2: Biological Reference Points Working Document

IBPBass 2018 Biological Reference Points Sea bass 8.ab

1 Current reference points

There are no current Biological Reference Points for the Sea bass (*Dicentrarchus labrax*) in divisions 8.ab (Bay of Biscay North and Central).

2 Source of data

The Sea bass 8.ab stock is intending to be a category 1 stock with an analytical assessment based on a Stock Synthesis 3 (SS3) modelling approach. Data used in the analysis were taken from the final assessment model obtained during the benchmark meeting ICES WKBASS 2018.

3 Methods used

All analyses were conducted with EQSIM in R. To do so, the SS3 model output was converted to an FLStock object in order to run EQSIM. All model and data selection setting are presented in Table 1.

Table 1. Model and data selection settings.

DATA AND PARAMETERS	SETTING	COMMENTS
SSB-recruitment data	Full dataseries (years classes 1985–2016)	
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Exploitation pattern	2007–2016	
Assessment error in the advisory year. CV of F	0.212	Set ICES default value
Autocorrelation in assessment error in the advisory year	0.423	Set ICES default value

4 Results

4.1 Stock–Recruitment relationship

The S–R relationship was explored using age 0 as age of recruitment. As no fishing mortality occurs for most fish below or equal to age 3, we assumed that considering age 3 as age of recruitment rather than age 0 would not provide any better information. Several models were fitted to the S–R relationship (Figure 1). The most statistically appropriate model seems to be a Ricker model, which model some density-dependence at high SSB. However, a segmented regression was considered as an appropriate S–R model given the lack of biologically understandable trends in S–R that would justify a density-dependent process occurring at current stock state.

Based on the S–R relationship classification proposed by ICES (2017), the sea bass stock can be categorised as a type 6 S–R plot. This is a stock with a narrow dynamic range of SSB and showing no evidence of past or present impaired recruitment. Thus, it is justified to consider B_{pa} at the breakpoint of a segmented regression (Figure 1).

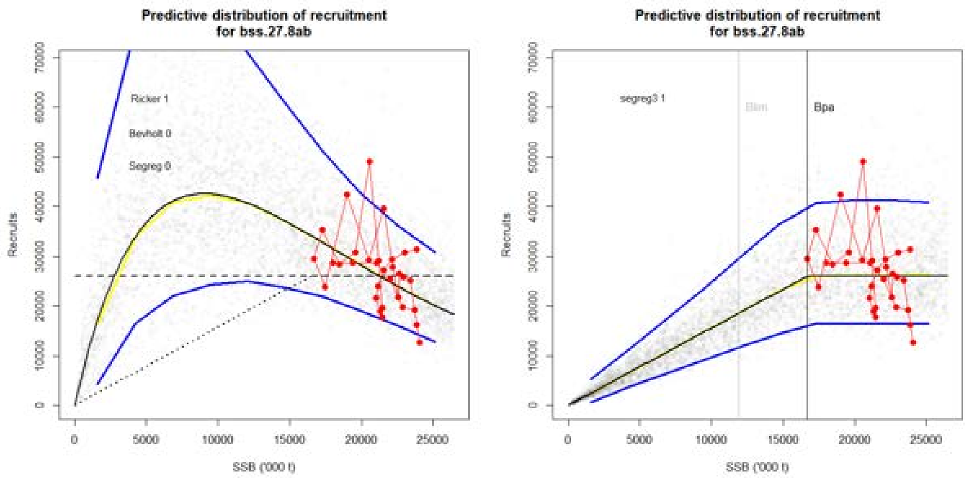

Figure 6. Stock–recruitment relationship for the seabass in divisions 8.ab.

B_{pa} is estimated to be equal to B_{loss}. This implies a B_{pa} of 16 688 tonnes with a $B_{lim} = B_{pa}$ / exp(CV * 1.645) = B_{pa} / 1.4 = 11 920 tonnes, with CV taken equal to 0.2045 (default value recommended by ICES).

4.2 Yield and SSB

F_{MSY} is estimated from the base run and taken as the peak of the median landings equilibrium yield curve. The F_{MSY} range is calculated as those F values associated with median yield that is 95% of the peak of the median yield curve.

4.2.1 Eqsim analysis

a) Segmented regression method, full SR time-series, without $B_{trigger}$

F_{lim} and F_{pa} was estimated using the EqSim software to run the simulation with $B_{trigger}$ set to 0 (i.e. no $B_{trigger}$ used), $F_{cv} = F_{phi} = 0$ (i.e. no assessment/advice error set for this first run) and the segmented regression as the only SR method. F_{lim} is estimated as the fishing mortality that, at equilibrium from a long-term stochastic projection, leads to a 50% probability of having SSB above B_{lim}. F_{lim} was estimated to be 0.172, and F_{pa} is estimated to be 0.123 based on the following equation [$F_{pa} = F_{lim}$/exp(CV * 1.645)].

Initially, F_{MSY} is calculated as the fishing mortality that maximises median long-term yield in stochastic simulations under constant F exploitation (i.e. without MSY $B_{trigger}$). Using the same simulation method with the inclusion of assessment/advice error default values: F_{cv}=0.212, F_{phi}=0.423 from WKMSYREF4 (ICES, 2016). F_{MSY} = 0.138 and is thus above F_{pa} = 0.123, see Figure 2 and Figure 3. In such a case, F_{MSY} is reduced to F_{pa} (i.e. F_{MSY} cannot exceed F_{pa}).

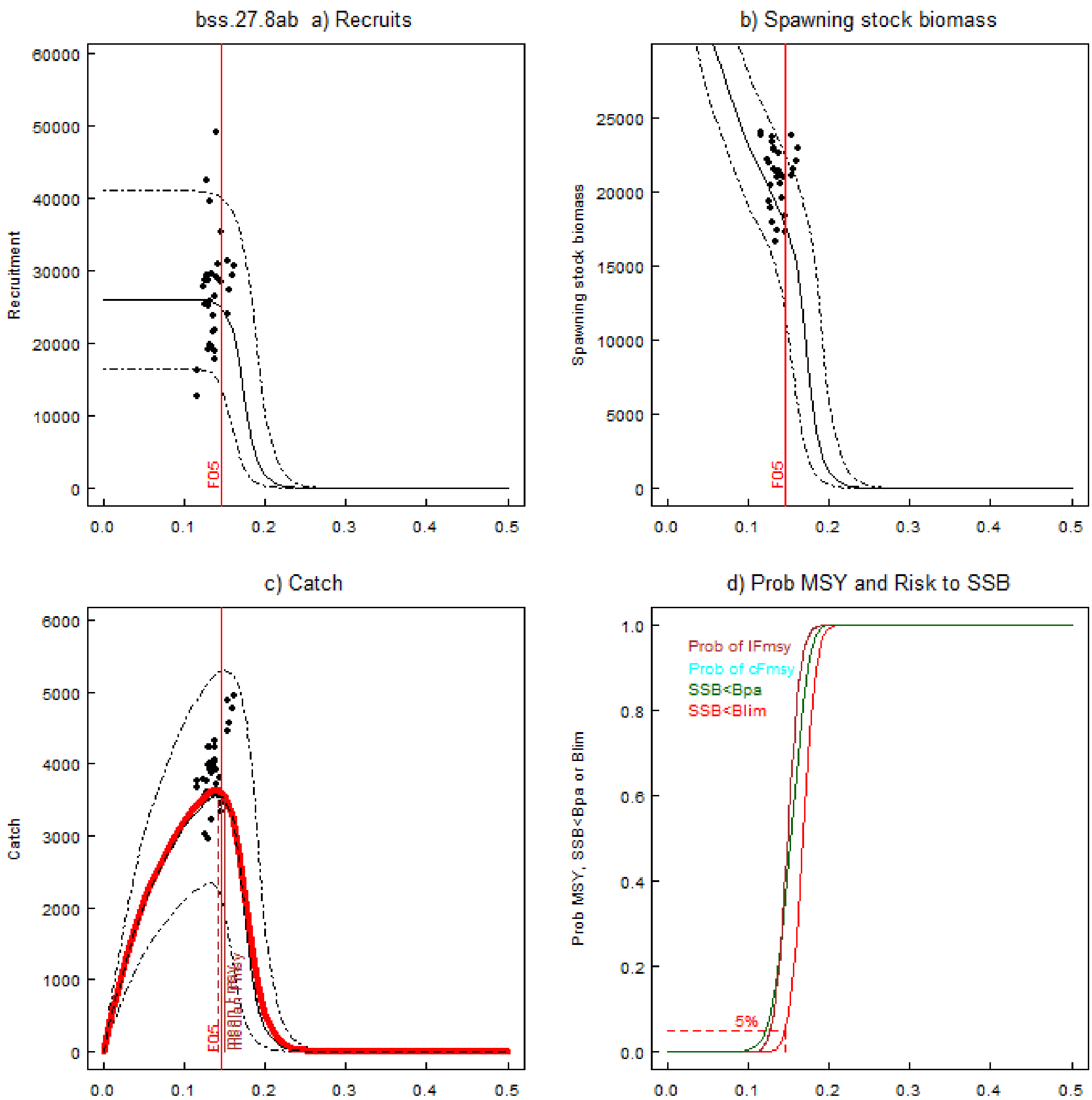

Figure 7. Eqsim summary plot without $B_{trigger}$. Panels a to c: historic values (dots) median (solid black) and 90% intervals (dotted black) recruitment, SSB and landings for exploitation at fixed values of F. Panel c also shows mean landings (red solid line). Panel d shows the probability of SSB<B_{lim} (red), SSB<B_{pa} (green) and the cumulative distribution of F_{MSY} based on yield as landings (brown).

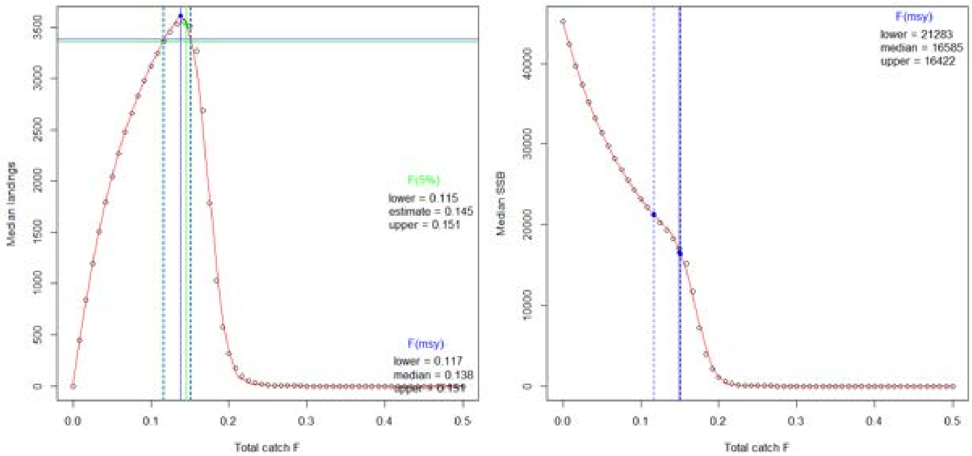

Figure 8. Left) Eqsim median landings yield curve with estimated reference points without $B_{trigger}$. Blue lines: F_{MSY} estimate (solid) and range at 95% of maximum yield (dotted). Green lines: F (5%) estimate (solid) and range at 95% of yield implied by F (5%) (Dotted). Right) Eqsim median SSB curve with estimated reference points without $B_{trigger}$. Blue dots: lower and upper SSB corresponding to lower and upper F_{MSY}.

b) Segmented regression method, full SR time-series, with $B_{trigger}$

ICES defines MSY $B_{trigger}$ as the 5th percentile of the distribution of SSB when fishing at F_{MSY}. However if the stock has not been fished at F_{MSY}, as in this case, then MSY $B_{trigger}$ is set to B_{pa}.

For this final run, assessment/advice error were included using the same default values and MSY $B_{trigger}$ was set to 16 688 tonnes. As shown in Figure 4, EqSim output $F_{p.05}$ (fishing mortality that gives 5% probability of SSB below B_{lim}) equals 0.186. As F_{MSY} estimated in the first run is below $F_{p.05}$, then F_{MSY} is kept to 0.123.

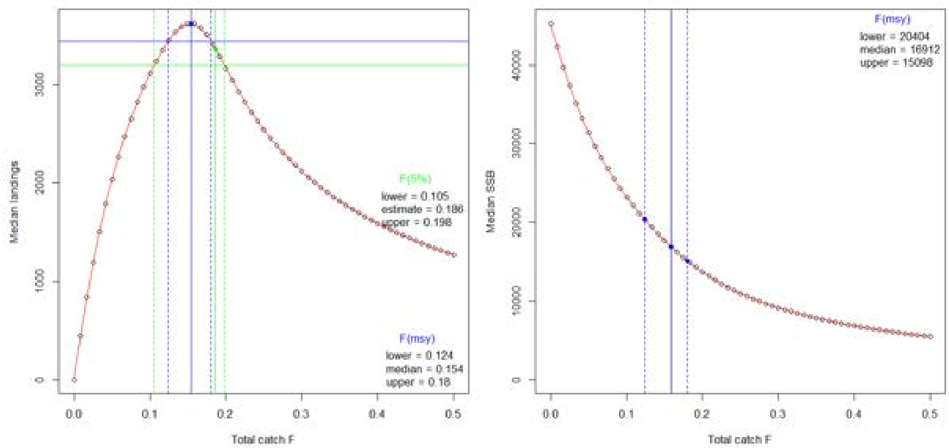

Figure 9. Eqsim median landings yield curve with estimated reference points with $B_{trigger}$. Blue lines: F_{MSY} estimate (solid) and range at 95% of maximum yield (dotted). Green lines: F (5%) estimate (solid) and range at 95% of yield implied by F (5%) (Dotted).

4.2.2 Proposed reference points

For the sea bass in division 8ab stock, the proposed reference points are reported in the Table 2. Those proposed reference points are then displayed on the diagnostic plots of the final assessment (Figure 5), i.e. the recruitment, the SSB and the F_{bar} (computed from ages 4–15) time-series.

Table 2. Summary table of proposed stock reference points for method Eqsim.

STOCK		Seabass divisions 8ab	
PA Reference points	Value	Rational	
B_{lim}	11 920 t	B_{pa} / 1.4	
B_{pa}	16 688 t	Lowest observed SSB	
F_{lim}	0.172	In equilibrium gives a 50% probability of SSB>B_{lim}	
F_{pa}	0.123	F_{pa} = F_{lim} / 1.4	
MSY Reference point	Value		
F_{MSY} without $B_{trigger}$	0.138		
F_{MSY} lower without $B_{trigger}$	0.117		
F_{MSY} upper without $B_{trigger}$	0.150		
$F_{P.05}$ (5% risk to B_{lim} without $B_{trigger}$)	0.145		
F_{MSY} upper precautionary without $B_{trigger}$	0.151		
MSY $B_{trigger}$	16 688 t	Value reduced to B_{pa}. Never fished at F_{MSY} before. (originally equals to 17 715 t)	
$F_{P.05}$ (5% risk to B_{lim} with $B_{trigger}$)	0.186		With WKMSYREF4 default values for assessment/advice error
F_{MSY} with $B_{trigger}$	0.123	Reduced value (originally equals to 0.154)	
F_{MSY} lower with $B_{trigger}$	0.123		
F_{MSY} upper with $B_{trigger}$	0.180		
F_{MSY} upper precautionary with $B_{trigger}$	0.180		
Median SSB at F_{MSY}	20 528 t		
Median SSB lower precautionary (median at F_{MSY} upper precautionary)	15 123 t		
Median SSB upper (median at F_{MSY} lower)	20 528 t		

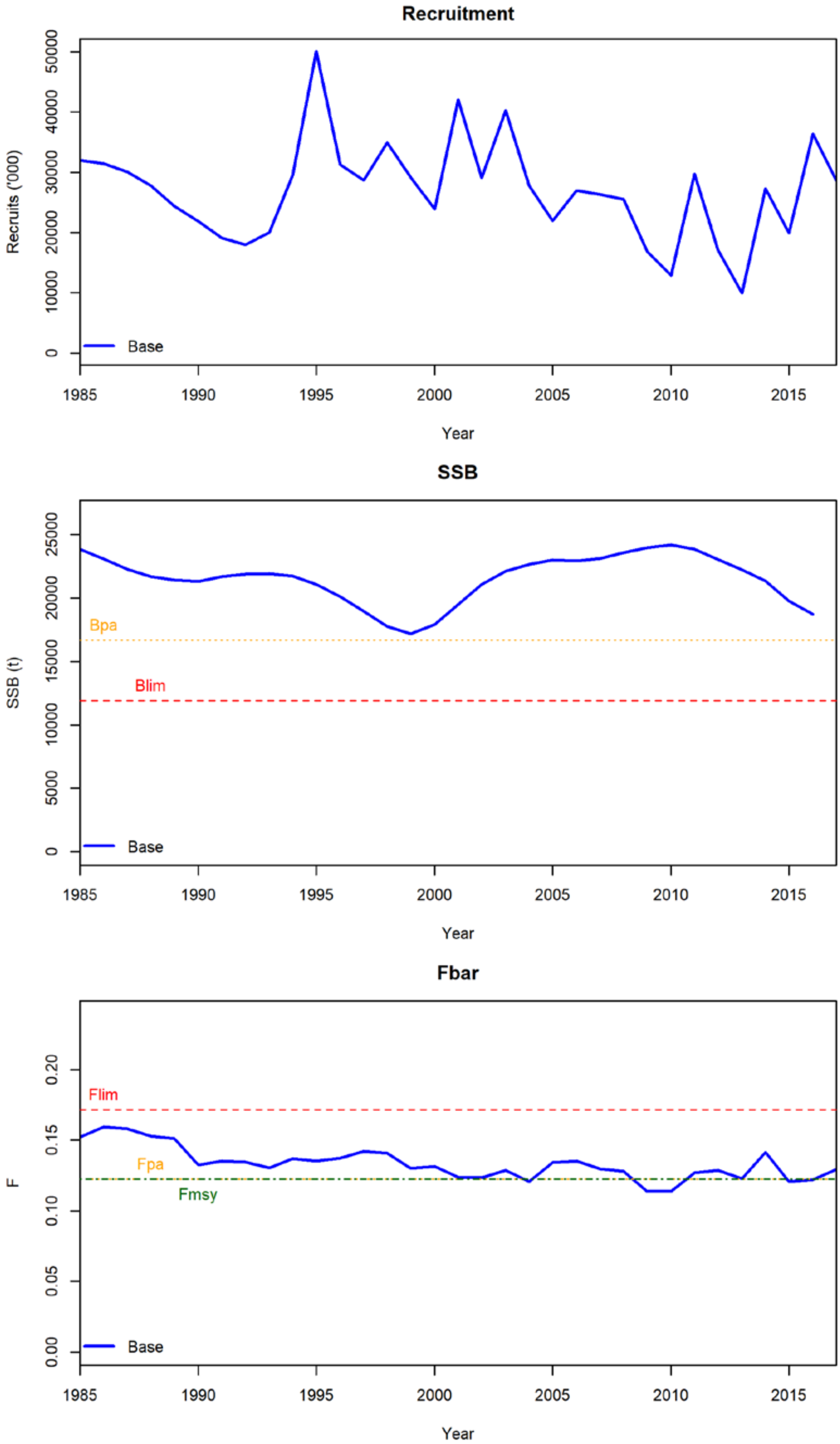

Figure 10. Recruitment, SSB and F_{bar} time-series with IBP2018 biological reference points.