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Estimation of the reference points for the different OMs in the Cod 3M MSE.

by

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ABSTRACT

This paper presents different methods to estimate the reference points (Blim, Bmsy and Fmsy) to be used in the 3M NAFO cod MSE. Reference points should be specific for each of the possible realities, what defines the different possible realities are the different OMs and, within each OM, the different iterations. The methods presented here try to estimate the reference points by iteration for the different OMs since it is assuming that the reference points will be interpreted as a characteristic of the "real" population. The results of some of the methods proposed to estimate the management reference points (limit and target) seem to be not consistent between them. The results show that in this case the proxy used as Fmsy (F30%SpR) seems quite reasonable.

INTRODUCTION

The objective of this document is to present possible methods to estimate the Reference Points for the different Operating Models (OMs) in the 3M Cod Management Strategies Evaluation (MSE). The NAFO SC (NAFO, 2018) suggested studying the possibility of estimating the reference points (Blim, Bmsy, Flim) by OM and iteration.

This paper proposes methods for estimating the References Points by iteration of candidate OMs (conditioned to the data) to perform the MSE of 3M Cod presented in another document for discussion by the NAFO SC (Gonzalez-Costas *et al.*, 2019).

RESULTS

Assuming that the reference points will be interpreted as a characteristic of the "real" population and not as a characteristic of a "real" population together with a stock assessment (as ICES implicitly seems to do), it would be more appropriate to estimate the reference points for each OM and iteration as this is what represents a potential "real" population. In other words, if the reference points are specific for each of the possible realities, what defines the different possible realities are the different OMs and, within each OM, the different iterations.

Blim estimation.

Blim Method1:

To estimate the Blim of the different OMs following a similar method that has been used to estimate it in the Base Case in June 2018 in the NAFO SC. The method used for the Base Case was by eye observing an SSB / Recruitment plot made with the medians of the results of the assessment carried out in 2018 (González-Troncoso *et al.*, 2018).

Figure 1 presents the plots made with the medians of the recruitments and SSB of the different candidate OMs (Gonzalez-Costas *et al.*, 2019). The values of the points that appear in the plot are the SSB in year *y* that produces the recruitment at age 1 in year *y+1*. It is a similar plot that was used in June 2018 by the NAFO SC to decide the Blim value for the Base Case. A possible value of Blim has been plotted for each candidate OM using the same reasoning that was used in June, an SSB level below which only low recruitments are observed. This is a subjective value because it is estimated by eye.

Figure 2 present the recruitment / SSB plots with the results of all the iterations by candidate OM. The value of the points that appear in the plot are the SSB in year *y* that produces the recruitment at age 1 in the year *y+1*. In this plot the horizontal line is the average of all the observed recruitments and the vertical line the candidate value of Blim previously estimated (Figure 1).

A potential method to automate the Blim estimation by iteration in the Base Case OM could be based on the following idea: taking a look to the Base Case OM stock-recruitment plot from which Blim was estimated by the NAFO SC (using the median values of SSB and R estimated by the stock assessment), the selected Blim value (20,000 tons) can be expressed as a linear combination of the median SSB of years 1994 and 2007, i.e.:

Blim = 20000 = ϒ * median(SSB1994) + (1- ϒ) * median(SSB2007)

We can find the value of ϒ that fulfils this equation. We can then apply this formula to the SSB1994 and SSB2007 iteration by iteration, with the value of ϒ previously calculated, in order to calculate a Blim for each iteration in the Base Case OM.

For the rest of the OMs considered, as can be seen in Figure 1, the estimated Blim also falls between the SSB values of the year 1994 and 2007. The results seem quite appropriate for all OMs except for OMAnt where those reference years are not so clear. These SSB values (1994 and 2007) have been used to perform the linear combination together with the value of ϒ in order to estimate a Blim by iteration for the different OMs. Table 1 shows the OM Blim, the ϒ values and the reference years to estimated Blim by iteration for the different OMs.

Figure 3 shows the estimated Blim by iteration (circles) for each OM using the method described above. The black horizontal line is the OM Blim estimated by eye (Figure 1) and the red vertical line is the median of the Blim by iteration. For the five OMs presented the medians of all iterations are very similar to the OM value estimated by eye. The dispersion of the Blim by iteration around the median is very similar in all OMs and does not present appreciable patterns.

Blim Method2:

Some of the members of the technical team consider that the Blim values estimated by the Blim Method1 are quite subjective and may be overestimated.

One of the possible fallback approaches to estimate Blim presented in the Report of the NAFO Study Group on Limit Reference Points (NAFO, 2004) is the "The SSB from which the stock could recover to the “safe zone” in one generation under good productivity conditions". The average SSB levels for the period 2005-2007 seem to meet this condition in all the proposed OMs. Those SSB levels allowed the recovery of the stock after many years collapsed. Figure 4 presents the Blim by iteration and its median for the different OMs estimated with this method. It can be seen that the values estimated are significantly lower than those estimated with the Blim Method1.

Fmsy estimation by OM and iteration.

At this moment, the SC approved an Flim proxy for Cod 3M as the F30%SpR, estimated with the average of the last three years for the inputs that the calculation of F30%SpR requires. It would be necessary to decide the input data and how to estimate the Flim. One of the options could be to estimate only one Fmsy by OM and iteration as proposed in the case of Blim. One problem is the great variability of the biological parameters observed in the past in the case of 3M Cod as pointed out by Gonzalez-Troncoso *et al.* (2018).

Fmsy Method1:

One method to estimate the Flim by OM and iteration could be to take the actual approved Flim proxy (F30%SpR). To solve the problem of the great variability of biological parameters, a dynamic Flim could be estimated using the average of the last three years as inputs values. This means that for each OM and iteration each projected year we would estimate one Flim with the inputs of the mobile three years mean.

Figure 5 shows the Flim = F30% SpR median and 90% intervals estimated with average inputs for the mobile three years in the Base Case OM and for the three different projection scenarios proposed by Gonzalez-Costas *et al.* (2019). The annual variability of the estimated Flim values for the ProjOM2 and ProjOM3 scenarios is much greater than that observed in the ProjOM1 scenario and it can be observed that the median Flim and the 90% intervals by year values for all the scenarios are quite similar between years. When we examine the Flim values of the 10 iterations randomly chosen, it is observed that although the values of the median and 90% intervals are fairly constant , the interannual variability within each iteration is quite large. So establishing a dynamic Flim may be justified.

Fmsy Method2:

Another way to estimate Fmsy is to look for the F that gives us greater sustainable yield in a long-term projection. We have used the Base Case to estimate the Fmsy with this method. Recruitments to carry out the projections were extracted from a segmented regression fitted by iteration with the cut-off point (Blim) fixed with values similar to those estimated with the Blim Method1 and Blim Method2 (20000 and 10000). The biological parameters of the projections were the mean of two different periods: the most recent 3 years (2015-2017) or the whole series (1998-2017). Table 2 shows the values of the median of all iterations of the Fmsy Method2, F30% SpR=Flim, Bmsy and MSY values estimated in the Base Case with the average of the whole period or the average of the last three years, and assuming a Blim of 10000 or 20000 tons. When we use as inputs the average of the whole period, it seems that the values of F30% SpR= Flim are quite similar to the Fmsy values estimated with the Method2, the ratio (Fmsy/ F30% SpR) is slightly below 1 when we use a Blim = 20,000 and slightly higher when we use a Blim of 10000 (Figure 6). When we use as inputs the average of the most recent period (last three years), the results are quite similar but it seems that the ratio (Fmsy/ F30% SpR) is around 1 when we use a Blim of 10000 and around 0.85 when we use a Blim = 20,000 (Figure 7). With Method2 only one Fmsy is calculated per iteration, which could be a problem due to the great variation of the biological parameters observed.

Bmsy estimation by OM and iteration.

As with the other Reference Points, the value of the Bmsy could be estimated by OM and iteration and it would be necessary to decide the input data and how the Bmsy will be estimated. Until now, the SC has not approved any value for Bmsy for the 3M cod. In the 3M cod case it is quite difficult to estimate a Bmsy since there is no clear stock - recruitment relationship.

Bmsy Method1:

One way to estimate Bmsy by OM and iteration could be estimated Bmsy as the recruitment value of the segmented regression Break Point multiplied by the Spawner per Recruit value of the Fmsy proxy= F30%SpR (Fmsy Method1). Each year and iteration would have a value of Bmsy since the value of Fmsy Method1 would vary each year if it is decided to estimate the Fmsy = F30% SpR with input equal to the moving average of the last three years. This would imply a dynamic Bmsy.

Figure 8 shows the Base Case median and 90% intervals of Bmsy estimated with this method for the three different projection scenarios proposed by Gonzalez-Costas et al. (2019). As with Flim, the variability between years of the median and 90% intervals of Bmsy is quite small although the variability between years for each of the iterations is appreciable.

Bmsy Method2:

Based on the results of the Figure 1, an alternative way of estimating a possible Bmsy value is to look for the SSB levels for which only high recruitment values have been observed. If we applied this method, we could estimate possible Bmsy values for most of the OMs and iteration as the average of the SSB observed in the years 1990,1991, 2010 and 2011. These are the 4 years where the largest recruitments have been observed for almost all proposed OMs. Applying this method a single Bmsy is estimated by OM and iteration, not as in the previous case that the Blim was estimated by OM, iteration and year. Figure 9 shows the possible Bmsy values estimate by OM and iteration using this method.

Bmsy Method3:

Another way to estimate Bmsy is to look for the biomass that gives us greater sustainable yield in a long-term projection. As it was done in the Fmsy Method2 case, we have used the Base Case to estimate the Bmsy with this method. Recruitments to carry out the projections were extracted from a segmented regression fitted by iteration with the cut-off point (Blim) fixed with values similar to those estimated with the Method1 and Method2 (20000 and 10000). The biological parameters of the projections were the mean of two different periods: the most recent 3 years (2015-2017) and the whole series (1998-2017). When we use as inputs the average of the whole period, the mean values of Bmsy for the case of Blim = 10000 is around 40000 and for the case of Blim = 20000 is around 55000 (Figure 10). With the most recent period (last three years) inputs, the mean Bmsy results are around 28000 when we use a Blim of 10000 and around 35000 when we use a Blim = 20,000 (Figure 11).

DISCUSSION

The results of some of the methods proposed to estimate the management reference points (limit and target) seem to be inconsistent.

The results presented in Table 2 show that for the Base Case OM, the F30% SpR is an acceptable Flim proxy since, independently of the cases, the ratio (Fmsy/F30%SpR) is very close to 1.

Table 3 shows the values of the median of the Blim and Bmsy estimated for the different OMs with the different methods discussed in this document. The Bmsy value estimated thru the SpR (Bmsy Method 1) that appears in the Table 3 is the median of mean of the period (2018-2037) by iteration. Each of the methods described to estimate Blim gives a very similar level for all OMs while the level of Blim estimated is quite different according to the method used. The Blim Method1, which is the one used by SC to estimate the current Blim, gives values of double that calculated with the Blim Method2.

The Bmsy levels estimated with the different methods are quite different. The Bmsy values estimated with Method1 (SpR) are very low and quite inconsistent with the estimated Blim values. This method gives Bmsy values that are very similar or are below the Blim values estimated with the two different methods.

In the Base Case, the Bmsy levels estimated with Method2, Method3 with the average of the whole series and a Blim of 10000, and Method3 with the average of the last 3 years and a Blim of 20000 are very similar (40000), and reasonable given the Blim values estimated. In the first two cases the values of Blim are around 25-30% of the Bmsy estimated levels. This percentage is one of the references established by the NAFO PA to estimate Blim when Bmsy is known.

Acknowledges

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Table 1. General Blim by OM, reference years and ϒ values to estimated Blim by iteration with the Blim Method1 for the different OMs.

OM	Blim	Reference Years	Estimated ϒ
OMBC	20000	1994/2007	0.805
OMFix	17000	1994/2007	0.756
OMMatrix	21000	1994/2007	0.794
OMAnt	20000	1994/2007	0.410
OMCV	19000	1994/2007	0.794
OMQs	19000	1994/2007	0.634

Table 2. Median values of all iterations of the Fmsy Method2, Bmsy Method3, F30% SpR=Flim, and MSY estimated for the Base Case with the inputs being the average of the whole period or the average of the last three years, and assuming a Blim of 10,000 or 20,000 tons. Fratio = Fmsy/F30%SpR.

Inputs	1998-2017		2015-2017	
Blim	10000	20000	10000	20000
F30%SpR	0.263	0.263	0.154	0.154
Fmsy	0.273	0.248	0.155	0.131
Fratio	1.04	0.94	1.01	0.85
Bmsy	40441	52201	25461	35064
MSY	15901	18775	9300	10641

Table 3. Cod 3M median values of Blim and Bmsy estimated with the different methods for the proposed OMs. The Bmsy value estimated thru the SpR that appears in the Table 3 is the median of mean of the period (2018-2037) by iteration.

	OM1	OM2	OM3	OM4	OM5	OM6
Blim (June 2018)	20086	17028	21049	20069	19043	19096
Blim(Mean 2005-2007)	10749	7882	11639	10256	9643	11180
Bmsy (SpR)	15394	29593	6673	22508	18132	16749
Bmsy (Mean 90-91 10-11)	42311	34102	45052	57986	40557	42599
Bmsy (98-17 10000)	40441					
Bmsy (98-17 20000)	52201					
Bmsy (15-17 10000)	25461					
Bmsy (15-17 20000)	35064					

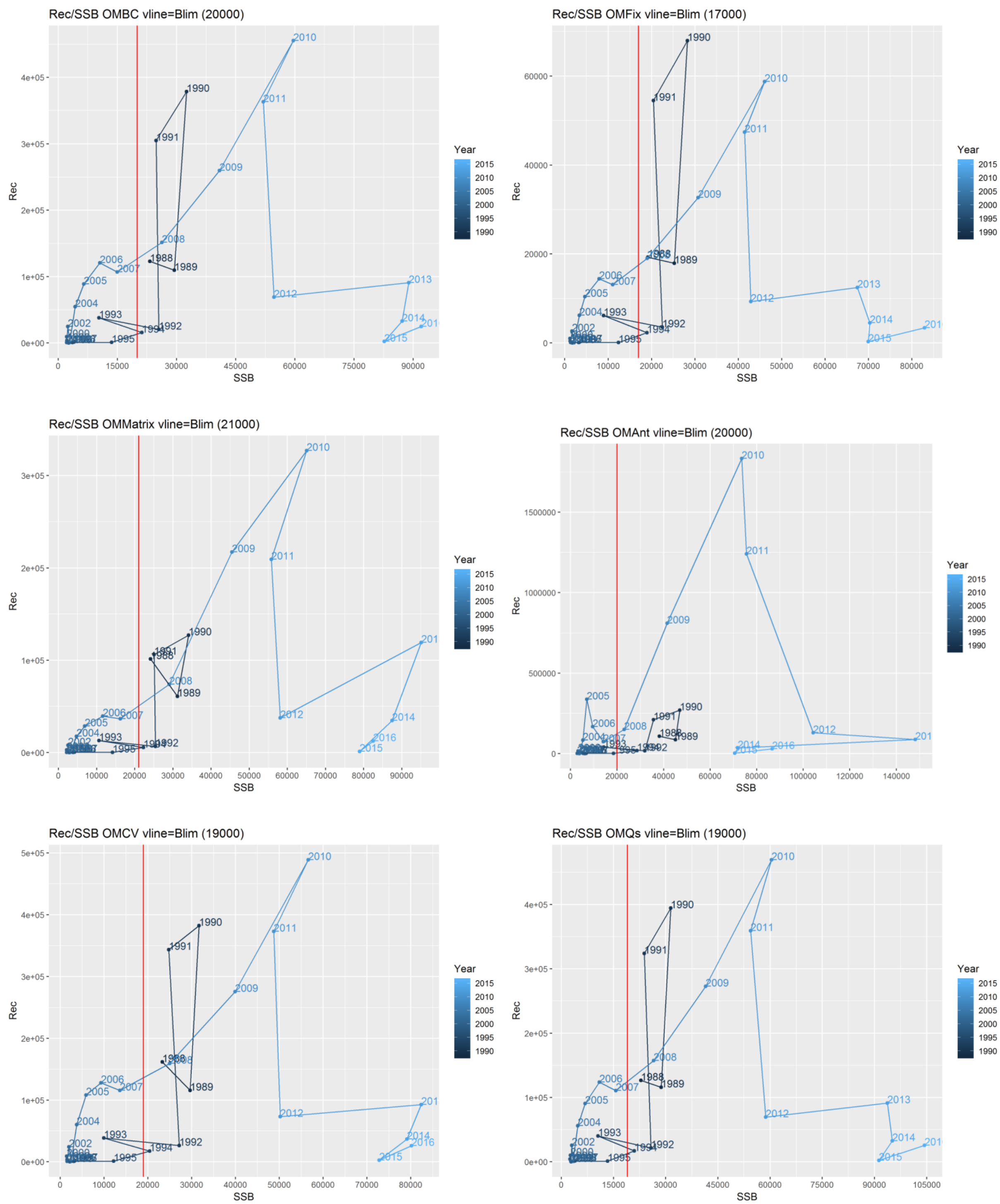

Fig. 1. Medians of the recruitments and SSB of the different candidates OMs (conditioned to the data). The vertical red line is the proposed value for Blim by OM.

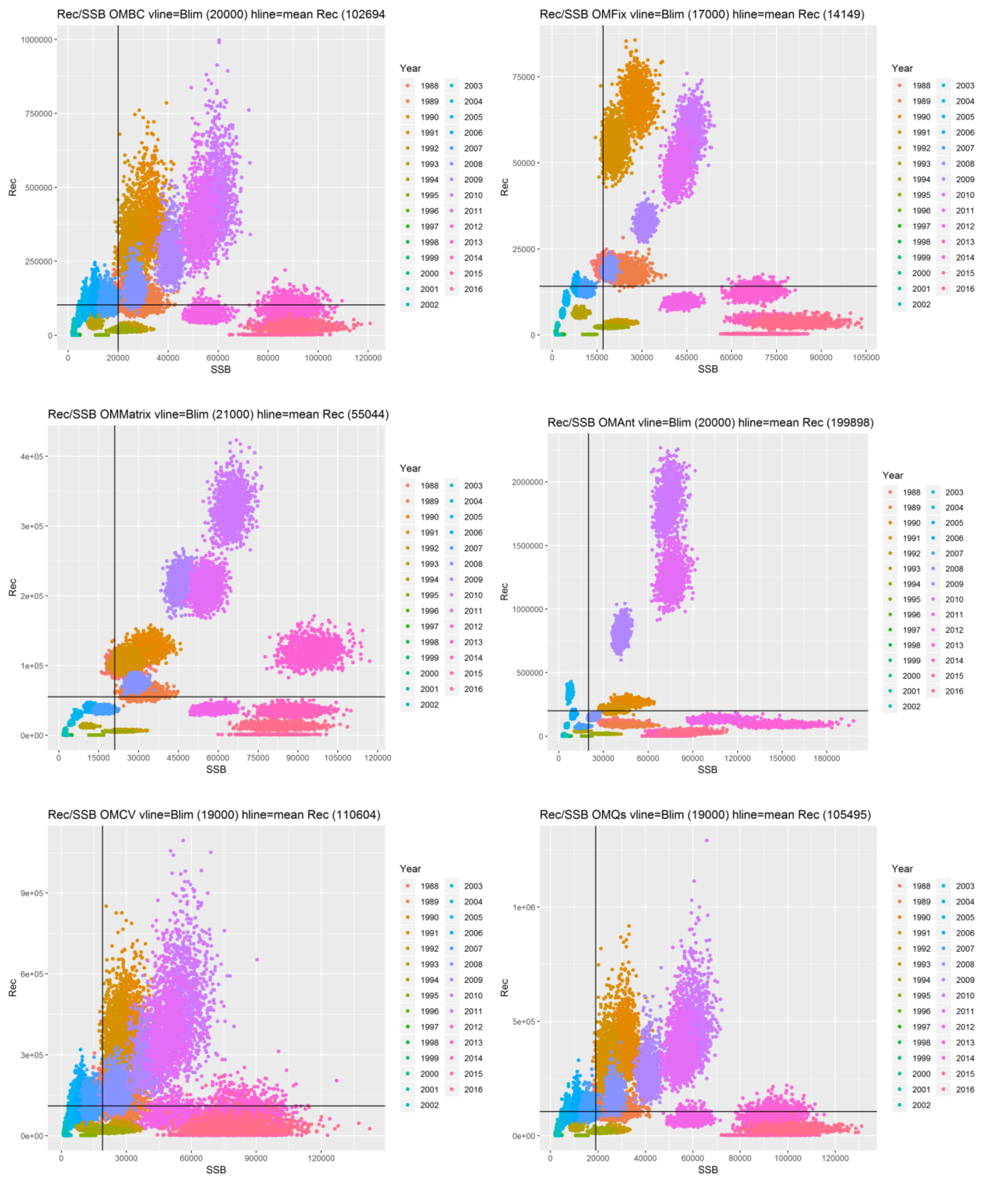

Fig. 2. Recruitments and SSB of the different iteration by candidates OMs (conditioned to the data). The vertical line is the proposed value for Blim by OM and the horizontal line is the mean recruitment of all iteration in the period 1989-2017.

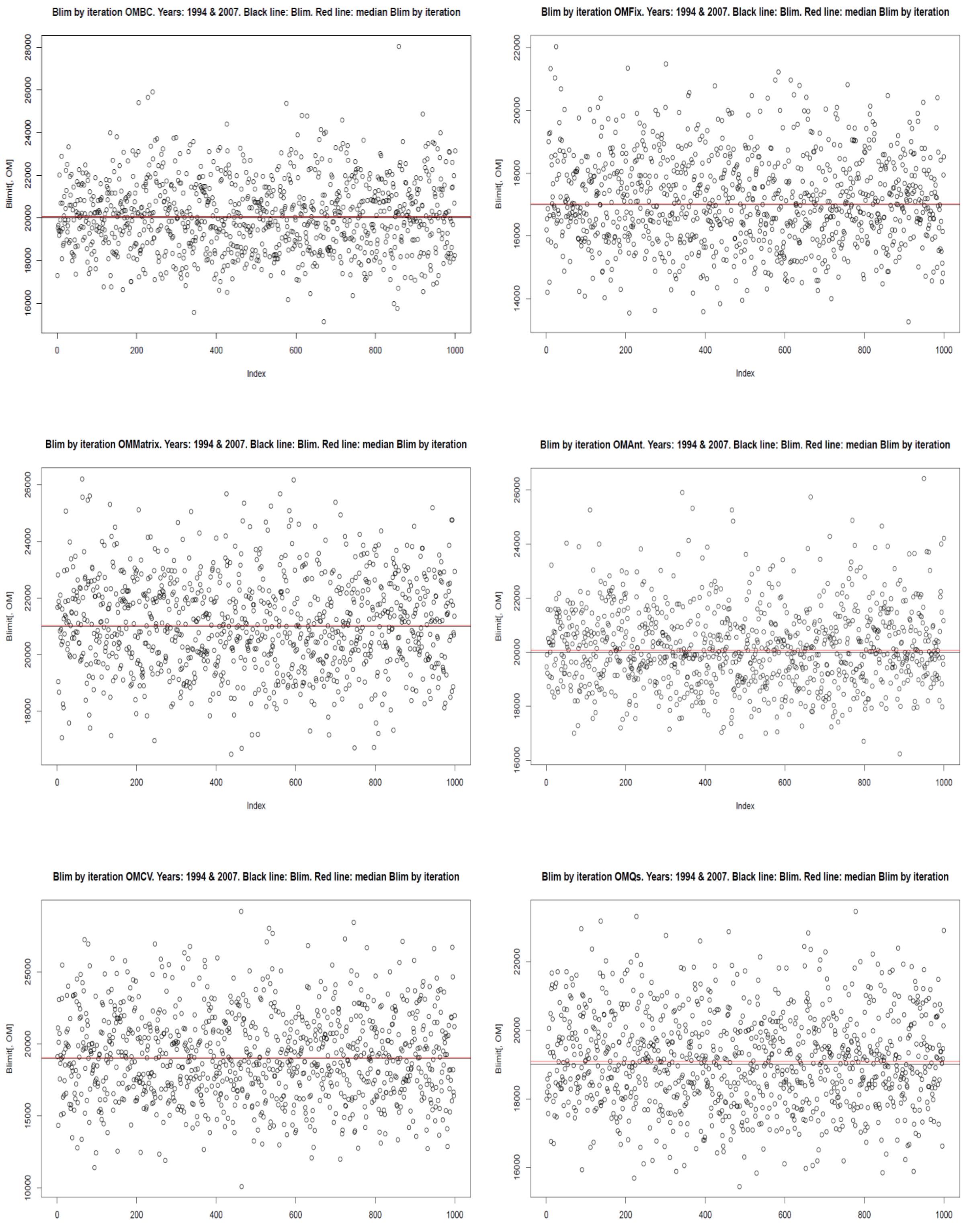

Fig. 3. Estimated Blim by iteration (circles) for each OM using the Blim Method1. The black horizontal line is the OM Blim estimated by eye (Figure 1) and the red vertical line is the median of the Blim by iteration.

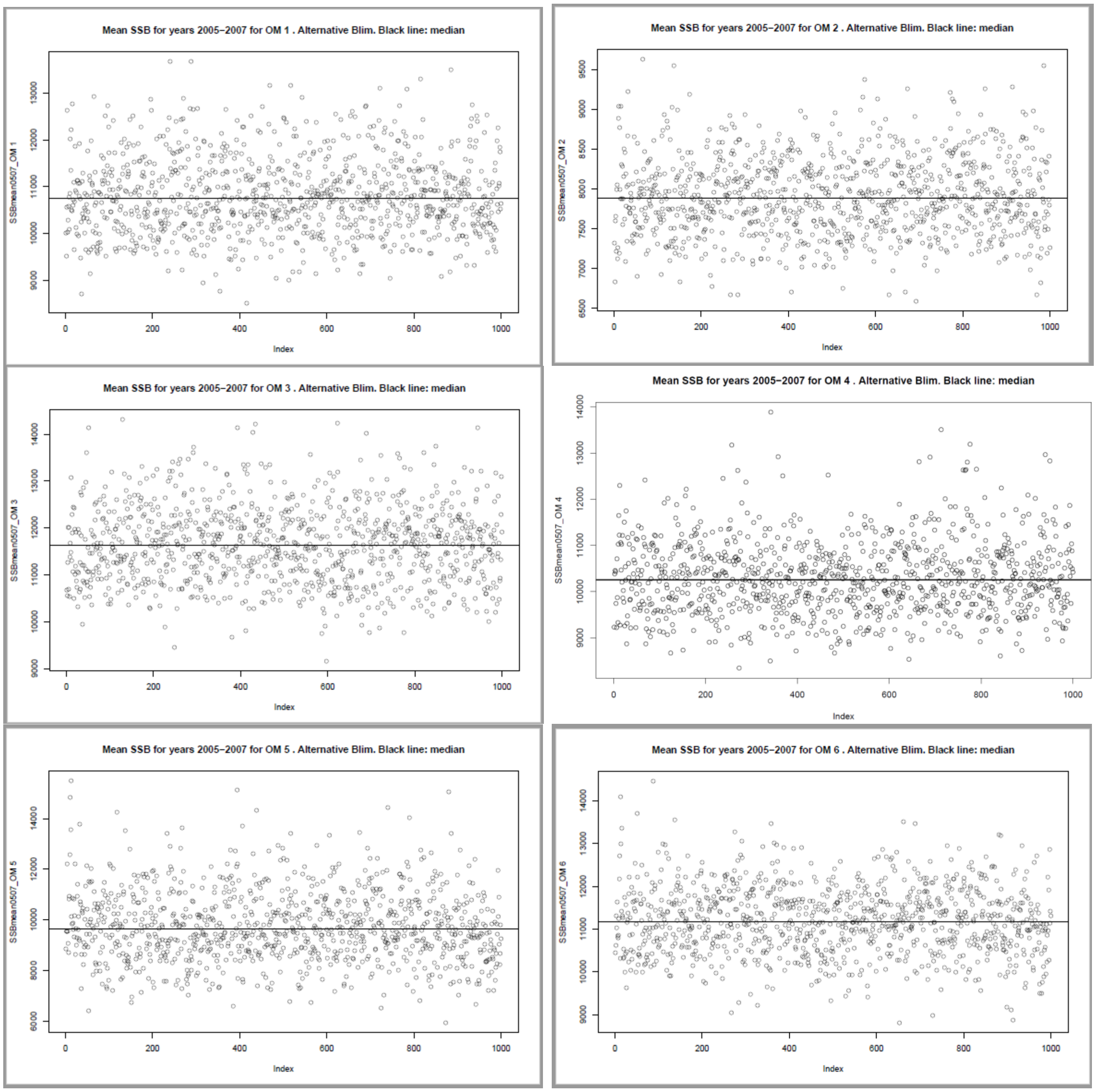

Fig. 4. Estimated Blim by iteration (circles) for each OM using the Blim Method2. The black horizontal line is the median of all iteration of Blim.

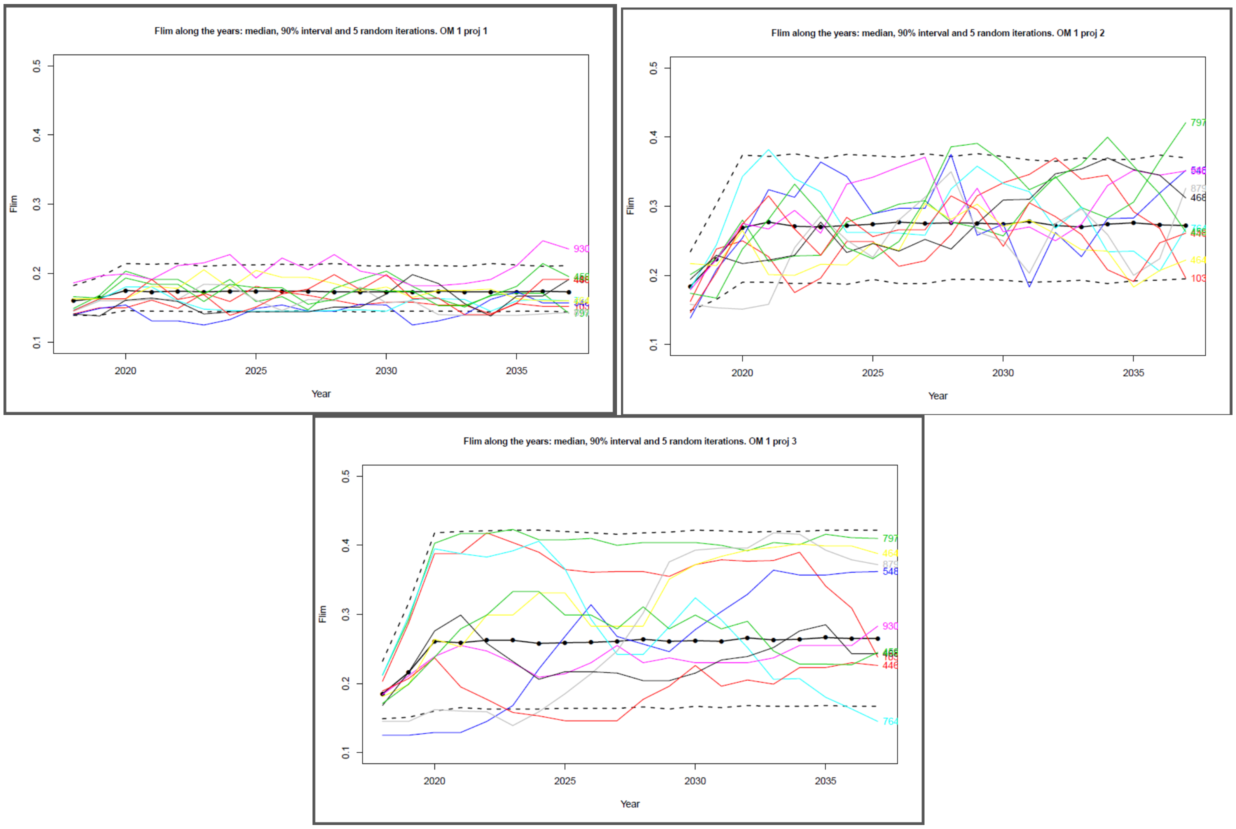

Fig. 5. Estimated median and 90% intervals of Flim=F30%SpR by year for the Base Case under the three different projections scenarios (**ProjOM1, ProjOM2 and ProjOM3)** with the Fmsy Method1. The colour lines represent the values of 10 iterations random chosen.

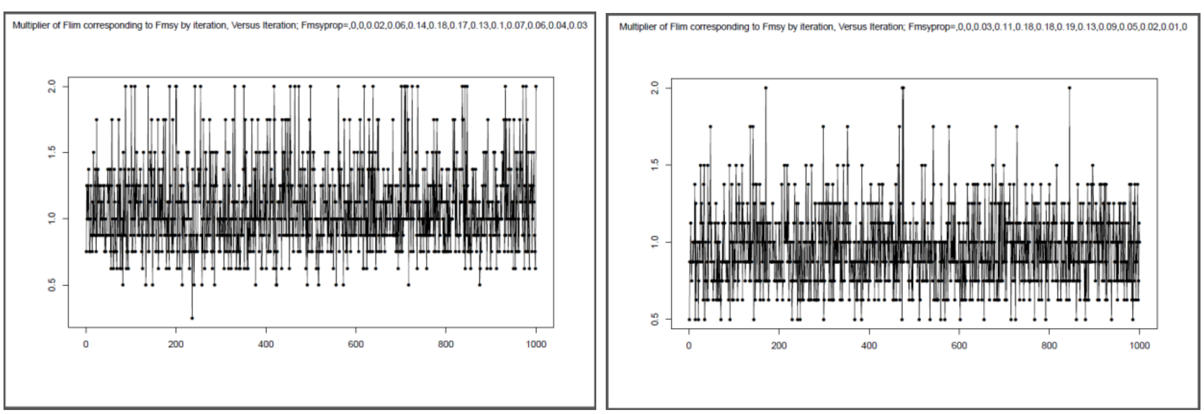

Fig. 6. Ratio (F30%SpR/Fmsy Method2) estimated with the mean inputs of the whole series (1988-2017) with a segmented regression fitted by iteration with the cut-off point (Blim) fixed with 10000 (left plot) and 20000(right plot).

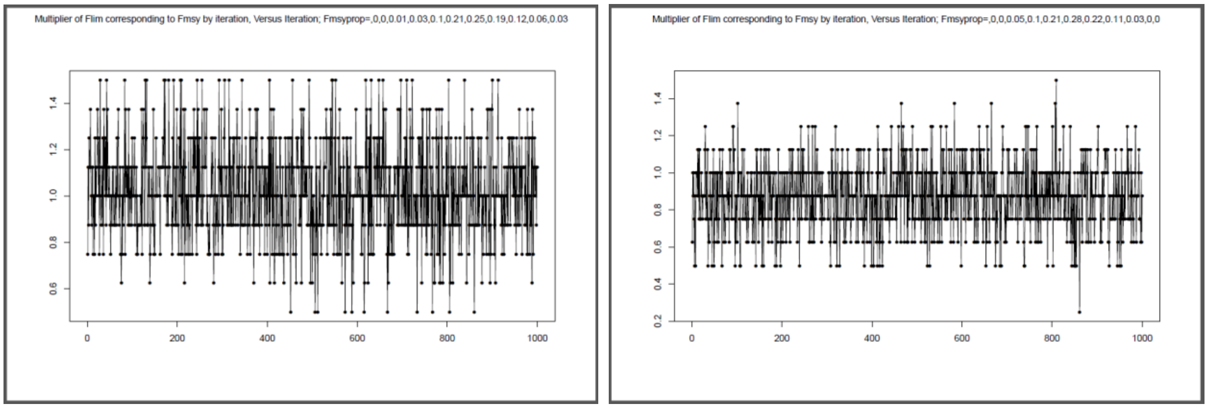

Fig. 7. Ratio (F30%SpR/Fmsy Method2) estimated with the mean inputs of the most recent period (2018-2017) with a segmented regression fitted by iteration with the cut-off point (Blim) fixed with 10000 (left plot) and 20000(right plot).

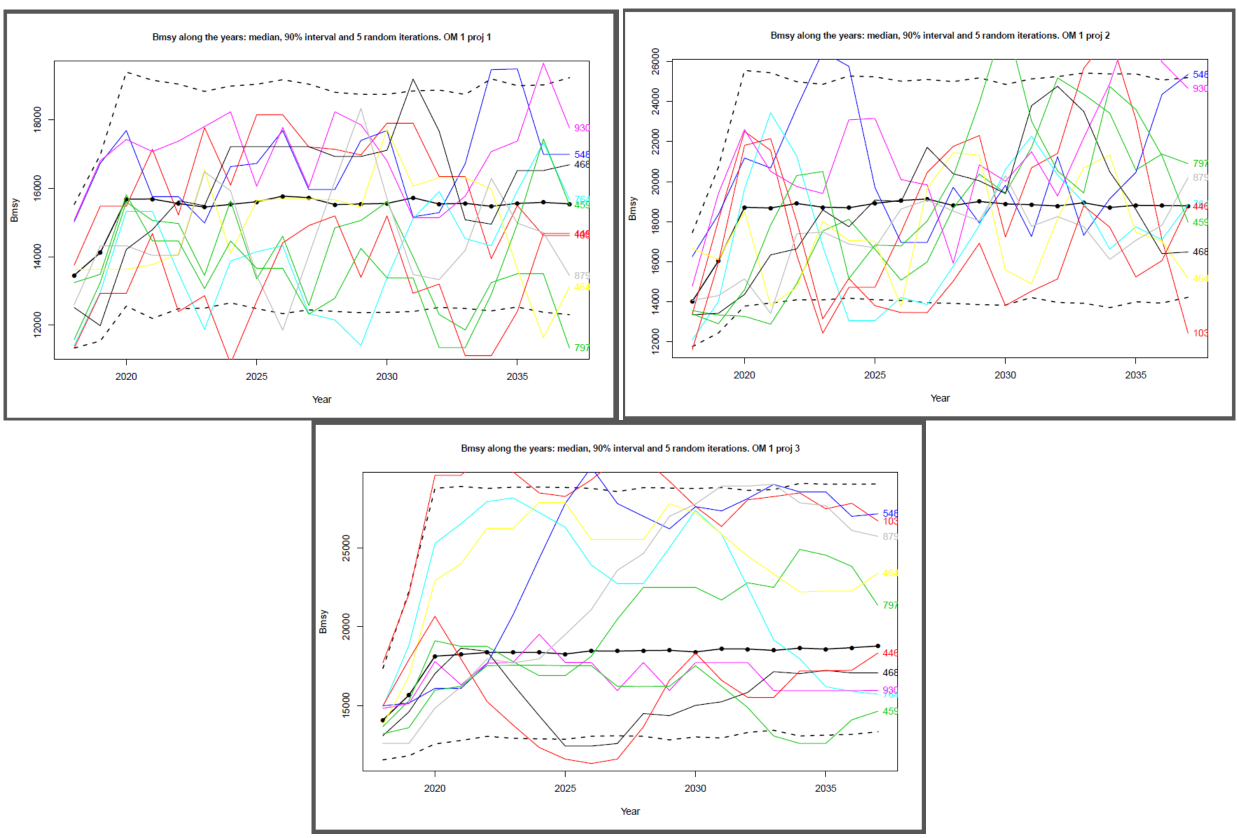

Fig. 8. Median and 90% intervals of Bmsy by year for the Base Case under the three different projections scenarios (**ProjOM1, ProjOM2 and ProjOM3)** estimated with the Bmsy Method1. The colour lines represent the values of 10 iterations random chosen.

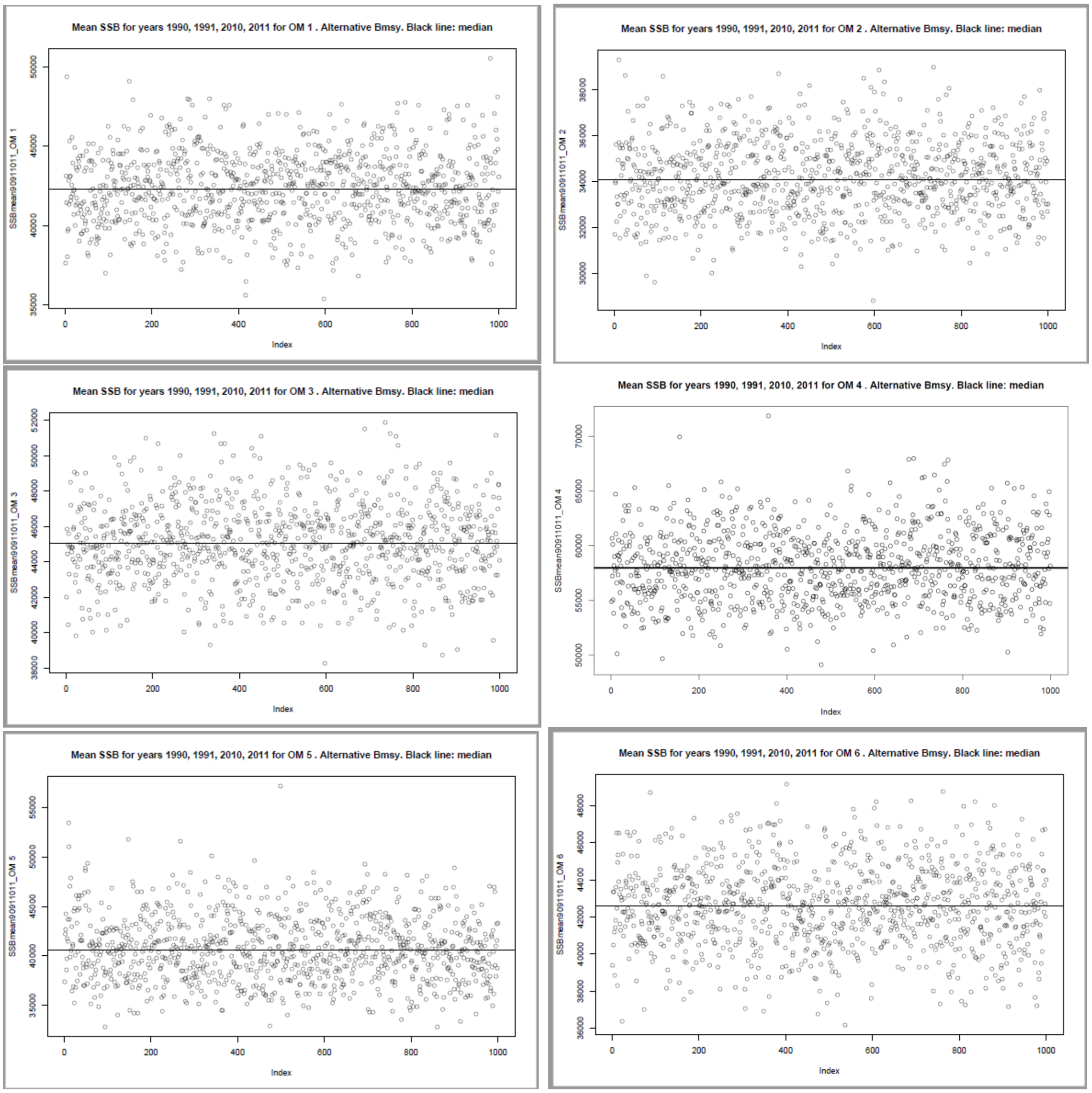

Fig. 9. Proposed Bmsy by iteration (circles) for each OM using the Method2 (mean SSB 1990, 1991, 2010 and 2011). The black horizontal line is the median of all iteration of the Bmsy.

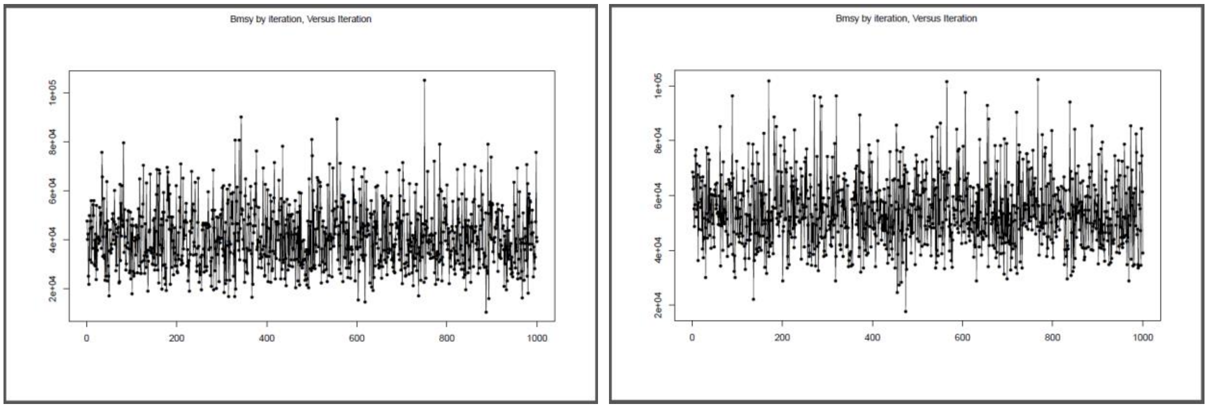

Fig. 10. Method 3. Bmsy estimated with the mean inputs of the whole series (1988-2017) with a segmented regression fitted by iteration with the cut-off point (Blim) fixed with 10000 (left plot) and 20000(right plot).

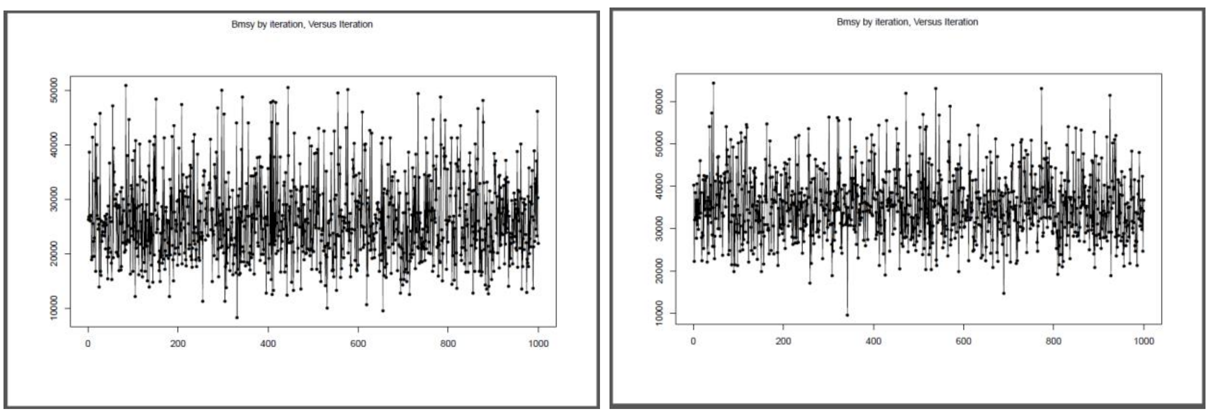

Fig. 11. Method 3. Bmsy estimated with the mean inputs of the most recent period (2015-2017) with a segmented regression fitted by iteration with the cut-off point (Blim) fixed with 10000 (left plot) and 20000(right plot).