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3M cod MSE: Different OMs based on M calculated in steps

by

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Abstract

Within the OMs to implement the 3M cod MSE, one in which the M is calculated by two-years steps was developed. Five attempts of this OM were settled. The aim of this work is to present the specifications and the results of these attempts to the NAFO Scientific Council in order to decide which of them is the most appropriate to be used in the MSE.

Introduction

A MSE process for the 3M cod is being developed within NAFO for reaching a HCR that ensure the sustainability of this stock in the long term. Several OMs have been performed for this stock, all of them based on a Bayesian Statistical Catch-at-Age (SCAA) methodology (González-Troncoso *et al.*, 2019). Within them, an OM in which the M is calculated by steps was developed. Just one OM with these specifications is presented as possible OM candidates for consideration to the SC, but several more were developed. The aim of this work is to present the specifications and the results of these OMs.

Material and Methods

Data

The data used in the developed OMs are the same used in the assessment approved in 2018 by the NAFO Scientific Council (González-Troncoso *et al.*, 2018).

Specification of the Operating Models (OMs)

Three different OMs changing the way the M is estimated by steps of two years were analyzed. The specifications are the same as those used in the Bayesian SCAA approved in 2018 by the Scientific Council except for the case of the M. A summary of them are as following:

1. OMsteps_1:

First, and assessment between 1988 and 2005 is performed with a M constant and estimated by a prior. With the posterior of this M, the second step is to perform an assessment for 1988 to 2007 in which M is fix for 1988-2005 and equal to the posterior median of the first step and M for years 2006 and 2007 is estimated constant by a prior of mean the median posterior of the first step. The M for those years is the posterior median of M in that assessment multiplied by a vector. The posterior median of this prior is the value to be fix in the third step for M. The third, fourth, fifth and sixth steps are made repeating the first and second steps. Schematically:

Step 1. y= 88-05, $ln(\mathrm{M}_{88\text{-}95}) \sim N(ln(0.218)\ ,\ 0.3)$ => exp posterior median $M_{88-05}^{allages}$

Step 2. y=88-07, $\mathrm{M}_{88\text{-}05} = M_{88-05}^{allages}$

$ln(\mathrm{M}_{06\text{-}07}) \sim N(ln(M_{88-05}^{allages}),\ 0.3)$ => exp posterior median $M_{06-07}^{allages}$ => $M_{06-07}^{a} = M_{06-07}^{allages} * vectM[a]$, a=1-8+

Step 3. y=88-09, $\mathrm{M}_{88\text{-}05} = M_{88-05}^{allages}$; $\mathrm{M}_{06\text{-}07}[a] = M_{06-07}^{a}$, a=1-8

$ln(\mathrm{M}_{07\text{-}08}) \sim \mathrm{N}(ln(M_{06-07}^{allages}),\ 0.3)$ => exp posterior median $M_{07-08}^{allages}$ => $M_{07-08}^{a} = M_{07-08}^{allages} * vectM[a]$, a=1-8+

Step 4 to 7: As 2 and 3, to finalize in y=88-17

Final M:

$M_{88-17} =$

	1	2	…	7	8
1988	M_{88-05}	M_{88-05}	…	M_{88-05}	M_{88-05}
1989	M_{88-05}	M_{88-05}	…	M_{88-05}	M_{88-05}
…	…	…	…	…	…
2004	M_{88-05}	M_{88-05}	…	M_{88-05}	M_{88-05}
2005	M_{88-05}	M_{88-05}	…	M_{88-05}	M_{88-05}
2006	M_{06-07}^{1}	M_{06-07}^{2}	…	M_{06-07}^{7}	M_{06-07}^{8}
2007	M_{06-07}^{1}	M_{06-07}^{2}	…	M_{06-07}^{7}	M_{06-07}^{8}
2008	M_{08-09}^{1}	M_{08-09}^{2}	…	M_{08-09}^{7}	M_{08-09}^{8}
2009	M_{08-09}^{1}	M_{08-09}^{2}	…	M_{08-09}^{7}	M_{08-09}^{8}
…	…	…	…	…	…
2016	M_{16-17}^{1}	M_{16-17}^{2}	…	M_{16-17}^{7}	M_{16-17}^{8}
2017	M_{16-17}^{1}	M_{16-17}^{2}	…	M_{16-17}^{7}	M_{16-17}^{8}

2. OMsteps_2:

First, and assessment between 1988 and 2005 is performed with a M constant and estimated by a prior. With the posterior of this M, the second step is to perform an assessment for 1988 to 2007 in another two substeps: in the first substep the M is fix for 1988-2005 and equal to the median posterior of first step and the M for ages 2006 and 2007 is estimated constant by a prior of mean the median posterior of the first step. With the posterior of this run, a second substep is made performing an assessment from 2006 to 2007 with M fix for 1988 to 2005 and M for 2006 and 2007 estimated by age with a prior of mean the median of the first substep. The corresponding value of M for those years is the posterior median of the second substep multiplied by a vector. The posterior median of the second subset is the value of the mean of the prior of M in the third step for years

2008 and 2009. The third to sixth steps are as the second one with two more years in the assessment. Schematically:

Step 1. y= 88-05, $ln(\mathrm{M}_{88\text{-}95}) \sim N(ln(0.218), 0.3)$ => exp posterior median $M^{allages}_{88-05}$

Step 2. Step 2.1: y=88-07, $\mathrm{M}_{88\text{-}05} = M^{allages}_{88-05}$

$ln(\mathrm{M}_{06\text{-}07}) \sim N(ln(M^{allages}_{88-05}), 0.3)$ => exp posterior median $M^{allages}_{06-07}$

Step 2.2: y=88-07, $\mathrm{M}_{88\text{-}05} = M^{allages}_{88-05}$

$ln(\mathrm{M}_{06\text{-}07}[a]) \sim N(ln(M^{allages}_{06-07}), 0.3)$ => exp posterior median $M'^{allages}_{06-07}$ => $M^{a}_{06-07} = M'^{allages}_{06-07} * vectM[a]$, a=1-8+

Step 3. Step 3.1: y=88-09, $\mathrm{M}_{88\text{-}05} = M^{allages}_{88-05}$; $\mathrm{M}_{06\text{-}07}[a] = M^{a}_{06-07}$, a=1-8+

$ln(\mathrm{M}_{08\text{-}09}) \sim N(\ln(M'^{allages}_{06-07}), 0.3)$ => exp posterior median $M^{allages}_{08-09}$

Step 3.2: y=88-09, $\mathrm{M}_{88\text{-}05} = M^{allages}_{88-05}$; $\mathrm{M}_{06\text{-}07}[a] = M^{a}_{06-07}$, a=1-8+

$ln(\mathrm{M}_{08\text{-}09}[a]) \sim N(ln(M^{allages}_{08-09}), 0.3)$ => exp posterior median $M'^{allages}_{08-09}$ => $M^{a}_{08-09} = M'^{allages}_{08-09} * vectM[a]$, a=1-8+

Step 4 to 7: As 2 and 3, to finalize in y=88-17

Final M:

$M_{88-17} =$

	1	2	…	7	8
1988	M_{88-05}	M_{88-05}	…	M_{88-05}	M_{88-05}
1989	M_{88-05}	M_{88-05}	…	M_{88-05}	M_{88-05}
…	…	…	…	…	…
2004	M_{88-05}	M_{88-05}	…	M_{88-05}	M_{88-05}
2005	M_{88-05}	M_{88-05}	…	M_{88-05}	M_{88-05}
2006	M^{1}_{06-07}	M^{2}_{06-07}	…	M^{7}_{06-07}	M^{8}_{06-07}
2007	M^{1}_{06-07}	M^{2}_{06-07}	…	M^{7}_{06-07}	M^{8}_{06-07}
2008	M^{1}_{08-09}	M^{2}_{08-09}	…	M^{7}_{08-09}	M^{8}_{08-09}
2009	M^{1}_{08-09}	M^{2}_{08-09}	…	M^{7}_{08-09}	M^{8}_{08-09}
…	…	…	…	…	…
2016	M^{1}_{16-17}	M^{2}_{16-17}	…	M^{7}_{16-17}	M^{8}_{16-17}
2017	M^{1}_{16-17}	M^{2}_{16-17}	…	M^{7}_{16-17}	M^{8}_{16-17}

3. OMsteps 3:

First, and assessment between 1988 and 2005 is performed with a M constant and estimated by a prior. With the posterior of this M, the second step is to perform an assessment for 1988 to 2007 in another two substeps: in the first substep the M is fix for 1988-2005 and equal to the median posterior of first step and the M for ages 2006 and 2007 is estimated constant by a prior of mean the median posterior of the first step. With the posterior of this run, a second substep is made performing an assessment from 2006 to 2007 with M fix for 1988 to 2005 and M for 2006 and 2007 estimated by age with a prior of mean the median of the first step multiplied by a vector. The posterior median of this prior (one by age) is the value to be fix in the third step (for years 2008 and 2009) for M. The posterior median of the first subset is the value of the mean of the prior of M in the third step for years 2008 and 2009. Schematically:

Step 1. y= 88-05, $ln(\mathrm{M}_{88\text{-}95}) \sim N(ln(0.218), 0.3)$ => exp posterior median $M_{88-05}^{allages}$

Step 2. Step 2.1: y=88-07, $\mathrm{M}_{88\text{-}05} = M_{88-05}^{allages}$

$$ln(\mathrm{M}_{06\text{-}07}) \sim N(ln(M_{88-05}^{allages}), 0.3) \Rightarrow \text{exp posterior median } M_{06-07}^{allages}$$

Step 2.2: y=88-07, $\mathrm{M}_{88\text{-}05} = M_{88-05}^{allages}$

$$ln(\mathrm{M}_{06\text{-}07}[a]) \sim N(ln(M_{06-07}^{allages} * vectM[a]), 0.3) \Rightarrow \text{exp posterior median } M_{06-07}^{a}, \text{ a=1,…,8+}$$

Step 3. Step 3.1: y=88-09, $\mathrm{M}_{88\text{-}05} = M_{88-05}^{allages}$; $\mathrm{M}_{06\text{-}07}[a] = M_{06-07}^{a}$, a=1,…,8+

$$ln(\mathrm{M}_{08\text{-}09}) \sim N(ln(M_{06-07}^{allages}), 0.3) \Rightarrow \text{exp posterior median } M_{08-09}^{allages}$$

Step 3.2: y=88-09, $\mathrm{M}_{88\text{-}05} = M_{88-05}^{allages}$; $\mathrm{M}_{06\text{-}07}[a] = M_{06-07}^{a}$, a=1,…,8+

$$ln(\mathrm{M}_{08\text{-}09}[a]) \sim N(ln(M_{08-09}^{allages} * vectM[a]), 0.3) \Rightarrow \text{exp posterior median } M_{08-09}^{a}, \text{ a=1,…,8+}$$

Step 4 to 7: As 2 and 3, to finalize in y=88-17

Final M:

$M_{88-17} =$

	1	2	…	7	8
1988	M_{88-05}	M_{88-05}	…	M_{88-05}	M_{88-05}
1989	M_{88-05}	M_{88-05}	…	M_{88-05}	M_{88-05}
…	…	…	…	…	…
2004	M_{88-05}	M_{88-05}	…	M_{88-05}	M_{88-05}
2005	M_{88-05}	M_{88-05}	…	M_{88-05}	M_{88-05}
2006	M_{06-07}^{1}	M_{06-07}^{2}	…	M_{06-07}^{7}	M_{06-07}^{8}
2007	M_{06-07}^{1}	M_{06-07}^{2}	…	M_{06-07}^{7}	M_{06-07}^{8}
2008	M_{08-09}^{1}	M_{08-09}^{2}	…	M_{08-09}^{7}	M_{08-09}^{8}
2009	M_{08-09}^{1}	M_{08-09}^{2}	…	M_{08-09}^{7}	M_{08-09}^{8}
…	…	…	…	…	…
2016	M_{16-17}^{1}	M_{16-17}^{2}	…	M_{16-17}^{7}	M_{16-17}^{8}
2017	M_{16-17}^{1}	M_{16-17}^{2}	…	M_{16-17}^{7}	M_{16-17}^{8}

As for years 2002-2005 no catch-at-age is available due to the low catches in those years, the fact that the last year in the first step is 2005 could overestimate the value of M for 1988 to 2005. In order to see the effect of this fact, this OM was run again being the first step until 2006 instead of 2005. This OM is called OMsteps_3b.

A new specification was set in the very last moment, equal to OMsteps_3b but the CV of the caa grouped in three groups (2, 3-6, 4+) instead of four groups as the base case (1, 2, 3, 4+). This OM is called OMsteps_3c.

In all the cases, *vectM* is set as the vector used in the base case normalized to the mean of ages 6 to 8 (Table 1).

The CV of the priors is 0.3 in all cases.

In all the cases, the results of the Base Case, the one approved for the Scientific Council in 2018, are presented together with the rest of the OMs.

The detailed specifications of the Base Case and OMsteps_3c are in González-Troncoso *et al.* (2019).

Results

The median posterior results for M are in Table 2 and Figure 1 by year and age, and Figure 2 by step and age. Both if in the first step the assessment finalizes in 2005 or 2006, the value of M given for years 1988-2005/2006 for all ages is quite high compared with the assumed value of M for this stock, around 0.2. In the case of finalizing in 2005, the value of the median posterior of M is 0.64, 0.60 in case of finalizing in 2006 and 0.58 changing the groups of the caa CV. So, the difference between finalizing the first assessment in 2005 or in 2006 is quite low. This is because the SCAA is a forward model, so adding just one year to it does not make a big difference.

These results are different when we look to the value of M in the subsequent steps. Making the assessment since 2006 (first case) or since 2007 (second case) makes some differences. In the second step (first case: 06-07, second case: 07-08) and in the fifth step (first case:12-13, second case 13-14), M is lower in the second case, but in the rest of the steps M is higher in the first case. Age by age, it seems that the first case gives results with periods of time highly marked, since in the second case the values of M are more smothered. In almost all the cases, the M value of 2012 and 2013 are in the highest.

The OMs results about Total Biomass, SSB, R and F_{bar} are in Tables 3-6 and Figure 3. All the OMs estimate a much higher R than the base case between 2010 and 2013, where the R was highest, as in the case of the Total Biomass. In the case of the SSB, the OMsteps3_c estimates the lower SSB and the biggest F_{bar} of all the OMs for all the period. It is remarkable the behavior of the Total Biomass: for all the OMs, the Btotal peaks in 2012, but for the OMs finishing the first step in 2005, the biomass abruptly decreases in 2013 and 2014 and then remains stable or even increase. For the other case, the biomass decreases constantly until 2017. The SSB presents a similar behavior, although in that case the OMsteps3_b increases for the period 2013-2014.

Discussion

After a first run of these OMs that was presented to the technical EU group, an error was encountered in the code of the scenarios. With the former results, the OMsteps3 was set as the best case to be presented to the SC. Looking to these new results, this matter is open to discussion. All the scenarios seem to have strengths and weaknesses.

References

González-Troncoso, D., F. González Costas, C. Fernández A. Urtizberea, R. Alpoim, A. Avila de Melo, T. Brunel, J. De Oliveira and P. Apostolaki, 2019. Specifications of the OMs and the projections for the 3M cod MSE. NAFO SCR Doc. 19/006 Serial No. N6908.

González-Troncoso, D., C. Fernández and F. González Costas, 2018. Assessment of the Cod Stock in NAFO Division 3M. NAFO SCR Doc. 18/042. Serial No. N6833.

Table 1. Vector used in the approved assessment in 2018 as prior of the M (*Vector_asses*) as well as vector applied as prior of the M in the OMs (*VectM*).

Age	1	2	3	4	5	6	7	8
Vector_asses	1.26	0.65	0.44	0.35	0.30	0.27	0.24	0.24
VectM	5.04	2.60	1.76	1.40	1.20	1.08	0.96	0.96

Table 2. M results by age (median) of the six OMs, included the Base Case. BC: Base Case; OM1: OMsteps_1; OM2: OMsteps_2, OM3: OMsteps_3; OM3b: OMsteps_3b: OMsteps3 with the first step until 2006; OM3c: OMsteps_3c: OMsteps3_b with three groups in the CV of the caa. The Ms are grouped in years with the same value.

Age	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
BC_88-17	1.35	0.62	0.37	0.26	0.27	0.35	0.31	0.38
OM1_88-05	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64
OM1_06-07	1.66	0.86	0.58	0.46	0.40	0.36	0.32	0.32
OM1_08-09	0.69	0.36	0.24	0.19	0.17	0.15	0.13	0.13
OM1_10-11	0.70	0.36	0.24	0.19	0.17	0.15	0.13	0.13
OM1_12-13	2.32	1.20	0.81	0.65	0.55	0.50	0.44	0.44
OM1_14-15	0.92	0.47	0.32	0.26	0.22	0.20	0.18	0.18
OM1_16-17	0.73	0.38	0.26	0.20	0.17	0.16	0.14	0.14
OM2_88-05	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64
OM2_06-07	1.35	0.69	0.47	0.37	0.32	0.29	0.26	0.26
OM2_08-09	0.54	0.28	0.19	0.15	0.13	0.12	0.10	0.10
OM2_10-11	0.87	0.45	0.30	0.24	0.21	0.19	0.17	0.17
OM2_12-13	2.74	1.41	0.96	0.76	0.65	0.59	0.52	0.52
OM2_14-15	0.60	0.31	0.21	0.17	0.14	0.13	0.11	0.11
OM2_16-17	0.67	0.35	0.24	0.19	0.16	0.14	0.13	0.13
OM3_88-05	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64
OM3_06-07	1.76	1.78	0.54	0.34	0.22	0.19	0.20	0.21
OM3_08-09	0.77	0.36	0.19	0.15	0.15	0.14	0.12	0.15
OM3_10-11	0.80	0.36	0.35	0.29	0.19	0.18	0.19	0.16
OM3_12-13	1.82	1.19	2.13	1.07	0.61	0.63	0.63	0.54
OM3_14-15	0.90	0.42	0.44	0.30	0.15	0.16	0.17	0.18
OM3_16-17	0.81	0.35	0.52	0.19	0.18	0.18	0.17	0.22
OM3b_88-06	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
OM3b_07-08	0.67	0.54	0.48	0.28	0.21	0.17	0.19	0.21
OM3b_09-10	0.79	0.41	0.47	0.35	0.31	0.42	0.25	0.23
OM3b_11-12	1.40	0.97	0.57	0.33	0.26	0.28	0.23	0.20
OM3b_13-14	1.90	0.87	0.41	0.36	0.27	0.22	0.23	0.24
OM3b_15-16	1.20	0.49	0.33	0.44	0.90	0.32	0.37	0.44
OM3b_17	1.16	0.53	0.36	0.44	0.20	0.21	0.20	0.25
OM3c_88-06	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
OM3c_07-08	0.97	0.67	0.59	0.34	0.26	0.21	0.20	0.23
OM3c_09-10	1.02	0.56	0.45	0.48	0.41	0.39	0.26	0.25
OM3c_11-12	1.52	1.25	0.63	0.42	0.31	0.33	0.28	0.28
OM3c_13-14	1.89	0.80	0.56	0.42	0.27	0.23	0.22	0.23
OM3c_15-16	1.28	0.53	0.45	0.55	0.51	0.31	0.31	0.34
OM3c_17	1.19	0.52	0.35	0.36	0.23	0.24	0.23	0.24

Table 3. Total Biomass results of the six OMs, included the Base Case. Median and 90% CI. BC: Base Case; OM1: OMsteps_1; OM2: OMsteps_2; OM3: OMsteps_3; OM3b: OMsteps_3b: OMsteps_3 with the first step until 2006; OM3c: OMsteps_3c: OMsteps3_b with three groups in the CV of the caa.

	Btotal 50%						Btotal 5%						9Btotal 5%					
Year	BC	OM1	OM2	OM3	OM3b	OM3c	BC	OM1	OM2	OM3	OM3b	OM3c	BC	OM1	OM2	OM3	OM3b	OM3c
1988	86327	148886	148234	148126	135175	108608	80652	142048	141448	141449	128762	100124	92957	155599	155703	155112	141613	116403
1989	96807	154043	153773	153696	142436	117802	90779	146222	146048	146117	134862	107972	103317	162199	162079	162280	150384	127835
1990	88336	130457	130159	130643	121709	98218	82746	123335	123540	123917	115633	89380	94646	137642	137539	137761	128543	108460
1991	74514	95575	95397	96480	88631	67692	67416	90740	90586	91519	84350	61176	85467	100882	100411	101804	93453	75348
1992	88009	107116	106721	109254	100439	84718	80072	101888	101798	103731	95863	77866	98514	112761	112069	114907	105521	91821
1993	62018	87432	87075	89128	82076	74535	56926	82478	82332	84058	77469	69024	68333	92946	92204	94007	87017	80824
1994	54370	73260	73179	74693	69949	65914	50150	68749	68577	70196	65528	60330	58991	78395	78069	79648	74271	72412
1995	19787	29384	29269	29519	27285	22918	18330	27431	27524	27545	25532	20913	21458	31216	31126	31480	29189	24777
1996	7320	14192	14093	14221	12634	10421	6800	13292	13239	13337	11890	9674	7929	15195	15107	15222	13455	11227
1997	6176	11665	11570	11680	10492	8304	5731	10763	10717	10834	9723	7597	6666	12644	12568	12702	11309	9046
1998	3044	7105	7031	7084	6278	4412	2746	6381	6326	6401	5672	3965	3407	7922	7859	7931	6919	4953
1999	2454	5225	5159	5193	4693	2961	2145	4630	4592	4632	4188	2591	2831	5877	5841	5891	5254	3423
2000	2761	4668	4591	4637	4286	2567	2369	4140	4089	4131	3805	2201	3240	5264	5187	5259	4804	3007
2001	3498	5306	5150	5224	4927	3115	3017	4731	4645	4718	4459	2726	4108	5925	5715	5823	5462	3593
2002	3823	6452	6198	6257	6155	4086	3329	5758	5600	5666	5536	3583	4339	7261	6866	6966	6803	4693
2003	5013	6622	6268	6250	6463	4373	4397	5946	5662	5646	5868	3855	5859	7396	6913	6903	7108	5010
2004	8505	12176	11283	11073	12020	8098	7502	10947	10094	9974	10932	7167	9822	13570	12427	12244	13239	9411
2005	13344	14031	12488	16791	13821	10225	11671	12740	11341	15435	12621	9114	15913	15529	13735	18456	15157	11679
2006	29599	37409	28941	73658	28720	27618	25935	34078	26595	67449	26454	24637	35474	40732	31384	80760	31410	30964
2007	44414	45734	41008	66588	45536	52523	39723	42149	37832	60952	41962	47110	51140	49763	44405	72534	49406	58671
2008	59847	47576	48784	50257	63929	66606	54145	43935	45198	46747	59225	60161	67273	51653	52750	54290	68977	73601
2009	80731	74388	80667	85959	86602	80593	73608	68930	74959	80111	80586	73889	89939	80377	86889	92638	93282	88112
2010	108112	118079	140682	176754	123587	113231	99173	109414	130659	164527	115737	104584	120556	127466	151277	190781	132912	123309
2011	113019	157637	185439	281500	163492	151935	103250	144570	171413	261125	151830	139961	126378	171405	200275	305987	177368	166466
2012	158845	395736	499386	700939	258109	232554	141644	357707	454072	643498	237451	210393	182168	433712	550711	769433	282536	260439
2013	146820	219502	217888	321906	210681	153008	133202	198999	198723	294786	193540	138944	162416	240697	238668	355514	230085	170143
2014	140686	146340	124758	120324	196811	133387	128178	131850	112645	110866	179758	120059	154563	162064	137780	132236	217470	149132
2015	122445	137133	125174	114797	170992	107647	110663	122492	112105	104732	155143	95471	134515	152926	139399	126786	189702	121537
2016	127326	155985	152948	130044	146236	95804	114258	137726	136360	116929	131547	83850	141224	175702	173143	145283	163258	109981
2017	114530	165989	164389	128925	109437	78682	101066	144191	144427	114277	96860	67481	129343	188119	188189	145419	124010	92388

Table 4. SSB results of the six OMs, included the Base Case. Median and 90% CI. BC: Base Case; OM1: OMsteps_1; OM2: OMsteps_2; OM3: OMsteps_3; OM3b: OMsteps_3b: OMsteps_3 with the first step until 2006; OM3c: OMsteps_3c: OMsteps3_b with three groups in the CV of the caa.

	SSB 50%						SSB 5%						SSB 95%					
Year	BC	OM1	OM2	OM3	OM3b	OM3c	BC	OM1	OM2	OM3	OM3b	OM3c	BC	OM1	OM2	OM3	OM3b	OM3c
1988	23334	38648	38361	38205	35325	24810	18757	30523	30367	30209	28066	18635	29239	48943	48995	48455	44717	33234
1989	29415	45662	45265	45086	42538	32575	23613	36648	36830	36425	34085	25145	36125	56313	56131	55990	52336	41258
1990	32536	47343	47376	46917	44333	34404	27451	40131	39969	39677	37620	28120	38004	55460	55281	54996	52212	41639
1991	24812	36007	35770	35690	33834	22812	21032	30233	30488	30261	28472	18104	29119	42312	42361	41946	39672	27937
1992	25456	32075	31965	31870	30659	18153	22328	28172	28262	27907	27031	14143	29188	36721	36545	36506	35235	23807
1993	10351	14295	14268	14312	13577	7612	8961	12186	12200	12212	11625	6048	12235	16871	16738	16950	16014	9880
1994	21223	28089	28083	28554	26954	19712	18072	24120	24249	24491	23460	15352	24672	32214	32529	32970	31186	25003
1995	13530	18388	18375	18456	17575	13457	12219	16698	16763	16651	15945	11520	14883	20161	20133	20244	19386	15215
1996	3603	5577	5591	5532	5187	4048	3207	5010	4980	4948	4652	3405	4036	6283	6243	6187	5819	4770
1997	3976	6643	6616	6688	6115	4779	3582	5986	6005	5977	5540	4225	4394	7445	7424	7466	6783	5428
1998	2636	6164	6115	6161	5467	3847	2351	5492	5450	5515	4913	3424	2953	6929	6907	6974	6115	4342
1999	2187	4569	4522	4564	4140	2627	1876	3991	3984	4013	3643	2287	2551	5197	5159	5226	4682	3087
2000	2140	3613	3568	3610	3364	2044	1785	3105	3112	3111	2932	1720	2538	4236	4183	4179	3883	2453
2001	2142	2888	2852	2882	2792	1697	1821	2539	2519	2552	2465	1443	2505	3282	3256	3303	3172	2019
2002	2429	3224	3143	3213	3135	1984	2109	2812	2758	2804	2759	1685	2773	3654	3583	3658	3569	2338
2003	2866	3965	3808	3846	3947	2650	2520	3439	3388	3374	3469	2273	3231	4499	4371	4386	4484	3123
2004	4280	5567	5304	5315	5735	4029	3813	4924	4735	4764	5094	3492	4815	6295	5975	5989	6410	4689
2005	6496	7428	6882	6955	7675	5348	5675	6448	5971	6025	6749	4595	7519	8564	7910	8256	8774	6299
2006	10532	10344	9467	9499	10983	7638	9458	9200	8430	8469	9959	6719	11910	11659	10552	10744	12191	8931
2007	14960	14104	13708	14057	13721	11165	13123	12215	11939	12324	11843	9158	18433	17539	16796	17259	17217	14951
2008	26315	22528	23670	23001	27947	25486	23597	20383	21290	20906	25331	22267	29301	24900	25988	25302	31063	29210
2009	40919	40066	43742	41508	46639	43519	37166	36470	39838	37964	42502	38619	45023	44079	47813	45465	51253	48885
2010	59591	65957	75417	73568	66638	56942	53763	59984	68018	66523	60724	50162	66042	73657	83218	81837	73610	63967
2011	51956	68228	76118	75586	57606	44707	47340	61655	68767	68100	52398	39428	57702	75958	84403	84052	64086	50645
2012	54637	90272	97642	104274	63586	43970	49506	80535	87825	93258	57460	38451	60469	100933	109021	119883	71179	50045
2013	88899	123741	120917	148128	111862	76142	79680	110363	108536	130625	100697	66790	99214	139208	134647	169165	125921	85593
2014	87226	94326	82348	71911	114826	71789	77760	83690	72781	64335	101634	62519	97782	107556	92324	80578	131079	81905
2015	82684	94948	86710	70536	115924	68156	73175	83425	76205	62559	102469	58675	93315	108006	98327	79746	132255	78539
2016	92143	114574	111270	86583	103174	66810	81091	100064	97028	75598	90434	56672	104660	131371	127244	99126	118616	77700
2017	99098	143120	140513	105150	92176	65858	87008	123383	122398	92460	80360	55200	113640	163510	162010	120474	105611	78359

Table 5. R results of the six OMs, included the Base Case. Median and 90% CI. BC: Base Case; OM1: OMsteps_1; OM2: OMsteps_2; OM3: OMsteps_3; OM3b: OMsteps_3b: OMsteps_3 with the first step until 2006; OM3c: OMsteps_3c: OMsteps3_b with three groups in the CV of the caa.

	R 50%						R 5%						R 95%					
Year	**BC**	**OM1**	**OM2**	**OM3**	**OM3b**	**OM3c**	**BC**	**OM1**	**OM2**	**OM3**	**OM3b**	**OM3c**	**BC**	**OM1**	**OM2**	**OM3**	**OM3b**	**OM3c**
1988	62566	54825	54489	56659	46560	38311	44890	48545	48219	50277	41477	30910	92516	61699	61960	64041	52945	48970
1989	123085	102637	101917	107613	88055	90323	89468	90301	89341	94470	77460	73868	187160	116841	115544	121874	101607	111830
1990	109808	82608	81874	86846	72436	46500	79469	72258	72220	76610	63206	36367	166464	94268	94163	99359	82747	61354
1991	378437	264132	261300	270018	229574	244611	277237	235145	233348	241209	206178	200961	563544	295355	292577	299081	254645	288933
1992	305060	206373	205161	210047	181171	229235	224962	184484	185511	187423	161264	192145	450742	231177	229649	235533	203482	269073
1993	20626	16983	16744	17085	14388	18944	15027	15178	15121	15354	12798	14940	30434	19003	18871	19240	15904	24160
1994	37947	40523	40008	40993	32784	30985	27545	36055	35865	36649	29325	25892	57210	45491	44984	45871	36610	37704
1995	15898	19140	18904	19220	15226	12721	11676	16915	16623	17104	13575	10632	23949	21769	21310	22029	17184	14967
1996	985	1217	1189	1208	974	798	719	1043	1016	1036	837	657	1499	1406	1384	1416	1133	974
1997	862	1079	1047	1059	867	660	625	930	895	907	741	541	1317	1257	1219	1236	1017	792
1998	1434	1859	1801	1844	1497	711	1039	1555	1525	1576	1264	578	2215	2183	2133	2212	1771	865
1999	217	249	236	239	201	123	153	203	192	195	164	100	344	300	288	294	247	152
2000	3987	5514	5235	5486	4648	2928	2932	4721	4500	4623	3943	2373	6040	6539	6161	6497	5488	3587
2001	9480	10961	10287	10162	9795	6827	6889	9308	8772	8801	8410	5653	14322	12701	11945	11818	11241	8301
2002	919	915	847	796	808	498	650	775	721	676	684	400	1420	1079	1006	948	958	623
2003	24862	18859	16897	16321	17179	10919	18204	16385	14674	14223	15030	9185	36879	21667	19145	18640	19568	13172
2004	759	554	476	499	498	237	547	478	411	430	427	196	1127	636	551	584	571	287
2005	54653	37421	29526	83741	32098	31654	40204	32946	26055	73830	28541	26550	82061	42654	33295	94628	36249	37545
2006	88734	131805	83830	337214	49759	73508	64698	116496	74239	298497	44280	61841	131654	148217	94783	379940	56239	86095
2007	120800	126449	92208	167342	70875	91079	89220	112457	81152	146796	62892	76625	179475	142533	104057	187256	79519	106943
2008	107008	52850	48744	74287	56496	65743	78515	47071	43188	66091	50270	54507	162901	60178	54781	84469	63960	77302
2009	151489	92148	97236	149665	99738	110062	110626	81122	87092	132123	88311	93171	225812	104873	110172	172310	113304	130003
2010	259836	216658	307662	810282	290578	401597	189907	189124	271985	711205	257614	341562	386047	244998	351305	919097	330185	476240
2011	455238	626769	893755	1833707	1043830	1264131	332912	540398	781934	1619728	919537	1069973	683227	719242	1022365	2097576	1194431	1498911
2012	363180	1671209	2583324	1241508	733937	693332	261029	1431416	2213632	1071174	635626	563547	541769	1948922	2983431	1458751	850743	830055
2013	69224	188826	227735	130010	182474	115528	49437	158823	193623	110155	154416	93536	103896	224695	271800	155132	216495	141599
2014	90916	75148	49694	88382	182227	152161	64712	61556	41530	73040	150434	119274	136019	90690	59768	110410	223946	190664
2015	32879	29763	22090	35636	36453	34573	21840	23703	17670	28101	29162	26226	49538	37603	27927	44323	44680	44721
2016	2357	2206	2053	2607	2786	2350	1548	1580	1469	1811	2136	1696	3747	3062	2912	3937	3639	3276
2017	24865	23744	22323	29135	28604	24801	15747	16397	15267	19018	17824	15349	43523	35590	33337	47803	48811	41475

Table 6. F_{bar} (ages 3 to 5) results of the six OMs, included the Base Case. Median and 90% CI. BC: BC: Base Case; OM1: OMsteps_1; OM2: OMsteps_2; OM3: OMsteps_3; OM3b: OMsteps_3b: OMsteps_3 with the first step until 2006; OM3c: OMsteps_3c: OMsteps3_b with three groups in the CV of the caa.

	Fbar 50%						Fbar 5%						Fbar 95%					
Year	BC	OM1	OM2	OM3	OM3b	OM3c	BC	OM1	OM2	OM3	OM3b	OM3c	BC	OM1	OM2	OM3	OM3b	OM3c
1988	0.519	0.328	0.330	0.330	0.354	0.406	0.464	0.291	0.294	0.295	0.313	0.340	0.576	0.367	0.366	0.370	0.393	0.480
1989	0.622	0.398	0.400	0.404	0.429	0.502	0.567	0.361	0.362	0.365	0.389	0.434	0.684	0.442	0.444	0.446	0.471	0.581
1990	0.734	0.470	0.472	0.476	0.503	0.742	0.666	0.425	0.427	0.428	0.458	0.630	0.804	0.518	0.519	0.526	0.554	0.873
1991	0.433	0.309	0.311	0.314	0.327	0.499	0.383	0.279	0.278	0.276	0.292	0.394	0.489	0.350	0.352	0.352	0.372	0.630
1992	1.398	1.074	1.075	1.105	1.127	1.379	1.279	0.979	0.978	1.011	1.027	1.123	1.517	1.170	1.175	1.206	1.234	1.638
1993	0.961	0.730	0.730	0.740	0.763	0.800	0.868	0.659	0.655	0.673	0.693	0.675	1.055	0.802	0.804	0.818	0.843	0.957
1994	1.365	1.075	1.080	1.095	1.119	1.371	1.262	0.993	0.999	1.008	1.035	1.197	1.459	1.164	1.164	1.181	1.209	1.536
1995	1.300	0.921	0.921	0.931	0.979	1.091	1.194	0.838	0.839	0.854	0.894	0.923	1.408	1.000	0.998	1.017	1.062	1.277
1996	0.477	0.290	0.292	0.294	0.318	0.382	0.422	0.255	0.259	0.256	0.279	0.320	0.533	0.332	0.330	0.334	0.358	0.452
1997	0.920	0.451	0.449	0.458	0.506	0.606	0.828	0.393	0.396	0.397	0.445	0.501	1.020	0.510	0.510	0.518	0.569	0.706
1998	0.326	0.133	0.134	0.134	0.152	0.245	0.278	0.115	0.116	0.115	0.130	0.202	0.377	0.155	0.156	0.156	0.175	0.297
1999	0.210	0.094	0.094	0.094	0.104	0.114	0.175	0.078	0.079	0.079	0.086	0.085	0.253	0.111	0.113	0.112	0.122	0.153
2000	0.065	0.031	0.032	0.032	0.034	0.023	0.052	0.026	0.026	0.026	0.028	0.016	0.079	0.038	0.039	0.039	0.042	0.033
2001	0.075	0.043	0.044	0.045	0.045	0.021	0.057	0.033	0.034	0.035	0.035	0.014	0.101	0.057	0.056	0.057	0.059	0.030
2002	0.021	0.011	0.011	0.011	0.011	0.014	0.017	0.009	0.009	0.009	0.009	0.010	0.025	0.013	0.014	0.013	0.014	0.020
2003	0.006	0.004	0.004	0.004	0.004	0.006	0.005	0.003	0.003	0.003	0.003	0.004	0.008	0.005	0.005	0.005	0.005	0.007
2004	0.002	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.002
2005	0.002	0.002	0.002	0.002	0.002	0.003	0.002	0.001	0.002	0.002	0.001	0.002	0.003	0.002	0.002	0.002	0.002	0.004
2006	0.054	0.050	0.054	0.054	0.050	0.041	0.045	0.042	0.046	0.045	0.043	0.030	0.064	0.059	0.064	0.064	0.059	0.053
2007	0.015	0.016	0.016	0.016	0.015	0.018	0.012	0.013	0.013	0.013	0.013	0.014	0.017	0.018	0.018	0.018	0.017	0.024
2008	0.028	0.031	0.029	0.031	0.025	0.023	0.024	0.027	0.025	0.027	0.022	0.019	0.032	0.036	0.034	0.036	0.030	0.029
2009	0.021	0.021	0.019	0.020	0.019	0.021	0.018	0.018	0.016	0.018	0.016	0.018	0.024	0.024	0.022	0.023	0.022	0.025
2010	0.130	0.112	0.099	0.101	0.119	0.127	0.113	0.097	0.086	0.087	0.103	0.102	0.150	0.129	0.115	0.115	0.136	0.156
2011	0.140	0.100	0.091	0.081	0.124	0.162	0.121	0.086	0.078	0.071	0.107	0.125	0.162	0.116	0.105	0.094	0.143	0.203
2012	0.095	0.064	0.060	0.051	0.079	0.119	0.082	0.054	0.052	0.044	0.068	0.089	0.111	0.074	0.071	0.060	0.093	0.153
2013	0.094	0.080	0.086	0.081	0.075	0.106	0.081	0.068	0.073	0.069	0.064	0.083	0.110	0.093	0.100	0.094	0.088	0.135
2014	0.068	0.066	0.075	0.080	0.050	0.090	0.058	0.056	0.064	0.068	0.043	0.070	0.081	0.079	0.089	0.094	0.059	0.113
2015	0.076	0.068	0.071	0.076	0.060	0.093	0.065	0.057	0.059	0.064	0.051	0.070	0.089	0.081	0.083	0.090	0.071	0.119
2016	0.083	0.065	0.062	0.067	0.072	0.083	0.069	0.054	0.052	0.056	0.060	0.059	0.101	0.078	0.075	0.080	0.086	0.113
2017	0.059	0.038	0.036	0.039	0.052	0.072	0.049	0.031	0.029	0.032	0.042	0.047	0.072	0.048	0.044	0.049	0.065	0.111

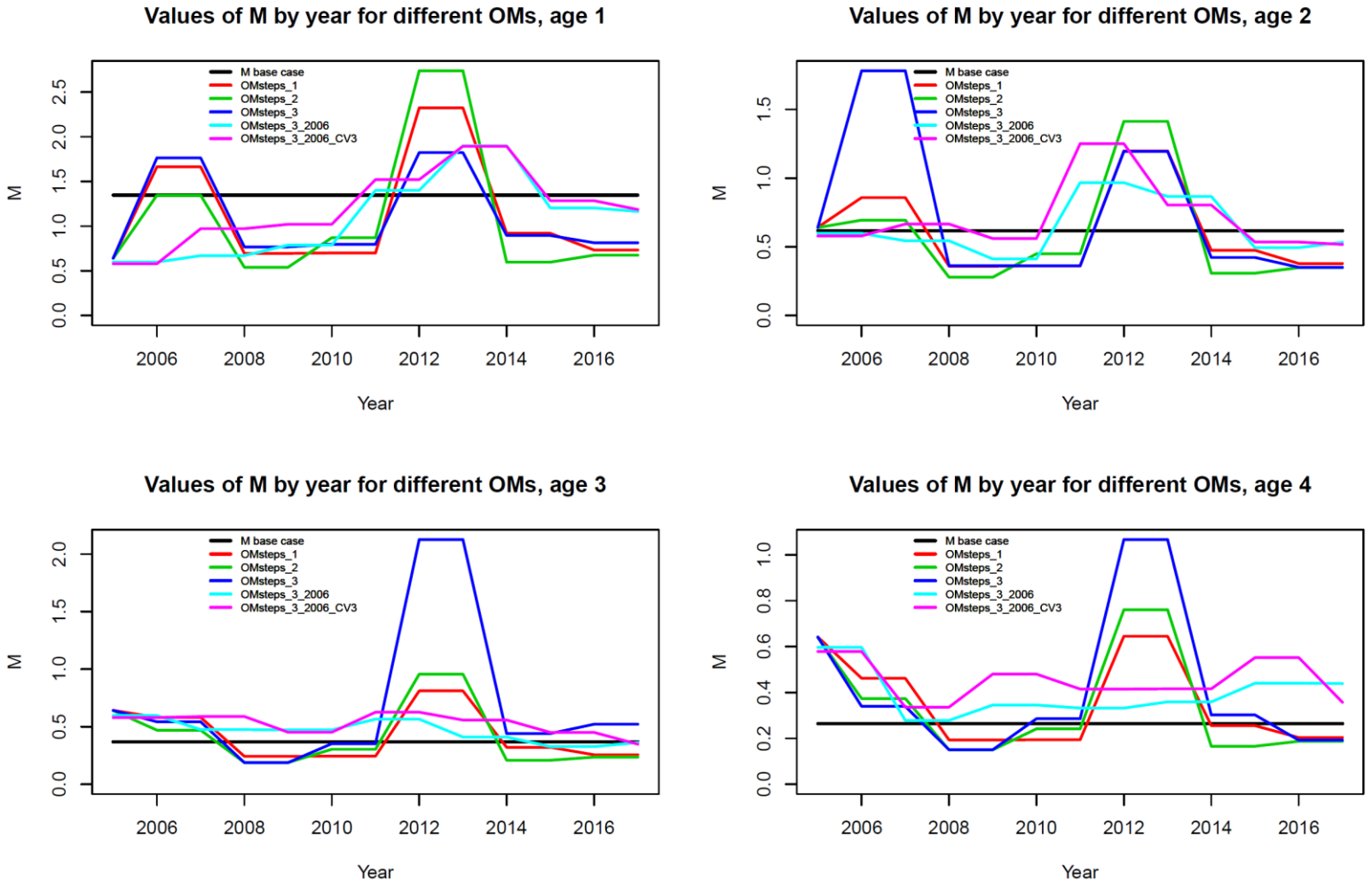

Figure 1. M results by age (median) of the six OMs, included the Base Case.

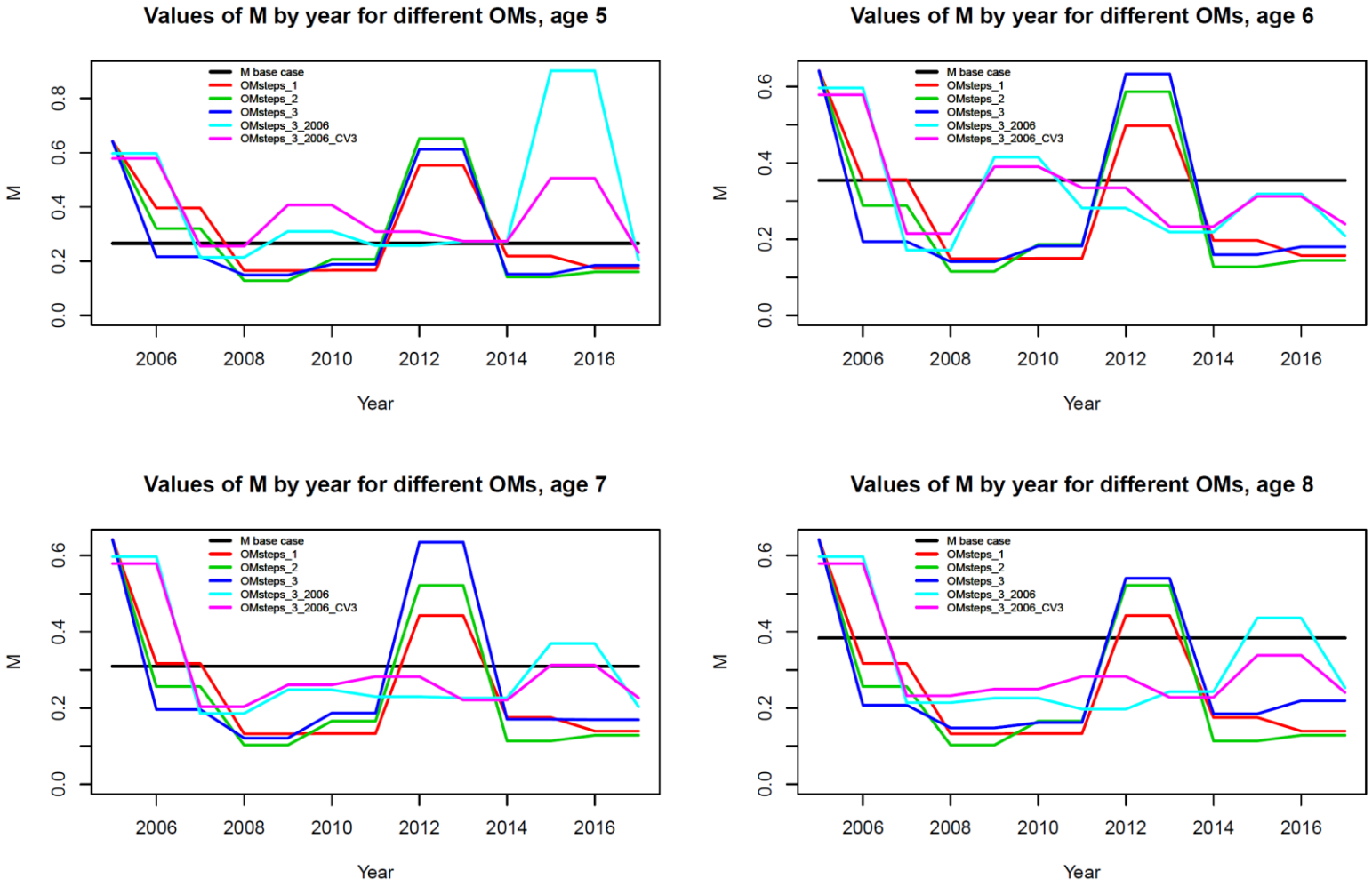

Figure 1 (cont.). M results by age (median) of the six OMs, included the Base Case.

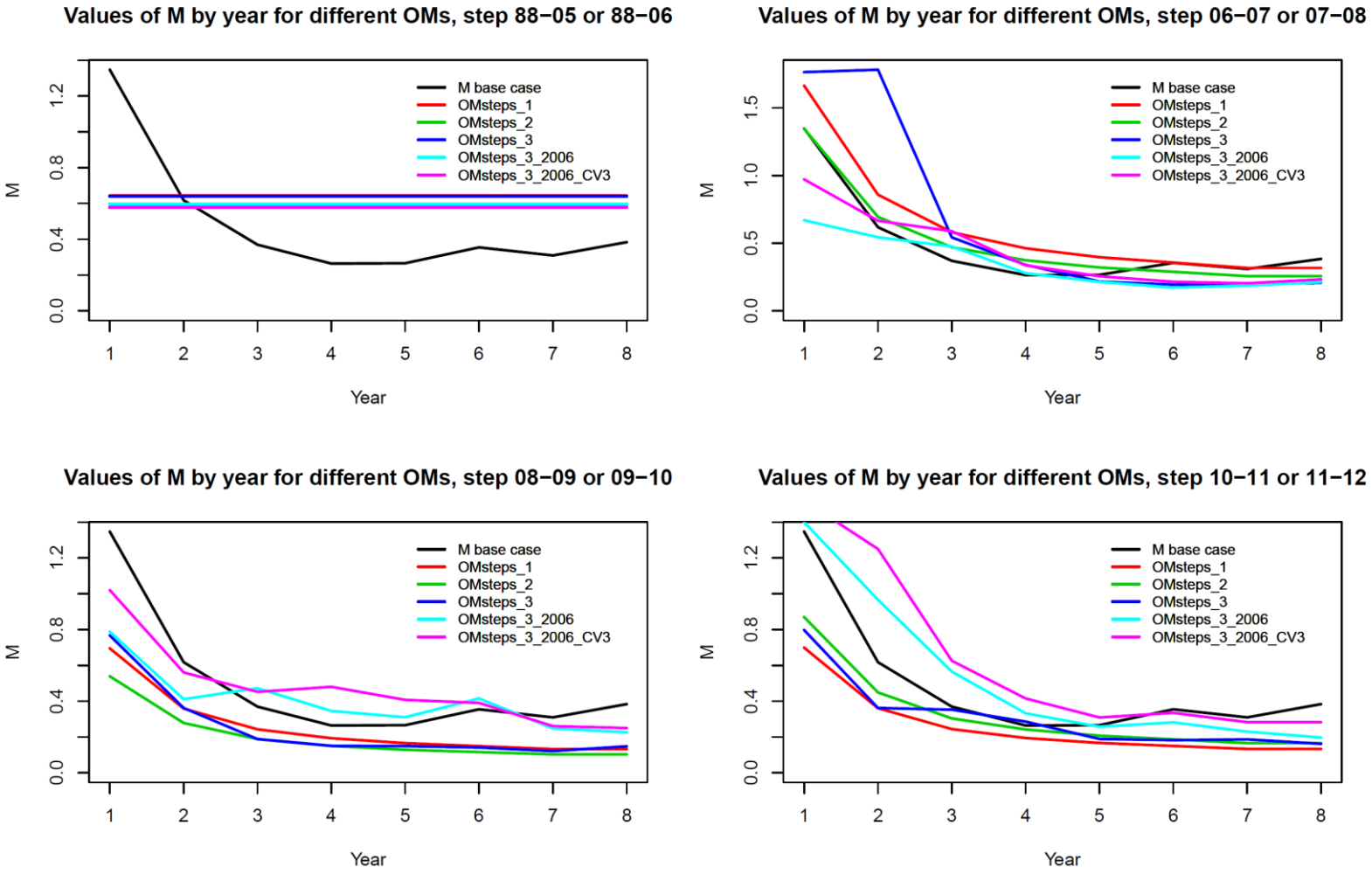

Figure 2. M results by step (median) of the six OMs, included the Base Case.

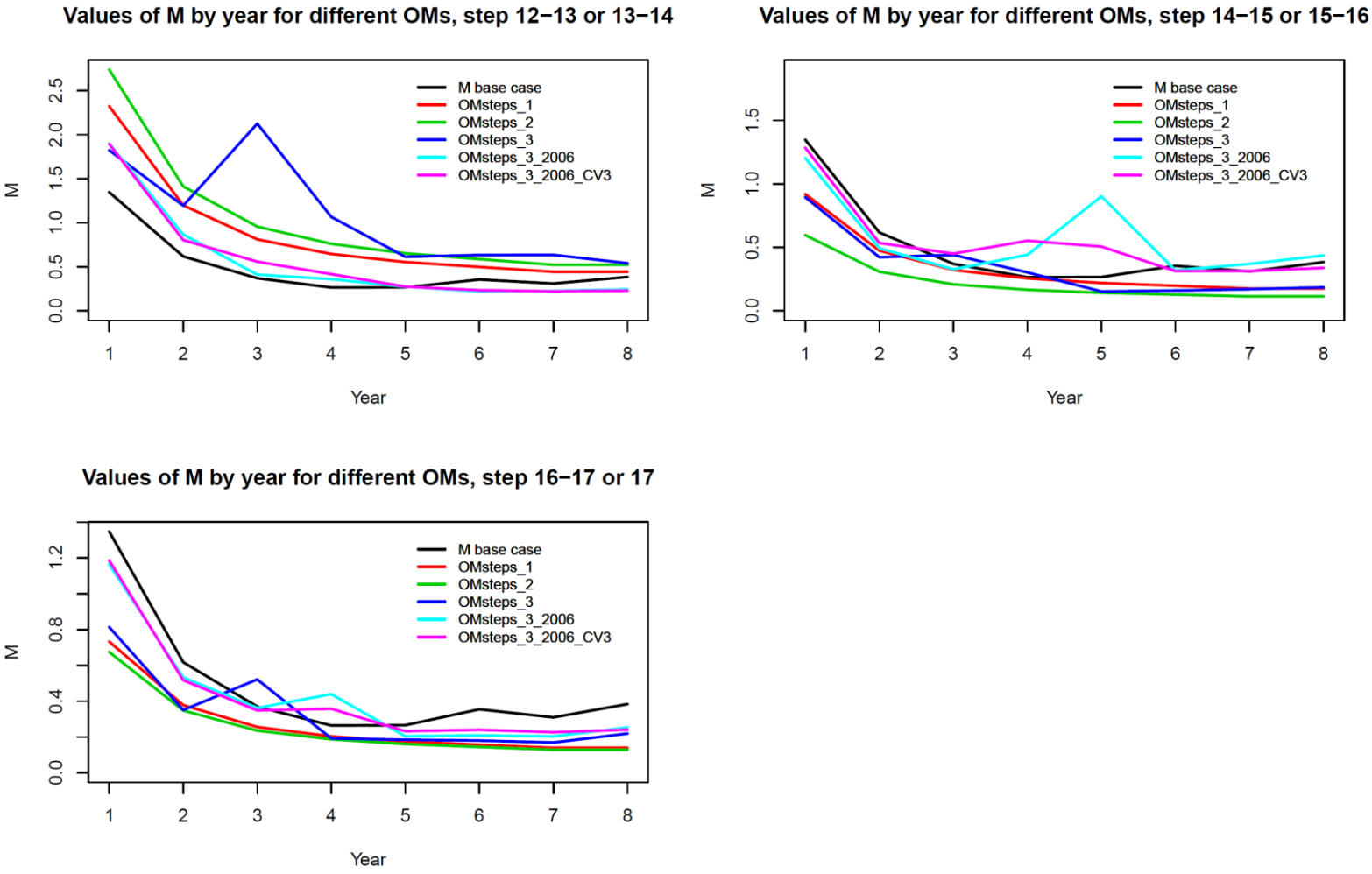

Figure 2 (cont.). M results by step (median) of the six OMs, included the Base Case.

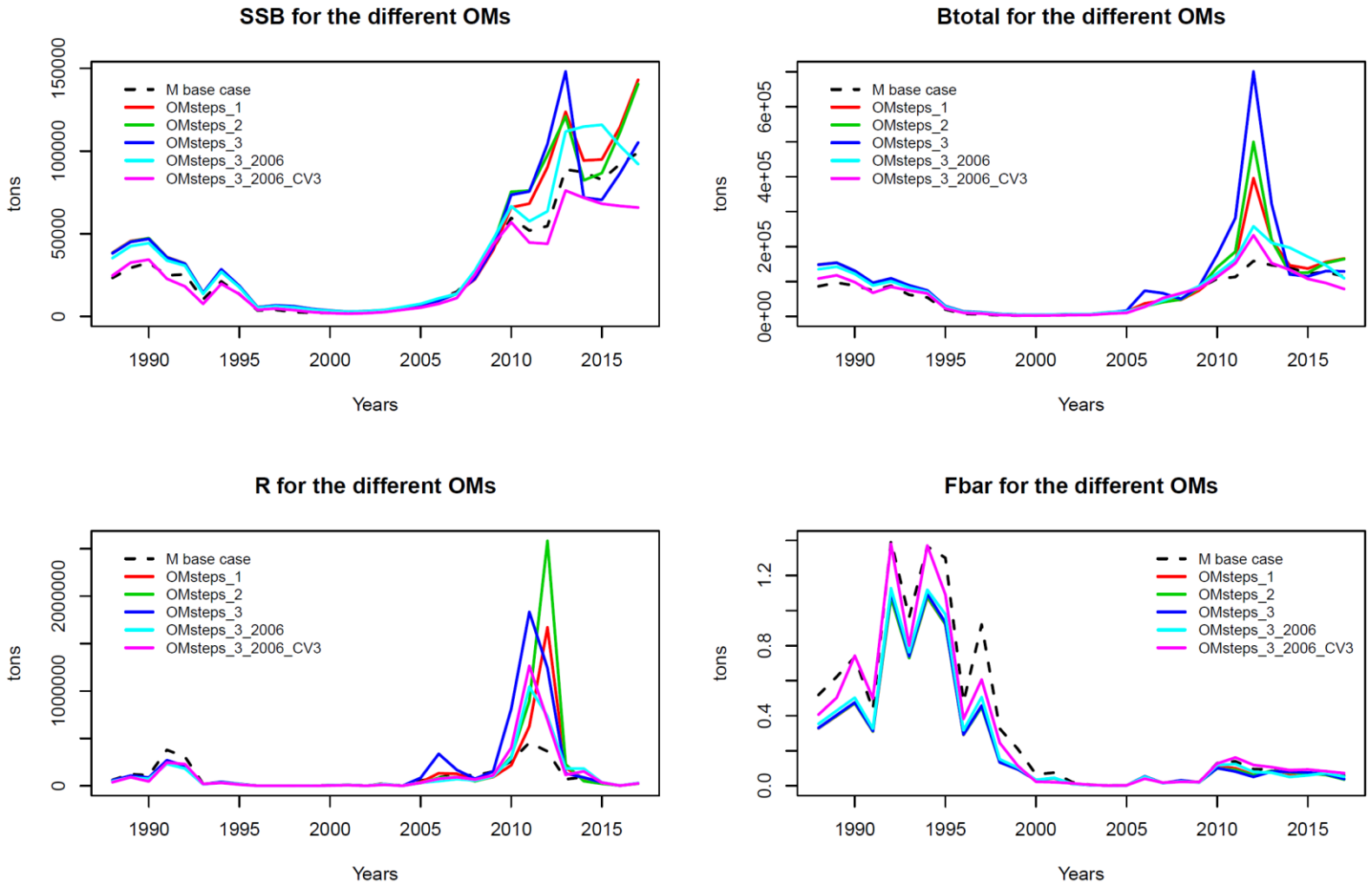

Figure 3. SSB, Btotal, R and Fbar results (medians) of the six OMs, included the Base Case.