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MSE Mackerel using a Surplus Production Model as biological OM

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Surplus Production Model as biological OM.

The carrying capacity parameter of the model (SB_0 or K) was estimated based on: 1) a meta-analysis by Thorson *et al.* (2012) who showed that the average Surplus Production Model (SPM) shape parameter phi (φ) (= B_{MSY}/SB_0) is 0.353 for Perciformes fish, 2) Sparholt *et al.* (2019) who estimated that F_{MSY} for mackerel is 0.2412 (in the SPM F-"currency"), and 3) a fit to observed mackerel surplus production for 1980-2017 (assuming the mid-level of misreporting given in ICES 2013).

We use the formulation of Thorson *et al*. (2012) of the surplus production, S_t, with re-parameterized maximum sustainable yield (MSY) as a proportion of carrying capacity (y = MSY/SB_0):

$$\widehat{S}_t = \gamma \cdot y \cdot \mathrm{SB}_t - \gamma \cdot y \cdot \mathrm{SB}_0 \cdot \left(\frac{\mathrm{SB}_t}{\mathrm{SB}_0}\right)^{\varphi} \qquad \gamma = \frac{\varphi^{\varphi/_{\varphi-1}}}{\varphi - 1}$$

When phi = 0.353 then gamma (ϒ) is -32.61. $MSY/B_{MSY} = F_{MSY} = 0.2412$ which gives y = 0.0847. SB_0 (in the metric total stock biomass) was then estimated to be 18.556 million t. The resultant model is shown in Fig.1.

The analysis behind this is given in WKMSEMAC Doc HS 1 and 2.

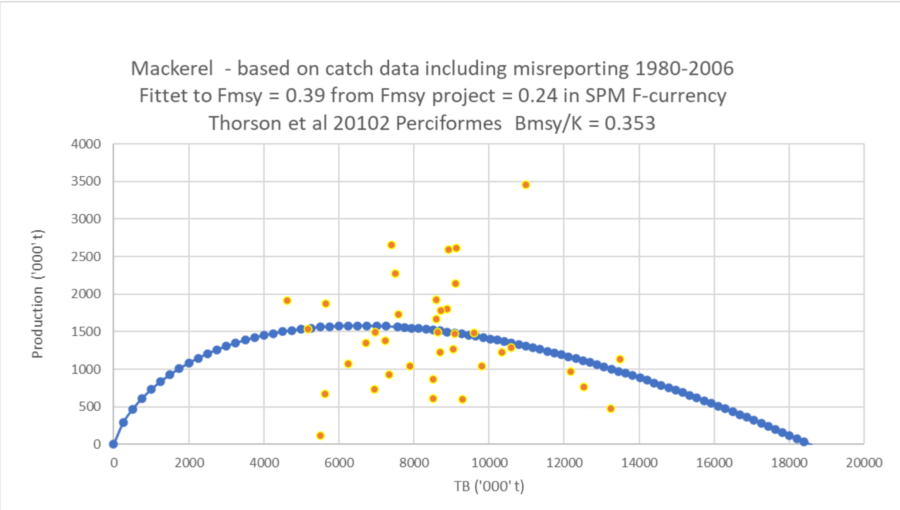

Figure 1. *Mackerel. A SPM model with F_{MSY} = 0.2412 (from the Fmsy project) , n (above called phi) = 0.353 (from Thorson et al. 2012 Perciformes fish) and K (above called SB_0) estimated by fitting to observed SP*

from an assessment by ICES (2013) including misreport of mackerel catches 1980-2006, extended to include 2007-2017.

MSE

The simulations are done as described below:

1) start with the observed TB (2020).

2) The real TB is obtained taking observation error into account (log normally distributed obtained from historic assessment).

3) Then the SP is obtained considering process error (assumed normally distributed and CV linearly related to TB).

4) The real SSB is obtained by a linear link to TB influenced by F (regression obtained from the historic assessment).

5) Then the observed SSB is obtained taking account of observation error.

6) Then intended F is obtained taking account of the HCR (linearly reduced when SSB < $MSYB_{trigger}$).

7) The TAC is then obtained.

8) The realised yield obtained taking implementation error into account.

9) The real TB for the following year is then obtained from the real TB the current year + real SP – realised yield.

10) The observed TB the following year is obtained from the real TB and observation error.

…repeat the sequence from stage 3) above for each year into the future in the simulations.

In this way it is a full feedback MSE because the TAC in each future year are based on observed quantities rather than on OM quantities. It is based the observed TB and SSB estimated each year from the assessment model simulated via empiric observation error. Obviously, the SPM OM cannot provide stock number by age each year in the simulations so an age-based assessment cannot be done in future years in the simulations. The observation error is based on the historical performance of the assessment.

Simulations were done in Excel. Excel is quite fast nowadays and did about 0.5 million formula calculations in a split second. We also intend to make an R code programme to be able to repeat the analysis and take advantage of the extra options an R code programme offers compared to Excel.

Total stock biomass (TB) is used as stock biomass in the MSE to be consistent with the SPM model and its parameters. ICES (2019) value of TB(2020) = 5685 thousand t is used as starting point in the simulations. Other input data are given in the table below:

Input:				Fmsy =MSY/Bmsy=	0.2412	
Bpa =	2500			K=	18556	
Blim =	1990			n (called phi in formula)=	0.92	Autocorr.
MSYBtrigger =	2500			SP process error STD=TB*q, q=	0.012	0.00
MS type =	MS1			Observation CV =	0.09	0.00
B year 2020 =	5685			Implementation CV =	0.01	0.00
SSB vs TB coefficients:		a=	-0.3735	b=	0.8032	
F target (SPM currency) =	0.2412	Ratio F (SPM currency vs F (ICES currency) =			0.6236	

The process error and observation error together gave a CV =0.49 of observed SP at TB equal to B_{MSY} and this corresponds well to a value obtained from the F_{MSY} project of the CV of SP = 0.54 of all stocks. It also gives a spread around the production curve of simulated observed SP vs observed TB (see Figure 2) like the one seen historically (Figure 1). The process error was assumed to be normally distributed with a STD proportional to TB. SSB was obtained by a relationship to TB as a function of F. The parameters were obtained from the historic assessment.

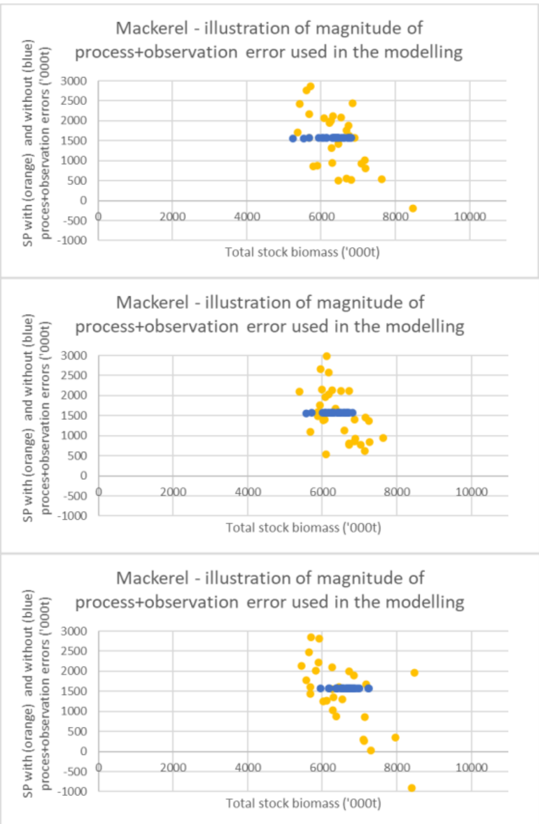

Figure 2. *Mackerel. Three random example of simulated observed SP vs observed TB. The spread of points around the blue line should be like the spread shown in Figure 1 if the assumed process and observation error in the simulations are assigned proper values.*

Table 1. *Mackerel. Results of simulations using as OM an SPM model with Fmsy = 0.2412 (from the Fmsy project) , n = 0.353 (from Thorson et al 2012 Perciformes fish) and K estimated by fitting to observed SP from an assessment by ICES 2013 including misreport of mackerel catches 1980-2006, extended to include 2007-2017.*

F	TB 2060	Y 2060	Y 2020-2024	Y 2025-2029	SSB 2060	TAC variation (CV) from year to year	5% per-centile of SSB 2060
0.00	18616	0	0	0	14952	-	12708
0.02	16880	337	900	1376	13432	14	11445
0.04	15490	616	1479	2478	12210	13	10530
0.06	14157	852	2216	3520	11053	13	9596
0.08	12914	1049	3043	4475	9986	13	8689
0.1	11934	1187	3698	5367	9140	12	7925
0.12	10928	1312	3988	5966	8288	15	7057
0.14	9979	1404	4926	6436	7493	13	6461
0.16	9212	1464	5573	7233	6849	13	5884
0.18	8501	1517	5925	7003	6257	16	5275
0.2	7872	1552	6800	7451	5735	14	4856
0.22	7127	1570	6290	7613	5139	14	4422
0.24	6595	1578	6949	7332	4706	12	4096
0.26	5998	1569	7225	7439	4235	14	3659
0.28	5606	1565	7641	7925	3916	14	3302
0.3	5207	1542	8036	7840	3599	16	2944
0.32	4698	1510	8641	7855	3212	16	2741
0.34	4438	1491	9469	7621	3001	16	2487
0.36	4106	1450	7568	7388	2746	18	2310
0.38	3847	1434	8872	7792	2544	25	2124
0.4	3748	1415	9780	6986	2450	29	2001
0.42	3561	1393	8981	6770	2302	32	1883
0.44	3447	1374	9553	6855	2202	33	1818
0.46	3399	1372	10821	6685	2146	34	1783
0.48	3360	1364	9448	6707	2097	35	1750
0.5	3248	1342	9154	6970	2002	39	1640
0.52	3263	1345	9822	7260	1987	37	1622
0.54	3119	1321	9171	7224	1876	44	1490
0.56	3114	1330	10100	6662	1850	38	1493
0.58	3097	1324	9040	6547	1817	42	1463
0.6	3057	1308	10012	6610	1770	42	1423

*A single iteration (data for 2060 taken as mean of 2060-2259)

The simulations were run until 2259 and the mean taken over 2060-2259 of the performance parameters. This was tested against running 200 simulations until 2059 and comparing the mean and variances. As these differed only very slightly and unsystematically, of practical reasons the first approach was preferred.

Table 1 and Figures 3 and 4 give the results in terms of performance parameters by F level. The highest yield in 2060 is obtained with an F of 0.24. The yield is estimated to be 1588 ‘000t. The corresponding SSB is 4682 ‘000t and the 5% lower confidence limit is 3993 ‘000t, i.e. well above Blim of 1990 ‘000t. The TAC variability from year to year is almost constant until an F value of 0.35 when it steeply increases to above 40%. It seems that F can be increased to 0.40 without losing very much in yield, and without risking SSB to be lower than Blim with a higher probability than 5%. However, the TAC variability increases significantly for an F value of around 0.35 and above. Thus, any target F value lower than 0.35 seems to be precautionary and deliver sustainable yield, with an MSY at an F value of 0.24.

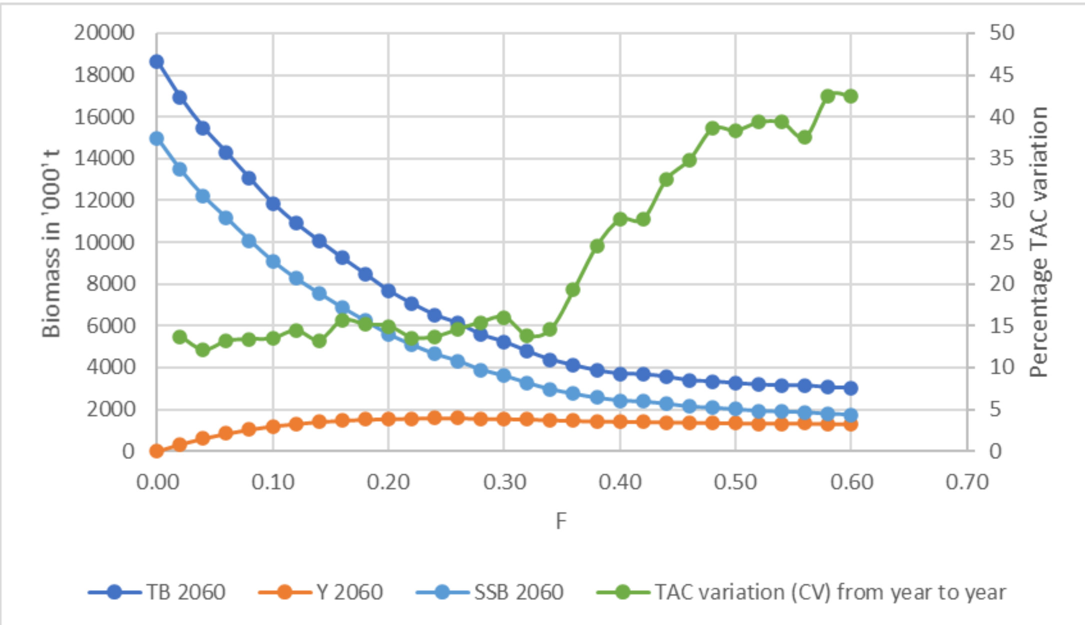

Figure 3. *Mackerel. Mean TB (total stock biomass), SSB, yield, and TAC annual variability in 2060 vs target F value given the ICES default HCR.*

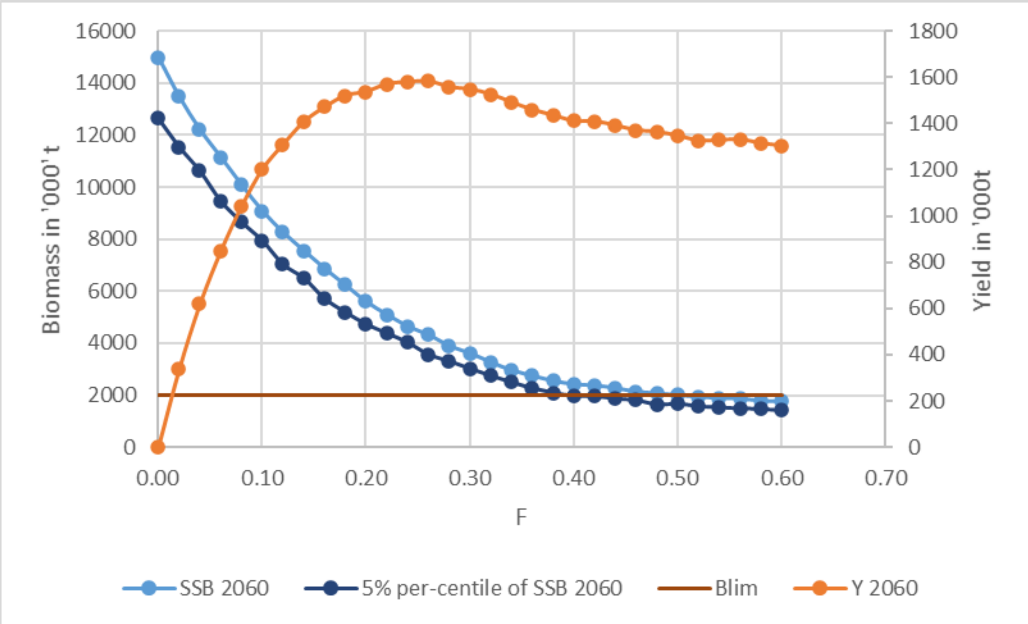

Figure 4. *Mackerel. Mean SSB, Yield, and 5% lower confidence limit form SSB in 2060 vs target F given ICES default HCR*.

The development in SSB and yield until 2060 for an F value of 0.24 and one iteration is shown in Figure 5. Both SSB and yield are stable and slightly higher than the values in 2020 and fluctuate about 20% from year to year.

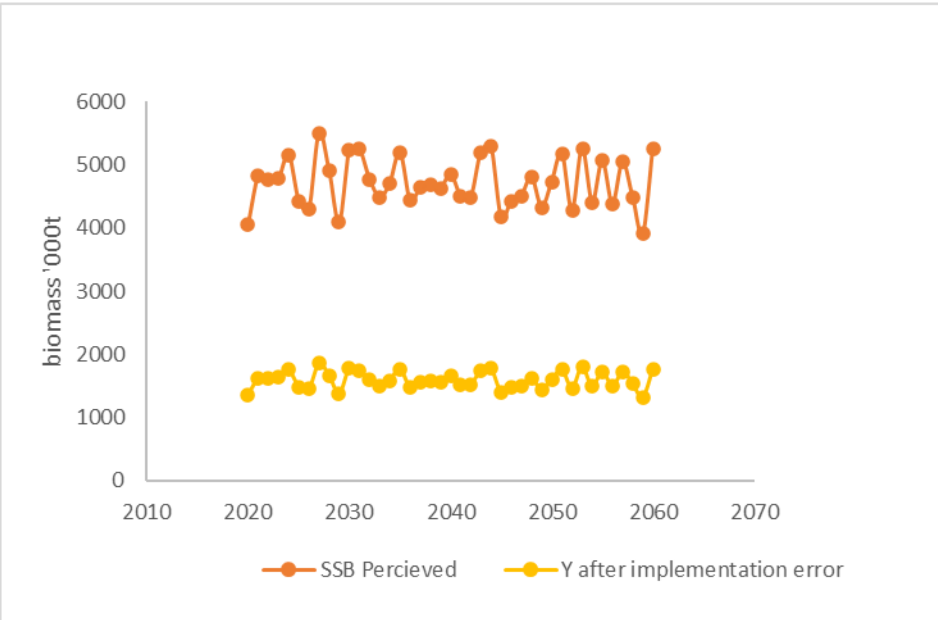

Figure 5. *Mackerel. Development in SSB and yield 2020-2060 for an F value of 0.24 from one randomly chosen simulation*.

The yield with 95% confidence intervals in 2060 as a function of target F applied in all years until 2060 and the default HCR with a $MSYB_{trigger}$ of 2.5 million t SSB are shown in Figure 6. The intervals increase somewhat from an F value of 0.35 and upwards. If compared with historic time series it should be remembered that F (the X-axis) is without observation error in Figure 6. If this had included observation error the confidence intervals would be wider.

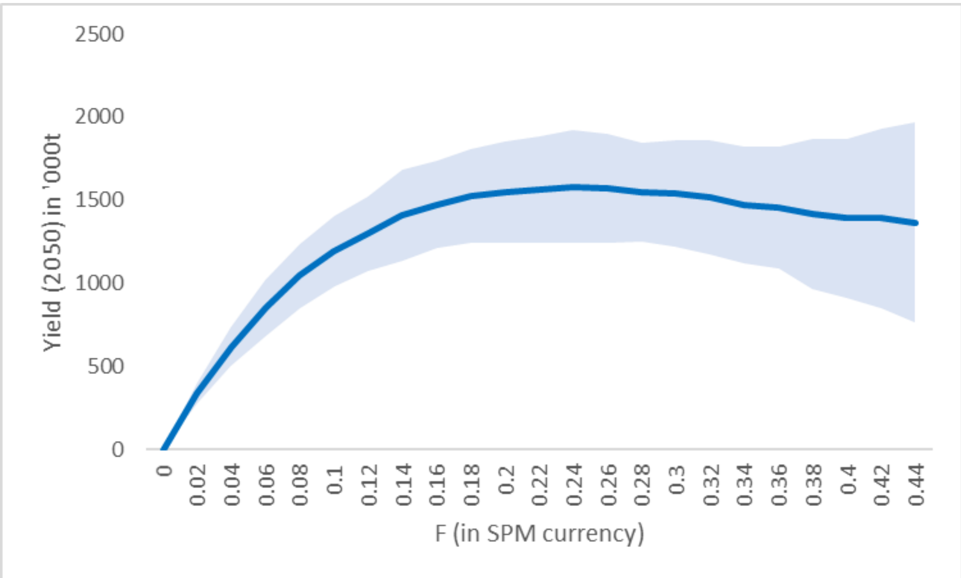

Figure 6. *Mackerel. Mean and 95% confidence intervals for the yield in 2060 vs target F given the ICES default HCR*. *The confidence interval looks a bit narrow, but F on the X-axis is not including observation error.*

Weak point. The observation error of the TB from the annual assessment should be biased in the first years (maybe 10-20 years) if the annual assessment in future does not include mis-reported catches in 1980-2006. This has not yet been modelled and might not matter for the results in 2060 but it will matter for the results of medium-term yield (Y2020-2024 and Y2025-2029).

Conclusion

Any target F value lower than 0.35 seems to be precautionary and deliver sustainable yield, with an MSY at an F value of 0.24. The TAC variability from year to year increases steeply from an F above 0.35.

In an ecosystem approach to management it might be prudent to aim for at target F slightly higher than Fmsy because it will reduce the stock size of mackerel and thus leave more food available to other fish species in the ecosystem while only reducing the yield marginally. A target F of for instance 0.30 will reduce the stock size by 1.4 million t (21%), while only reducing the yield by 0.028 million t (2 %) compared to the Fmsy values.

References.

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