The operating model for an anchovy-only OMP-18rev

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The components of the Operating Model used to simulation test candidate Management Procedures (CMPs) during the development of an anchovy-only OMP-18rev are detailed.

Keywords: anchovy, management procedure, operating model

This document details the various components of the Operating Model (OM) used to simulation test candidate Management Procedures (CMPs) during the development of an anchovy-only OMP-18rev. It differs from de Moor (2020b) through the exclusion of all sardine components, including the previously assumed correlation between anchovy and sardine survey observations and the potential closure of the anchovy fishery due to an OMP calculated small sardine TAB with anchovy directed fishing being reached. A summary of assumptions made in this OM are listed below. Appendix A provides the full details, with data used listed in the tables at the end of the Appendix.

Summary list of assumptions made in the OM to be used to simulation test OMP-18rev

1) Half the juvenile anchovy is caught between 1 November and 30 June and half from 1 July to 31 October.
2) Half the adult anchovy is caught between 1 November and 31 March and half from 1 April to 31 October.
3) The assumptions made during the development of the underlying population dynamics OMs (de Moor 2020a), such as maturity ogives (in recent years) and stock-recruitment relationships and differences in these assumptions between alternative OMs (robustness tests), are carried forward during projections.
4) The recruit survey is simulated to commence mid-May each year.
5) Half of $TAB^A = 500t$ is taken by the end of June, with the remaining half taken by the end of the season.
6) The initial anchovy TAC, $TAC_y^{1,A}$, is caught by the end of June, and 76% of this is caught by the end of May with the remaining 24% caught during June.
7) 29% of the total anchovy catch landed by the end of June ($TAC_y^{1,A} + \frac{1}{2}TAB^A$) are juveniles caught by mid-May.
8) The annual adult anchovy catch is 38% of the anchovy catch landed by the end of June ($TAC_y^{1,A} + \frac{1}{2}TAB^A$).
9) For all catches simulated, an upper limit is placed on the industry's efficiency by assuming that no more than 95% of the selectivity-weighted stock abundance may be caught.
10) Future survey observations are generated with the variance based on a regression between historical survey CV and model predicted abundance.
11) TAC/Bs and anchovy catches already known for 2020 and initial TAC for 2021 have been used instead of model simulated values. The survey recruitment observation simulated to occur in mid-May 2020 is checked against the confidence intervals of that observed by the survey in June 2020.

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Appendix A: The OM used to simulation test an anchovy-only MP for South African anchovy: OMP-18rev

In this appendix, the OM used to simulation test OMP-18rev is detailed. The OM consists of a population dynamics model for future simulation of the effects of CMPs on the anchovy population, an implementation model which generates future catches-at-age given annual TAC/Bs, and an observation model which generates the necessary survey data to be input into the Harvest Control Rules. Catches-at-age are given in numbers of fish (billions), whereas the TACs and TABs are given in biomass (in thousands of tons). All parameters are listed in Table A1.

Population dynamics model

Given the numbers-at-age at the beginning of the projection period (i.e., November 2019), and values for future catches output from the implementation model, $C^{A}_{j,y,a}$, (see below), the population dynamics model projects numbers-at-age and spawning biomass at the beginning of November for $2020 \leq y \leq 2040$ as follows. The anchovy recruit catch is assumed to be taken in a pulse on 1st July and the adult catch is assumed to be taken in a pulse on 1st April. All notation allows for multiple components, though only a single stock for anchovy is considered in all OMs.

Anchovy:

$$\begin{aligned}
N^{A,pred}_{j,y,1} &= \left(N^{A,pred}_{j,y-1,0}e^{-8M^{A}_{ju}/12} - C^{A,pred}_{j,y,0}\right)e^{-4M^{A}_{ju}/12}\\
N^{A,pred}_{j,y,2} &= \left(N^{A,pred}_{j,y-1,1}e^{-5M^{A}_{ad}/12} - C^{A,pred}_{j,y,1}\right)e^{-7M^{A}_{ad}/12}\\
N^{A,pred}_{j,y,3} &= N^{A,pred}_{j,y-1,2}e^{-M^{A}_{ad}}\\
N^{A,pred}_{j,y,4^+} &= N^{A,pred}_{j,y-1,3}e^{-M^{A}_{ad}} + N^{A,pred}_{j,y-1,4^+}e^{-M^{A}_{ad}}\\
B^{A,pred}_{j,y} &= \textstyle\sum_{a=0}^{4+} N^{A,pred}_{j,y,a}\,\overline{w}^{A}_{j,a}\\
SSB^{A,pred}_{j,y} &= \textstyle\sum_{a=1}^{4+} f^{A}_{j,a}N^{A,pred}_{j,y,a}\,\overline{w}^{A}_{j,a}
\end{aligned}\tag{A.1}$$

Letting $f\left(SSB^{A,pred}_{j,y}\right)$ denote the stock recruitment relationship of the chosen model, with parameters a^{A}_{j} and b^{A}_{j}, then future recruitment $N^{A,pred}_{j,y,0}$ is assumed to be log-normally distributed about a stock recruitment relationship as follows:

$$N^{A,pred}_{j,y,0} = f\left(SSB^{A,pred}_{j,y}\right)e^{\varepsilon^{A}_{j,y}\sigma^{A}_{j,r} - 0.5\left(\sigma^{A}_{j,r}\right)^2} \tag{A.2}$$

where

$$\varepsilon^{A}_{j,y} = s^{A}_{j,cor}\varepsilon^{A}_{j,y-1} + \omega^{A}_{j,y}\sqrt{1-\left(s^{A}_{j,cor}\right)^2}, \text{ where } \omega^{A}_{j,y} \sim N(0,1) \tag{A.3}$$

These standardised residuals, $\varepsilon^{A}_{j,y}$, are restricted to the historical minimum and maximum residuals[1]. In addition, future anchovy recruitment is restricted to a maximum of the 99%ile of that estimated in the peak recruitment year (November 2000).

Implementation model

The CMPs output the following TAC/Bs:

1) An initial and final anchovy TAC ($TAC^{1,A}_{y}$ and $TAC^{2,A}_{y}$).

[1] Any values outside this range are set to the minimum/maximum, rather than re-sampled, to ensure the sequence of random numbers remains unchanged between OMs.

2) An annual time-invariant anchovy TAB for sardine only right holders, TAB^A.

Given these TAC/Bs output from the CMP (in thousands of tons), the implementation model simulates the implementation of these catch limits by the industry to yield future catches-at-age (in billions).

Anchovy 1-year-old catch

Between 2006 and 2015, the total (annual) 1$^+$-year-old catch in tons constituted, on average, 38%[2] of the anchovy catch biomass between January and June (the period to which $TAC_y^{1,A}$ and half of TAB^A is taken to apply). Almost all of this catch consisted of 1-year-olds (de Moor 2016). The anchovy 1-year-old catch is thus taken to be:

$$C_{1,y,1}^{A,pred} = 0.38 \times \frac{TAC_y^{1,A}+0.5TAB^A}{\bar{w}_{1c}^A}. \quad (A.4)$$

Anchovy 0-year-old catch

Between 2006 and 2015 the anchovy recruit catch in tons from 1st January to 30th April, together with half the May juvenile catch in tons was 29%[3] of the total anchovy catch biomass from January to June. Using the above assumption that $TAC_y^{1,A}$ and half of TAB^A is caught by the end of June, the anchovy 0-year-old catch taken prior to the recruit survey is:

$$C_{1,y,Obs}^{A,pred} = 0.29 \times \frac{TAC_y^{1,A}+0.5TAB^A}{\bar{w}_{0c}^A}. \quad (A.5)$$

and for the whole year:

$$C_{1,y,O}^{A,pred} = \frac{1}{\bar{w}_{0c}^A}\left(TAC_y^{2,A} + TAB^A - \bar{w}_{1c}^A C_{1,y,1}^{A,pred}\right) \quad (A.6)$$

General

For all catches simulated in the OM, an upper limit is placed on the industry's efficiency by assuming that no more than 95% of the selectivity-weighted abundance may be caught at the time of the pulse.

Observation Model

The survey estimates for total biomass and recruitment are generated as follows:

$$B_{j,y}^{A,obs} = k_{j,N}^A B_{j,y}^{A,pred} e^{\varepsilon_{j,y,Nov}^A} \quad (A.7)$$

where $\varepsilon_{1,y,Nov}^A = \eta_{1,y,Nov}^A \tilde{\sigma}_{j,y,Nov}^A$, where $\eta_{1,y,Nov}^A \sim N(0,1)$ (A.8)

and $$\tilde{\sigma}_{1,y,Nov}^A = \sqrt{min\left(0.4096^2; 0.0253 + \frac{12.5768}{B_{1,y}^{A,pred}}\right) + (\varphi_{ac}^A)^2 + (\lambda_N^A)^2} \quad (A.9)$$

obtained from a regression of the observed CV against the base case OM predicted biomass between 1984 and 2019 at the joint posterior mode (Figure A1).

$$N_{j,y,r}^{A,obs} = k_{j,r}^A N_{j,y,r}^{A,pred} e^{\varepsilon_{j,y,rec}^A}, \quad (A.10)$$

where $\varepsilon_{1,y,rec}^A = \eta_{1,y,rec}^A \tilde{\sigma}_{j,y,rec}^A$, where $\eta_{1,y,rec}^A \sim N(0,1)$. (A.11)

[2] 37% for 1984 to 2015

[3] 27% for 1984 to 2015

and $$\tilde{\sigma}^A_{1,y,rec} = \sqrt{min\left(0.3356^2; 0.0398 + \frac{0.4921}{N^{A,pred}_{1,y,r}}\right) + (\varphi^A_{ac})^2 + (\lambda^A_r)^2} \quad (A.12)$$

obtained from a regression of the observed CV against the base case OM predicted recruitment between 1985 and 2019 at the joint posterior mode (Figure A1).

Assuming that the recruit survey begins mid-May each year, and that juvenile anchovy caught prior to the survey are taken in a pulse on 1st May, we simulate:

$$N^{A,pred}_{j,y,r} = \left(N^{A,pred}_{j,y-1,0} e^{-0.5M^A_{ju}} - C^{A,pred}_{j,y,0bs}\right) e^{-0.5M^A_{ju}/12} \quad (A.13)$$

Assumptions made for 2020

As the stock assessments (de Moor 2020a) covered the period to November 2019, the OM begins from November 2019 and projects to November 2040. A number of parameters that would be simulated in the testing framework for 2020, have, however, already been observed. Thus the following changes are made to the simulation framework above for 2020:

i) The TAC/TABs (in thousands of tons) for 2020 have already been set using ad hoc advice based on short term projections, thus $TAC^{1,A}_{2020} = 200.000$ and $TAC^{2,A}_{2020} = 350.000$. However, given catch data available by November 2020, the anchovy catch for 2020 is restricted to a maximum $TAC^{2,A}_{2020} = 290.000$, lower than the actual TAC of 350 000t.

ii) The initial 2021 TAC is $TAC^{1,A}_{2020} = 299.700$.

iii) The model predicted recruitment in November 2019 comes from the stock recruitment curve, i.e. equations (A.5), (A.6) and (A.8).

For past OMP development, the recruitment in the initial year was calculated with the inverse variance weighting average of the logarithms of two estimates: (a) recruitment calculated from the stock-recruitment relationship (ii above) and (b) that back-projected from the subsequent winter survey (de Moor 2018). This is problematic when the winter recruitment survey indicating substantially higher/lower recruitment does not correspond closely with the following November survey's length frequency. Instead, the distribution of simulated mid-May 2020 recruitment from equation (A.37) will be compared with that observed from mid-June 2020.

Table A1. Parameter definitions.

	Operating Model parameters	Units	Equation	Notes
$N_{j,y,a}^{A,pred}$	OM predicted numbers at age a, component j, at the beginning of November in year y	Billions	A.1, (A.13)	$N_{j,2015,a}^{A,pred}$ sampled from Bayesian posterior distributions of de Moor (2020a)
M_{ju}^{A}	Natural mortality rate of juvenile (age 0) fish	Year^{-1}	(A.1, A.13)	sampled from Bayesian posterior distributions of de Moor (2020a)
M_{ad}^{A}	Natural mortality rate of adult (age 1^{+}) fish	Year^{-1}	(A.1)	sampled from Bayesian posterior distributions of de Moor (2020a)
$C_{j,y,a}^{A,pred}$	OM predicted future catches at age a in year y of component j	Billions	A.4, (A.1, A.6)	
$C_{j,y,0bs}^{A,pred}$	OM predicted future catches at age 0 prior to the May recruit survey in year y of component j	Billions	A.5, (A.13)	
$B_{j,y}^{A,pred}$	OM predicted November total biomass in year y of component j	Thousands of tons	A.1, (A.7, A9)	
$SSB_{j,y}^{A,pred}$	OM predicted November spawner biomass in year y of component j	Thousands of tons	A.1, (A.2)	
$\overline{w}_{j,a}^{A}$	Historical average November weights-at-age a of component j	Grams	(A.1)	Weight is given by length in the OM, and thus: $w_a^A = \sum_l w_l^A A_{a,l}^{sur} = \sum_l 0.0079 \times l^{3.0979} A_{a,l}^{sur}$ [4]
$f_{j,a}^{A}$	Proportion of component j of species i that is mature at age a	-	(A.1)	Maturity is given by length in the OM, and thus: $f_a^A = \sum_{y=2105}^{2019} \sum_l f_{y,l}^A A_{a,l}^{sur}$
$\overline{w}_{j,ac}^{A}$	Historical posterior average catch weights-at-age a from component j	grams	(A.4, A.5, A.6)	$\overline{w}_{0c}^{A} = 0.5(\overline{w}_{j,a}^{A} + \overline{w}_{j,a+1}^{A}) = 5.08$ [5] $\overline{w}_{1c}^{A} = 0.5(\overline{w}_{j,a}^{A} + \overline{w}_{j,a+1}^{A}) = 12.20$
a_j^A	Stock-recruitment parameter for component j (e.g. maximum median recruitment in Hockey Stick stock-recruitment relationship)	e.g. billions	(A.2)	Sampled from Bayesian posterior distributions of de Moor (2020a)
b_j^A	Stock-recruitment parameter for component j (e.g. spawner biomass below which median recruitment declines)	e.g. thousands of tons	(A.2)	Sampled from Bayesian posterior distributions of de Moor (2020a)
$\varepsilon_{j,y}^{A}$	Standardised November recruitment residual for component j in year y		A.3, (A.2)	$\varepsilon_{j,2018}^{A}$ sampled from Bayesian posterior distributions of de Moor (2020a)
$\sigma_{j,r}^{A}$	Standard deviation of the recruitment residuals for component j		(A.2)	Sampled from Bayesian posterior distributions of de Moor (2020a)
$s_{j,cor}^{A}$	Recruitment serial correlation for component j		(A.3)	Sampled from Bayesian posterior distributions of de Moor (2020a)
$\omega_{j,y}^{A}$	Random variable	-	A.3	$\omega_{j,y}^{A} \sim N(0,1)$

[4] This differs for each sample from the posterior distribution and thus a table of weights is not provided in this document.

[5] The median values for $\overline{w}_{j,a}^{A}$ are used here

Table A1 (continued).

	Operating Model parameters	Units	Used in Equation	Notes
$N_{j,y,r}^{A,obs}$	Acoustic survey estimate of recruitment of component j for May/June of year y	Billions	(A.10)	Observed data input to the Harvest Control Rule; simulated during OMP testing by equation A.10
$N_{j,y,r}^{A,pred}$	OM predicted recruitment of component j in November $y-1$, projected forward to the time of the recruit survey in May/June y	billions	A.13, (A.10,A.12)	
$B_{j,y}^{A,obs}$	November acoustic survey estimate of total biomass of component j in year y	Thousands of tons	A.7	Observed data input to the Harvest Control Rule; simulated during OMP testing by equation A.7
$k_{j,N}^{A}$	Multiplicative bias associated with the acoustic survey estimate of November total biomass of component	-	(A.7,A.14)	Sampled from Bayesian posterior distributions of de Moor (2020a)
$\varepsilon_{j,y,Nov}^{A}$	Residuals in the simulated observation of November survey estimate of total biomass from OM predicted November biomass in year y of component j	-	A.8, (A.7)	
$\tilde{\sigma}_{j,y,Nov}^{A}$	Standard deviation of the residuals $\varepsilon_{j,y,Nov}^{A}$, being the November survey sampling CV	-	A.9, (A.8)	
φ_{ac}^{A}	CV associated with the factors which cause bias in the acoustic survey estimates and which vary inter-annually rather than remain fixed over time		(A.9, A.12)	$(\varphi_{ac}^{A})^2 = 0.039$ from de Moor (2020a)
$(\lambda_N^A)^2$	Additional variance (over and above the survey sampling CV and $(\varphi_{ac}^{A})^2$) associated with the November survey		(A.9)	
$k_{j,r}^{A}$	Multiplicative bias associated with the acoustic survey estimate of May recruitment of component j	-	(A.10)	Sampled from Bayesian posterior distributions of de Moor (2020a)
$\varepsilon_{j,y,rec}^{A}$	Residuals in the simulated observation of May survey estimate of recruitment from OM predicted recruitment in year y of component j	-	A.11, (A.10)	
$\tilde{\sigma}_{j,y,rec}^{A}$	Standard deviation of the residuals $\varepsilon_{j,y,rec}^{A}$, being the May recruit survey sampling CV	-	A.12, (A.11)	
$(\lambda_r^A)^2$	Additional variance (over and above the survey sampling CV) associated with the May recruit survey		(A.12)	

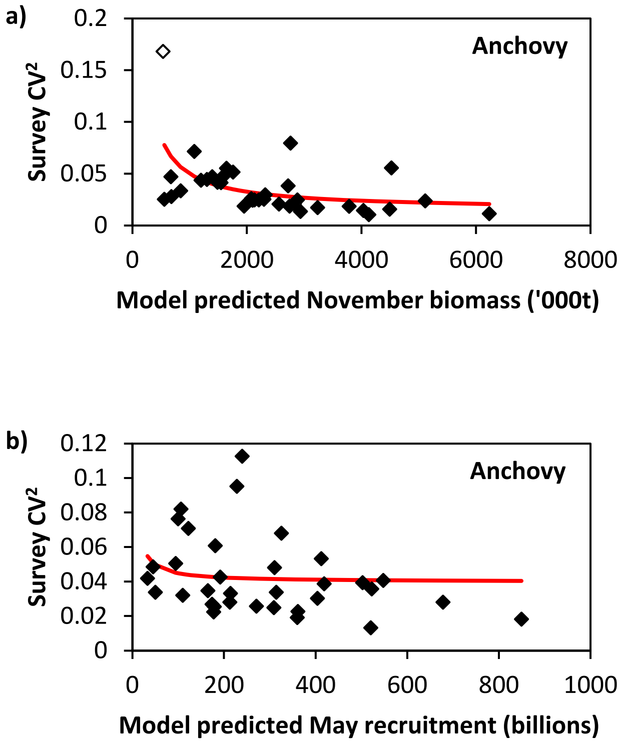

Figure A1. The regressions between observed survey CV^2 and model predicted abundance for a) November and b) May, used in equations (A.9) and (A.12). In a) the outlier (536,0.17) was excluded from the regression.