A summary of the operating models being used to simulation test OMP-18 for South African sardine and anchovy

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This document considers alternative Operating Models being used to simulation test OMP-18, and key alternatives for these OMs. The document focuses on the sardine resource only and is written to provide background information to the key question to the panel "Have we an adequate reference set of operating models for sardine?"

Background

The Operating Models (OMs) being used during the development of OMP-18 were conditioned on data available from 1984 to 2015. This document focuses only on the sardine two component OM, with the details of the assessment conditioned to these data provided in de Moor et al. (2017a,b). The anchovy OM is described in de Moor (2016, 2017a) and the sardine single stock OM[1] is described in de Moor and Butterworth (2016) and de Moor (2017a).

The two sardine component OM assumes a west and south component of sardine separated at Cape Agulhas (Butterworth et al. 2016). Two types of "mixing" between these components are considered:

i) Movement of sardine from the west component to the south component. This has historically been informed by survey abundance and length frequency data, and in recent years by parasite prevalence-by-length data. The assumption has been made that once west component fish move to the south coast they remain part of the south component[2]. Survey and commercial data indicate this movement to occur some point after the May/June recruit survey. For simplicity, movement is modelled to occur on the 1st November (at the time when sardine "age"), and is age-dependent. Movement of 1-year-olds is estimated to vary annually while movement of 2+ sardine is estimated to be a proportion of that estimated for 1-year-olds[3].

ii) Contribution of south component spawning to west component recruitment. Some eggs and larvae from the south coast are successfully transported to west coast nursery areas (Miller et al. 2006, Coetzee 2016, McGrath and van der Lingen pers comm).

The OMs used to simulate future population dynamics are somewhat simpler than those conditioned to historical data, for example component-specific selectivity, maturity and weight are summarised by age during projections, based on the historical length-structured relationships (de Moor 2017a).

West to South Movement

Given the models estimate the west component to be substantially more productive than the south component (on a recruits per spawner basis), future assumptions regarding the movement of sardine from the west to the south component

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[1] While it is accepted that South African sardine does not consist of a single homogeneously distributed population, this alternative is retained primarily for the purposes of comparison with past assessments and OMPs.

[2] Future OMs are currently planned to model south-from-west fish separately to south-from-south fish in order to model differences in parasite intensity-by-length, which are expected to correspond with the duration a fish has spent on the west coast.

[3] Further age-dependence of this estimated movement will be possible only – if at all – given parasite intensity-at-length data which may help distinguish between different older age groups.

are highly influential on future projected west and south component biomass levels and simulated future catches. This is because, in simple terms, the lower the movement of sardine from the west to the south coast, the greater/faster the potential for recovery to the west component spawner biomass, with possible increases in median recruitment[4], and higher future catches.

A number of hypotheses for future movement have previously been considered, including one linking increasing/decreasing regimes of movement to 'environmental switches' ("MoveE") and one linking the proportion of movement in year *y* to the ratio of west to south biomass in year *y*-1 ("MoveB"). Following recommendations from the 2016 panel report of the International Stock Assessment Workshop (Dunn et al. 2016), both "MoveE" and "MoveB" were dropped in favour of a baseline hypothesis of "MoveR" (see Appendix). This hypothesis assumes future movement is randomly drawn from that estimated between 2006 and 2015 (Figure 1) and allows for some high and some low proportions movingin the future. Following the November 2016 hydroacoustic survey, which indicated a greater proportion of sardine than in the preceding two years to be distributed on the west coast (Figure 8 of Coetzee et al. 2017), a hypothesis of "0.5MoveR" has also been used to test the robustness of candidate Management Procedures to the alternative of future movement being half of that randomly drawn from the 2006 to 2015 estimated values.

South Coast Contribution to West Coast Recruitment

Coetzee (2016) estimated the average biomass-weighted proportion (*p*) of sardine eggs and larvae that are spawned on the South Coast and subsequently successfully transported to West Coast nursery areas to be 8%. This value is not expected to vary much if monthly outputs for the proportion moving are weighted by monthly gonado-somatic index (GSI) values of sardine off the South Coast (van der Lingen and McGrath 2017, Dunn et al. (2016) B.1.1). Results to be made available soon indicate that an updated biomass-weighted *p* based on the output from an updated IBM linked to a highly-resolved 3D hydrodynamic model is again unlikely to differ substantially from the 8% previously estimated (van der Lingen and McGrath pers. comm). Given variability about this estimate, OMs have been developed for values of 0%, 8% and 20%. In addition, a more extreme alternative assuming 60% of South Coast spawning contributes to West Coast recruitment is also modelled. Higher values for *p* were proposed based on stock-recruitment model 'fits' to model estimates at the joint posterior mode (Dunn et al. (2016) B.1.4 and de Moor et al. 2017c for response).

Peak spawning is assumed to occur in late spring / early summer[5], and the spawner stock recruitment relationships are modelled to represent the recruits spawned at 1 November each year. Recruitment to the fishery, however, occurs only from late summer / early autumn when (for west component fish) the recruits migrate from the nursery areas in the north down the west coast. The *p* referred to above relates to the movement of spawning products at the time of spawning (i.e. 1 November according to the model). This could be modelled as a proportion of the 'recruits' (spawning products) spawned on the South Coast which subsequently move to the West Coast in November each year. In this situation separate stock-recruitment relationships are estimated for the west and south components and a proportion of the estimated number of south recruits are then added to the west recruitment. Alternatively, it could be modelled as a

[4] Dependent on stock-recruitment relationship assumed.
[5] South coast winter spawning does, however, occur.

proportion of the south component spawner biomass forming part of the west component 'effective' spawner biomass, which is the biomass on which the stock recruitment relationship is based. The results presented to the workshop assume the latter.

Estimating stock recruitment relationships

The stock recruitment relationship can either be estimated as part of the model during conditioning, or conditioning can estimate annual recruitment and a stock recruitment relationship can then be subsequently estimated by fitting to the time series of model predicted spawner biomass and recruitment. While initial comparisons indicated the estimation of a hockey stick stock recruitment relationship during conditioning resulted in less optimistic projections for sardine in absolute terms (de Moor 2017b), the use of models with the stock recruitment curve estimated after conditioning has been preferred for baseline OMs. This has allowed for multiple alternatives (in stock recruitment functional forms and *p* values) to be considered in a more time-efficient manner, since alternative fits to the MCMC output are much quicker to run than new MCMC chains. In doing so, the parameters of a stock recruitment relationship (e.g. hockey stick curve) are estimated at the joint posterior mode for each draw from the posterior distribution. These 'mle' estimates are then used, such that the posterior distribution of a given stock recruitment parameter consists of the distribution of that parameter estimated for all draws from the posterior distributions of time series of spawner biomass and recruitment, and does not consider any further variability in the individual 'mle' estimates.

Discussion

- While Dunn et al. (2016) recommend performance statistics from candidate MPs be considered separately, some local stakeholders would prefer to consider performance statistics weighted across alternative *p* and movement hypotheses to simplify initial presentation of results. To this end, an initial weightings have been proposed (Table 1).
- Practical time constraints play a major role in selecting the method to estimate stock recruitment relationships.
- Assessment and management of the South African sardine and anchovy resources tends to follow a cycle in which the assessment is 'overhauled' about every four years at the start of a new MP development process. As we are nearing the end of the cycle in testing candidate MPs, substantially different OMs/hypotheses will rather be considered during the next comprehensive assessment cycle. A number of alternatives have already been proposed including the consideration of south coast winter spawning and the inclusion of parasite intensity data in the model likelihood to better inform age-dependent west to south movement. Alternative ideas for the longer term are welcomed at this stage as prioritisation will only occur at the start of the next 'cycle'. However, the primary consideration of the questions below relate to any 'quick and easy' changes to the OMs currently available.

Discussion Points

Discussion and recommendations towards the following questions are sought:

i) Have we an adequate reference set of operating models for sardine?

ii) Should some further *p* values be considered and/or some existing ones removed?

iii) Should alternative west to south movement hypotheses be considered and/or some existing ones removed?

iv) Should reporting of performance statistics continue to be shown for different baseline OMs, or should performance statistics be weighted across alternative *p* values? If the latter, please comment on the weightings proposed by OMP Task Team members in Table 1.

v) Should OMs be based on the available analyses for which a hockey stick stock-recruitment relationship was estimated during or after conditioning. If after conditioning, is the method used thus far adequate?

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Table 1. Weightings for alternative Operating Model assumptions for the proportion of South Coast spawning contributing to West Coast recruitment (p), and the hypotheses for future west to south movement. Weightings were proposed by five members of the OMP Task Team based on personal interpretation of the data and/or analyses available thus far.

	$p = 0.0$	$p = 0.08$	$p = 0.2$	$p = 0.6$		MoveR	0.5MoveR
Option 1	0.05	0.50	0.35	0.10		0.75	0.25
Option 2	0.01	0.29	0.40	0.30		0.75	0.25
Option 3	0.01	0.04	0.30	0.65		0.30	0.70
Option 4	0.05	0.55	0.30	0.10		0.80	0.20
Option 5	0.20	0.50	0.20	0.10		0.80	0.20
Average	0.064	0.376	0.310	0.250		0.68	0.32
Median	0.050	0.500	0.300	0.100		0.75	0.25
Renormalised Median	0.053	0.526	0.316	0.105		0.75	0.25

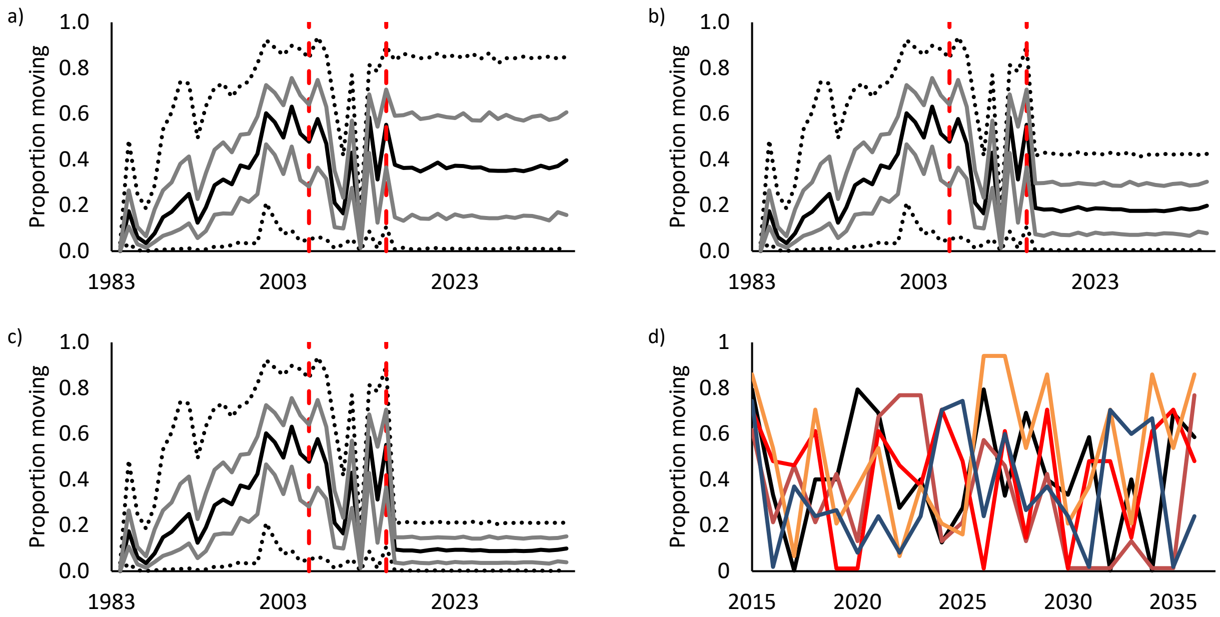

Figure 1. The proportion of 1-year old sardine moving from the west component to the south component in November each year under the two component hypothesis with the stock recruitment relationship estimated after conditioning for a) MoveR, b) 50% of MoveR and c) 25% of MoveR (from de Moor 2017b). The red vertical lines denote the 2006 to 2015 period from which future movement is drawn randomly. The proportion of 2+ sardine which move from the west to the south component is linked to this variable proportion of 1-year-olds moving. Figure d) shows some example worm plots for projections of future proportions of 1-year old sardine which move from the west to the south component.

Appendix: Reconsidering the "MoveB" hypothesis of west to south coast sardine movement

"MoveR" assumes future proportions of 1-year-old sardine moving from the west to the south component to be drawn randomly from those proportions estimated from 2006 to 2015. "MoveB" assumes future proportions of sardine moving is related to the ratio of south to west component biomass, according to a relationship estimated based on past data (Figure A1). The hypothesis for "MoveB" could be indicative of entrainment, in which a higher relative south coast biomass could better facilitate the movement of more recruits, or that a higher ratio of south to west biomass may be a proxy to indicate improved environmental suitability for both juveniles and adult sardine east rather than west of Cape Agulhas. Dunn et al. (2016) queried the causality of this relationship and recommended patterns in future simulated proportions of 1-year-old sardine moving to be investigated.

Figures A2, A3 and A4 consider future proportions moving under both "MoveR" and "MoveB" using an earlier form of de Moor (2017a) and assuming either no future catches or catches under an MP (the version of which is not important for these comparisons). Plotting the median and 10%ile of proportions moving for incremental 'bins' of the south:west biomass shows little change in the proportion over the range of biomass ratios, except for extremely high south:west ratios. These patterns do not match that of the relationship estimated in Figure A1 and "MoveB" was thus considered less plausible as a future movement hypothesis. An alternative dome-shaped relationship against the ratio of south to west biomass in the previous year has yet to be tested.

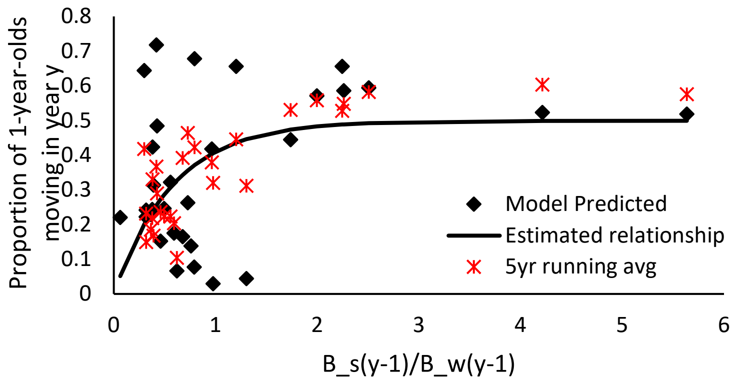

Figure A1. The posterior median movement of 1-year olds from the west to the south component in November of year y plotted against ratio of south:west coast biomass in November of year y-1 for the two component hypothesis with no south coast contribution to west coast recruitment.

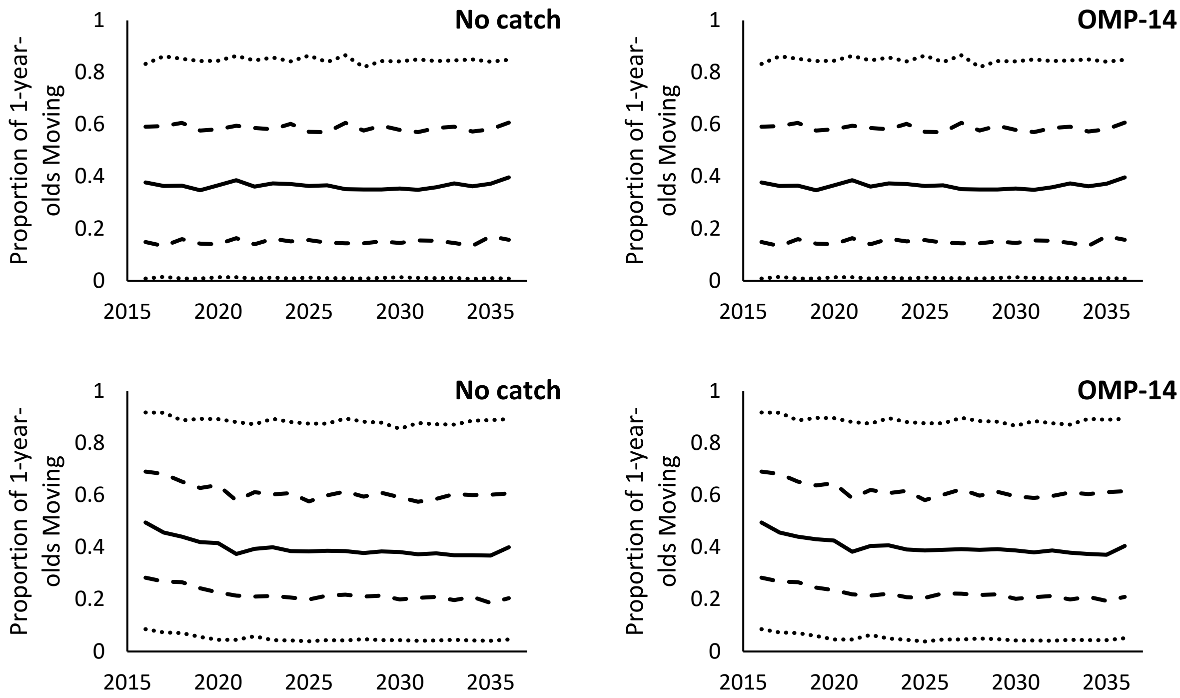

Figure A2. The median, 50%ile and 95%ile of future proportions of west component 1-year-olds moving to the south coast under the MoveR (top row) and MoveB (lower row) hypotheses and assuming no future catch (left) and 'updated OMP-14' (right).

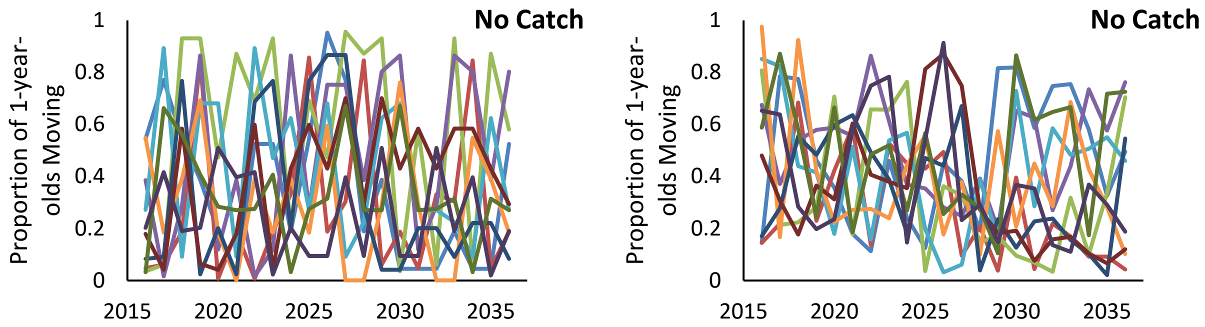

Figure A3. Ten individual trajectories under MoveR (left) and MoveB (right) assuming no future catch.

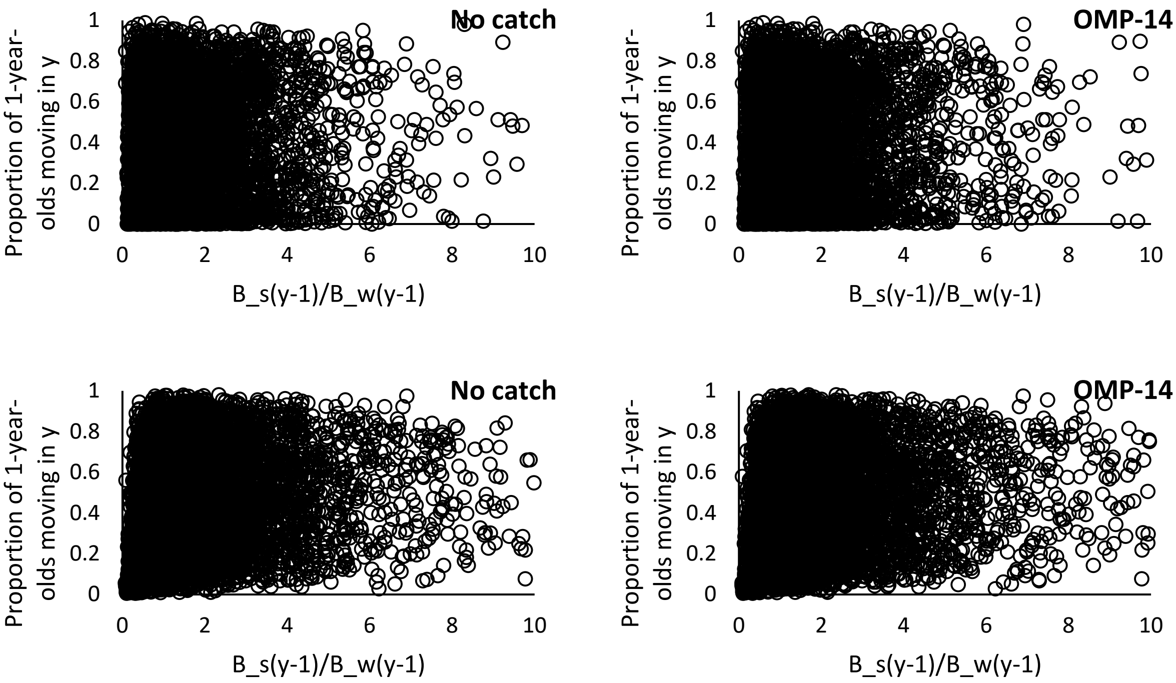

Figure A4. Future proportions of 1-year-olds moving (2017-2024) plotted against the south:west ratio of biomass in the previous year (2016-2023) for MoveR (top row) and MoveB (bottom row). Note the horizontal axis is restricted to the lower range of predicted values to compare with the relationship obtained from historical 'data'.

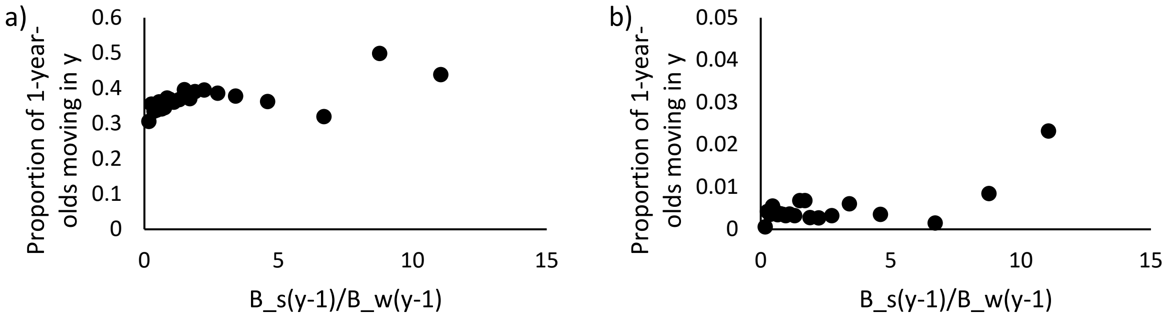

Figure A5. The a) median and b) 10%ile of future proportions of 1-year-olds moving (2017-2024) per 'bin' of the median south:west biomass in the previous year (2016-2035). Bins do not contain equal sample sizes.