

Discussion of OMP-17 simulation projection framework in respect of sardine

C.L. de Moor* , D.S. Butterworth* , J.C. Coetzee⁺

Correspondence email: carryn.demoor@uct.ac.za

Background

The simulation projection framework to be used to test Candidate Management Procedures for OMP-17 is yet to be developed (cf de Moor and Butterworth (2013a) for the framework used when developing OMP-14). However, given experience gained during the testing of OMP-14, some initial assessment results (de Moor and Butterworth 2016a,b) and discussions in the SPSWG, we can begin to consider some alternative key assumptions to be used in the simulation projection framework to be used for developing OMP-17.

Primary Comparisons

There are two main hypotheses for sardine: a single stock hypothesis or a two-mixing stock hypothesis (with “west coast” and “south coast” stocks). The stocks modelled in the two mixing stock hypothesis correspond to “separate spawning aggregations” (Coetzee et al. 2008, van der Lingen et al. 2009). They denote two distinct biological units rather than, necessarily, distinct biological stocks. The proposed two-area management options link up with these units, and as such, productivity of each unit has been assessed separately so that the impact of future area-based management on these units can be correctly simulated. Further reference to these “west coast” and “south coast” stocks in this document will therefore be “sub-stocks”, given that there is mixing between these two stocks. Two different types of candidate MPs have been proposed:

- a) Candidate MPs which recommend a single directed >14cm sardine TAC and associated \leq 14cm sardine bycatch.
- b) Candidate MPs which recommend a separate directed >14cm sardine TAC for “west coast” and “south coast”, and an associated split in the \leq 14cm sardine bycatch. Note that the sardine TAB with directed sardine TAC on the south coast will likely be a lower proportion than that on the west coast – historical catch data will be examined to provide appropriate proportions.

All other sardine bycatches are assumed to be taken from the single stock or west coast sub-stock only.

There are thus four general alternative possible combinations of sardine TAC/B by area / sub-stock:

- i) A single area sardine TAC/B and a single sardine stock.
- ii) A two-area sardine TAC/B and a single sardine stock.

* MARAM (Marine Resource Assessment and Management Group), Department of Mathematics and Applied Mathematics, University of Cape Town, Rondebosch, 7701, South Africa.

⁺ Department of Agriculture, Forestry and Fisheries – Branch Fisheries, Private Bag X2, Rogge Bay, 8012, South Africa.

- iii) A single area sardine TAC/B and two sardine sub-stocks.
- iv) A two-area sardine TAC/B and two sardine sub-stocks.

The following assumptions will be made in the implementation simulation of Candidate MPs:

- i) All sardine catch/bycatch is from the single stock.
- ii) The TAC/Bs are added and all catch/bycatch is from the single stock.
- iii) The TAC/Bs are split by sub-stock in a pre-defined (and possibly year-specific) proportion.
- iv) The TAC/B for west of Cape Agulhas is assumed taken from the west coast sub-stock and the TAC/B for east of Cape Agulhas is assumed taken from the south coast sub-stock.

Alternative hypotheses

While a number of robustness tests have already been suggested, such tests are frequently considered only towards the end of the MP development process. The two mixing stock hypothesis assumes sardine form “west coast” and “south coast” sub-stocks, separated at Cape Agulhas, with movement of sardine from the west coast to the south coast. Recruitments to the west and south coast sub-stocks are assumed to be dependent on west and south coast SSB’s, respectively.

The alternative hypothesis agreed will consider some south coast SSB to contribute to west coast recruitment. The proportion of south coast SSB contributing to west coast effective SSB will be year dependent, based on the proportions calculated by Coetzee (2016). (These proportions averaged 8% over 1984-2015.) Future annual proportions would then be drawn randomly from these past proportions.

Future movement could be assumed as follows:

MoveA: The proportion of 1 year olds which move is assumed to be autocorrelated (Appendix), using the autocorrelation coefficient¹ estimated during OM conditioning. However, the movement parameters are more precisely estimated for the latter years as a consequence of the availability of parasite prevalence by length data:

¹ This coefficient differs for each sample from the posterior distribution

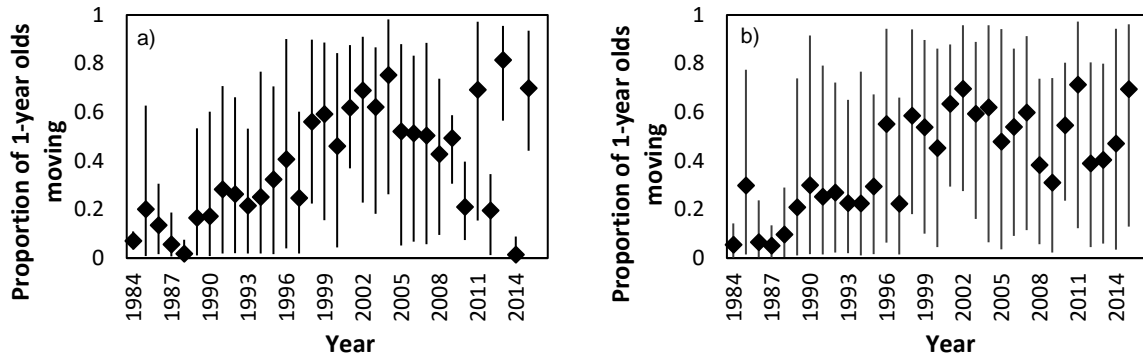


Figure 1 [Fig. S6 of de Moor et al. (In Review)]: The posterior median and 95% probability intervals of proportions of 1-year olds estimated to move from the west to the south stock each November, for a) S_{with} and b) $S_{without}$.

The (untransformed) autocorrelation coefficient at the joint posterior mode over 1984-2015, for example, is 0.71, but is 0.04 from 2008-2015 for the two sub-stock hypothesis with separate stock-recruitment relationships. The autocorrelation is 0.64 over 1984-2015, but is 0.06 from 2008-2015 for the two sub-stock hypothesis with south coast SSB contributing to west coast recruitment:

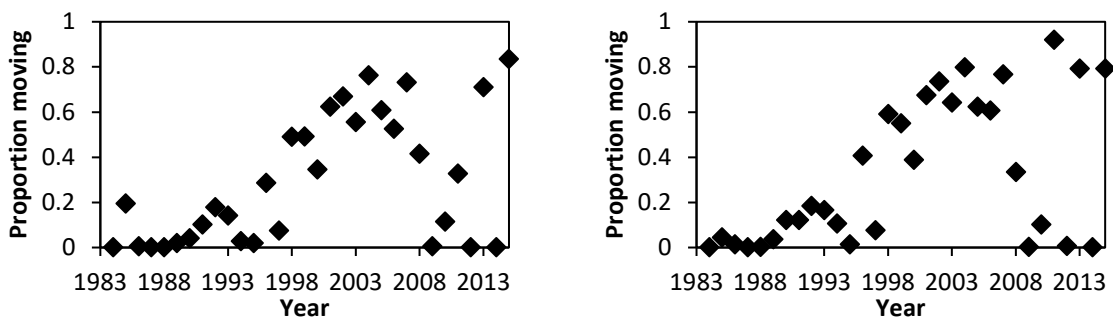


Figure 2: The proportion of age-1 sardine moving from the west to south coast sub-stock at the joint posterior mode for a) the two sub-stock hypothesis with separate stock-recruitment relationships (de Moor and Butterworth 2016b) and b) the two sub-stock hypothesis with south coast SSB contributing to west coast recruitment (de Moor 2016).

Given the low autocorrelation in recent years, this MoveA hypothesis received a low priority from the SPSWG in earlier discussions.

MoveR: The proportion of 1-year-olds which move is drawn randomly from the proportions estimated by the model between 2006-2015. (For each of the 1000 simulations, the projected proportions will be drawn randomly from the estimated 2006-2015 proportions for that *same* simulation.)

MoveE: The proportion of 1 year olds which move is assumed to be linked to some environmental index. An application of the STARS method to an extended time series of upwelling for Cape Agulhas (an update of Blamey et al. 2012) shows no further “switch points” from those assumed by de Moor and Butterworth (2013b):

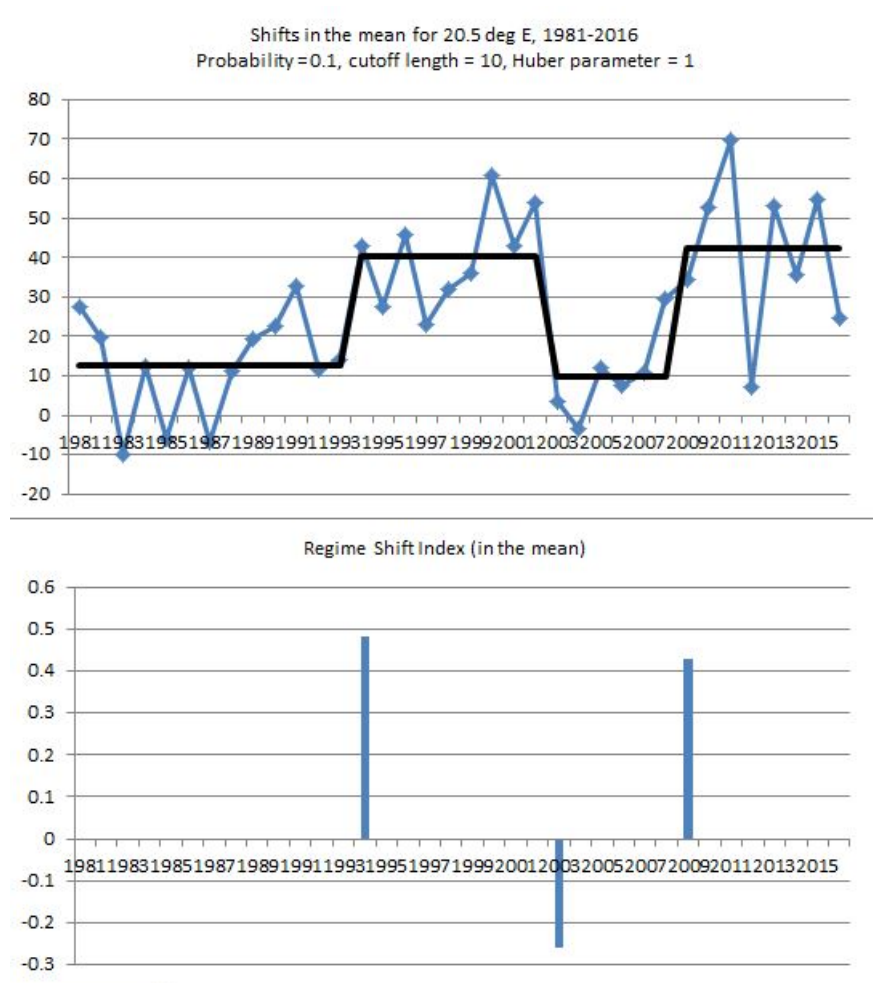


Figure 3 (Laura Blamey pers comm): The updated application of the STARS method to the time series of upwelling for Cape Agulhas, showing “switch points” of 1994, 2003 and 2009.

The concern with this movement hypothesis that arose during OMP-14 development was the frequency with which future switches from increasing to decreasing proportions moving would occur, and the lack of further switches in the update does not help solve this concern. In addition, following the 2009 “switch”, movement is now more precisely estimated and does not indicate a pattern of generally increasing or generally decreasing proportions moving (see Figure 1). The authors thus recommend this is given a low priority.

MoveD1: The proportion of 1 year olds which move in year y is assumed to be related to the west coast biomass in year $y-1$. This hypothesis is based on the idea that movement is density dependent, with more sardine moving from the west coast in years of high west coast biomass.

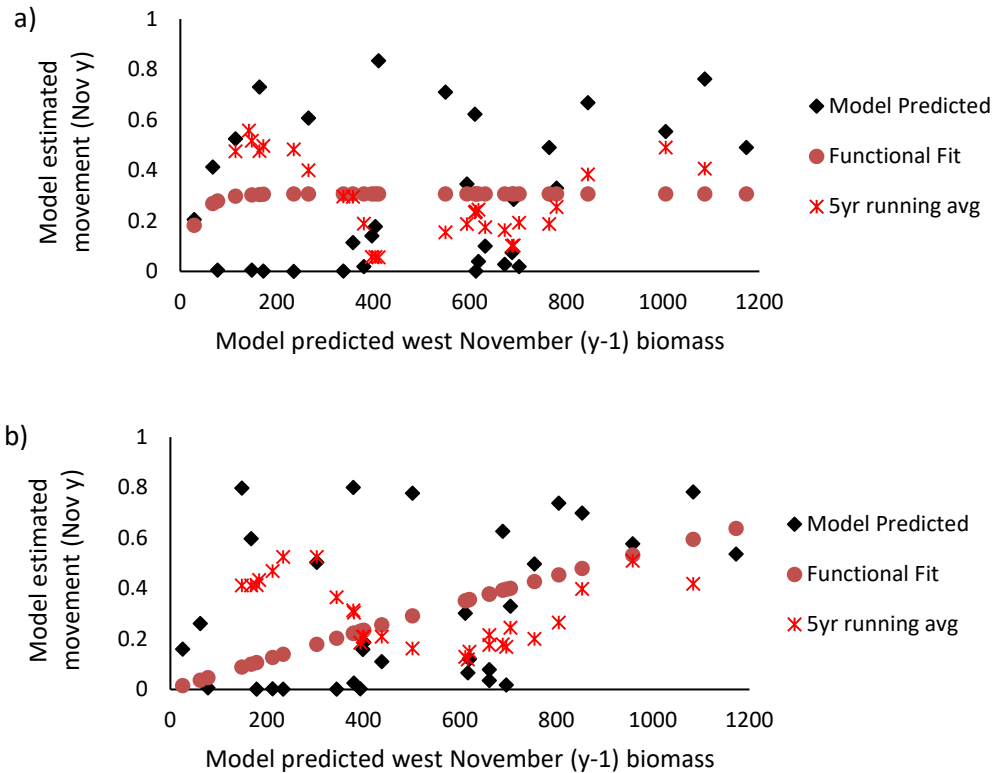


Figure 4: The model estimated movement in November of year y plotted against west coast biomass in November of year $y-1$ for a) the two sub-stock hypothesis with separate stock-recruitment relationships and b) the two sub-stock hypothesis with south coast SSB contributing to west coast recruitment.

A 5-year running average fitted functional form to these data does not show any clear pattern indicating this movement hypothesis should have a low priority.

MoveD2: The proportion of 1 year olds which move in year y is assumed to be related to the west coast biomass in year y immediately preceding movement. This hypothesis is also based on a density dependent mechanism, with more sardine moving from the west coast in years of high west coast biomass.

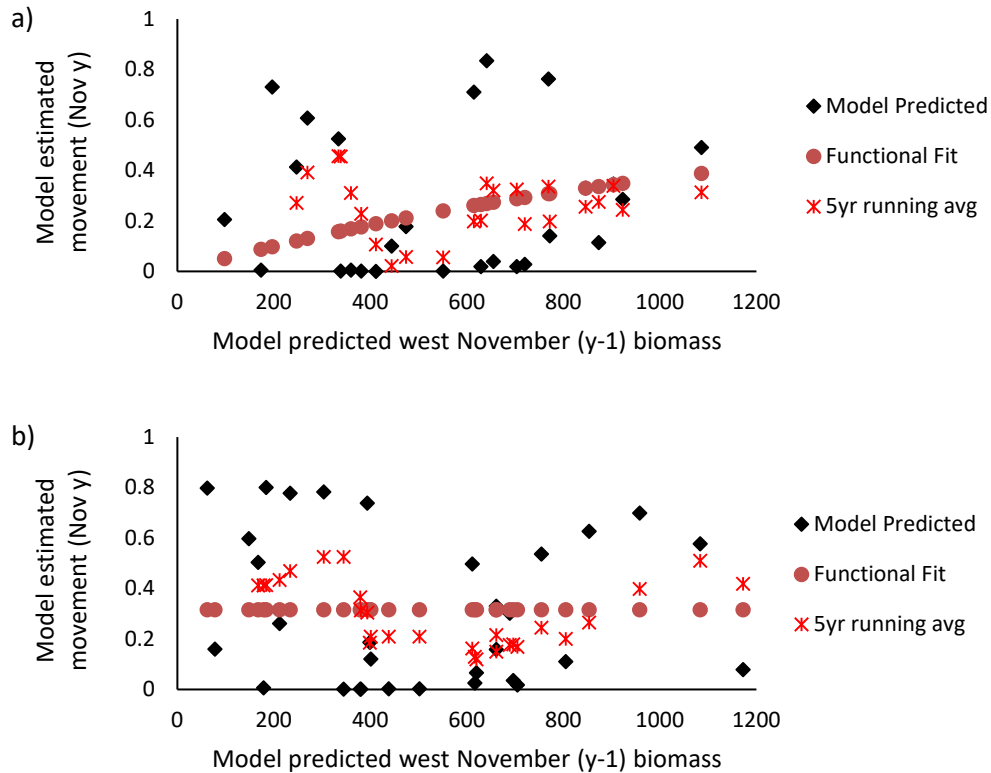


Figure 5: The model estimated movement in November of year y plotted against west coast biomass in November of year y immediately preceding movement for a) the two sub-stock hypothesis with separate stock-recruitment relationships and b) the two sub-stock hypothesis with south coast SSB contributing to west coast recruitment.

A 5-year running average fitted functional form to these data does not show any clear pattern indicating this movement hypothesis, while preferred over MoveD1, should have a low priority.

MoveB: The proportion of 1 year olds which move in November year y is assumed to be related to the ratio of south:west biomass in November year $y-1$. This hypothesis suggests that the proportion moving drops from a maximum as the south coast biomass relative to that of the west decreases below a threshold of about 1.7. This could be indicative of entrainment, in which a higher relative south coast biomass the previous year (which could be considered a surrogate to the 2+ biomass in the current year) could better facilitate the movement of more recruits in the current year. Another possibility is that a higher ratio of south to west coast November biomass may be a proxy to indicate improved environmental suitability for both juvenile and adult sardine east rather than west of Cape Agulhas.

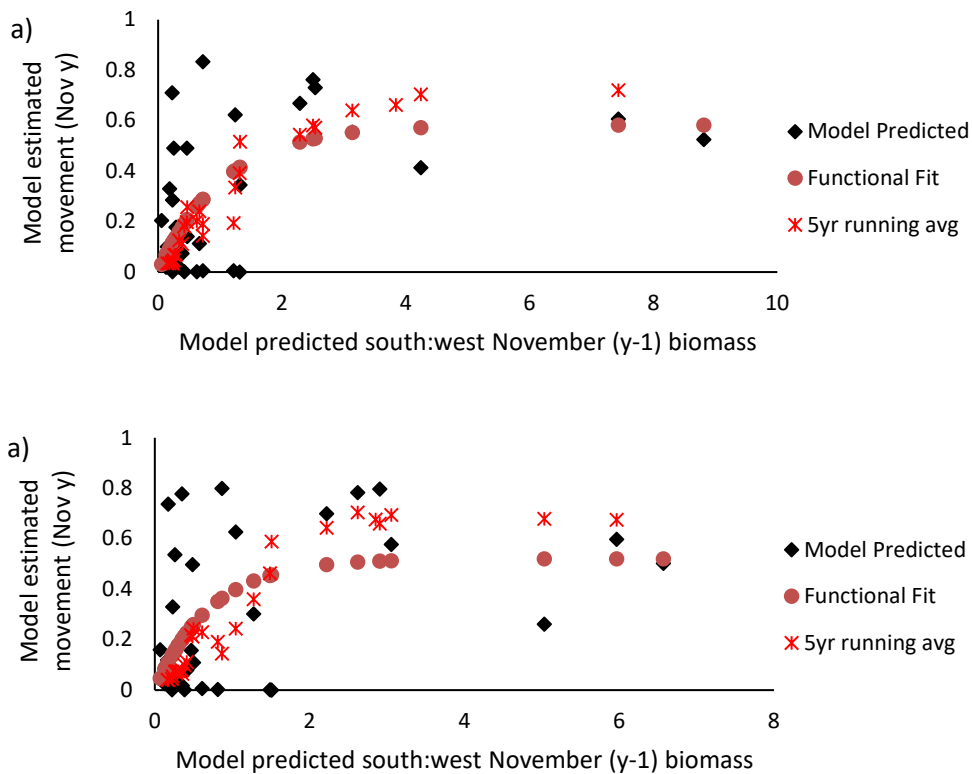


Figure 6: The model estimated movement in November of year y plotted against ratio of south:west coast biomass in November of year $y-1$ for a) the two sub-stock hypothesis with separate stock-recruitment relationships and b) the sub-stock hypothesis with south coast SSB contributing to west coast recruitment.

A 5-year running average and functional form fitted to the results at the joint posterior mode indicate this hypothesis should receive high priority.

Move N: The proportion of 1 year olds which move in November of year y is assumed to be related to the contribution to West Coast recruitment from South Coast spawning in year $y-1$, i.e., recruits from eggs spawned on the South Coast move back to the South Coast at the end of the year (natal homing). The contribution from South Coast spawning is based on annual (biomass-weighted) estimates of egg movement from the hydrodynamic model (Coetzee 2016), as used in de Moor (2016).



Figure 7: The model estimated movement in November of year y plotted against the proportion of south coast spawner biomass estimated to contribute to west coast recruitment in November of year $y-1$ for a) the two sub-stock hypothesis with separate stock-recruitment relationships and b) the two sub-stock hypothesis with south coast SSB contributing to west coast recruitment.

A 5-year running average fitted functional form to these data does not show any clear pattern indicating this MoveN movement hypothesis should have a low priority.

The proportion of 2+ sardine which move continue to be a fixed proportion (<1) of 1+ sardine which move in the same year; this proportion having been estimated during OM conditioning

Implementation Model

This relates to how the Harvest Control Rule simulated TACs are taken in practice. What is of importance here that may require updating from de Moor and Butterworth (2013a) is from which sub-stock catches are assumed to come. Options i), ii) and iv) from page 1 are relatively straightforward to apply.

For iii), de Moor and Butterworth (2013a) split the TAC/Bs by west/south coast sub-stocks based ratio of the TAC to the west coast total biomass (de Moor et al. 2013). This was based on the idea that if the TAC were small relative to the biomass available on the west coast, most of the TAC would be caught on the west coast, and that targeting of sardine off the south coast would occur only should the industry find it difficult to catch the required quota from the west coast. This relationship remains strong at the joint posterior mode for the updated assessment:

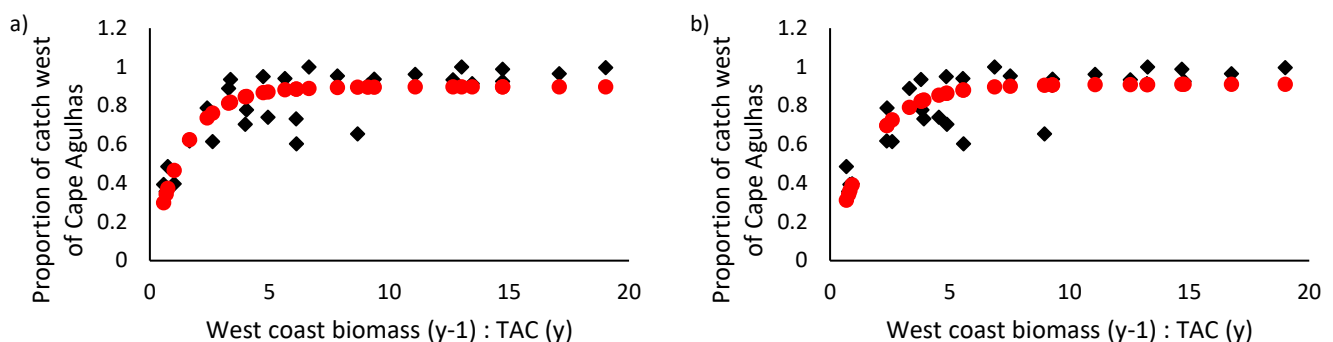


Figure 8: The proportion of catch west of Cape Agulhas in year y plotted against the ratio of west coast biomass in November $y-1$: TAC in year y for a) the two sub-stock hypothesis with separate stock-recruitment relationships and b) the two sub-stock hypothesis with south coast SSB contributing to west coast recruitment.

The SPSWG agreed in earlier discussions to continue to use this relationship for option iii), together with some stochasticity about the relationship (not yet defined).

A further modification to this relationship may include setting around 20 000t (industry to advise) which will likely be caught on the south coast for the Mossel Bay-based cannery every year. However, the dependence of such landings on the availability of sardine on the south coast would also need to be taken into account.

One proposal for a two-area sardine TAC included restricting the west coast TAC to be caught west of and including pelagic fishing blocks 5151, 5101 and 6111, while the south coast TAC to be caught east of and including pelagic fishing blocks 5050, 5000 and 6010. This would allow for some flexibility for the industry when targeting fish schools which move about the 20°E longitude line. Simulation of this HCR would need to consider the additional risk to the sub-stocks of a higher directed catch being taken than that intended by the two-area TAC; the additional catch would be simulated based on past catches in these pelagic fishing blocks.

Alternative forms of Harvest Control Rules

The “basic” HCR used for sardine, prior to the application of any constraints, buffer rules or exceptional circumstances is to calculate the directed sardine TAC for year y as a proportion of the observed sardine biomass in November $y-1$, i.e. $\beta B_{y-1,Nov}^{obs,S}$.

An alternative that could be tested would be to calculate the directed sardine TAC for year y as a proportion of the weighted average of the observed sardine biomass during the most recent two November surveys together with the most recent recruit survey estimate of recruit biomass, i.e. $\beta (w_1 B_{y-2,Nov}^{obs,S} + w_2 R_{y-1,May}^{obs,S} + w_3 B_{y-1,Nov}^{obs,S})$, where the weights are determined by a best fit to past model estimates.

Some changes to HCR constraints can always be simulation tested – note that constraints can be area-specific for the two-area HCR.

Harvest Control Rules for Two-Area sardine TACs

Initial crude testing to inform alternative two area rules could include the single area HCR formula being used to calculate a sardine TAC and then assuming a fixed percentage (0%, 20%, 40%, 60%, 80%) of that TAC to always be caught east of Cape Agulhas.

The alternative two-area sardine TAC HCR considered during OMP-14 development was to have separately estimated control parameters for west/east of Cape Agulhas, but the same general formula, i.e. the “base” rule for sardine would be $\beta_{area} B_{area,y-1,Nov}^{obs,S}$.

The SPSWG agreed that the default rule to begin MP testing would be based on the original “gentleman’s agreement” and would have a single control parameter, with the TAC then split by area according to the average of the proportion of biomass simulated to be observed west/east of Cape Agulhas in the most recent two surveys, i.e.

$$TAC_{west} = 0.5 \times \left(\frac{B_{west,y-1,Nov}^{obs,S}}{B_{west,y-1,Nov}^{obs,S} + B_{south,y-1,Nov}^{obs,S}} + \frac{B_{west,y-2,Nov}^{obs,S}}{B_{west,y-2,Nov}^{obs,S} + B_{south,y-2,Nov}^{obs,S}} \right) \times \beta \times (B_{west,y-1,Nov}^{obs,S} + B_{south,y-1,Nov}^{obs,S})$$

A lower priority alternative also suggested was to average over the most recent three surveys, i.e.

$$TAC_{west} = 0.33 \times \left(\frac{B_{west,y-1,Nov}^{obs,S}}{B_{west,y-1,Nov}^{obs,S} + B_{south,y-1,Nov}^{obs,S}} + \frac{B_{west,y-2,Nov}^{obs,S}}{B_{west,y-2,Nov}^{obs,S} + B_{south,y-2,Nov}^{obs,S}} + \frac{B_{west,y-3,Nov}^{obs,S}}{B_{west,y-3,Nov}^{obs,S} + B_{south,y-3,Nov}^{obs,S}} \right) \times \beta \\ \times (B_{west,y-1,Nov}^{obs,S} + B_{south,y-1,Nov}^{obs,S})$$

References

- Blamey, L.K., Howard, J.A.E., Agengag, J., and Jarre, A. 2012. Regime-shifts in the southern Benguela shelf and inshore region. *Prog. Oceanogr.* 106:80-95.
- Coetzee, J.C. 2016. Estimation of the effective proportion of sardine biomass contributing to putative western stock recruitment by including the proportion of eggs transported to the West Coast nursery area from South Coast spawning areas. DAFF: Branch Fisheries Document FISHERIES/2016/AUG/SWG-PEL/37.
- Coetzee, J.C., van der Lingen, C.D., Hutchings, L., and Fairweather, T.P. 2008. Has the fishery contributed to a major shift in the distribution of South African sardine? *ICES Journal of Marine Science* 65: 1676-1688.
- de Moor, C.L. 2016. An alternative two mixing stock hypothesis for South African sardine. DAFF: Branch Fisheries Document FISHERIES/2016/OCT/SWG-PEL/45.
- de Moor, C.L. and Butterworth, D.S. 2013a. The simulation testing framework used during the development of OMP-13. DAFF: Branch Fisheries Document FISHERIES/2013/OCT/SWG-PEL/26.
- de Moor, C.L. and Butterworth, D.S. 2013b. An alternative relationship to determine future movement of sardine recruits between the “west” and “south” stocks. DAFF: Branch Fisheries Document FISHERIES/2013/OCT/SWG-PEL/29.
- de Moor, C.L., and Butterworth, D.S. 2016a. Assessment of the South African sardine resource using data from 1984-2015: Results at the joint posterior model for the single stock hypothesis. DAFF: Branch Fisheries Document FISHERIES/2016/JUL/SWG-PEL/23REV.
- de Moor, C.L., and Butterworth, D.S. 2016b. Assessment of the South African sardine resource using data from 1984-2015: Results at the joint posterior mode for the two mixing-stock hypothesis. DAFF: Branch Fisheries Document FISHERIES/2016/JUL/SWG-PEL/22REV2.
- de Moor, C.L., Butterworth, D.S., and Coetzee, J.C. 2013. Proposals to Split Sardine Catch West and East of Cape Agulhas. DAFF: Branch Fisheries Document FISHERIES/2013/SEP/SWG-PEL/24.
- de Moor, C.L., Butterworth, D.S., and van der Lingen, C.D. In Review. The Quantitative Use of Parasite Data in Multi-Stock Modeling of South African Sardine (*Sardinops sagax*). *Canadian Journal of Fisheries and Aquatic Sciences*.
- van der Lingen, C.D., Durholtz, M.D., Fairweather, T.P. and Melo, Y. 2009. Spatial variability in biological characteristics of southern Benguela sardine and the possible existence of two stocks. *Marine and Coastal Management document* MCM/2009/SWG-PEL/39.

Appendix : Autocorrelated movement

In order to maintain $0 \leq move_{y,1} \leq 1$, the autocorrelated movement is calculated in logit-space. Thus setting

$$move_{y,1}^* = \ln\left(\frac{move_{y,1}}{1 - move_{y,1}}\right), \text{ for } y_1 \leq y \leq 2015, \text{ where } y_1 \text{ is to be discussed (see above)}$$

$$\rho_{move} = \frac{\sum_{y=y_1}^{2015} move_{y,1}^* move_{y+1,1}^*}{\sum_{y=y_1}^{2015} (move_{y,1}^*)^2}$$

$$\sigma_{move}^2 = \frac{\sum_{y=y_1}^{2015} (move_{y+1,1}^* - \rho_{move} move_{y,1}^*)^2}{2015 - y_1 + 1}$$

Future proportions moving are thus calculated as follows:

$$move_{y,1} = \frac{\exp(move_{y,1}^*)}{1 + \exp(move_{y,1}^*)}, \text{ where}$$

$$move_{y,1}^* = \rho_{move} \times move_{y-1,1}^* + \sqrt{1 - \rho_{move}^2} \varepsilon_{y,1}, \text{ with } \varepsilon_y \sim N(0, \sigma_{move}^2)$$