Progress report on recommendations from the International review panel report for the 2013 International Fisheries Stock Assessment Workshop: Sardine.

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The international review panel report (MARAM/IWS/DEC13/General/4 Final Report) contained the following recommendations pertinent to sardine in response to key questions put to them at the annual stock assessment review meeting held at UCT from 2-6 December 2013.

Comments on any progress in response to these recommendations are inserted in italics. As a general point of background information, the Small Pelagic Scientific Working Group agreed earlier in 2014 to finalise OMP-14 based on a single sardine stock operating model only, but coupled with some spatial management, the spirit of which is to be a "warm up period" with the expectation that the next OMP will quite likely require spatial management components. The development of new operating models and a new OMP is to be brought forward, commencing in early 2015 with the aim of being finalised before the end of 2016.

Summary of general issues: Sardine

- The Panel was impressed by the biological and modelling work undertaken for the sardine two-stock hypothesis.
- The biological studies and stock assessment model favour a two-stock sardine population scenario with movement of age-0 fish from the west stock to the south stock.
- Although a two-stock model with no movement is possible, fits of the assessment model to the recruitment and abundance data are poor when there is no movement from the west stock to the south stock.
- While the two-stock model with movement should continue to be taken into account in finalising a revised OMP, the Panel recommends that further stock and recruitment scenarios be explored, including fitting to parasite data, and that additional precaution be exercised in setting TACs until this process reaches finality.
- The Panel recommends that further model development occur in the short-term even though there is strong desire by all participants to complete the OMP revision soon.
- The alternative models identified in Section C may lead to qualitatively different outcomes through the inclusion of additional data and should lead to a broader range of models that better encapsulate the uncertainty regarding the population dynamics of the South African sardine resource.
- The Panel suggests that the performance metrics identified to evaluate alternative OMPs might benefit from a wider discussion on objectives and trade-offs, which might possibly lead also to the use of a broader range of operating models, as well as to the definition of a set of additional conditions that may invoke the Exceptional Circumstances provisions under an OMP.

Recommendations: Sardine

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C.1 (*) The Panel agrees that the evidence from biological studies favours a two-stock sardine population scenario with movement of age-0 fish from the west stock to the south stock. Although a two-stock model with no movement is possible, fits of the assessment model to the recruitment and abundance data are poor when there is no movement from the west stock to the south stock.

No response necessary, this is consistent with present thinking and the current sardine two-stock model.

C.2 (*) Abundance of age-0 sardine in the south coast November survey does not appear large enough to explain the observed scale and trends of age-1+ south coast abundance. Further, age-1+ biomass on the south coast is not correlated with the south coast recruit survey while it is correlated with the west coast recruit survey estimates. These observations support the hypothesis that immigrants from the west have made large contributions to the south stock abundance, at least over the period for which observations are available.

No response necessary, this is consistent with the current sardine two-stock model.

C.3 (*) Projections of the sardine population in the absence of exploitation under the assumption that the movement rate is related to environmental conditions on the south coast leads to median population sizes substantially lower than current population sizes, with smaller population sizes for longer environmental regimes. Risk measures will need to be redefined if OMP decisions are to be based on models with these characteristics. For example, a reference point of the average 1+ biomass over 1991-94 is not meaningful for the west coast stock if this stock is projected to collapse even under zero catch.

The choice of risk measures will be re-considered during the development of OMP-16 which will be simulation tested for both single and revised two stock hypothesis operating models.

C.4 (H) The two-stock sardine model with movement from the west to south stock is able to fit the available data on age-1+ abundance as well as the trends in the west coast recruit survey. The model attributes the large increase in south coast biomass to movement from the west coast. However, there are no direct estimates of the extent of movement. MARAM IWS/DEC13/Sardine/P6 presents information suggesting that prevalence of *Cardiocephaloides* parasites increases with body length for sardine on both coasts. This parasite is found in some age-0 sardine off the west coast but in no age-0 sardine on the south coast. The data on presence of parasites by length should be included in the assessment as a "biologically-tagged" population component; potentially this could provide a bound for the average movement rate of age-0 animals from the west to the south stocks.

van der Lingen and Winker (2014) and Ross-Gillespie and Butterworth (2014) confirmed that the parasite prevalence of infection does increases with length for sardine on the south coast which are assumed to be bigger than 1 year olds. This means that the models considered last year which assumed no movement beyond that of recruits of the year from west to south coasts need reconsideration.

Other potential changes to the 2015 assessment are explored in de Moor et al. (2014b), while de Moor et al. (2014c) [QUESTION 1] list some ideas for future use of the parasite data.

C.5 (H) The magnitude of age-0 sardine movement from the west stock to the east stock remains a critical uncertainty for the two-stock model. It is therefore important to consider a range of alternative models for sardine. The Panel identified several alternative models / modelling assumptions

5.1. (H) Exclude the south coast recruit survey from the assessment because it involves questionable assumptions about the relative scales and correlations between recruits resulting from winter (not observed) and summer spawning.

This alternative has not yet been attempted. Initial attempts at modelling two sardine stocks showed an improvement in model fit to survey estimates of 1+ biomass when the time series of survey estimates of recruitment to the south stock were included (de Moor and Butterworth 2009a,b). Admittedly, the model has been adapted quite substantially since that work, and it is anticipated that this alternative will be attempted during the development of the 2015 assessment.

5.2. (H) Collate data on age-0 abundance from the November surveys and include these data in the assessment by allowing in addition for winter recruitment cohorts in the model. This would involve assuming that the current south coast survey indexes some time-varying proportion of the total annual recruitment while the November survey indexes the rest of the annual recruitment. In such a model, the relative bias parameter for the recruitment survey on the south coast relative to the west coast may need to be removed to avoid confounding with the added recruitment series.

Assuming a constant cut-off length of 8cm between recruits and 1+ sardine in the November survey east of Cape Agulhas, de Moor et al. (2014a) showed that, on average, winter-spawned recruits contributed 26% to the total recruitment of the year, and in two years the contribution by winter-spawned recruits was greater than that of summer-spawned recruits. However, they also showed that even if the May survey fails to cover the majority of south stock recruits, it is still likely that the increase in south stock biomass in the early 2000s was primarily a result of movement of sardine from the west to the south stock.

Please see de Moor et al. (2014c) [QUESTION 4] for proposed future work.

5.3. (L) Assume that density-dependence is a function of the total spawning biomass rather than the spawning biomass by stock. This model can be implemented by estimating (i) annual deviates about the common stock-recruitment relationship and (ii) the annual proportions of total recruitment "settling" to the west and south coast areas. This hypothesis is worth modelling even though the presence of two spawning grounds, along with winter spawning only on the south coast, is less plausible than the current two-spawning stock approach given oceanographic model results (see recommendation C.8).

Given the low priority, this has not yet been done. de Moor et al. (2014c) [QUESTION 2] lists some hesitation to the above recommendation and provides some ideas for future stock-recruitment modelling.

5.4. (H) The probability of population persistence is related to (a) the rate of movement from the west to the south coast (lower for higher rates of movement), (b) the form of the stock-recruitment relationship (lower for a hockey-stick stock-recruitment relationship than for a relationship which is more compensatory at lower stock size), and (c) the relative recruits/spawner ratios on the west and south coasts. Constraints (ideally based on analogy for similar resources elsewhere in the world) on each of these factors should be imposed so that there is an acceptable probability that the population persists in the absence of exploitation.

A person/project has yet to be identified to undertake this research, ideally first considering the RAM legacy database and also making contact with scientists undertaking quantitative assessments of major sardine resources worldwide.

C.6 (H) The Panel finds that the evidence in favour of movement proportion being a function of the ratio of the south coast to west coast biomass is weak (Model Move B) and recommends that more weight be assigned to the model in which movement rates are related to environmental change (Model Move E). A simpler way to model the probability of moving from the west to south coast would be as an autocorrelated time-series.

An operating model with autocorrelated future sardine movement ("MoveAutoC") was developed (de Moor and Butterworth 2014). The Small Pelagic Scientific Working Group agreed to concentrate on "Move E" and a new alternative "MoveAutoC" for the short-term. The alternative movement hypotheses will be revisited during the development of operating models for OMP-16.

C.7 (L) Conduct a retrospective analysis in which the two-stock model is projected forward from (say) 2003 with the observed recruitments and catches by coast but with movement governed by the postulated movement models.

de Moor (2014) projected the operating model forward for 8 years with the following changes from the simulation testing framework used to develop OMP-14:
a) the sardine and anchovy starting numbers-at-age, 1+ biomass and SSB match those in November 2003 instead of November 2011.
b) the November 2003 recruitment is informed by the May 2004 survey observation and the stock-recruitment curve.
c) the proportion of west stock recruits moving to the south stock in the "most recent year" is changed from that estimated in November 2011 to 2003, for use in future movement scenarios that use the former year's proportion in calculating the current year's proportion moving. In the "MoveE" hypothesis, the "switch" years are fixed at 2003 and 2009.
d) the anchovy and directed sardine TACs are fixed at the 2004 to 2011 values, while the anchovy catch-at-age 0 and 1 are fixed at the (lower than TAC) 2004 to 2011 observations.
Note, however, that the observed recruitments in May each year were not used to over-ride the model generated recruitment from the stock-recruitment relationship.

The above changes resulted in projections of sardine 1+ biomass relatively near to the actual observations from November 2004 to 2011 under "MoveE" and "MoveAutoC", while under "NoMove" the survey observations are outside the model projected sardine 1+ biomass 90% probability interval for some years.

C.8 (L) The egg/larval individual based model is a useful way to develop hypotheses regarding movement patterns of age-0 fish and to establish the likelihood that fish spawned by one stock move to the area in which the other stock is predominantly found. However, the value of this tool would be enhanced, and the ability to draw conclusions strengthened, if it proves possible to extend the model to account for variation in oceanographic conditions as well as in the distribution of predators and prey.

Coetzee (2014) further investigated the potential contribution of sardine spawning on the west and south coasts to recruitment on both coasts, by considering the IBM analyses of Miller et al. (2006). This shows that a larger proportion of eggs spawned on the west coast are "lost". Assuming the movement/retention of eggs correlates directly with sardine recruitment, Coetzee (2014) reports there

to be a greater probability that south coast spawning makes a contribution to recruitment on the west coast than west coast spawning does to the south coast recruitment.

de Moor et al. (2014b) consider alternative hypotheses (the "A" hypotheses) of two mixing sardine stocks based on this work, assuming the "effective" spawning biomass of each stock is a proportion of both stocks. de Moor et al. (2014c) [QUESTION 3] question if alternative hypotheses can be prioritised.

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