Response to the review panel report for the 2015 International Fisheries Stock Assessment Workshop : Sardine

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The international review panel report (Dunn et al. 2015) contains 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 30 November to 4 December 2015.

Comments on these recommendations are inserted in italics.

The Panel was pleased to note the increased number of fish for which parasite data are available. The increased sample sizes allowed a more accurate estimate of the prevalence of parasites in the south coast stock sardines. The Panel supports efforts to formally include the parasite data in the assessment, but also emphasizes the importance of identifying and resolving some software development issues that may be hampering the ability to fit the model to the data.

This has been done, e.g. MARAM/IWS/DEC16/Sardine/P1 and MARAM/IWS/DEC16/Sardine/P2.

D.1 (*) The Panel is concerned that the sardine model was unable to converge (i.e., lead to a positive definite Hessian matrix), which meant that all of the analyses reviewed during the workshop were considered 'preliminary'. A 'best practices' guide for developing and fitting models is needed. This could be developed by collaborating with researchers (including current and past Panel members) who are using AD Model Builder. Appendix C summaries some initial deliberations on how the code could be improved and some principles for setting up ADMB models.

Changes to the code in response to Appendix C recommendations are commented upon below. The convergence of the sardine assessment model to provide a positive definite Hessian is now far more frequent.

D.2 (H) The updated base-case model for sardine should be based on the specifications in MARAM/IWS/DEC15/Sardine/P1, with the following modifications:

- the log-normal commercial selectivity function should be replaced by one that allows more flexibility on the right-hand descending limb (including the possibility of an asymptotically flat selectivity function);
  After some initial testing with alternative functions, a logistic function was selected (Equation A.15 and Figure 8 of MARAM/IWS/DEC16/Sardine/P2) which still maintains a good fit to the commercial LFs at high lengths (Figure 10 of MARAM/IWS/DEC16/Sardine/P2).

- the parasite prevalence data for the south coast from the November survey should be based on animals sampled east of 22^{0}E (this is to exclude age-1 animals that may be from the west coast);
  Done (MARAM/IWS/DEC16/Sardine/P1 and MARAM/IWS/DEC16/Sardine/P2). MARAM/IWS/DEC16/Sardine/BG9 shows that the estimated movement parameters in some recent years are sensitive to the inclusion of the data between 20 and 22°E.

- estimate all the west to east movement parameters based on a normal prior for transformed movement rate that has the same variance as the current U[0,1] prior
  The prior $move_y$~U[0,1] was replaced with $move_y$~Beta(1.05,1.05), and movement for all years is now estimated (MARAM/IWS/DEC16/Sardine/P1 and MARAM/IWS/DEC16/Sardine/P2).

- as needed, adjust the likelihood for the parasite data to account for overdispersion; and
  A binomial likelihood is used for the parasite prevalence-by-length data

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(MARAM/IWS/DEC16/Sardine/P1 and MARAM/IWS/DEC16/Sardine/P2). Defining $p_{j,y,l}^{obs/mod}$ as the observed or model predicted proportion of sardine infected with the parasite in length class l of stock j during year y, and $N_{j,y,l}^{obs}$ as the sample number from length class l of stock j during year y, $\frac{\sum_{y,l}\left(p_{j,y,l}^{obs}-p_{j,y,l}^{mod}\right)^2}{\sum_{y,l}p_{j,y,l}^{mod}\left(1-p_{j,y,l}^{mod}\right)/N_{j,y,l}^{obs}}$ *is 1.03 for the west stock and 1.38 for the south stock, indicating little need for correction for the west stock. This indicates little overdispersion for the west stock. The effect on the south stock is also not large, but sensitivity to allowing for this will be checked in due course.*

- estimate the annual infection rates from 2006 as a random effect (although data are available from 2010 onwards only, the population in 2010 comprised animals spawned from 2006) (estimate the mean of the distribution for the infection rates, but pre-specify the variance of this distribution).

  Infection rates are estimated from 2008 onwards, given the very small proportion of the population surviving to ages 2$^+$, with uniform prior distributions (MARAM/IWS/DEC16/Sardine/P1 and MARAM/IWS/DEC16/Sardine/P2).

D.3 (H) Conduct the following sensitivity analyses once a base-case model has been selected:

- base the parasite prevalence data for the south coast from the November survey on animals sampled east of 20^{0}E;

  Done (MARAM/IWS/DEC16/Sardine/BG9).

- ignore the recruitment survey data for the south coast (these data are very noisy and the model fails to mimic the current indices); and

  Done (MARAM/IWS/DEC16/Sardine/BG8).

- consider a model in which the south coast stock consists of two cohorts.

  The implementation of this option was deferred given other Small Pelagic Scientific Working Group priorities this year.

D.4 (M) Improve the fits to the survey and catch length-composition data. The residuals about the fits to these data (MARAM/IWS/DEC15/Sardine/P3) show patterns suggestive of model mis-specification. Consider (a) "blocking" of selectivity, (b) time-varying growth, and
(c) random effects for length-specific selectivity deviations over time.

Commercial selectivity has been "blocked" into four pre-specified time periods selected based on residuals in the absence of blocking (Figure 8 of MARAM/IWS/DEC16/Sardine/P2 and Figure 8 of MARAM/IWS/DEC16/Sardine/BG6). This produced some improvement in the model fit, but some patterns in the residuals remain (Figure 9 of MARAM/IWS/DEC16/Sardine/P2 and Table 4 and Figure 9 of MARAM/IWS/DEC16/Sardine/BG6). The age at which length is zero is now estimated to vary between years, thereby mimicking early and late recruitment about the mean of 1 November. This resulted in a much better fit to the data (Figure 11 of MARAM/IWS/DEC16/Sardine/P2 and Table 4 and Figure 11 of MARAM/IWS/DEC16/Sardine/BG6). Given time constraints, consideration of random effects for deviations in length-specific selectivity over time, which would first be implemented for the "slope" parameter of the logistic curve, has not yet been attempted.

D.5 (M) Progress has been made on conducting a meta-analysis of stock and recruitment data for sardine to examine whether the pattern of an initial linear relationship between recruitment and spawning stock occurs for other stocks. At least one stock (Pacific sardine) exhibited this pattern. Further data sets should be obtained from the RAM Legacy Database when available, and their results collated and summarized.

This is awaiting an update to the RAM Legacy Database.

APPENDIX C

SOME NOTES RELATED TO THE CODE FOR THE SARDINE MODEL

The Panel reviewed the sardine ADMB model code, and made the following suggestions for investigation to try to improve model performance and convergence.

1. Ensure that the model is initialised with a large value for the maximum recruitment on the stock-recruitment relationship (parameter *a*) and a minimal value for the inflection point (parameter *b*), so that recruitment is initially scaled about a median value and allows for all historical catches to have been taken.
   Done.

2. When choosing in which phase to estimate parameters, first estimate key biomass scaling parameters (average recruitment, catchability parameters, and selectivity parameters) before estimating the secondary parameters such as for growth, and for the stock-recruitment relationship.
   Done.

3. Annual movements: Estimate annual age-1 movements in an early phase and the proportion of adults that move in a later phase.
   Done.

4. The Panel was uncertain whether the Normal component on the left of the commercial fishery selectivity curve was required to fit the small mode of fish observed at shorter lengths or whether the observations were simply a reflection of the availability of a cohort of recruits. The Panel also queried the use of a rigid dome-shape selectivity function (a reverse log-normal of fixed variance at larger lengths) to fit the commercial fishery catch proportions-at-length, as this may force an inappropriately sharp decrease at larger lengths. The Panel recommends initially assuming a simple (logistic style) selectivity, then using the residual structure from the fits to inform the choice of whether a more complex selectivity pattern – including domed selectivity and the left hand “bump” in the current selectivity, are required. The Panel also notes that instead of using two normal distributions, the same effect can be achieved, in part, by using a double normal (Equation 1) with the right variance set at a large value to assess fit, then freed up in a later run if required.

   Equation 1: The double normal selectivity

$$f(x) = 2^{-\left[(x-a_1)/sL\right]^2}, \qquad (x \le a_1)$$

$$= 2^{-\left[(x-a_1)/sR\right]^2}, \qquad (x > a_1)$$

   The normal component is required to fit the commercial LFs at smaller lengths, particularly on the west coast (results not shown in MARAM/IWS/DEC16/Sardine/P2, but available upon request). After some initial testing with alternative functions, a logistic function was selected for the commercial selectivity for larger lengths (Equation A.15 and Figure 8 of MARAM/IWS/DEC16/Sardine/P2) which still achieves a good fit to the commercial LFs at larger lengths (Figure 10 of MARAM/IWS/DEC16/Sardine/P2).

5. Since selectivity-at-length is [0,1], change the maximum exploitation rate penalty from

$$S_{j,y,l}F_{j,y,q} < 0.95 \text{ to } F_{j,y,q} < 0.95.$$

   Done.

6. Rescale the maximum exploitation rate penalty multiplier to a lower value and change the *eps* parameter used in the AMDB posfun function to be a softer constraint, for example it may be better to set *eps* at 0.01 for the maximum exploitation rate penalty instead of 0.0001.
Done.

7. Remove the penalty on N and Nrec (used to penalise cases where the sardine bycatch and recruit catch taken by the fishery before the survey are larger than available biomass estimated by the model) and rather impose a maximum exploitation rate penalty on the sardine bycatch and recruit catch in the same manner as for the other fisheries.
Done.

The Panel also made some additional considerations secondary to the above. These were:

8. With regard to the estimation of σR^2, start model runs with a reasonably large value and estimate the value of this parameter only in one of the last phases. Alternatively, consider calculating a closed-form solution for each model run before the prior is added to the objective function.
The model runs are initiated with σ_R^2 relatively high and estimated only in one of the final phases. However, given $\varepsilon_{j,y}^S \sim N(0, \sigma_R^2)$, if the closed form solution $\sigma_R = \sqrt{\sum_y \left(\varepsilon_{j,y}^S\right)^2}$ was used, the model unfortunately goes to the global minimum with all $\varepsilon_{j,y}^S \to 0$ instead of being able to locate a local minimum at some non-zero σ_R.

9. Consider the possibility of an informed prior on the estimated numbers at age in the first year of the model to assist the model minimisation and subsequent MCMC performance.
This proved not to be required.

10. Growth curve parameterisation: re-parametrising the growth curve to estimate mean lengths at reference ages rather than in terms of L_∞ and t_0, as per Schnute and Fournier (1980) may assist minimisation and MCMC performance by reducing the correlations between the von Bertalanffy parameters in estimation.
This was done, estimating the length at ages 0 and 1, together with the growth parameter κ (MARAM/IWS/DEC16/Sardine/P1 and MARAM/IWS/DEC16/Sardine/P2).

11. Consider imposing a relationship between age and the CV of the age-length relationship to deal with the problem of the model estimating the age 0 CV close to the upper bound. Possible relationships to consider could include quadratic or negative exponential.
This was not done as the variability about age 0 is no longer estimated near to the upper bound.

12. Consider assuming a log-normal rather than a normal distribution for the prior for the bias in the estimate of sardine abundance from acoustic surveys (parameter k_{ac}).
Done (Supplementary Material of MARAM/IWS/DEC16/Sardine/P1 and Appendix B of MARAM/IWS/DEC16/Sardine/P2).

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