Base operating model for Indian Ocean albacore tuna, scenarios included and model conditioning

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Following the workplan adopted by the last session of the Working Party on Methods (WPM, 2012), work has been carried out for the development of an operating model for Indian Ocean albacore. The current version, presented here, is based on the feedback offered by the last session of the Working Party on Temperate Tuna (WPTmT, 2014).

Base population model

The current iteration of the IO albacore operating model is based on the latest stock assessment model presented at the Fifth Session of the Working Party on Temperate Tunas (Hoyle et al, 2014), with two major simplifications:

- No separate N & S areas for the TWN LL fleet.
- A single time period for the same fleet.

A detailed explanation of all other structural elements can be found in Hoyle et al (2014).

The perception of stock dynamics obtained from the OM base case run is slightly different for that used by WPTmT to provide advice in its latest report (Figure 1).

These differences are obviously translated into the estimates of references points, with F at MSY coming at a much lower value (Table 1). The apparent difference in stock productivity, i.e. how much fishing intensity is able to sustain in the long term, will require further investigation, as is likely to be linked to the fact that MSY is actually determined by two parameters (M and steepness), fixed in

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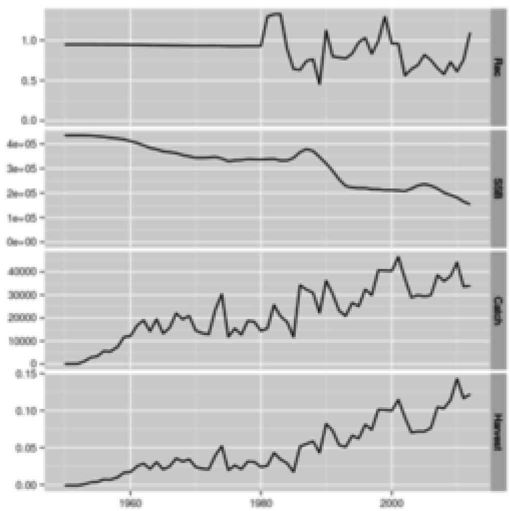

Figure 1: Time series of recruitment (Rec), spanwning stock biomass (SSB), total catch (Catch) and fishing mortality (Harvest) estimated by the base case SS3 model employed in the albacore OM

the model runs, with no regard to the correlation among them (Mangel et al., 2013).

Ref. Point	WPTmT SS3	OM Base Case
MSY	47600	40586
SSB_{MSY}	39200	86550
F_{MSY}	0.31	0.096

Table 1: Reference points obtained during the stock assessment conducted by WPTmT (2014) and in the base case run used to build the operating model.

Uncertainties considered

A number of factors identified in the past as likely to produce the greatest uncertainties in our ability to estimate the dynamics of this stock and fishery were selected, and alternative values were proposed to cover the range of options deemed to be worth of investigation (see past reports of the WPM MSE team meetings).

The final grid applied to construct this operating model includes the following factors and values.

Natural mortality (M)

- Constant values of M at age: 0.2, 0.3 and 0.4
- Vectors of decreasing M at age: starting at 0.4 (for ages 1-5) and lowering progressively to values of 0.2 and 0.3 for ages greater than 5.

The vectors finally applied are shown in Figure 2.

An exploration of other possible vectors was carried out, by applying two procedures for calculating natural mortality values using life history and biological information, updated versions of Pauly (1980), $M_{est} = 4.118K^{-0.73}L_{\infty}^{-0.33}$ and Hoenig (1983), $M = a \cdot t_m^b$, as recommended by a recent review of their performance (Then et al., 2014).

The values obtained for Indian Ocean albacore were $M = 0.2619$ and $M = 0.4368$ for Pauly's and Hoenig's, respectively. The first of them is already covered by the range of values initially considered, while the second, higher than the current extreme value, was later found to be incompatible with other data and assumptions in the current model. Values for M higher than 0.4 for the mature ages gave rise to estimates of virgin biomass that could not be considered realistic for this stock (between 1 and 4 million t), specially when combined with a selectivity function than decreased markedly with age (e.g. double normal)

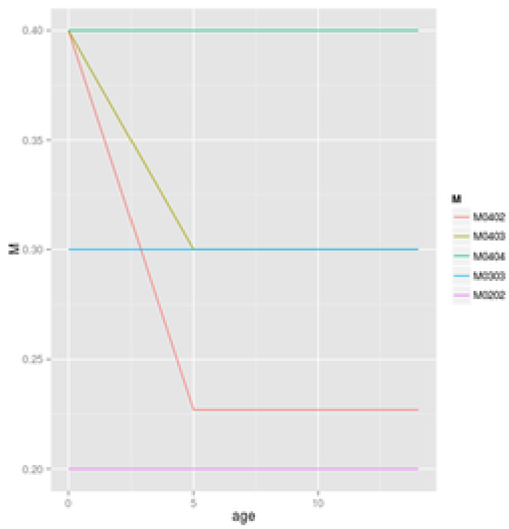

Figure 2: Alternative vectors of yearly natural mortality (M) used in conditioning the operating model

Variability in recruitment

Two values were considered for the true variability of recruitment in the population (`sigmaR`), 0.4 and 0.6. Their effect on the base case run is shown in Figure 3

Steepness of stock recruitment relationship

Three values for the steepness (h) of the stock-recruitment relationship, model using a Beverton & Holt formulation, were considered: (0.7, 0.8, and 0.9.

Coefficient of variation of the CPUE series

Two values for the coefficient of variation in the CPUe series were included: 10% and 20%.

Weight in final likelihood of trends in length composition

Three values were applied to the relative weight of length sampling data in the total likelihood, through changes in the effective sampling size parameter, of 20, 50 and 100. This alters the relative weighting of length samples and CPUE

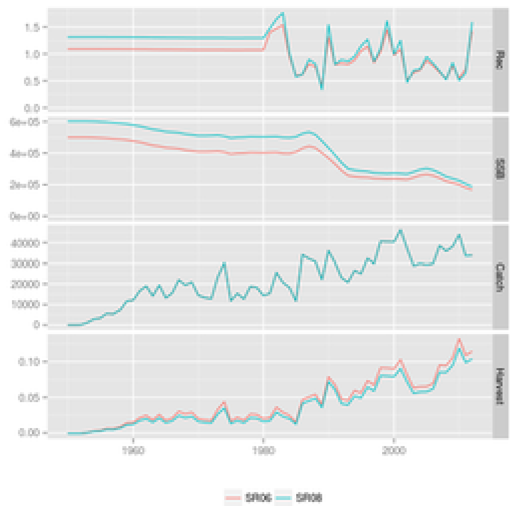

Figure 3: Time series of population estimates from both options for the `sigmaR` parameter, 0.4 and 0.6

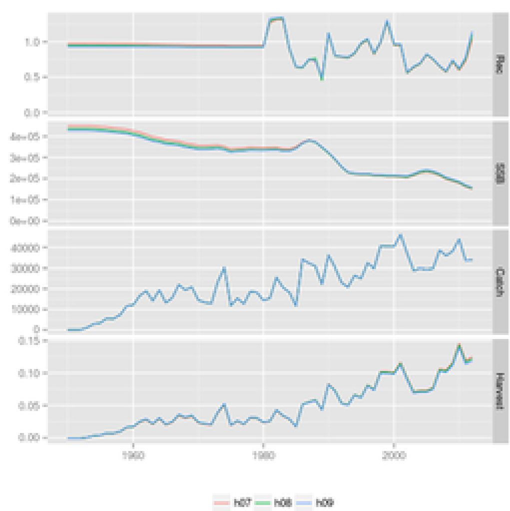

Figure 4: Time series of population estimates from the three options of the stock-rectruitment steepness parameter, 0.7, 0.8 and 0.9

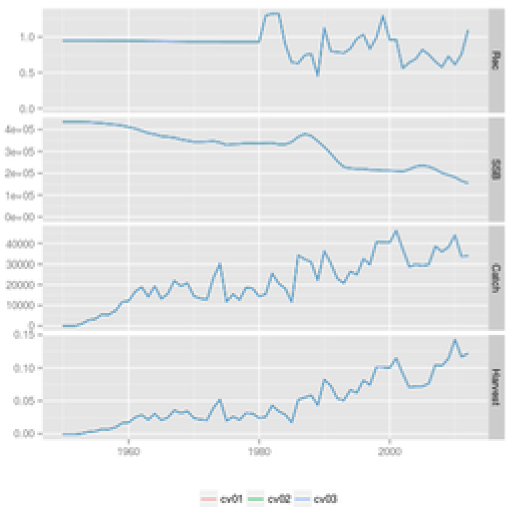

Figure 5: Time series of population estimates from both options of the CV(CPUE) parameter, 0.1 and 0.2

series in informing the model about stock dynamics and the effects of fishing at length.

Effective catchability trends over time for CPUE series

Two scenarios were considered for the effective catchability of the CPUE fleet. On the first one it was assumed that the fleet had not improved its ability to fish for albacore over time, or that any increase had been captured by the CPUE standardization process. An alternative scenario considered a 2.5% increase in catchability by correcting the CPUE index to reflect this.

Selectivity function of CPUE fleet

Two possible functional forms for the selectivity of the CPUE LL fleet were considered: a logistic function (Log), where selectivity stays at the maximum level, or double normal (DoNorm), where selectivity drops at some point in the age range.

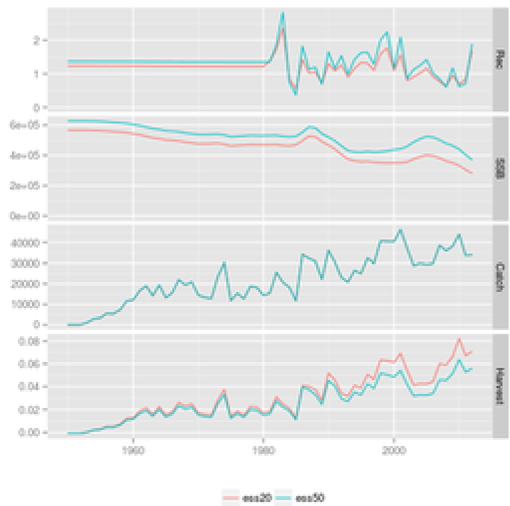

Figure 6: Time series of population estimates from the three options of weight (effective sampling size) of the length composition data for the CPUE fleet, 20, 50 and 100

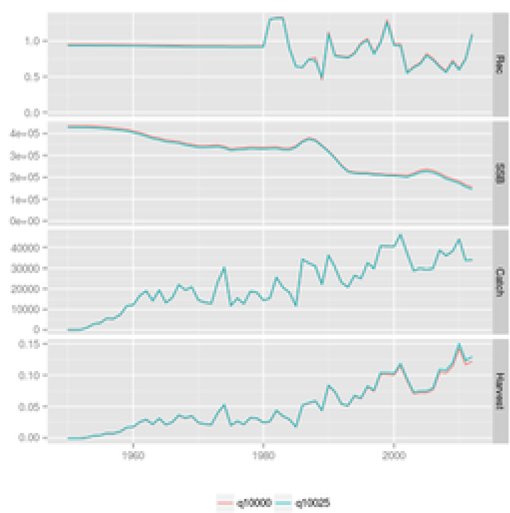

Figure 7: Time series of population estimates from the two scenarios on time trends in CPUE fleet catchability, constant or increasing by 2.5% per year

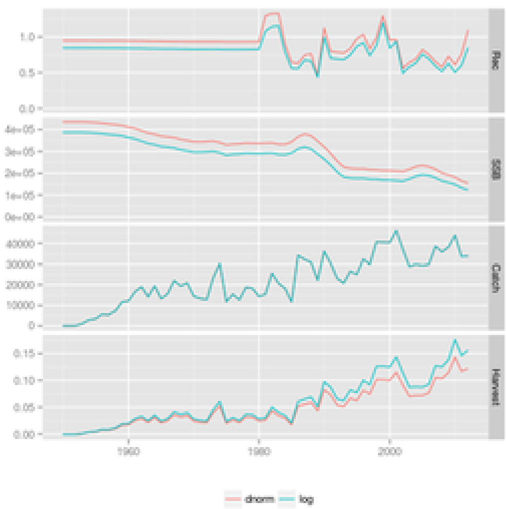

Figure 8: Time series of population estimates from the two scenarios on the funtional form of the selectivity for the CPUE fleet catchability, logistic (Log) or double normal (DoNorm)

Conditioning and post-fitting selection

The full set of 720 runs was inspected and parameter values, or combinations of them giving rise to populations dynamics that could reasonably be considered unfeasible were selected and dropped from the final operating model.

A plot of the distribution of estimates of SSB in 1950, at the start of series (Figure 9), showed three separated clusters of values, where two of them reflected biomass that would be generally deemed to be too large.

Final operating model

The final model grid consisted of 721 runs of the Stock Synthesis 3 (Methot & wetzel, 2013) model, using version 3.24f[1], on a 40-core Linux machine under Ubuntu 12.04.

Tests of model dynamics

A set of simple projections were carried out to check out the model dynamics when projected into the future. Recruitment was calculated according the

[1] http://nft.nefsc.noaa.gov/SS3.html

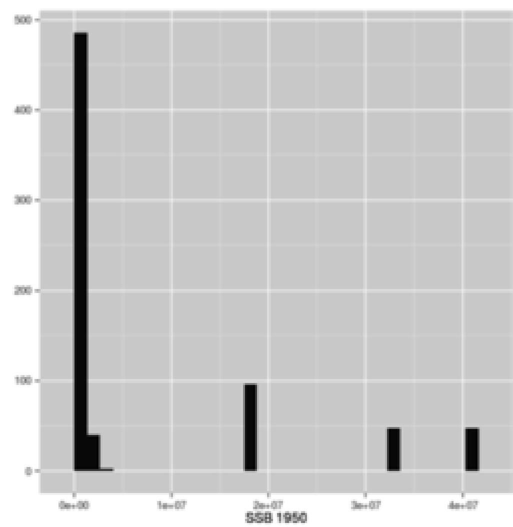

Figure 9: Histogram of estimated values for SSB in 1950 over the full set of SS3 runs.

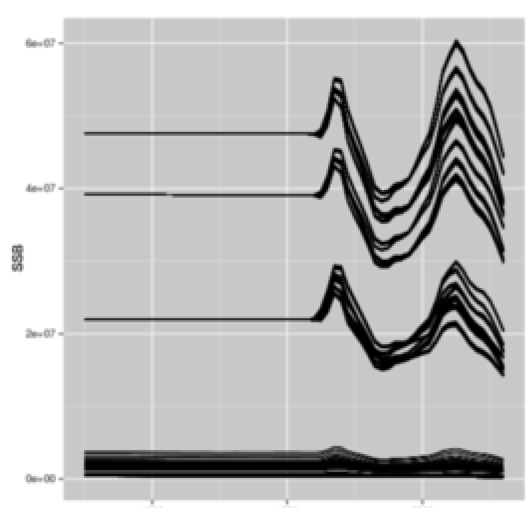

Figure 10: Histogram of estimated values for SSB in 1950 over the full set of SS3 runs.

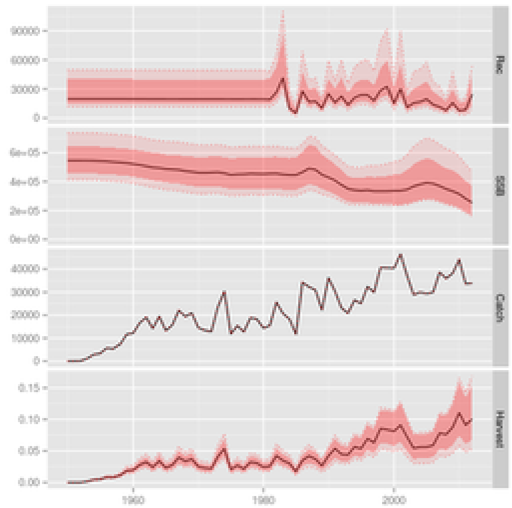

Figure 11: Time series (recruitment, SSB, catch and F) of the final operating model. Line shows median values, ribbons show the 25-75% and 10-90% quantiles, respectively.

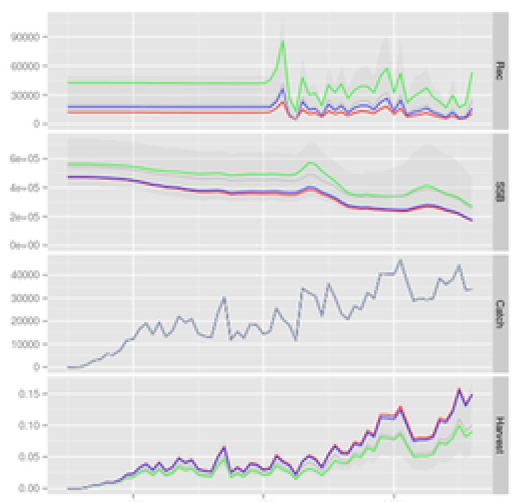

Figure 12: Time series (recruitment, SSB, catch and F) of the final operating model with some inidvidual runs superimposed. Ribbons show the 10-90% quantiles.

stock-recruitment relationship fit on each model iteration, with no uncertainty added.

Constant catch

The population model was projected forward for the 2013-2025 period with constant catches at three levels: equal to 2012 (33,900 t), half of those (16,950 t) and with a 50% increase (50,850 t).

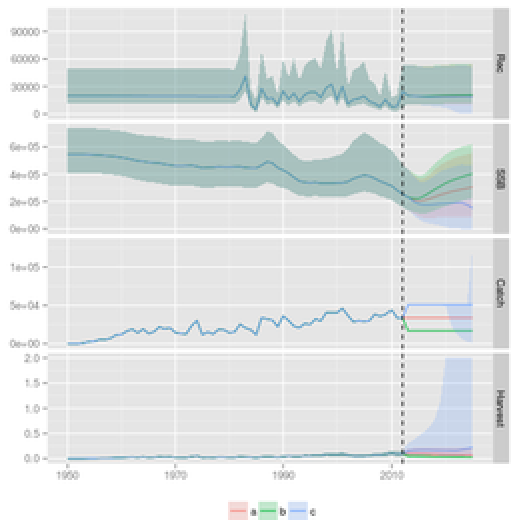

Figure 13: Time series (recruitment, SSB, catch and F) of future projections of the final operating model with catches equal to 2012 levels (a), half of those (b) and with a 50% increase (c).

Constant fishing mortality

A similar procedure was carried out with different levels of fishing mortality, taken as $\bar{F}$, the mean fishing mortality across the fully selected ages (5-10): equal to 2012 (0.10), half that value (0.05), and with a 50% increase (0.15).

Discussion

The work presented here attempts to provide a base for initial evaluation of management procedures, including harvest control rules, for the Indian Ocean albacore stock, by extending the current stock assessment to better cover the

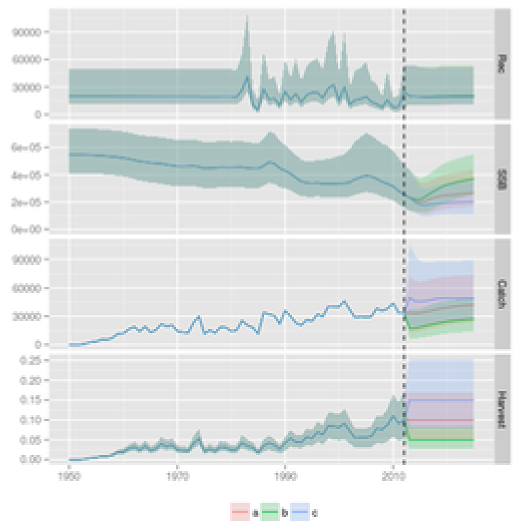

Figure 14: Time series (recruitment, SSB, catch and F) of future projections of the final operating model with F equal to 2012 levels (a), half of those (b) and with a 50% increase (c).

most likely sources of uncertainty about the stock dynamics. The range of options currently included is open to discussion and a number of possible extensions are mentioned below, but feedback on this greatly encouraged.

Data for this stock is limited in scope and information level, in contrast with many other situations where fisheries-independent data might be available (e.g. tagging). This makes the population model very dependent on the choice of parameter values and the interaction among them. For example, some model runs with extremely unlikely estimates of biomass returned a likelihood value not too distant to that of the base case, indicating that likelihood maxima are poorly defined. Although this is of less concern when an operating model is constructed, compared with attempts at providing management advice based on best estimates of uncertain parameters, it still affects the strength of inferences obtained from this operating model.

The use of a platform, Stock Synthesis 3 (Methot & Wetzel, 2013), originally designed for stock assessment, to construct an operating model, is not without problems. Although the formulation of the model appears to be made simpler, and the closeness to what the Working Party is used to might make it simpler to be understood, other factors play heavily against this application of the platform. Automatic modification of input and control options, as required when setting up a number (720 in this case) alternative model structures, is not trivial and easy to introduce errors. Differences between the time-area structure of model dynamics (e.g. a seasonal model) and that use in projections (yearly) are another source of extra labor.

Exceptional circumstances

An important consideration when adopting an operating model for subsequent testing of management procedures is to clarify the range of situations in stock and fleet dynamics for which the model inferences are valid, as when the system falls outside of that range, the behaviour of the management procedure is likely to deviate from what could be expected (Punt et al, 2015).

The operating model presented here covers at this stage a relatively limited range of circumstances, mostly those that have been observed in the 60 years of history of this fishery. Some probable hypothesis on environmental influences in recruitment, growth and catchability could be constructed to further expand the scenarios for which this operating model could be informative about.

Future work

Models of this kind are complex structures, with assumptions, some clearly specified and other more subtle, and likely to contain errors and omissions. A sufficiently detailed peer-review of the current work would thus be extremely beneficial, specially as this stage on the MSE process in IOTC, as it could not only improve the MSE work for albacore but also provide useful insights for future developments for other stocks.

Alternative hypothesis related to environmental factors likely to have affected albacore recruitment, growth, natural mortality or catchability in the past could possibly be constructed and their translation into trends in parameters included in the model be tested, so as to better understand the robustness of the operating model to alternative and maybe more extreme environmental scenarios that could be repeated in the future. A set of robustness operating models could then be used to test the extremes of the performance of alternative management procedures.

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APPENDIX: Source code

Copies of the all the source code and SS3 input files are available at the iotcwpm/ALB repository at https://github.com/iotcwpm/ALB/