Risk assessment of Indian Ocean albacore stock status using an age-structured production model

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1 Introduction

This document details the application of a simple age-structured production model to Indian Ocean albacore. An even simpler surplus production model was applied before but given the clear age-specific nature of the catches (younger fish are rarely caught) it was decided that the assumptions made when using a surplus production model (all the age classes are fished) would lead to biased and likely over-pessimistic results. One clear issue with Indian Ocean albacore is the lack of conclusive biological information on growth, maturity and natural mortality. In this document we look at the effect of the interaction between age at selection by the fishery and age-at-maturity and how this might affect our view of stock status. It should be noted this work is more of risk assessment not a stock assessment given there are still many issues that need to be settled before a true assessment of this stock can likely be undertaken. The aim is to look at a range of plausible scenarios and see whether they indicate any imminent problems and also highlight potential future directions.

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2 Data & Methods

The population model used in this work is age-structured but still quite simple - single area with simple representations of how selectivity and maturity processes occur. Given there are still potential issues with the current catch-at-age data we use only catch biomass and CPUE data to estimate the key parameters of the model. The population model works as follows:

2.1 Population model

We have numbers-at-age $N_{y,a}$ from 1950 to 2007 and for ages 1 to 9 so that the recruited fish dynamics are defined as follows:

$$N_{y,a} = N_{y-1,a-1}e^{-M}\left(1 - s_{a-1}h_{y-1}\right) \tag{1}$$

where the exploitation rate, h_y, is defined as the ratio of catch to exploitable biomass:

$$h_y = \frac{C_y}{\sum_{a=1}^{9} w_a s_a N_{y,a}} \tag{2}$$

where w_a and s_a are the weight and selectivity-at-age vectors. Recruitment is defined directly from the stock-recruit curve (assuming a Beverton-Holt relationship) so that

$$N_{y,1} = \frac{\alpha S_{y-1}}{\beta + S_{y-1}} \tag{3}$$

where S_y is the spawning stock biomass:

$$S_y = \sum_{a=1}^{9} w_a m_a N_{y,a} \tag{4}$$

where m_a is the maturity ogive. We do not attempt to estimate recruitment deviations - we have only a preliminary CPUE series and no catch-at-length or age data so very little data with which to estimate both abundance and year-class strength together at this point.

2.2 Maturity & selectivity

A major issue with Indian Ocean albacore is the paucity of biological data available for key processes. It will become clear that the age at which both spawning and the selection of fish occurs will become crucial to our idea of stock status and MSY. To look at a plausible range of possibilities we first define a simple ogive that we use to define both selectivity and maturity. Let us call this ogive ν_a so that for $a < a_{50}$ $\nu_a = 0$, $\nu_{a_{50}} = 0.5$ and for $a > a_{50}$ $\nu_a = 1$. For maturity and selectivity we then have ages-at-50% of a_{50}^m and a_{50}^s, respectively.

We do have some information on both these processes from information from other stocks and by simple inspection of the catch-at-age data. For maturity we assume a value of $a_{50}^m = 5$ (given we have used maturity occurring between ages 4 and 6 for our construction of an M value) and from looking at the catch-at-age data it is clear that somewhere between 4 and 5 there is a substantial and sustained increase in the number of fish caught. We look at two values for the selectivity of $a_{50}^s = 4, 5$ - this is also interesting from a life-history vs exploitation point of view as we could easily have a situation where we exploit the animals at the onset of sexual maturity or at the same time. Given we assume that spawning occurs before fishing this will have a direct and highly influential effect on the estimates of MSY and, hence, stock status.

2.3 Stock-recruit parameters & natural mortality

In paper IOTC-2008-WPTe-6 we demonstrated how to use life-history information to estimate natural mortality (mean 0.34, CV 0.09) and we also assumed a simple distribution for the steepness values (mean 0.75, CV 0.1) and we use these two Monte Carlo samples in our age-structured production model to explore some of the uncertainty in the stock dynamics.

2.4 Catch and CPUE data

The total catch biomass (1950-2007) and Taiwanese long-line CPUE data (1980-2006) used to estimate the parameters of the model can be seen in Figure 1. With respect to the likelihood for the CPUE we assumed a log-normal relationship between CPUE and exploitable stock biomass with the catchability coefficient estimated as a nuisance parameter. The other estimated parameter is the unexploited spawning biomass, B_0.

3 Results

Recall we have to scenarios - one where selection begins essentially one age-class before maturation (Case 1; $a^s_{50} = 4$, $a^m_{50} = 5$) and one where selection follows the maturity ogive (Case 2; $a^s_{50} = a^m_{50} = 5$) but spawning occurs before fishing. From Figure 2 it is clear that the fits to the data are not great for both cases but very similar - they cannot fit the more extreme trends in the CPUE but do fit the general decline. It is worth noting that a model that estimated both B_0 and recruitment deviations (over years where the CPUE would realistically possess data on them) was attempted and that it is clear that even for small deviations (i.e. a recruitment CV of 0.1 penalty term) there is not enough information on both abundance (B_0) and recruitment - more data is needed such as the catch-at-age data.

For Case 1 we estimated a B_0 - in tonnes - with mean (and CV) of 120,037 (0.14) and for Case 2 we had a mean and CV of 154,642 (0.1). Figure 3 plots the stock dynamics summary for both cases, in terms of SSB and exploitation rate dynamics and relative to expected MSY levels. Clearly the results from Case 1 and Case 2 differ substantially - not in terms of stock status (biomass levels above MSY and exploitation rate levels below MSY) but for Case 1 catches are predicted to have exceeded MSY recently so if kept at this level would eventually lead to over-fishing. For Case 2 current SSB is predicted to be well above MSY with the harvest rate well below MSY - see Table 1 for a probabilistic summary. One point to strongly emphasise is the role the interaction of age-at-maturity and age-at-selection plays in the results. For Case 1 we begin to select fish a little earlier than they mature - we are not fully selecting immature fish but do begin to take them before they can effectively spawn. For Case 2 the ages at selection and maturation are the same and given that the population model assumes that fishing occurs post-spawning all fish are allowed to spawn at least once before they are exploited. This makes a huge difference to the estimated MSY levels. For the values of steepness here (in fact even for lower values) if the fish are permitted to spawn at least once before being exploited then the population can permanently sustain very high levels of exploitation (up to around 90%). Figure 4 shows the current-to-MSY ratio histograms for both cases and the differences between the two cases are clear to see.

One would expect that the processes of maturation and selection are more complex than the simple cases outlined in this work. In terms of realism Case 2 would be closer to what we might expect (the sudden and order-of-magnitude increase in catch numbers occurs at age 5) but there is doubtless an overlap in the increase in selection and the maturation of the animals. If maturation occurs at a similar time to selection then we would expect that the stock can sustain much higher levels of exploitation than if selection occurred before maturation, as was seen in the differences between the results for Case 1 and Case 2.

4 Discussion

A simple age-structured production model was applied to the catch biomass and Taiwanese CPUE data but more in terms of a risk assessment for the status of Indian Ocean albacore, not a stock assessment. Clearly the exploitation of albacore seems to undergo a sharp transition at around ages 4 and 5 with a rapid increase in the numbers of fish caught, suggesting a sharp increase in selectivity at around age 5. Unfortunately there was not time to fully parameterise a statistical catch-at-age assessment model for albacore as we currently lack certainty in key processes - particularly maturation and growth - and issues with respect to potential discarding were raised at the Working Party, making a more obvious interpretation of the catch-at-age data potentially problematic. This meant that we could not really estimate selectivity or recruitment deviations.

To explore the importance of what age classes are selected and what age classes are mature we looked at two simple cases where selection preceded maturation by one age-class (Case 1) and where selection and maturation followed the same age-specific trend (Case 2). For both cases there was no real indication that either the stock was over-fished or that over-fishing was occurring. For Case 1 current catches were predicted to be above MSY but not for Case 2. Case 2 was noticeable more optimistic in terms of its prediction of current stock status, with current SSB predicted to be almost certainly above MSY with current exploitation rates and catches predicted to be below MSY with high probability.

It would be inadvisable to use the results of these exploratory runs as a stock assessment but perhaps it could be said that it is likely that the stock is not currently over-fished and that we are not over-fishing the stock at present, but that levels of catch at the historical maximum (*ca.* 40,000 tonnes) would almost certainly exceed MSY levels of catch even in the most optimistic scenario.

What is apparent is that there appears to be a well defined spatial nature to the dynamics of albacore, with the juvenile and immature fish not being available in anything like the numbers of mature fish and likely located in the more tropical areas. With more information on the spawning condition of fish by location and with some more information on growth and maturity, as well as more work done on developing indices of abundance and how to interpret the catch data, one can conceive of creating a well defined spatial assessment model for albacore in the future.

5 Tables & Figures

Table 1: Albacore risk assessment summary table.

Scenario	$a_{50}^{s} = 4$ & $a_{50}^{m} = 5$	$a_{50}^{s} = 5$ & $a_{50}^{m} = 5$
$B_0\,(t)$	120,037 (CV 0.14)	154,642 (CV 0.1)
$p\,(B_{2007} < B_{MSY})$	0.01	0
$p\,(h_{2007} < h_{MSY})$	0.66	1
$p\,(C_{2007} < C_{MSY})$	0.03	0.85

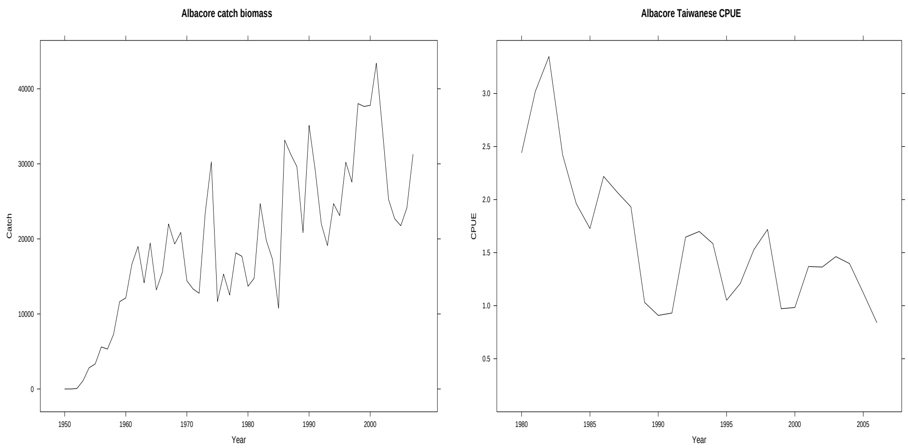

Figure 1: *Albacore catch (left) and Taiwanese long-line CPUE (right).*

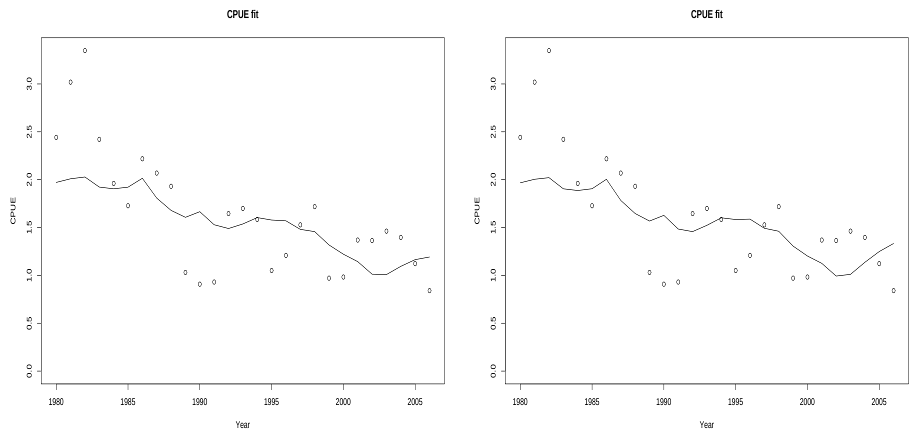

Figure 2: *Fits to the Taiwanese CPUE data for Case 1 (left) and Case 2 (right).*

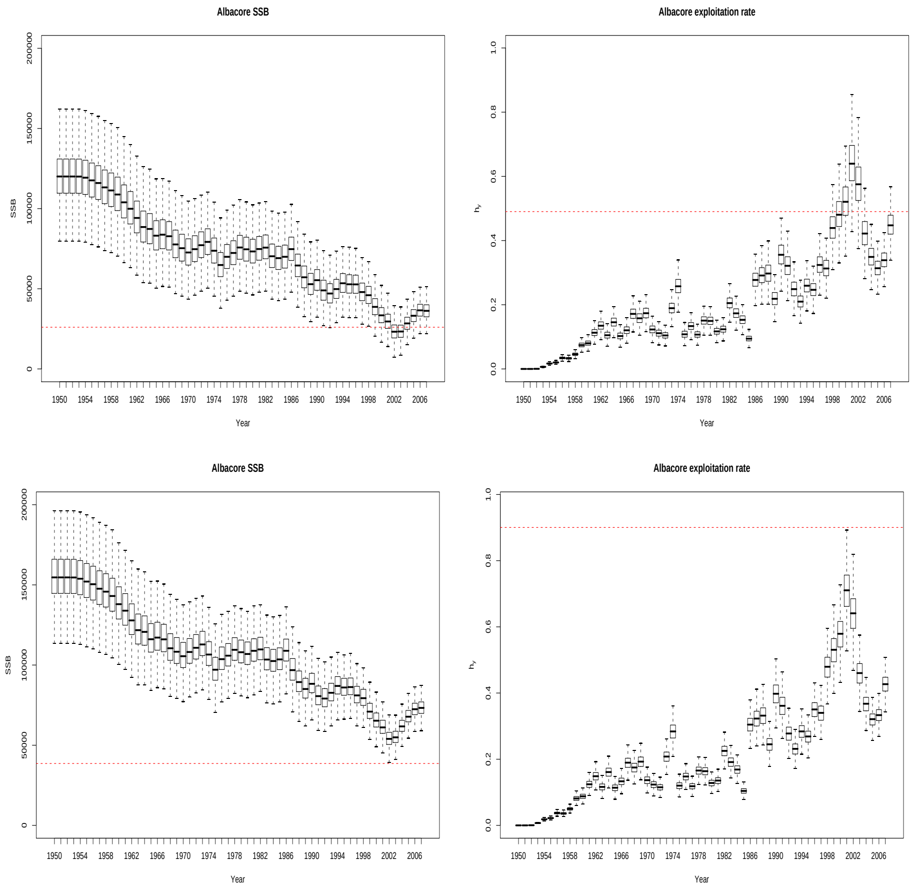

Figure 3: *Stock dynamics summary for Case 1 (top; SSB left and exploitation rate right) and Case 2 (bottom; SSB left and exploitation rate right). In all cases the dotted red line represents the expected MSY level.*

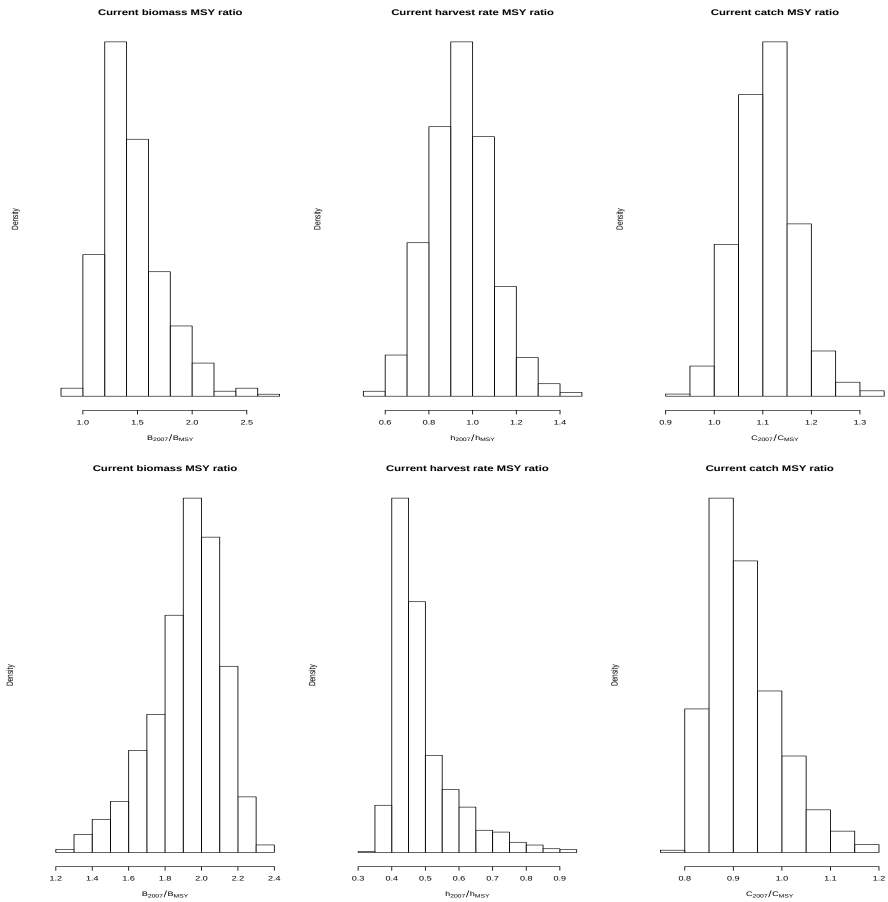

Figure 4: *Current-to-MSY ratio summary histograms for Case 1 (top) and Case 2 (bottom).*