Surplus production analyses for Indian Ocean albacore

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1 Introduction

This document details the application of a Pella-Tomlinson surplus production model to Taiwanese CPUE and total catch biomass data for Indian Ocean albacore tuna. We have catch data from 1950 to 2007 and standardised Taiwanese CPUE data from 1980 to 2006. As was done previously Monte Carlo distributions for key parameters (M, age at maturity and steepness) are defined and are then used to estimate r the intrinsic rate of increase parameter for the surplus production model. The reason for this is that the available CPUE (as is the case for the other long-line CPUE for yellowfin and bigeye) displays classical one-way trip attributes and the CPUE are unlikely to possess information on both the r and K parameters simultaneously.

The basic model uses parametric bootstrap methods to explore uncertainty in both our model assumptions (range of values for the Pella-Tomlinson shape parameter) and in the parameter estimates themselves. As a sensitivity we also look at allowing yearly random deviations in catchability to see if this would affect the outcomes of the base case model runs.

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2 Data & Methods

The population dynamics model assumed is a Pella-Tomlinson production biomass-dynamic model for the exploitable stock biomass, B_y:

$$B_y = B_{y-1} + rB_{y-1}\left(1 - B_{y-1}^{m-1}\right) - \frac{C_{y-1}}{K}, \tag{1}$$

where r is the intrinsic rate of increase parameter, K is the carrying capacity, m is the shape parameter and C_y is the catch. For our purposes we assume that B_y is in fact the ratio of stock biomass to carrying capacity as this helps reduce correlation in estimated parameters.

With respect to the CPUE series, $I_{y,g}$ we assume them to be lognormally distributed about their model-predicted counterparts, $\widehat{I}_{y,g} = q_g B_y$, with some standard deviation $\sigma_{g,y}$. In the estimation routine the catchability parameters, q_g, are estimated as nuisance parameters. For the case where we allow random variations in catchability we assume these deviations to be lognormal in nature with a pre-defined CV that effectively penalises deviations from constant catchability.

The parametric bootstrap operates by first drawing a value of r from its pre-defined distribution (conditional on M, age at maturity and steepness) and then I estimate a value of K for this value of r. This is done for 1000 draws of r from which we obtain a 1000 values of K and the biomass dynamics over time.

2.1 Catch and CPUE data

Figure 1 shows the total catch tonnage for albacore. Figure 2 shows the standardised Taiwanese CPUE series for Indian Ocean albacore tuna, the derivation of which is detailed in document IOTC-2008-WPTeT-5.

2.2 Derivation of r distribution

To derive a distribution for the r parameter of the Pella-Tomlinson model we need to know three key parameters: natural mortality, age-at-maturity and the stock-recruit parameter steepness. For natural mortality we use to life-history methods to obtain a combined estimate of M for Indian Ocean albacore. The first method we use is that detailed in Hewitt & Hoenig (2005) which uses the concept of maximum age; the second uses the work of Charnov (1990) that detailed a linear proportionality between expected female lifespan and age-at-maturity. In Hewitt & Hoenig (2005) they used the idea that if we can define a maximum age-class $\tilde{A}$ where only a proportion of $\tilde{\pi}$ exceed, then we have the following relationship:

$$\prod_{a=1}^{\tilde{A}} e^{-Ma} = \tilde{\pi}, \tag{2}$$

where M is the rate of natural mortality. A simple rearrangement gives us the following equation for M:

$$M = -\frac{\ln \tilde{\pi}}{\tilde{A}}. \tag{3}$$

We assumed a maximum age-class of 9 with a CV of 0.1 to obtain a distribution of potential M values using this method. The second method uses the work detailed in Charnov (1990) which detailed a proportional relationship (for different species groups) between expected (female) lifespan ℓ_f and age-at-maturity A_m: $\ell_f = \mu A_m$ with the constant of proportionality, μ, for fish being estimated to be around 0.5 - the expected lifespan is around half of the age at maturity. Expected lifespan (from age 1) can be defined in terms of natural mortality as follows:

$$\ell = \frac{A_m}{2} = \sum_{a=1}^{\infty} e^{-Ma}. \tag{4}$$

Assuming an age-at-maturity between 4 and 6 (age 5 with CV 0.1) we then solved the above equation for M. Our two Monte Carlo distributions for M using the different methods were then combined together to give an averaged distribution for M and all three can be seen in Figure 3. The two estimates using different techniques were close

(Hewitt & Hoenig: 0.32 (CV 0.08); Charnov: 0.35 (CV 0.1)) giving us a final estimate of $M = 0.335$ with CV 0.09.

We have already defined our distribution for age-at-maturity so we defined a steepness distribution using a beta distribution with a mean and CV of 0.8 and 0.05. The resultant distribution of r can be found in Figure 4 resulting in a mean and CV for r of 0.43 and 0.14. For the m shape parameter (which influences where the MSY values are located on the equilibrium curve) we assumed a uniform distribution between 1.5 and 2.

2.3 CPUE catchability sensitivity

To look for potential catchability trends over time we allowed yearly random variation in catchability when fitting to the CPUE series. These yearly variations were assumed independent across years and were assumed to be lognormal with a fixed CV of 0.1. The main reason for picking a value of 0.1 was to allow for variation but not basically invalidate the potential abundance information within the CPUE - allowing for stronger variation in yearly catchability would effectively say that the data do not possess any information on abundance.

3 Albacore results

The fits to the CPUE data for the base-case (fixed q) and sensitivity (variable q with 10% CV) can be seen in Figure 5. As is clear from this figure the fit to the data does not drastically change with allowing for a time-varying catchability - they do improve but those high initial CPUE values and period lower values cannot be explained as just small changes in catchability. The more you relax the constraints on changes in q the better you fit the CPUE but you effectively lose any information on abundance. Figure 6 summarises the autocorrelation and distributional assumptions for the catchability variations with little evidence of non-lognormality but some evidence of significant lag 1 autocorrelation. It should be noted that the stock summary conclusions for this sensitivity are almost identical to the base-case.

Figure 7 shows the summary of the stock dynamics which shows biomass being predicted to be very close to B_{MSY} but with the current exploitation rate predicted to be above MSY, an indication of potential over-fishing. A summary of the (probabilistic) MSY rations can be found in Table 1 with the associated MSY plot summary in Figure 8.

4 Summary

Using the simplistic Pella-Tomlinson biomass-dynamic model we have presented a preliminary assessment of albacore in the Indian Ocean, using the Taiwanese CPUE (1980-2006) as the tuning index. Life-history methods are used to estimate Monte Carlo distributions for natural mortality and the intrinsic rate of increase, r. The base-case assumes a fixed catchability but we looked at allowing catchability to vary over time (with a 10% CV) but found that this sort of level of variation could not answer the observed trends in the CPUE series.

In terms of predicted stock-status the model predicted that the stock biomass was very close to MSY but that the current harvest rate was above the MSY level indicating that over-fishing may be occurring. The 2007 catch level (31,226 tonnes) was predicted to be above the MSY level (27,022 tonnes) with high probability. This assessment is very preliminary and it should be recommended that a more realistic fully age/length structured model be developed for the future to assess this stock.

5 Figures

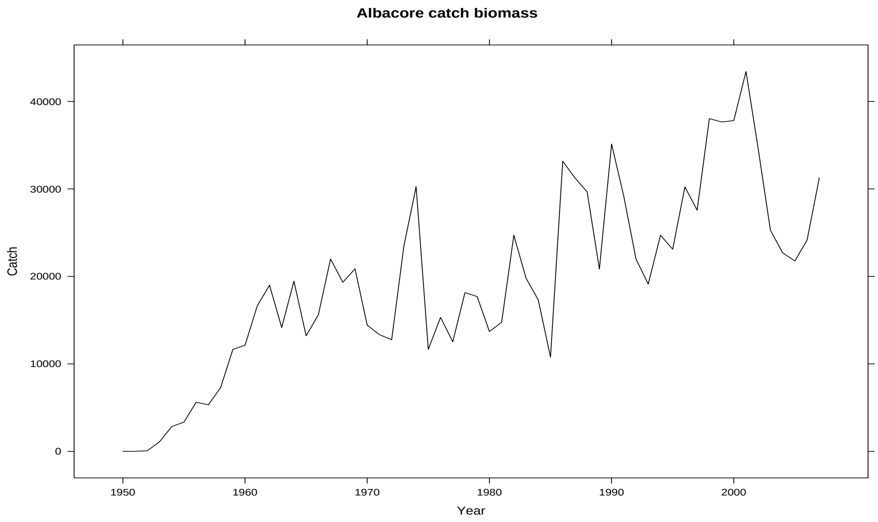

Figure 1: *Total catch tonnage for albacore in the Indian Ocean.*

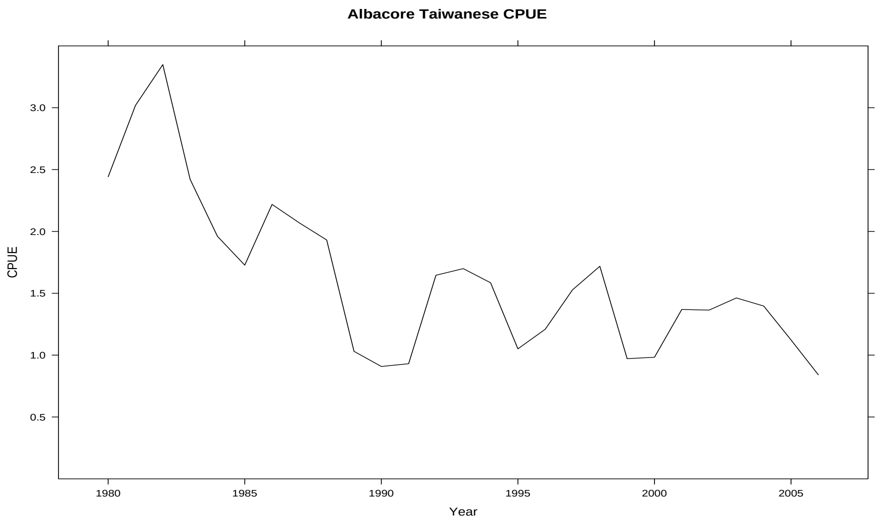

Figure 2: *Standardised Taiwanese albacore CPUE series.*

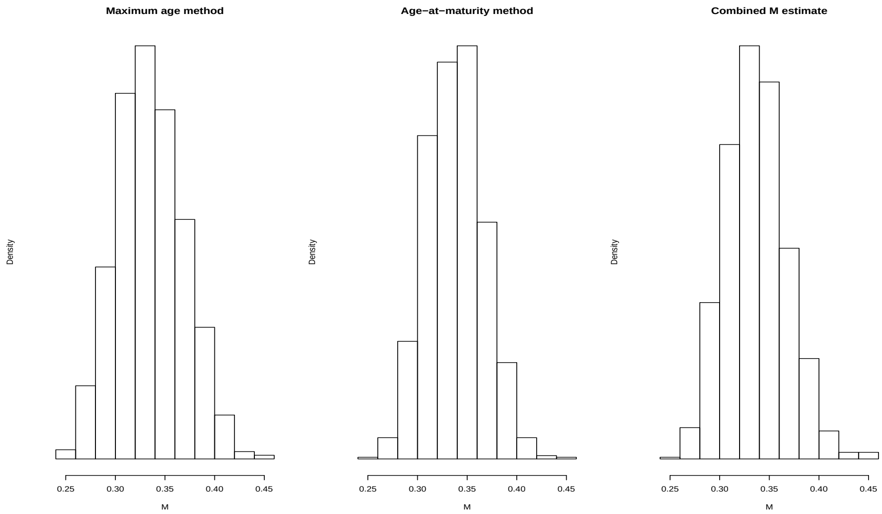

Figure 3: *Hewitt & Hoenig (left), Charnov (middle) and combined (right) estimates of M for Indian Ocean albacore.*

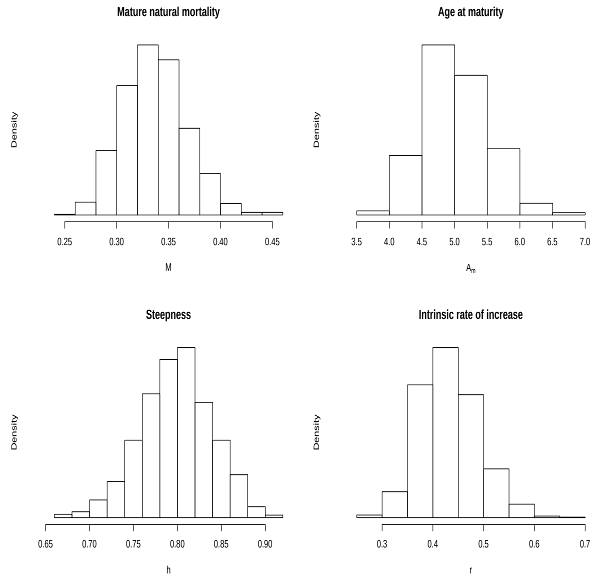

Figure 4: *Monte Carlo distributions for M, steepness and age-at-maturity used to define the distribution for the r (bottom right) parameter for albacore.*

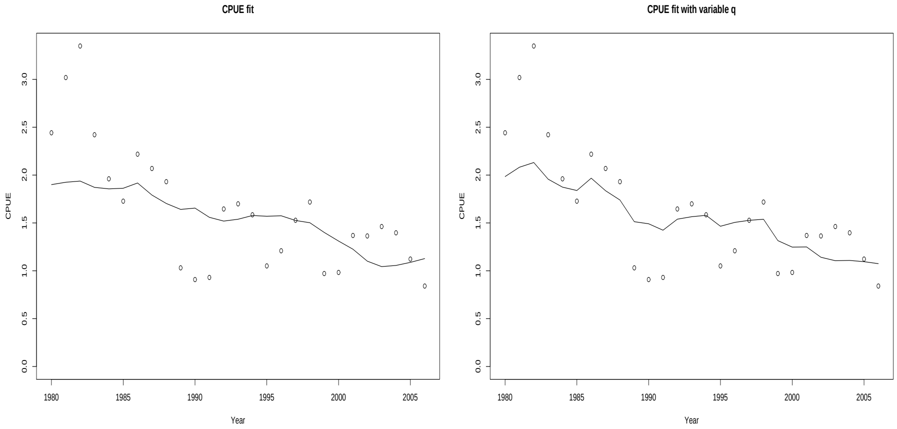

Figure 5: *Base-case (left, assuming a fixed catchability) and sensitivity (right, assuming a variable q with 10% CV) fits to the Taiwanese albacore CPUE series.*

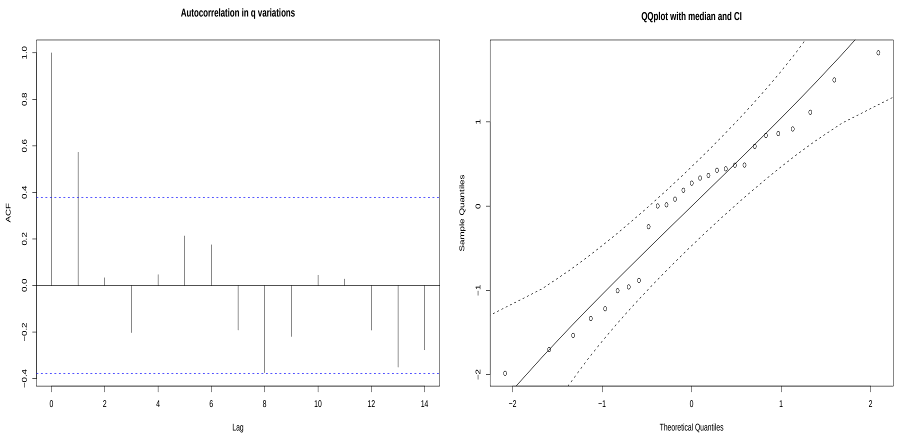

Figure 6: *Autocorrelation (left) QQ (right) plot (and approximate confidence intervals) for the log-deviations in catchability estimated for the sensitivity case.*

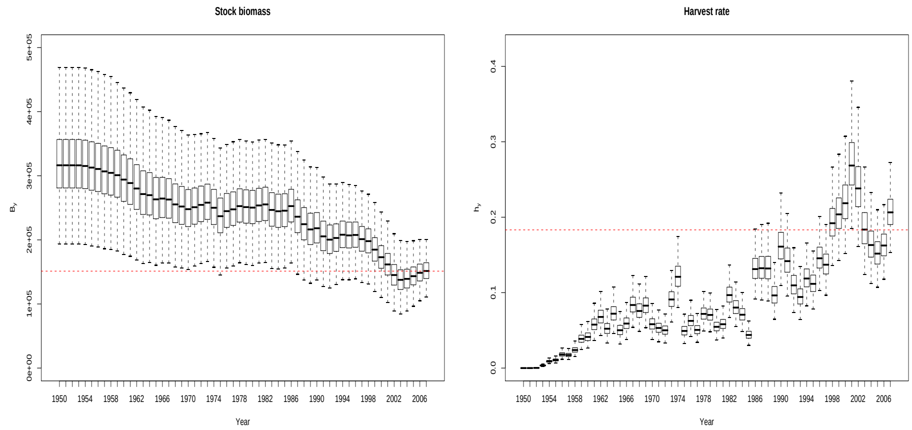

Figure 7: *Albacore stock biomass (left) and harvest rate (right) dynamics for the base-case (fixed catchability) run. The red line represents the expected MSY level.*

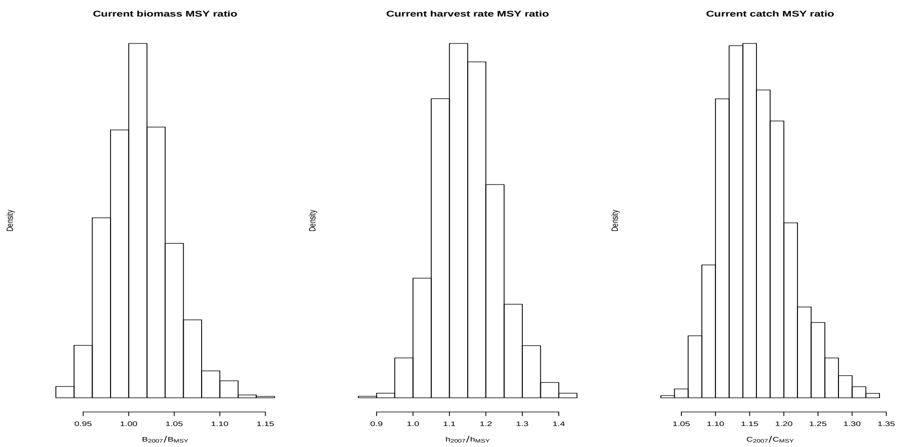

Figure 8: *MSY summary distributions for* B_{2007}/B_{MSY} *(left),* h_{2007}/h_{MSY} *(middle) and* C_{2007}/C_{MSY} *(right).*

Table 1: Albacore assessment summary table.

$p\left(B_{2007} < B_{MSY}\right)$	$p\left(h_{2007} < h_{MSY}\right)$	$p\left(C_{2007} < C_{MSY}\right)$
0.35	0.029	0