Exploratory assessment models for Indian Ocean Yellowfin tuna using a Bayesian Pella-Tomlinson framework

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1 Details

To assess the impact of using an alternative, non age-structured assessment model for the Indian Ocean yellowfin tuna catch and CPUE data, we implemented a Bayesian implementation of the Pella-Tomlinson production model, using the FLBayes package, found in the FLR software (Kell *et al.*, 2006). The main point of this document is to explore the very different stock scenarios that are apparent when using the Japanese or the Taiwanese CPUE data. An informative prior is developed for the intrinsic rate of increase, r, which is a key parameter in the Pella-Tomlinson model, yet is almost always very difficult, if not impossible, to estimate in conjunction with the carrying capacity, K.

Our implementation can be described as follows:

- We use the total catch (in tonnes) and the Japanese and Taiwanese LL CPUE series.
- We construct an informative prior for r, using biological data, as we have 'one way trip' data for both cases.

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Table 1: Table of parameter distributions used when estimating r.

Parameter	Distribution
Natural mortality (M)	Lognormal, mean 0.6, CV = 0.1
Steepness (h)	Uniform between 0.75 and 0.85
Age at maturity (A_m)	Uniform between 2.5 and 3.5

- The estimation scheme is Bayesian, using MCMC techniques, giving us uncertainty in both historical dynamics and MSY information.

1.1 Defining a prior for r

An informative prior for r can be estimated, given information on the likely distribution of the following vital rates: age at maturity, A_m, natural mortality on the mature ages, M, and the steepness, h. The following equation was derived by Myers *et al.* (1997) which is a reworking of the classical Euler-Lotka equation:

$$e^{rA_m} - e^{M} e^{r(A_m-1)} - \alpha = 0, \tag{1}$$

where α is the dimensionless slope of the stock-recruit curve (i.e. normalised by the SSB per unit recruit), and assuming a Beverton-Holt stock-recruit relationship, we have that

$$\alpha = \frac{4h}{1-h}. \tag{2}$$

Table 1.1 summarises the assumed distributions for the vital rates seen in Eqn. (1).

Using the *estrm()* function in the FLR::FLBayes package, we solve Eqn. (1) for r and we have that $E(r) = 0.85$ and that $CV(r) = 0.12$, so the vital rates assumed/estimated for this stock suggest a productive stock, which one might expect of a fast growing, early maturing species such as yellowfin.

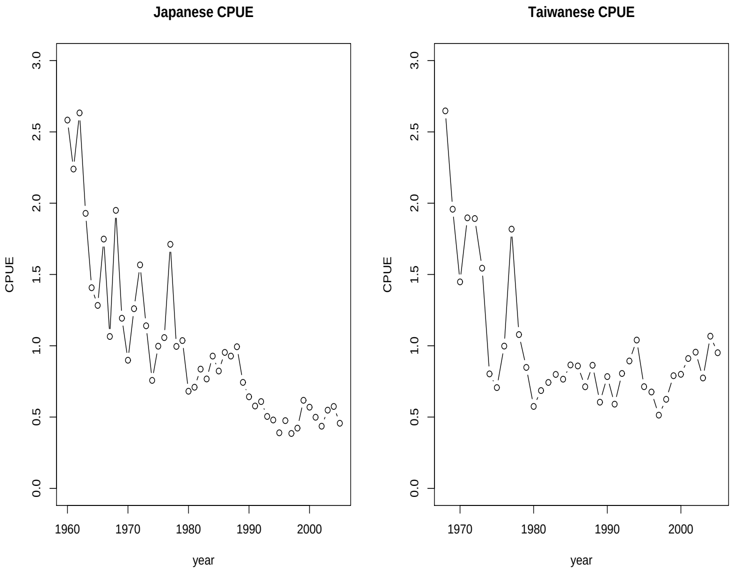

Figure 1: *Mean-standardised Japanese (left) and Taiwanese (right) long-line CPUE series.*

1.2 The two CPUE series

Figure 1 shows the two CPUE series (Japanese and Taiwanese long-line) used for tuning purposes as an index of exploitable abundance. The Japanese data appear to display a strong downward trend in abundance in the early years, followed by a slowing of this decreasing trend, as industrial fishing begins. The interpretation of this early trend is still an ongoing debate, and we will talk about how the model tries to interpret this trend later in the paper. The Taiwanese data shows a similar strong initial downward trend in CPUE over the 1970s, which subsequently levels out over the last twenty five years - this will be a key factor in the differences we see in the two CPUE assessment scenarios.

1.3 The scenario results

We will just call the results scenario results, not assessment results, for the remains of the paper, as we do not believe that this work has produced one reliable stock assessment run. Just for useful reference, here are the standard MSY equations for the standard Pella-Tomlinson model, in terms of the two main parameters, r and K:

$$B_{msy} = \frac{K}{2}, \tag{3}$$
$$C_{msy} = \frac{rK}{4}, \tag{4}$$
$$H_{msy} = \frac{r}{2}. \tag{5}$$

For both runs, the posterior distributions for both the catchability constant, $Q = q \times K$, and the carrying capacity, K, strongly update the prior distributions but, as is expected, the posterior distribution for r is virtually identical to the prior.

For the remains of this paper, the results are displayed in a comparative fashion, and in relation to the estimated distributions of the MSY parameters, (see Eqns. 3, 4 and 5). The reason for this is that we feel that it is the relative differences in stock status that the two CPUE scenarios display that is important, not necessarily the numbers themselves - these differences are obvious when we see the stock status predicted by the two scenarios. Figures 2, 3 & 4 shows the MSY ratios - biomass, catch and harvest rate, respectively - for the two CPUE scenarios.

One thing is clear when looking at Figures 2, 3 & 4 - depending on which CPUE series we use, we get a very different picture of stock status:

When using the Japanese CPUE data, the 2005 biomass is predicted to be well below B_{msy}, recent catches are well above C_{msy} and the current harvest rate is, on average, twice H_{msy}. When using the Taiwanese data, we see that the recent biomass is estimated to be comfortably above B_{msy}, even the recent record high catches are, on average, lower than C_{msy} and recent harvest rates are below H_{msy}. Table 1.3 displays the two perceptions of stock status in terms of the probabilities of being below (biomass) and above (catch and harvest rate) the MSY levels. This table serves to show even more clearly the different perceptions we have of stock status, using the two CPUE series. For the Japanese case, practically every alarm signal is triggered, we are, as of 2005, below (biomass) and above

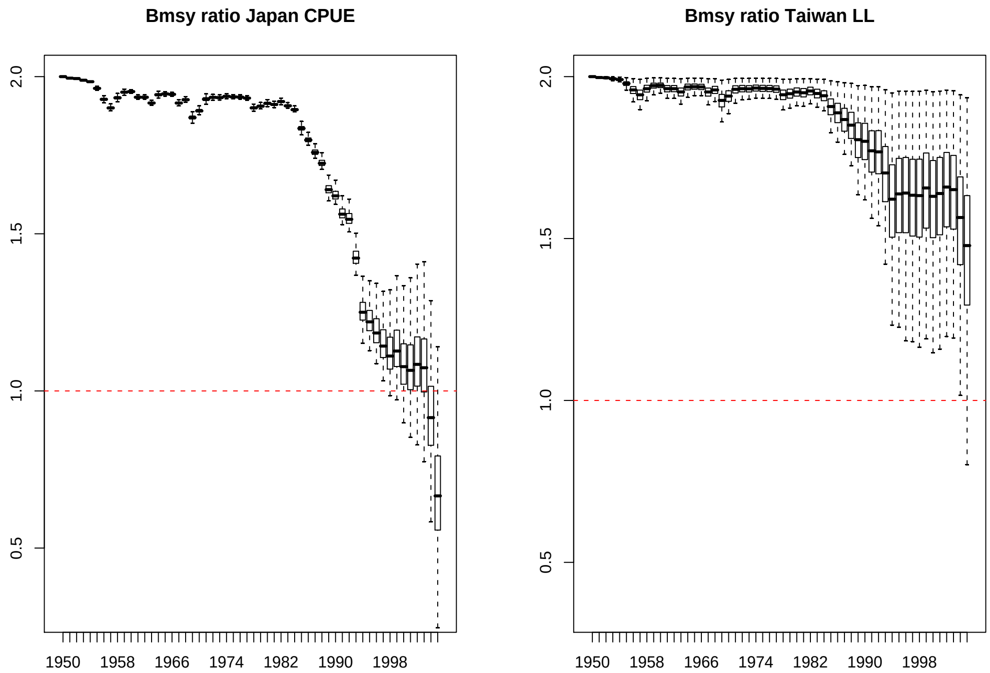

Figure 2: *Ratio of (exploitable) stock biomass to B_{msy}, when using the Japanese (left) and Taiwanese (right) CPUE series as abundance indices. The red line symbolises the level at which the ratio is equal to 1 - the stock is at B_{msy}.*

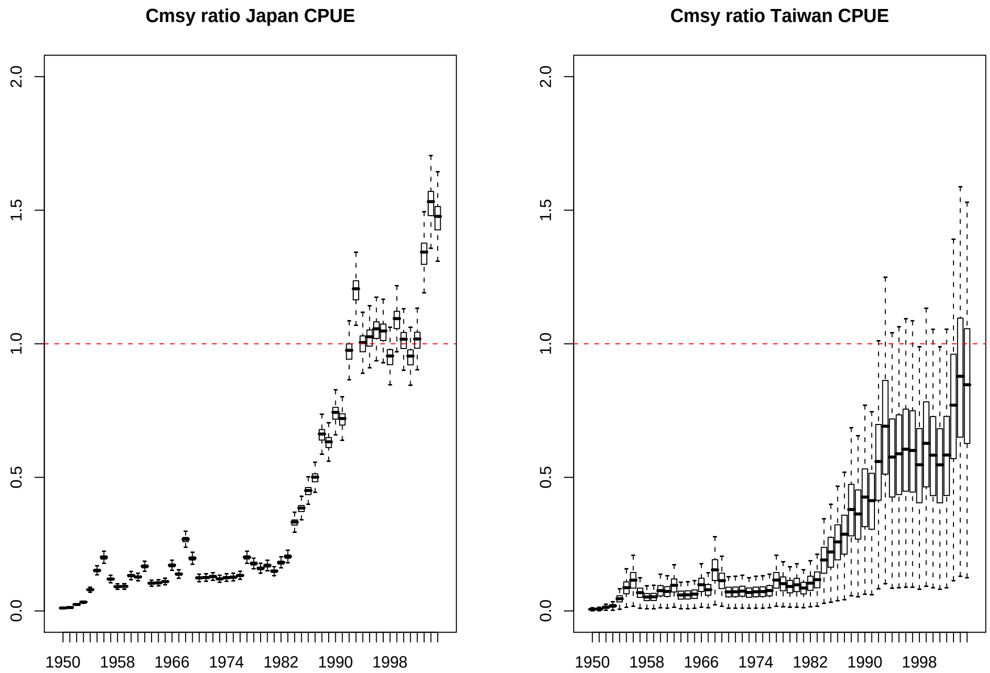

Figure 3: *Ratio of total catch biomass to C_{msy}, when using the Japanese (left) and Taiwanese (right) CPUE series as abundance indices. The red line symbolises the level at which the ratio is equal to 1 - the catch is at C_{msy}.*

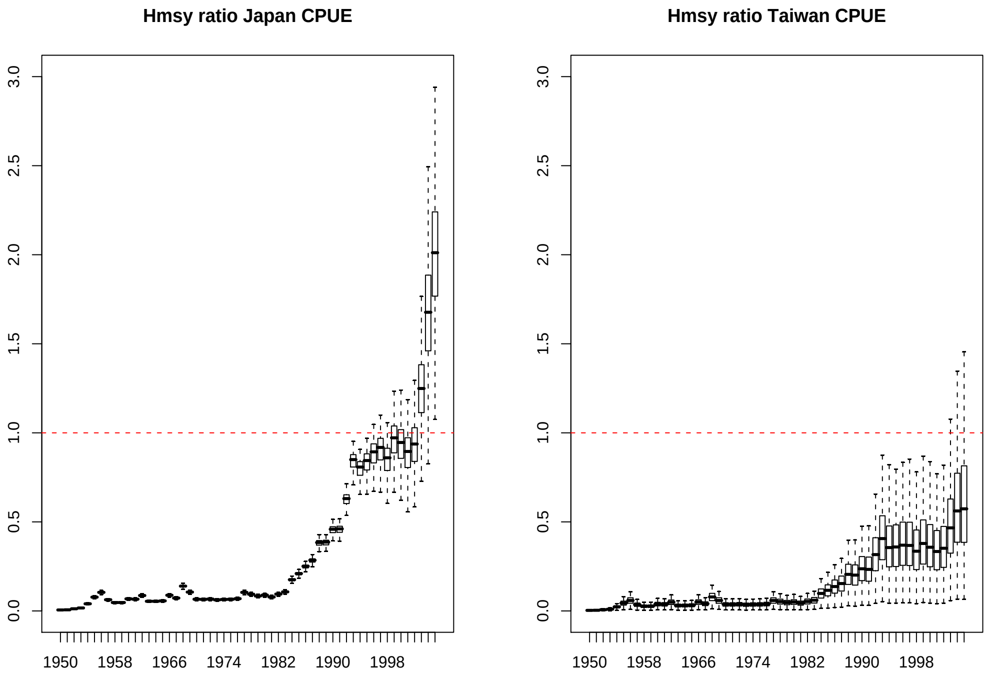

Figure 4: *Ratio of harvest rate to H_{msy}, when using the Japanese (left) and Taiwanese (right) CPUE series as abundance indices. The red line symbolises the level at which the ratio is equal to 1 - the harvest rate is at H_{msy}.*

(catch, harvest rate) MSY levels with probability greater than 0.95. For the Taiwanese case, in 2005 we are almost certainly above B_{msy}, and are below C_{msy} and H_{msy} with probability greater than 0.65.

Table 2: Table summarising the probabilistic state of the stocks as of 2005, relative to the estimated MSY parameters, for both the CPUE scenarios.

CPUE scenario	$p(B_{2005} < B_{msy})$	$p(C_{2005} > C_{msy})$	$p(H_{2005} > H_{msy})$
Japanese long-line	0.968	0.999	0.993
Taiwanese long-line	0.04	0.32	0.136

1.4 Why such a huge difference?

We must ask why we have such drastically different stock status predictions, and the answer is partly contained in how the model fits to the two data sets. Figure 5 shows the fits to the two CPUE series, in terms of the median and 95% probability intervals.

Concentrating on the fits to the Japanese data first (left-hand side of Figure 5), we see that the model essentially ignores the initial high CPUE points; it treats them as effective outliers, and fits reasonably well to the observed downward biomass trend seen in these data, when ignoring these large initial CPUE data. With regards to the fits to the Taiwanese data, these high initial CPUE points are not treated as outliers, more as highly uncertain data points in an abundance series displaying a largely stable temporal trend. In the Japanese case, given that we are effectively fixing our distribution of r, the only way to obtain the observed downward abundance trend is to estimate a "low", quite precise ($CV(K^{\mathrm{Jap}}) = 0.12$) distribution of carrying capacity; for the Taiwanese CPUE scenario, to obtain a reasonably stable biomass trend over the last 35 years and to fit the early high CPUE points, we estimate a "high", imprecise ($CV(K^{\mathrm{Tai}}) = 0.62$) distribution of carrying capacity. It is this which drives the differences seen in the two perceptions of stock status.

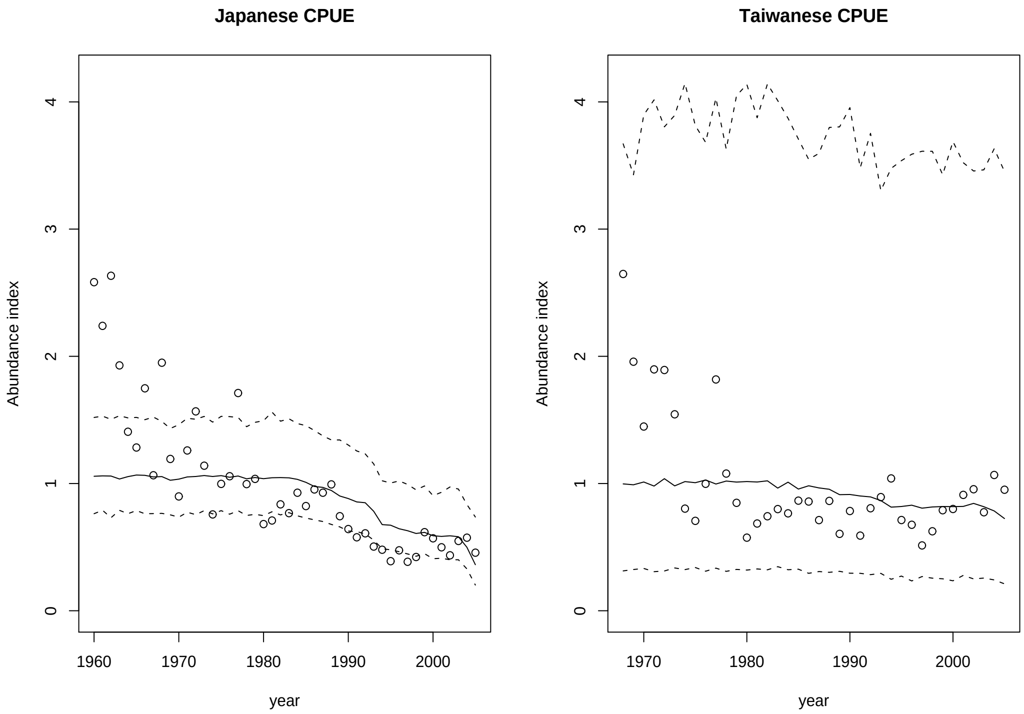

Figure 5: *Observed (points) versus predicted median (full line) and 95% probability interval (dotted lines) CPUE for the Japanese (left) and Taiwanese (right) scenarios.*

2 Summary

As already mentioned, we cannot make any claim as to which of these scenarios should be recommended as an assessment of the status of yellowfin tuna in the Indian Ocean. From our perspective, all these analyses show is that there is considerably different signals coming from the two long-line CPUE series, when fitting even a simple population model to them. It is not hard to see that, when moving to a more complex assessment model, such as those offered by the Stock Synthesis II or CASAL type packages, this situation will probably continue, and perhaps get even worse, as we are asking more detailed questions of the data in such a complex, age-length structured stock assessment.

References

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