Stock assessment of Indian Ocean yellowfin using a biomass production model

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Abstract

In 2018, a new stock assessment was carried out for yellowfin in the IOTC area using Stock Synthesis III (SS3), a fully integrated model that is used for the three tropical tuna stocks in the IOTC (bigeye, yellowfin and skipjack). However, the lack of understanding of stock dynamics due to various uncertainties led the IOTC's Scientific Committee (SC) to develop a workplan to address these uncertainties in 2019 before providing management advice. One of the items of this workplan is to characterize model uncertainty by using alternative stock assessment models. Here, we use a relatively simple biomass dynamic model that uses total catch and catch per unit of effort trends to estimate biomass and fishing mortality trajectories and to estimate fishery's reference points. The 2018 SC acknowledged that the uncertainties on this fishery need to be explored and characterized and we do this by generating nine alternative scenarios for this stock assessment. We explore uncertainty in catch, abundance indices, population dynamics and the searching space for parameter estimation. Our preliminary results estimate a range of very different stock status and productivity and, corroborate that the existing uncertainty on this fishery can lead to opposite stock status estimates. However, we propose a series of diagnostics to help deciding on a reference case, a group of reference models or on a number of factors to be included in a potential grid of reference models. These diagnostics suggest that modelling choices such as the constraints on the searching space of parameters, initial values of parameters and the shape of the production function would be more influential on the result of the assessment than choices on the available datasets. The available catch and CPUE series seem to be insufficient to produce stable and robust estimates of stock status and reference points. Therefore, none of the results shown here should be taken as valid estimates of stock status trajectories or productivity.

1. Introduction

In 2018, a new stock assessment was carried out for yellowfin in the IOTC area using Stock Synthesis III (SS3), a fully integrated model that is used for the three tropical tuna stocks in the IOTC (bigeye, yellowfin and skipjack). In 2018, the results of 24 scenarios were used to advice IOTC Commission on yellowfin stock status, which was considered overfished and subject to overfishing. However, the SC noted that the retrospective and hindcasting analysis suggested that the 2018 stock assessment model had poor predictive capacity, which led the SC not to provide specific catch limits advice. The lack of understanding of stock dynamics due to various uncertainties led the IOTC's Scientific Committee (SC) to develop a workplan to address these uncertainties in 2019 (IOTC, 2018a). One of the items of this workplan is to explore simpler models to characterize the dynamics of Indian Ocean yellowfin. Here, we use the biomass dynamic model *mpb (Kell, 2016)* to explore potential scenarios for a stock assessment, to produce diagnostics to evaluate each one of them. We also discuss the potential utility of simple models to evaluate complex fisheries like the IOTC yellowfin tuna.

2. Material and Methods

The data

In this study we have used the time series of total catch data made available by IOTC Secretariat (Figure 1) and two series of catch per unit of effort (CPUE) available for this stock assessment (Figure 2): (i) the joint longline CPUE index for the western tropical region (R2) for the period 1972-2018 (Hoyle et al., 2019) and the purse seine free school CPUE for the period 1991-2017.

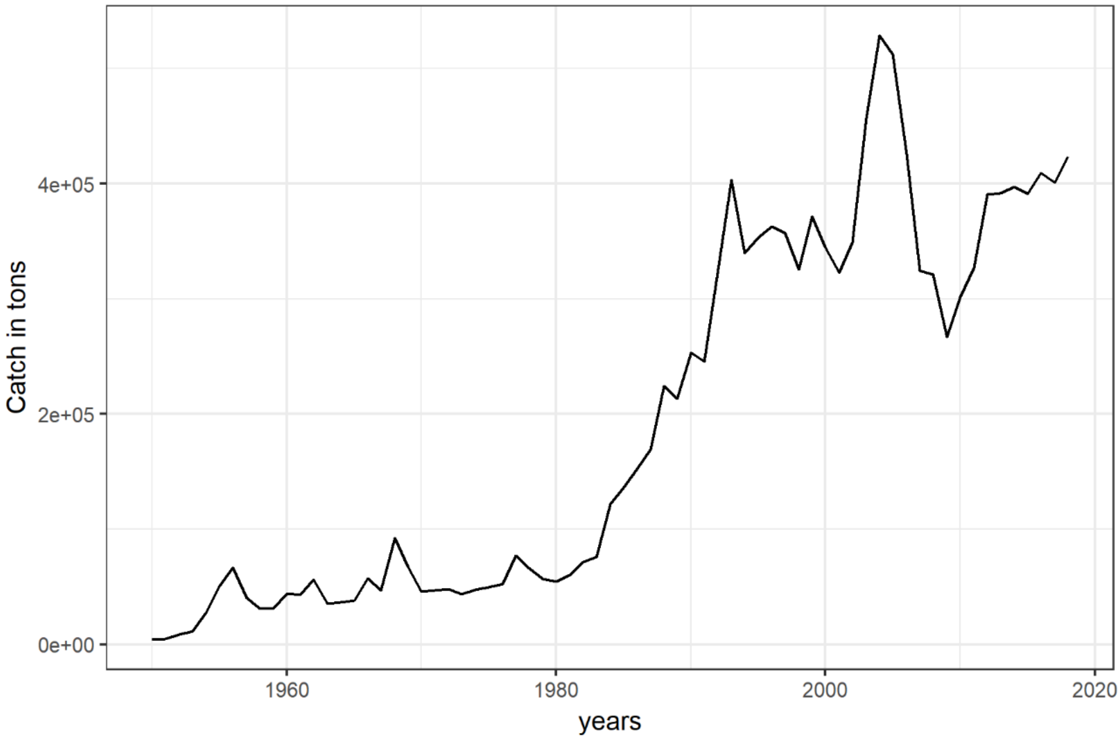


Figure 1. Yellowfin tuna historical catch used in this work.

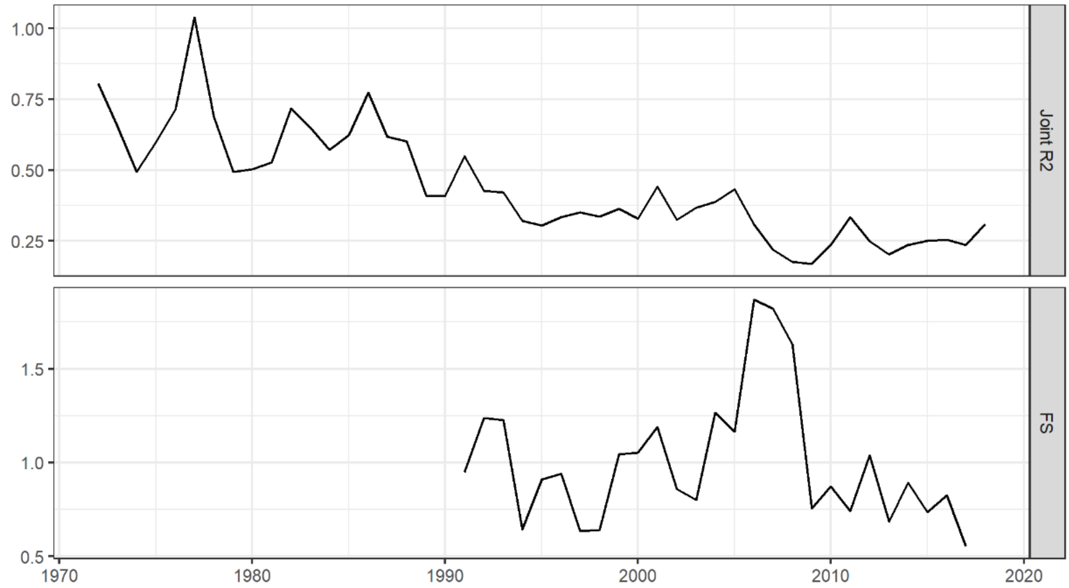


Figure 2. CPUEs for Joint longline in Region 2 (Joint R2) and free school CPUE (FS).

The two indices are almost uncorrelated (Figure 3), but if any, this correlation would be positive.

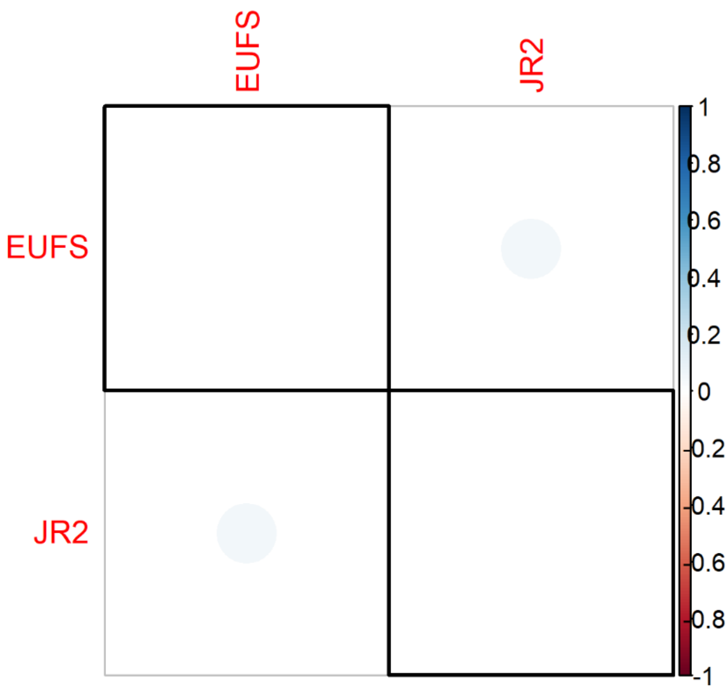


Figure 3. Correlation between the available Joint longline and purse seine free school indices.

The model

This stock assessment consists on fitting the available information to a biomass dynamic model. This is done using an R package for running and simulation-testing biomass-based stock assessment models, *mpb (Kell, 2016).* The package is part of FLR (Kell, Mosqueira et al. 2007), a suite of open source R packages that are extensible and able to interact with many R packages (see www.flr-project.org). The package has methods for plotting, examining goodness of fit, deriving quantities used to provide management advice, estimating uncertainly, and running projections.

Sceanarios

For the exploratory purpose of this study we develop nine different scenarios:

- Scenario 1) Total catch for the period 1950-2018 and Joint LL CPUE for R2 for the period 1972-2018 are fitted using Fox's model (Fox, 1970).
- Scenario 2) Idem to scenario 1 but with catch starting in 1972.
- Scenario 3) Idem to scenario 1 but Joint LL CPUE starting in 1979.
- Scenario 4) Idem to scenario 1 but purse seine free school CPUE added for the period (1991-2017)
- Scenario 5) Idem to scenario 4 but the two CPUEs cover different periods. The Joint index is used for the period 1972-2007 and the purse seine CPUE is used for 2008-2017.
- Scenario 6) Idem to scenario 6 but the purse seine CPUE is modified to consider a 1% annual increase in the catchability of this fleet.
- Scenario 7) Bounds are removed for the searching space of parameters.
- Scenario 8) Idem to 1 but with a logistic model (Schaefer, 1954).
- Scenario 9) The annual catch considered as *poor* and *very poor (IOTC, 2018b)* is inflated 50%.

Initial parameter values

The scenarios are fitted using the following starting parameters:

- r_init = 0.57 (value taken from www.FishBase.org for yellowfin).
- K_init = 3.834460 M tons (calculated as 20 x the average catch across the period).
- $B_{t=0}$ = 0.95 x K.

3. Results

The 9 fits to the scenarios converged and produced estimates of stock trajectory and fishing mortality (Figure 4).

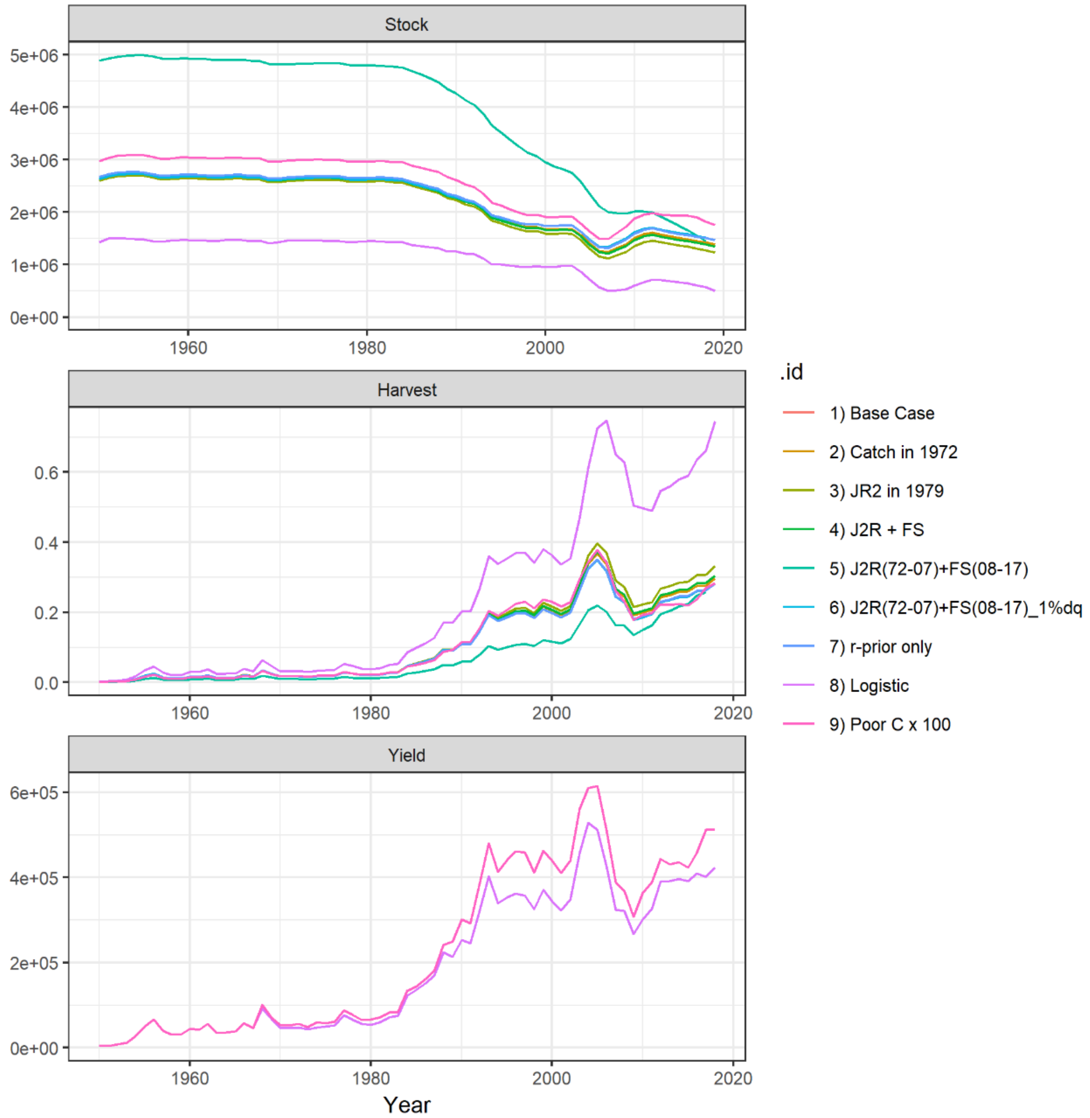


Figure 4. Fits to the 9 scenarios evaluated.

The analysis of the residual of fits suggests that the model has fitted data adequately (Figure 5). The upper panel shows the residuals for each scenario, which suggest that there is a similar number of positive and negative residuals. The middle panel shows the estimated fits to the used indices and the lower panel shows the distribution of residuals, which show a normal distribution of residuals.

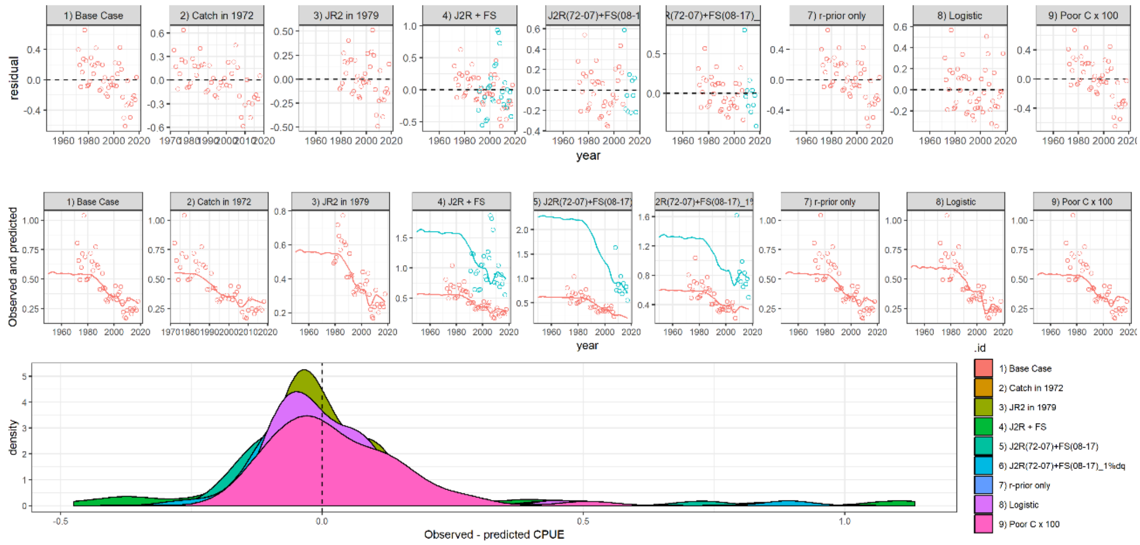


Figure 5. Plots of the residuals of fit for the 9 scenarios considered.

Figure 6 shows the bootstrapped fits to the scenarios and in some cases there are differences in the trajectories estimated on the deterministic fits and the resampled fits. Fits and median bootstrapped trajectories are almost identical for scenarios 1, 2, 4, 6, 7 and 9.

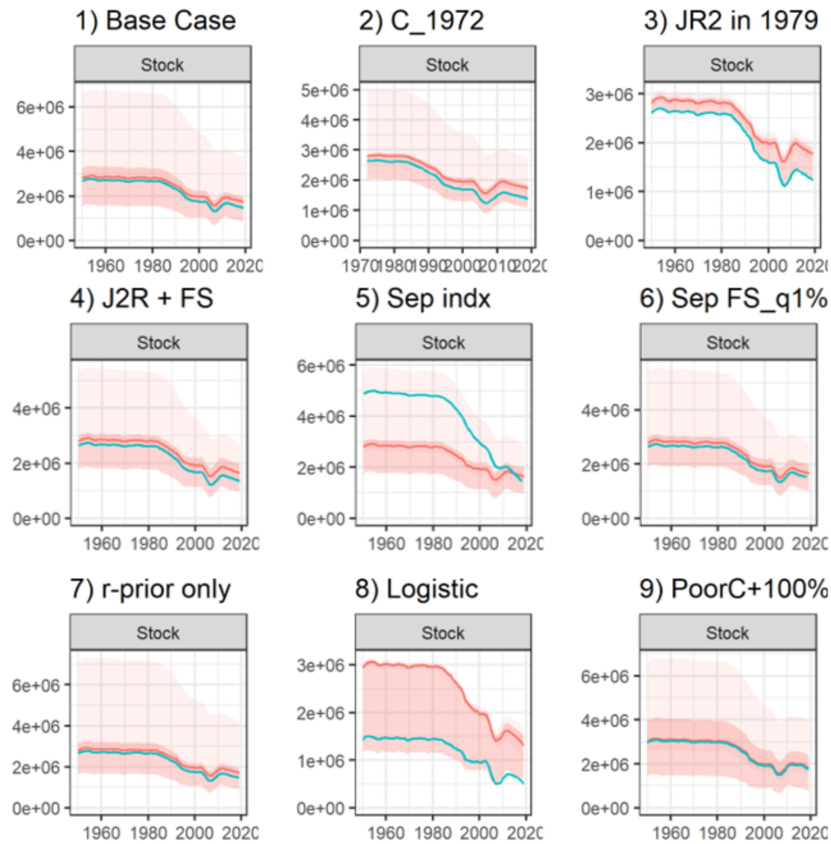


Figure 6. Deterministic (blue) and bootstrap fits (red) to the scenarios. The red line is the median trajectory, dark pink is the 25-75% quantiles and the pale pink represents the 95% fits.

Figures 7 shows the likelihood profiles of the intrinsic growth rate parameter (r) for the 9 scenarios. There is no single scenario where the value of the fit corresponds to the the minimum value of the likelihood function. In some scenarios the difference are smaller than others (i.e. scenario 6) but for others the fitted value is not nearby the lowest likelihood value. Also, this figure shows the differences between the estimated value of the parameter in deterministic fits (black dashed lines) and the mean value from the bootstrapped fits (blue dashed line). In some cases these are very similar (scenario 2, 6, 7) while for others they are very different (scenario 5, 8, 9).

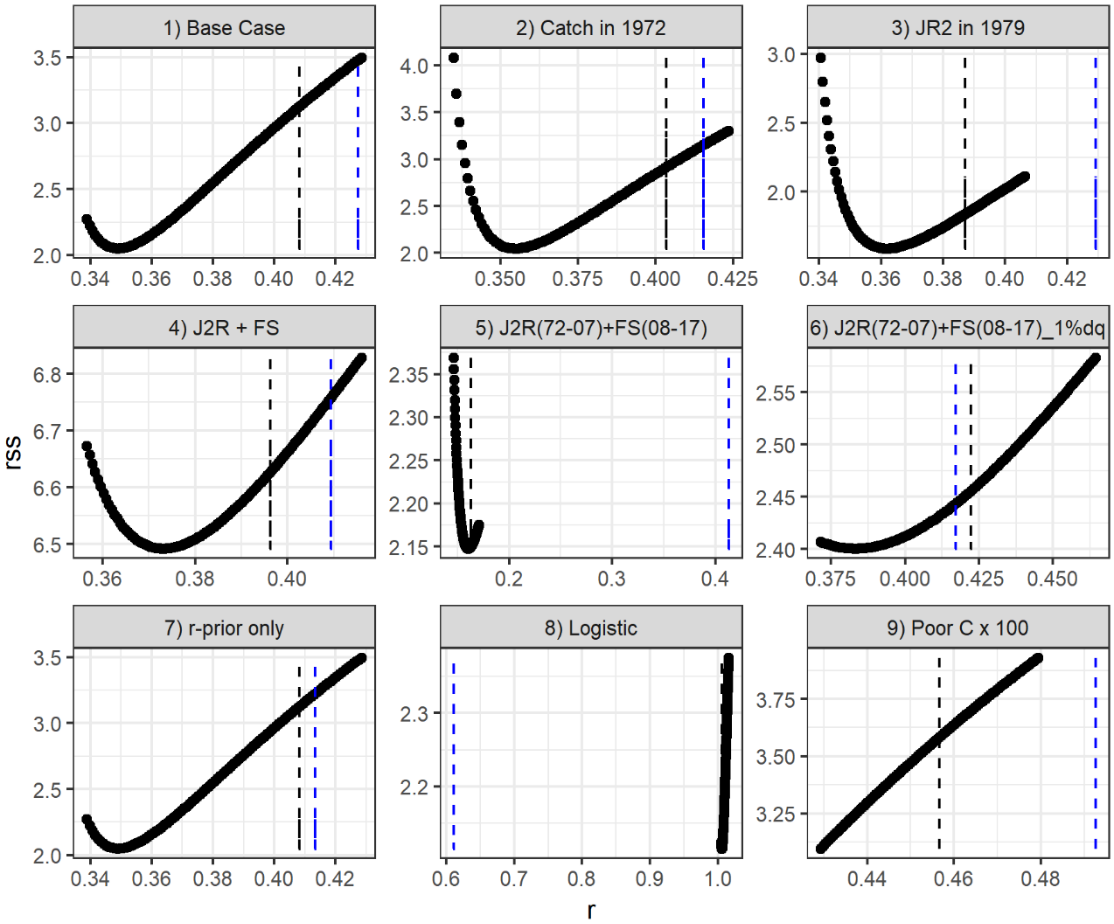


Figure 7. Likelihood profiles of intrinsic growth rate compared to values obtained from fits (black dashed line) and mean value from bootstraps (dashed blue).

Figure 8 shows the likelihood of r and carrying capacity (k) combinations. These parameters are inversely correlated in biomass production functions and this is shown in this figure. From the scenarios, some seem to produce unstable correlations but for scenario 6, the correlation between the two estimated parameters is almost perfect across the explored space of values.

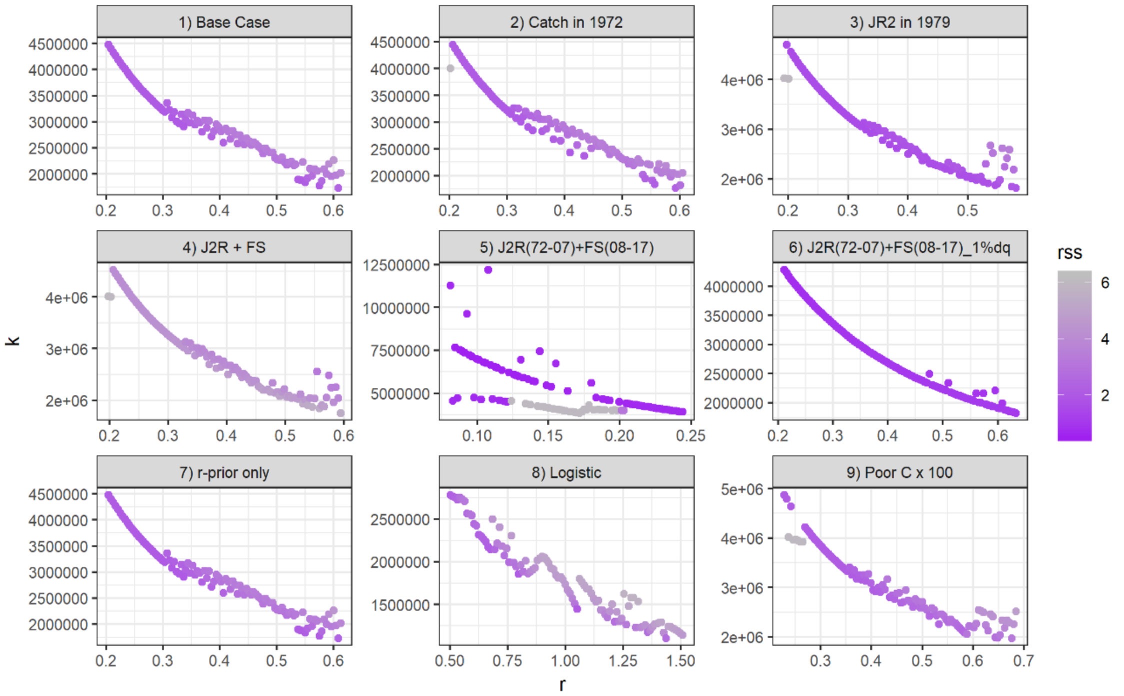


Figure 9 shows a Jackknife analysis for the nine scenarios. For this test one point of the CPUE series is removed a time and we show how the deterministic estimate would change in relation to MSY and to the relative biomass in 2018 without those points. For scenarios 1,2,3,7,8 and 9 the analysis is carried out over the Joint LL index while for the scenarios 6,7 and 8, the analysis is done for the purse seine free CPUE. This figure suggests that none of the scenarios is particularly robust. For example, scenario 1 shows that the fits are sensitive to each individual point of the recent period and that if these would be removed the relative biomass and estimated productivity would be lower than in the fit to the entire series. In general, removing one data produces lower estimates of biomass and MSY in scenarios 1,2,3,7 and 9 and higher estimates for the scenarios using purse seine CPUE and scenario 8 (biomass). The scenario that uses both indices seems particularly sensitive to each point of the CPUE index.

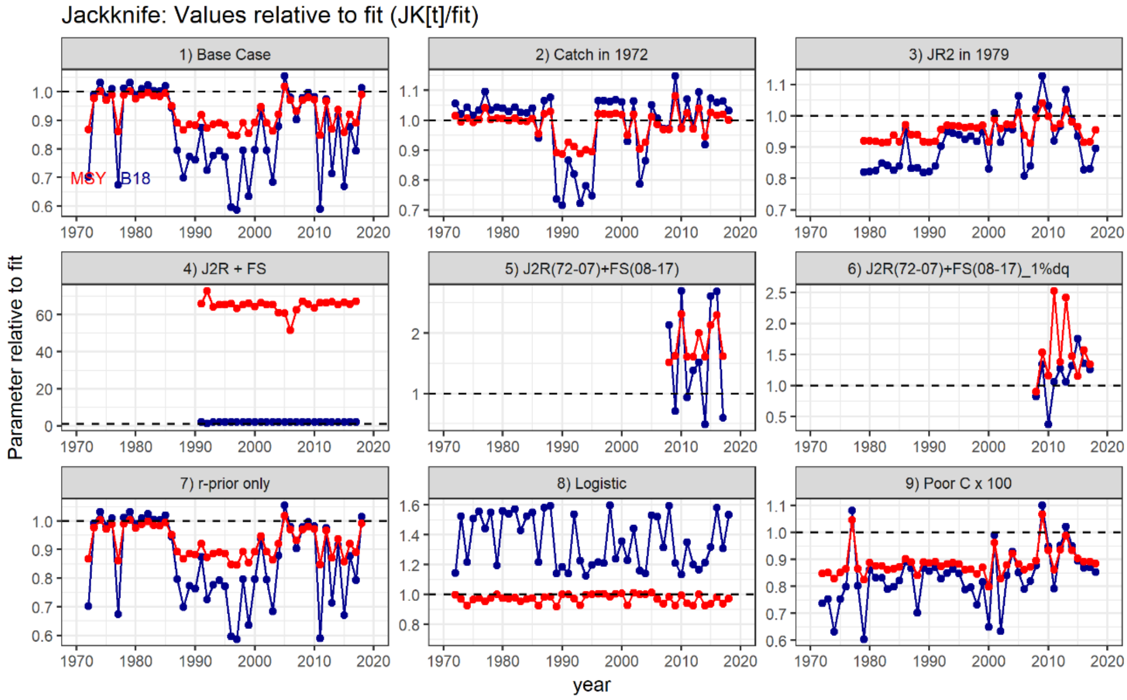


Figure 8. Jackknife analysis on the nine scenarios. Red points are estimated MSY and blue points are biomass estimate in 2018.

The last diagnostics shown here are the retrospective fits Figure 9. This figure shows the estimated total biomass trajectories for the nine scenarios by removing the most recent data (1yr, 3yrs, 5yrs, 7yrs and 10yrs). Overall, the scenarios are not able to produce consistent results when removing the most recent data.

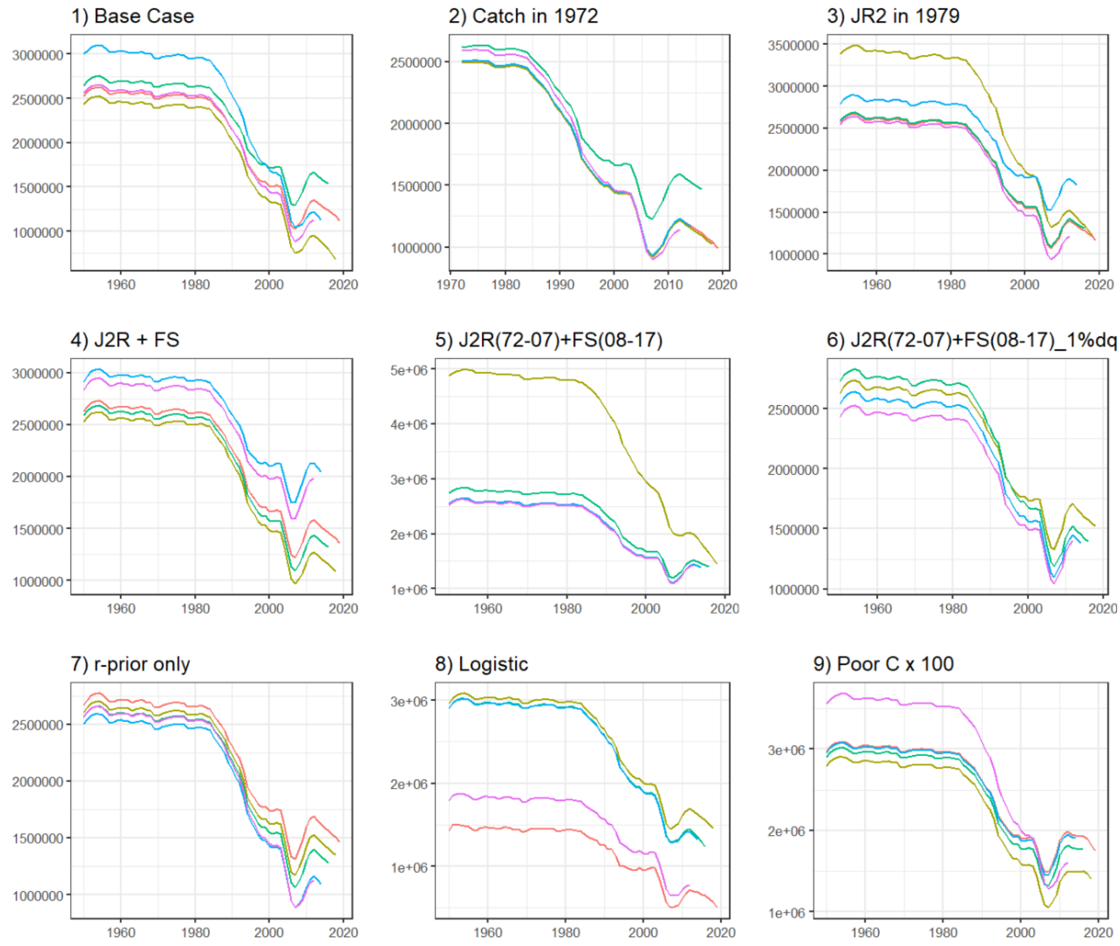
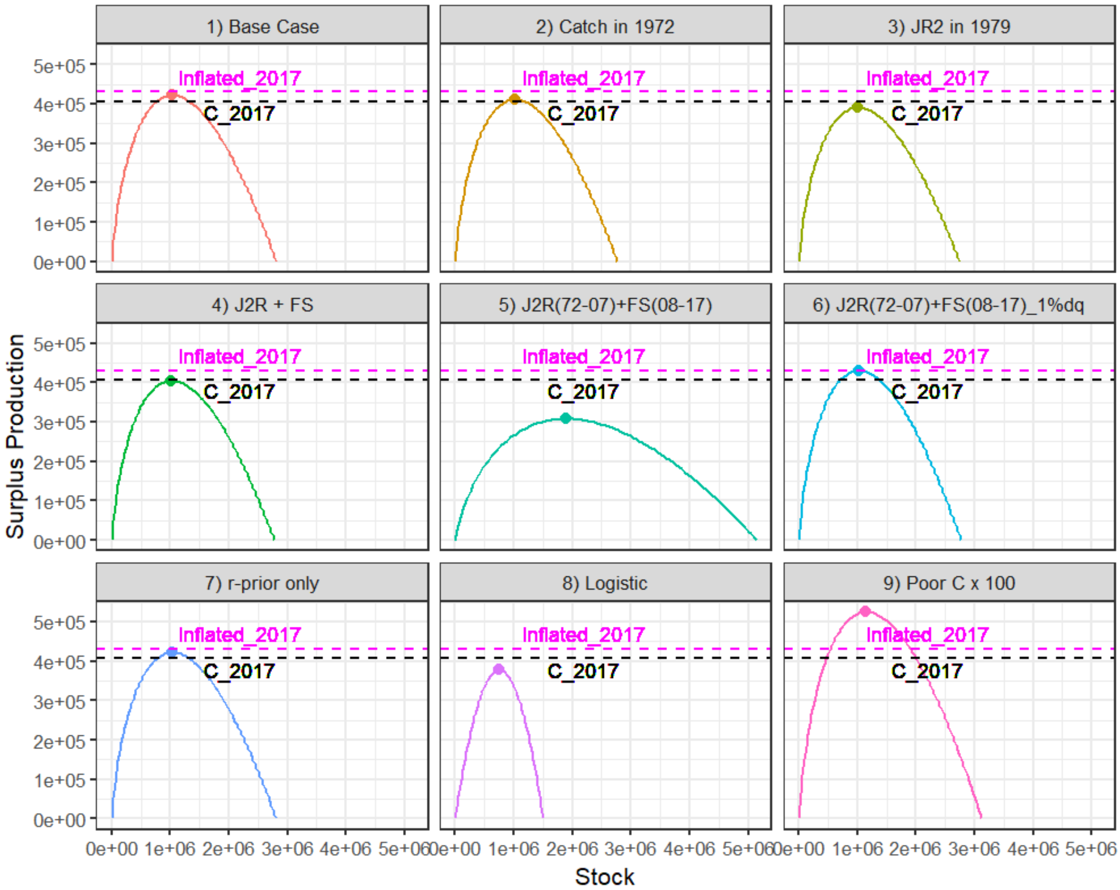


Figure 9. Estimates of total biomass trajectories for retrospective scenarios.

The value of this study is not the result of the assessment but to identify plausible scenarios for more complex models. For this reason the estimated relative trajectories for the different scenarios are not shown here.

Figure 10 shows the estimated production functions for the nine scenarios and the catch data for 2018 (and inflated estimate). Overall, most of the scenarios estimate that current catch is nearby yellowfin's MSY. These production functions are calculated from deterministic fits to the scenarios.



Discussion

Biomass production models cannot account for the changes in selectivity that have occurred in tropical tunas recently. Therefore, these types of models are not the most adequate tool to produce scientific advice on stock status and productivity. In this study, we use the model *mpb* to evaluate the quality of the fits of catch and CPUE data under several modelling assumptions. Overall, it seems that the model gets information on the biomass trends from CPUE but it is unable to estimate robust and consistent estimates of stock trajectory and productivity. This may be because the declining trend in the CPUE is relatively constant and there is not enough information to estimate productivity adequately. The predicted trends of biomass appear to mirror relatively well the trajectories of the CPUE, but these are relatively constant (declining) through the time series. The CPUEs do not change direction across the time series and it seems that this makes the model to find fits nearby the starting values for r and k. Productivity estimates seem to be driven by the most recent catch. Changes in the initial values of the parameters of interest and model configurations can produce large differences in estimates and therefore, the model configurations explored here are not robust and consistent and therefore, caution should be taken when looking at this analysis. <u>None of the results shown here should be taken as valid estimates of stock status trajectories or productivity.</u> The potential implications of this analysis on the configuration of more complex models for the 2019 stock assessment of Indian Ocean yellowfin will be discussed in the 2019 Working Party of Tropical Tunas.

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