INDIAN OCEAN YELLOWFIN TUNA SS3 MODEL PROJECTIONS

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Executive Summary

This document presents the projections and Kobe II Strategy Matrix (K2SM) for the 2021 Indian Ocean yellowfin Stock Synthesis assessment model. Deterministic projections for 2021-2030 were conducted for the 96 reference grid scenarios assuming a constant level of catch at 60%-120% of the 2020 catch. The projections incorporate the range of uncertainty among alternative model structures but do not describe uncertainty due to parameter estimation error or stochastic future recruitment variability.

The present projections incorporate an explicit recruitment bias adjustment to avoid the likely overly optimistic results as identified by the Working Party on Tropical Tunas during the 23rd WPTT Stock Assessment meeting (WPTT, 2021, paragraph 125), if no explicit bias adjustment controls are used in the forecast. Also, as requested at the WPTT 23rd Stock Assessment meeting, we examine a reference model with and without bias correction to see how different the output projections are. It is important to note the importance of adjusting bias correctly in this and other stocks where projections are used to develop management advice.

1. Introduction

At the 23rd IOTC Working Party on Tropical tuna (WPTT), a preliminary stock assessment for yellowfin tuna (Thunnus albacares) in the Indian Ocean was presented (Fu et al, 2021). The assessment was implemented using the Stock Synthesis software with the inclusion of fishery data up to 2020 (final model year). The WPTT agreed to adopt a reference grid of 96 models to capture major sources of uncertainty and to assist the formulation of help formulate management advice (IOTC–WPTT23 2021). The model grid incorporated alternative spatial configurations (2), levels of steepness (3), hypotheses on catchability (2), growth (2) and natural mortality (2), and tag data weighting (2). The overall stock status is estimated to be overfished (average SSB/SSBmsy=0.78) and subject to overfishing (F/Fmsy=1.27).

During the meeting, the WPTT noted that there was an issue with the configuration of the projections that would cause them to be overly optimistic. It was noted that this issue was occurring because default bias adjustment controls were incorporated into the model which resulted in too much bias adjustment being applied to the forecasts. Also, the WPTT suggested examining a single run from the reference model without bias correction to see how different the output projections were.

Subsequently, the WPTT noted that the SS3 projections would be conducted intersessionally including the bias adjustment to develop the K2SM from the final SS3 model grid to provide management advice.

In this document we first show the projections from a reference case (*io_h80_q1_Gbase_Mbase_tlambda1*) to demonstrate that the previous configuration needed to be adjusted. Second, we show the results of the final projections with the K2SM.

2. Methods

Recruitment bias adjustment

The initial model configuration overlooked an important aspect of the spawner-recruit configuration. The models were run with the SS3.30 configured so as not to use the advanced recruitment deviation settings. These settings are designed to optimize the bias adjustment, which determines the difference between recruitment during the model fit and the forecast. The resultant change in mean recruitment was noticeable because the full (default) adjustment during the time series was too large (Figures 1 and 2), causing the model to produce more recruits in the forecast than were estimated during the model fit to data. This likely produces an overly optimistic trend in biomass during the projection period.

The function '*SS_fitbiasramp()*' from the *r4ss* library was run on the output from the converged reference model, to generate recommended settings for the bias adjustment ramp. All of these settings were used in the corrected configuration of the projections (Figure 3 and 4).

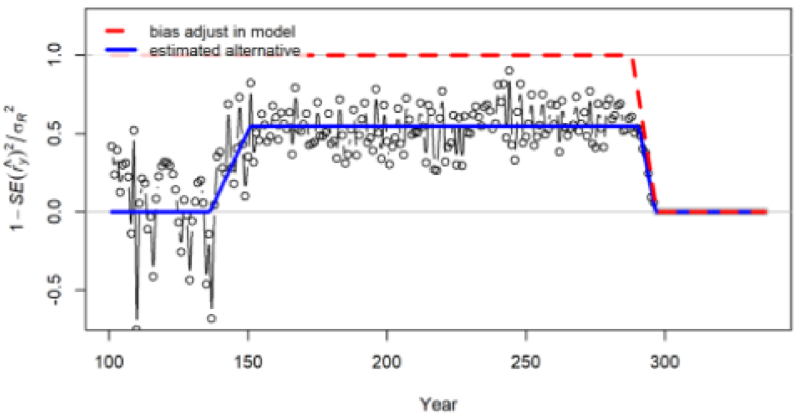

Figure 1. Red line shows the original settings for lognormal bias adjustment in recruitment deviations. The red line shows the default bias adjustment originally applied, while the blue line shows the appropriate level of bias adjustment, as estimated by r4ss. The difference between the red and blue trajectories explains the jump at the beginning of the projection period (Year 298) based on the default assumption about lognormal recruitment bias. At this point, the bias is removed and the projections are made with more recruits than were estimated during the model fit.

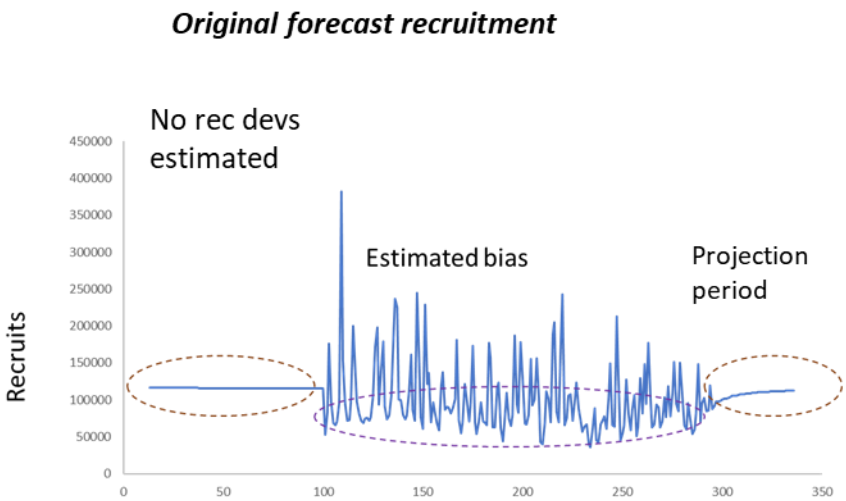

Figure 2. Recruitments in the three model periods. The model estimates recruitments during the model fit period, which are then used to estimate the appropriate level of lognormal bias adjustment. Bias adjustment is not applied in the forecast period.

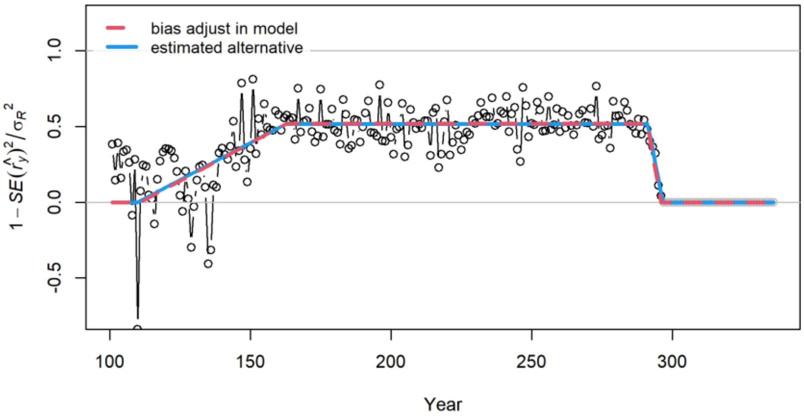

Figure 3. Estimated bias and adjustment in the model. In the corrected bias adjustment model, the bias adjust and the estimated bias are consistent.

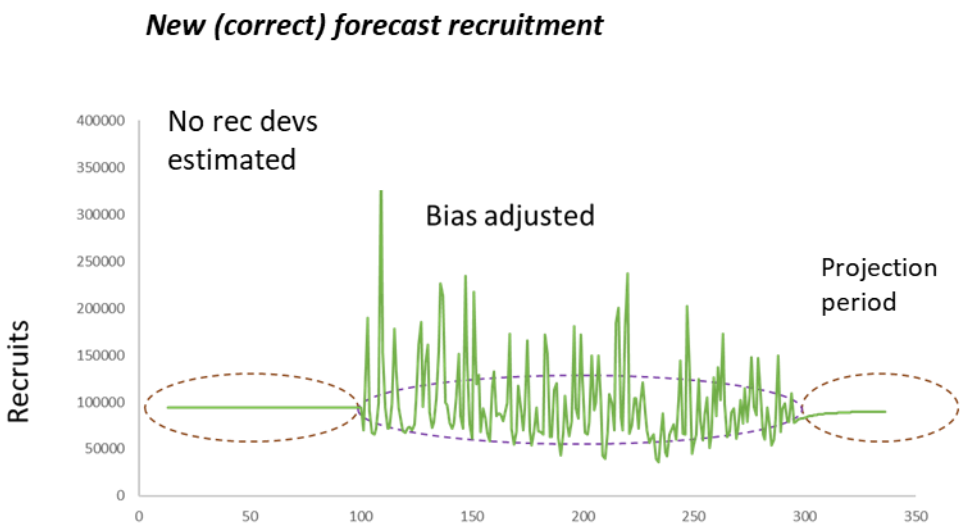

Figure 4. In the bias adjusted (corrected) forecast configuration there is no bias of recruitment across periods (fit and forecast).

In order to visualize the impact of the bias adjustment a projection was run with a selected reference model io_h80_q1_Gbase_Mbase_tlambda1 with current catch (100%). Figure 5 shows that when the original model configuration was projected forward, despite Fcurrent being greater than Fmsy, the stock would start to recover with current catch due to larger than average recruitments. In contrast, when the bias is adjusted, current catches would exacerbate stock decline as expected.

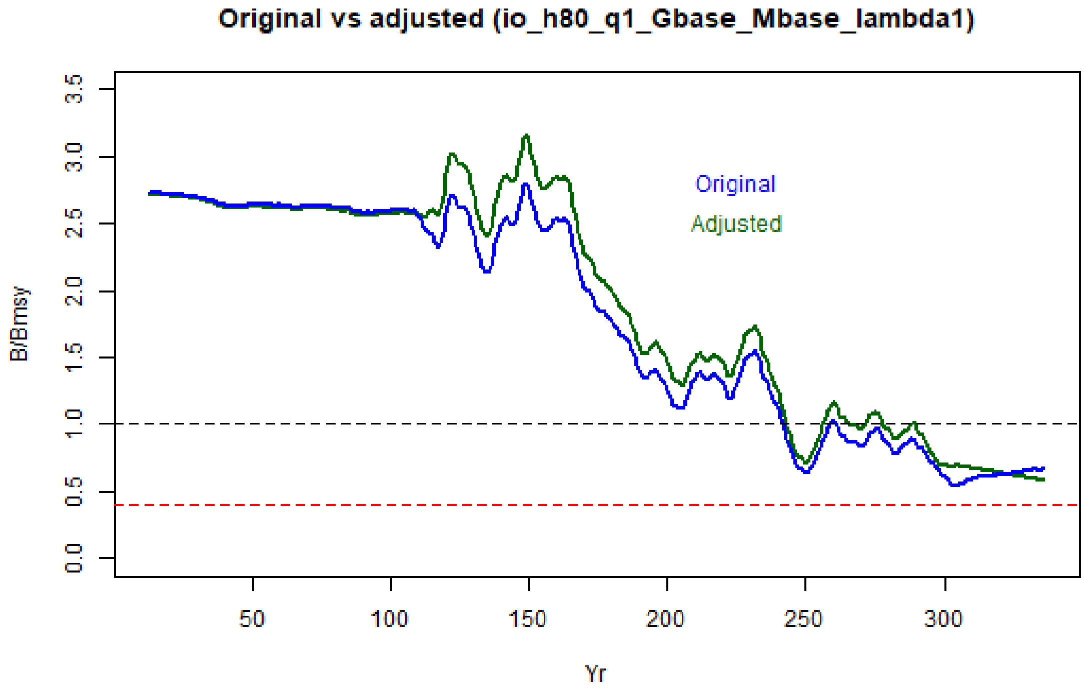

Figure 5. Comparison of relative biomass projections of current catch with bias correction (green) and bias not adjusted (blue).

Projections set-up

Projections were conducted for a 10-year period (2021–2030) from the Maximum Posterior Density (MPD) estimates of all grid models at a constant level of catch as a multiple of the fishery catches in 2020. Seven levels of catch were investigated representing 60% to 120% of the 2020 catch level (in increments of 10%). The catch allocations among fisheries were based on the catch shares in 2020 amongst fleets defined in the SS3 model. The projections used deterministic recruitment from the stock recruitment relationship. The Kobe2 Strategy Matrix probabilities were calculated from the 96 reference grid scenarios. The projections were summarized as a weighted average of results that describe the proportion of scenarios in which the spawning stock biomass falls below the target and limit reference points (SSB_{MSY} and $0.4xSSB_{MSY}$ respectively), and the fishing mortality exceeds the target and limit reference points (F_{MSY} and $1.4F_{MSY}$).

3. Results and discussion

The results of projections of the 96 grid SS3.30 models are provided in the form of probabilities that $F > F_{MSY}$, $SSB < SSB_{MSY}$ and $F > F_{Lim}$, $SSB < SSB_{Lim}$ in a K2SM framework (Table 1). The projections indicate the levels of catch and their associated probability for the stock to be overfished (B<Bmsy), subject to overfishing (F>Fmsy) and the probability of violating limit reference points (B<Blim and F>Flim) in 2023 and 2030 (Table 1).

TABLE 1. Yellowfin tuna: Stock synthesis assessment Kobe II Strategy Matrix. Probability (percentage) of violating the MSY-based target (top) and limit (bottom) reference points for constant catch projections (relative to the catch level from 2020 -40%, - 30%, -20%, -15%, -10%, ± 10%, +20%) projected for 3 and 10 years.

Alternative catch projections (relative to the catch level from 2020) and probability (%) of violating MSY-based target reference points ($B_{targ} = B_{MSY}$; $F_{targ} = F_{MSY}$)							
Reference point and projection timeframe	60%	70%	80%	90%	100%	110%	120%
$B_{2023} < B_{MSY}$	0.45	0.56	0.68	0.74	0.76	0.82	0.88
$F_{2023} > F_{MSY}$	0.13	0.30	0.53	0.63	0.72	0.82	0.91
$B_{2030} < B_{MSY}$	0.1	0.33	0.54	0.76	0.93	0.99	1
$F_{2030} > F_{MSY}$	0.07	0.31	0.49	0.69	0.84	0.97	0.99
Alternative catch projections (relative to the catch level from 2020) and probability (%) of violating MSY-based limit reference points ($B_{lim} = 0.4\ B_{MSY}$; $F_{Lim} = 1.4\ F_{MSY}$)							
Reference point and projection timeframe	60%	70%	80%	90%	100%	110%	120%
$B_{2023} < B_{Lim}$	0	0	0	0.05	0.07	0.1	0.16
$F_{2023} > F_{Lim}$	0.03	0.11	0.25	0.43	0.52	0.63	0.78
$B_{2030} < B_{Lim}$	0	0	0.01	0.18	0.64	1	1
$F_{2030} > F_{Lim}$	0.02	0.19	0.33	0.60	0.78	0.98	0.98

According to the K2SM the stock would only recover to levels above Bmsy by 2023 if catches are reduced 40% from current levels. In order to recover the stock to levels above Bmsy by 2030 with 50% probability or more, current catch would need to be reduced by more than 20%. In order to reduce overfishing (F<Fmsy) by 2023, levels would need to reduce more than 20% from current levels and to achieve this by 2030, catches would need to reduce by 20%. The probability of breaching the biological limit reference point with current catches is 7% by 2023 and 64% by 2030. The probability of breaching the F limit reference point with current catch is 52% by 2023 and 78% by 2030.