

Assessment of Indian Ocean yellowfin (*Thunnus albacares*) using a biomass dynamic model

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Abstract

In the 17th session of the Indian Ocean Tuna Commission's (IOTC) Working Party on Tropical Tunas (WPTT), the stock status of yellowfin was estimated to be in the red area of the Kobe diagram with 94% probability. As a consequence, on its 20th session (S20), the IOTC Commission adopted an interim plan for rebuilding this stock (Res 16/01) introducing a scheme for a reduction of catches and requested its Scientific Committee (SC) via the WPTT to conduct a new assessment of the status of yellowfin in 2016, using all available information. In 2015, the stock status was provided using Stock Synthesis (SS3), an integrated age structured statistical model, and in 2016 it is expected to be assessed again by SS3. In this paper we present a stock assessment for Indian Ocean yellowfin using a biomass dynamic model and four modelling scenarios that aim at supporting the work of the WPTT. Overall, using the new information made available by the Secretariat with the four scenarios, we estimate that the stock is overfished and undergoing overexploitation with a 50% of probability, notably in a better condition than in the estimation from 2015 WPTT. However, significant differences are found between logistic and skewed production functions and with the inclusion/exclusion of data prior to 1970. We present a full set of diagnostics for each run, including residuals, retrospective analyses, bootstrapped and jackknife estimates and likelihood profiles, in order to facilitate the selection of modelling choices. Such diagnostics can be applied to a wide variety of models. We also present the results of catch projections and their impact through Kobe 2 Strategy Matrices (K2SM). According to these, catches would need to be below 330,000 tons (19% less than in 2015) so that the stock is at levels equal or above B_{MSY} with 50% of probability in 2020. Finally, we show the results of projections with alternative Harvest Control Rules through K2SM and catch matrices.

Introduction

In 2015, the three stock assessment models used to estimate the stock status of yellowfin tuna yielded similar results, i.e. it was estimated that the stock was overexploited and undergoing overexploitation with very high probability. Therefore, the WPTT recommended a notable reduction of catches (IOTC, 2015), which was adopted in the 20th session of the IOTC Commission meeting (IOTC, 2016). Among other measures, an overall reduction of ~10% from 2014 catch (estimated at 430,327 t) was adopted to be distributed among the different fleets exploiting this stock. In addition, the Commission requested the SC and WPTT to conduct a new stock assessment of the status of the yellowfin stock using all available information in 2016. The new information available for stock assessment is a reviewed series of catch statistics and six CPUE series made available by IOTC Secretariat. How this new information may change the estimation of the overview of yellowfin using SS3 is yet to be assessed but here we present a stock assessment using all the updated information and a biomass

production model (Kell, 2016), which has not been applied to IOTC stocks, but that has been used to assess tropical and temperate stocks in the International Commission for the Conservation of Atlantic Tunas (ICCAT).

As the complexity of models increases, diagnostics become more important to understand the robustness of estimates and how they propagate through to advice. Diagnostics also make the stock assessment process more transparent (Kell and Merino, 2015). In this paper we show a series of diagnostics that aim at facilitating the modelling choices required to conduct a stock assessment. In this case, we use the available information to fit two surplus production models (logistic and Fox) in alternative ways: The six CPUE series made available by the Secretariat are used in isolation and in combinations (regions, type and all combined). The results shown in this paper refer to fits using the six CPUE series together in both logistic and skewed models. However, all the individual fits are also prone to be analyzed in the WPTT if requested. In addition, we tested the impact of removing data before 1970 from the assessment. The diagnostics shown here may suggest using one or other modelling set-up, but the overall results are shown averaging across the four options with the combined indices. This may be modified at request during the WPTT too.

In IOTC, management advice is provided through projections of constant catch and their impact is analyzed on the estimated future status of stocks through K2SM. Here, we follow a similar procedure with the K2SM averaged from the projections of the four modelling scenarios. In addition, the results of projections through a series of HCRs are shown through K2SM and catch matrices.

Material and Methods

Data

In prevision of the new stock assessment of yellowfin, the IOTC Secretariat made available series of catch and CPUE. The catch statistics made available in 2016 downscale the catch in 2014 notably (5.1%, Figure 1) compared to the data used for the 2015 stock assessment.

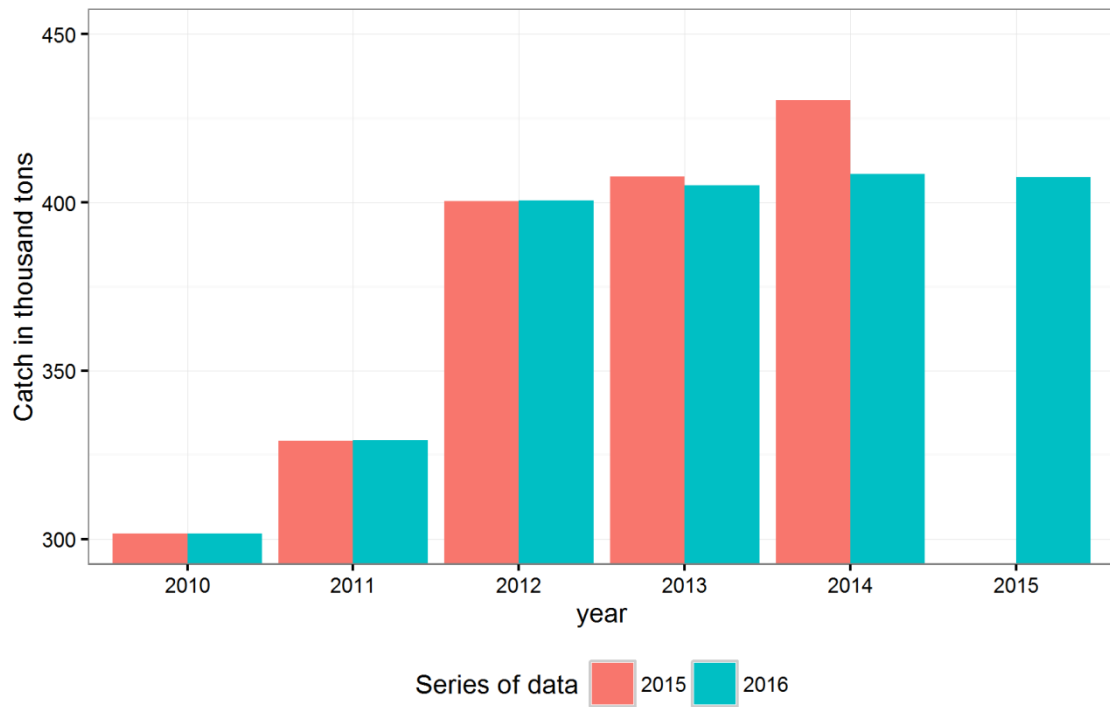


Figure 1. Catch series made available by IOTC Secretariat for 2015 and 2016 assessments of yellowfin.

With regards to the CPUE series, six series were made available (Figure 2). The series correspond to regions 2 (*R2*, Western Indian Ocean) and 5 (*R5*, Eastern Indian Ocean), see Figure 1 from (Langley et al., 2011), with and without boat identification (*Boat* and *NoID*) and the years used for standardization (all years except 1979-2015 in the indices 7915).

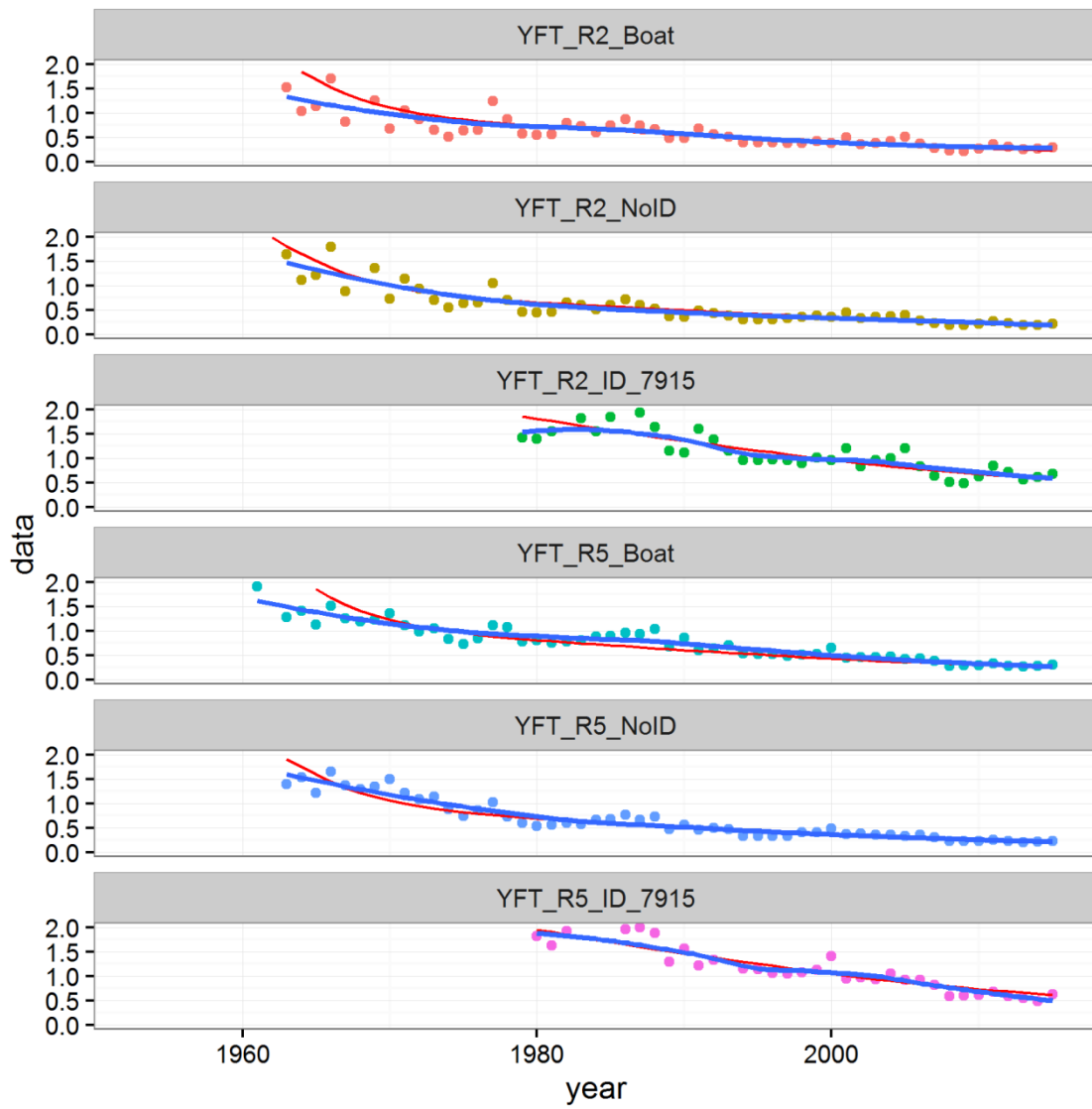


Figure 2. CPUE Series used in the biomass dynamic stock assessment as potential proxies for stock abundance; points are the standardised values, lines the prediction from a GAM fitted either to all the indices with year as a smooth term and index as a factor (red) and by index individually (blue).

The six series are notably correlated as shown in Figure 3:

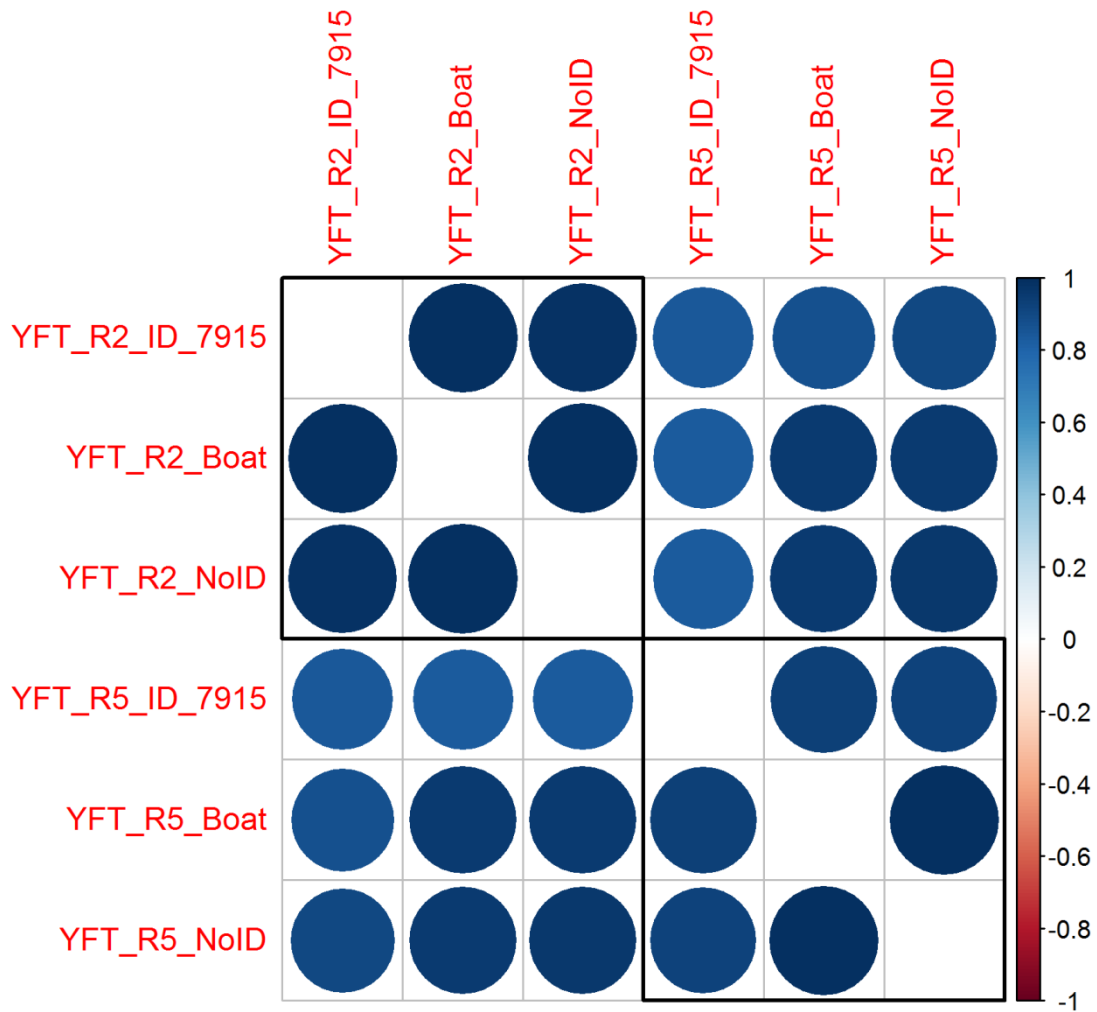


Figure 3. Correlation matrix for the indices; blue indicate positive and red negative correlations, the order of the indices.

Model

In a biomass dynamic model the stock next year (B_{t+1}) is the sum of the current biomass (B_t) less the catch (C_t) plus the surplus production (P_t) i.e.

$$B_{t+1} = B_t - C_t + P_t$$

There are various forms of production functions (P_t), e.g. the symmetric logistic (Hassel, 1975) or the generalized (Pella and Tomlinson, 1969) forms. The logistic production function is probably not appropriate for tuna species, due to high steepness (Maunder, 2003) and a Pella-Tomlinson form with $B_{MSY} < 0.5B_0$ is perhaps more realistic, e.g.

$$\frac{r}{p} \cdot B \left(1 - \left(\frac{B}{K} \right)^p \right)$$

where (r) is the intrinsic rate of increase, (K) the carry capacity (p) the shape of the surplus production function. If $p < 1$ then the curve is skewed to the left. The dynamics, i.e. productivity and reference points and the response of the stock to perturbations, are determined by r and the shape of the production function p . If $p = 1$ then MSY is found halfway between 0 and K , as p increases MSY shifts to the right. Here, we fitted the available data to two production functions: logistic and skewed to the left ($p=0.001$, Fox).

The software used to apply the models is *mpb* (Kell, 2016), an R Package for modelling Management Procedures, based on biomass dynamic stock assessment models and empirical harvest control rules. In order to facilitate the modelling choices required for the assessment of this stock, a series of diagnostics were also estimated (Kell and Merino, 2015) using *mpb*.

Results

The estimated parameters for the four main fits are shown in Table 1 (all runs' in the Appendix).

1950	MSY	Fmsy	Bmsy	r	k	p	B0
Log combined	343013.883	0.26849775	1277529.84	0.53699549	2555059.67	1	1
Fox combined	337462.554	0.30538149	1105052.41	0.30568687	3002343.33	0.001	1
1970	MSY	Fmsy	Bmsy	r	k	p	B0
Log combined	354797.666	0.16157895	2195816.14	0.3231579	4391632.28	1	1
Fox combined	323947.618	0.22374255	1447858.81	0.22396629	3933722.25	0.001	1

Table 1. Estimated Reference Points and parameters from the fits to the four modelling scenarios.

Patterns in the residuals from the fits to the CPUE, may indicate biased estimates of parameters, reference points and stock trends. Therefore when fitting a model, the residuals should be checked to identify violations of the assumptions. Initially, the residuals of a fit should be distributed normally and a similar way in the entire time series. The residuals estimated for the four runs are the following:

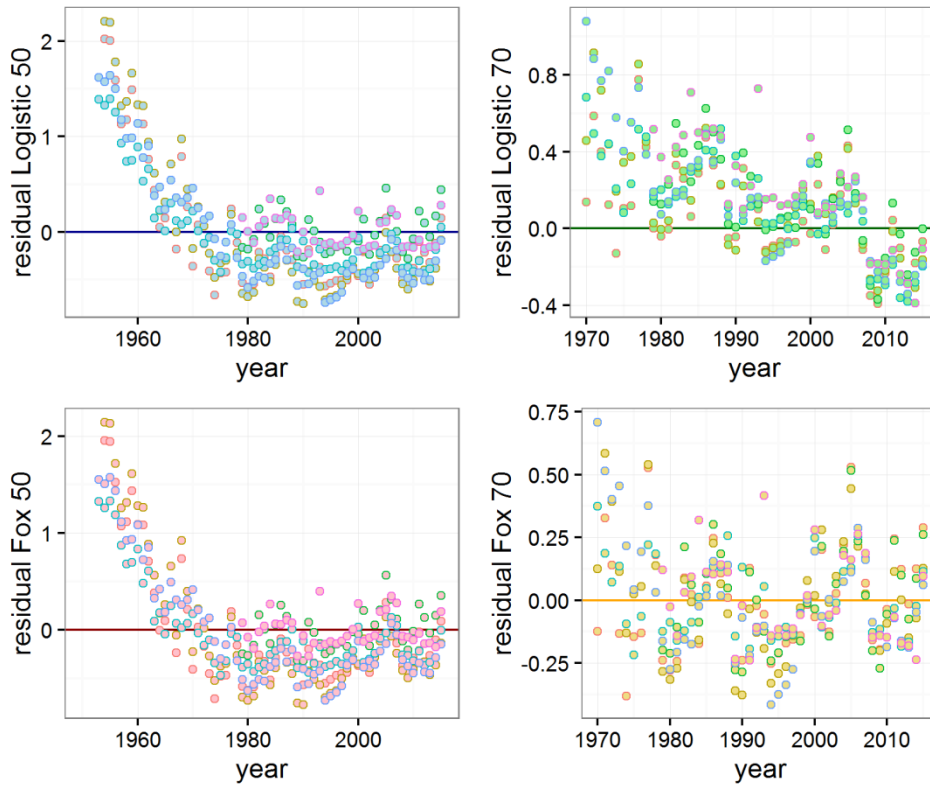


Figure 4. Residuals by year. The different colors in the outer of the points represent each of the CPUE series used; the color of the inner part of the points and in the y=0 line represent each of the four runs. The outer colors of the points are the six indices used.

And the estimated differences between observed and predicted indices of abundance:

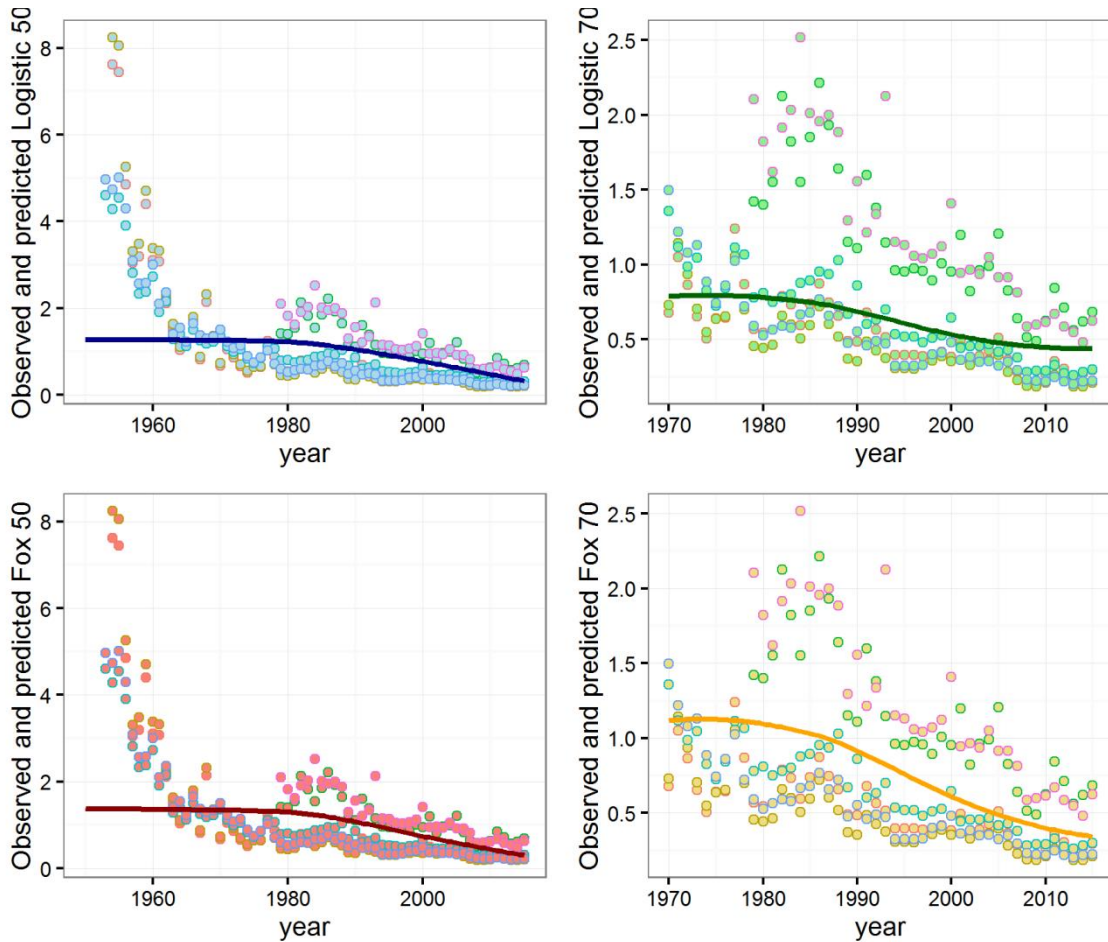


Figure 5. Model predicted and observed abundance. The color of the inner part of the points and in the lines represent each of the four runs. The outer colors of the points are the six indices used.

From Figures 4 and 5, it is noted that the models are not fitting the CPUE series before the mid 1960s-early 1970s. Note that in Figure 4, the residuals for the Fox 70 model are evenly distributed in all periods.

Simulation methods such as the jackknife or bootstrap identify problems with the data and model specifications; e.g. due to highly correlated or ill-defined parameters. Results of the jackknife analyses were made to check for influence of individual CPUE points are shown in Figure 6:

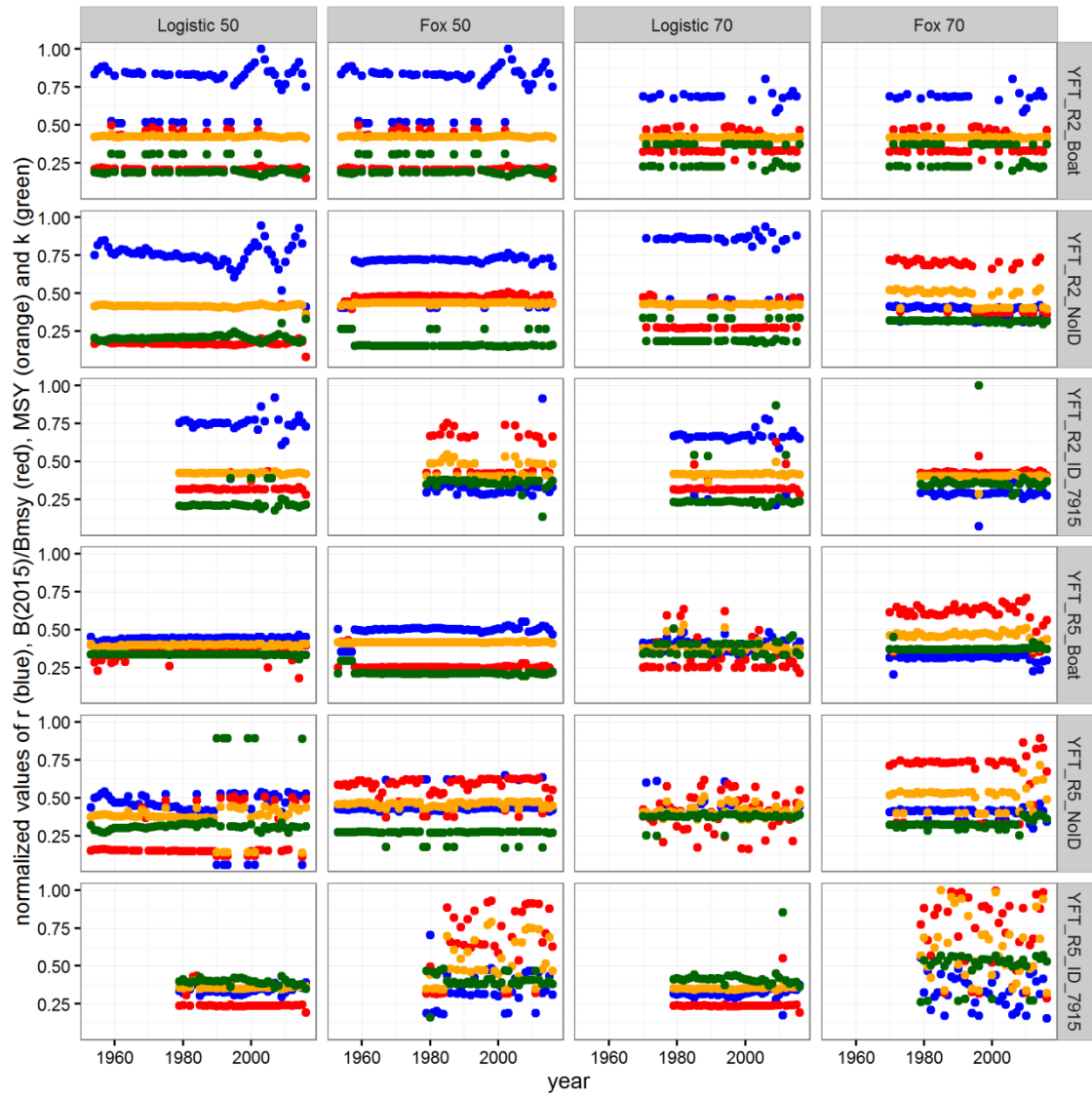


Figure 6. Jackknife analyses applied to the CPUE data series used.

The fits obtained were bootstrapped and probability distributions found for fishery indicators in 2015 and throughout the time series. In addition, differences between bootstrapped results and direct fits were checked, noting that fitted and bootstrapped median were very similar (Figure 7):

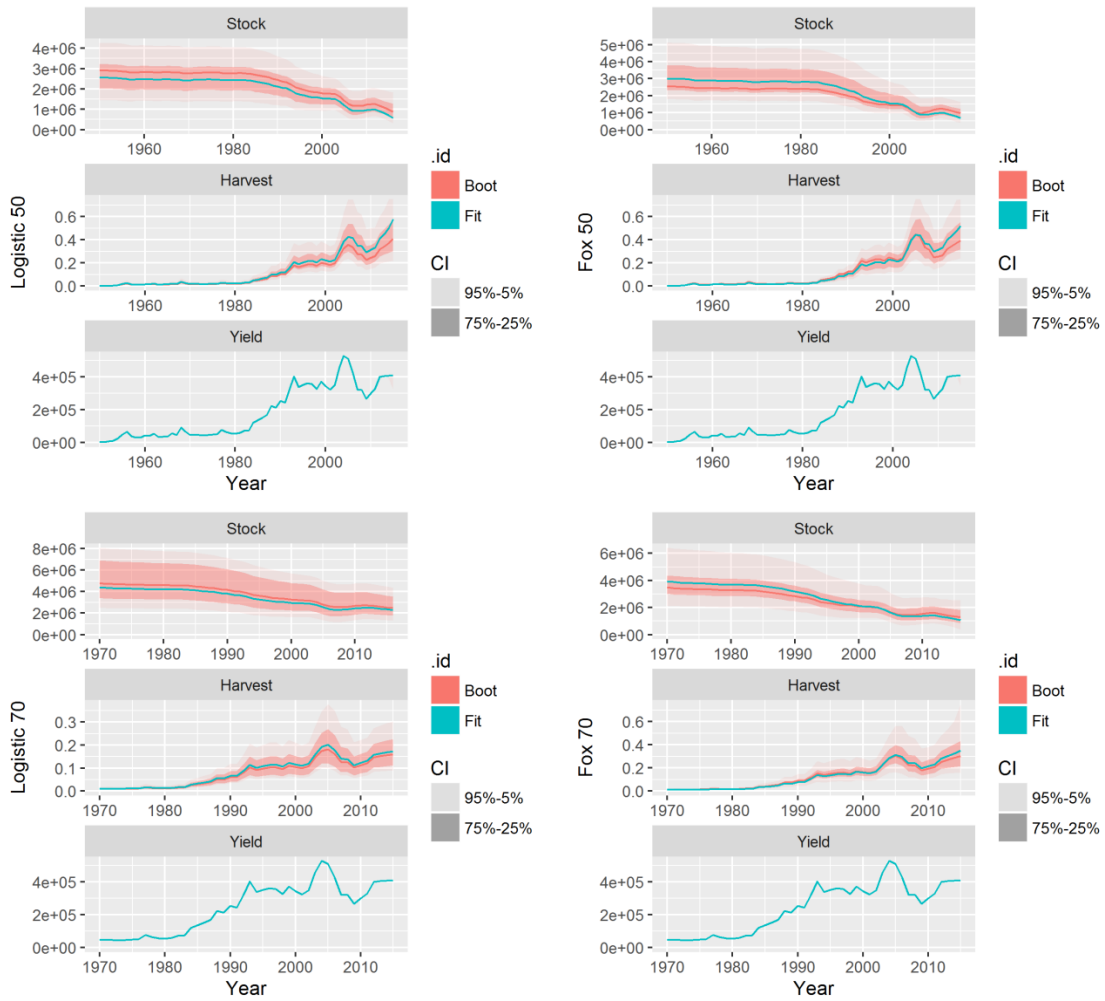


Figure 7. Bootstrapped and fitted results for the four main runs.

The median bootstrap trajectory and the 500 iterations for the stock status in 2015 were plotted in a Kobe diagram (Figure 8):

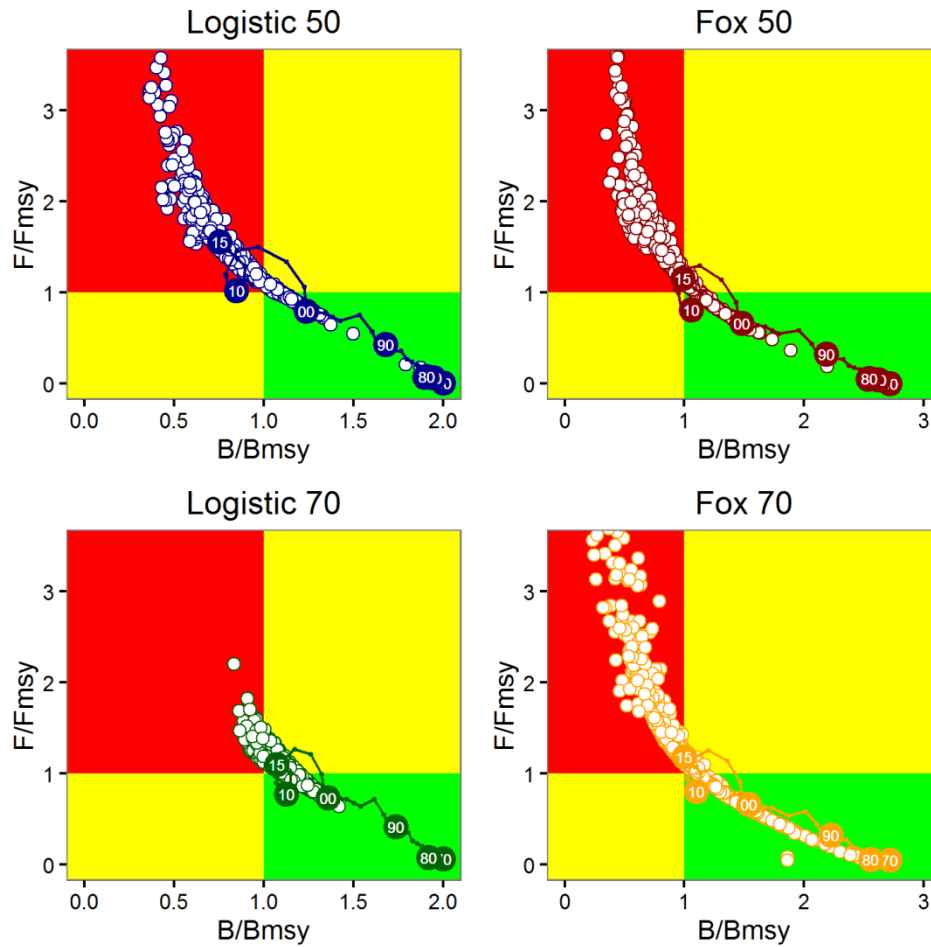


Figure 8. Relative biomass and Relative fishing mortality trajectories (median from bootstrap) and bootstrapped stock status for the four scenarios tested.

The probabilities from bootstrapped stock status are also displayed in a single Kobe diagram with densities for the estimated relative F and relative B in Figure 9. Note that current stock status (relative F and relative B) are more precisely estimated by the Fox model when data prior to 1970 are discarded:

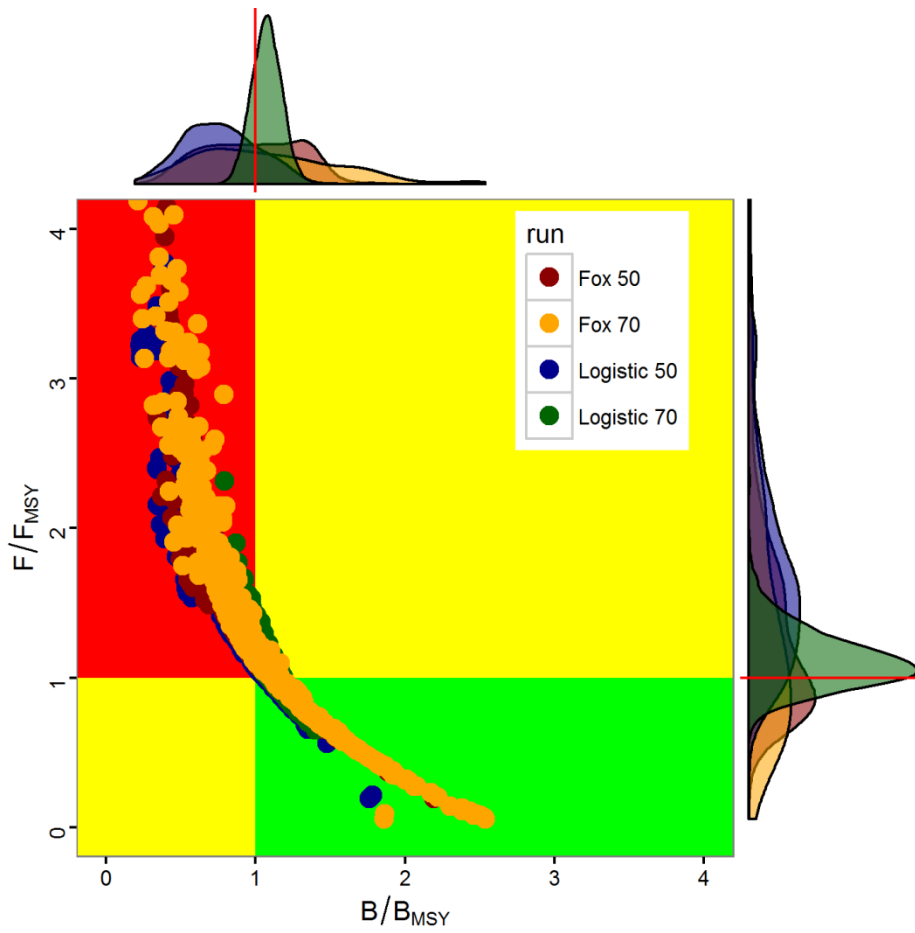
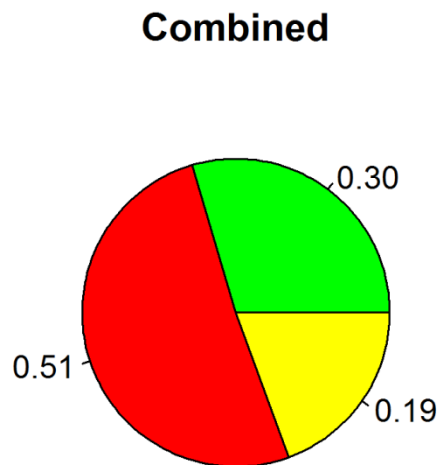


Figure 9. Relative stock status in 2015 with densities shown in the margins of the figure.

Overall current stock status and for each run is also shown with pie charts in Figure 10:



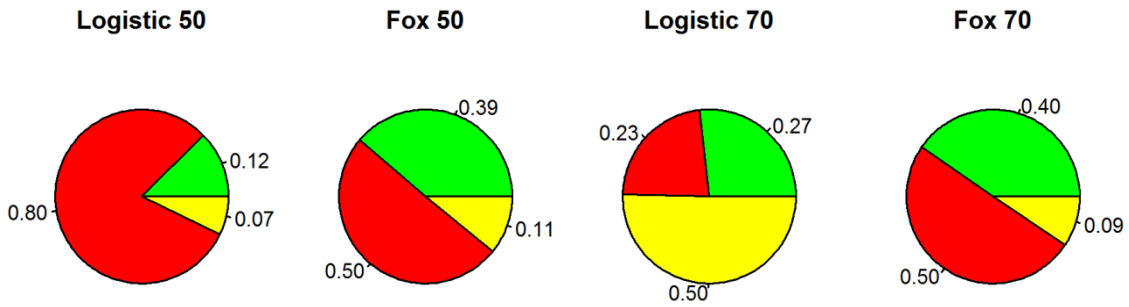


Figure 10. Pie charts with probabilities of the stock to be in 2015 in the different regions of the Kobe diagram.

The production functions and time series of yield vs stock biomass are presented in Figure 11. These show that catch has most of the time been above the surplus production of the stock for the corresponding stock abundance. The production functions also show that catch in the last three years has been well above the estimated MSY for all models.

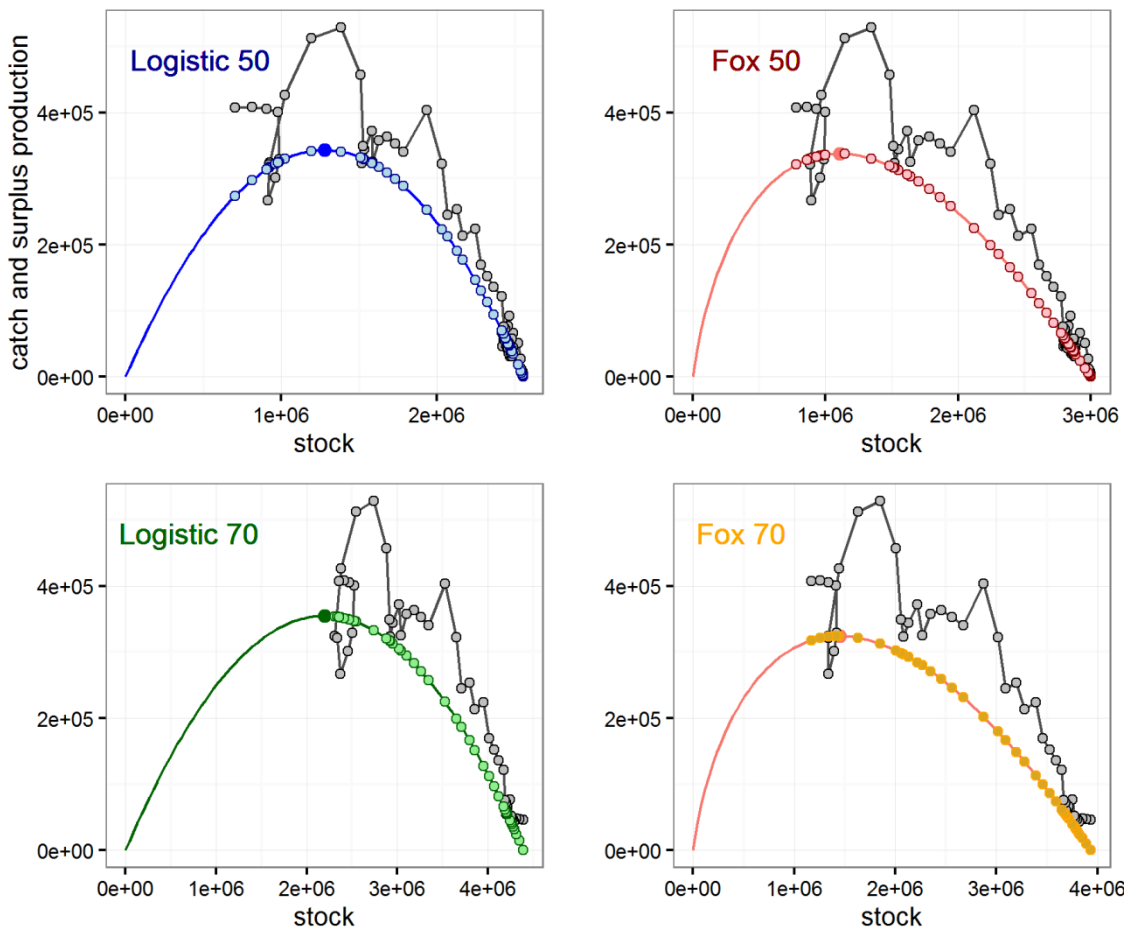


Figure 11. Production functions and time series of yield vs stock biomass.

Likelihood profiles are used to check that a solution has actually been found and to evaluate the information content of the data. It is not uncommon for indices to contain insufficient information to estimate the parameters of a stock assessment model. Indices may also be conflicting and fitting therefore involves weighting averages of contradictory trends. The profiles of the fits obtained in the four runs are shown in Figure 12:

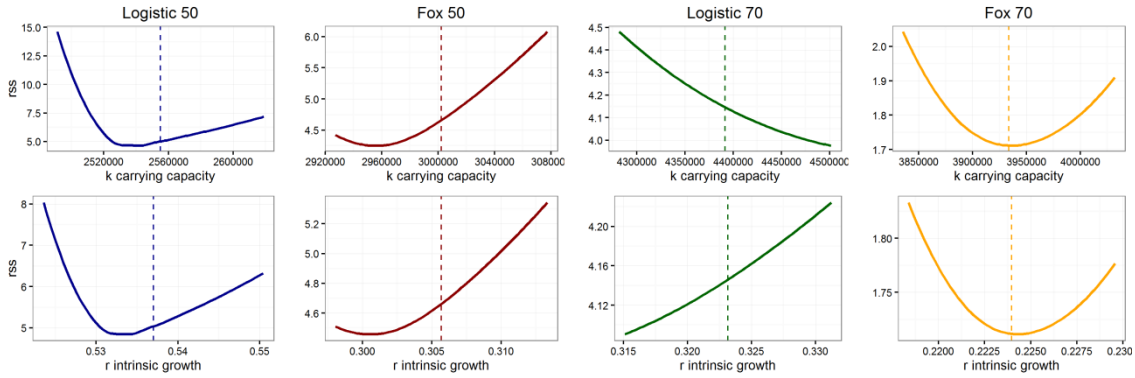


Figure 12. Likelihood profiles for r and K .

The *residual sum of squares (rss)* shown in Figure 12 corresponds to the *summed rss* for all indices in each run. From Figure 12 it is noted that the Logistic 70 scenario is finding an intermediate solution instead of a value of minimum error. Both r and K are more precisely estimated by the Fox model when data prior to 1970 are discarded. In figure 13, we also check for the correlation between r and K from the bootstrapped results. The models with the same shape in the production function seem to follow the same correlation trajectory (i.e. blue and green (logistics), and yellow and red (Fox)).

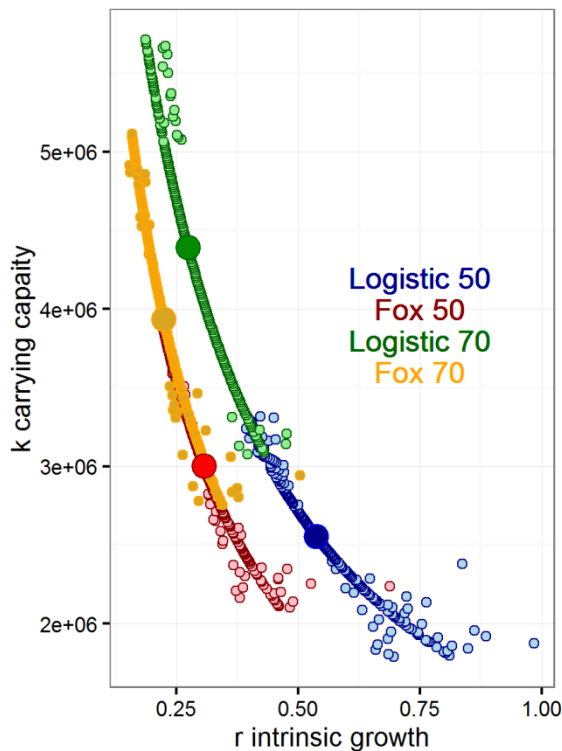


Figure 13. Correlation between the bootstrapped r and K for the four runs.

Another diagnostic shown here is the retrospective analysis of the median trajectory of the bootstraps. We have fitted and bootstrapped the results obtained by fitting one year less from the available data and the results are shown in Figure 14:

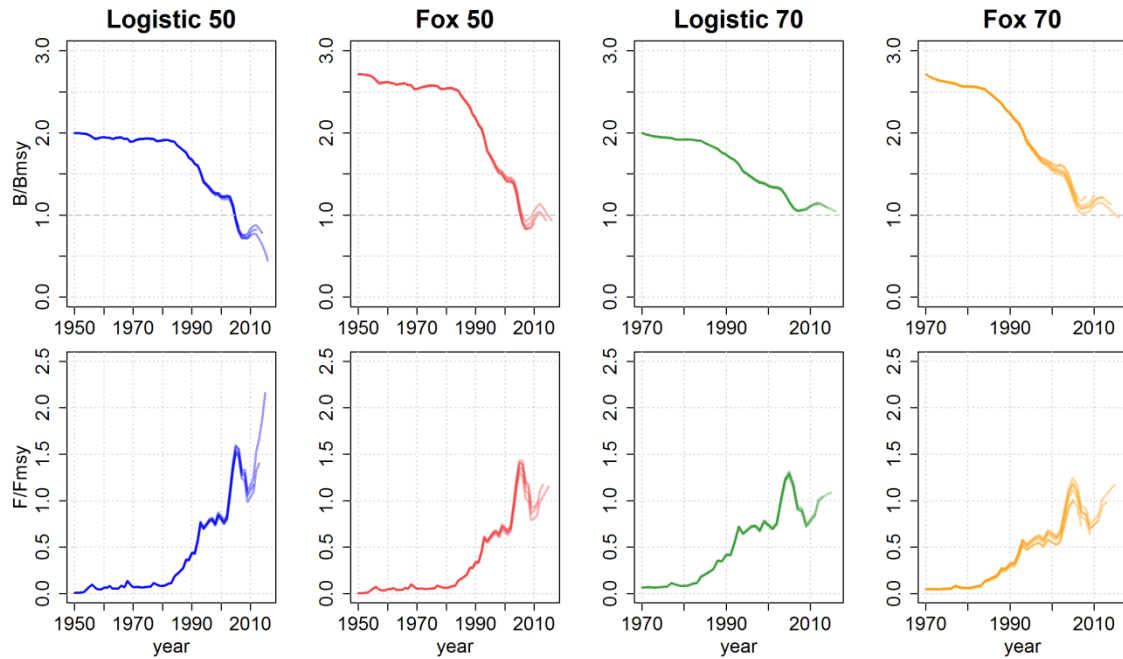


Figure 14. Retrospective analyses of bootstrapped results for the four runs.

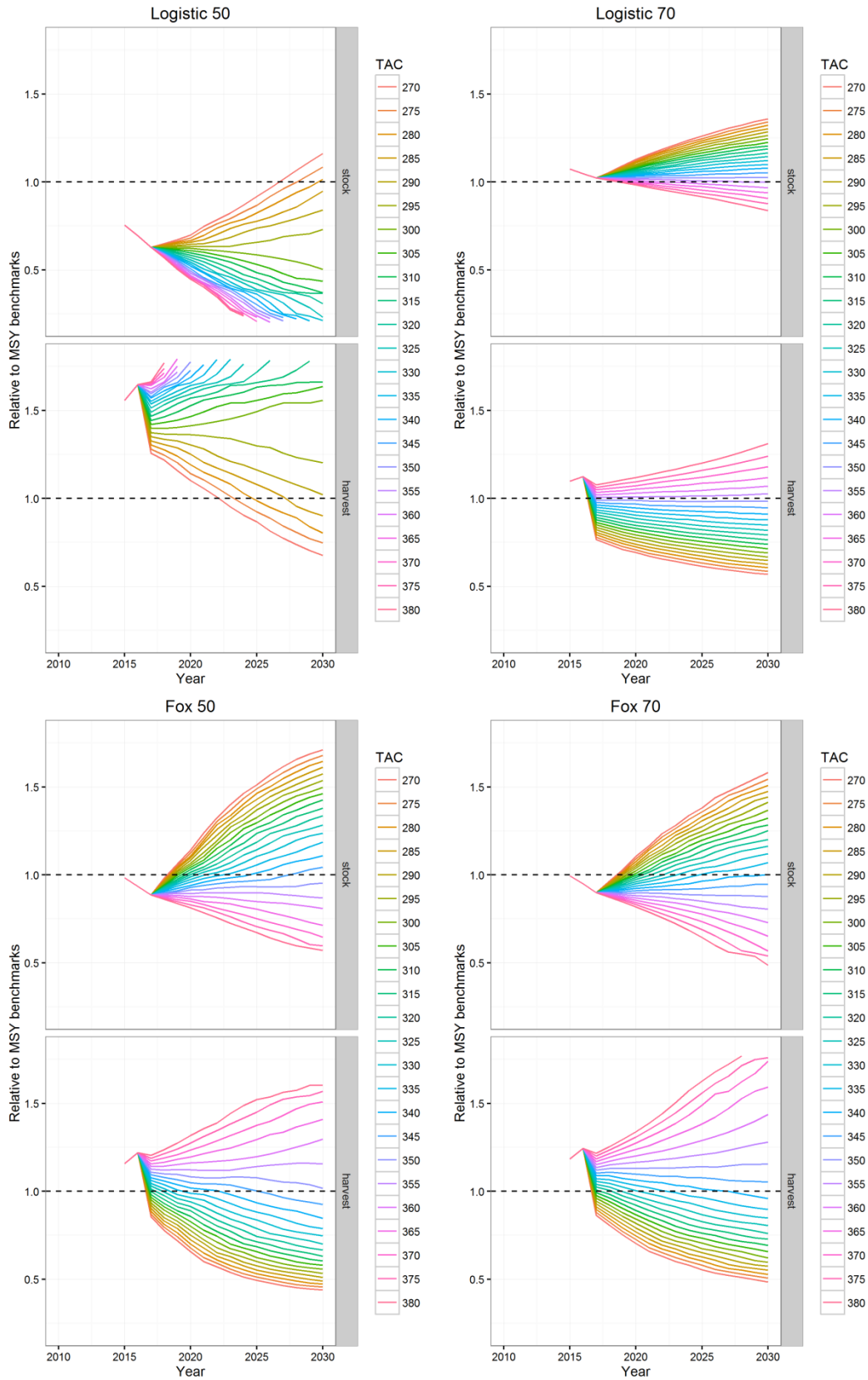
According to Figure 14, there is not a strong retrospective pattern and the trajectories estimated with all the series are very similar in all the four runs.

The values shown to describe the status of IOTC stocks is shown in Table 2, including catch in 2015, average catch 2011-2015, MSY , F_{MSY} , B_{MSY} , F_{2015}/F_{MSY} , B_{2015}/B_{MSY} , B_{2015}/B_0 . Note that MSY estimates in all runs are (5-18%) lower than the MSY average estimated in 2015 which was 421 (IOTC, 2015). Note also that the confidence intervals for RPs and parameters are wide except for the Logistic 70 model. This was visible also in the densities from Figure 9.

<i>variable</i>	<i>mean</i>	<i>median</i>	<i>10% CI</i>	<i>90% CI</i>	<i>model</i>
MSY	365580.196	353006.040	300976.611	399689.592	Combined
Bmsy	1612169.075	1438813.790	822529.558	2853755.321	Combined
Fmsy	0.288	0.240	0.109	0.458	Combined
Catch15	407575.000	407575.000	407575.000	407575.000	Combined
Catch1115	390185.400	390185.400	390185.400	390185.400	Combined
Fcur	1.398	1.208	0.751	2.245	Combined
Bcur	0.973	0.992	0.547	1.362	Combined
BcurK	0.419	0.435	0.225	0.585	Combined
MSY	353741.556	350168.823	317163.392	383286.441	Logistic 50
Bmsy	1393321.570	1454605.273	792318.752	1959249.188	Logistic 50
Fmsy	0.289	0.236	0.166	0.474	Logistic 50
Catch15	407575.000	407575.000	407575.000	407575.000	Logistic 50
Catch1115	390185.400	390185.400	390185.400	390185.400	Logistic 50
Fcur	1.681	1.558	0.972	2.558	Logistic 50
Bcur	0.707	0.754	0.460	1.117	Logistic 50
BcurK	0.353	0.347	0.176	0.544	Logistic 50
MSY	358053.306	360572.951	298937.781	400449.730	Fox 50
Bmsy	1109467.997	935246.590	737374.354	1761161.427	Fox 50
Fmsy	0.369	0.407	0.171	0.499	Fox 50
Catch15	407575.000	407575.000	407575.000	407575.000	Fox 50
Catch1115	390185.400	390185.400	390185.400	390185.400	Fox 50
Fcur	1.354	1.157	0.739	2.163	Fox 50
Bcur	0.927	0.984	0.554	1.379	Fox 50
BcurK	0.341	0.344	0.179	0.494	Fox 50
MSY	346150.767	349612.081	301218.154	380721.302	Logistic 70
Bmsy	2551815.268	2388480.030	1350748.066	3901602.258	Logistic 70
Fmsy	0.162	0.145	0.080	0.278	Logistic 70
Catch15	407575.000	407575.000	407575.000	407575.000	Logistic 70
Catch1115	390185.400	390185.400	390185.400	390185.400	Logistic 70
Fcur	1.123	1.099	0.901	1.374	Logistic 70
Bcur	1.046	1.073	0.950	1.198	Logistic 70
BcurK	0.523	0.524	0.459	0.588	Logistic 70
MSY	404375.153	351599.728	282289.389	473687.615	Fox 70
Bmsy	1394071.464	1285704.162	903775.543	2016877.908	Fox 70
Fmsy	0.334	0.286	0.145	0.478	Fox 70
Catch15	407575.000	407575.000	407575.000	407575.000	Fox 70
Catch1115	390185.400	390185.400	390185.400	390185.400	Fox 70
Fcur	1.432	1.184	0.505	2.593	Fox 70
Bcur	1.027	0.996	0.537	1.705	Fox 70
BcurK	0.378	0.349	0.162	0.618	Fox 70

Table 2. Bootstrapped Reference Points and other indicators.

The bootstrapped stock status and parameters were projected into the future (2030) for a range of alternative catch limits ranging from 270,001 to 380,001 tons. The median relative biomass and relative fishing mortalities for the four runs are shown in Figure 15.



The resulting probability of $B > B_{MSY}$ averaged across the four runs is shown through a K2SM (Table 3). The K2SM for the catch projections for each scenario are shown in the Appendix.

catch	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
270000	0.42	0.51	0.58	0.62	0.66	0.68	0.71	0.73	0.75	0.76	0.77	0.79	0.80	0.80	0.81
275000	0.42	0.51	0.56	0.61	0.65	0.67	0.70	0.72	0.74	0.75	0.76	0.77	0.78	0.79	0.80
280000	0.42	0.51	0.56	0.60	0.64	0.66	0.68	0.70	0.72	0.73	0.74	0.75	0.76	0.77	0.78
285000	0.42	0.50	0.55	0.60	0.62	0.65	0.67	0.69	0.70	0.72	0.72	0.74	0.75	0.75	0.76
290000	0.42	0.50	0.54	0.58	0.61	0.64	0.66	0.68	0.69	0.70	0.71	0.71	0.72	0.74	0.74
295000	0.42	0.50	0.53	0.57	0.61	0.62	0.65	0.66	0.68	0.69	0.69	0.70	0.71	0.71	0.72
300000	0.42	0.49	0.53	0.56	0.59	0.61	0.63	0.65	0.66	0.67	0.68	0.69	0.69	0.70	0.70
305000	0.42	0.48	0.52	0.55	0.57	0.60	0.61	0.63	0.64	0.65	0.66	0.67	0.68	0.68	0.68
310000	0.42	0.47	0.51	0.53	0.56	0.58	0.60	0.61	0.62	0.63	0.64	0.65	0.65	0.66	0.67
315000	0.42	0.47	0.50	0.53	0.55	0.57	0.59	0.60	0.61	0.62	0.62	0.63	0.64	0.64	0.64
320000	0.42	0.46	0.50	0.52	0.53	0.55	0.57	0.58	0.59	0.60	0.60	0.61	0.62	0.62	0.62
325000	0.42	0.46	0.49	0.51	0.53	0.53	0.54	0.56	0.57	0.58	0.58	0.59	0.59	0.59	0.60
330000	0.42	0.45	0.48	0.50	0.51	0.52	0.52	0.53	0.54	0.54	0.56	0.56	0.56	0.57	0.58
335000	0.42	0.45	0.47	0.48	0.50	0.50	0.51	0.51	0.52	0.53	0.53	0.54	0.54	0.55	0.55
340000	0.42	0.45	0.46	0.47	0.48	0.49	0.49	0.50	0.50	0.50	0.50	0.51	0.51	0.51	0.52
345000	0.42	0.44	0.45	0.45	0.46	0.46	0.47	0.47	0.48	0.48	0.48	0.48	0.48	0.48	0.48
350000	0.42	0.43	0.44	0.44	0.44	0.44	0.44	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
355000	0.42	0.42	0.43	0.43	0.43	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
360000	0.42	0.42	0.41	0.41	0.40	0.40	0.40	0.40	0.40	0.39	0.39	0.39	0.38	0.38	0.38
365000	0.42	0.41	0.40	0.39	0.39	0.38	0.38	0.38	0.37	0.37	0.37	0.36	0.36	0.36	0.35
370000	0.42	0.41	0.39	0.38	0.37	0.37	0.36	0.36	0.35	0.34	0.33	0.33	0.32	0.32	0.32
375000	0.42	0.40	0.38	0.37	0.36	0.35	0.34	0.32	0.31	0.31	0.30	0.29	0.28	0.27	0.27
380000	0.42	0.40	0.37	0.36	0.34	0.33	0.30	0.29	0.28	0.27	0.26	0.25	0.25	0.24	0.23

Table 3. Kobe 2 Strategy Matrix, the indicated values are probabilities of the stock being above BMSY for each year.

In addition, projections were made with a series of Harvest Control Rules (HCR). The HCR tested are linear and defined by F_{lim} , B_{lim} , F_{tar} and B_{thresh} . K2SM for each HCR and their estimated catch are shown in Tables 4 and 5, averaged across all four runs. The K2SM and Catch projections obtained with the HCRs in the four scenarios are shown in the Appendix.

Ftar	Btrig	Blim	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
0.75	0.3	0.1	0.44	0.53	0.64	0.73	0.80	0.86	0.91	0.93	0.96	0.97	0.98	0.98	0.99	0.99	0.99
0.8	0.3	0.1	0.43	0.51	0.61	0.71	0.78	0.84	0.89	0.92	0.95	0.96	0.97	0.98	0.98	0.99	0.99
0.85	0.3	0.1	0.42	0.49	0.57	0.67	0.75	0.80	0.86	0.90	0.93	0.95	0.96	0.97	0.97	0.98	0.99
0.9	0.3	0.1	0.41	0.46	0.53	0.63	0.70	0.77	0.82	0.85	0.90	0.93	0.94	0.95	0.96	0.97	0.97
0.95	0.3	0.1	0.40	0.43	0.48	0.55	0.63	0.70	0.75	0.78	0.82	0.85	0.89	0.91	0.92	0.94	0.94
1	0.3	0.1	0.39	0.39	0.40	0.43	0.46	0.51	0.53	0.53	0.54	0.55	0.55	0.55	0.55	0.55	0.55
0.75	0.4	0.1	0.44	0.56	0.68	0.77	0.85	0.91	0.94	0.96	0.98	0.98	0.99	0.99	0.99	1.00	1.00
0.8	0.4	0.1	0.44	0.54	0.66	0.75	0.81	0.90	0.93	0.95	0.97	0.98	0.99	0.99	0.99	0.99	1.00
0.85	0.4	0.1	0.43	0.52	0.63	0.73	0.80	0.88	0.92	0.94	0.96	0.98	0.98	0.99	0.99	0.99	0.99
0.9	0.4	0.1	0.41	0.50	0.61	0.70	0.77	0.84	0.90	0.92	0.95	0.97	0.97	0.98	0.99	0.99	0.99
0.95	0.4	0.1	0.41	0.47	0.57	0.65	0.73	0.78	0.85	0.89	0.92	0.94	0.95	0.96	0.97	0.98	0.98
1	0.4	0.1	0.39	0.42	0.51	0.58	0.64	0.68	0.73	0.74	0.76	0.77	0.77	0.77	0.77	0.78	0.78
0.75	0.5	0.1	0.45	0.58	0.72	0.82	0.88	0.93	0.95	0.97	0.98	0.99	0.99	1.00	1.00	1.00	1.00
0.8	0.5	0.1	0.45	0.57	0.70	0.80	0.88	0.92	0.95	0.97	0.98	0.99	0.99	0.99	1.00	1.00	1.00
0.85	0.5	0.1	0.44	0.55	0.68	0.79	0.87	0.92	0.94	0.96	0.98	0.99	0.99	0.99	1.00	1.00	1.00
0.9	0.5	0.1	0.43	0.53	0.66	0.76	0.85	0.91	0.94	0.96	0.98	0.98	0.99	0.99	1.00	1.00	1.00
0.95	0.5	0.1	0.42	0.51	0.63	0.73	0.83	0.90	0.93	0.95	0.97	0.98	0.99	0.99	0.99	1.00	1.00
1	0.5	0.1	0.40	0.47	0.57	0.65	0.77	0.86	0.89	0.92	0.94	0.95	0.96	0.97	0.97	0.98	0.98
0.75	0.3	0.2	0.44	0.53	0.66	0.76	0.83	0.89	0.94	0.96	0.97	0.98	0.99	0.99	0.99	1.00	1.00
0.8	0.3	0.2	0.43	0.52	0.63	0.74	0.80	0.87	0.92	0.95	0.96	0.98	0.98	0.99	0.99	0.99	1.00
0.85	0.3	0.2	0.42	0.49	0.60	0.70	0.78	0.84	0.90	0.93	0.96	0.97	0.97	0.98	0.99	0.99	0.99
0.9	0.3	0.2	0.41	0.47	0.56	0.66	0.73	0.81	0.86	0.90	0.93	0.95	0.96	0.97	0.98	0.98	0.99
0.95	0.3	0.2	0.40	0.43	0.50	0.60	0.67	0.74	0.80	0.84	0.87	0.90	0.92	0.94	0.95	0.96	0.96
1	0.3	0.2	0.39	0.39	0.43	0.47	0.51	0.55	0.59	0.60	0.61	0.61	0.61	0.61	0.61	0.61	0.61
0.75	0.4	0.2	0.45	0.58	0.70	0.79	0.88	0.93	0.95	0.97	0.98	0.99	0.99	1.00	1.00	1.00	1.00
0.8	0.4	0.2	0.44	0.56	0.69	0.78	0.86	0.92	0.95	0.97	0.98	0.99	0.99	0.99	1.00	1.00	1.00
0.85	0.4	0.2	0.43	0.55	0.66	0.76	0.82	0.90	0.94	0.96	0.98	0.98	0.99	0.99	1.00	1.00	1.00
0.9	0.4	0.2	0.42	0.52	0.64	0.73	0.79	0.88	0.93	0.95	0.97	0.98	0.98	0.99	0.99	0.99	0.99
0.95	0.4	0.2	0.41	0.49	0.61	0.69	0.76	0.83	0.88	0.92	0.94	0.95	0.96	0.97	0.98	0.98	0.99
1	0.4	0.2	0.39	0.46	0.56	0.63	0.67	0.73	0.77	0.78	0.79	0.80	0.80	0.80	0.81	0.81	0.81
0.75	0.5	0.2	0.45	0.60	0.74	0.84	0.91	0.94	0.96	0.98	0.99	0.99	0.99	1.00	1.00	1.00	1.00
0.8	0.5	0.2	0.45	0.59	0.73	0.83	0.90	0.94	0.96	0.98	0.99	0.99	0.99	1.00	1.00	1.00	1.00
0.85	0.5	0.2	0.44	0.57	0.71	0.82	0.89	0.93	0.96	0.98	0.99	0.99	0.99	1.00	1.00	1.00	1.00
0.9	0.5	0.2	0.43	0.55	0.69	0.80	0.89	0.93	0.96	0.98	0.99	0.99	0.99	1.00	1.00	1.00	1.00
0.95	0.5	0.2	0.42	0.52	0.66	0.78	0.87	0.92	0.95	0.97	0.98	0.99	0.99	1.00	1.00	1.00	1.00
1	0.5	0.2	0.41	0.50	0.60	0.69	0.82	0.89	0.92	0.94	0.97	0.98	0.98	0.99	0.99	1.00	1.00

Table 4. K2SM for the HCRs defined by Ftar, Btrig and Blim. The numbers indicate the probability of B>Bmsy.

Ftar	Btrig	Blim	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
0.75	0.3	0.1	242	259	269	281	288	304	321	325	328	333	335	336	338	339	339
0.8	0.3	0.1	256	270	279	290	296	312	330	333	336	341	342	344	345	345	346
0.85	0.3	0.1	269	281	288	298	303	319	337	340	342	347	348	349	350	351	352
0.9	0.3	0.1	282	292	297	305	309	325	344	346	348	352	353	354	355	355	356
0.95	0.3	0.1	295	302	305	311	314	330	349	350	352	356	356	357	358	358	359
1	0.3	0.1	308	311	312	316	318	335	354	354	355	359	359	360	360	360	360
0.75	0.4	0.1	230	247	257	272	278	299	328	329	331	338	338	339	340	340	341
0.8	0.4	0.1	244	258	267	280	286	307	338	337	340	346	346	347	347	348	348
0.85	0.4	0.1	256	268	276	288	293	315	347	345	347	353	352	353	354	354	354
0.9	0.4	0.1	269	278	284	294	299	321	354	351	353	359	357	358	358	358	358
0.95	0.4	0.1	281	288	292	300	304	326	360	356	357	363	361	361	361	361	361
1	0.4	0.1	294	297	299	304	308	329	363	358	359	367	364	364	363	362	362
0.75	0.5	0.1	214	230	241	258	264	290	334	329	333	341	340	340	340	340	340
0.8	0.5	0.1	226	240	249	265	271	297	342	337	341	349	347	347	345	346	345
0.85	0.5	0.1	237	250	258	272	277	303	349	343	347	356	353	352	350	350	350
0.9	0.5	0.1	249	260	265	277	283	308	356	348	352	361	358	357	353	354	353
0.95	0.5	0.1	260	269	272	282	288	312	361	353	357	366	362	360	356	357	356
1	0.5	0.1	272	278	278	285	291	315	365	356	361	370	366	363	359	359	358
0.75	0.3	0.2	236	251	261	276	280	301	327	329	331	336	337	338	339	340	341
0.8	0.3	0.2	249	262	270	284	288	309	336	337	339	344	344	346	346	347	347
0.85	0.3	0.2	262	273	279	292	295	316	344	345	346	351	351	352	352	353	353
0.9	0.3	0.2	275	283	287	299	300	322	352	351	352	356	356	356	357	357	357
0.95	0.3	0.2	288	293	295	305	305	328	358	356	357	361	360	360	360	360	360
1	0.3	0.2	300	302	301	310	309	332	364	361	360	364	363	362	362	362	362
0.75	0.4	0.2	222	236	246	265	269	295	336	333	335	341	340	341	342	342	342
0.8	0.4	0.2	234	246	255	273	276	304	346	342	343	350	348	349	349	349	349
0.85	0.4	0.2	246	256	264	280	283	312	356	350	351	357	355	355	355	355	355
0.9	0.4	0.2	258	266	271	286	288	318	365	358	357	363	361	361	360	360	360
0.95	0.4	0.2	270	275	278	291	293	323	372	363	362	368	365	364	363	363	362
1	0.4	0.2	282	284	285	295	296	326	376	366	365	373	368	367	365	364	362
0.75	0.5	0.2	202	216	226	248	252	286	343	335	336	345	343	343	341	341	341
0.8	0.5	0.2	213	226	234	255	259	292	353	343	345	353	350	349	346	346	345
0.85	0.5	0.2	224	235	242	260	264	298	361	350	352	360	357	354	349	350	349
0.9	0.5	0.2	235	244	249	265	269	303	369	355	358	367	362	359	352	353	351
0.95	0.5	0.2	246	252	254	269	273	307	376	360	364	372	367	362	354	355	353
1	0.5	0.2	256	261	259	272	276	311	382	365	368	377	371	365	356	357	354

Table 5. Estimated catch for the HCRs defined by Ftar, Btrig and Blim in thousands of tons.

Discussion

The stock status of Indian Ocean yellowfin estimated using the information available in 2016 and biomass dynamic models from the library *mpb* (Kell, 2016) is notably more optimistic than the 2015 estimate using SS3 (IOTC, 2015). Averaging across four modelling scenarios, we estimate that the stock is overfished and undergoing overexploitation with a 50% of probability, but neither overfished nor undergoing overfishing with a probability of 30%.

The differences between the stock status estimated here and the 2015 stock assessment can be attributed to the different modelling approaches and the data used. The impact of the different modelling platforms will be discussed during the WPTT but there is one notable change in the data used: In 2016, the catch series have been revised with a 5% reduction of the catch assigned to 2014 (from 430,327 to 408,497 tons). According to these, our estimated MSY was exceeded by 11% in 2014 and not 19% as measured in 2015.

The estimates shown in this document are obtained by averaging over four modelling scenarios. However, we include a series of diagnostics that suggest that some modelling

scenarios are less plausible than others since model assumptions are violated. For example, residuals from the fits (Figure 4) are more evenly distributed across the time series in the scenarios that discard data prior to 1970, i.e. they dynamics at the beginning of the fishery differ from the current dynamics. The fit to the Fox model appear to be more consistent with model assumptions. i.e. residuals are *normally* distributed and not in the Logistic. All model runs show good retrospective fits, i.e. the estimated trajectories with shortened series of data are within the trajectories of the complete series'. The jackknife analyses yield comparable results across the abundance indices: The MSY estimates are relatively stable when one point of the index is dropped, but r and K differ notably with some indices. For example, the estimates using the CPUE from identified boats in region 5 (YFT_R5_Boat) are relatively stable for all models. However, further analyses of the jackknife shown here may be necessary if a single index is to be chosen as abundance index for the stock assessment. With regards to the likelihood, there is one model that shows a poor profile: For the logistic using data after 1970, the model is estimating intermediate values of r and K . The other four models show relatively good profiles.

In the projections averaged for the four scenarios, we estimate that the stock would be at levels equal or above B_{MSY} with a 50% probability in 2020 for catches not exceeding 330,000 tons (19% less than 2015) (Figure 15 and Table 3).

In 2016, the IOTC agreed implementing a Harvest Control Rule for the management of skipjack, one of the three stocks considered as tropical tunas in IOTC. It also encouraged continuing the assessment of HCRs through Management Strategy Evaluation. Here, using forward projections, we estimated the ability of a series of Harvest Control Rules to achieve conservation management objectives and evaluated their impact on the overall catch of yellowfin tuna (Tables 4 and 5).

The scripts used to produce all the results shown in this paper will be available at request to all the participants to the 18th session of the WPTT. Furthermore, suggestion to the modelling choices, information used and results display will be accepted and added during the WPTT.

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Appendix

1) Reference Points and parameters

1950	MSY	Fmsy	Bmsy	r	k	p	B0
Log combined	343013.883	0.26849775	1277529.84	0.53699549	2555059.67	1	1
Fox combined	337462.554	0.30538149	1105052.41	0.30568687	3002343.33	0.001	1
Log_YFT_R2_Boat	356592.482	0.35852845	994600.245	0.7170569	1989200.49	1	1
Log_YFT_R2_NovessID	362782.234	0.22363578	1622201.19	0.44727157	3244402.37	1	1
Log_YFT_R2_VessID_79-15	356075.686	0.32292169	1102668.84	0.64584338	2205337.68	1	1
Log_YFT_R5_Boat	120449.666	0.02500001	4817985.32	0.05000001	9635970.63	1	1
Log_YFT_R5_NovessID	315372.445	0.19034857	1656815.43	0.38069714	3313630.87	1	1
Log_YFT_R5_VessID_79-15	298953.41	0.14033485	2130286.27	0.28066971	4260572.53	1	1
Log_YFT_R2	361360.302	0.37244604	970235.316	0.74489208	1940470.63	1	1
Log_YFT_R5	316335.935	0.18054365	1752129.91	0.36108731	3504259.81	1	1
Log_YFT_R2&5_Boat	348463.121	0.21556555	1616506.57	0.43113109	3233013.14	1	1
Log_YFT_R2&5_NovessID	355788.615	0.22152201	1606109.52	0.44304403	3212219.05	1	1
Log_YFT_R2&5_VessID_79-15	332163.195	0.21592884	1538299.37	0.43185768	3076598.74	1	1
Fox_YFT_R2_Boat	363749.1	0.54993551	661439.559	0.55048544	1797080.97	0.001	1
Fox_YFT_R2_NovessID	340712.56	0.32848345	1037229	0.32881193	2818072.28	0.001	1
Fox_YFT_R2_VessID_79-15	339268.737	0.25030387	1355427.43	0.25055418	3682593.22	0.001	1
Fox_YFT_R5_Boat	350714.256	0.42938824	816776.573	0.42981763	2219119.82	0.001	1
Fox_YFT_R5_NovessID	360903.971	0.53265631	677555.045	0.53318897	1840865.52	0.001	1
Fox_YFT_R5_VessID_79-15	292260.012	0.15975451	1829431.97	0.15991427	4970427.49	0.001	1
Fox_YFT_R2	351582.126	0.3680787	955181.929	0.36844678	2595156.64	0.001	1
Fox_YFT_R5	427866.51	0.35426471	1207759.32	0.35461898	3281390.2	0.001	1
Fox_YFT_R2&5_Boat	456540.241	0.38865533	1174666.11	0.38904398	3191478.46	0.001	1
Fox_YFT_R2&5_NovessID	420076.513	0.37090877	1132560.21	0.37127968	3077079.95	0.001	1
Fox_YFT_R2&5_VessID_79-15	313606.515	0.19406304	1616003.29	0.19425711	4390558	0.001	1
1970	MSY	Fmsy	Bmsy	r	k	p	B0
Log combined	354797.666	0.16157895	2195816.14	0.3231579	4391632.28	1	1
Fox combined	323947.618	0.22374255	1447858.81	0.22396629	3933722.25	0.001	1
Log_YFT_R2_Boat	352642.396	0.29557364	1193077.96	0.59114728	2386155.92	1	1
Log_YFT_R2_NovessID	326825.36	0.16788687	1946699.94	0.33577374	3893399.89	1	1
Log_YFT_R2_VessID_79-15	341488.768	0.16873969	2023760.79	0.33747938	4047521.57	1	1
Log_YFT_R5_Boat	317230.643	0.16332692	1942304.68	0.32665384	3884609.37	1	1
Log_YFT_R5_NovessID	334471.939	0.16907992	1978188.44	0.33815983	3956376.89	1	1
Log_YFT_R5_VessID_79-15	337827.229	0.16397922	2060183.14	0.32795844	4120366.29	1	1
Log_YFT_R2	356146.156	0.32758626	1087182.81	0.65517253	2174365.63	1	1
Log_YFT_R5	318044.197	0.17961127	1770736.36	0.35922253	3541472.71	1	1
Log_YFT_R2&5_Boat	336271.282	0.22972884	1463774.75	0.45945769	2927549.5	1	1
Log_YFT_R2&5_NovessID	344750.492	0.17144002	2010910.21	0.34288005	4021820.42	1	1
Log_YFT_R2&5_VessID_79-15	332824.232	0.21832885	1524417.1	0.4366577	3048834.2	1	1
Fox_YFT_R2_Boat	380349.362	0.28227815	1347427.56	0.28256043	3660858.19	0.001	1
Fox_YFT_R2_NovessID	477737.575	0.33620996	1420950.08	0.33654617	3860613.29	0.001	1
Fox_YFT_R2_VessID_79-15	443381.941	0.3044182	1456489.59	0.30472262	3957171.41	0.001	1
Fox_YFT_R5_Boat	428254.107	0.30744563	1392942.57	0.30775308	3784518.99	0.001	1
Fox_YFT_R5_NovessID	392951.373	0.28388497	1384192.22	0.28416886	3760744.96	0.001	1
Fox_YFT_R5_VessID_79-15	386965.262	0.26427125	1464273.02	0.26453552	3978318.41	0.001	1
Fox_YFT_R2	340576.6	0.26161062	1301845.45	0.26187223	3537015.05	0.001	1
Fox_YFT_R5	311372.375	0.19873719	1566754.44	0.19893593	4256752.63	0.001	1
Fox_YFT_R2&5_Boat	321305.829	0.20965051	1532578.34	0.20986016	4163898.77	0.001	1
Fox_YFT_R2&5_NovessID	421393.338	0.29751244	1416388.96	0.29780995	3848221.06	0.001	1
Fox_YFT_R2&5_VessID_79-15	410362.14	0.28280142	1451061.09	0.28308422	3942422.61	0.001	1

2) Catch projections

catchLog50	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
270000	0.13	0.21	0.25	0.30	0.35	0.38	0.41	0.43	0.46	0.48	0.50	0.52	0.54	0.55	0.55
275000	0.13	0.20	0.24	0.30	0.34	0.37	0.40	0.43	0.44	0.47	0.48	0.50	0.51	0.52	0.54
280000	0.13	0.20	0.24	0.28	0.32	0.36	0.38	0.41	0.43	0.44	0.47	0.48	0.49	0.51	0.51
285000	0.13	0.20	0.23	0.27	0.31	0.35	0.37	0.40	0.42	0.43	0.44	0.45	0.47	0.48	0.49
290000	0.13	0.20	0.23	0.26	0.31	0.34	0.36	0.38	0.40	0.41	0.42	0.43	0.44	0.46	0.47
295000	0.13	0.19	0.23	0.25	0.30	0.32	0.35	0.37	0.38	0.40	0.41	0.42	0.42	0.43	0.43
300000	0.13	0.19	0.22	0.25	0.28	0.31	0.34	0.35	0.37	0.38	0.40	0.40	0.41	0.42	0.42
305000	0.13	0.19	0.21	0.24	0.27	0.30	0.32	0.34	0.35	0.37	0.38	0.39	0.40	0.40	0.41
310000	0.13	0.18	0.21	0.23	0.26	0.28	0.31	0.32	0.34	0.35	0.36	0.37	0.38	0.39	0.40
315000	0.13	0.18	0.21	0.23	0.25	0.27	0.30	0.31	0.32	0.34	0.35	0.36	0.36	0.37	0.37
320000	0.13	0.17	0.20	0.22	0.23	0.26	0.28	0.30	0.31	0.31	0.32	0.34	0.35	0.35	0.36
325000	0.13	0.17	0.20	0.21	0.23	0.24	0.26	0.28	0.29	0.30	0.31	0.31	0.32	0.33	0.34
330000	0.13	0.16	0.19	0.21	0.23	0.23	0.25	0.26	0.27	0.28	0.29	0.30	0.30	0.31	0.31
335000	0.13	0.16	0.19	0.20	0.21	0.23	0.24	0.25	0.26	0.26	0.27	0.28	0.29	0.29	0.30
340000	0.13	0.16	0.18	0.19	0.21	0.22	0.23	0.23	0.24	0.25	0.25	0.26	0.26	0.27	0.27
345000	0.13	0.16	0.18	0.19	0.20	0.20	0.21	0.23	0.23	0.23	0.24	0.24	0.24	0.25	0.25
350000	0.13	0.15	0.17	0.18	0.19	0.19	0.20	0.21	0.21	0.22	0.22	0.23	0.23	0.23	0.23
355000	0.13	0.14	0.16	0.18	0.18	0.18	0.19	0.19	0.19	0.19	0.20	0.21	0.21	0.21	0.22
360000	0.13	0.14	0.15	0.16	0.17	0.18	0.18	0.18	0.18	0.18	0.19	0.19	0.19	0.19	0.19
365000	0.13	0.14	0.15	0.15	0.16	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
370000	0.13	0.14	0.14	0.15	0.15	0.15	0.16	0.16	0.16	0.17	0.17	0.17	0.17	0.17	0.17
375000	0.13	0.14	0.14	0.14	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
380000	0.13	0.13	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13

catchFox50	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
270000	0.39	0.48	0.54	0.57	0.61	0.64	0.69	0.72	0.73	0.75	0.76	0.78	0.79	0.80	0.80
275000	0.39	0.47	0.53	0.57	0.60	0.63	0.67	0.70	0.73	0.74	0.75	0.76	0.77	0.78	0.79
280000	0.39	0.47	0.52	0.56	0.59	0.61	0.65	0.68	0.71	0.73	0.74	0.75	0.76	0.76	0.77
285000	0.39	0.47	0.52	0.55	0.58	0.60	0.63	0.66	0.69	0.71	0.72	0.73	0.74	0.75	0.75
290000	0.39	0.47	0.51	0.55	0.57	0.60	0.62	0.64	0.66	0.68	0.70	0.71	0.72	0.73	0.74
295000	0.39	0.46	0.51	0.54	0.57	0.58	0.60	0.63	0.64	0.66	0.67	0.69	0.71	0.71	0.71
300000	0.39	0.46	0.51	0.53	0.56	0.57	0.60	0.61	0.63	0.64	0.66	0.67	0.67	0.69	0.69
305000	0.39	0.45	0.50	0.52	0.54	0.57	0.58	0.60	0.61	0.63	0.64	0.64	0.66	0.67	0.67
310000	0.39	0.45	0.49	0.51	0.54	0.56	0.57	0.58	0.59	0.61	0.62	0.63	0.64	0.64	0.65
315000	0.39	0.44	0.48	0.51	0.52	0.54	0.56	0.57	0.58	0.59	0.59	0.60	0.61	0.62	0.63
320000	0.39	0.44	0.47	0.50	0.51	0.53	0.55	0.56	0.56	0.57	0.58	0.59	0.59	0.60	0.60
325000	0.39	0.43	0.46	0.49	0.51	0.51	0.53	0.54	0.56	0.56	0.56	0.57	0.58	0.58	0.59
330000	0.39	0.43	0.46	0.47	0.50	0.51	0.51	0.53	0.54	0.54	0.55	0.55	0.56	0.56	0.57
335000	0.39	0.43	0.45	0.47	0.49	0.50	0.50	0.51	0.52	0.53	0.53	0.54	0.55	0.55	0.55
340000	0.39	0.42	0.44	0.46	0.47	0.49	0.50	0.50	0.50	0.51	0.51	0.52	0.52	0.52	0.53
345000	0.39	0.42	0.44	0.45	0.45	0.47	0.48	0.49	0.49	0.49	0.49	0.50	0.51	0.51	0.51
350000	0.39	0.42	0.43	0.44	0.45	0.45	0.46	0.47	0.48	0.48	0.48	0.49	0.49	0.49	0.49
355000	0.39	0.41	0.42	0.43	0.44	0.44	0.45	0.45	0.45	0.45	0.46	0.46	0.47	0.48	0.48
360000	0.39	0.40	0.41	0.42	0.42	0.43	0.43	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.45
365000	0.39	0.40	0.40	0.40	0.41	0.41	0.42	0.42	0.43	0.43	0.43	0.43	0.43	0.43	0.43
370000	0.39	0.39	0.39	0.39	0.39	0.40	0.40	0.39	0.40	0.40	0.40	0.40	0.40	0.40	0.39
375000	0.39	0.39	0.39	0.39	0.39	0.38	0.38	0.38	0.38	0.38	0.38	0.37	0.37	0.36	0.36
380000	0.39	0.38	0.38	0.38	0.37	0.37	0.36	0.36	0.36	0.35	0.34	0.34	0.33	0.33	0.33

catchLog70	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
270000	0.57	0.69	0.76	0.81	0.84	0.86	0.87	0.89	0.90	0.91	0.91	0.92	0.93	0.93	0.94
275000	0.57	0.68	0.74	0.79	0.82	0.84	0.86	0.87	0.89	0.90	0.90	0.91	0.92	0.92	0.92
280000	0.57	0.68	0.74	0.79	0.81	0.84	0.85	0.86	0.87	0.87	0.89	0.90	0.90	0.90	0.91
285000	0.57	0.67	0.73	0.78	0.80	0.83	0.84	0.85	0.85	0.86	0.87	0.88	0.89	0.89	0.89
290000	0.57	0.67	0.71	0.76	0.79	0.81	0.83	0.84	0.85	0.85	0.85	0.86	0.87	0.87	0.88
295000	0.57	0.66	0.70	0.75	0.78	0.80	0.81	0.82	0.84	0.84	0.84	0.85	0.85	0.85	0.86
300000	0.57	0.65	0.69	0.73	0.76	0.78	0.79	0.81	0.82	0.83	0.83	0.83	0.84	0.84	0.84
305000	0.57	0.64	0.69	0.71	0.74	0.76	0.77	0.78	0.80	0.80	0.81	0.82	0.82	0.82	0.83
310000	0.57	0.63	0.67	0.70	0.72	0.75	0.76	0.77	0.78	0.79	0.79	0.80	0.80	0.80	0.81
315000	0.57	0.62	0.67	0.69	0.71	0.73	0.74	0.76	0.77	0.77	0.78	0.78	0.78	0.78	0.78
320000	0.57	0.62	0.65	0.68	0.69	0.71	0.73	0.73	0.74	0.75	0.75	0.76	0.76	0.76	0.77
325000	0.57	0.62	0.64	0.67	0.68	0.68	0.69	0.71	0.72	0.72	0.73	0.73	0.73	0.73	0.73
330000	0.57	0.61	0.63	0.65	0.66	0.67	0.67	0.67	0.68	0.68	0.69	0.69	0.70	0.70	0.71
335000	0.57	0.60	0.62	0.63	0.64	0.64	0.64	0.64	0.65	0.66	0.66	0.67	0.67	0.67	0.68
340000	0.57	0.60	0.61	0.61	0.62	0.62	0.62	0.63	0.63	0.63	0.62	0.62	0.63	0.63	0.63
345000	0.57	0.59	0.60	0.59	0.59	0.59	0.59	0.59	0.59	0.60	0.60	0.59	0.59	0.59	0.59
350000	0.57	0.58	0.58	0.57	0.57	0.57	0.56	0.56	0.56	0.56	0.55	0.55	0.54	0.55	0.54
355000	0.57	0.57	0.56	0.56	0.55	0.54	0.53	0.52	0.52	0.51	0.50	0.50	0.50	0.50	0.49
360000	0.57	0.56	0.54	0.53	0.51	0.50	0.49	0.49	0.48	0.47	0.46	0.46	0.45	0.44	0.44
365000	0.57	0.56	0.53	0.50	0.49	0.48	0.47	0.45	0.45	0.44	0.43	0.42	0.42	0.41	0.40
370000	0.57	0.55	0.52	0.49	0.47	0.46	0.44	0.43	0.41	0.40	0.38	0.38	0.36	0.36	0.35
375000	0.57	0.54	0.50	0.47	0.45	0.43	0.41	0.38	0.36	0.35	0.34	0.32	0.31	0.29	0.28
380000	0.57	0.54	0.49	0.46	0.42	0.40	0.36	0.34	0.32	0.31	0.28	0.28	0.26	0.24	0.23

catchFox70	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
270000	0.45	0.49	0.52	0.55	0.58	0.60	0.62	0.65	0.66	0.67	0.69	0.69	0.70	0.70	0.71
275000	0.45	0.48	0.51	0.54	0.57	0.59	0.61	0.63	0.65	0.66	0.67	0.69	0.69	0.69	0.70
280000	0.45	0.48	0.51	0.54	0.56	0.58	0.60	0.62	0.64	0.65	0.66	0.67	0.68	0.69	0.69
285000	0.45	0.48	0.50	0.54	0.56	0.58	0.59	0.60	0.62	0.63	0.65	0.66	0.67	0.67	0.68
290000	0.45	0.48	0.50	0.53	0.55	0.56	0.58	0.59	0.60	0.62	0.63	0.64	0.65	0.66	0.67
295000	0.45	0.48	0.49	0.52	0.54	0.56	0.58	0.59	0.59	0.60	0.61	0.62	0.63	0.64	0.65
300000	0.45	0.48	0.49	0.51	0.54	0.55	0.56	0.58	0.59	0.59	0.60	0.60	0.61	0.62	0.63
305000	0.45	0.47	0.49	0.51	0.53	0.55	0.55	0.57	0.58	0.59	0.59	0.59	0.60	0.60	0.61
310000	0.45	0.47	0.49	0.50	0.52	0.53	0.55	0.55	0.56	0.57	0.58	0.59	0.59	0.59	0.59
315000	0.45	0.47	0.49	0.49	0.51	0.52	0.53	0.55	0.55	0.56	0.57	0.57	0.58	0.58	0.59
320000	0.45	0.47	0.48	0.49	0.50	0.51	0.52	0.53	0.54	0.54	0.55	0.56	0.56	0.56	0.57
325000	0.45	0.47	0.48	0.49	0.49	0.50	0.51	0.52	0.52	0.53	0.54	0.54	0.54	0.55	0.55
330000	0.45	0.47	0.48	0.48	0.49	0.49	0.50	0.51	0.52	0.52	0.52	0.53	0.53	0.53	0.53
335000	0.45	0.46	0.47	0.48	0.48	0.49	0.49	0.49	0.50	0.51	0.51	0.51	0.52	0.52	0.52
340000	0.45	0.45	0.46	0.47	0.47	0.48	0.48	0.48	0.49	0.49	0.49	0.49	0.50	0.50	0.50
345000	0.45	0.45	0.46	0.46	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.48	0.48	0.48	0.48
350000	0.45	0.45	0.45	0.46	0.46	0.46	0.46	0.47	0.46	0.46	0.46	0.47	0.47	0.47	0.47
355000	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
360000	0.45	0.45	0.44	0.44	0.45	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44
365000	0.45	0.44	0.44	0.44	0.43	0.44	0.43	0.43	0.42	0.42	0.42	0.42	0.42	0.42	0.42
370000	0.45	0.44	0.43	0.43	0.43	0.41	0.41	0.41	0.41	0.40	0.40	0.40	0.40	0.39	0.39
375000	0.45	0.44	0.43	0.43	0.41	0.41	0.40	0.40	0.40	0.39	0.38	0.38	0.38	0.38	0.38
380000	0.45	0.44	0.43	0.42	0.40	0.40	0.40	0.39	0.38	0.38	0.37	0.37	0.37	0.37	0.37

3) HCR projections

a. K2SM

Logistic 50

Ftar	Btrig	Blim	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
0.75	0.3	0.1	0.14	0.21	0.31	0.44	0.55	0.66	0.80	0.84	0.90	0.93	0.95	0.97	0.98	0.98	0.99
0.8	0.3	0.1	0.14	0.21	0.28	0.39	0.51	0.60	0.72	0.81	0.88	0.90	0.93	0.95	0.97	0.98	0.98
0.85	0.3	0.1	0.14	0.20	0.25	0.33	0.46	0.54	0.64	0.75	0.84	0.88	0.90	0.92	0.94	0.96	0.98
0.9	0.3	0.1	0.14	0.18	0.22	0.28	0.38	0.49	0.56	0.63	0.76	0.84	0.86	0.89	0.91	0.93	0.93
0.95	0.3	0.1	0.14	0.16	0.19	0.22	0.28	0.37	0.47	0.52	0.58	0.66	0.75	0.82	0.84	0.87	0.88
1	0.3	0.1	0.14	0.13	0.14	0.14	0.14	0.17	0.21	0.21	0.23	0.25	0.25	0.25	0.25	0.25	0.25
0.75	0.4	0.1	0.14	0.21	0.32	0.48	0.63	0.79	0.85	0.91	0.96	0.97	0.98	0.98	0.99	0.99	0.99
0.8	0.4	0.1	0.14	0.21	0.30	0.44	0.54	0.76	0.85	0.89	0.94	0.97	0.97	0.98	0.99	0.99	0.99
0.85	0.4	0.1	0.14	0.20	0.25	0.40	0.51	0.73	0.83	0.87	0.93	0.96	0.97	0.98	0.99	0.99	0.99
0.9	0.4	0.1	0.14	0.18	0.23	0.35	0.45	0.63	0.79	0.85	0.91	0.94	0.95	0.97	0.97	0.98	0.99
0.95	0.4	0.1	0.14	0.16	0.19	0.28	0.39	0.47	0.69	0.78	0.85	0.89	0.91	0.94	0.95	0.96	0.97
1	0.4	0.1	0.14	0.13	0.14	0.18	0.25	0.31	0.46	0.48	0.51	0.54	0.54	0.54	0.54	0.54	0.54
0.75	0.5	0.1	0.14	0.23	0.41	0.59	0.73	0.83	0.89	0.94	0.97	0.98	0.98	0.99	0.99	0.99	1.00
0.8	0.5	0.1	0.14	0.21	0.38	0.56	0.72	0.83	0.88	0.93	0.97	0.98	0.98	0.99	0.99	0.99	1.00
0.85	0.5	0.1	0.14	0.20	0.35	0.53	0.70	0.82	0.88	0.93	0.97	0.98	0.98	0.99	0.99	0.99	1.00
0.9	0.5	0.1	0.14	0.18	0.31	0.49	0.67	0.81	0.87	0.92	0.96	0.97	0.98	0.99	0.99	0.99	0.99
0.95	0.5	0.1	0.14	0.16	0.27	0.41	0.65	0.80	0.86	0.92	0.96	0.97	0.98	0.99	0.99	0.99	0.99
1	0.5	0.1	0.14	0.13	0.19	0.30	0.56	0.78	0.85	0.91	0.96	0.97	0.98	0.98	0.99	0.99	0.99
0.75	0.3	0.2	0.14	0.21	0.31	0.46	0.57	0.71	0.84	0.89	0.93	0.96	0.98	0.99	0.99	0.99	0.99
0.8	0.3	0.2	0.14	0.21	0.28	0.42	0.53	0.64	0.80	0.86	0.91	0.95	0.96	0.98	0.99	0.99	0.99
0.85	0.3	0.2	0.14	0.20	0.25	0.37	0.48	0.58	0.74	0.83	0.89	0.92	0.94	0.96	0.98	0.99	0.99
0.9	0.3	0.2	0.14	0.18	0.22	0.33	0.40	0.52	0.66	0.74	0.82	0.88	0.91	0.92	0.95	0.96	0.97
0.95	0.3	0.2	0.14	0.16	0.19	0.26	0.33	0.41	0.55	0.63	0.69	0.75	0.81	0.86	0.89	0.91	0.92
1	0.3	0.2	0.14	0.13	0.14	0.16	0.18	0.22	0.31	0.32	0.34	0.35	0.35	0.35	0.35	0.35	0.35
0.75	0.4	0.2	0.14	0.21	0.34	0.51	0.72	0.84	0.91	0.95	0.97	0.98	0.99	0.99	0.99	1.00	1.00
0.8	0.4	0.2	0.14	0.21	0.32	0.46	0.67	0.82	0.90	0.95	0.97	0.98	0.99	0.99	0.99	0.99	1.00
0.85	0.4	0.2	0.14	0.20	0.28	0.42	0.54	0.79	0.89	0.94	0.97	0.98	0.98	0.99	0.99	0.99	1.00
0.9	0.4	0.2	0.14	0.18	0.25	0.38	0.48	0.74	0.86	0.91	0.95	0.98	0.98	0.98	0.99	0.99	0.99
0.95	0.4	0.2	0.14	0.16	0.22	0.31	0.42	0.63	0.78	0.85	0.92	0.95	0.96	0.97	0.98	0.99	0.99
1	0.4	0.2	0.14	0.13	0.16	0.22	0.28	0.44	0.57	0.60	0.63	0.65	0.65	0.65	0.66	0.66	0.66
0.75	0.5	0.2	0.14	0.23	0.44	0.63	0.80	0.86	0.92	0.96	0.98	0.99	0.99	0.99	0.99	1.00	1.00
0.8	0.5	0.2	0.14	0.22	0.42	0.62	0.79	0.86	0.92	0.96	0.98	0.99	0.99	0.99	0.99	1.00	1.00
0.85	0.5	0.2	0.14	0.20	0.38	0.61	0.77	0.85	0.92	0.96	0.98	0.99	0.99	0.99	0.99	1.00	1.00
0.9	0.5	0.2	0.14	0.18	0.35	0.59	0.76	0.85	0.92	0.96	0.97	0.99	0.99	0.99	0.99	1.00	1.00
0.95	0.5	0.2	0.14	0.16	0.32	0.54	0.75	0.85	0.92	0.95	0.97	0.99	0.99	0.99	0.99	1.00	1.00
1	0.5	0.2	0.14	0.13	0.25	0.35	0.70	0.85	0.91	0.95	0.97	0.99	0.99	0.99	0.99	1.00	1.00

Fox 50

Ftar	Btrig	Blim	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
0.75	0.3	0.1	0.40	0.52	0.67	0.79	0.86	0.91	0.95	0.97	0.98	0.99	1.00	1.00	1.00	1.00	1.00
0.8	0.3	0.1	0.40	0.51	0.64	0.76	0.83	0.89	0.94	0.96	0.98	0.99	1.00	1.00	1.00	1.00	1.00
0.85	0.3	0.1	0.40	0.48	0.61	0.75	0.81	0.86	0.94	0.95	0.97	0.99	1.00	1.00	1.00	1.00	1.00
0.9	0.3	0.1	0.40	0.46	0.57	0.71	0.78	0.84	0.90	0.94	0.96	0.98	0.99	1.00	1.00	1.00	1.00
0.95	0.3	0.1	0.40	0.43	0.51	0.65	0.74	0.80	0.86	0.88	0.92	0.96	0.98	0.98	0.99	0.99	0.99
1	0.3	0.1	0.40	0.40	0.42	0.50	0.55	0.60	0.65	0.65	0.66	0.67	0.67	0.67	0.68	0.68	0.68
0.75	0.4	0.1	0.40	0.55	0.75	0.85	0.90	0.94	0.96	0.98	0.99	0.99	1.00	1.00	1.00	1.00	1.00
0.8	0.4	0.1	0.40	0.54	0.74	0.84	0.89	0.94	0.96	0.98	0.99	0.99	1.00	1.00	1.00	1.00	1.00
0.85	0.4	0.1	0.40	0.53	0.72	0.84	0.89	0.93	0.96	0.98	0.99	0.99	1.00	1.00	1.00	1.00	1.00
0.9	0.4	0.1	0.40	0.51	0.72	0.82	0.89	0.93	0.96	0.97	0.98	0.99	1.00	1.00	1.00	1.00	1.00
0.95	0.4	0.1	0.40	0.48	0.70	0.81	0.88	0.93	0.96	0.97	0.98	0.99	1.00	1.00	1.00	1.00	1.00
1	0.4	0.1	0.40	0.44	0.67	0.79	0.87	0.93	0.96	0.97	0.98	0.99	1.00	1.00	1.00	1.00	1.00
0.75	0.5	0.1	0.40	0.58	0.78	0.87	0.92	0.94	0.96	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00
0.8	0.5	0.1	0.40	0.57	0.77	0.87	0.92	0.94	0.96	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00
0.85	0.5	0.1	0.40	0.57	0.77	0.86	0.92	0.94	0.96	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00
0.9	0.5	0.1	0.40	0.57	0.77	0.86	0.91	0.94	0.96	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00
0.95	0.5	0.1	0.40	0.56	0.76	0.86	0.91	0.94	0.96	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00
1	0.5	0.1	0.40	0.55	0.75	0.85	0.90	0.94	0.96	0.98	0.99	0.99	1.00	1.00	1.00	1.00	1.00
0.75	0.3	0.2	0.40	0.52	0.72	0.82	0.89	0.95	0.97	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00
0.8	0.3	0.2	0.40	0.51	0.69	0.79	0.86	0.95	0.97	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00
0.85	0.3	0.2	0.40	0.48	0.67	0.78	0.84	0.93	0.97	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00
0.9	0.3	0.2	0.40	0.46	0.62	0.74	0.82	0.90	0.95	0.98	0.99	0.99	1.00	1.00	1.00	1.00	1.00
0.95	0.3	0.2	0.40	0.43	0.57	0.69	0.78	0.87	0.92	0.94	0.97	0.99	0.99	0.99	1.00	1.00	1.00
1	0.3	0.2	0.40	0.40	0.49	0.55	0.61	0.68	0.72	0.73	0.74	0.74	0.74	0.74	0.75	0.75	0.75
0.75	0.4	0.2	0.40	0.57	0.79	0.88	0.93	0.96	0.97	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00
0.8	0.4	0.2	0.40	0.57	0.79	0.87	0.93	0.96	0.97	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00
0.85	0.4	0.2	0.40	0.56	0.77	0.87	0.93	0.96	0.97	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00
0.9	0.4	0.2	0.40	0.54	0.77	0.87	0.92	0.96	0.97	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00
0.95	0.4	0.2	0.40	0.52	0.76	0.86	0.92	0.96	0.97	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00
1	0.4	0.2	0.40	0.49	0.74	0.85	0.92	0.96	0.97	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00
0.75	0.5	0.2	0.40	0.60	0.81	0.89	0.93	0.96	0.97	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00
0.8	0.5	0.2	0.40	0.60	0.81	0.88	0.93	0.96	0.97	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00
0.85	0.5	0.2	0.40	0.60	0.81	0.88	0.93	0.96	0.97	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00
0.9	0.5	0.2	0.40	0.59	0.80	0.88	0.93	0.96	0.97	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00
0.95	0.5	0.2	0.40	0.58	0.80	0.88	0.93	0.96	0.97	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00
1	0.5	0.2	0.40	0.58	0.80	0.88	0.93	0.96	0.97	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00

Logistic 70

Ftar	Btrig	Blim	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
0.75	0.3	0.1	0.72	0.82	0.89	0.92	0.96	0.98	0.98	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00
0.8	0.3	0.1	0.70	0.79	0.86	0.91	0.93	0.96	0.97	0.98	0.99	0.99	0.99	1.00	1.00	1.00	1.00
0.85	0.3	0.1	0.68	0.75	0.82	0.87	0.91	0.92	0.95	0.96	0.98	0.98	0.98	0.99	0.99	1.00	1.00
0.9	0.3	0.1	0.64	0.71	0.76	0.82	0.86	0.88	0.91	0.92	0.94	0.96	0.97	0.98	0.98	0.98	0.99
0.95	0.3	0.1	0.61	0.65	0.69	0.73	0.77	0.80	0.83	0.86	0.87	0.89	0.91	0.92	0.93	0.95	0.96
1	0.3	0.1	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57
0.75	0.4	0.1	0.72	0.82	0.89	0.92	0.96	0.98	0.98	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00
0.8	0.4	0.1	0.70	0.79	0.86	0.91	0.93	0.96	0.97	0.98	0.99	0.99	0.99	1.00	1.00	1.00	1.00
0.85	0.4	0.1	0.68	0.75	0.82	0.87	0.91	0.92	0.95	0.96	0.98	0.98	0.98	0.99	0.99	1.00	1.00
0.9	0.4	0.1	0.64	0.71	0.76	0.82	0.86	0.88	0.91	0.92	0.94	0.96	0.97	0.98	0.98	0.98	0.99
0.95	0.4	0.1	0.61	0.65	0.69	0.73	0.77	0.80	0.83	0.86	0.87	0.89	0.91	0.92	0.93	0.95	0.96
1	0.4	0.1	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57
0.75	0.5	0.1	0.72	0.84	0.91	0.95	0.98	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.8	0.5	0.1	0.70	0.81	0.87	0.93	0.97	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.85	0.5	0.1	0.68	0.77	0.85	0.90	0.95	0.98	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.9	0.5	0.1	0.64	0.72	0.80	0.87	0.91	0.95	0.97	0.98	0.99	0.99	1.00	1.00	1.00	1.00	1.00
0.95	0.5	0.1	0.61	0.65	0.72	0.81	0.86	0.91	0.93	0.95	0.98	0.99	0.99	0.99	1.00	1.00	1.00
1	0.5	0.1	0.57	0.57	0.57	0.61	0.71	0.77	0.80	0.84	0.86	0.87	0.88	0.91	0.92	0.93	0.94
0.75	0.3	0.2	0.72	0.82	0.89	0.92	0.96	0.98	0.98	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00
0.8	0.3	0.2	0.70	0.79	0.86	0.91	0.93	0.96	0.97	0.98	0.99	0.99	0.99	1.00	1.00	1.00	1.00
0.85	0.3	0.2	0.68	0.75	0.82	0.87	0.91	0.92	0.95	0.96	0.98	0.98	0.98	0.99	0.99	1.00	1.00
0.9	0.3	0.2	0.64	0.71	0.76	0.82	0.86	0.88	0.91	0.92	0.94	0.96	0.97	0.98	0.98	0.98	0.99
0.95	0.3	0.2	0.61	0.65	0.69	0.73	0.77	0.80	0.83	0.86	0.87	0.89	0.91	0.92	0.93	0.95	0.96
1	0.3	0.2	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57
0.75	0.4	0.2	0.72	0.82	0.89	0.92	0.96	0.98	0.98	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00
0.8	0.4	0.2	0.70	0.79	0.86	0.91	0.93	0.96	0.97	0.98	0.99	0.99	0.99	1.00	1.00	1.00	1.00
0.85	0.4	0.2	0.68	0.75	0.82	0.87	0.91	0.92	0.95	0.96	0.98	0.98	0.98	0.99	0.99	1.00	1.00
0.9	0.4	0.2	0.64	0.71	0.76	0.82	0.86	0.88	0.91	0.92	0.94	0.96	0.97	0.98	0.98	0.98	0.99
0.95	0.4	0.2	0.61	0.65	0.69	0.73	0.77	0.80	0.83	0.86	0.87	0.89	0.91	0.92	0.93	0.95	0.96
1	0.4	0.2	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57
0.75	0.5	0.2	0.72	0.85	0.91	0.96	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.8	0.5	0.2	0.70	0.82	0.88	0.95	0.98	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.85	0.5	0.2	0.68	0.77	0.85	0.92	0.96	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.9	0.5	0.2	0.64	0.73	0.81	0.87	0.93	0.97	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.95	0.5	0.2	0.61	0.65	0.73	0.82	0.88	0.93	0.96	0.98	0.99	0.99	1.00	1.00	1.00	1.00	1.00
1	0.5	0.2	0.57	0.57	0.58	0.65	0.75	0.82	0.85	0.87	0.92	0.94	0.96	0.98	0.99	0.99	1.00

Fox 70

Ftar	Btrig	Blim	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
0.75	0.3	0.1	0.49	0.57	0.68	0.78	0.85	0.91	0.92	0.94	0.96	0.96	0.96	0.97	0.98	0.98	0.99
0.8	0.3	0.1	0.48	0.56	0.64	0.76	0.85	0.90	0.92	0.94	0.95	0.96	0.96	0.96	0.97	0.97	0.98
0.85	0.3	0.1	0.48	0.53	0.61	0.74	0.83	0.88	0.91	0.92	0.94	0.95	0.96	0.96	0.96	0.97	0.97
0.9	0.3	0.1	0.47	0.50	0.57	0.69	0.79	0.87	0.89	0.91	0.93	0.94	0.94	0.95	0.96	0.96	0.96
0.95	0.3	0.1	0.46	0.48	0.52	0.61	0.73	0.83	0.84	0.87	0.90	0.91	0.92	0.93	0.93	0.94	0.94
1	0.3	0.1	0.44	0.45	0.47	0.51	0.60	0.67	0.68	0.68	0.70	0.70	0.70	0.70	0.70	0.70	0.70
0.75	0.4	0.1	0.51	0.65	0.75	0.84	0.89	0.93	0.94	0.95	0.97	0.97	0.98	0.99	0.99	0.99	0.99
0.8	0.4	0.1	0.50	0.63	0.74	0.83	0.89	0.93	0.94	0.95	0.97	0.97	0.98	0.98	0.99	0.99	0.99
0.85	0.4	0.1	0.49	0.61	0.73	0.82	0.88	0.92	0.94	0.95	0.97	0.97	0.98	0.98	0.99	0.99	0.99
0.9	0.4	0.1	0.48	0.60	0.72	0.82	0.88	0.92	0.94	0.95	0.96	0.97	0.98	0.98	0.99	0.99	0.99
0.95	0.4	0.1	0.47	0.59	0.70	0.80	0.87	0.92	0.93	0.95	0.96	0.97	0.97	0.98	0.98	0.99	0.99
1	0.4	0.1	0.44	0.54	0.67	0.79	0.87	0.92	0.93	0.95	0.96	0.96	0.97	0.98	0.98	0.99	0.99
0.75	0.5	0.1	0.55	0.69	0.77	0.85	0.90	0.93	0.95	0.96	0.97	0.98	0.98	0.99	0.99	0.99	0.99
0.8	0.5	0.1	0.54	0.68	0.77	0.85	0.90	0.93	0.95	0.96	0.97	0.98	0.98	0.99	0.99	0.99	0.99
0.85	0.5	0.1	0.53	0.68	0.77	0.85	0.90	0.93	0.95	0.96	0.97	0.98	0.98	0.99	0.99	0.99	0.99
0.9	0.5	0.1	0.53	0.67	0.76	0.84	0.90	0.93	0.95	0.96	0.97	0.97	0.98	0.99	0.99	0.99	0.99
0.95	0.5	0.1	0.52	0.67	0.76	0.84	0.90	0.93	0.94	0.96	0.97	0.97	0.98	0.99	0.99	0.99	0.99
1	0.5	0.1	0.51	0.64	0.75	0.84	0.89	0.93	0.94	0.95	0.97	0.97	0.98	0.99	0.99	0.99	0.99
0.75	0.3	0.2	0.49	0.58	0.73	0.84	0.90	0.93	0.95	0.96	0.97	0.97	0.98	0.99	0.99	0.99	0.99
0.8	0.3	0.2	0.48	0.57	0.70	0.83	0.89	0.92	0.94	0.96	0.97	0.97	0.98	0.99	0.99	0.99	0.99
0.85	0.3	0.2	0.48	0.54	0.66	0.80	0.88	0.92	0.94	0.95	0.97	0.97	0.97	0.99	0.99	0.99	0.99
0.9	0.3	0.2	0.47	0.52	0.62	0.76	0.85	0.91	0.94	0.94	0.96	0.96	0.97	0.98	0.98	0.99	0.99
0.95	0.3	0.2	0.46	0.49	0.56	0.71	0.81	0.88	0.90	0.93	0.95	0.95	0.95	0.97	0.97	0.98	0.98
1	0.3	0.2	0.44	0.46	0.51	0.61	0.69	0.74	0.75	0.76	0.77	0.77	0.77	0.78	0.78	0.78	0.78
0.75	0.4	0.2	0.53	0.69	0.78	0.87	0.91	0.94	0.96	0.97	0.98	0.98	0.99	0.99	0.99	0.99	0.99
0.8	0.4	0.2	0.52	0.68	0.78	0.87	0.91	0.94	0.96	0.97	0.98	0.98	0.99	0.99	0.99	0.99	0.99
0.85	0.4	0.2	0.51	0.67	0.78	0.87	0.91	0.94	0.96	0.96	0.98	0.98	0.99	0.99	0.99	0.99	0.99
0.9	0.4	0.2	0.49	0.66	0.77	0.86	0.91	0.94	0.96	0.96	0.98	0.98	0.99	0.99	0.99	0.99	0.99
0.95	0.4	0.2	0.48	0.65	0.77	0.86	0.91	0.94	0.95	0.96	0.98	0.98	0.99	0.99	0.99	0.99	0.99
1	0.4	0.2	0.46	0.63	0.76	0.86	0.91	0.94	0.95	0.96	0.98	0.98	0.99	0.99	0.99	0.99	0.99
0.75	0.5	0.2	0.56	0.71	0.80	0.88	0.92	0.94	0.96	0.97	0.98	0.98	0.99	0.99	0.99	0.99	0.99
0.8	0.5	0.2	0.56	0.71	0.80	0.88	0.92	0.94	0.96	0.97	0.98	0.98	0.99	0.99	0.99	0.99	0.99
0.85	0.5	0.2	0.55	0.71	0.80	0.87	0.92	0.94	0.96	0.97	0.98	0.98	0.99	0.99	0.99	0.99	0.99
0.9	0.5	0.2	0.55	0.71	0.80	0.87	0.92	0.94	0.96	0.97	0.98	0.98	0.99	0.99	0.99	0.99	0.99
0.95	0.5	0.2	0.55	0.70	0.80	0.87	0.92	0.94	0.96	0.97	0.98	0.98	0.99	0.99	0.99	0.99	0.99
1	0.5	0.2	0.54	0.70	0.79	0.87	0.92	0.94	0.96	0.97	0.98	0.98	0.99	0.99	0.99	0.99	0.99

b. Catch

Logistic 50

Ftar	Btrig	Blim	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
0.75	0.3	0.1	174	193	214	224	239	250	291	298	303	314	317	320	323	324	326
0.8	0.3	0.1	185	203	223	232	245	257	299	306	311	322	325	328	331	332	334
0.85	0.3	0.1	196	212	232	238	251	262	307	312	317	329	332	334	337	338	340
0.9	0.3	0.1	208	222	239	244	256	267	313	318	322	334	337	339	342	343	344
0.95	0.3	0.1	219	230	247	249	260	271	318	322	326	339	341	343	345	346	347
1	0.3	0.1	230	239	253	253	264	273	322	325	329	342	343	345	347	348	349
0.75	0.4	0.1	162	180	201	214	227	238	301	303	305	321	322	324	326	327	328
0.8	0.4	0.1	173	190	210	221	234	245	311	312	314	330	331	332	335	335	336
0.85	0.4	0.1	183	199	218	227	240	250	320	320	321	338	339	339	342	342	343
0.9	0.4	0.1	194	207	225	232	245	255	328	326	327	345	345	345	347	347	348
0.95	0.4	0.1	204	216	232	237	249	259	335	332	332	351	350	349	351	351	351
1	0.4	0.1	215	224	239	241	252	262	341	337	336	355	353	352	354	353	353
0.75	0.5	0.1	144	161	181	201	213	222	310	306	306	328	327	327	330	330	330
0.8	0.5	0.1	154	170	189	208	220	229	322	316	315	338	337	336	339	338	338
0.85	0.5	0.1	163	178	197	213	225	235	333	325	323	348	345	344	346	346	345
0.9	0.5	0.1	172	186	204	219	230	240	343	333	330	356	353	351	353	352	351
0.95	0.5	0.1	181	193	211	223	235	244	351	340	336	363	359	356	358	356	355
1	0.5	0.1	191	201	217	227	238	248	359	345	340	369	364	360	362	359	358
0.75	0.3	0.2	170	188	208	215	227	237	299	303	306	319	321	323	325	326	327
0.8	0.3	0.2	181	197	217	222	233	242	309	312	315	327	329	331	333	334	335
0.85	0.3	0.2	192	207	225	228	239	247	318	320	322	335	336	338	340	341	342
0.9	0.3	0.2	203	216	233	233	243	251	326	326	328	341	342	343	345	346	346
0.95	0.3	0.2	214	224	240	237	246	254	334	332	333	346	346	347	349	349	350
1	0.3	0.2	225	233	246	241	249	256	340	337	336	349	349	349	351	351	351
0.75	0.4	0.2	154	171	190	204	215	223	311	308	309	326	326	326	328	329	329
0.8	0.4	0.2	164	180	198	211	221	229	322	318	318	336	335	335	337	337	338
0.85	0.4	0.2	175	188	205	216	226	234	334	327	326	344	343	343	344	344	344
0.9	0.4	0.2	184	196	212	221	230	238	344	335	333	352	350	349	350	350	350
0.95	0.4	0.2	194	204	219	225	234	242	353	343	339	358	355	354	354	354	353
1	0.4	0.2	204	212	225	228	237	244	362	349	344	363	360	357	357	356	355
0.75	0.5	0.2	133	148	165	190	199	206	322	312	309	333	331	330	332	331	331
0.8	0.5	0.2	142	156	173	196	205	212	336	323	319	344	341	339	341	340	340
0.85	0.5	0.2	150	163	180	201	210	217	349	333	328	354	350	347	349	348	347
0.9	0.5	0.2	159	170	186	206	214	221	361	342	336	362	358	354	355	354	352
0.95	0.5	0.2	167	177	193	210	218	225	373	351	343	370	364	360	360	358	357
1	0.5	0.2	176	184	199	213	221	228	384	358	348	377	369	364	364	361	359

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Ftar	Btrig	Blim	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
0.75	0.3	0.1	233	252	269	290	298	303	332	332	334	338	339	339	341	341	342
0.8	0.3	0.1	249	264	279	298	305	310	340	339	340	344	346	345	347	346	348
0.85	0.3	0.1	264	275	288	305	311	315	346	345	346	349	350	350	351	351	352
0.9	0.3	0.1	279	286	296	311	316	319	352	350	350	354	354	353	355	354	355
0.95	0.3	0.1	295	296	303	316	320	322	357	354	353	357	357	356	357	356	357
1	0.3	0.1	310	305	310	320	323	325	361	357	356	359	359	358	358	357	358
0.75	0.4	0.1	215	232	249	276	284	289	346	340	338	344	344	343	345	344	344
0.8	0.4	0.1	230	243	258	284	291	295	356	348	345	351	350	349	351	350	350
0.85	0.4	0.1	244	254	266	290	296	300	365	355	351	357	356	354	356	354	355
0.9	0.4	0.1	258	264	274	295	301	304	373	361	356	362	360	358	359	358	358
0.95	0.4	0.1	272	273	281	298	304	308	378	364	358	365	363	360	361	359	360
1	0.4	0.1	286	282	288	300	306	310	377	363	358	369	366	363	360	359	360
0.75	0.5	0.1	189	207	223	255	263	268	361	345	338	349	346	344	341	341	342
0.8	0.5	0.1	201	217	232	259	268	273	369	351	343	354	351	349	340	342	344
0.85	0.5	0.1	214	226	241	263	272	278	375	355	347	358	355	352	340	343	345
0.9	0.5	0.1	226	236	248	266	276	282	380	359	350	361	358	355	341	343	346
0.95	0.5	0.1	238	244	256	268	279	285	384	361	352	363	360	357	342	345	348
1	0.5	0.1	251	253	262	269	281	288	387	363	354	365	362	359	343	346	349
0.75	0.3	0.2	223	239	252	289	293	296	339	337	337	341	342	342	343	342	343
0.8	0.3	0.2	238	250	261	298	300	302	348	345	344	348	348	348	349	348	349
0.85	0.3	0.2	253	260	269	305	306	307	356	351	350	354	354	353	353	353	353
0.9	0.3	0.2	267	270	277	312	311	311	363	357	355	358	358	356	357	356	356
0.95	0.3	0.2	282	279	284	317	315	314	369	362	359	362	361	359	359	358	358
1	0.3	0.2	297	288	289	322	317	316	374	365	361	364	363	361	361	359	360
0.75	0.4	0.2	201	215	227	271	275	277	358	347	343	348	347	345	347	345	346
0.8	0.4	0.2	215	225	236	278	281	283	370	356	350	356	354	352	353	351	351
0.85	0.4	0.2	228	234	243	285	287	288	380	364	357	362	360	357	358	356	356
0.9	0.4	0.2	241	243	250	289	291	292	391	372	363	368	364	361	362	360	359
0.95	0.4	0.2	254	252	256	292	293	294	398	376	366	371	367	363	363	361	361
1	0.4	0.2	267	260	262	293	295	296	397	375	365	379	372	367	361	360	361
0.75	0.5	0.2	171	185	198	244	249	252	377	354	343	354	350	347	341	341	342
0.8	0.5	0.2	182	194	206	247	253	256	388	361	349	359	356	352	339	341	343
0.85	0.5	0.2	193	202	213	250	256	260	397	367	354	364	360	356	336	340	343
0.9	0.5	0.2	204	211	220	251	259	263	405	371	357	368	364	359	334	338	342
0.95	0.5	0.2	215	218	226	252	261	266	411	375	360	372	367	362	332	337	342
1	0.5	0.2	226	226	232	252	262	268	417	378	362	375	369	364	330	336	341

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Ftar	Btrig	Blim	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
0.75	0.3	0.1	276	283	290	295	300	303	306	309	311	313	314	315	317	318	318
0.8	0.3	0.1	292	298	303	307	311	314	317	319	320	322	323	324	325	326	327
0.85	0.3	0.1	307	312	316	319	322	324	326	327	329	330	331	332	333	333	334
0.9	0.3	0.1	323	325	328	330	331	333	334	335	336	337	337	338	338	339	339
0.95	0.3	0.1	338	338	339	339	340	341	341	341	342	342	342	343	343	343	343
1	0.3	0.1	353	351	350	349	348	347	347	347	347	347	346	346	346	346	346
0.75	0.4	0.1	276	283	290	295	300	303	306	309	311	313	314	315	317	318	318
0.8	0.4	0.1	292	298	303	307	311	314	317	319	320	322	323	324	325	326	327
0.85	0.4	0.1	307	312	316	319	322	324	326	327	329	330	331	332	333	333	334
0.9	0.4	0.1	323	325	328	329	331	333	334	335	336	337	337	338	338	339	339
0.95	0.4	0.1	338	338	339	339	340	341	341	341	342	342	342	343	343	343	343
1	0.4	0.1	353	351	349	348	348	347	347	347	347	347	346	346	346	346	346
0.75	0.5	0.1	273	281	286	291	296	305	307	310	312	314	315	316	317	318	319
0.8	0.5	0.1	289	295	299	303	307	316	318	320	322	323	324	325	326	327	327
0.85	0.5	0.1	304	309	310	314	317	326	327	328	330	331	332	333	334	334	335
0.9	0.5	0.1	319	322	321	324	326	334	335	336	338	338	339	339	340	340	340
0.95	0.5	0.1	334	335	332	333	334	342	342	342	344	344	344	345	345	345	345
1	0.5	0.1	349	347	341	341	341	348	347	347	350	349	348	349	348	348	348
0.75	0.3	0.2	276	283	290	295	300	303	306	309	311	313	314	315	317	318	318
0.8	0.3	0.2	292	298	303	307	311	314	317	319	320	322	323	324	325	326	327
0.85	0.3	0.2	307	312	316	319	322	324	326	327	329	330	331	332	333	333	334
0.9	0.3	0.2	323	325	328	330	331	333	334	335	336	337	337	338	338	339	339
0.95	0.3	0.2	338	338	339	339	340	341	341	341	342	342	342	343	343	343	343
1	0.3	0.2	353	351	350	349	348	347	347	347	347	347	346	346	346	346	346
0.75	0.4	0.2	276	283	290	295	300	303	306	309	311	313	314	315	317	318	318
0.8	0.4	0.2	292	298	303	307	311	314	317	319	320	322	323	324	325	326	327
0.85	0.4	0.2	307	312	316	319	321	324	326	327	329	330	331	332	333	333	334
0.9	0.4	0.2	323	325	327	329	331	333	334	335	336	337	337	338	338	339	339
0.95	0.4	0.2	338	338	339	339	340	341	341	341	342	342	342	343	343	343	343
1	0.4	0.2	353	351	349	348	348	348	347	347	347	347	346	346	346	346	346
0.75	0.5	0.2	272	280	285	290	295	305	308	310	312	314	315	316	317	318	319
0.8	0.5	0.2	287	294	297	302	306	316	318	320	322	323	325	326	326	327	328
0.85	0.5	0.2	303	308	309	312	315	326	328	329	331	332	333	333	334	334	335
0.9	0.5	0.2	318	321	319	322	324	335	336	337	339	339	339	340	340	340	341
0.95	0.5	0.2	333	334	329	331	332	343	343	343	345	345	345	345	345	345	345
1	0.5	0.2	348	346	338	339	339	349	348	348	351	350	349	350	349	349	348

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Ftar	Btrig	Blim	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
0.75	0.3	0.1	285	307	303	316	316	359	356	362	365	369	367	371	370	371	372
0.8	0.3	0.1	297	317	311	324	322	368	364	369	372	375	374	377	376	377	377
0.85	0.3	0.1	309	327	318	330	328	375	371	375	378	381	379	382	381	382	382
0.9	0.3	0.1	320	335	324	335	333	382	376	380	382	385	382	385	384	385	385
0.95	0.3	0.1	330	343	330	340	336	388	381	384	386	388	385	388	387	387	387
1	0.3	0.1	340	350	334	343	340	393	385	387	389	391	387	390	388	389	388
0.75	0.4	0.1	268	290	290	303	302	367	360	363	371	373	370	375	373	374	374
0.8	0.4	0.1	280	300	298	310	308	376	368	370	379	380	377	381	379	380	380
0.85	0.4	0.1	291	309	304	316	314	385	375	377	386	386	383	386	384	385	385
0.9	0.4	0.1	302	317	310	321	318	393	382	382	391	391	387	391	388	388	388
0.95	0.4	0.1	311	325	314	325	322	398	385	385	394	394	390	392	390	390	389
1	0.4	0.1	321	332	318	328	325	397	385	386	396	396	391	393	391	391	388
0.75	0.5	0.1	248	270	272	285	284	366	356	358	376	376	371	375	373	373	371
0.8	0.5	0.1	259	279	278	291	290	370	360	362	382	381	376	377	375	376	372
0.85	0.5	0.1	269	288	283	296	295	372	363	364	388	386	381	380	378	378	373
0.9	0.5	0.1	279	296	286	300	299	374	364	366	392	390	384	382	380	381	374
0.95	0.5	0.1	288	303	289	303	303	376	366	368	396	393	387	384	382	382	375
1	0.5	0.1	297	310	290	305	305	377	367	369	399	396	389	385	383	384	376
0.75	0.3	0.2	274	295	293	304	302	368	362	366	370	373	370	373	372	373	373
0.8	0.3	0.2	286	304	300	310	307	378	371	373	377	380	377	380	378	379	379
0.85	0.3	0.2	297	313	307	316	312	387	378	380	384	386	382	385	383	384	383
0.9	0.3	0.2	308	321	312	321	316	395	385	385	389	390	387	389	387	387	387
0.95	0.3	0.2	318	329	317	324	319	403	391	390	394	394	390	392	389	390	389
1	0.3	0.2	327	335	321	327	322	409	396	394	397	397	392	394	391	391	390
0.75	0.4	0.2	255	274	278	289	286	378	367	368	376	377	373	378	375	376	376
0.8	0.4	0.2	265	283	285	295	292	389	377	376	385	385	380	384	382	382	382
0.85	0.4	0.2	276	291	291	300	297	400	385	383	392	391	386	390	387	387	387
0.9	0.4	0.2	285	299	296	305	301	410	393	389	398	397	391	394	391	391	390
0.95	0.4	0.2	295	305	299	308	303	417	398	393	401	399	393	396	393	393	392
1	0.4	0.2	303	312	302	310	306	416	398	393	405	401	395	398	395	394	387
0.75	0.5	0.2	232	251	256	268	266	380	364	363	381	380	374	378	375	375	371
0.8	0.5	0.2	241	259	262	274	271	385	368	367	389	386	380	379	377	377	370
0.85	0.5	0.2	251	267	266	278	275	388	372	369	396	392	385	380	378	379	370
0.9	0.5	0.2	259	274	268	281	279	392	374	371	402	397	389	381	379	380	369
0.95	0.5	0.2	268	280	269	282	281	396	376	373	407	401	392	382	380	380	369
1	0.5	0.2	276	286	269	283	282	399	378	374	412	404	395	382	380	381	368