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An update of the 2015 Indian Ocean Yellowfin Tuna stock assessment for 2016

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1. Introduction

A stock assessment of the Indian Ocean yellowfin tuna was conducted in 2015 and reviewed at the 17th session of the IOTC Working Party on Tropical Tunas (IOTC–WPTT17–2015). Three different modelling approaches were applied to the assessment of yellowfin tuna in 2015, including an assessment implemented using the Stock Synthesis software (SS3) (Langley 2015). The WPTT agreed that the base case model run from the SS3 stock assessment would be used for development of management advice for the Scientific Committee's consideration.

In reviewing the status of the yellowfin tuna stock, the Scientific Committee (SC18) concluded that *"fishing mortality estimates for 2014 was 34% (2–67%) higher than the corresponding fishing mortality rate that would produce MSY. Thus, on the weight-of-evidence available in 2015, the yellowfin tuna stock is determined to be* ***overfished*** *and* ***subject to overfishing"*** (IOTC–SC18 2015).

In response to the advice of the Scientific Committee, the Indian Ocean Tuna Commission (S20) adopted an *Interim Plan for Rebuilding the Indian Ocean Yellowfin Tuna Stock in the IOTC area of competence* (Resolution 16/01). Paragraph 9 of the resolution specified that "*the Scientific Committee via its Working Party on Tropical Tunas, shall in 2016, conduct a new assessment of the status of the Yellowfin stock using all available data*".

The IOTC consultant responsible for the 2015 yellowfin tuna SS3 stock assessment (Adam Langley) had been contracted to undertaken a stock assessment of bigeye tuna for WPTT18. In consultation with the Chair of the Scientific Committee and the Interim Executive Secretary, it was agreed that the consultant would also conduct an update of the 2015 yellowfin tuna assessment for the WPTT18 meeting. It was considered that a full stock assessment of yellowfin tuna was not warranted on the basis that 1) 2015 assessment had included a comprehensive analysis of the main structural assumptions of the stock assessment model and 2) limited new data were available from the fishery from the interim period (2015).

2. Model configuration

The 2015 IO yellowfin tuna assessment model is documented in Langley (2015). For the 2015 assessment, stock status was reported for the terminal year of the model (2014).

The current assessment is an update of the 2015 base case model. The model structure was updated to extend the model period to include the 2015 year. The following sequence of changes were made to the 2015 assessment during the 2016 update process.

Initial	*Base2015*	Base case model from WPTT17
Step 1	*Base2015_SS24z*	Stock Synthesis Version 24z
Step 2	*LLCPUE*	Revised Longline CPUE indices Model extended to include 2015, 2015 catches equivalent to 2014 catches.
Step 3	*Catch2016*	Updated fishery catches, including 2015 catch (source: IOTC Secretariat)
Step 4	*Update2016*	Extend period of estimation for Recruitment deviates (to 2014). Definition of F-age for determination of MSY (2014-2015).

The 2015 stock assessment used the 3.24f version of the Stock Synthesis software that was available on the NOAA toolbox website. The version of the code had a bug related to the growth function applied to determine spawning biomass; the yellowfin assessment includes deviates from the Von

Bertalannfy growth function however the deviates were not incorporated in the growth function applied to determine spawning biomass (and MSY reference points). The bug was fixed in subsequent versions of the SS code. The impact of the change in code was determined by rerunning the 2015 base model with the latest version of the SS code (*Base2015_SS24z*).

Standardised CPUE indices were derived using generalized linear models (GLM) from operational longline catch and effort data provided by Japan, Korea, and Taiwan,China (Hoyle *et al* 2016). Cluster analyses of species composition data by vessel-month for each fleet were used to separate datasets into fisheries understood to target different species. Selected clusters were then combined and standardized using generalized linear models. Yellowfin catch (numbers of fish) was the dependent variable of the positive catch model (lognormal error structure), while the presence/absence of yellowfin tuna in the catch was the dependent variable in the binomial model. In addition to the year-quarter, models included covariates for vessel identity, 5° square location, number of hooks, and either cluster (for region 3) or HBF (for regions 1 and 4).

For the 2016 assessment, three sets of CPUE indices were derived based on different treatment of the fishing vessel variable in the CPUE modelling (Hoyle *et al* 2016). The assessment modelling incorporated the *boat_allyears* set of CPUE indices on the basis that the indices represented the longest time series (1953–2015) and incorporated vessel effects for the period when individual vessel identifiers were available (1979–2015).

The CPUE indices from the years prior to 1972 were not included in the assessment model (as for the 2015 assessment). The regional CPUE indices were normalised and rescaled to area weightings as per 2015 assessment. All CPUE indices were assigned a CV of 0.30.

The following Table specifies the individual sets of CPUE indices used for each model region.

Region	Model variables	Indices series name
1	No cluster, HBF	*Joint_regY_R2_dellog_boat_allyrs*
2	Cluster, no HBF	*Joint_regY_R3_dellog_boat_allyrs*
3	No cluster, HBF	*Joint_regY_R4_dellog_boat_allyrs* [Note: insufficient cl_nohbf indices available for region 3 so used nocl_hbf.]
4	No cluster, HBF	*Joint_regY_R5_dellog_boat_allyrs*

Overall, the extent of the decline in the combined logsheet CPUE indices was less than the magnitude of the decline in the standardised Japanese longline CPUE indices that were incorporated in the 2015 base case model (Figure 1). The combined logsheet CPUE indices provided a more comprehensive time-series of CPUE indices from the western equatorial region in the most recent years (from 2010). In addition, the new analysis extended the CPUE indices to include the four quarters of 2015.

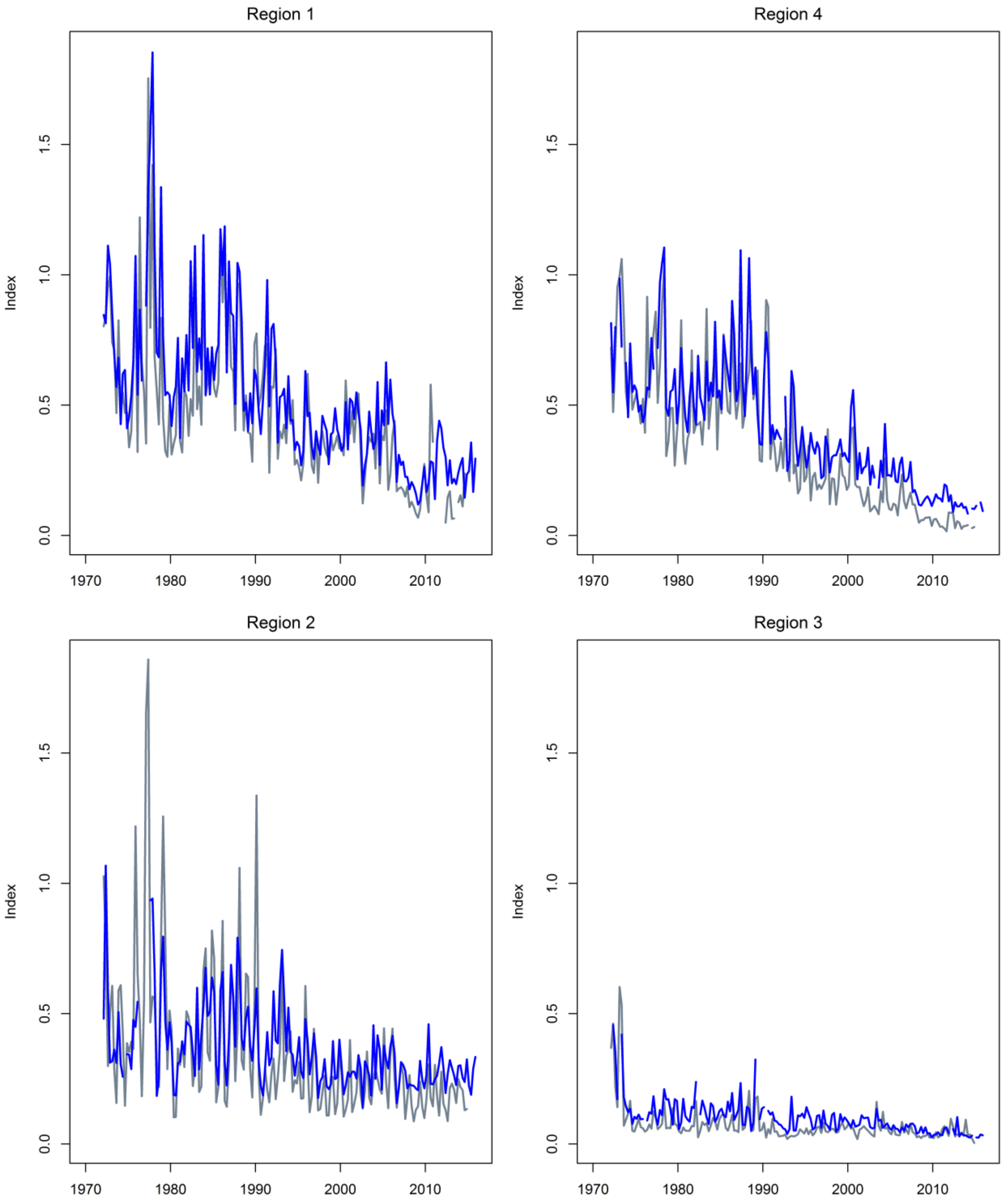

Figure 1. A comparison of the longline CPUE indices included in the 2015 stock assessment (grey line) and the 2016 stock assessment update (blue line).

An update of quarterly catches by fishery was provided by the IOTC Secretariat, including catches from 2015 (as at 17/9/2016). For each fishery, the time series of catches were very similar to the catch series included in the 2015 assessment. The apparent large differences in catch for the longline fisheries is due to a change in the catch units from numbers of fish (1000s) to metric tonnes for the 2016 assessment update. The other appreciable differences in annualised catches relate to the purse seine fisheries in the south-western region (PSLS2 and PSFS 2). For these fisheries, the revised catches for 2014 are considerably lower than the 2014 catch included in the 2015 assessment model.

Total annual catches for 2014 and 2015 included in the updated catch history are 408,511 mt and 407,574 mt, respectively.

For each of the model options, stock status was reported for 2015 and, for comparison with the previous assessment, 2014.

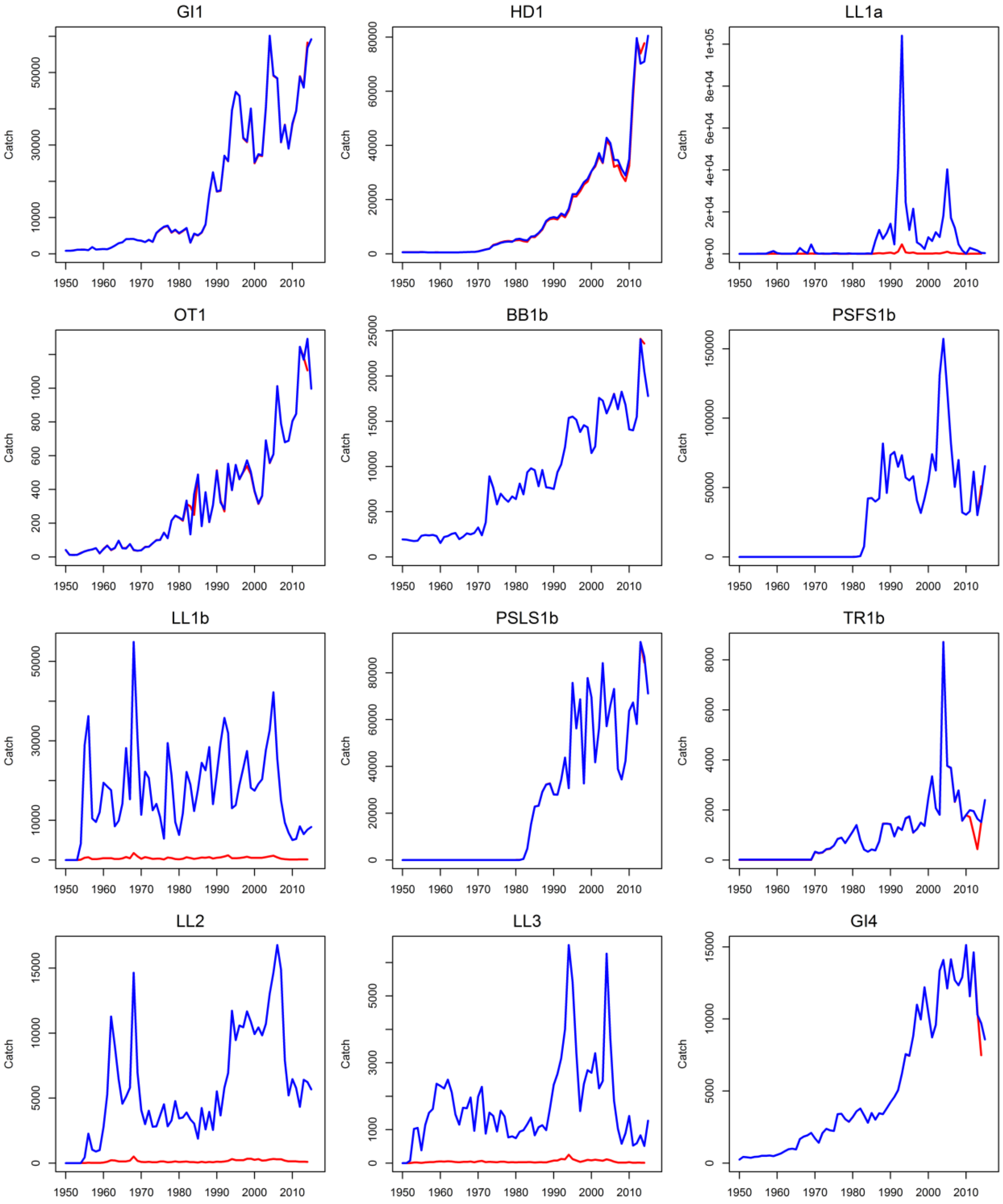

Figure 2a. A comparison of the annualised fishery catches included in the 2015 stock assessment (red line) and the 2016 stock assessment update (blue line).

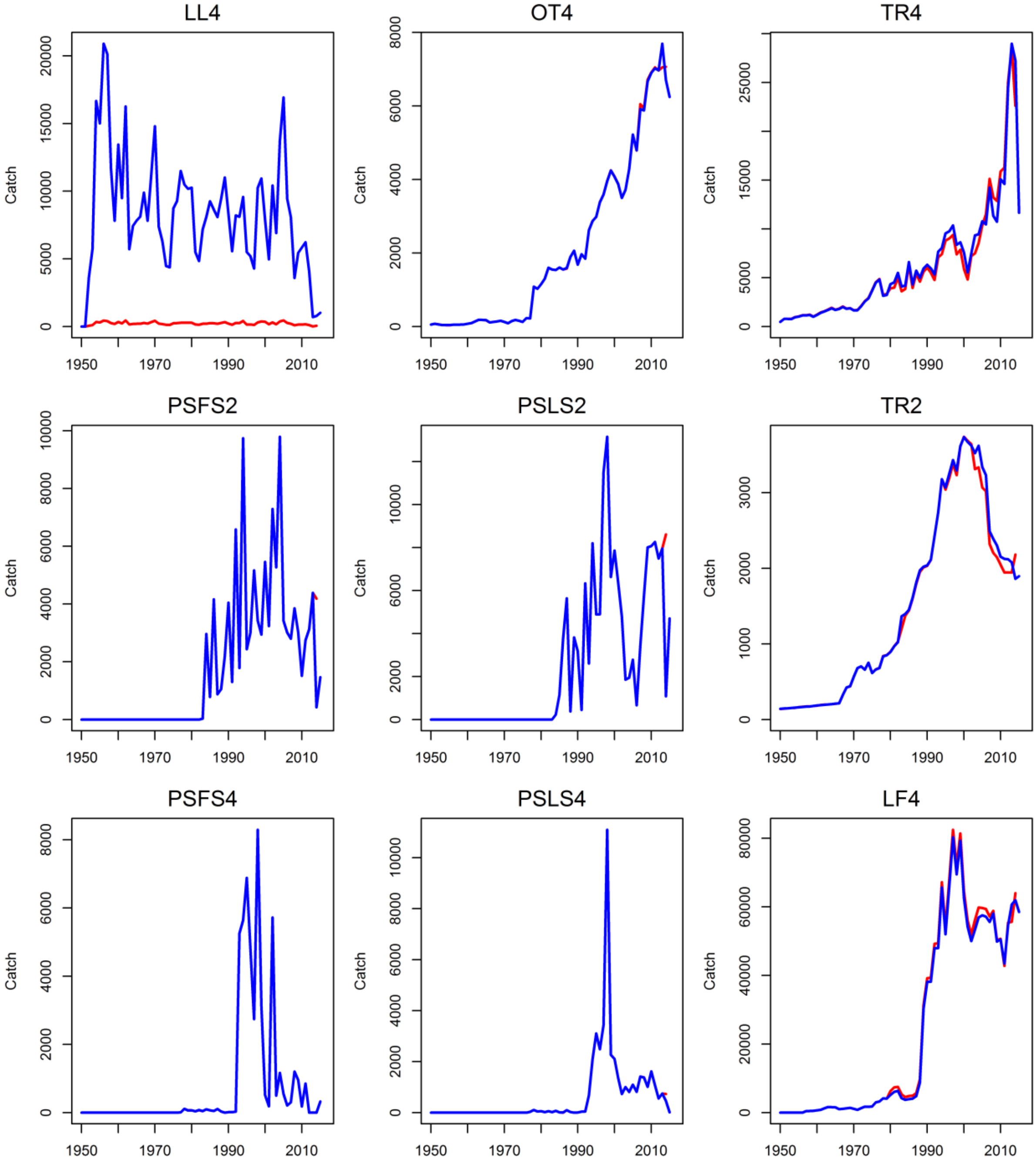

Figure 2b. A comparison of the annualised fishery catches included in the 2015 stock assessment (red line) and the 2016 stock assessment update (blue line).

3. Model update

The latest version of the SS code (Version SS24z) estimated a lower overall level of spawning biomass due to the correction of the computation of spawning biomass to incorporate the deviates from the VB growth function. Nonetheless, the relative trend in spawning stock biomass was comparable to the 2015 base case model and, consequently, the estimates of 2014 stock status were comparable for the two model options.

Substituting the combined logsheet longline CPUE indices for the Japanese longline CPUE indices reduced the overall extent of the decline in spawning biomass. This resulted in a somewhat more optimistic estimate of 2014 stock status; SB_{2014}/SB_{MSY} increased from 0.68 to 0.89 and F_{2014}/F_{MSY} .decreased from 1.36 to 1.27. There was a further slight improvement in 2014 stock status with the updated fishery catch history (*Catch2016*).

Updating the model to extend the period of estimation of recruitment deviates and the period for defining the F-at-age matrix (for computing MSY) resulted in a small increase in the F_{2014}/F_{MSY} ratio (from 1.20 to 1.23) (*Update2016*).

For the model options extended to include 2015, spawning biomass was estimated to be lower in 2015 than 2014 and, consequently, there was a small decline in the SB/SB_{MSY} ratio between the two years. However, there was also a small decline in the F/F_{MSY} ratio between the two years.

The somewhat paradoxical decline in both spawning biomass and fishing mortality between 2014 and 2015 is due to the strong recruitment estimated in 2011 and 2012. This higher level of recruitment has sustained the catches from the fisheries catching smaller (predominantly immature) yellowfin, while the recruitment has yet to contribute substantially to the spawning biomass.

Overall, the incorporation of the new combined logsheet CPUE indices resulted in a slightly more optimistic stock assessment than the 2015 assessment. However, the overall stock status conclusions do not differ substantially from the previous assessment; current (2015) spawning biomass is estimated to be below SB_{MSY} (SB_{2015}/SB_{MSY} = 0.89) and fishing mortality is estimated to be above F_{MSY} (F_{2015}/F_{MSY} = 1.11).

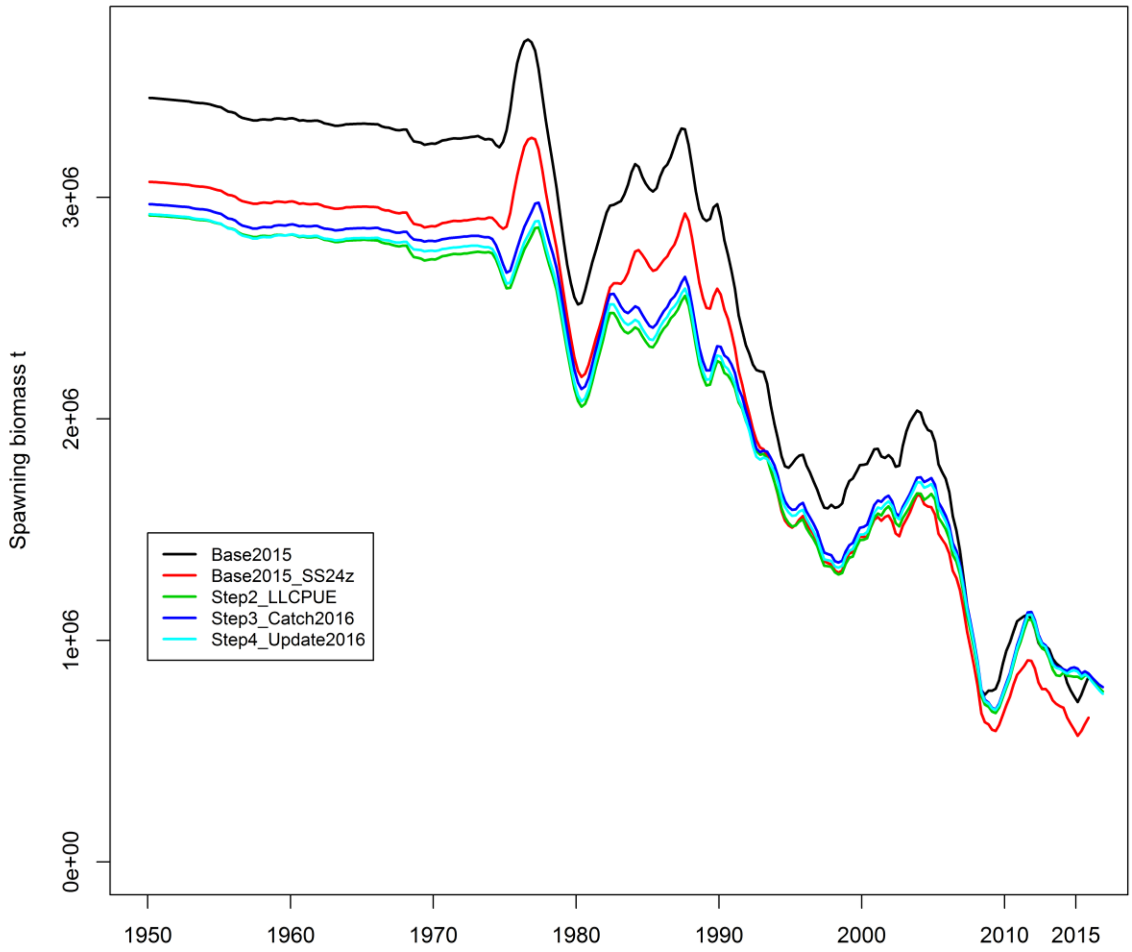

Figure 3. Spawning biomass trajectories for IO yellowfin tuna from the step-wise model updates for 2016 (from Base 2015).

Table 1. Estimates of management quantities for the step-wise updates of the 2015 stock assessment model.

Option	SB_0	SB_{MSY}	MSY	SB_{2014}	SB_{2015}	SB_{2014}/SB_{MSY}	SB_{2015}/SB_{MSY}	F_{2014}/F_{MSY}	F_{2015}/F_{MSY}
Base2015	3,448,810	1,216,510	421,304	799,560	-	0.66	-	1.34	-
Base2015_SS24z	3,069,620	1,009,930	416,788	642,177	-	0.64	-	1.36	-
LLCPUE	2,918,940	951,564	409,984	842,204	836,790	0.89	0.88	1.27	1.20
Catch2016	2,968,840	965,757	423,620	871,229	858,410	0.90	0.89	1.20	1.05
Update2016	2,923,680	947,250	421,840	858,661	844,042	0.91	0.89	1.23	1.11

4. Model sensitivities

A range of model sensitivities were conducted based on the *Update2016* model as the reference (base) model. The specifications of the changes to the reference model are described in the following Table.

The range of sensitivities includes the model options that incorporate standardised CPUE indices from the EU FAD and free-school fisheries (Katara *et al* 2016).

Model option	**Description**
Update2016	Reference model
TagDwt01	Tag dwt lambda = 0.1 for both components of tag likelihood. Represents an arbitrary level of weighting applied to the tag data set that is 10% of the weight associated with the actual number of tag recoveries.
PS_FAD_CPUE	- incorporate region 1 PS FAD CPUE indices, high weighting CV 0.1 - CPUE indices annual - applied to the third quarter - selectivity of PS FAD CPUE linked to PSLS fishery - tag data lambda 1.0
PS_FAD_CPUE_TagDwt01	- incorporate region 1 PS FAD CPUE indices, high weighting CV 0.1 - CPUE indices annual - applied to the third quarter - selectivity of PS FAD CPUE linked to PSLS fishery - tag data lambda 0.1
PS_FAD_SCH_CPUE	- incorporate region 1 PS FAD CPUE indices, high weighting CV 0.1 - incorporate region 1 PS SCH CPUE indices, high weighting CV 0.1 - PS CPUE indices annual - applied to the third quarter. - selectivity of PS FAD CPUE linked to PSLS fishery 24. - selectivity of PS SCH CPUE linked to Fishery 23. - tag data lambda 1.0 - Dwt LL region 1 CPUE indices = CV 1.0
TagMix8Q	- increase tag mix period to 8Q from 3Q. - tag data lambda 1.0

For the reference (*Update2016*) model, there is a relatively good fit to the tag recoveries from the PS SCH fishery. However, the fit to the tag recoveries from the PS FAD (LS) fishery is poor and the model substantially under-estimates the number of tags recovered in the 7–12 quarter age classes.

The following paragraphs provide a summary of the diagnostics and outputs from each of the model sensitivities.

TagDwt01 - Tag data down weighted in the total model likelihood.

- Substantially higher level of stock biomass (R0).
- General decline in recruitment over model period and especially low recruitment during the last decade (from 2005). Relative trends in recruitment are similar to the base model option.
- Modest improvement in fit to the CPUE indices (Survey likelihood -453.112 to -462.047), mainly for LL2. LL selectivity very similar to the base model.
- Further deterioration in the fit to the tag recoveries from the PS LS fishery and deterioration in fit to tag recoveries from PS SCH fishery.
- Considerably higher estimate of *MSY*.
- Change in stock status relative to SB_{MSY} and F_{MSY} compared to reference model.

PS_FAD_CPUE – incorporate EU PS FAD CPUE indices 2004–2014.

- Slight deterioration to fit to LL CPUE indices.
- Poor fit to PS FAD CPUE indices, especially during 2004–2014, apparently due to conflict with tag data.

PS_FAD_CPUE_ TagDwt01

- Deterioration in fit to LL1 CPUE indices, improvement in fit to LL2 CPUE indices.
- Further deterioration in the fit to the tag recoveries from the PS LS fishery and deterioration in fit to tag recoveries from PS SCH fishery.
- Considerable improvement in fit to PS FAD CPUE indices from 2004–2014 compared to *PS_FAD_CPUE*.
- Substantially higher level of stock biomass (R0).
- Considerably higher estimate of *MSY*.
- Change in stock status relative to SB_{MSY} and F_{MSY} compared to reference model.

PS_FAD_CPUE – incorporate EU PS FAD CPUE indices 2004–2014 and SCH CPUE indices 1984–2015.

- LL1 CPUE indices have negligible influence in model fitting (low weighting). Very poor fit to both LL1 and LL2 CPUE.
- Reasonable fit to PS SCH CPUE indices.
- Poor fit to PS FAD CPUE indices, especially during 2004–2014 (probably due to conflict with tag data).
- Change in stock status relative to SB_{MSY} compared to reference model. Lower estimate of *MSY*.

TagMix8Q – increase tag mix period to 8Q from 3Q.

- Reduces contribution of tag data to the likelihood as more tags are excluded from the data set due to the longer tag mixing period.
- Qualitatively, an improvement in the fit to the tag recoveries from PS LS and SCH fisheries (not possible to compare directly).
- Improved fit to the LL1 and LL2 CPUE indices.
- Change in stock status relative to F_{MSY} compared to reference model. Higher estimate of *MSY*.

Other observations

For comparison, an additional model option approximated the exclusion of the tagging data set (weighting lambda 0.01). The model estimated recent (2015) spawning biomass to be approximately three times the magnitude of the biomass estimated by the *Update2016* model and estimated *MSY* at 770,000 t. For the range of model options, the statistical uncertainty associated with the estimates of recent biomass was relatively low (CV 10–15%).

Estimation of *MSY* and stock status was sensitive to the period of recruitment estimation. An additional model option with tag data lambda 0.1 and recruitment deviates estimated for 1984–2014 (compared to 1972–2014) yielded an *MSY* estimate of 520,000 t (compared to 594,000 t for the TagDwt01 model option).

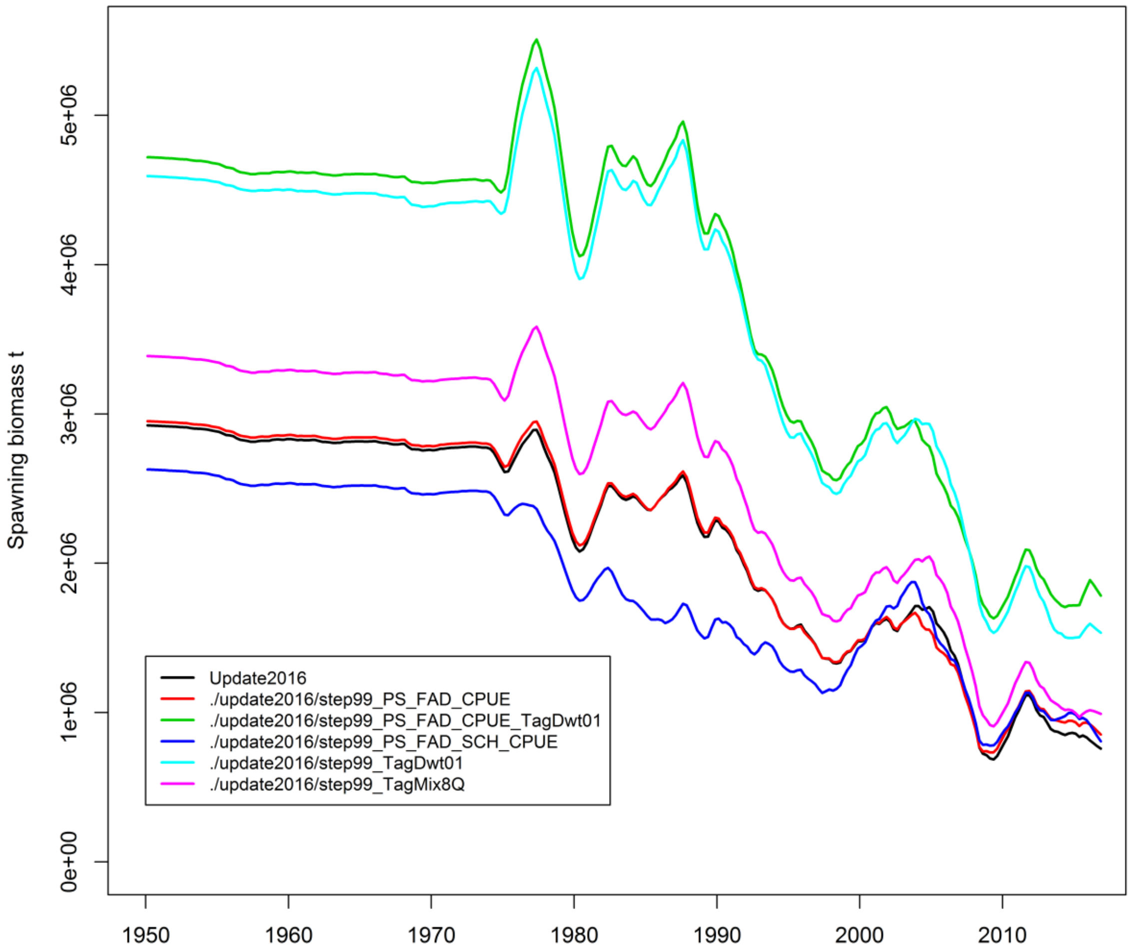

Figure 4. Comparison of spawning biomass trajectories for IO yellowfin tuna from the range of 2016 model options (relative to the reference model *Update2016*).

Table 2. Estimates of management quantities for the 2016 model sensitivities (relative to the reference model *Update2016*).

Option	SB_0	SB_{MSY}	*MSY*	SB_{2015}	SB_{2015}/SB_{MSY}	F_{2015}/F_{MSY}
Update2016	2,923,680	947,250	421,840	844,042	0.89	1.11
TagDwt01	4,592,790	1,468,100	594,012	1,529,253	1.04	0.71
PS_FAD_CPUE	2,951,670	961,572	420,648	927,047	0.96	1.03
PS_FAD_CPUE_TagDwt01	4,719,290	1,467,960	619,156	1,763,688	1.20	0.54
PS_FAD_SCH_CPUE	2,627,980	859,299	376,607	964,547	1.12	1.06
TagMix8Q	3,388,010	1,134,010	463,416	991,493	0.87	0.96

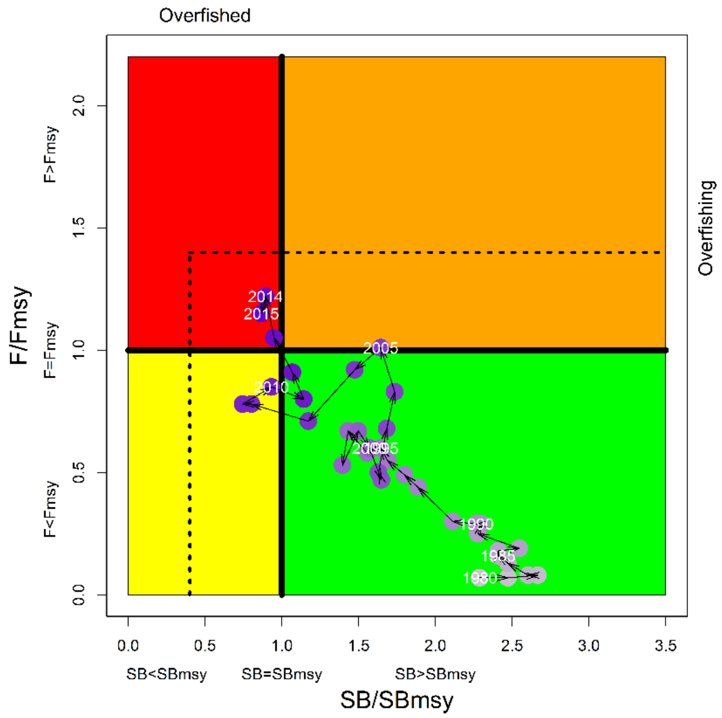

Figure 5. Kobe plot for the *Update2016* model (dynamic MSY).

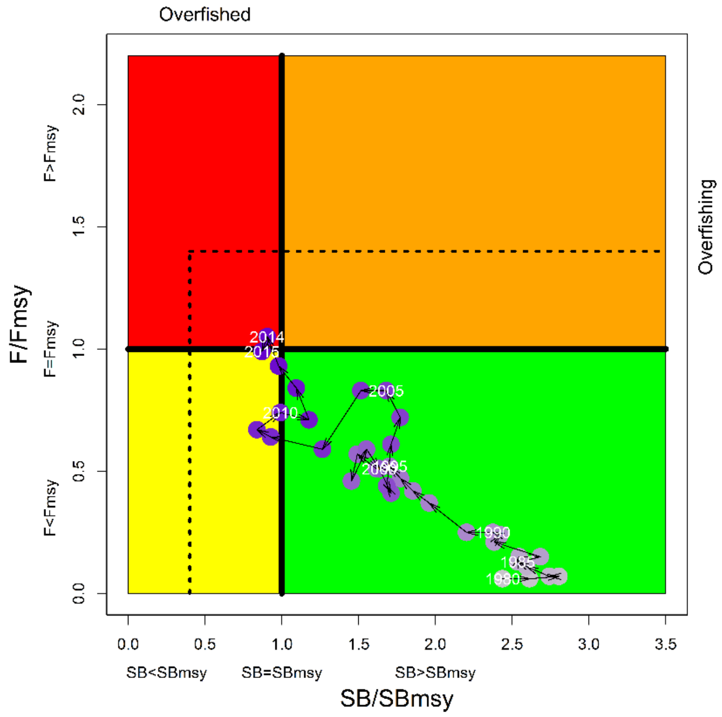

Figure 6. Kobe plot for the *TagMix8Q* model (dynamic MSY).

5. Conclusions

i. The updated assessment model (*Update2016*) is more optimistic than the 2015 assessment, primarily due to the adoption of a new set of longline CPUE indices derived from the combined logsheet data. Nonetheless, the overall stock status conclusions do not differ substantially between the two model options.

ii. There is conflict between the tag release/recovery data and the CPUE data. The relative weighting of each data type influences the population scale parameter (R0). Stock status conclusions are sensitive to the weighting of the tagging data set.

iii. The reliability of the LL CPUE indices as an index of stock abundance is unknown. There are limited data available to evaluate these data. An additional series of abundance indices are available from Indian longline surveys (presented at WPTT17). The trend in the survey indices was generally comparable with the LL CPUE indices; however, the length/age selectivity of the survey is unknown.

iv. More detailed analysis of the tag release/recovery data set is required. For all model options, there is a poor fit to the tag recoveries from the PS LS (FAD) fishery. It appears likely that tag dispersal (after 3 quarters) was inadequate to achieve a sufficient degree of mixing of tagged fish within the western equatorial region. It is assumed that extending the tag mixing period to 8 quarters is likely to have improved the degree of mixing, although additional analyses are required to evaluate the tag mixing assumptions.

v. The length frequency data and CPUE indices appear to be relatively uninformative regarding population age structure. Relative trends in recruitment appear to be influenced by the catch history from the PS LS fisheries. However, the models have considerable flexibility in the estimation of recruitment (R0 and deviates) to account for the contrasting abundance information in the tag and CPUE data sets. The resulting estimates of R0 directly influence the estimates of *MSY* and *MSY* based stock status.

vi. The utility of the PS FAD and SCH CPUE indices as indices of abundance needs to be evaluated by WPTT18.

6. References

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