Indian Ocean yellowfin workplan (2019-2020)

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Abstract

In 2018, the IOTC Scientific Committee (SC) adopted a workplan to reduce the uncertainties of the stock assessment of Indian Ocean yellowfin tuna. In 2019, several tasks of the workplan were addressed and reported to the 21st Working Party of Tropical Tunas (WPTT). However, the WPTT agreed that the progress on the workplan was insufficient to provide new management advice in 2019. The main reasons for this were the complexity of the endeavour, the lack of agreement on key model aspects and time constraints for a thorough examination of the new model during the WPTT meeting. During 2020, works with the yellowfin model have continued. In particular, on clarifying the treatment done to tagging data, on simplifying the model configuration and developing a new approach to produce a new reference case and on a weighting scheme for the uncertainty grid agreed in 2019.

Introduction

In 2018, the IOTC Scientific Committee adopted a workplan to address the uncertainties of the yellowfin tuna stock assessment (Table 1). This workplan contains two main components: *Uncertainty in Data* and *Model Uncertainty*, each one with several tasks with specific activities, responsibilities and timelines. In the first component, the workplan aimed at reviewing and exploring alternatives for the sources of data used in the stock assessment (catch, tagging data, size frequency data and catch per unit of effort (CPUE)). In the second, the workplan aimed at exploring alternative models, alternative model configurations and developing a better characterization of uncertainty. The *Model Uncertainty* component required characterizing the structural uncertainty through alternative key biological parameters and data sources, the statistical uncertainty through resampling techniques and the model uncertainty across model options. Also, this component requests developing a list of diagnostics of model fits to validate stock assessment results and help deciding on alternative modelling options. Finally, the workplan also expects that the Management Strategy Evaluation (MSE) under development for the tropical tunas contributes to improve the stock assessment.

Table 1. Workplan to improve the current assessment of yellowfin tuna (from IOTC-2018-SC21-R[E], Appendix 38).

Item	Options	Responsibility	Timeline*
Uncertainty in Data			
Catch	Explore scenarios of alternative time series/catch histories	Secretariat in collaboration with Chair/Vice-Chair	Short term
Tagging Data	Evaluate alternative use of tagging data	Secretariat for SA	Short term
Size data	Review of size frequency data	Secretariat through a consultancy	Short term
CPUE	Alternative series (EU, Maldives)	CPCs	Short term
	Options for LL CPUE • Joint • Clustering to identify targeting • Long series	CPCs, Consultant identified by IOTC	Short term
Model Uncertainty			
Alternative models	• Biomass dynamic (JABBA, mpb) • Age/size structured (VPA) • Fully integrated (SS3)	CPCs, modelers, WPTT contractor, Secretariat	Short term
Spatial and stock structure	1, 2, 4 areas?	CPCs, modelers, WPTT, contractor, Secretariat	Short, mid-term
Key uncertainty inputs • Weighting of data sources • Key parameters (Growth, tag mortality, steepness) • Catch reporting scenarios	• Weighting of data sources • Decision on options for parameters and seek agreement to reduce options	• Group of experts • data prep • workshop	Short to mid-term
Statistical uncertainty	Bootstraps, Delta methods (Ref case), others…	Modelers, contractor, Secretariat	Short, mid-term
Characterization of uncertainty	• Across models • Across scenarios • Statistical analyses	Modelers, contractor, Secretariat	Short, mid-term
Agreed set of diagnostics (compulsory)	• Retrospectives, likelihoods, jitter analysis hindcasting… similar to the stock assessment, at least on a proposed Reference Case. • Develop protocol for retrospectives correction in stock status	Modelers, contractor, Secretariat, WPTT, WPM	Short, mid-term
Management Strategy Evaluation (contribution to SA)	• Evaluate influence of data • Characterize sources of uncertainty • Improve fits	Contractor, modeler, WPTT, WPM	Short, mid-term

* Short term – Pre WPTT21, Mid-term – Pre SC22

In 2019, a number of these tasks were carried out, but others remain to be done. In this document we provide an overview of the progress made in each task and the model configurations discussed in the 21st Working Party of Tropical Tunas (San Sebastian, Spain, 21-26th October, 2019). We also identify opportunities for addressing the remaining tasks of the workplan and to continue improving the yellowfin stock assessment.

Current development of the workplan for yellowfin

Uncertainty in Data

Under this component, the workplan proposes to review the data sets currently in use for yellowfin and the other tropical tuna stocks. The four sources of data used in the yellowfin stock assessment are catch data, tagging data, size-frequency data and CPUE indices.

Catch data

Under this item, the yellowfin workplan aims at improving the nominal catch series used in the stock assessment. Catch data known as *nominal catch* was reviewed by the IOTC Secretariat in 2019 and a new data set was made available for the 2019 WPTT. The catch data indicates that the total catch levels for all tropical tuna (skipjack, yellowfin and bigeye) combined in 2018 almost reached the same levels as in pre-piracy years (over 1.1 M t) and that this was mainly due to an increase in the catch of skipjack tuna, including increase in catches of yellowfin and bigeye tuna. According to the documents presented by the IOTC Secretariat and the report of the 2019 WPTT, there are still issues with the nominal catches that have not been addressed (IOTC, 2019), including issues with catch series from certain gillnet and purse seine fleets. With regards to the potential issues with the catch composition from EU purse seine fleets the WPTT agreed to re-estimate catch for 2018 using 2017 proportions of species composition applied to the total catch of the EU-Spain fleet of 2018. This re-estimation method was used in the 2019 assessment of bigeye and could potentially be used for yellowfin. A comprehensive information document of this re-estimation procedure was submitted to WPDCS- 2019.

With regards to other issues with purse seine species composition data, a revision of the T3[1] methodology was presented to the WPTT (Duparc, 2019). This study aimed at reducing potential biases on purse seine species composition estimates using statistical models that account for the spatial and temporal structure of the catch. The approach presented in Duparc (2019) has some advantages including that species composition is estimated by sets, which enables finer spatial distribution of the catch by species and that it also enables calculating estimates of the error on catch composition. The WPTT discussed the potential of this new approach to estimate the species composition of catches of tropical tuna in the purse seine fishery.

One of the objectives of the IOTC workplan for yellowfin is to characterize the potential impact of the uncertainty on catches by exploring alternative scenarios of catch for yellowfin. One study presented to the 21st WPTT (Merino et al., 2019), carried-out an exploratory analysis of the potential impact of misreporting of artisanal fisheries' catch of yellowfin. In this work, authors generated three scenarios of underreporting from the catch series available in 2018 and re-run the stock assessment model of 2018. In this paper, a range of exploratory values for inflating the catch that is considered *poor* and *very poor* are used (50%, 100% and 150% inflation). The stock assessment model was run with the new input files with inflated data. Outputs were compared with special attention to estimated time series and stock productivity (estimated Maximum Sustainable Yield (MSY)). The preliminary results suggested that the current uncertainty in the catch information of artisanal fisheries does not produce a noticeable impact on the estimates

[1] A methodology adopted for estimating nominal catch and its species composition for EU PS fleets operating in the Indian Ocean

of stock status, but it does produce changes in the estimated productivity of the stock. In this regard, the WPTT noted that trends in catch misreporting are likely to create more complicated biases than the ones explored with this method, and such scenarios may be more difficult to derive.

Tagging data

One way to investigate fish and fishery dynamics is tagging fish. Fish are tagged and released to obtain information on their movements and biological features such as growth and natural mortality. In theory, fish tagging information can contribute to more reliable estimates of fish population dynamics contributing effective management of fish stocks. The Indian Ocean Tuna Tagging Programme (IO-RTTP) tagging data currently included in the yellowfin stock assessment has a significant impact on estimates of stock productivity and status, and therefore, these data needed careful examination. Unfortunately this task was not completed before the WPTT (a EU science grant funded project on spatial and temporal modelling of the IO-RTTP tagging data was delayed due to the loss of key modellers).

However, during the WPTT, the problems associated with these data were discussed (IOTC, 2019). It was highlighted that the tagging data has a very strong influence in biomass estimates and when tags are wrongly assumed to be mixed over the area, they may provide misleading regional biomass scaling information. This is because if fishing is concentrated where tags are, then the fishing mortality is overestimated and thus, the biomass and productivity estimates tend to be negatively biased. For this reason, tagging data should be modelled at fine spatial scale, which is not the case currently. A proposed idea discussed in the WPTT was to analyse tag data separately and to introduce the results into the model rather than introducing the tagging data into the model as it is done now. These discussions highlight the relevance of analysing tagging data appropriately and suggest that these data will need to be conveniently analysed to improve the current stock assessment. For this, it was important to clarify how tagging data is treated when producing inputs for the stock assessment model.

In 2020, following the parts of the workplan that were not completed in 2019, the IOTC Secretariat prepared the document IOTC-2020-WPTT22(DP)-10. In this document, the procedures used for processing the tag data in the most recent IOTC tropical tuna stock assessments are summarized. These include a detailed description of how data is extracted, filtered to discard errors, assigned to each fishery and age, the application of a tag-induced mortality (and chronic tag loss), and estimating reporting rates. There is a tendency to unify the treatment of tagging data in the three tropical tuna stock assessments but still, there are some differences that needed to be explained to the WPTT.

Size frequency data

In the IOTC, size data are comprised of individual body lengths of IOTC species per fleet, year, gear, type of school, month by 5 degrees square areas (IOTC, 2018c). The IOTC Secretariat has identified several issues with these data and this is the reason why their revision was included in the workplan. The issues include problems with size frequency statistics from longline fleets of Taiwan, China and Japan that remain unresolved. In particular, inconsistencies between the length frequency data and catch-and-effort of longline fleets reported by Taiwan, China since mid-2000s need to be clarified.

Other issues with size frequency data are the lack of reporting of this information by several CPCs for their gillnet, longline and other artisanal fleets (handlines, trolling lines). Size data from some years is not available from important coastal states (IOTC, 2018c).

Some of these issues may have large influence on the yellowfin stock assessment. This is the case of the potential misreporting of small size fish by industrial longlines since 2004 (Sharma, 2018), which affect the size frequency data of the recent years as input for the assessment, but also can potentially affect the joint longline CPUE, which is the main (and currently only) abundance index used in the yellowfin stock assessment (Hoyle et al., 2018, Hoyle et al., 2019). For this, in 2019, the IOTC Secretariat funded a consultancy to identify the issues with length-frequency data and to make recommendations on how they should be used in the stock assessment. This task has been delayed and the project will start in October 2020. Therefore, this task of the workplan will not be completed by the WPTT in 2020.

Catch per unit of effort (CPUE)

Catch and fishing effort can be treated together when producing data for stock assessments. Both data of effort and catch provide indices related to fishing mortality and the density of the exploited stock (FAO, 2019). In the IOTC, catch and effort data refers to the fine-scale data – usually from logbooks – reported in aggregated format: per fleet, year, gear, type of school, month, grid and species. Information on the use of fish aggregating devices (FADs) and activity of vessels that assist industrial purse seiners to locate tuna schools (supply vessels) is also collected (IOTC, 2018c). The 2018 models used to estimate the stock status of yellowfin used only the joint longline CPUE as abundance index. It is considered that other important fisheries' catch-and-effort are either not available or are considered of poor quality (IOTC, 2018c).

This means that for estimation of stock status and historical trends, the stock assessment relied in 2018 on the joint longline index only. This index is the result of a collaborative study conducted by a consultant and experts from the nations with longline fleets operating in the Indian Ocean (Hoyle et al., 2018, Hoyle et al., 2019). The standardization method used in 2018 raised a number of concerns (Sharma, 2018), including the low coverage of some fleets in the fishing areas off the Western Indian Ocean that may be underestimating yellowfin abundance, and the potential impact of unreported discards of small fish on longline fleets, which could potentially cause bias in the abundance index. The extent to which these problems may affect the abundance index and the stock assessment requires further exploration but in the 2019 workshop to produce the joint index these issues were discussed and to the possible extent included in the standardization process (i.e. discards) (Hoyle et al., 2019).

Also, in 2019, two additional abundance indices were developed for Indian Ocean yellowfin with potential to improve the current stock assessment: The EU purse seine free school CPUE (Guéry et al., 2019b) and the fishery independent Buoy Abundance Index (Santiago et al., 2019b). These two indices are derived from the area off the Western Indian Ocean and reflect the catch rates of the purse seine fleets, which have been affected by Somalian piracy in a lesser extent than the longline fleets:

- The 2019 standardization of CPUE for EU purse seines targeting free schools during the 1991-2017 period (Guéry et al., 2019b) contains methodological differences with the index presented in 2018 (Katara et al., 2018), and that was not considered for the 2018 model due to unexplained confidence intervals, absence of differences between the standardized and the nominal indices and that it may suggest that yellowfin biomass was higher in 2018 than 20-30 years before (IOTC, 2018a). The index produced in 2019 followed the approach of the index used in the Atlantic yellowfin stock assessment in 2019 (Guéry et al., 2019a) using a delta-lognormal Generalized Linear Mixed Model (GLMM) with three components: (i) a Poisson distribution to model the density of free schools based on the number of sets (positive and null) per unit of searching time, (ii) a binomial component for the fraction of the free schools with large yellowfin and, (iii) a lognormal component to model the size of free schools with large yellowfin. Along with the usual covariates that describe vessels characteristics and spatio-temporal variability, this study includes null sets (considered as presence of yellowfin in free schools), fishing days without set (considering the absence of free schools), the time spent by boat and day in each location, an index of fishing concentration (Gulland, 1956) and importantly, accounts for piracy as a presence/absence variable, among other improvements, which is not considered in the joint longline CPUE. With regards to this purse seine index, the WPTT noted the high catch rates estimated around the year 2006, which is associated to unusual oceanographic conditions, that could have potentially increased abundance or purse seine catchability. The WPTT agreed to explore the impact of this index on the yellowfin stock assessment but did not recommend its inclusion at this stage. The WPTT noted that there are still things that need further investigation such as the potential effect of Fish Aggregating Devices (FADs) on free-school operations and the potential effect of technological improvements that need to be considered carefully.
- The collaboration with the Spanish vessel-owners associations and the buoy-providers companies, has allowed the recovery of the information recorded by the satellite linked GPS tracking echosounder buoys used by the Spanish tropical tuna purse seiners and associated fleet in the Indian Ocean since 2010 (Santiago et al., 2019b). These instrumental buoys inform fishers remotely in real-time about the accurate geolocation of the FAD and the presence and abundance of fish aggregations underneath them. Apart from its impact in the conception of a reliable CPUE index from the tropical purse seine tuna fisheries fishing on FADs, echosounder buoys have also the potential of being an observation platform to evaluate abundances of tunas and accompanying species using catch-independent data. Current echosounder buoys provide a single acoustic value without discriminating species or size composition of the fish underneath the FAD. Therefore, it has been necessary to combine the echosounder buoys data with fishery data, species composition and average size, to obtain a specific indicator. This index was used in the 2019 stock assessment of Atlantic yellowfin (Santiago et al., 2019a) and the WPTT encouraged further work to refine its estimates. Potential avenues for further exploration suggested by the WPTT include the calibration of signal strength with biomass estimated from catch, further comparisons between brands and models, alternative time windows for sampling and for re-defining aggregation dynamics (IOTC, 2019).

It is also noted the work being done in the Maldives on standardizing yellowfin CPUE from baitboat (pole-and-line) and handline fisheries' catch and effort data. Preliminary results were presented in 2017/2018 WPTT sessions and the use of these data should also be explored further as part of the workplan.

Model Uncertainty

The second component of the workplan aims at adopting best practices of stock assessment including uncertainty quantification and diagnostics. For example, the workplan requested that alternative models are to be considered including alternative spatial structures (IOTC, 2018b). The workplan also requests that the WPTT develops an agreed set of diagnostics to evaluate model performance. Each of the items of this component of the workplan have been somewhat addressed but there is still research to conduct to improve the current stock assessment models for yellowfin:

<u>Alternative models</u>

The 2018 Scientific Committee workplan for yellowfin (IOTC, 2018b) includes the evaluation of alternative models to characterize model uncertainty, ranging from relatively simple biomass dynamic models to fully integrated models like SS3.

In 2019, two stock assessment models different from SS3 were presented to the 2019 WPTT:

- First, the biomass dynamic model *mpb* (Kell, 2016) was used to explore the potential impacts of the existing uncertainties on catch, abundance indices, population dynamics and the searching space for parameter estimation (Merino et al., 2019). The results shown estimate a range of very different stock status and productivity and suggest that the existing uncertainty on this fishery can lead to opposite stock status estimates. The model was accompanied with a number of diagnostic tests, which suggested that the modelling choices such as the constrains on the searching space of parameters, initial values of parameters and the shape of the production function considered would be more influential on the stock status outcomes than choices on the available datasets.
- Second, an alternative assessment using the Bayesian surplus production model *JABBA* (Winker et al., 2018) was presented with generic diagnostics of goodness of fit (Kell and Sharma, 2019). The objective of this work was to assist the IOTC SC in providing robust management advice for yellowfin by evaluating alternative methods and scenarios that reflect the uncertainty on the assumptions and datasets used in the assessment. All the scenarios evaluated with this model indicate that the stock is overfished and undergoing overexploitation, in line with the results of the 2018 stock assessment for yellowfin. An important aspect of this study is that provides a generic set of diagnostics that allows models to be validated using prediction residual and prediction skill. Importantly the framework allows model performance to be compared across different platforms with different model assumptions and datasets. In this regard, the WPTT noted that the paper had some good examples of model diagnostics that might be applied more generally in the IOTC stock assessment process. The models were not intended to provide management advice but rather insight into the uncertainty in the IOTC yellowfin dynamics.

The scientific advice on the stock status of Indian Ocean yellowfin has been developed from the results of the SS3 model (Methot Jr and Wetzel, 2013) applications since 2015 (Fu et al., 2018, Langley, 2015, Langley, 2016). In 2019, an alternative SS3 model was presented to the WPTT which included a proposal for a new reference model configuration (Urtizberea et al., 2019). This model was developed accounting for the recommendations of the external reviewer to the 2018 stock assessment (Sharma, 2018) and additional recommendations by the SS3 model developer (Methot Jr, 2019). This new model was developed from the 2018 stock assessment model and the main changes proposed relative to the 2018 model configuration were the following (more technical details available in Urtizberea et al., 2019):

- *The use of the new version of SS3 (v.3.30)*. For this, the features of the 2018 model were migrated to the new mode version and it was checked that results were equivalent.
- *Reducing or omitting the influence of tagging data*. After a number of diagnostic analyses it was proposed that tagging and environmental data do not contain enough information to estimate the movement between the 4 areas defined in the 2018 model (western-tropical, western-temperate, eastern-tropical and eastern-temperate), and that these data tend to make the model unstable.
- *Spatial structure*: Following the previous comment with regards to information on movement across areas, three spatial configuration options were explored: Two area model (West and East regions), three area model (aggregating regions 3 and 4 of the 2018 model), and the four area configuration from the 2018 model. Results of different analyses suggest that the two-area model is the most stable and therefore, the two-area model configuration was proposed for the reference model.
- *Update with new data*: The proposed reference model was updated with the data available for the 2019 WPTT. The catch and length-frequency data were updated until 2018 and new estimates of the joint index were used. The 2018 reference model was proven to be very sensitive to the most recent length-frequency data and a similar conclusion was raised from the proposed model for 2019. The residuals of fit show that there seem to be systematic changes in the length composition of longline fleets. In the Joint longline CPUE workshop (Hoyle et al., 2019) it was suggested that this could be due to potential lack of reporting of small fish (high-grading) or a sudden change in selectivity. This feature seems systematic across other tuna RFMOs assessments of yellowfin tuna and therefore merits further investigation. For this reason, it was proposed to use the time period of length frequency data as in the 2018 assessment, and thus only data until 2014 were considered.
- *Sensitivity runs*: Several sensitivity runs were also included in this study starting from the proposed new reference model. These include evaluating the impact of two alternative abundance indices developed in 2019 (Guéry et al., 2019b, Santiago et al., 2019b) (see previous section on CPUE), comparisons with the performance of the 4 areas models with different weightings for tagging data, alternative mixing periods for the tagging data, alternative steepness values, natural mortality and constraints to the fit of recruitment deviates.

- *Diagnostics*: Different diagnostics were used to help the development of the reference model. These include jittering, assessment of the likelihood components and convergence of different model configurations, residuals distribution and retrospective fits. This analysis included several of the diagnostics recommended by the WPTT (see below *Diagnostics*). For example, jitter analyses suggested that the two-area model without tagging data is more stable than the four area models used in 2018 and, that residuals of fits improve when size frequency data from longlines after 2014 are omitted.

The WPTT discussed a potential grid that could be developed for scientific advice starting from the proposed reference model including options for growth, mortality and steepness, but also including models with tagging data and four-area spatial structures. From the preliminary results of these, the WPTT noted that there was no strong evidence indicating a qualitative difference on the advice provided in 2018. Instead, there was evidence that key aspects of the model need to be further investigated and clarified. Therefore, the WPTT recommended that more intersessional work should be conducted. Overall, the WPTT noted that the proposed new model represents the culmination of a substantial intersessional collaborative effort to improve the yellowfin assessment using SS3, but further research was necessary before a new advice is provided relative to the status of the stock and before the projections are carried out to build advice on catch limits. The reasons of this are the complexity of the work, the lack of agreement on key model aspects and time constrains during the meeting.

<u>Spatial and stock structure</u>

The most appropriate structure for the stock assessment is still to be discussed. In 2019, there was a proposal (Urtizberea et al., 2019) submitted to the WPTT that recommended a simpler spatial structure using two areas instead of the four-area configuration of the 2018 model (see previous section on the alternative models submitted to the 2019 WPTT). This study analysed the performance of two, three and four area model configurations and supported the two-area model based on a better performance on model diagnostics (jitter analyses and stability) and doubts on the total mixing of the tagging data. This proposal also recommended to omit or reduce the influence of the tagging data. Note that the four area configuration was developed to accommodate tagging data in the first Stock Synthesis model of Indian Ocean yellowfin (Langley, 2015). The WPTT recommended to include the two area model without tagging information as an option for further development but also recommended to keep models with four areas in order to include tagging data (IOTC, 2019).

<u>Key uncertainty inputs</u>

In 2019, different model configurations using alternative values for the growth function, natural mortality and steepness were run as sensitivity tests (Urtizberea et al., 2019). In general, the WPTT noted that options for natural mortality and growth are key parameters in the outcome of the stock assessment using Stock Synthesis and recommended further exploring the most adequate values for these. As a first step, the WPTT recommended exploring two values of natural mortality and growth functions during the WPTT. These include the values used in the last assessments and new options for mortality based on Atlantic Ocean aging information and the growth functions derived from otolith reading, tagged and recaptured fish and length frequency data (Dortel et al., 2015). Also, the different options used in other tuna RFMOs were discussed but the WPTT did not agree on the most adequate values to use and this will need to be explored further in the future. The WPTT did recommend keeping the steepness alternatives used in the previous stock assessments (0.7, 0.8 and 0.9) (IOTC, 2019).

Two other key parameters identified for yellowfin and the other tropical tuna stock assessments are the values of tag-release and tag-loss mortality. These are used to increase reliability of tagging data for use in stock assessment. In the recent sessions of the WPTT discussions were raised on the most appropriate estimates to be used for tropical tuna stocks (IOTC, 2018a), and two alternative options were used in the grid of models used to produce scientific advice. During the 2019 WPTT this matter was further clarified after one study was presented to the group (Hoyle et al., 2015) and the WPTT agreed that the values of release mortality and tag loss included in this study should be adopted for the assessment of the three tropical tuna stocks in the Indian Ocean. The WPTT also noted that new studies are being initiated to re-consider how to utilise tagging data, and the outcomes of this may result in revisions to these values in the future, but the values provided in this paper are the best available estimates currently.

With regards to the current stock assessment model configuration, the WPTT noted that there is some model sensitivity to the choice of method used for weighting different data series and the time period in which recruitment deviates are active. An investigation was undertaken during the WPTT, but the results were not conclusive enough to change the structure of the data weighting in the models. However, alternative weightings will need to be further explored.

With regards to catch reporting scenarios, these have been explained in the *Uncertainty of Data/Catch data* section of this document.

Statistical uncertainty

In the 2018 stock assessment, the impact of statistical uncertainty was not explored. This is usually done using statistical techniques such as bootstrapping, Hessian matrices, Delta methods or other re-sampling methods. In the 2019 WPTT a study presented an application of a multivariate lognormal approach to estimate statistical uncertainty about stock status and future projections for Indian Ocean yellowfin tuna (Winker and Walter, 2019). This method was first used in the 2018 stock assessment of Atlantic bigeye (ICCAT, 2018). This method was also presented to the 2019 Working Party on Methods (WPM) and this recommended its use for the summary plots of the three tropical tuna stocks of the IOTC. The WPTT noted the importance of this approach and also recommended its use (IOTC, 2019), because it provides a visual representation of uncertainty within and among models that appears to describe the expected covariance among stock status indicators.

Characterization of uncertainty

This task of the workplan is somewhat addressed in other sections. This refers to how the structural and statistical uncertainties inherent to the yellowfin stock assessment are characterized across models, scenarios and statistical analyses. When making predictions with computer models two sources of structural uncertainty are encountered: First is referred to the uncertainty about the functional relationships between inputs and outputs (*model uncertainty*) (Strong and Oakley, 2014) and the uncertainty arising when there is no certainty about input parameters or the quality of the different sources of information (*input uncertainty*). The first is generally characterized using stock assessment models developed under different principles and the second is characterized through alternative scenarios built using different key parameters as input and using (or weighting) alternative series of information. In 2019, both sources of uncertainty have been explored (see other sections). Simple models like biomass dynamic models *(mpb* and *JABBA)* have been used together with SS3. Also, scenarios with alternative values of steepness, growth, natural mortality and sources of data (weighting of tagging data and alternative CPUE) have been used to characterize structural uncertainty.

With regards to the statistical uncertainty, as said, the WPTT agreed on using the multivariate lognormal approach to characterize statistical uncertainty on the yellowfin and other stocks' assessments.

Diagnostics

In 2018, several diagnostics were developed for the yellowfin stock assessment. However, an agreed protocol of diagnostics was not adopted (IOTC, 2018b). The 2019 WPTT agreed on a number of diagnostics to be applied to the stock assessment models that include likelihood profiles, jitter analyses, hindcasting, retrospectives and methods to evaluate the robustness of the models. However, the WPTT discussed and noted that diagnostic cannot automate the model selection process but can help choices on the use of different datasets and model configurations (IOTC, 2019). Many of these diagnostics were included in the different stock assessments discussed during the WPTT.

In 2018, the WPTT agreed that it would be useful to carry out a comparison between estimates from current assessments and projection estimates from previous assessments in order to better evaluate the predictive power of the models and to ensure consistency between assessments. This was somewhat attempted through retrospective and hindcast analyses. However, it was noted that hindcast techniques require time for computations and it would be more appropriate to run them before the assessments are presented rather than during the stock assessment session.

MSE contribution to the stock assessment

The yellowfin and other stocks MSE process is helping to quantify the impacts of several sources of uncertainty on the outcome of the stock assessments. With regards to yellowfin, the WPTT agreed to explore further the uncertainty on spatial structure (2-4 regions), stock-recruitment function (steepness values of 0.7, 0.8 and 0.9), natural mortality (base case, ICCAT and WCPFC values), weighting of tag-recapture data (no weight, moderate weight, full weight), growth (models 2 and 3 of Dortel et al (2015)), CPUE catchability trend for longline (0-1% per annum), tropical longline CPUE standardization method (hooks between floats, cluster analysis), longline CPUE error assumption (σ_{CPUE}=0.1 and 0.3), longline regional scaling factors (reference case and alternate) and tag mixing periods (4 and 8 quarters).

The way forward of the yellowfin workplan

In 2019, tasks of the IOTC Scientific Committee workplan for yellowfin were addressed to the possible extent. This includes the proposal for a new reference model using Stock Synthesis (Urtizberea, 2019). However, despite noting the effort and work conducted, the WPTT did not consider that the model had improved enough to justify providing a new advice. Instead, the WPTT identified future developments towards improving the current model and advice.

According to the discussions during the 2019 WPTT the biggest challenge is probably the treatment to tagging data and to model explicit movement. This has implications on the spatial configuration of the model and has a notable impact on the outcome of the stock assessment of yellowfin and the other tropical tuna stocks too. Other challenges include the systematic changes in length composition of the longline fleets, which may be due to high grading, a change in selectivity or change in reporting (Hoyle et al., 2019). Other aspects that require careful investigation are two key biological parameters (natural mortality and growth). These are estimated to have major implications on the outcome of the stock assessment and therefore, merit attention for the development of this model.

In 2019 a number of opportunities to address these issues under this workplan were identified. However, due to the covid-19 pandemic, only a few of these have been possible:

- With regards to the spatial structure, the Indian Ocean yellowfin was selected as one of the two case studies for the Spatial Stock Assessment Methods workshop that was to be held just after the 2020 World Fisheries Congress (Adelaide, Australia, October 2020). The attendance of the main Stock Synthesis developers and those that have been involved in the development of the yellowfin models were planned to help improve the current spatial structure of the model. However, both the 2020 World Fisheries Congress and the workshop have been delayed (in principle until 2021). We will continue exploring possibilities of attending both the workshop and the Congrees.
- The WPTT noted that the results of a consultancy to identify and overcome issues inherent with longline length-frequency data would be provided in the first quarter of 2020. Also in this regard, noting that this issue affects other yellowfin stock assessments in the Pacific and the Atlantic, the 2019 yellowfin model analyst attended the 2nd External review of IATTC staff's stock assessment of yellowfin tuna in the eastern Pacific Ocean (La Jolla, US, 2-6th December 2019). Unfortunately, the review of the size frequency data used in the IOTC has been delayed and revised data will not be used in 2020. In contrast, the attendance to the IATTC meeting has been useful to develop the approach that will be presented to the WPTT in 2020.
- Also, it is important to elucidate the adequate values for key biological parameters. In this regard, the Natural Mortality workshop by the Center for the Advancement of Population Assessment Methodology (CAPAM, 23-27 March, 2020) represented a good opportunity to discuss this matter with top notch

scientists. Unfortunately, this course was also cancelled due to the covid-19 pandemic.

- Further intersessional work will also be required. The WPTT recommended that a data preparatory meeting is scheduled well in advance of the assessment meeting to discuss all data issues before the assessment. This will also allow intersessional work between the data preparatory and assessment meetings. In June 2020, the first WPTT Data Preparatory meeting was held electronically. However, only data for the 2020 skipjack assessment was discussed in this meeting. For the 2020 work on yellowfin, the data available in 2019 will be used.
- The intersessional collaborative work carried out during 2019 should continue using electronic tools (project management tools, shared space for model output and other communication software). This will be coordinated by the Chair of the WPTT (as in 2019).
- Another aspect that requires intersessional analyses is the options for weighting the data series in the model. Further analysis is necessary to investigate alternative periods for recruitment deviates, that could enable better recruitment deviates' patterns, especially in recent years, a very important aspects due to is influence in the projections made to produce advice of tropical tuna stocks.

2020 developments of the Indian Ocean yellowfin stock assessment model

In a brief intersessional meeting between the Chair of the SC, Chair of the WPTT, the Chair of the WPM and the IOTC Secretariat it was agreed to focus the 2020 development of the yellowfin model towards refining the issues found in the 2019 WPTT based on the grid agreed by the group and propose a new advice on stock status and catch limits. In this regards, the model development has included progress towards a more parsimonious model (that will not be included in 2020 but can be useful in the future) and the selection of a reduced group of models based on diagnostics to fit. This methodology will be presented to the WPTT in 2020.

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