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POTENTIAL IMPROVEMENTS TO THE EPO SKIPJACK TUNA STOCK ASSESSMENT FOR THE 2024 BENCHMARK ASSESSMENT

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SUMMARY

The stock assessment for skipjack tuna (SKJ; *Katsuwonus pelamis*) in the eastern Pacific Ocean (EPO) conducted in 2022 was the first assessment undertaken by the IATTC scientific staff since 2005, and it is also the first conventional stock assessment considered reliable by the staff for use in management advice. The stock assessment was conducted using an integrated statistical age-structured catch-at-length approach using Stock Synthesis (Methot and Wetzel, 2013). In 2022 the skipjack assessment was subject to an external review with the objective of improving the assessment. The panel agreed that the basic stock assessment modeling approach was sound but had particular concerns about both indices of abundance (longline and echosounder buoy), the level of natural mortality and its dependence on age, and the strongly dome shaped selectivity for the purse seine fisheries. There are also several other sources of information that can be used to improve the skipjack assessment. These include lessons learnt in the development of the EPO yellowfin and bigeye tuna assessments, lessons from assessments of tuna and other species conducted by other organizations, and information from the CAPAM workshop series and other workshops. Although the management results were found to be robust to these uncertainties, the management advice could be improved by further improvements to the model. A new approach using spatio-temporal models has been developed for analyzing the skipjack tagging data. The results of this analysis will be included in the skipjack assessment. This document describes possible improvements to the skipjack assessment that will be considered for the 2024 benchmark assessment.

1. INTRODUCTION

The stock assessment for skipjack tuna (SKJ; *Katsuwonus pelamis*) in the eastern Pacific Ocean (EPO) conducted in 2022 (Maunder et al. 2022) was the first assessment undertaken by the IATTC scientific staff since 2005, and it is also the first conventional stock assessment considered reliable by the staff for use in management advice. The stock assessment was conducted using an integrated statistical age-structured catch-at-length approach using Stock Synthesis (Methot and Wetzel, 2013). Although the assessment is termed *interim* by the staff, the staff considers it reliable for management advice. The term *interim* results from additional improvements being expected in the skipjack assessment under the ongoing 2021-proposed methodology and workplan to develop a stock assessment for skipjack in the EPO that includes tagging data (see Document SAC-12-06).

The previous benchmark assessment was carried out in 2005 using the ASCALA methodology (Maunder and Harley, 2005). This assessment was considered preliminary and not considered reliable for management advice because it was not known whether catch-per-day fished for purse-seine fisheries was proportional to abundance nor whether the purse-seine selectivity was dome-shaped. Other attempts at evaluating the stock status of skipjack in the EPO used a variety of methods (fishery and biological indicators, analysis of tagging data, a length-structured stock assessment model, and a Spatial Ecosystem and Population Dynamic Model (SEAPODYM); see Maunder (2012)). Evaluation of the skipjack stock status relative to traditional reference points (e.g., MSY-based) was not possible with these methods and the IATTC staff relied on a Productivity and Susceptibility Analysis (PSA) rationale to make inferences about the stock status of skipjack. Through this PSA assessment rationale, since skipjack and bigeye have about the same susceptibility to the purse-seine gear in the EPO PSA (Duffy et al. 2019), and skipjack is the most productive of the two species, if bigeye is healthy skipjack can be inferred to be healthy. More recently, in 2020, the staff has combined the PSA rationale with the quantitative elements of the risk analysis for tropical tuna in the EPO. This combined PSA-risk analysis assessment indicated that the skipjack stock status at the start of 2020, reflecting the stock status associated with *status quo* fishing mortality conditions (2017-2019), was healthy.

An important development from the implementation of Resolution C-21-04 is that the PSA rationale previously used by the staff to assess skipjack on an interim basis is no longer valid. Since the additional measures established under C-21-04 were specifically designed to prevent the *status quo* conditions to be breached for bigeye (the species with the strictest need for management measures), these measures do not necessary prevent increased fishing mortality for the other two species, in particular skipjack. For example, the new individual vessel threshold scheme for bigeye catches could result in a change of fishing strategies by purse-seine vessels with increased fishing mortality for skipjack. Therefore, the stock status of skipjack can only be evaluated through a conventional stock assessment. In 2021, the staff put forward a plan to develop a new (*interim)* stock assessment for skipjack (IATTC-98 INF-F), the 2022 stock assessment being the product of that plan.

In 2022 the skipjack assessment was independently reviewed (see Report of the 1st External Review of the Skipjack Assessment) with the objective of improving the assessment. The review panel was charged with reviewing and making recommendations both with respect to the 2023 assessment and for a tagging analysis and how to use that analysis in future assessments. The panel agreed that the basic stock assessment modeling approach was sound but had particular concerns about both indices of abundance (longline and echosounder buoy), the level of natural mortality and its dependence on age, and the strongly dome shaped selectivity for the purse seine fisheries. There is also conflict in the data, both between the two indices of abundance and between the indices and the composition data. Therefore, there is uncertainty about the absolute abundance and the status of the stock relative to biomass and fishing mortality reference points. Although the management results were found to be robust to these uncertainties, the management advice could be improved by further improvements to the model. The panel suggested that improvements in the model would not remove the substantial uncertainty in the scale of the stock size and strongly recommended further development of the tagging model to provide information on absolute abundance. The estimate of absolute abundance from the tagging analysis would be integrated into the stock assessment model.

A new approach using spatio-temporal models has been developed for analyzing the skipjack recently available tagging data obtained by the IATTC multi-year Regional Tuna Tagging Program in the EPO (RTTP-EPO 2019-2020, see Document SAC-14-07). This approach has been specifically designed to deal with the non-mixing of tags due to practicalities of tagging skipjack and maximize the information content from the data. The model can potentially estimate absolute biomass, fishing mortality, and natural mortality. The results of this analysis will be included in the skipjack assessment (see Document SAC-14 INF-E).

There are also several other sources of information that can be used to improve the skipjack assessment. These include lessons learnt in the development of the EPO yellowfin and bigeye tuna assessments, lessons from assessments of tuna and other species conducted by other organizations, and information from the [CAPAM workshop series] and other workshops. CAPAM has conducted several workshops over the past 20 years starting off as the IATTC October stock assessment workshops and moving to the more formal CAPAM series. The workshops have recently been summarized with a workshop on general stock assessment good practices at FAO in Rome 2022 and one more specific to tuna stock assessment good practices in Wellington, New Zealand, in 2023. The lessons learnt from these workshops will be applied to the skipjack tuna assessment.

This document describes possible improvements to the skipjack assessment that will be considered for the 2024 benchmark assessment.

2. POTENTIAL IMPROVEMENTS

Here we outline the potential improvements to the skipjack assessment. Not all these improvements will be necessary, and some might not be possible in the timeframe before the 2024 benchmark assessment.

2.1. Conceptual model

A conceptual model describes the characteristics of the stock and fishery. It provides a better understanding to create the stock assessment and alternative hypotheses about the stock and fishery dynamics that will be included in the model ensemble to provide management advice. A conceptual model describes characteristics and the available information about them. The characteristics include stock-structure, biological parameters, fisheries, and data. There have been many studies about different aspects of the skipjack stock, but no complete conceptual model has been developed that includes recent information. Creating a conceptual model is a challenging task as it requires collecting and assimilating all the available information, usually taking a considerable amount of time.

2.2. Stock and fishery structure

A single stock of skipjack is assumed in the EPO and the areas as fisheries approach is used to model any spatial structure. The method to determine fishery structure from the length composition data should be extended to allow for irregular spatial definitions and additional covariates. The development of a conceptual model will also help improve the stock and fishery definitions.

2.3. Catch data

The majority of the catch of skipjack comes from the purse seine data, which catches all three species of tropical tunas. A port sampling program is used to determine the species and size composition of the catch. The current program has limited sampling and there can be many space-time strata with no data and therefore information must be borrowed from other strata. A spatio-temporal model of the species proportions (and length composition) might improve the catch estimates. A CAR model has been developed to improve the estimates during COVID years for which the sampling was reduced and this or a related approach could be used for all years (see [Document SAC-13-05]).

The uncertainty in the catch estimates could also be explicitly included in the assessment model. However, the catch uncertainty for skipjack is probably low since it is the largest component of the catch and the improvements listed here may be more important for the yellowfin and bigeye assessments.

2.4. Length composition data

As mentioned in the catch data section, there may be spatio-temporal strata with missing length composition data and a spatio-temporal model might improve the estimates for both the purse seine and longline fisheries. The model might also be able to provide estimates of effective sample size to use in the stock assessment. The length composition data for the indices should be area weighted by CPUE. The length composition data for the fisheries should be weighed by catch.

Weighting of the length composition data needs further consideration. This might include estimating the effective sample size outside the model, using automatic data weighting methods, down weighting or removing length composition from fleets that have unreliable or sparse data (e.g. the dolphin associated purse seine fishery). The approach used may differ by fishery.

The longline length composition data is highly influential in the assessment because this fishery is assumed to have asymptotic selectivity. The quality of this data needs to be investigated to ensure that it is providing reliable information. Longline length composition data from other flags should also be considered for inclusion in the model to confirm the data from the Japanese longline fleet.

2.5. Longline index of abundance

The longline index only covers part of the skipjack stock and skipjack is not a target species and may therefore be subject to unreported discards. Therefore, a more thorough evaluation of the fishery, its data, and the resulting index is needed. For example, information on the discards and their variability over time is needed to ensure the index is reliable.

Unlike the BET and YFT longline CPUE based indices of abundance, the skipjack index is based on nominal CPUE and is not standardized. This approach was taken due to the limited amount of skipjack caught in the longline fishery. However, the application of spatio-temporal methods to standardize the CPUE as done for BET and YFT should be investigated. This includes considering covariates such as hooks between floats and environmental variables.

The length composition data for the longline index is sparce, highly variable, not well fit by the stock assessment model, and is cut off at 60cm. Further investigation of the length composition data is needed including the application of a spatio-temporal model to fill in cells with no length composition samples and the composition data for the index area weighed by the CPUE.

2.6. Echosounder buoy index of abundance

The echosounder buoy index is a collaboration between ASTI and the IATTC (Project J.3.a) and is undergoing continuous improvements including adding new historical data and updating with current data. The index was based on data from the offshore area and new data from more inshore areas is being added. Related, is the mismatch between the spatial distribution used to create the index and the fishery data used to determine the species and size composition. Future work will look at using the composition data for the same areas as the index data is derived and expanding the index data to a wider spatial coverage.

2.7. Selectivity

The assessment results and management advice are highly sensitive to the assumptions about selectivity, particularly whether the purse seine fisheries have asymptotic selectivity. Further work is needed to determine the most appropriate selectivity for the assessment. This might also require redefinition of the fisheries by area, season, or other factors to ensure that the selectivities are "regular" (i.e. double normal or logistic).

2.8. Natural Mortality

The natural mortality used in the assessment was taken from tagging studies in the WCPO. Given the current uncertainty about tagging studies for tunas and the good practice recommendations from the CAPAM workshops, the level of natural mortality and how it varies with age need to be reconsidered. The new spatio-temporal model for analyzing the SKJ tagging data shows promise in estimating natural mortality.

The natural mortality used in the assessments increases for medium aged fish and this is not consistent with the good practices. Although, it is a similar assumption to that assumed for the bigeye and yellowfin assessments where females are assumed to have an increased natural mortality when they mature based on the sex ratio of larger individuals favoring males. This assumption is now being questioned for bigeye and yellowfin due to an indication that maximum size may differ between females and males. Further investigation into the magnitude of M and how it changes with age is needed. Initial good practices indicate that the magnitude should be based on maximum age and M should decline with size based on the Lorenzen relationship. Unfortunately, there is no reliable aging method for skipjack and tag recoveries are generally not available from the longline fleets which catch the largest bigeye. Therefore, maximum age is unknown and other methods need to be investigated to determine the magnitude.

There may be an interaction between natural mortality and selectivity, particularly for the longline fishery or between natural mortality and whether the unassociated fishery has dome shape selectivity. This may require the assumptions about selectivity and natural mortality to be considered together.

The new spatio-temporal tagging analysis is the most promising source of estimates of M. However, several issues still need to be considered such as tagging related mortality, reporting rates, tag shedding, and dome shaped selectivity. The estimates of M from Peatman et al. (2022) should also be considered.

2.9. **Growth**

Estimating growth for skipjack tuna is problematic because reliable aging data is not available and there are few, if any, tag recaptures of large skipjack from the longline fisheries. The tag growth increment data provides substantial information on growth of intermediate aged skipjack, but the absolute age is uncertain and there is little information on the asymptotic age. Research is needed to improve the growth estimates, including variation of length-at-age, and to determine approaches that reduce the sensitivity of the results to uncertainty in growth.

The assessment uses the growth cessation model, but it is uncertain if this is the best model for skipjack. Other models such as the Richards growth curve should also be considered. Fitting the growth model inside the stock assessment should be considered. The length composition data may prove information on growth and the variation of length-at-age.

2.10. **Analysis of TAGGING DATA**

The analysis of tagging data can potentially estimate absolute biomass, fishing mortality, and natural mortality. This information is critical for reducing the uncertainty in the stock assessment and management advice. A spatio-temporal model of the tagging data has been developed to minimize the effects of non-mixing and maximize the information content of the tagging data (SAC-13-08). The estimates of absolute biomass and natural mortality can be integrated into the skipjack stock assessment. The tagging analysis is being conducted by DTU and is continuously being improved (SAC-14 INF-E).

There are several improvements that can be made to the tagging analysis. For example, the processes (e.g. fishing mortality, natural mortality, movement) can be made a function of length. Account should be made for tag loss, tag reporting, and tag related mortality. Diagnostics and sensitivity analyses should be developed to determine the reliability of the estimates and identify model misspecification so the model can be improved. Additional covariates and interactions among covariates for movement could be investigated including ocean currents. Coastal boundaries could be added to the analysis and tag location uncertainty could be included. See the report of the skipjack review for other suggestions.

In the long-term, the tagging analysis could be developed into a standalone assessment method, used directly for management advice, integrated into a harvest control rule, or used as a stock status indicator for monitoring the stock between full stock assessments.

3. INTEGRATION OF THE RESULTS FROM THE TAGGING ANALYSIS INTO THE STOCK ASSESSMENT

The result from the tagging analysis will be integrated into the stock assessment model. This might include estimates of absolute abundance, natural mortality, and/or fishing mortality. The form of the integration will depend on the results produced and their reliability. It is likely that length-group specific estimates of absolute abundance and length-group estimates of natural mortality will be used. The abundance estimates will likely be integrated into the assessment as data and fit using a likelihood function while the estimates of natural mortality will likely be used as priors. Both will include measures of uncertainty.

4. REFERENCES

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