INTER-AMERICAN TROPICAL TUNA COMMISSION

1st EXTERNAL REVIEW OF IATTC STAFF'S STOCK ASSESSMENT OF SKIPJACK TUNA IN THE EASTERN PACIFIC OCEAN

La Jolla, California (USA)
7-10 November 2022
(*participation by teleconferencing optional*)

REPORT OF THE MEETING

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This report is based on discussions during the meeting, interactions of the Panel after the meeting, and feedback provided by IATTC staff on a draft version of this report.

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Overview of the meeting

The 1st review of the stock assessment of skipjack tuna in the Eastern Pacific Ocean was held in La Jolla, California, USA from 7-10 November 2022. The meeting was chaired by James Bence of Michigan State University. The panel was charged with reviewing and making recommendations both with respect to the current assessment and for a tagging analysis and how to use that analysis in future assessments (see Terms of Reference (TORs) in Appendix 1). Participants of the meeting are listed in Appendix 2, and the agenda for the meeting is in Appendix 3.

Summary of the assessment model

An integrated statistical age-structured catch-at-length stock assessment was developed for skipjack tuna in the Eastern Pacific Ocean using Stock Synthesis (SS). A reference model was chosen and sensitivity to key model assumptions were tested relative to the reference model. The assessment model used an 'areas as fleets' approach, with twelve defined fisheries. Ten of these were from purse seines (PS) defined by sets that were associated with dolphins (DEL), floating objects (OBJ), or unassociated (NOA). These PS groups were further split into areas. The areas were different for each fleet type and were defined based on latitude and longitude breaks established by analysis of length compositions. There was a single longline (LL) fishery for the entire assessment area. Catch from gears other than longline and purse seine was added to the coastal OBJ fishery, given the relatively low magnitude of these other fisheries. Discarded catch from the PS fishery was also included as the 12th fishery. Four abundance indices were considered but only two (longline CPUE and echosounder buoy index of biomass) were used in the reference assessment because the purse seine CPUE indices were considered unreliable (i.e., likely not proportional to abundance). Given skipjack cannot be reliably aged, the model was fitted to length compositions of the catch and abundance indices. Model parameters were estimated by penalized maximum likelihood using pre-specified variances and effective sample sizes (for the assumed multinomial distribution for the composition data).

Thirteen sets of length frequency composition data (LFs) were modeled. These include LFs for each of the purse seine fisheries and for the longline fishery, and LFs for the two PS indices and the LL index. The model assumed that the PS OBJ index LF applied to the ECHO index. There was no length composition for the discard fishery, but rather an assumption of constant selectivity between 30 and 40 cm. See Appendix 3 for a listing of the LFs.

Three main dynamic mechanisms, growth, natural mortality and maturity-at-age, were fixed. Due to difficulties with age estimation for skipjack using daily rings in otoliths, growth was assumed to follow a linear growth-cessation model with asymptotic age being fixed. The Richards maturity estimates were taken from the central area.

Length-specific natural mortality (M) was determined from Hampton (2000), but in the reference model natural mortality was fixed at the rate for 65 cm fish, for larger fish, rather than continuing to increase. Length-based M was converted to age-based M for use in the assessment model.

Selectivity was modeled as a function of length for each purse seine fishery using splines with selectivity set to zero at specified lower and upper values. This produced generally dome-shaped selectivity, although the estimated selectivity patterns were sometimes modestly bimodal. The length-specific selectivity for the longline fishery was also estimated by a spline but allowed for non-zero selectivity across sizes, with estimated constant selectivity above a defined length.

Retrospective analyses were done and fits to observed data were presented for the reference model. In general, the reference model (the model considered most plausible) fit the data well and did not show strong patterns in the residuals, or strong retrospective patterns, although no Mohn's rho values were calculated. Results from Age Structured Production Models (ASPM) and catch curve analyses on the reference model suggest that the scale of the abundance estimates was strongly influenced by the length composition data and the indices of abundance were less informative. Likelihood profile plots suggested there were conflicts among the data sources. In particular, the negative log likelihood (NLL) components for the LL and Echo indices increased and decreased, respectively with the scale of recruitment, and the profiles for the associated LFs appeared to be in conflict with their index of abundance.

The stock assessment report provided to the panel identified the assumption of dome shaped selectivity for the purse seine fishery as an uncertainty of concern and also indicated concern about the reliability of various data sources, and hence the report evaluated how sensitive the model was to assumptions and data sources using sensitivity analyses.

The estimated exploitation rate from the reference model in 2021 was slightly higher than the average for 2017-2019, which is similar to what was seen in most of the sensitivity models. The reference model and most of the sensitivity analyses estimated a current biomass above the target reference point (30% of unfished biomass was used as a proxy target reference point for the report) and a fishing mortality below target. The 30% biomass target was based on that target for Bigeye and Yellowfin tuna and an assumption that SKJ would be at least as productive as those species. Spawning biomass was near its lowest value during the assessment period at its start (2006), fluctuated over an approximate four-fold range, and now resides at an intermediate point within that range (based on the reference model). Near the start of the assessment period, spawning biomass dipped below the putative target of 30%, but never approached the limit point of 7.7% of unfished spawning biomass. Estimates of recruitment varied substantially from quarter to quarter but showed not evident trends over time. During the meeting the panel was informed that the target reference point used in the stock assessment report was not accepted by the MSC. Therefore, the panel was requested to review the evaluation of this reference point and alternative reference points presented below. The only sensitivity analyses included in the assessment report provided to the panel that had current spawning biomass below the reference point (and in one case with F above the reference point assumed non-domed or asymptotic selectivity for at least one component of the purse seine fishery (and in some cases excluded the long line index and associated length composition).

The panel agreed that the basic stock assessment modeling approach was sound and did not recommend a major overhaul of model structure in the short term. However, the panel had concerns about the reliability of both abundance indices, the assumed level of natural mortality (and its dependence on age), and the estimated selectivities, particularly regarding the assumed strongly domed shaped selectivity for the purse seine fisheries. To address these concerns, the panel requested the assessment team provide additional data summaries and assessment runs. Several of the requests focused on the longline length composition and index of abundance. The presence of large fish (~80 cm or larger) in the LL LFs is critical to supporting the assumed domed shaped selectivity for the purse seine. All the partitions of the Japanese longline length composition data used in the assessment, examinations of other longline length composition data, and comparisons of LL and PS LFs for data subsets indicated that these large fish are a real feature of the stock and are systematically seen in the LL only in times and places they are not in the PS. The panel requested a sensitivity run leaving out the LL index but not its LF and this showed that the estimated abundance scale depends critically on this index. The current index is nominal LL CPUE, i.e., simply aggregate catch divided by aggregate effort and this makes strong assumptions that might be addressed by standardization (adjusting for other factors). A presentation of temporal and spatial patterns in hooks between floats, which could influence catchability, suggests that standardization approaches could improve this index, and the panel recommends development of a standardization unit for use in future assessments. The assessment results were also sensitive to the echosounder buoy index so the panel requested information on geographical coverage of the echosounder buoys data used in constructing the biomass index. Results showed that the echosounder buoy locations were spatially restricted but generally consistent over years. In the short term, before the next assessment, the panel recommends that the LF data used in association with the index be selected from the same spatial area the echosounder buoys are located. In the longer term, the panel recommended that IATTC work with Industry to expand the spatial range of available echosounder data. Previous and panel requested sensitivity runs demonstrated that assessment results are sensitive to assumptions about natural mortality and that estimation of the level of M internally within the current assessment model is not feasible. The panel recommends use of a different M schedule than was used in the reference model, but the panel notes that this did not change the qualitative status of stock status nor remove uncertainty about M.

Although the panel have made recommendations with regard to M and work on the abundance indices, the panel does not think this work will remove the substantial uncertainty regarding the scale of abundance in the assessment. This suggests that an external estimate of absolute biomass would be of great value to this assessment. Therefore, the panel strongly recommends further work to develop estimates of absolute biomass from tagging data, and that these estimates be integrated into the next assessment as an additional data input.

Recently, due to the lack of reliable biomass estimates by classical stock assessment models and fisheries data, alternative methodologies were sought to assist the skipjack stock assessment in the EPO. New methods were proposed based on the use of conventional and archival tagging data within a spatiotemporal model describing the most probable movements of tagged fish. Two types of modelling approaches were explored: i) matrix exponential approach to compute movement of for each individual tag between release and recapture positions given the underlying spatiotemporal model describing advection and diffusion processes, and ii) state-space model describing the individual fish movement. In both approaches, the movement of tagged fish was governed by a two-dimensional field describing skipjack habitat preferences. The second approach coupled with the Kalman filter was selected for parameter estimation as it was less costly in terms of computation time and memory demands. Movement and habitat parameters were informed from 2152 recovered conventional and 35 archival tags. Mortality rates, both fishing and natural, were estimated by defining the likelihood of tag recapture and non-recapture at a given location and assuming that 100% of recaptured tags are reported and no tag shedding nor tagging induced mortality. Reasonable estimates of thermal preferences, movement, and mortality rates were obtained providing proof of the methods' adequacy. A rough estimation of population biomass could be derived using the Baranov catch equation from nominal catch data and yearly mortality rates estimated from tagging data. The panel recommends continued work on the tagging model in the short term and longer term. In the short term, it will be important to incorporate length-based processes (e.g., changes in environmental preferences with size, selectivity) and natural mortality as functions of length (age) in the tag models, and account for tag loss, tagging related mortality, and reporting rates, as well as providing diagnostics and sensitivity analyses. In the long term, the panel recommends consideration of refined and/or additional covariates to define habitat preference fields, potential interactive effects among covariates in determining the field, and considering the inclusion of ocean currents as part of the movement model. In the long term, the panel recommends further development of the spatial-temporal tagging model to incorporate catch and length frequency data into the model to estimate biomass and production within a single model.

List of analyses requested by the panel and summary of outcomes from the requests

Day 2 requests

Exploration of data:

1. Provide estimates of the proportion of effort and catch included in the grids used in calculating CPUE indices for purse seine by year.

   Rationale: These indices are being used to represent the entire stock but it's conceivable that the spatial distributions change over time so that what appears as a change in abundance could be a change in the proportion of the fish in the included grids.

   Results: Proportions were provided by year for both the NOA and OBJ purse seine data. Generally, the catch and effort data coverage within the grids of OBJ and NOA core areas were consistently over 0.9 and 0.7 respectively. There were no obvious patterns in the proportions that might suggest that CPUE was being unduly influenced by changes in the distribution of fish relative to the core grids.

2. Provide alternative indices based on just raw catch/effort using all grids for purse seine.

   Rationale: This will illustrate how much the choices of leaving out grids (because of issues with including them in the model) and the adjustments being made by the standardization model collectively are influencing the input indices of relative abundance.

Results: The unstandardized CPUE closely tracked the standardized index, although the match was not as good for the OBJ compared to the NOA index. For the NOA index, the standardized index showed larger fluctuations over time than the unstandardized index.

3. Plot the standardized (Z score) of the nominal CPUE for Bigeye, SKJ, and YFT. From the longline fishery from Japan.

   Rationale: To check if the SKJ catch fluctuations were related to fluctuations of other species (high grading or targeting might produce such patterns)

   Results: The standardized Z scores did not show strong negative correlations as might be expected if discard increased when the other tuna catches decreased.

4. Look at overlap of the PS fishery with the LL fishery and compare length compositions in data restricted to be where the LL and PS are both operating.

   Rationale: To see if the large fish observed in the LL fishery were also observed in places where the PS operates.

   Results: LF distribution plots were produced for 5-year blocks East of 125W and West of 125W (i.e., six strata) separately for the OBJ and LL fisheries. From these figures it was clear that the large fish caught in the LL fishery were not caught in the PS fishery despite fishing in similar broad-scale locations and times.

5. Calculate residuals for length compositions adjusted to deal with negative correlation among length classes for multinomial.

   Rationale: Anders Nielsen recommended using PIT (probability integral transformed) residuals for the length compositions rather than simple standardized residuals. The observed and predicted age compositions and associated information were provided by Mark Maunder to Anders Nielsen who calculated the PIT residuals using his R package 'compResidual' (https://github.com/fishfollower/compResidual).

   Results: Although there was some patterning of the residuals, in general, there were not many extreme values or patterning over length bins or years that are a cause for concern.

Stock assessment model runs and summaries of assessment results:

1. Refit the assessment model assuming Lorenzen natural mortality with the scale estimated.

   Rationale:M might be different than assumed.

   a. Set the assumed age at 37 cm is 3 quarters old and estimate M.

      Rationale:Concern that M and growth could be confounded.

   b. Change to the von Bertalanffy with L_∞ and t_0 fixed, K estimated, and estimate M as in 1.

      Rationale:Concern that growth is higher below 40 cm, M and growth could be confounded.

      Results:The von Bertalanffy was not estimated but used parameters that were as consistent as possible with the growth cessation model. The runs where M were estimated for both growth models (growth cessation and von Bertalanffy) produced substantially lower estimates of M, substantially higher biomass, and substantially lower F (but higher "depletion", i.e., lower SBR). These results, although formally fitting the data better, were deemed unreasonable.

2. Fit the assessment model with a higher SE for log-scale catch. A value of 0.1 seems reasonable although using a higher value based on older bootstrap estimates that were mentioned during the meeting (and thought to show higher levels of uncertainty) should also be tried.

   Rationale:The current value of 0.01 appears quite small given what seems to be substantial uncertainty associated with the processes of allocating catch to "fishery" (strata) and species. Recommendation. If this fails then maybe refit the model multiple times to simulated data based on assumed higher level of error.

   Results: This produced little change in biomass or F from the reference fit.

3. Check that tail compression is used when fitting to the LFs. If not then turn on and do model run.

   Rationale: Not applying tail compression to LF data can result in inefficiencies in model runs as the model attempts to fit to many observed proportions of zero. More importantly, attempting to fit to zero proportions can produce large residuals in the outputs and these can overwhelm presentation of residuals in plots.

   Results: It was found that tail compression was not turned on in the reference model (but probably should be). Turning on this option made little difference to the model results.

4. Do a model run with simpler selectivity curves (i.e., double-normal for PS and logistic for LL).

   Rationale:The complex selectivities defined using splines were bimodal in some cases. However, bimodal selectivity is not necessarily required to fit bimodal LFs as bimodality can be explained by other processes (e.g., recruitment / strong year-classes).

   Results: The model was fit using parametric selectivity patterns (i.e., double-normal selectivities for the PS fisheries and logistic for the LL CPUE). Predictably, this model run resulted in a worse total likelihood. However, the fits to all but two of the bimodal LFs were reasonable suggesting that some simplification of the selectivities could be done and that further exploration of the bimodal LFs is warranted to see if these LFs can be further split into smaller fisheries.

5. Redo the likelihood profile plots for the reference model given the vertical lines in different places.

   Rationale:The vertical lines for the figures in the report are not the same for the different plots of the likelihood profiles.

   Results: The profile had been done correctly originally but the wrong plots had been included in the report. The correct plots were presented and did not change the qualitative interpretation that the length compositions and abundance indices were in conflict.

6. Redo sensitivity analysis g: "No longline index of abundance. The longline index of abundance and its associated length composition data are excluded from the model. The selectivity of the longline fishery is fixed at that estimated by the reference case." Requested change is to keep the length composition data and still estimate selectivity for this fishery but do not use the index of abundance.

   Rationale:The length composition for the LL can be used to inform the domed shaped selectivity of the PS fisheries without the LL CPUE but may result in different estimates.

   Results: Leaving out only the abundance index but keeping the associated length composition and estimating selectivity led to an overall substantially higher scaling of biomass over the time series relative to the reference run (Figure 3). In contrast with the original sensitivity analysis g, the higher biomass seen early was higher in run g and did not converge fully on the lower biomass of the reference run by the end of the time series, as the original run g did. This showed that the model results were highly sensitive to both the longline abundance index and the longline length composition, not just one or the other.

Day 3 requests

1. Provide maps showing the locations of the echosounder buoys used to create the echosounder index, overall, and by year or year blocks.

   Rationale:Indices of abundance are most useful when they are representative of the population and there was concern that the index may be spatially restricted relative to the wider distributed fishery. Additionally, there was concern that the high values and decreasing trend at the beginning of the time series might be due to small samples.

   Results:The echosounder buoys used to create the index were in a restricted area relative to the overall distribution of FADs. The annual spatial distributions were reasonably consistent over time, but the sample sizes in 2012 were much smaller in all cells than subsequent years. Echosounder data used in the index were absent from the eastern part of the assessment region for the entire time series.

2. Provide longline species composition over time, and also longline catch Z scores over time for all three tuna species.

   Rationale:Concern about the robustness of the trend in longline abundance index and hence overall biomass estimation.

   Results: A more expansive analysis than requested was presented, showing species compositions, Z-scores of catch, and correlations of log-scale catch over time for the major species caught in the longline fishery. In general, there were no strong negative correlations of the catch among species. The strongest (positive) correlation was observed with shortbill spearfish followed by swordfish. This could reflect a common technical issue but also could reflect a common response of abundance to the environment or targeting of the longline fleet.

3. For longline length composition data, evaluate whether there is an effect of the data origin (by flag, or measured by a Japanese training vessel, by observer, or by crew) on the length frequency of skipjack, e.g., by comparing length compositions of data subsets.

   Rationale:Concerns that length compositions from the Japanese longline was truncated at 62 cm, which may not represent the catch but may be influenced by a lack of retention of small fish, and that fish over 80 cm in the Japanese longline data might be an artifact (e.g., by conversion from weight to length).

   Results:In all the length compositions, there were substantial proportions of fish over 80 cm for the longline fisheries. This was true for the Japanese, South Korean, and French Polynesian flagged vessels as well as for observer data. There were substantial differences in the length compositions among flags for smaller fish. Neither the Korean nor the French Polynesian length compositions were truncated at 62 cm like the Japanese length compositions. The French Polynesian length compositions included a wide range of smaller fish below 50 cm not seen in the other length compositions. The observer length compositions included substantial numbers of fish over 80 cm, and some fish below 62 cm, although there seemed to be a sharp decline in the proportion at exactly 62 cm. These qualitative patterns were seen for observer data both east and west of 120, although the proportion of fish over 80 cm was greater for the observer data east of 120. There was some concern that the data included skipjack that were larger than 100 cm, which was deemed to be biologically implausible and could be a result of data entry errors.

4. Investigate whether the Japanese longline data was collected in length or was transformed from weight.

   Rationale:Errors may have arisen during the conversion from weight to length.

   Results:It was not possible to follow up on this during the review.

5. Not really a run request or specific data analysis but: Are there any data on variables that could influence catchability of longline, such as hook size or hook depth? What can be said in general about potential for changes in catchability/fishing power for the longline fishery which could explain the positive trend in the derived biomass index?

   Rationale:The panel envisions having a discussion on this rather than just looking at results of specific analysis.

   Results: Data on hooks between floats were presented. Other data might be obtainable but not during the review. The hooks between floats is indicative of depth fished as more hooks between floats will fish deeper. There was a general increase in the hooks between floats and some change in the skew of the distribution over time and within a year substantial variation. There was also evidence that there was spatial variation in the distribution of hooks between floats that changed over time. This variable might be valuable in a standardization if catch per hook turns out to depend on it.

6. Calculate CPUE for the longline data by east/west of 120.

   Rationale: The panel realizes this will be sparse and perhaps with no observations for one of the regions in some years, but looking to see if overall trend is potentially influenced by location.

   Results:The patterns were quite erratic and it seems likely that some of this was due to large observation errors due to small numbers of sets.

7. Do a model run using Francis iterative reweighting of the LF likelihoods (or if not feasible lower level of the effective sample size).

   Rationale:Relative data set weighting between indices of abundance and LFs and among the different LFs can result in very different stock assessment outcomes.

   Results:The model run that used the Francis reweighting method resulted in a very different trend in the biomass through time and a different perspective of the stock status. This result is not surprising but is a concern.

8. Provide a Kobe plot for the panel requested runs with runs distinguished so individual models can be identified. The panel is fine with using the same reference points for standardization as were used in the plot in the assessment report.

   Rationale:Evaluate the robustness of the management recommendation to alternatives.

   Results:Most runs produced biomass/F pairs in the right lower quadrant where biomass is above the reference and F is below the reference. Exceptions included the runs where natural mortality was substantially lower than the reference run, where the results were in the upper left quadrant (overfished and overfishing) and the Francis reweighting case that was in the lower left quadrant (overfished not overfishing).

9. Analysis with alternative M from Peatman et al. 2022 (a. pttp early mixing of 2 and b. averaged across tagging programs and mixing periods).

   Rationale:Estimates of natural mortality from Peatman et al 2022 are thought to be more reasonable than Hampton 2000 because the models are on a quarterly time step (consistent with the assessment model), account for time varying fishing mortality, and are from the most recent tagging program.

   Results:The model with the average M at age from Peatman et al 2022 was similar to the reference case but marginally more pessimistic. The model that used the estimates of M from the PTTP with a mixing period of 2 quarters had a lower M for the older ages and resulted in a slightly larger biomass but a much more depleted SBR and dynamic SBR. Estimates of depletion appear to be very dependent on the assumed value of natural mortality for the oldest ages.

10. Check if sigma R given as input is consistent with the temporal variation in the recruitment estimates. If not, adjust the sigma R and do a run with the new value of sigma R. Here sigma R input is the assumed standard deviation specified when fitting the model and the output is the empirically calculated standard deviations of recruitment estimates.

    Rationale:The panel interpreted some Stock Synthesis output as suggesting the standard deviation of the estimated recruitment was much higher than was specified as an input.

    Results:The output sigma was actually only modestly less than the input sigma and using the output sigma as a new input sigma did not make an appreciable difference to the reference model.

Panel Deliberations Relative to Each TOR

Integrated stock assessment model

Species composition and catch

The species split of SKJ, yellowfin, and bigeye is important as it is used to derive many data sources including splitting the catch, producing the LFs (i.e., these are weighted by the catch), and the split of species in the echosounder indices. It was clear from discussions during the review that there is substantial uncertainty associated with allocating total catch to SKJ and other species. An alternative approach to that currently used that the panel thinks is worth considering is to develop a model of the proportion of species in each stratum (i.e., set type, area, month, vessel size class area) which can then be applied to the relevant data sets. For example, a multinomial GLMM could be fitted to the number of each species caught within each stratum (or even at a lower level such as the well) enabling predictions of the proportion of each species to be made at any level (e.g., Roberts et al. in prep.).

The panel recommends that uncertainty associated with the SKJ catch by fishery (for each quarter) be estimated by accounting for uncertainty in the allocation processes described above and that, based on this, more realistic standard deviations for catch be used as an input in the stock assessment. While a larger SD used in a requested model run during the review had no influence, it is conceivable that the catch is more uncertain than was assumed. An alternative approach would be to fit the model using alternative catch histories in a Monte-Carlo bootstrap ensemble (Ducharme-Barth & Vincent 2022) or test sensitivity to these different catch histories (rather than higher SDs on the catch).

Natural mortality

There is considerable uncertainty with the estimates of natural mortality (M) used in the reference model. The reference model assumed a fixed natural mortality estimated by an external study in 10 cm bins (Hampton, 2000) translated to age by the growth curve. The stock assessment group investigated the robustness of biomass estimates with respect to uncertainty in natural mortality rates for older fish by using the estimates in Hampton (2000) for sizes greater than 65 cm as a sensitivity and with a Lorenzen natural mortality curve scaled to the estimates for the 41-50 cm and 51-60 cm size bins. Due to high uncertainty of this estimate, the panel requested additional runs with Lorenzen mortality with an estimated mean scale as well as with the estimates made by Peatman et al. (2022).

M for SKJ is very high relative to other species, which is supported by several studies (Hampton 2000, Hillary & Eveson 2015, Peatman et al 2022). Estimating M within the assessment model resulted in estimates of natural mortality that were approximately 0.44 $year^{-1}$, which are considerably lower than other estimates for this species. The models that estimated natural mortality resulted in numbers of fish in the plus group at the same level of abundance as the recruits, which was deemed unreasonable by the panel. It appears that the length composition data (likely the longline) is best fit by having a very large number of fish in the plus group, which could be due to a lack of overlap of the LL length composition with those observed in the PS fleets. This conclusion is supported by a better likelihood for the Peatman PTTP Mix 2 mortality rates compared to the Peatman average M's, which were most different for the largest fish (Figure 4). There was concern that the highly flexible spline function and truncated length frequency of the longline fishery did not overlap with other data sources; thus, the model may have difficulty estimating the scale of abundance from the longline information alone.

As a result of the uncertainty in the estimates of M and the sensitivity to these assumptions, the panel recommends:

1. Further testing the sensitivity of natural mortality values in combination with alternative functional forms of selectivity for the LL fishery (e.g., simple logistic)
2. Test the sensitivity of biomass estimates to M values with alternative LL length composition data that has larger overlap with the NOA length composition.
3. Using estimates of M from the Brownie analysis of Peatman et al (2022) instead of Hampton (2000), if not using estimates from tagging in the EPO.
4. Long term, use estimates of natural mortality from the tagging analysis once the model incorporates all tag loss processes (e.g., tag shedding and tagging mortality).

Growth

Growth (length-at-age and its variation) is integral to the assessment as the composition data are length-frequency data (no age composition data is available). Growth was estimated outside the stock assessment model using two separate models: a measurement error model; and a growth cessation model. Both models were fitted to tag-recapture data with measurements of the size at release and recapture. The range of sizes at capture and recapture is limited to between 40-70 cm, meaning that there is considerable uncertainty about the growth of fish smaller than 40 cm and larger than 70 cm. The growth model estimated the age at capture for each tagged fish (as a fixed effect). However, the growth cessation form was assumed so the panel suggests a similar approach trialed with different growth functions.

The observation/measurement error was estimated by extrapolating based on decreasing time at liberty, but was found to be too low when attempting to use it within the assessment model, so this value was arbitrarily inflated.

The panel recommends:

- Fitting to the growth model within the assessment model as the abundance indices and LFs will provide some information about growth, measurement error, and process error.
- Consider using a length-based model rather than an age-based model to avoid needing to develop a length-at-age curve.
- Conduct field experiments to estimate a skipjack specific shrinkage correction factor.
- Further refine the high confidence tag recaptures to better understand or reduce the measurement uncertainty.

Length frequency data

There are three important aspects to consider when developing and fitting to LFs in stock assessment:

1. how the proportions at length within each LF are derived;
2. how to assign a measure of uncertainty to each LF; and
3. how to assign relative data set weights to each data set (including the LFs) within the stock assessment.

Generally, proportions at length are derived empirically and are weighted by the catch or an index of abundance. However, recent work has investigated standardizing LFs (e.g., Thorson 2014, Webber 2022). Standardizing LFs solves two main issues: (1) if LF data are missing within a stratum (e.g., an area wasn't sampled in a year/month), but there was some catch taken from that stratum, then the aggregated LF scaled by the catch may not be representative of the entire catch; and (2) the standardization model can provide a measure of relative uncertainty for each LF.

The measure of uncertainty (e.g., the effective sample size) used in the likelihood for composition data can have a substantial effect on the results of any stock assessment. Fish caught by a particular gear can have substantial correlation in their age or size in a set, trip, or a time-spatial strata. Therefore, the sample size of the composition data should be analyzed outside the stock assessment model. There are three broad approaches for doing this:

- choose an appropriate measure of sample size (e.g., number of sets or trips);
- using empirical bootstrap analysis (Bull & Dunn 2002); or
- a model-based approach (Thorson 2016; Neubauer & Tremblay-Boyer 2019; Webber 2022).

Finally, relative data set weighting can have a big impact on stock assessment outcomes. The McAllister & Ianelli (1997) weighting approach was used to derive the relative data set weight for each LF in the SKJ stock assessment, using as the input sample sizes for the purse-seine fisheries the number of wells (recognizing the number of fish would overstate the information content of the length compositions, due to correlations due to fish sampled from the same school). Nevertheless, the LFs are highly informative of the biomass in the reference model. Alternative approaches for iterative reweighting have been developed by Francis (2011).

Therefore, the panel recommends:

1. Attempting a model-based approach to standardizing the LFs (i.e., predicting the expected proportions for each LF) and deriving relative uncertainty for each LF
2. Consider alternative approaches to weighting the length compositions (e.g., self-weighting Dirichlet distribution, iterative procedures such as Francis 2011). When doing this keep in mind

that external estimates of uncertainty likely overestimate the information content when the assessment model does not allow for process variation in selectivity.

3. Check the logbook data to confirm that the Japanese LL LFs are sensible or not, in particular if the substantial numbers of skipjack >80cm can be trusted. Consider using length frequency data from other LL flags.
4. Rather than using the catch per set weighted LF from the PS OBJ fishery for the ECHO index, limit the PS OBJ LF data to the spatial range of the ECHO CPUE data and reweight to the relative abundance to estimate a new selectivity fitted to these LFs.
5. Test sensitivity of the model results to the down-weighting value of the PS DEL length composition sample size. Alternative methods that are less subjective could include weighting the sample sizes relative to the PS OBJ sample sizes based on the relative catch of the two fleets.

Abundance indices

The reference assessment model fitted to two indices of abundance: an index of abundance based on echosounder buoys (ECHO), and catch in numbers of fish per hook in the Japanese longline (LL) fishery. The length composition of the catch per set of the PS OBJ index was assumed to apply for the ECHO indices (so when both the PS OBJ and ECHO index were in the model they had the same selectivity). The LL CPUE series had its own LFs which were fitted with its own selectivity curve.

The panel was concerned that the LL index only covers a small portion of the stock (i.e., spatially restricted and small proportion of the catch), skipjack is not a targeted species of the LL and the catch may be subject to unreported discards, the LFs associated with the LL index were relatively poor quality (i.e., based on few length samples), and the model fits to the LL LFs were poor in some years (Figure 1).

The panel was also concerned that the ECHO index was not providing a reliable index of SKJ abundance due to some of the assumptions that are currently made. Currently the exclusion of small organisms (e.g., phytoplankton/zooplankton) is done by considering the acoustic response from below 25 m under each buoy, which was empirically estimated from the Indian Ocean study. Then the skipjack tuna abundance is derived from the species composition in associated OBJ catches. Not considering other species around the buoys (below 25m) and the empirical species splits based on the fisheries data indicate high uncertainty of the derived biomass index. The echosounder buoy data used in the index are spatially restricted both with respect to the overall assessment area and to the PS OBJ sets (which provide the LF and species compositions). Regarding length distributions, it seems likely that there is little gear size selectivity related to targets included in the recorded biomass. Thus, assuming the same size distribution for the echosounder and PS OBJ indices implicitly assumes that the selectivity for the PS OBJ index is driven by where the sets occur, not gear selectivity. Furthermore, the two abundance indices appeared conflict with each other, with the LL CPUE suggesting an increasing trend and a lower R_0 compared to the echosounder indices (Figure 2).

The panel recommends:

1. Standardizing the LL CPUE series.
2. Verifying with the data providers that the LL catch data are not likely to be subject to high variability in discard over time.
3. Further work on the echosounder buoy abundance indices and inclusion of uncertainty in the assessment that corresponds to the R^2 =0.39 relationship of tuna catch with buoy biomass estimates.

Reference points

The panel was advised that the biomass reference point of 30% of unfished level (as a conservative level based on reference points used for other tunas) had not been accepted, and additional analyses were presented as a basis for selecting an alternative biomass (and associated F) reference point.

During the meeting Mark Maunder presented new analyses to evaluate and estimate a reference point and soon after the meeting he provided the panel a rough draft report providing additional background on those analyses. The approach consisted of taking the stock synthesis assessment parameter estimates but replacing the h=1.0 used during estimation by a lower but deemed conservative value of h=0.75 to calculate MSY spawning biomass and associated F. For the reference model, MSY spawning biomass was estimated to be 15% of the unfished biomass, and across all the assessment sensitivity runs most were near this value and the maximum MSY biomass was 23% of the unfished biomass.

The panel concludes that the 30% value used in the original assessment report is conservative as a surrogate for MSY biomass, assuming that h=0.75 is indeed a plausible lower bound. Given the use of h=1.0 in the reference assessment, 30% of unfished spawning biomass corresponds to an SPR (spawning biomass per recruit) of 30%. The panel thinks the draft report could benefit by some review of what assessment results suggest regarding recruitment versus stock size relationships. In particular, can it be shown that h<0.75 is implausible for SKJ? The draft report also includes some evaluation of the probability of the stock size being below various proposed target reference points and the limit reference point. The probability of being below the limit reference points is essentially zero across all sensitivity runs (if this probability was greater than 10% management action is required). All sensitivity runs that assumed dome shaped selectivity for the purse seine fisheries also estimated probabilities of less than 10% of being below the target reference point. Projections for the reference model also indicated that the probability of falling below the 30% reference value were less than 10% over the next decade, at current fishing mortality rates.

Tagging analysis methods

Two modeling approaches were explored for tagging data analysis. First, the matrix exponential method applied to spatiotemporal advection-diffusion model (Thorson et al., 2021) was used to compute tags movements. In this case, the matrix exponential operator was used to integrate instantaneous movement rates between adjacent cells during the time at liberty interval, then this movement matrix was used to calculate the probability of moving from release to recapture position and to estimate the model parameters, advection and diffusion rates. However, due to the need for time and space discretization this method was rejected for being impractical due to long computing times, and for sensitivity to the spatial scale of discretization. For the second approach a state-space equation describing fish movements in continuous space (but discrete time) due to advection and diffusion was proposed, with individual movement probability approximated using a Kalman filter. For the conventional tags, the trajectory of each tag was modeled independently, with the release position known and predicting the intermediate positions at discrete time intervals, as well as recapture position. The recapture positions of conventional tags are augmented to the likelihood computed via a Kalman filter. For archival tags, each observed location, including those between release and recapture, are included in the likelihood, allowing for a more natural use of these data than was possible with the discrete-space approach.

The habitat preference fields were defined by the sum of three-knot splines. In this first study, four environmental covariates were considered: sea surface temperature (SST), mixed layer depth (MLD), chl-a concentration, and eddy kinetic energy (EKE). The environmental variables have different spatio-temporal resolutions: from 1°x1° and weekly to 5°x5° and monthly. The resulting estimation of habitat preference indicated that skipjack is mainly sensitive to SST, preferring temperatures around 25-26°C.

The panel recommends using higher resolution environmental variables, with 0.25°x0.25° and finer to include mesoscale features of ocean dynamics. Such data from ocean general circulation model (OGCM) models and satellite observations can be downloaded from Copernicus Marine Service platform (https://marine.copernicus.eu/). Also, due to high demands of skipjack for oxygen levels (Brill, 1994), the use of dissolved oxygen fields may greatly improve the habitat preferences estimation. The dissolved oxygen fields are available either as observed monthly average fields (World Ocean Atlas climatology), or as model variable predicted by BGCH model coupled with one of the OGCM.

With regards to the habitat model, the panel recommends revision of current additive formulation. This habitat function may not be suitable for species preferences with multiple factors. In particular, an additive habitat function could drive fish into areas where only one factor is optimal, while the optimality of others is not met. The product of splines or other non-linear functions may be more appropriate to account for the combination of factors, where optimal conditions for all are met.

The advection rate, characterizing the velocity of directed movement of individual fish, is assumed to be proportional to the gradient of habitat preference. Given the importance of passive drift by ocean currents, which are characterized by complex current systems and high velocities in the EPO, the panel recommends including ocean currents to improve representation of tag movements.

The diffusion rate, i.e., velocity of non-directional movement component, relates non-linearly to the sum of spline functions of environmental covariates. This approach implies that the functional relationships between movement rates and environmental variables will be estimated from tagging data. The results obtained using the Kalman filter suggested that diffusion rate increases with increasing temperatures.

Since the movement estimates are the result of the interplay between diffusion and advection processes, the current modeling of advection rate might bias the estimation of the diffusion to habitat relationship. In the current estimation, diffusion rate is estimated to increase with SST, while the advection rate, being proportional to the habitat gradient, moves the fish towards the best habitat defined by the narrow temperature range. As a result, the fish will move towards areas with 25-26°C, where they will experience low advection and intermediate to high diffusion rates. At the same time, in the areas with poorest habitat, the movement of fish is driven purely by advection and not by diffusion (lowest in these areas). In the first case, it seems contradictory that fish would be moving away from the optimal habitat. In the second, the assumption that fish move 100% directionally and in the right direction (based on the gradient) needs to be justified. The panel recommends performing additional sensitivity runs to verify robustness of the diffusion and advection estimation.

The computer code of the model is well optimized in terms of computation time and memory. The habitat preference fields are computed along the modeled trajectory only and interpolated locally so that the habitat function is differentiable to the third order. Currently, the model boundary conditions are implemented only for the open ocean boundaries. The panel recommends implementing a coastal boundary condition in the state-space model to avoid fish on land.

Mortality rates were estimated by calculating the likelihood of tag recapture and non-recapture at a given time. The current definition assumes that the reporting rate is 1. As the tag recapture probability depends on both reporting rates and the gear selectivity, the panel recommends incorporating length-based fishing (selectivity) and natural mortality as functions of length (age) in the tag models. Also, considering uncertainty of the recapture position and time of conventional tags may influence the capture probability and hence the estimation of mortality rates.

The population biomass is estimated based on the Baranov catch equation using the total catch information and the estimated fishing and natural mortality rates. Since such estimation depends on availability of catch data, the extrapolation to the unobserved grid cells was modeled as an autocorrelated process in time assuming that the residual abundance variations were described by a Gaussian-Markov random field. Interestingly, this preliminary method allowed estimating the biomass levels that are consistent with current stock assessment as well as with external spatio-temporal modelling (Senina et al., 2020).

The presentation of the tagging model stimulated a discussion regarding which effort data should be used to model the fishing mortality. Potential options for further consideration were to use only the OBJ sets, use all sets combines, or keep all three set types. Mark Maunder raised the idea of possibly estimating the absolute biomass without using any effort data. The current implementation of the tagging models uses efficient numerical methods of solving advection-diffusion equation with matrix exponentials, which can provide the estimation of population biomass. Therefore, it seems reasonable to explore the potential for estimating dynamic rates within the tag movement model.

The preliminary results of the tagging analysis were encouraging and provide an alternative approach for estimating dynamic rates based on a reliable data source not commonly used in stock assessment. The panel recommends that these new developments be continued with additional funding to further improve the quantitative modeling approach and research associated with these methods. The panel also recommends that funding be continued to support efforts to collect high quality tagging data and to improve collaboration with industry.

Data, fishery or analysis related issues raised by the public

1. Simon Hoyle raised concern about the possibility of suppressed growth associated with a tagging event. Growth suppression may be temporary due to infection associated with the tag (i.e., spending energy on the immune response).
2. Simon Hoyle stated that spatial variation in growth and size are both important. Spatial size variation will affect fishery definitions. Simon stated that there is very large spatial size variation in the EPO for YFT and BET based on longline data. In the WCPO skipjack are bigger further east and the same may happen in the EPO. Spatial growth variation breaks one of the most important assumptions in the age-based model and it could make the fits to the size data much less informative about F, etc. It's quite difficult to explore when you can't age fish but there's enough tagging data to explore it. It's another reason to consider using a size-based model, because it is difficult to model mixing and spatial growth variation with an age-based model.

Prioritized recommendations for research and data collection

Short term (for the next assessment)

1. Further develop the tagging model approach to estimate absolute abundance and evaluate the value of this type of input data to the age-structured catch at length assessment. The panel provides detailed recommendations regarding the tagging modelling work as part of the long-term recommendations, although certain aspects of this work (see overall summary of the assessment) are a priority for producing reliable estimates of biomass.
2. Evaluate the reliability of the longline index of abundance and consider refinements to the index and associated length compositions.
    a. Evaluate catch data for the longline fishery and the potential that discard and changes in discard over time could be influencing estimates of the index based on these data.
    b. Consider model-based indices rather than an index based on aggregate catch per effort. Refine length compositions similarly.

3. Explore alternative functional forms of growth.
4. The reference point analyses should be supported by more analysis of estimated relationships between recruitment and stock size, as they depend critically on h >= 0.75. While target biomass and associated F is currently equated to equilibrium MSY levels, the panel wonders if an additional consideration should be to avoid a high probability of stock size falling below the limit level over some defined time horizon, which might be interpretable as putting the capacity of the stock to achieve MSY at risk. This was implicitly evaluated for the reference case by looking at 10-year projections.

Long-term

The panel provides some general big picture long term recommendations covering both the current assessment and the tagging study, followed by a more detailed set of recommendations regarding the tagging work.

1. For the areas as fisheries approach, consider defining irregular regions instead of splitting by longitude and latitude. The area selection can be based not only on fisheries characteristics, but also on oceanographic variables, current systems, ecoregions etc.
2. Explore options for turning the tagging model into an assessment model useful for management in its own right. This will require more than just biomass values but also estimates of fishing mortality and approaches for setting reference points to use the tagging assessment results in management.
3. Consider alternative approaches to the current assessment model. These could include:
    a. a length-structured (rather than age-structured) approach to avoid needing to establish a length versus age function in the absence of actual age data;
    b. a state-space model incorporating more process variation, particularly to allow for temporal variation in catchability and selectivity.
4. Continue efforts to estimate quantities needed to produce reliable mortality and abundance estimates from tagging, such as tag reporting and how it varies over space and time, tag shedding, and tag induced mortality. Continue investing in tag recovery efforts, such as using tag recovery officers to obtain high confidence recoveries.
5. Work to maintain good relationships with industry, to promote assistance in obtaining quality data, such as maintaining high tag return rates, obtaining historical FAD data etc.
6. Stock identification or spatial structure workshop to construct a conceptual model for skipjack similar to those created for other species in the EPO.

Recommendations for further developments of spatial tagging model

Panel recommendations for habitat fields modelling:

1. Given that the habitat preference is estimated to be mainly driven by sea surface temperature (SST), consider revising the use of mixed layer depth (MLD). It seems reasonable to assume that SST is already a good proxy for the ambient temperature for skipjack staying in the mixed layer.
2. Use the information from archival tags about SKJ diel vertical migrations to improve the estimation of habitat fields and eventually movement parameters. If these data show that SKJ occupy depths below the MLD, it might be critical to use the 3D temperature fields to be included

in the habitat spline function. This is where the low oxygen levels can be used to explain the maximal depth accessible by skipjack.

Recommendations to explore alternative definitions of advection and diffusion rates:

1. Instead of using the habitat gradient to compute the velocity of directed movement of fish, consider using habitat index value to compute the speed (e.g., simple linear vmax*(1-h) relationship) and the habitat gradient for direction only. This formulation seems more appropriate for the individual movement as one fish does not know the gradient once it moves (e.g., see Faugeras and Maury, 2007).

2. It seems important considering the size information available in the tagging dataset as the fish velocity and its environmental preferences are known to vary with fish size. In particular, due to linear growth estimated to be the most accurate description of skipjack growth in line with the EPO tagging data, it is expected to see the rapid and significant changes in the thermal preferences of tagged tuna with longer time at liberty.

3. Mortality estimation

   Incorporate tag loss processes such as tagging induced mortality, tag shedding and reporting rates to the movement model, either as additional parameters to be estimated, or as fixed parameters. Consider creating spatially variable reporting rate fields based on tag seeding data to the port of landing and then back calculate with the location of catch corresponding to these ports.

Validation

1. Calculate movement speed predicted from the models and verify that they are consistent with biologically plausible maximum swimming speeds, which may need to be adjusted for oceanic current speeds.

2. Test sensitivities of the biomass estimates to the environmental covariates assumed for the movement model.

3. To validate the method's capacity to reliably estimate the movement and mortality rates, consider developing a set of validation diagnostics providing metrics of the fit between observed and predicted distributions of tag recaptures, their number and time at liberty.

4. Since the model parameters (nine currently – four spline parameters, three fisheries parameters, sigma and mortality rate) are invariant in time and space, consider validating this hypothesis with independent dataset, i.e., those collected in WCPO. Although it might be complicated given the scarcity of the tagging data, sensitivity runs with data subsets can be performed to see the variability of the movement and mortality rates with the time period and region selected.

General recommendations

Future work with the tagging data to expand the model to be a spatial explicit surplus production or delay difference model that incorporates the catch data into the model is a suggested next step. If development of the production model is successful and is able to provide a reasonable estimate of biomass, then further expansion of the model to incorporate size-based dynamics and length frequency data could be beneficial. These approaches would be novel and would benefit from simulation testing of any models that are developed.

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FIGURES

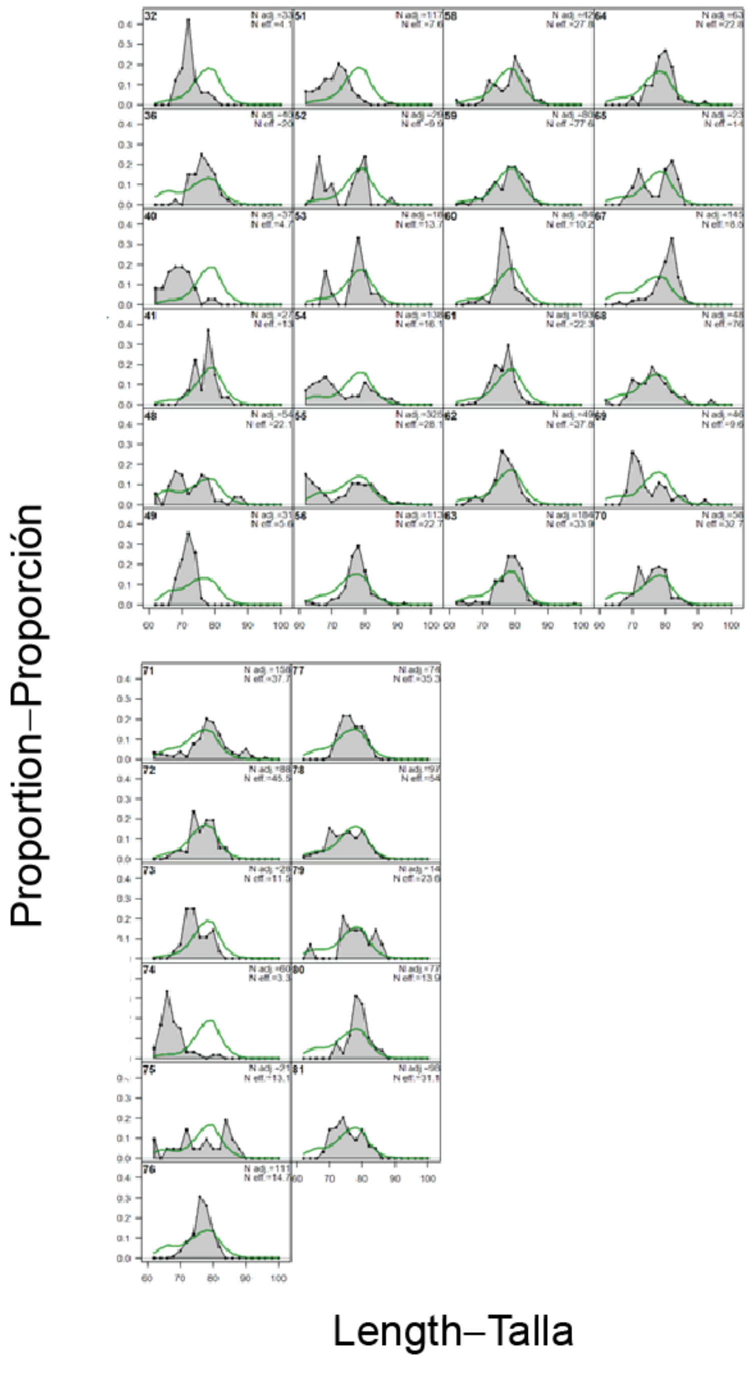

FIGURE 1. Model fits (green line) to the Japanese longline length frequencies for each year/quarter.
FIGURA 1. Ajustes del modelo (línea verde) a las frecuencias de talla de palangre de Japón para cada año/trimestre.

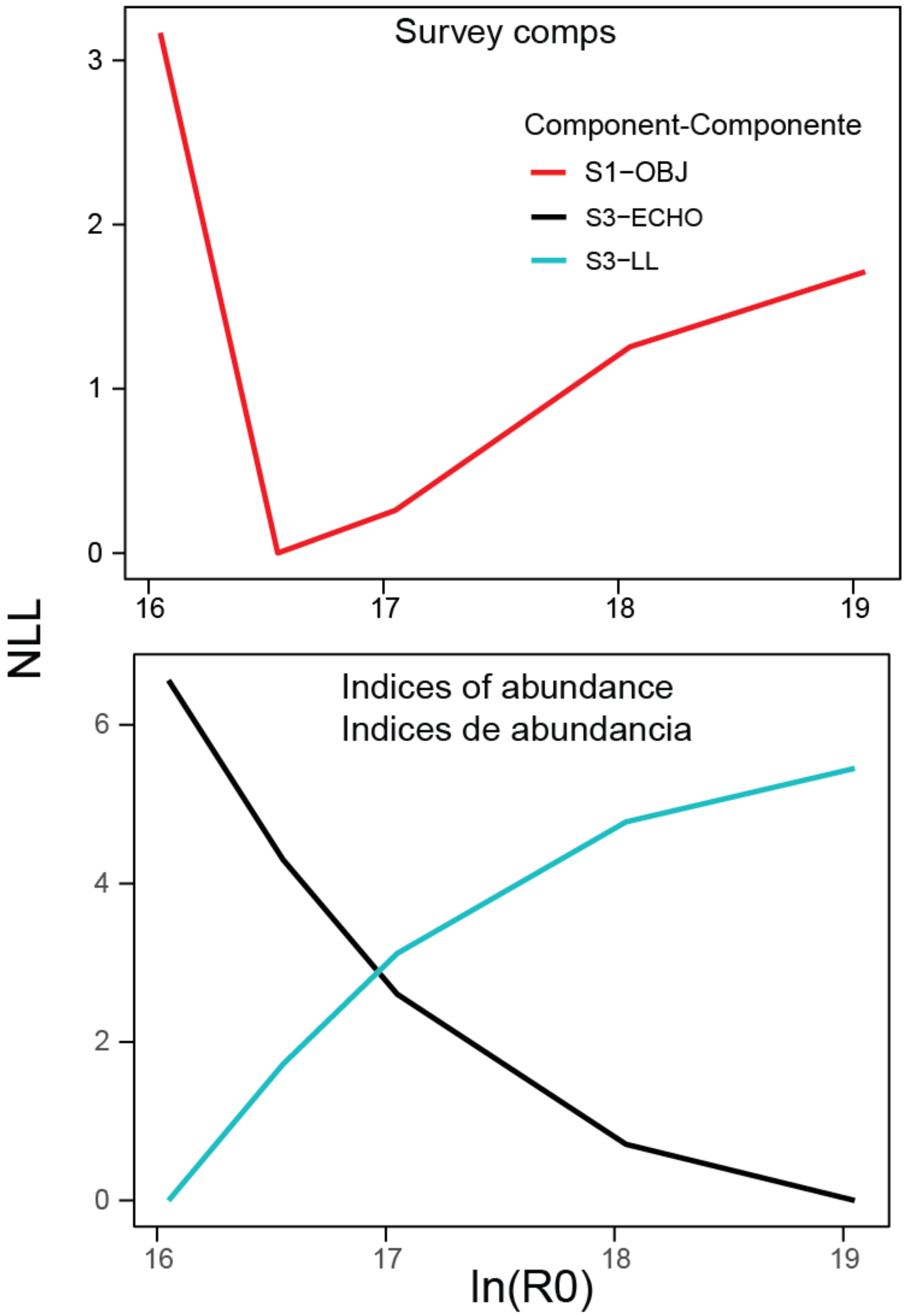

FIGURE 2. Corrected likelihood profile for the indices of abundance.
FIGURA 2. Perfil de verosimilitud corregido para los índices de abundancia.

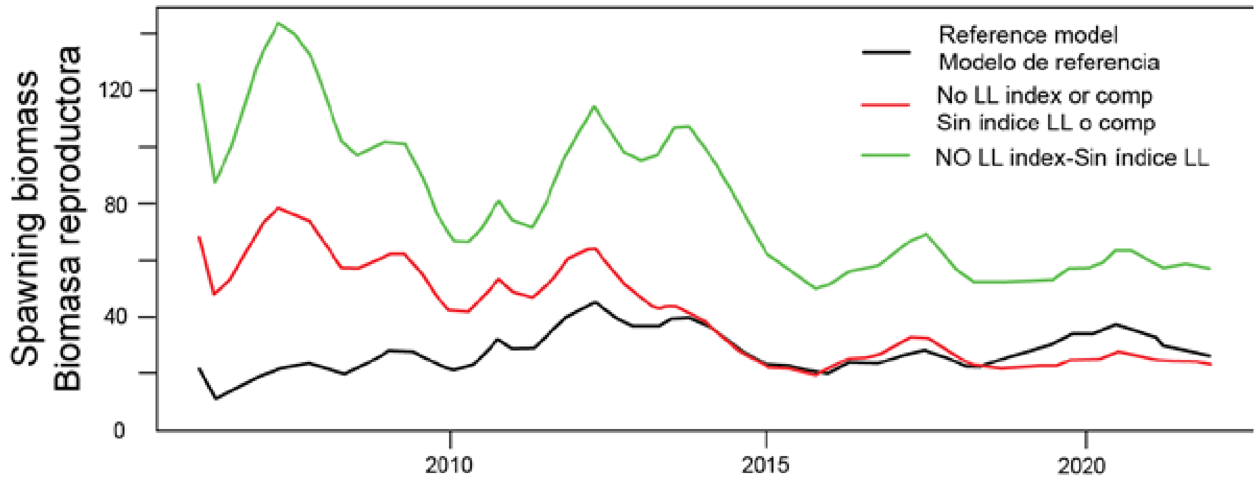

FIGURE 3. Spawning biomass estimates from the reference model compared to model runs with the longline index removed and a model with the longline index and length composition removed.
FIGURA 3. Estimaciones de biomasa reproductora del modelo de referencia comparadas con ejecuciones del modelo sin el índice de palangre y un modelo sin el índice de palangre ni la composición por talla.

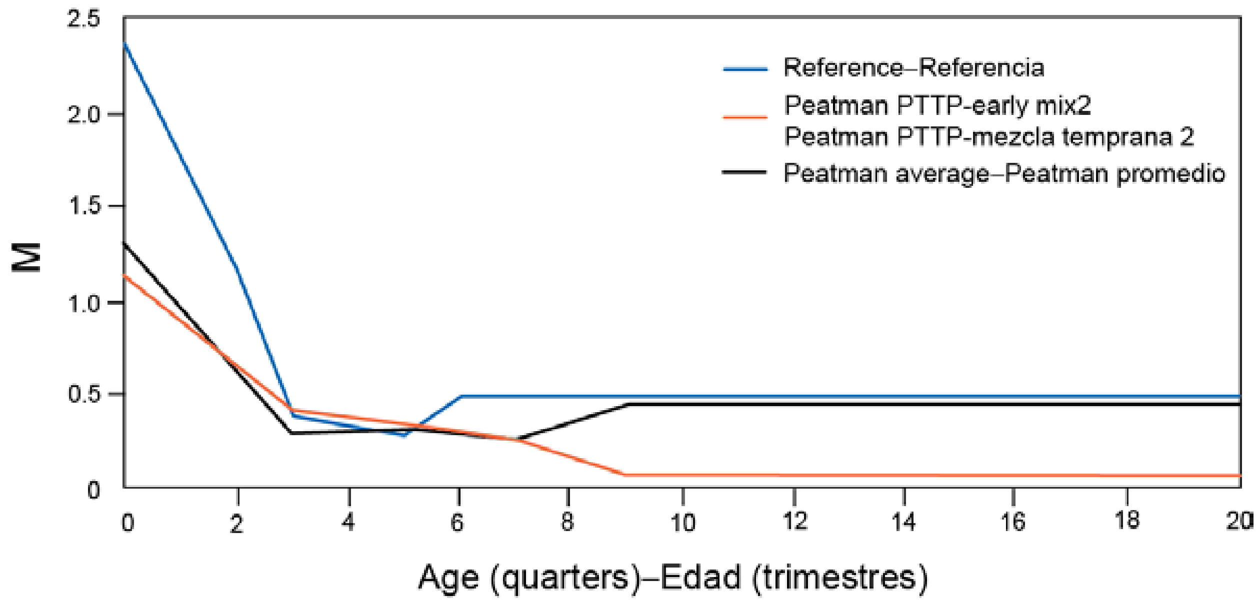

FIGURE 4. Natural mortality-at-age rates assumed for the reference model and two sensitivities created from external estimates for skipjack in the western central Pacific Ocean.
FIGURA 4. Tasas de mortalidad natural por edad supuestas para el modelo de referencia y dos análisis de sensibilidad creados a partir de estimaciones externas para el barrilete en el Océano Pacífico occidental y central.

APPENDIX 1: TERMS OF REFERENCE FOR THE PANEL REVIEW

INTER-AMERICAN TROPICAL TUNA COMMISSION

1st REVIEW OF THE STOCK ASSESSMENT OF SKIPJACK TUNA IN THE EASTERN PACIFIC OCEAN

La Jolla, California (USA)
7-10 November 2022
(*participation by teleconferencing optional*)

TERMS OF REFERENCE

1. GOALS AND OBJECTIVES

The purpose of the review of the assessment conducted by the IATTC staff of the skipjack stock in the eastern Pacific Ocean and the tagging analysis is to provide information that will improve the analyses used for providing management advice.

To this end, the goals and objectives of this review are to:

a. identify the best available science for use in the skipjack stock assessment and tagging analysis;
b. provide an independent review of the assessment and tagging analysis;
c. provide recommendations on how to integrate the tagging information into the assessment and/or management advice; and
d. provide advice on future research and data collection that will improve the assessment, tagging analysis, and the provision of management advice.

2. REVIEW PANEL RESPONSIBILITIES

The main responsibility of the Review Panel is to perform an adequate technical review of the skipjack assessment and tagging analysis. To ensure the greatest objectivity in this exercise, the members of the Panel should disclose any conflicts of interest they may have, including, but not limited to, personal financial interests and investments, employer affiliations, and consulting arrangements, grants, or contracts, etc.

The specific responsibilities of the Panel are to:

a. be familiar with the Terms of Reference;
b. review background documents, data inputs, and analytical models, along with other pertinent information (*e.g.*, previous assessments and Review Panel reports);
c. discuss the technical merits and deficiencies of the input data and analytical methods, work with the IATTC staff and contractors to correct deficiencies, and, when possible, suggest new tools, analyses, and data collection methods to improve future assessments; and
d. draft a report of the meeting, to document the discussions and recommendations.

It is the Panel chair's responsibility to coordinate the discussions so that the review is completed in the time available.

3. PUBLIC COMMENT

During the meeting, time will be set aside for public comment. The Panel will take these comments into consideration, as appropriate, when developing its report.

4. REQUESTS FOR ADDITIONAL ANALYSES

Since the purpose of the meeting is to conduct a technical review of the assessment methodology, it may be beneficial to conduct analyses during the course of the meeting. The Panel may also request a reasonable number of sensitivity runs, as well as additional details on the models presented, or further analyses of alternative runs. However, any such requests must be clear, explicit, and be presented in writing, and be practical in terms of the time available. Such requests should be listed individually in the Panel's report, along with their rationale and the response. To the extent possible, analyses requested by the Panel should be completed during the meeting by the assessment team.

5. PANEL REPORT

The Panel's report should be drafted and approved shortly after the meeting. The report writing process will follow these steps:

a. Panel outlines report at meeting;
b. Panel writes and agrees draft report;
c. Panel provides draft report to IATTC staff for comment on technical accuracy; and
d. Panel reviews staff comments, and modifies report as necessary.

The report will include:

a. Names and affiliations of Panel members;
b. Brief overview of the meeting (location, agenda, main recommendations by Panel, *etc*.);
c. Brief summary of current assessment model, tagging analysis, data used, analyses presented, and proposed assessment model;
d. List of analyses requested by the Panel, rationale for each request, and brief summary of the response;
e. Comments on technical merits and/or deficiencies in the assessment and tagging analysis, and recommendations for remedies;
f. Unresolved problems and major uncertainties, *e.g.*, any special issues that complicate the assessment and/or interpretation of results;
g. Data, fishery or analysis related issues raised by the public; and
h. Prioritized recommendations for research and data collection for the subsequent assessment.

The Panel and the IATTC staff will strive to resolve any differences of opinion that may arise regarding the contents of the report. Any unresolved differences of opinion must be documented and reflected in the report, which will be published as an IATTC Special Report.

APPENDIX 2: MEETING AGENDA

INTER-AMERICAN TROPICAL TUNA COMMISSION

1st REVIEW OF THE STOCK ASSESSMENT OF SKIPJACK TUNA IN THE EASTERN PACIFIC OCEAN

La Jolla, California (USA)

7-10 November 2022

(*participation by teleconferencing optional*)

AGENDA

Monday 7 November

0900: Welcome and introduction	(*Alexandre Aires-da-Silva*)
0920: History of the skipjack assessment and issues identified	(*Alexandre Aires-da-Silva*)
1000: Coffee	
1030: Fishery data	(*Mark Maunder*)
1100: Fishery structure	(*Mark Maunder*)
1130: Indices of abundance derived from purse-seine CPUE	(*Haikun Xu*)
1200: Lunch	
1300: Indices of abundance derived from longline CPUE	(*Mark Maunder*)
1330: Discussion: Data	
1400: Biology	(*Dan Fuller*)
1430: Growth	(*Mark Maunder*)
1500: Coffee	
1530: Natural mortality	(*Mark Maunder*)
1600: Discussion: Biology	
1630: Public comment	

Tuesday 8 November

0900: Overview of 2022 assessment **1000:** Coffee	(*Mark Maunder*)
1030: Discussion: Assessment	
1100: Requests of model runs	(*Mark Maunder*)
1200: Lunch	

1300: An individual-based approach to large-scale fish population movement (*Anders Nielsen*) **1330:** Habitat preference and movement of Skipjack tuna in the eastern Pacific Ocean (*Tobias Mildenberger*)

1400: Estimating mortality rates and biomass from tagging and catch-and-effort data (*Tobias Mildenberger*)

1430: Discussion: Assessment

1500: Coffee

1530: Requests of tagging analysis

1600: Public comment

Wednesday 9 November

0900: Presentation of requested model runs: Assessment (*Mark Maunder*)

0930: Requests of model runs

1000: Coffee

1030: Presentation of requested model runs: Tagging analysis (*Tobias Mildenberger*) **1100:** Requests of tagging analysis

1200: Lunch

1300: Integrating tagging information into the stock assessment (*Mark Maunder/ Tobias Mildenberger*)

1330: Discussion: Integrating tagging information into the stock assessment

1500: Coffee

1600: Public comment

Thursday 10 November

0900: Presentation of requested model runs: Assessment (*Mark Maunder*)

1030: Presentation of requested model runs: Tagging analysis (*Tobias Mildenberger*)

1000: Coffee

1030: Discussions

1200: Lunch

1300: Review Panel summary

1330: Outlining report

1500: Coffee

WSSKJ-01 - Provisional agenda 2

APPENDIX 3: MEETING PARTICIPANTS

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APPENDIX 4: LISTING OF TYPES OF LENGTH FREQUENCY COMPOSITION DATA USED IN THE ASSESSMENT MODELS.

The length frequency composition data (LFs) include:

	Fleet	Label
1	Purse seine (PS)	F1-OBJ_OS
2		F2-OBJ_Nth
3		F3-OBJ_Sth
4		F4-OBJ_Coast
5		S1-OBJ
6		F5-NOA_OS
7		F6-NOA_Nth
8		F7-NOA_Cnt
9		F8-NOA_Coast
10		S2-NOA
11		F9-DEL_Sth
12		F10-DEL_Nth
13	Japanese longline (LL)	F12-LL