2022 Western and Central Pacific Ocean Skipjack tuna assessment: background paper for the Pre-assessment Workshop

Oceanic Fisheries Programme, SPC

Introduction

Stock assessments of skipjack tuna (*Katsuwonus pelamis*) in the Western and Central Pacific Fisheries Commission convention area (WCPFC-CA) (Fig. 1), have been conducted at three-year intervals since 2000 (Bigelow et al. 2000). The most recent assessment was conducted in 2019 (Vincent et al. 2019). That assessment is described in more detail below. The assessments apply the integrated assessment approach using the stock assessment framework Multifan-CL. The development of the 2022 assessment is based off the 2019 assessment and where possible aims to improve on the data inputs and modelling approaches applied. Major changes to structural assumptions may occur if reliable new information comes to light to support such changes. The Pre-assessment Workshop (PAW) discussions provide an important forum for information exchange, advice and constructive feedback to assist with the improvement and development of the new assessment. SPC scientists make the final decisions on the data inputs, preparatory analyses, structural and other assumptions required during model development, taking into consideration the advice and recommendations from the PAW and the available time and resources.

This background paper is aimed to provide a general introduction to skipjack fishery in the WCPFC-CA, the previous WCPFC-CA skipjack assessment, and the key aspects where changes/improvements in the assessment approach are being considered. Hopefully it provides useful background for your preparation to participate in the skipjack discussions at the PAW.

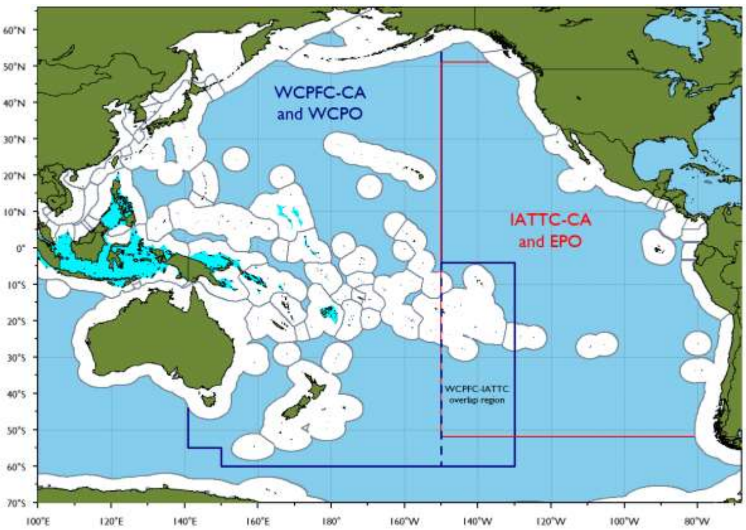

Figure 1. Important national, regional and management zones in the Pacific. The WCPFC Convention Area (WCPFC-CA) is outlined in dark blue, the IATTC Convention Area (IATTC-CA) area is outlined in red. The western and central Pacific Ocean (WCPO) includes all of the WCPFC-CA, minus the overlap with the IATTC-CA; the eastern Pacific Ocean (EPO) is coincident with the IATTC-CA. Pacific nation EEZs are outlined in grey and archipelagic waters are shaded turquoise (from Hare et al. (2021)).

WCPO skipjack fishery background

The skipjack tuna fishery in the WCPFC-CA accounts for approximately 35% of the global tuna catch, and around 60% of the global skipjack catch. The annual catch has ranged from around 1.6 to 2.04 million tonnes since 2015, with the largest catch recorded in 2019, estimated at approximately 2.042 million tonnes (Fig. 2) (Hare et al. 2021). The catches are dominated by the purse seine fishery, that has accounted for 77-83 % of the catch since 2015. This compares to the early 1980's when catches were in the order of 400 – 700 thousand tonnes and the pole and line fishery accounted for around 50-70 % of the catch. The majority of the WCPFC-CA skipjack catches in recent years are from the equatorial region between 10°N and 10°S (Fig. 3).

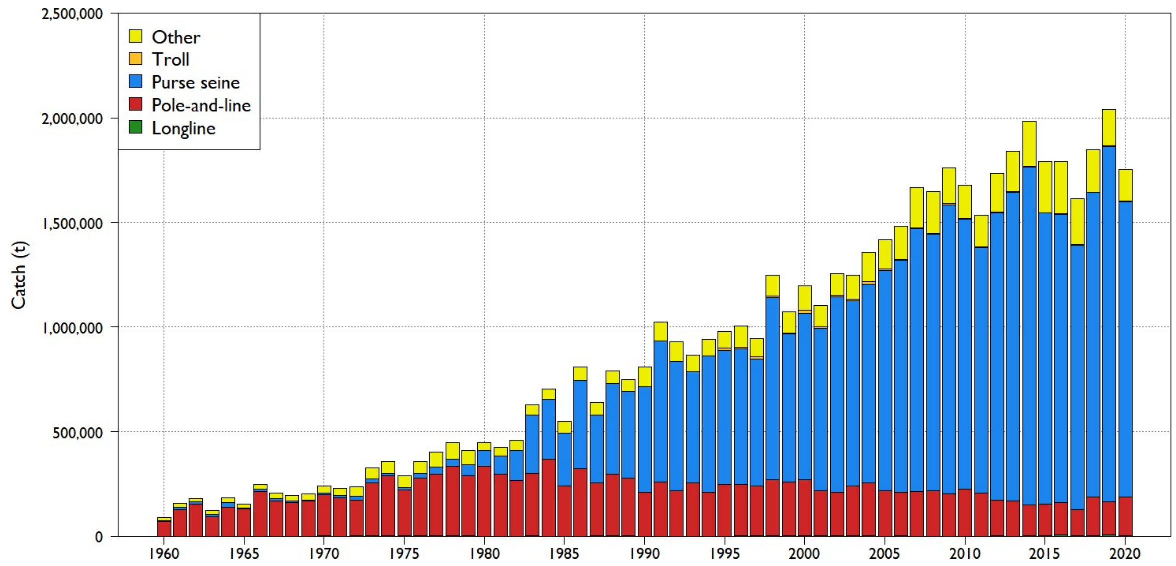

Figure 2. Skipjack tuna catch by gear in the WCPFC-CA since 1960.

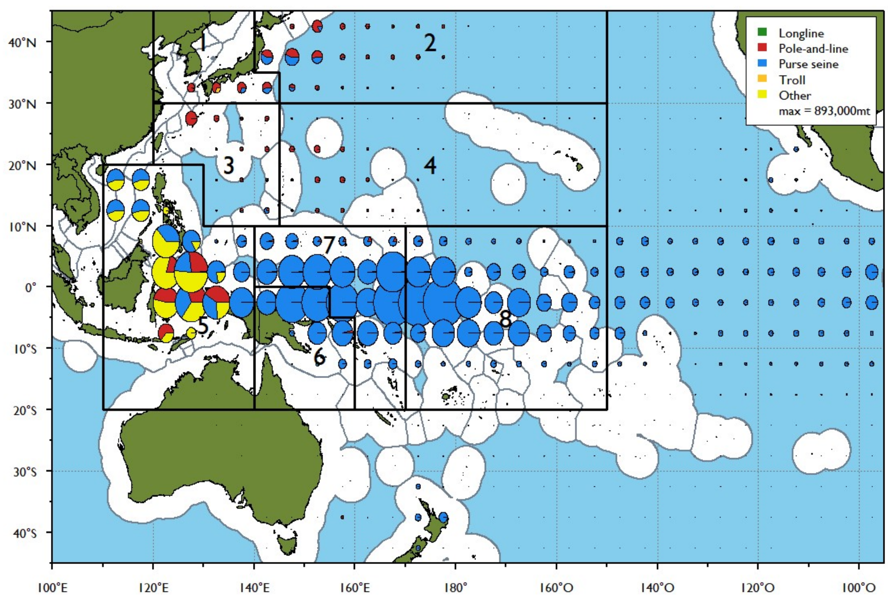

Figure 3. Skipjack tuna catch distribution by gear in the Pacific Ocean for 2016-2020. The 8 regions used for management advice in the 2019 assessment are overlayed.

The growth of the purse seine fishery took off from the mid-1980's (Fig. 2). There are two main modes of purse seine fishing: 'unassociated' (or free school) which refers to targeting free ranging tuna schools, and 'associated', which refers to purse seine sets targeting tuna schools aggregated around floating objects such a natural logs or purpose built anchored or drifting fish aggregation devices (FADs). Overtime the 'associated' fishing mode has become dominated by constructed drifting FADs (dFADs). This has been facilitated by the availability of satellite tracking buoys attached to the FAD rafts, and more recently, acoustic sensors added to the buoys that transmit information on the presence and biomass of tuna associated with individual dFADs. Despite the introduction of these FAD buoy technologies, the proportion of the purse seine skipjack catch taken by 'associated' and 'unassociated' fishing modes has remained relatively similar over the last decade.

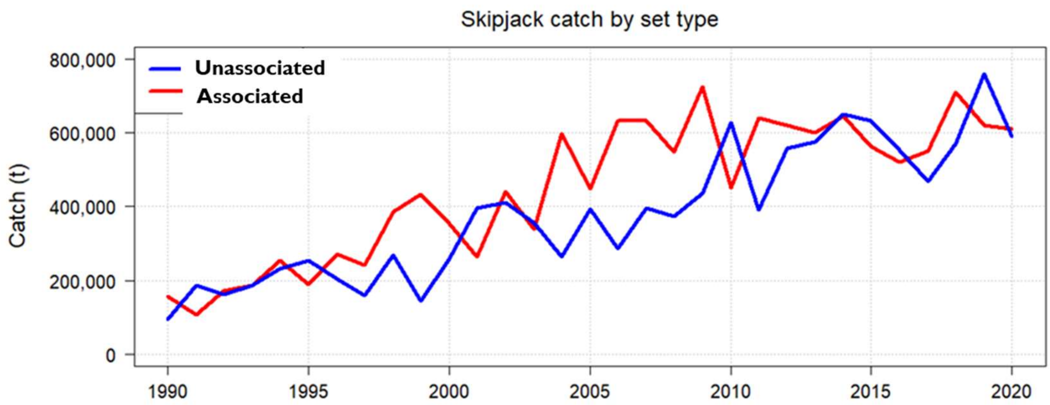

Figure 4. Comparison of annual skipjack catches by set type in the WCPO.

Small amounts of skipjack catch are taken by longline and troll fisheries (< 5,000 tonnes/year for each gear). 'Other' gears, which mostly refers to artisanal fishing gears in the Indonesia, Philippines and Vietnamese fisheries now account for a similar percentage, approximately 10%, of the catch as the pole and line fishery, although these fisheries catch higher numbers of fish due to their selectivity for smaller skipjack (Fig. 5).

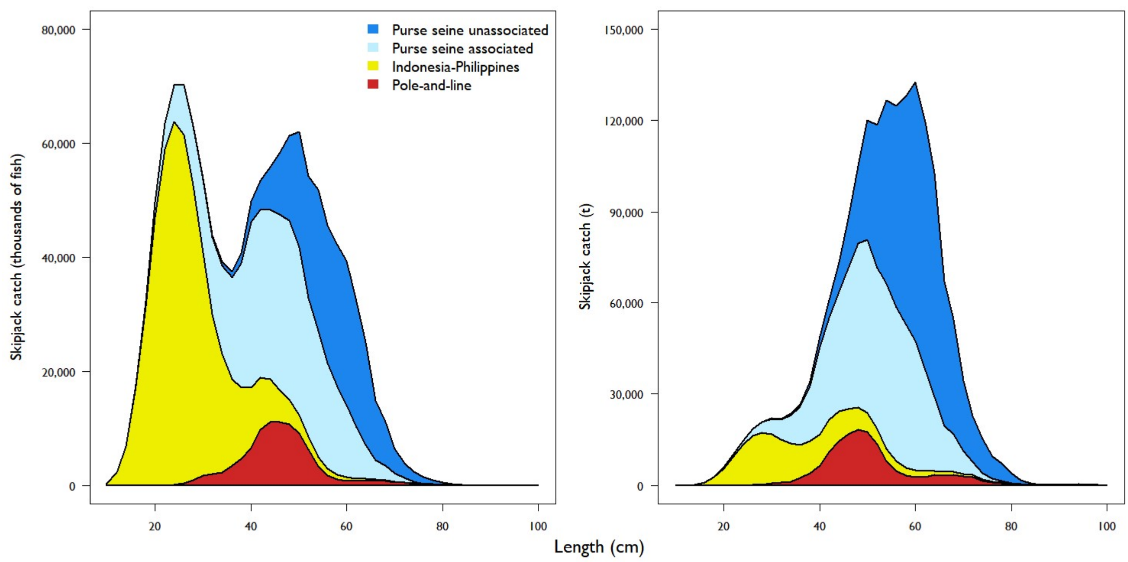

Figure 5. Size composition of skipjack tuna caught by various fishery components – by numbers (left) and tonnes (right).

The revenue derived from the skipjack fishery is incredibly important to Pacific Island countries. For some, the tuna resources within their exclusive economic zones (EEZs) represent their only significant renewable resource and their best opportunity for economic development. Pacific Island countries who are Parties to the Nauru Agreement (PNA) (Federated States of Micronesia, Kiribati, Marshall Islands, Nauru, Palau, Papua New Guinea, Solomon Islands and Tuvalu, plus Tokelau) control most of skipjack catch from the WCPFC-CA and obtain the most financial benefit from the resource through the Vessel Day Scheme (VDS) and other arrangement such as chartering. The VDS is a system of effort management that limits the number of purse seine fishing days in the PNA country EEZs, with days being sold at or above a minimum rate agreed by The Parties. The main controls on skipjack fishing overall are through limits on the number of purse seine fishing days either by the VDS or flag specific day limits on purse seine fishing on the high seas stipulated under the Western and Central Pacific Commission's tropical tuna conservation and management measure (CMM 2021-01) (although some flag based catch limits also apply). This CMM also provides the overarching stock conservation objectives for the management of the skipjack stock, as part of the broader tropical tuna fishery, including yellowfin and bigeye.

While CMM 2021-01 provides the current high-level guidance, objectives and management limits for the tropical tuna fisheries, including skipjack, this CMM is viewed as a bridging measure while a harvest strategy is developed and implemented. The development of the skipjack harvest strategy has progressed to the point where a fully functional MSE (Management Strategy Evaluation) framework is available and is being used for testing of candidate management procedures (including the harvest control rules). The WCPFC, under its current harvest strategy workplan (WCPFC Harvest Strategy Workplan Progress), is scheduled to adopt a management procedure for the WCPFC-CA skipjack stock by the end of 2022. The operating models in the skipjack MSE framework are based on the 2019 assessment. However, it is not necessary to update MSE operating models for every new assessment, so long as they continue to adequately incorporate the range of uncertainty in stock assessment predictions of stock status. The regular stock assessments (i.e., the new 2022 assessment) become a key part of the ongoing monitoring programme that tracks the performance of the harvest strategy overtime, and this will be discussed in sessions 10 and 11 on day 3 of the PAW.

Summary of the 2019 assessment

The 2019 WCPFC-CA skipjack assessment (Vincent et al. 2019) involved two spatial structures, a 5-region (similar to the 2016 assessment) and an 8-region structure (Fig. 6). While there were merits to both spatial structures, the 8-region structure was used as the diagnostic (base case) model and the 5-region model as a sensitivity. However, for the provision of management advice the **Scientific Committee (SC) 15 "*agreed to use the 8 region model to describe the stock status of skipjack tuna because SC15 considers that it better captures the biology of skipjack tuna than the existing 5 region structure" (SC15 Summary Report).***

The 8-region model included 31 fisheries, across pole and line, purse seine, longline, troll and other methods. The structural uncertainty grid used to represent uncertainty in model derived management quantities included axis for:

- Regional structure (5 and 8 regions - noting the 5-region model was dropped by SC15)
- Steepness (0.65, 0.80 as the diagnostic model, 0.95)
- Tag mixing period (1 quarter as the diagnostic, 2 quarters)
- Growth estimated internally from length composition modal structure (Default, low growth, and high growth)

- Length composition weighting factor (i.e., sample size devisor) (50, 100 as the diagnostic model, 200)

The assessment involved 108 models of which the spatial structure options were considered separately resulting in two sets of 54 models.

The main outcomes of the assessment (summarised in Figs. 7 and 8) were that:

- Total biomass and spawning potential remained relatively stable, with fluctuations, until the mid-2000s, after which it declined. Estimated recruitment showed an increasing trend from 1980 to the recent period.
- Average fishing mortality rates for juvenile and adult age-classes increase throughout the period of the assessment.
- The 8-region model structure provided slightly more optimistic estimates of stock status when compared to the 5-region model structure. In both cases, the stock was assessed to be above the adopted LRP, and fished at rates below F_{MSY}, with 100% probability. It was concluded the skipjack stock was not overfished, nor subject to overfishing.
- Overall median depletion over the recent period (2015-2018; $SB_{recent}/SB_{F=0}$) was 0.44 (80 percentile range 0.36-0.52) for the 8-region model, and 0.40 (80 percentile range 0.30-0.50) for the 5-region model.
- Results from both regional structures indicate a stock status currently on average below the interim TRP for skipjack at that time.
  - For the 8-region grid, 47 of the 54 models (85%) estimated $SB_{recent}/SB_{F=0}$ to be less than the TRP (50% $SB_{F=0}$).
  - For the 5-region grid, 48 of the 54 models (87%) estimated $SB_{recent}/SB_{F=0}$ to be less than the TRP (50% $SB_{F=0}$).
- Recent median fishing mortality (2014-2017; F_{recent}/F_{MSY}) was 0.44 (80 percentile range 0.34-0.61) for the 8-region model, and 0.48 (80 percentile range 0.35-0.66) for the 5 region model.

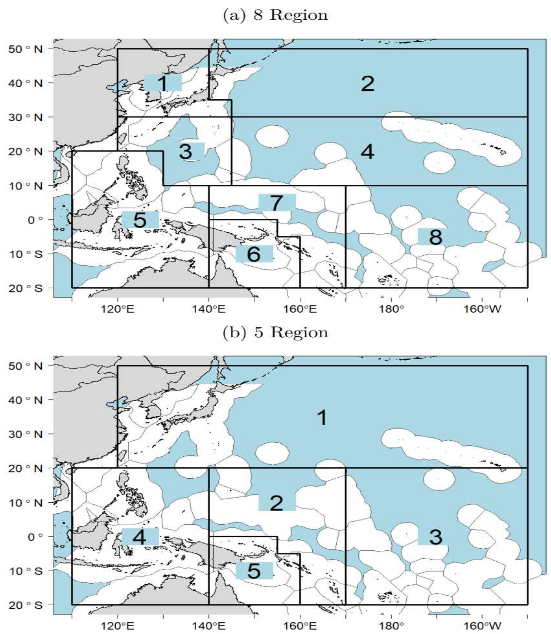

Figure 6. a) 8-region and b) 5-region model structures used in the 2019 WCPFC-CA skipjack stock assessment.

As noted above the SC15 favoured the 8-region model structure. For the provision of management advice, they also chose to down weight (x 0.8) some aspects of the uncertainty grid, including the higher and lower steepness values, and the length composition scalar of 50. The down weighting of these grid components had very minor influence (Fig. 7d).

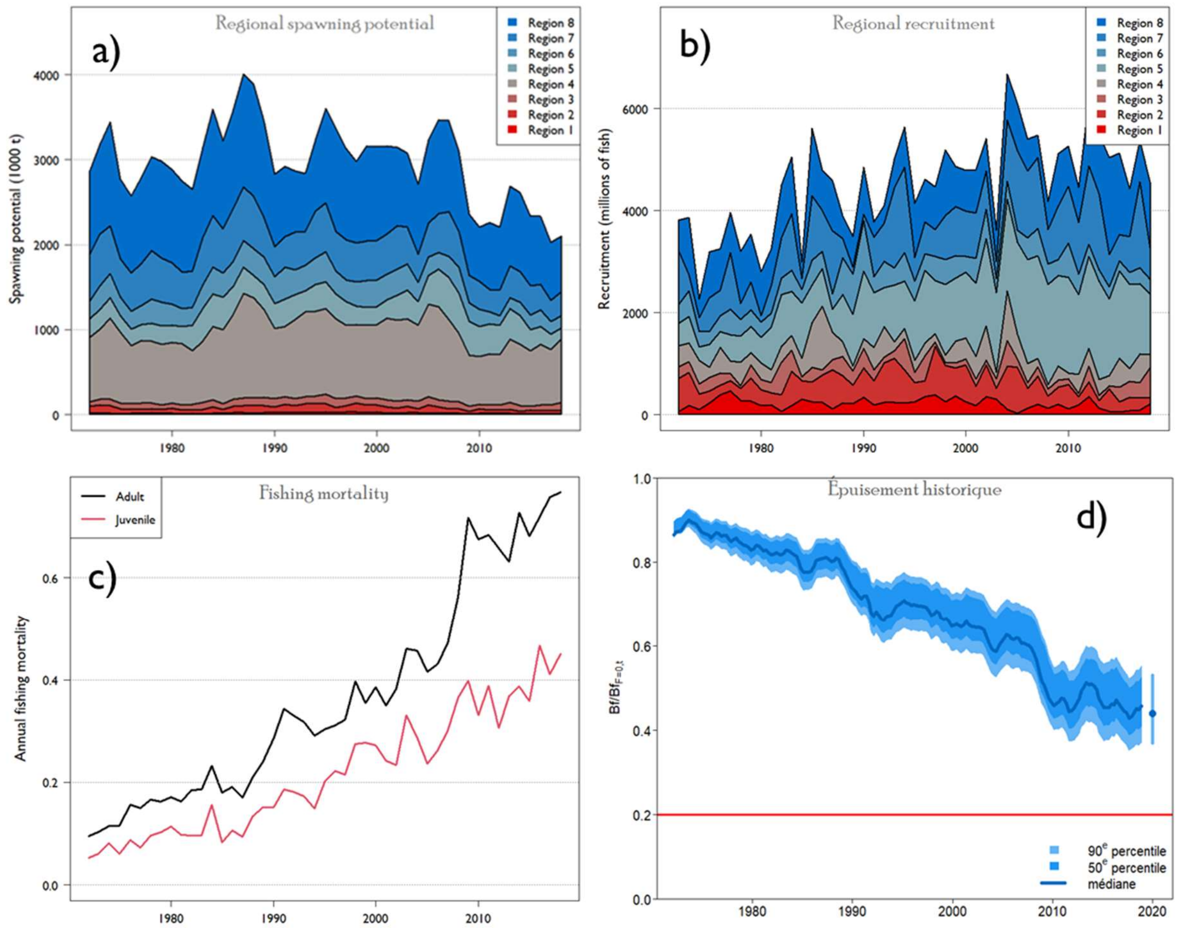

Figure 7. Estimated spawning potential time series by model region (a), recruitment by model region (b), fishing mortality for adults and juveniles from the skipjack diagnostic case model (c), and (d) spawning potential depletion across the uncertainty grid of 54 models (8-region structure), with the SC15 weighted median value illustrated by the large blue point.

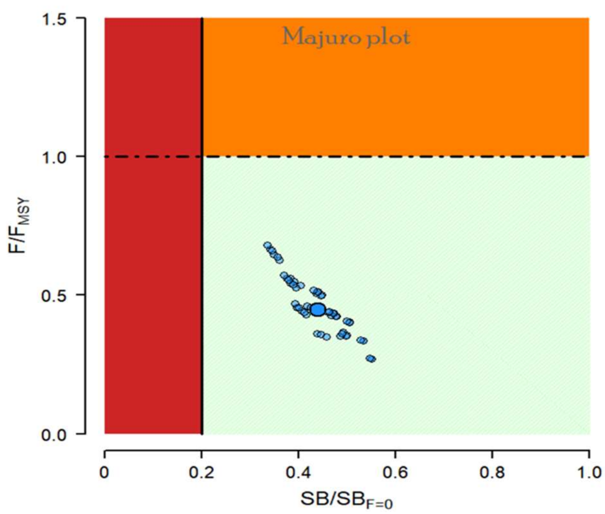

Figure 8. Majuro plot of the skipjack stock status for the 2019 assessment (last data year 2018) displayed as the end points from the uncertainty grid of 54 models (8-region structure).

2022 assessment planning summary

Spatial structure

An early step in the development of the assessment is to consider the spatial structure. This provides the basis for stratification of much of the data inputs and the assessment outcomes used for management advice. SC15 recommended that the 8-region model is preferrable over the 5-region model. As there is no new information on population structure of skipjack that could provide a strong basis for changing the 8-region model, to our knowledge, we propose to continue to use the 8-region model (Fig. 6a) for the 2022 diagnostic model. If PAW participants have strong concerns about the 8-region structure, they should raise these, and their reasoning for any alternatives. Sensitivity models on alternative structures can be attempted if there is a good reasoning for this, noting that running alternative spatial structures that do not simply involve combining (collapsing) regions of the 8-region structure involves much more work and may not be possible in the time frame available.

Fishery structure

Applying the 8-region structure will mean that changes to the general fisheries structure from 2019 are not necessary. The previous 8-region model had 31 fisheries across six gears/methods; pole and line (PL), long line (LL), purse seine 'associated' (SA), purse seine 'unassociated' (SU), purse seine not specified (S) and miscellaneous/artisanal gears ('other' gear) (i.e., small vessels in Philippines, Indonesia and Vietnam).

For the 2022 assessment we plan to apply an alternative approach to estimating fishing mortality, referred to as the 'catch-conditioned method'. The 'catch-conditioned' approach was initially considered for development in 2007 (Hampton et al. 2007) and is now available in the most recent version of MFCL (Vers. 2.0.8.4). Previous assessments have applied what is referred to as the 'catch-errors method'. The details of how these alternative methods differ will be presented in the PAW, session 4, day 1.

The catch-conditioned approach results in a large reduction in the numbers of parameters estimated. It assumes the catch data are correct (with no observation error) and solves the Baranov catch equation for fishing mortality. This method does not require estimation of the (often thousands of) additional parameters required for the catch-errors method and is thus computationally more efficient and less complex. The catch-conditioned method however adds a likelihood component for 'survey' indices of abundance that can provide information on relative abundance across space and time. This is particularly useful if the assumption of constant catchability can be made across fisheries operating in different model regions at the same time (something to discuss in the PAW). In WCPFC tuna assessments the indices of abundance are typically based on standardised fishery dependent CPUE time series. As such the catch- conditioned model requires specification of the additional 'survey' fisheries to provide the abundance indices.

For this assessment we propose to explore the application of the following 'survey' fisheries:

- The Japanese DW (distant water) and OS (offshore) pole and line fishery (regions 1- 8) (*using the VAST method, similar to previous assessment*)
- The equatorial purse seine fishery (regions 6, 7 and 8) (*previous assessment only included region 6 with GLMM, this assessment aims to apply a VAST model*)
- The Philippines purse seine fishery (region 5) (*as per previous assessment*)

The development of these indices will be discussed in session 3 of day 1. There are various ways in which these 'survey' fisheries could be used in the assessment depending on assumptions of shared catchability and how reliable they are thought to be as indicators of skipjack relative abundance trends across time and space. There are also some concerns around hyperstability of fishery dependent CPUE indices from skipjack fisheries that target schools and lack detailed information on effort related variables. These will be important topics to discuss in the PAW.

Model development

To develop the 2022 diagnostic model, we will follow a series of steps, often referred to as a 'stepwise' model development or 'bridging' analysis. The first step in this process is to run the 2019 diagnostic model with the most recent version of MFCL (2.0.8.4), and no other changes. This has been completed and has confirmed virtually identical results compared to the 2019 diagnostic model. The next step is to run the 2019 MFCL updated diagnostic model with a catch-conditioned approach. This has been the focus of recent work and will be discussed at the PAW. Once we are satisfied with a catch-conditioned version of the 2019 diagnostic model, we will conduct a series of one-off sensitivity tests to explore sensitivities to changes being considered for the new assessment, including data inputs, biological and structural uncertainties etc. The outcomes of these one-off sensitivities will be used to inform the structure of the final stepwise model development to establish the new diagnostic model. These one off-sensitivities will be conducted on the catch-conditioned 2019 diagnostic model, allowing us time to explore sensitivities earlier in the assessment time schedule, before the final data updates for the 2021 terminal year are completed in May. The PAW is an important forum for considering sensitivities to explore and discuss proposed changes from the 2019 to 2022 assessment. The final stepwise model development phase will occur when the new data inputs are finalized. Hopefully this will lead to fewer last-minute surprises.

Uncertainty treatment

Treatment of uncertainty in the assessment outcomes used for management advice is an important consideration of any assessment. Previous skipjack assessments have characterised uncertainty using a factorial grid approach (i.e., Table 1), that considers combinations of various components of structural (or model) uncertainty. These components and their respective levels/values in the uncertainty grid have been an important topic of discussion at the PAW, with the goal of developing a grid that incorporates the most important structural uncertainties, while limiting the total number of models required to be run. This group of models is used for formulating management advice, providing a range of potentially plausible states of the stock and fishing impacts against which managers can consider risk.

The model grid used in the 2019 assessment is shown in Table 1. The most influential uncertainties in the 2019 assessment were the mixing period, growth and steepness assumptions. The steepness assumptions applied are standard options applied to tropical tuna assessments and we propose to continue with the range of steepness values applied in 2019. PAW attendees may be aware of new work that could be important in refining the choice/range of skipjack tuna steepness assumptions, if so, please raise this.

Between each assessment, research should be ongoing to reduce uncertainties. In the case of skipjack, the choice of the growth relationship remains problematic due to the difficulty of obtaining accurate age estimates from hard parts such as otoliths. We are not aware of any new growth studies in the western and central Pacific which could be applied to the 2022 assessment. In terms of growth estimation, we plan to further explore the application of MFCL to estimate growth from length composition modal structures (to be discussed at the PAW) by initially placing high weight on the length composition data, as was done in the previous assessment, and applying the resulting estimated growth form externally to the final models, where the size composition receives lower weight. This may include attempting shorter time steps and selecting data that have clearer modal structures. We also plan to analyse tag-recapture growth increment data as a potential source of growth information that may lend support to the estimates derived from MFCL.

Natural mortality (M) at age was not included as an axis in the previous assessment but was estimated internally, meaning that for each model of the uncertainty grid a different M at age was estimated. Rather than allowing M at age to vary in relation to changes in other assumptions, an alternative is to determine M at age from an external analysis and apply these values as fixed inputs. We propose to explore this option for the 2022 assessment with a similar approach as applied to the 2021 South Pacific albacore assessment. The approach involves estimating growth models using MFCL (similar to the previous assessment), and then apply these growth parameters to estimate M at age using an approach that is based on that developed by Maunder and Wong (2009) and Maunder et al. (2011). This results in a combined growth and M at age axis for the uncertainty grid (see Castillo Jordan et al. (2021) appendix 1).

The most influential uncertainty in the 2019 assessment was the tag mixing period. While the general approaches to preparing the tagging data and incorporating tagging mortality, tag shedding, tagger effects and priors/penalties for tag reporting rates will not differ notably from the 2019 assessment, tag mixing has received targeted research focus. To include tag recaptures in the model estimation, it is assumed that tagged fish are fully mixed with the untagged population and hence are exposed to similar levels of fishing pressure as the untagged population. The time period that is required for this mixing to be complete is uncertain and is likely to vary among different tag release events. Previous assessments have simply applied assumptions of either one or two quarters for the mixing period to all release events. Recent work that will be presented in session 3, day 1, has developed a new tag mixing simulation approach. This approach incorporates environmental forcing on dispersal/movement of individual tagged fish (i.e., modelled particles) and those of untagged fished to estimate when simulated tagged fish have mixed to extent that they experience similar probabilities of being captured as untagged fish. It is possible that this simulation modelling can be applied to estimate tag mixing periods specific to each release event, rather than fixing the mixing period at one or two quarters for all release events. It is too early to decide whether this alternative to specifying tag mixing periods should be included in the assessment, either as the diagnostic case or as an alternative tag mixing axis in the uncertainty grid. This will be a key topic for discussion at the PAW.

Table 1. Structural uncertainty grid used in the 2019 WCPFC-CA skipjack assessment

Uncertainty	Option 1	Option 2	Option 3
Tag Mixing Period	1 quarter	2 quarter	
Length Scalar	50	**100**	200
Growth Model	Low	**Diagnostic**	High
Steepness (H)	0.65	**0.8**	0.95

Previous iterations of the skipjack assessment have not included parameter estimation uncertainty in the characterisation of uncertainty. Further, applying all of the grid axis/level combinations for management advice can result in the inclusion of combinations that are unlikely in reality, for example, low growth and high steepness, high growth and low M etc. The inclusion of grid combinations that have low plausibility can result in artificially expanding the range of uncertainty in management advice. In the past certain combinations of grid axis/levels have been down weighted for management advice during the SC meetings. This has been done in a fairly subjective manner, which is not desirable. Recent work in the area of ensemble model selection/filtering (i.e., 2021 Southwest Pacific swordfish assessment, Ducharme Barth et al. (2021)) and objective weighting approaches for model ensembles using various diagnostics provide some good direction for how to more appropriately characterise uncertainty in management quantities. This subject will also be discussed in relation to the follow-up work on model selection/weighting for the 2021 Southwest Pacific blue shark assessment in PAW session 7 of day 2. This is an active area of research and no general guidelines on approaches have been developed for WCPFC assessments. Discussions of approaches to characterising uncertainty that are feasible to apply to skipjack in the available time frame (models take approximately 7 hours to run) or as focus for further development are welcome.

References that are not hyperlinked:

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Maunder, M.N., Aires-da-Silva, A. Deriso, R.B., Schaefer, K. and Fuller, D., 2009. Preliminary estimation of age- and sex-specific natural mortality for bigeye tuna in the eastern Pacific Ocean by applying cohort analysis with auxiliary information to tagging data. Inter-Amer. Trop. Tuna Comm., Stock Assessment Report, 10: 253-278.