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**Recent progress in the technical development of harvest strategies for WCPFC
stocks and fisheries.**

WCPFC-SC17-2021/MI-WP-03

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Executive Summary

Under the harvest strategy workplan, WCPFC is scheduled to adopt management procedures for WCPO skipjack and South Pacific albacore in 2022. A number of technical developments to the evaluation frameworks will be necessary to support members in meeting that deadline.

For WCPO skipjack the modeling and evaluation framework is well advanced. At this point further technical work is limited to finalising the outstanding elements of the robustness set of operating models.

For South Pacific albacore it may be necessary to re-visit the conditioning of the operating models in the light of the most recent assessment although this depends to a large extent on the outcome of the stock assessment modeling work and the considerations of SC17 which at the time of writing are not yet completed. It will also be necessary to develop candidate model-based management procedures for South Pacific albacore following recent testing of a range of empirical approaches.

The next steps in the further development of the mixed fishery approach involve the conditioning of OMs for both bigeye and yellowfin; the development of candidate management procedures for bigeye and the development of mixed fishery performance indicators.

In some cases these outstanding tasks represent a large amount of work. Development of single species evaluation frameworks is broadly keeping pace with the workplan and the current deadlines for adoption of management procedures for skipjack and albacore remain technically feasible. Full development of the mixed fishery framework, however, is expected to take longer. Progress towards completing the mixed fishery framework will be enhanced by the agreement of TRPs for all species which will facilitate the development of HCRs and mixed fishery performance indicators.

Noting that some feedback has previously been received from the SC16 online forum, we continue to invite SC17 to provide feedback and direction on all aspects of the continuing work to develop harvest strategies for WCPFC tuna stocks and fisheries, including:

- advice on the adequacy of the sources, and ranges, of uncertainty currently considered in the skipjack and South Pacific albacore MSE frameworks;
- advice on, and suggestions for, HCR designs for both skipjack and South Pacific albacore;
- feedback on web-based tools and the presentation of MSE results to assist in decision making;
- feedback on, and suggestions for further developing communication, engagement and capacity building with respect to the technical development of the harvest strategy approach.

To progress the development of harvest strategies for the WCPFC stocks and fisheries SC17 may wish to seek advice from the Commission on the following issues:

- the definition of fisheries and fishery controls within the the harvest strategy;

- procedures for identifying, selecting and implementing the 'best performing' management procedure.

1 Introduction

Substantial technical progress towards the development of harvest strategies was made during 2020, specifically with regard to the development of candidate harvest control rule designs for both skipjack and South Pacific albacore; accounting for uncertainties in the MSE frameworks; development of an efficient estimation model for skipjack; calculation of performance indicators for the skipjack monitoring strategy and communication of MSE results for decision makers. However, SC16 was unable to discuss much of this work in part due to time restrictions of the online meeting format. Some members also felt they lacked a sufficient understanding of the topic to discuss these developments in detail. Due to the limited discussion of these issues, SC16 was unable to provide advice to WCPFC17 on a number of issues to guide the direction of further development of the harvest strategy approach. During both SC16 and WCPFC17 many members noted the need for further capacity building to better understand how harvest strategies function and their implications.

In response to these concerns the pace of development of the technical aspects of the evaluation framework has slowed in 2021 to allow greater focus on capacity building initiatives and to allow more time to review recent developments. Nonetheless, a number of important technical areas have been progressed in 2021, including initial evaluations of the mixed fishery framework (SC17-MI-WP-05); the simulation of CPUE data for South Pacific albacore tuna for input into candidate management procedures (SC17-MI-IP-01); and fine-tuning the evaluation framework for WCPO skipjack tuna (SC17-MI-WP-04).

This overview paper provides a brief summary of the work undertaken in 2021 to progress the development of the harvest strategy approach and places it in context with the technical developments that have been achieved in recent years. It summarises work undertaken to date, identifies priority work areas for future development and highlights some of the key decisions and considerations for both the SC and the Commission. The work presented to SC17 is underpinned by a large body of work submitted to previous meetings.

2 WCPFC harvest strategy workplan

WCPFC17 adopted an updated indicative workplan for the adoption of harvest strategies under CMM 2014-06. Key tasks requiring SC and Commission consideration in 2021 are to continue development and testing of management procedures for skipjack and South Pacific albacore and to agree target reference points (TRPs) for bigeye and yellowfin tuna. In addition, the mixed fishery framework should continue to be developed. The SC is further tasked to provide advice on new information on a TRP for skipjack and to consider any potential update of the TRP for South Pacific albacore in the light of the most recent assessment. The workplan extends only as far as

2022 at which point WCPFC is scheduled to adopt management procedures for WCPO skipjack and South Pacific albacore tuna.

Much of the work to progress the development of the harvest strategy approach, both in terms of technical development of the modeling framework and in capacity building, has been conducted under the New Zealand Ministry of Foreign Affairs and Trade (MFAT) funded project "Pacific Tuna Management Strategy Evaluation".

3 Skipjack tuna in the WCPO

The modeling framework for WCPO skipjack is well advanced. Many of the key technical challenges have been addressed and are documented in papers submitted to this, and previous, meetings of the Scientific Committee. Outstanding tasks include:

- finalising elements of the robustness set of operating models;
- evaluating any additional management procedures as proposed by members;
- further developments to the monitoring strategy, specifically regarding the format of the monitoring strategy report and calculation of some performance indicators.

3.1 MSE framework for WCPO skipjack

The technical details of the MSE framework for WCPO skipjack were described in SC16-MI-IP-08. This paper outlined the analyses undertaken to develop the operating models (OMs) that comprise the MSE uncertainty grid and sets the range of scenarios across which candidate management procedures (MPs) will be tested. Related to this is a description of the generation of simulated data within the framework that will feed into the management procedure (SC16-MI-IP-10).

The OMs are divided into a reference set and a robustness set (Rademeyer et al., 2007; Punt et al., 2014). The reference set is considered to reflect the most plausible hypotheses of fishery and stock dynamics and forms the primary basis for selecting the 'best performing' MP. The robustness set comprises scenarios that are considered less likely though still plausible and are used to give a secondary indication of the performance of a reduced subset of management procedures, for example in situations where the final selection must choose between two very similarly performing MPs. Work continues to finalise the outstanding elements of the OMs that will comprise the robustness set for WCPO skipjack (SC15-MI-WP-06). The absence of a completed robustness set at this point should not limit progress towards the final adoption of a management procedure.

Performance indicators measure the expected performance of each management procedure in relation to defined management objectives. They allow managers to identify and select the best performing management procedure. Performance indicators are calculated from the evaluations

across the range of scenarios included in the reference set. The methods for the calculation of the performance indicators is described in SC14-MI-WP-04. Not all of the specified performance indicators can be generated within the evaluation framework. In some cases performance indicators are based on proxies for the metric of interest, in other cases they are omitted from the MSE analyses but remain for consideration within the monitoring strategy. The skipjack MSE results are presented for a subset of 6 performance indicators (see SC17-MI-WP-04).

3.1.1 Candidate management procedures

Management procedures can be broadly classified as either empirical (in which the estimate of stock status is based on relatively unprocessed data e.g. CPUE trends) or model-based (in which the estimate of stock status is determined from an analytical stock assessment). Given the challenges associated with the interpretation of purse seine CPUE, the development of management procedures for WCPO skipjack have focused on model-based approaches that use an update MULTIFAN-CL assessment. The development, testing and performance of the estimation model is described in SC16-MI-IP-09.

The details of the management procedure for WCPO skipjack are provided in the appendices of SC17-MI-WP-04 including:

1. the management period (i.e. the frequency with which the management procedure is applied).
2. the fisheries that are under control of the management procedure (including any adjustment for archipelagic waters).
3. the unit of control (catch or effort) for each fishery.
4. the data collection protocols that are assumed to operate into the future.
5. the fixed settings to be used for the estimation model to estimate stock status.
6. the form and parameterisation of the harvest control rule including the baseline conditions (2012) to which it applies.

3.1.2 Skipjack TRP

To support discussions for a revised TRP for WCPO skipjack, SC17-MI-WP-02 indicates the changes in effort and biomass (depletion) from 2012 and recent (2015-2018 average) levels, and median equilibrium yield (as a proportion of MSY) associated with strategies that maintain a median of spawning biomass depletion ($SB/SB_{F=0}$) at Commission-specified depletion levels (ranging from 36% to 50%) using the agreed 2019 skipjack assessment. Agreement of a TRP by WCPFC18 would assist the evaluation of candidate MPs for skipjack.

3.2 Monitoring strategy

Once an MP has been selected and implemented, it should be monitored through time to ensure that it is performing as expected. The monitoring strategy:

1. collects the necessary data from the fishery to calculate performance indicators that are the same as (or as close as possible to) the performance indicators calculated from the evaluations and routinely checks that the observed performance of the MP is consistent with expected performance from the evaluations.
2. monitors the collection of new data to ensure that the basis of the evaluation framework and scenarios included in the uncertainty grid remain valid and appropriate.

An examination of data availability and the procedures for calculating performance indicators from observed data, as outlined in item 1 above, is provided in SC16-MI-IP-02.

As part of the monitoring strategy a stock assessment may be conducted. This stock assessment is different from the very tightly specified assessment that is conducted as part of the management procedure. Its purpose is to calculate performance indicators that are generated from stock assessment outputs (e.g. $SB/SB_{F=0}$) and to check that the evaluation framework continues to adequately represent the stock and fishery dynamics.

3.3 Summary

For WCPO skipjack the modeling and evaluation framework is well advanced. At this point further technical work is limited to finalising the outstanding elements of the robustness set of operating models.

4 South Pacific albacore tuna

The evaluation framework for South Pacific albacore is relatively well advanced. Recent work has focused on resolving a number of key technical challenges, most notably the process for generating future catch and effort data within the simulations. A specific challenge is to generate simulated catch and effort data that sufficiently reflect the level of variability observed in real data. Unlike skipjack, for which large quantities of tag release and recapture data are available to support the assessment, the assessment of South Pacific albacore is heavily reliant on available CPUE information. The 2018 assessment of South Pacific albacore (Tremblay-Boyer et al., 2018) included a large amount of work to revise and improve the CPUE information used in the assessment. Despite this work, some issues persist. Although key management quantities from the assessment (e.g. $SB/SB_{F=0}$) are less affected, aspects of the assessment continue to show retrospective patterns

through time that can have a significant impact on our ability to conduct projections and to simulate realistic data for the future.

When testing the expected performance of any harvest strategy, the ability to simulate realistic catch and effort data is clearly a priority. In the case of South Pacific albacore, for which initial investigations have focused on empirical approaches (where trends in CPUE are used to provide the estimate of stock status that is input to the HCR) it becomes especially important. A CPUE hindcasting analysis to examine how effectively catch and effort can be simulated within the South Pacific albacore evaluation framework was outlined in SC16-MI-IP-04 and is further developed in SC17-MI-IP-01. It highlights the difficulty in generating realistic nominal CPUE at the fishery level but indicates that, for some model regions, simulated CPUE for standardised index fisheries may be used as a basis for testing empirical management procedures.

4.1 MSE framework for South Pacific albacore tuna

An initial modeling framework for South Pacific albacore was first outlined in SC15-MI-WP-08. The framework was based very closely on the modeling approaches used for the 2018 south Pacific albacore stock assessment. The range of OMs used for the MSE evaluations retained the full 72 model stock assessment uncertainty grid with axes of uncertainty representing alternative assumptions for steepness of the stock and recruitment relationship, growth and natural mortality, as well as alternative relative weightings for size composition data and different methods for standardising CPUE. Variability in future recruitment is also included. The assessment for South Pacific albacore is characterised by substantial temporal variability in recruitment and this accounts for a large proportion of the uncertainty in future stock levels.

The modeling framework and the elements of the MSE uncertainty grid for South Pacific albacore may be reviewed in the light of the new stock assessment ([Castillo-Jordan et al., 2021](#)) and could be revised if the current ranges of uncertainty are considered insufficient or inappropriate. However, changes to the current MSE uncertainty grid might not be necessary. If the initial conditioning of the operating models has been completed successfully, the results of the new (2021) assessment should fall within the bounds of uncertainty currently assumed for the stock.

The derivation and calculation of performance indicators for South Pacific albacore is detailed in SC15-MI-WP-03. Similar to skipjack, not all of the performance indicators can be reported from the MSE analyses. In some cases they are based on proxies for the metric of interest, in other cases they are omitted from the MSE analyses but remain for consideration within the monitoring strategy.

4.2 Candidate management procedures

Under the initial technical workplan for developing harvest strategies for South Pacific albacore (SC14-MI-WP-02), the primary focus was to develop empirical management procedures using long-line CPUE as the indicator of stock status that is input to the HCR. It was noted that either a regional combined CPUE series or one derived from a localised 'reference' fleet may provide an appropriate signal with which to manage the overall fishery and should be investigated.

SC16-MI-IP-05 presented the results of South Pacific albacore MSE analyses conducted for empirical management procedures along with a number of design considerations for HCRs that take either CPUE or size composition data as input. The evaluations were exploratory in nature since it proved difficult to identify a single CPUE series that reliably tracked the underlying population biomass through time.

Analyses conducted to date have demonstrated the relative advantages and disadvantages of empirical management procedures. On the one hand, they are very simple in concept, often require minimal processing of input data and can be more closely aligned with economic objectives related to catch rates and vessel profitability. On the other, they rely heavily on a CPUE index that reliably tracks overall stock abundance. Such indices can be difficult to identify for a very widely dispersed stock for which multiple assessment regions are considered. Model-based approaches can address some of these problems and a next step in the development of harvest strategies for South Pacific albacore would be to develop model-based management procedures that use relatively simple biomass dynamic assessment models.

4.3 Monitoring strategy

The monitoring strategy for South Pacific albacore has received relatively little attention to date, although much of the work undertaken to develop methods for the monitoring strategy for skipjack can be similarly applied to albacore, particularly in situations where the management objectives and hence performance indicators for the stocks and fisheries are similar.

4.4 Summary

For South Pacific albacore it may be necessary to re-visit the conditioning of the operating models in the light of the most recent assessment although this depends to a large extent on the outcome of the stock assessment modeling work and the considerations of SC17 which at the time of writing are not yet completed. It will also be necessary to develop candidate model-based management procedures for South Pacific albacore following recent testing a range of empirical approaches.

5 Bigeye and yellowfin tunas in the WCPO

WCPFC12 agreed to a workplan for the adoption of harvest strategies for WCPO skipjack, bigeye, yellowfin and South Pacific albacore tuna. These four stocks are caught by an overlapping mix of fisheries. Management measures for one stock will impact fisheries that catch other stocks. An important consideration when developing harvest strategies for these stocks is to account for mixed fishery interactions.

5.1 Mixed fishery framework

The mixed fishery framework involves developing stock specific management procedures (MPs) for skipjack, South Pacific albacore and bigeye, in line with the agreed WCPFC harvest strategy workplan. The interaction of these MPs, as well as their impact on yellowfin, would then be evaluated using a combined evaluation framework. An implementation of this approach is described in SC17-MI-WP-05 which demonstrates an initial attempt at considering multi-species and mixed fisheries interactions based on single stock OMs for skipjack, bigeye and yellowfin.

This proof of concept analysis demonstrates that the technical challenges involved in implementing the multi-species modeling framework can be addressed and the conceptual approach remains tractable. The initial results are sufficiently encouraging to support the continued development of this approach.

5.2 Summary

The next steps in the further development of the mixed fishery approach involve the conditioning of OMs for both bigeye and yellowfin; the development of candidate management procedures for bigeye and the development of mixed fishery performance indicators. In order to fully develop performance indicators under the mixed fishery approach the adoption of TRPs for both bigeye and yellowfin tunas will be useful.

6 Support for decision making

The roles of scientists and managers and the key decisions and areas for advice from both the Scientific Committee and the Commission have been outlined in previous reports (SC14-MI-WP-05). Greater input from managers and stakeholders will be increasingly important over the coming year to guide the direction of formal evaluations. A common understanding and interpretation of the results and of the implications of the harvest strategy will be necessary to make informed decisions based on MSE outputs.

To facilitate this process, a number of web-based tools have been developed to present the results of the evaluations. They allow for interrogation of a range of performance indicators that are output from the simulations and will, hopefully, facilitate the identification and selection of the 'best performing' management procedure.

- PIMPLE (<https://ofp-sam.shinyapps.io/pimple/>) presents up to date results of the most recent MSE analyses for WCPO skipjack.
- SPAMPLE (<https://ofp-sam.shinyapps.io/spample/>) currently presents the results of preliminary MSE analyses for empirical management procedures for South Pacific albacore.

A similar application (The Hierophant, <https://ofp-sam.shinyapps.io/hierophant/>) has also been developed to allow exploration of the model diagnostics of MULTIFAN-CL assessment models. Currently the application presents the reference set of OMs from the WCPO skipjack evaluation framework.

We welcome feedback on these applications in terms of their overall utility in:

- helping to understand the evaluation process;
- interrogating the MSE results and
- facilitating the process of identifying and selecting the best performing management procedure.

6.1 Capacity building

Capacity building efforts to date have focused on running country specific harvest strategy workshops. A number of workshops have been run in the first half of 2021 and more are planned for later in the year. Efforts to increase the number of workshops in 2021 have been hindered by the continuing impacts of COVID and by difficulties encountered trying to find a suitable time slot in member's calendars.

In person workshops can be an effective way to present a large amount of information to a group over a number of days. Under the current restrictions, however, it has been necessary to move the workshops to an online format. Online workshops are generally less effective and the content of the workshops must be trimmed accordingly. To further support and augment the online workshops an *'Introduction to Harvest Strategies'* Moodle course has been developed. The course is hosted on the SPC learning management system <https://spc.learnbook.com.au/login/index.php> and can be accessed either with a username and password or using the guest login option. Elements of the site are still under development and more content will be added to the course in time. We welcome any feedback on the material presented on this site and any suggestions for improvement.

Capacity building and stakeholder engagement activities are further outlined in SC17-MI-IP-02

including further information on the tools developed for capacity building and decision making, the Pacific Island Fisheries Professional programme and additional engagement material.

7 Next steps

Under the harvest strategy workplan, WCPFC is scheduled to adopt management procedures for WCPO skipjack and South Pacific albacore in 2022. A number of technical developments to the evaluation frameworks will be necessary to support members in meeting that deadline.

Outstanding tasks include:

- **Skipjack:** finalising the outstanding elements of the robustness set of operating models;
- **Albacore:** develop candidate model-based management procedures;
- **Bigeye and Yellowfin:** development of candidate management procedures for bigeye and the development of mixed fishery performance indicators.

In some cases these outstanding tasks represent a large amount of work. Development of single species evaluation frameworks is broadly keeping pace with the workplan and the current deadlines for adoption of management procedures for skipjack and albacore remain technically feasible. Full development of the mixed fishery framework, however, is expected to take longer. Progress towards completing the mixed fishery framework will be enhanced by the agreement of TRPs for all species which will facilitate the development of HCRs and mixed fishery performance indicators.

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