SCIENTIFIC COMMITTEE
SIXTEENTH REGULAR SESSION

ELECTRONIC MEETING
11-20 August 2020

Further consideration of the mixed fishery management strategy evaluation framework for WCPO tuna stocks

WCPFC-SC16-2020/MI-IP-06

F. Scott[1], J. Singh, R. Scott, N. Yao, G. M. Pilling and J. Hampton

Oceanic Fisheries Programme, The Pacific Community

Contents

Executive Summary

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 which means that management measures aimed at one particular stock can therefore have impacts on other stocks. An important consideration when developing harvest strategies for these stocks is to account for mixed fishery interactions.

SC15 agreed to initially consider the 'hierarchical approach' (now referred to as the multi-species modelling framework) for developing a mixed fishery management strategy evaluation (MSE) framework for the four tuna stocks. This framework involves developing prospective single stock management procedures (MPs) for skipjack, South Pacific albacore and bigeye respectively, in line with the agreed WCPFC harvest strategy workplan. The impact of these MPs on yellowfin would then be evaluated using a combined evaluation framework. This approach should be regarded as an initial attempt at considering multi-species and mixed fisheries interactions. If it is found to be unsuccessful, in terms of achieving objectives for the four stocks, alternative approaches will need to be developed.

This report provides further consideration of this multi-species modelling framework, including identifying which model fisheries within the MSE framework would be managed through which MP and the proportions of recent catches they take. Technical challenges and necessary assumptions for the simulation framework are described.

Under the proposed framework, the majority of catches of skipjack and South Pacific albacore are managed through their own MPs, based on recent catch levels, supporting the current WCPFC harvest strategy workplan. Any candidate MPs developed using single-species MSE (such as the current South Pacific albacore and skipjack evaluations) will need to be tested with the mixed fishery MSE to fully evaluate their performance. Further progress in implementing this multi-species framework will be made when new assessments for bigeye and yellowfin are agreed by SC.

Implementing this multi-species modelling framework presents several technical challenges. It is thought that these challenges can be addressed and the modelling framework remains tractable. Additionally, several assumptions will need to be made to run the simulations, for example, continued application of the FAD closure for the purse seine fishery, proportional application of harvest control rules to different fisheries exploiting a species, treatment of fisheries in archipelagic waters and territorial seas and any redistribution of fishing effort. It is important that these assumptions are clearly defined and presented to stakeholders in a transparent manner to facilitate input on the modelling, and ultimately management, decisions.

We invite WCPFC-SC to note progress in developing the multi-species modelling framework as the initial approach for including mixed fishery interactions when developing and testing harvest strategies for the four main WCPO tuna stocks.

1 Introduction

WCPFC12 agreed to a workplan for the adoption of harvest strategies for WCPO skipjack, bigeye, yellowfin and South Pacific albacore tuna. These tuna stocks are caught by an overlapping mix of fisheries which means that management measures aimed at one particular stock can therefore have impacts on other stocks (Scott et al., 2019b). An important consideration when developing harvest strategies for these stocks is to account for mixed fishery interactions.

A key component of a harvest strategy is the management procedure (MP), which is a combination of data collection, the estimation method (to monitor stock status and provide the signal for management action), and a decision rule, known as a harvest control rule, that sets fishing opportunities based on the estimates of stock status (Punt et al., 2014). An MP is adopted on the basis that it is likely to achieve the agreed management objectives. Before an MP is adopted, the relative performance of candidate MPs, including the robustness to uncertainty, can be tested using management strategy evaluation (MSE) (Punt et al., 2014; Scott et al., 2019a).

Two possible approaches for modelling mixed fisheries in the harvest strategy MSE simulations were previously described: the fully integrated modelling approach and the hierarchical approach (subsequently renamed the multi-species approach) (Scott et al., 2019b). SC15 agreed to initially consider the multi-species modelling framework (WCPFC, 2019). This approach should be regarded as an initial attempt at considering multi-species and mixed fisheries. If this approach is found to be unsuccessful, in terms of achieving objectives for all four stocks, alternative approaches will need to be developed.

This report provides further consideration of this multi-species modelling framework, including identifying which model fisheries within the MSE framework would be managed through which MP and the proportions of recent catches they take. Technical challenges and necessary assumptions for the simulation framework are described.

2 Overview of the multi-species modelling framework

Including mixed fishery interactions in a harvest strategy can be challenging. The agreed WCPFC harvest strategy workplan recognised this and proposed that the initial focus be on skipjack, followed by South Pacific albacore, and then bigeye and yellowfin. This is because skipjack and South Pacific albacore are mainly caught by a single dominant fishery (purse seine and southern longline respectively) and so single stock evaluations could initially be developed. Progress has been made towards developing single stock MSE simulation frameworks for these stocks (Scott et al., 2019c; Yao et al., 2020; Scott et al., 2020, 2019a).

The multi-species modelling framework involves developing prospective single stock MPs for skipjack, South Pacific albacore and bigeye. The impact of these MPs on yellowfin would then be evaluated using a combined evaluation framework to identify whether the multi-species framework

Table 1: Proposed integration of stock-based management procedures (MPs) across fisheries under the multi-species modelling framework. The cells in bold signify the main fishery being controlled by the MP (adapted from Scott et al. (2019b)).

WCPO fishery	Skipjack	Yellowfin	Bigeye	South Pacific albacore
Tropical PS	**SKJ MP**	SKJ MP	SKJ MP	NA
Northern PS	SKJ MP	SKJ MP	SKJ MP	NA
Tropical LL	NA	BET MP	**BET MP**	BET MP
Northern LL	NA	BET MP	BET MP	NA
Southern LL	NA	ALB MP	ALB MP	**ALB MP**
Pole and line	SKJ MP	SKJ MP	SKJ MP	NA
ID/PH/VN (non-AW)	SKJ MP	SKJ MP	SKJ MP	NA
Southern Troll	NA	NA	NA	ALB MP
Archipelagic waters and territorial seas	Aligned to SKJ MP, national plan or local MP	Aligned to SKJ / BET MPs, national plan or local MP	Aligned to SKJ / BET / ALB MPs, national plan or local MP	Aligned to ALB MP, national plan or local MP.

can simultaneously achieve management objectives for the stocks. If not, alternative approaches will need to be developed. Any candidate MPs developed using single-species MSE (such as the current South Pacific albacore and skipjack evaluations) will need to be tested with the mixed fishery MSE to fully evaluate their performance. It is worth noting that the recent bigeye and yellowfin target reference point evaluations suggested that it is possible for these stocks to be sustainably managed if purse seine and longline fishing levels are kept at recent status quo levels (Pilling et al., 2019).

The three single stock MPs control the fishing opportunities for different WCPO fisheries by setting catch or effort limits based on status estimates of the associated stock (Table 1). Each fishery is controlled by one of the three single stock MPs. However, that fishery may catch a range of tuna stocks. It is noted that the definition and classification of the WCPO fisheries to different MPs under this approach is an initial proposal, and that alternative classifications may also be considered.

In Table 1 the longline fisheries are divided into three categories: northern, tropical and southern. Under the multi-species modelling framework these fisheries are managed through different stock-based MPs. An initial proposal for latitudinal range over which these fisheries operate is given in Table 2.

Table 2: Proposed latitude range of the different longline fisheries and the associated single stock management procedure that would manage it.

Fishery	Latitude range	Management procedure
Northern LL	20N - 50N	Bigeye
Tropical LL	10S - 20N	Bigeye
Southern LL	South of 10S	South Pacific albacore

Although Table 1 makes a distinction between northern and tropical purse seine, the multi-species modelling framework suggests that they are both managed through the skipjack MP so the latitudinal range of these fisheries does not need to be specified.

The multi-species modelling framework will allow the calculation of a range of performance indicators, including multi-species indicators that have been noted by WCPFC (Yao et al., 2019; Scott et al., 2018; WCPFC, 2017; OFP, 2017). For example, the probability of the spawning biomass depletion being greater than the limit reference point (LRP) can be calculated for each stock. Additionally, it will be possible to develop multi-species indicators that relate impacts on stock status and catches to changes in fishing pressure from the individual single stock MPs. For example, indicators can be developed that evaluate the impacts on the yellowfin and bigeye stocks and catches from changes in purse seine fishing pressure that would be managed through the skipjack MP.

It is worth noting that managing fisheries through MPs cannot necessarily encapsulate or replace all decisions that need to be made to implement a harvest strategy and there will need to be some over-arching agreements under which all potential MPs would operate, for example the continued application of the FAD closure for the purse seine fishery.

3 Management strategy evaluation model structure

In MSE modelling frameworks, the biological dynamics of the stocks and the fishery interactions are simulated by operating models (OMs) (Punt et al., 2014; Scott et al., 2019a). Under the multi-species modelling framework, the tuna stock will have individual OMs (Scott et al., 2019b). As described under the current harvest strategy workplan, progress has been made on developing individual MSE frameworks for skipjack and South Pacific albacore (Scott et al., 2019c; Yao et al., 2020; Scott et al., 2020, 2019a). The OMs in these frameworks are single stock Multifan-CL models and are based on the most recent stock assessments (Vincent et al., 2019; Tremblay-Boyer et al., 2018). OMs are yet to be developed for the bigeye and yellowfin stocks and it is assumed here that they will also use Multifan-CL and be based on the most recent stock assessments. The individual OMs will need to be included in a single MSE framework to simulate the full mixed fishery interactions.

3.1 Model fisheries

Similar to the WCPO tuna stock assessments, each single stock OM has several model regions. Each region has model fisheries representing fishing activity of a particular gear type. The model fisheries are not necessarily associated with any particular country. The regional and fishery structure are different for each stock, apart from bigeye and yellowfin which share the same structure.

To develop the mixed fishery MSE modelling framework it is necessary to determine which of the three single stock MPs manage the different model fisheries in each OM. For example, model purse seine fisheries in all model regions would be managed through the skipjack MP, while the model longline fisheries would be managed through either the South Pacific albacore or bigeye MP depending on the latitudinal range of the model region in which they operate (Tables 1 and 2). The maps in Appendix A illustrate which fisheries in which region would be managed through which MP.

3.2 The skipjack operating models

The fisheries in the skipjack OMs, based on the 2019 stock assessment, are a mix of purse seine, pole and line and longline as well as the fisheries of Indonesia, Philippines and Vietnam (Table 4). Under the multi-species modelling framework these fisheries, except for the longline fisheries, are potentially managed through the skipjack MP (Table 1). The longline fisheries in the skipjack OMs are included to provide size-based information to assist in model fitting and have extremely low catches. Although the longline fisheries would be managed through the South Pacific albacore and bigeye MPs, depending on region (Figure 1), they can be effectively ignored when running simulations.

3.3 The South Pacific albacore operating models

The fisheries in the South Pacific albacore OMs, based on the 2018 stock assessment, are a mix of southern and tropical longline and southern troll fisheries (Table 5). Under the proposed multi-species modelling framework the southern troll and southern longline fisheries are managed through the South Pacific albacore MP and the tropical longline is managed through the bigeye MP (Table 1). The latitudinal range of model region 4 in the OMs means that the longline fisheries in this region are managed through both the bigeye and South Pacific albacore MPs (Figure 2). This is one of the challenges that needs to be addressed when implementing the MSE framework (see Section 4).

3.4 The bigeye and yellowfin operating models

The bigeye and yellowfin OMs share the same regional and fishery structure. The fisheries of these OMs, based on the 2018 bigeye and 2017 yellowfin stock assessments, include purse seine, pole and line, longline and fisheries in Indonesia, Philippines and Vietnam (Table 6). Under the multi-species modelling framework purse seine, pole and line and fisheries of Indonesia, Philippines and Vietnam are potentially managed through the skipjack MP (Table 1). The longline fisheries are managed through the South Pacific albacore and bigeye MPs, depending on the latitudinal range (Figure 3). The yellowfin OMs are not associated with a specific yellowfin MP, but would be impacted by the yellowfin catches resulting from fishery settings provided by the other single stock MPs.

3.5 Summarising the operating models and management procedures

A simple metric of the recent impact of a model fishery on a stock is the proportion of total catches by weight taken by that fishery, averaged over the last three years of the most recent assessment for each stock (see Appendix B). The total proportions of recent average total catches in each OM that would potentially be managed through each single stock MP under the proposed multi-species modelling framework can then be calculated (Table 3). It should be noted that the catch proportions presented in Table 3 do not take into account the selectivity patterns of the fisheries or whether a fishery is catching juvenile or adult individuals which can impact the stock in different ways.

All of the skipjack catches are from fisheries that are managed through the skipjack MP. The majority of catches of South Pacific albacore are from fisheries that are managed through the South Pacific albacore MP. There are some catches of South Pacific albacore from fisheries that are managed through the bigeye MP (those in region 1), and some catches that are from fisheries that need to be distributed between the bigeye and South Pacific albacore MPs (those in region 4) (Figure 2). From a stock specific impact point of view, this supports the current WCPFC workplan of developing single-species MSE simulation frameworks for skipjack and South Pacific albacore that do not consider mixed fishery interactions. Any candidate MPs developed using single-species MSE in this way will need to be tested with the mixed fishery MSE to fully evaluate their performance.

The bigeye catches are mostly split between fisheries that are managed through the bigeye MP and those that are managed through the skipjack MP. Fisheries managed through the South Pacific albacore MP make up only a small proportion (those in regions 5, 6 and 9) (Figure 3). This demonstrates that when evaluating MPs for bigeye it is necessary to include the actions of the skipack MP. It should be noted that although the skipjack MP manages fisheries that catch about 50% of recent total bigeye catches, a key feature of skipjack management is the FAD closure which is implemented to limit impacts on bigeye. This means that concerns about bigeye are included in the skipjack management, but in a way, through the FAD closure, that is independent of the skipjack HCR. The associated purse seine fisheries that are managed through the skipjack MP tend to catch small bigeye. Assumptions about the continuation of the FAD closure into the future will need to be made when running the mixed fishery simulations.

Under the proposed multi-species modelling framework, there is no single stock MP for yellowfin. Instead yellowfin is managed through the other single stock MPs. The majority of yellowfin catches are from fisheries that are managed through the skipjack MP, with the remainder mostly from fisheries that are managed through the bigeye MP, and a small proportion from fisheries that are managed through the South Pacific albacore MP. As mentioned above, it will be possible to develop a range of multi-species performance indicators that relate impacts on stock status and catches to changes in fishing pressure from the individual single stock MPs.

Table 3: Proportion of average total catches by weight (taken from the last three years of the most recent assessment for each stock) in each operating model that would be potentially managed by each management procedure (MP). Fisheries operating in archipelagic waters of Papua New Guinea, Indonesia, Philippines and Vietnam are assumed to be managed through the skipjack MP but this may not necessarily be the case. Note that for some fisheries in the South Pacific albacore operating model, there is an overlap between the albacore and bigeye MPs.

Operating model	Skipjack MP	SP albacore MP	Bigeye MP	SP albacore / bigeye MP
Skipjack	1.000	0.000	0.000	0.000
South Pacific albacore	0.000	0.747	0.134	0.119
Bigeye	0.493	0.043	0.464	0.000
Yellowfin	0.797	0.028	0.175	0.000

4 Modelling challenges and uncertainties

Developing the multi-species modelling framework presents several technical challenges and requires assumptions to be made.

Longline fisheries in model regions that cross the 10° South boundary include tropical and southern longline fisheries, for example region 4 in the South Pacific albacore OM (Figure 2). It will be necessary to attribute the fishing pressure from these model fisheries to the South Pacific albacore and bigeye MPs. An initial approach could be to use the historical geographical distribution of catches within those regions, taken from the aggregated catch data in the WCPFC databases, to apportion the catches between those North and South of 10° South.

The multi-species modelling framework has three single stock MPs. A decision will need to be made on the timing of the MPs. For example, should all three MPs be used to determine new levels of catch or effort for the next management period in the same year, or should they be staggered, i.e. one MP is evaluated every year under a three year cycle. It should be noted that it is preferred that the MP for a stock is not evaluated in the same year as the main stock assessment.

The choice of mechanism through which the fishery impact on the stock will be controlled by management, e.g. catch or effort limits, has implications for the implementation of the projections. For example, the MP for bigeye may set the future level of tropical longline bigeye catch, rather than the future effort. To include the corresponding impact on yellowfin, recent work has assumed that a comparable change in tropical longline yellowfin catch might result (Pilling et al., 2019). However, it would be better to evaluate the equivalent level of tropical longline fishing effort that equates to that bigeye catch, in order to input that effort into evaluations of the impact on the yellowfin stock. In both cases, this would assume limited change in tropical longline targeting.

Following this, assumptions will need to be made about changes in the distribution of effort within the WCPO fishery. For example, if the MP for South Pacific albacore suggests a reduction in fishing activity in southern longline, assumptions will need to be made about the possible redistribution of effort, i.e. potential increases in tropical or northern longline fishing effort, or the removal of fishing effort from the system. This could be initially explored by running several different simulation scenarios, i.e. no redistribution of effort, all effort redistributed etc., to identify the potential impact on the overall performance of the MPs.

Assumptions will need to be made about whether the archipelagic waters of Papua New Guinea, Indonesia, Philippines and Vietnam will be managed through the single stock MPs. The maps and tables in the Appendix are based on the assumption that the fisheries in the archipelagic waters will fall under one of the single stock MPs. It will be necessary to estimate what proportion of the total catch of each stock occurs in archipelagic waters to understand how important these assumptions are. While the proposed multi-species modelling framework captures the potential impact of many of the main fishing gears, when considering yellowfin the activity of the 'other' fisheries that take 20% of the yellowfin catch needs to be considered (Scott et al., 2019b). Noting that much of this catch is from small scale gears operating within archipelagic waters, a decision on the feasibility of their inclusion within any MP, or assumptions to be made for these fisheries, is needed. Ultimately, as these are sovereign waters, each relevant CCM will decide on their approach (e.g. adopt the MP's decisions, compatible measures, etc.), which can be modelled within the framework.

As mentioned above, OMs will need to be developed for each of the four tuna stocks. These OMs comprise a grid of models that have been conditioned to capture the main sources of uncertainty. OMs for skipjack and South Pacific albacore have already been developed for the single species harvest strategy evaluations that are based on the most recent stock assessment (Vincent et al., 2019; Tremblay-Boyer et al., 2018). When conditioning the grid of OMs for the single species models, all combinations of the different conditioning factors are considered. For example, the OM grid for the skipjack evaluations has 6 factors, where each factor has 2 or 3 levels giving a total of 96 models in the grid. When developing the grid of OMs for the mixed fishery model, care will need to be taken to avoid 'factorial explosion' that can occur by considering all levels of all factors across the OMs of all stocks. For example, the current South Pacific albacore grid has 24 models and the current skipjack grid has 96 models meaning that a full factorial combination of just the models from these two stocks gives 2304 models. Including the grid of models for bigeye and yellowfin in the same way will make this number very large. One option is to decide on how many simulation replicates are required and then randomly sample that number independently from the available OMs for each species. It will mean that some OM combinations do not get sampled, and that there is a possibility that some will be sampled more than once. Additionally, it may be possible to identify correlations between model grid options to reduce the possible combinations of factors between stocks.

5 Summary

The proposed multi-species modelling framework involves developing prospective single stock MPs for skipjack, South Pacific albacore and bigeye respectively. There is no single stock MP for yellowfin. Instead, the impact of these MPs on yellowfin would then be evaluated using a combined evaluation framework.

Under the proposed multi-species modelling framework the majority of skipjack and South Pacific albacore catches are managed through their own MPs. The skipjack MP will also potentially manage fisheries that catch large proportions of yellowfin and bigeye. The mixed fishery MSE framework outlined here will help explore whether achieving objectives for skipjack and South Pacific albacore is also compatible with achieving objectives for bigeye and yellowfin.

Implementing this multi-species modelling framework presents several technical challenges. It is thought that these challenges can be addressed and the modelling framework remains tractable. Additionally, several assumptions will need to be made to run the simulations, for example, continued application of the FAD closure for the purse seine fishery, proportional application of harvest control rules to different fisheries exploiting a species, treatment of fisheries in archipelagic waters and territorial seas and any redistribution of fishing effort. It is important that these assumptions are clearly defined and presented to stakeholders in a transparent manner to facilitate input on the modelling, and ultimately management, decisions.

The next steps are to begin building the multispecies MSE modelling framework, including developing the OMs. The OMs will be based on the existing single stock evaluation frameworks for skipjack and South Pacific albacore. It will be necessary to develop OMs for yellowfin and bigeye and these will potentially be based on the most recent stock assessments.

Acknowledgments

We gratefully acknowledge funding for this work from the New Zealand Ministry of Foreign Affairs and Trade (MFAT) funded project “Pacific Tuna Management Strategy Evaluation”.

References

OFP (2017). Performance indicators and monitoring strategies for bigeye and yellowfin tuna compatible with candidate management objectives for the tropical longline fishery. WCPFC14-2017-IP04, Manilla, Philippines, 3-7 December 2017.

Pilling, G., Scott, F., and Hampton, S. (2019). Minimum Target Reference Points for WCPO yellowfin and bigeye tuna consistent with alternative LRP risk levels, and multispecies implications. Technical Report WCPFC-SC15-2019/MI-WP-01, Pohnpei, Federated States of Micronesia, 12–20 August 2019.

Punt, A., Butterworth, D., de Moor, C., De Oliveira, J., and Haddon, M. (2014). Management strategy evaluation: best practices. *Fish and Fisheries*, (DOI:10.111/faf12104).

Scott, F., Scott, R., Pilling, G., and Hampton, S. (2018). Performance indicators for comparing management procedures using the MSE modelling framework. WCPFC-SC14-2018/MI-WP-04, Busan, South Korea, 5–13 August 2018.

Scott, F., Scott, R. D., Pilling, G., and Hampton, S. (2019a). The WCPO Skipjack MSE Modelling Framework. WCPFC-SC15-2019/MI-IP-02, Pohnpei, Federated States of Micronesia, 12–20 August 2019.

Scott, F., Scott, R. D., Yao, N., Pilling, G., and Hampton, S. (2019b). Mixed Fishery and Multi-Species Issues in Harvest Strategy Evaluations. WCPFC-SC15-2019/MI-WP-04, Pohnpei, Federated States of Micronesia, 12–20 August 2019.

Scott, R., Scott, F., Yao, N., Singh, J., Pilling, G., Hampton, S., and Davies, N. (2020). Updating the WCPO skipjack operating models for the 2019 stock assessment. WCPFC-SC16-2020/MI-IP-08, 12–20 August 2020.

Scott, R., Yao, N., Scott, F., and Pilling, G. (2019c). South Pacific albacore management strategy evaluation framework. WCPFC-SC15-2019/MI-WP-08, Pohnpei, Federated States of Micronesia, 12–20 August 2019.

Tremblay-Boyer, L., Hampton, S., McKechnie, S., and Pilling, G. (2018). Stock assessment of South Pacific albacore tuna. WCPFC-SC14-2018/SA-WP-05, Busan, South Korea, 5–13 August 2018.

Vincent, M., Pilling, G., and Hampton, S. (2019). Stock assessment of skipjack tuna in the Western and Central Pacific Ocean - Rev.02. WCPFC-SC15-2019/SA-WP-05, Pohnpei, Federated States of Micronesia, 12–20 August 2019.

WCPFC (2017). Report of the Scientific Committee Thirteenth Regular Session. Technical report, Commission for the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean, Rarotonga, Cook Islands, 9–17 August 2017.

WCPFC (2019). Report of the Scientific Committee Fifteenth Regular Session. Technical report, Commission for the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean, Pohnpei, Federated States of Micronesia, 12–20 August 2019.

Yao, N., Scott, F., Scott, R., Pilling, G., and Hampton, S. (2019). Calculating performance indicators for South Pacific albacore. WCPFC-SC15-2019/MI-WP-10, Pohnpei, Federated States of Micronesia, 12–20 August 2019.

Yao, N., Singh, J., Scott, R., and Scott, F. (2020). HCR design considerations for south Pacific albacore. WCPFC-SC16-2020/MI-IP-05, 12–20 August 2020.

A Regional and fishery structure of the operating models (maps)

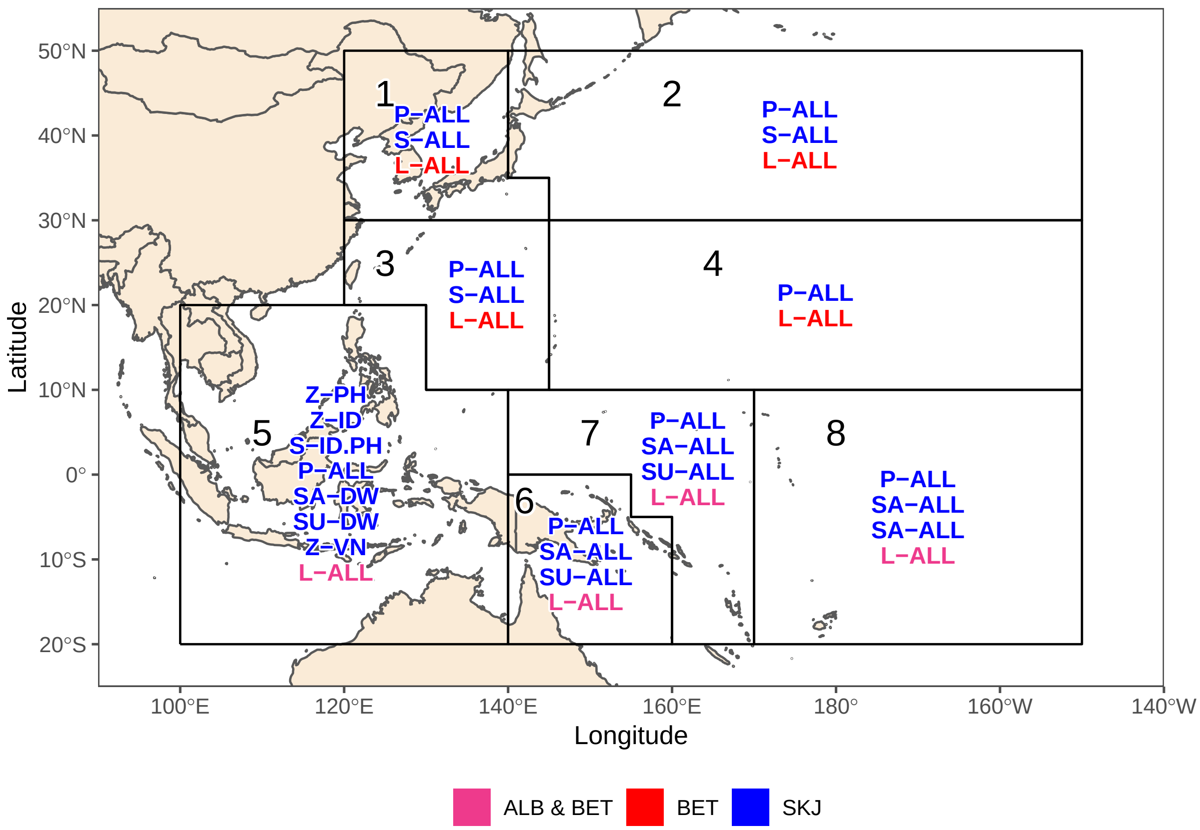

Figure 1: The regional and fishery structure of the most recent operating models for skipjack, based on the 2019 stock assessment. The names of the fisheries have been colour coded according to the proposed stock management procedure that would manage that fishery. The violet colour indicates the longline fisheries that could potentially fall under both the albacore and bigeye management procedure due to the latitudinal range. Fisheries operating in archipelagic waters of Papua New Guinea, Indonesia, Philippines and Vietnam are assumed to be managed through the skipjack MP but this may not necessarily be the case.

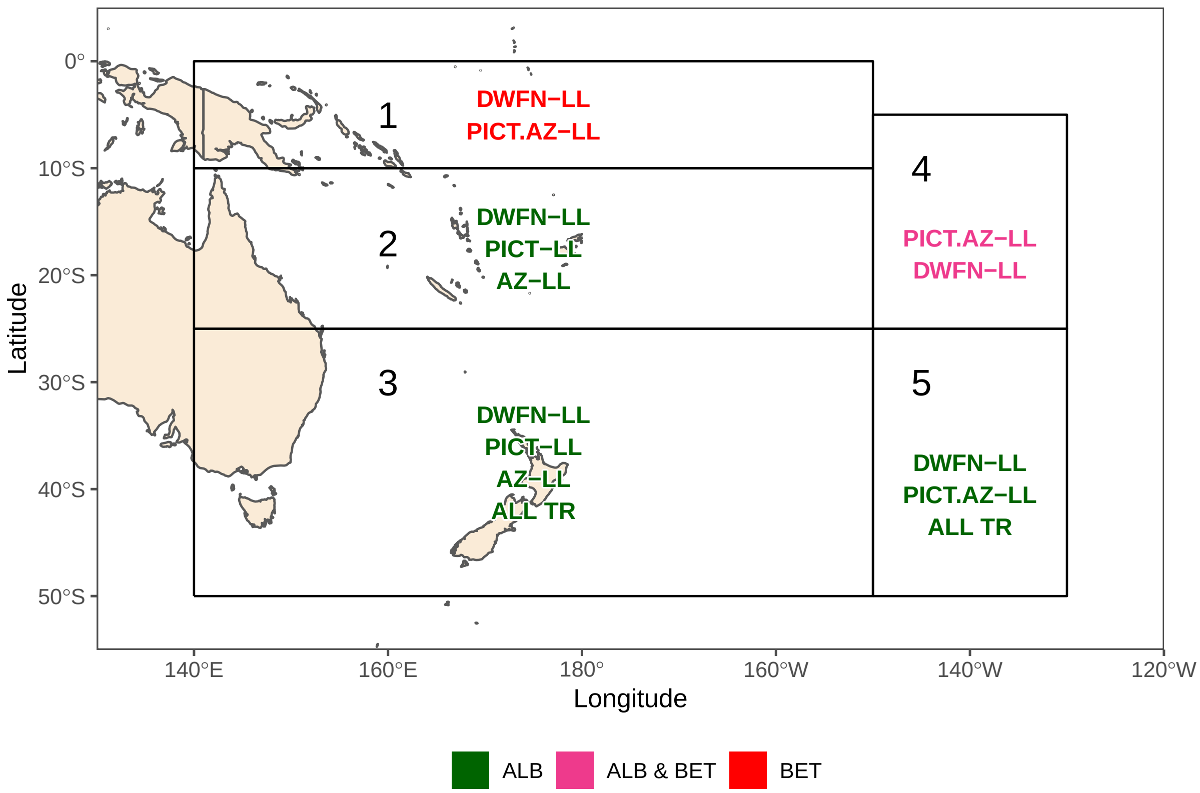

Figure 2: The regional and fishery structure of the most recent operating models for albacore, based on the 2018 stock assessment. The names of the fisheries have been colour coded according to the proposed stock management procedure that would manage that fishery. The violet colour indicates that the fishery could potentially fall under both the albacore and bigeye management procedure due to the latitudinal range.

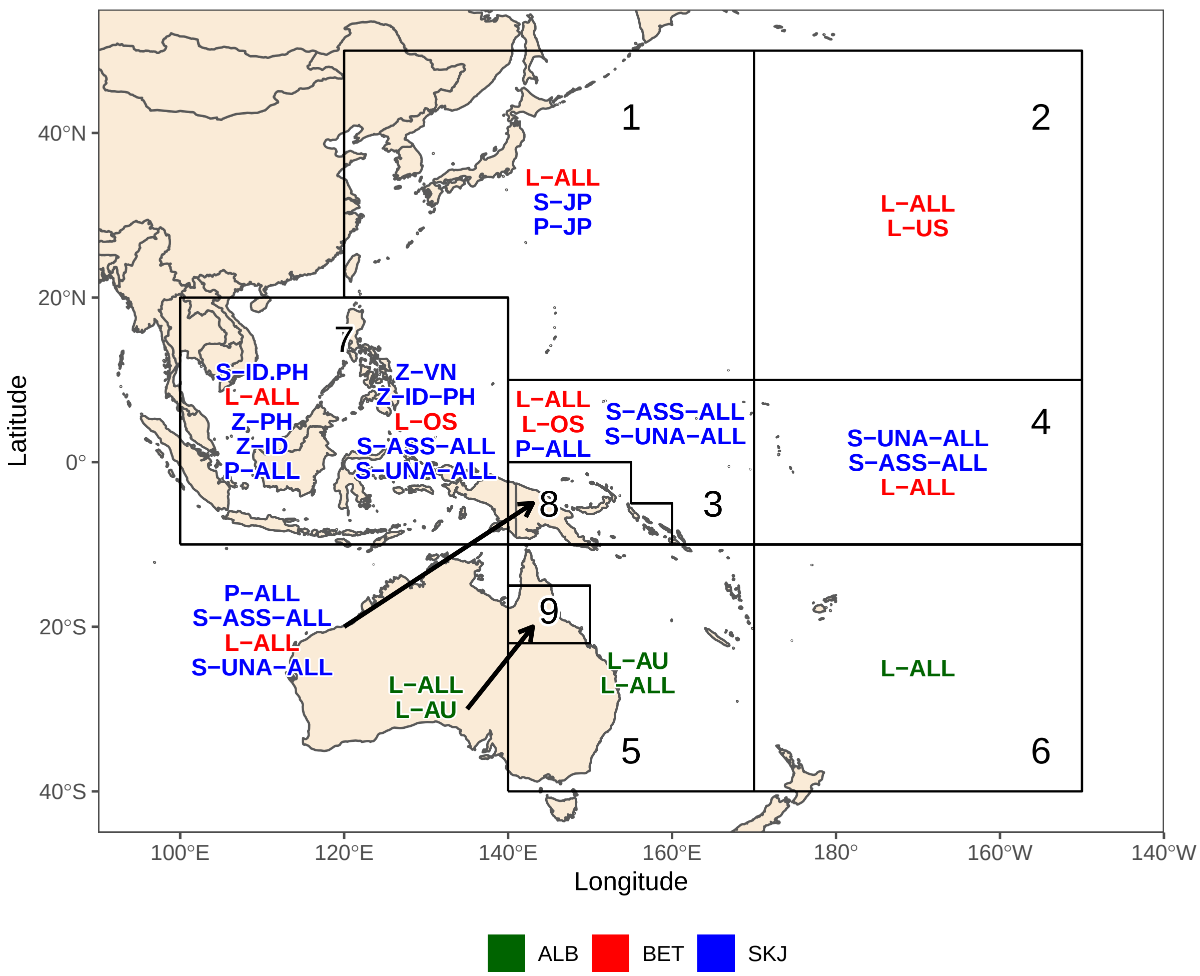

Figure 3: The regional and fishery structure of the most recent stock assessments of bigeye and yellowfin (2018 and 2017, respectively), based on the '10 degree North' model. The names of the fisheries have been colour coded according to the proposed stock management procedure that would manage that fishery. Fisheries operating in archipelagic waters of Papua New Guinea, Indonesia, Philippines and Vietnam are assumed to be managed through the skipjack MP but this may not necessarily be the case.

B Regional and fishery structure of the operating models (tables)

Table 4: Fisheries in the skipjack operating model, the associated WCPO fishery (from Table 1) and the proposed associated management procedure (MP). The *Catch prop.* column is the average proportion of total catches in biomass taken by that fishery in the years 2016 to 2018 (from the 2019 stock assessment). Due to their latitudinal range, the longline fisheries in regions 5, 6, 7 and 8 are associated with both the albacore and bigeye MPs. Fisheries operating in archipelagic waters of Papua New Guinea, Indonesia, Philippines and Vietnam are assumed to be managed through the skipjack MP but this may not necessarily be the case.

Model fishery	Gear	Region	Name	WCPO fishery	MP	Catch prop.
1	PL	1	P-ALL	PL	SKJ	0.006
2	PS	1	S-ALL	Northern PS	SKJ	0.002
3	LL	1	L-ALL	Northern LL	BET	0.000
4	PL	2	P-ALL	PL	SKJ	0.014
5	PS	2	S-ALL	Northern PS	SKJ	0.009
6	LL	2	L-ALL	Northern LL	BET	0.000
7	PL	3	P-ALL	PL	SKJ	0.009
8	PS	3	S-ALL	Northern & Tropical PS	SKJ	0.000
9	LL	3	L-ALL	Northern & Tropical LL	BET	0.000
10	DOM	5	Z-PH	ID/PH/VN	SKJ	0.011
11	DOM	5	Z-ID	ID/PH/VN	SKJ	0.076
12	PS	5	S-ID.PH	ID/PH/VN	SKJ	0.088
13	PL	5	P-ALL	PL	SKJ	0.044
14	PS	5	SA-DW	Tropical PS	SKJ	0.001
15	PS	5	SU-DW	Tropical PS	SKJ	0.005
16	DOM	5	Z-VN	ID/PH/VN	SKJ	0.048
17	LL	5	L-ALL	Tropical & Southern LL	ALB & BET	0.000
18	PL	6	P-ALL	PL	SKJ	0.000
19	PS	6	SA-ALL	Tropical PS	SKJ	0.022
20	PS	6	SU-ALL	Tropical PS	SKJ	0.054
21	LL	6	L-ALL	Tropical & Southern LL	ALB & BET	0.000
22	PL	4	P-ALL	PL	SKJ	0.007
23	LL	4	L-ALL	Northern & Tropical LL	BET	0.000
24	PL	7	P-ALL	PL	SKJ	0.001
25	PS	7	SA-ALL	Tropical PS	SKJ	0.100
26	PS	7	SU-ALL	Tropical PS	SKJ	0.157
27	LL	7	L-ALL	Southern LL	ALB & BET	0.000
28	PL	8	P-ALL	PL	SKJ	0.000
29	PS	8	SA-ALL	Tropical PS	SKJ	0.202
30	PS	8	SA-ALL	Tropical PS	SKJ	0.143
31	LL	8	L-ALL	Southern LL	ALB & BET	0.000

Table 5: Fisheries in the South Pacific albacore operating model, the associated WCPO fishery (from Table 1) and the proposed associated management procedure (MP). The *Catch prop.* column is the average proportion of total catches in biomass taken by that fishery in the years 2014 to 2016 (taken from the 2018 stock assessment). Due to their latitudinal range, the longline fisheries in region 4 are associated with both the albacore and bigeye management procedures. Note that the driftnet fisheries (15 and 16) no longer operate and are not considered here.

Model fishery	Gear	Region	Name	WCPO fishery	MP	Catch prop.
1	LL	1	DWFN-LL	Tropical LL	BET	0.073
2	LL	1	PICT.AZ-LL	Tropical LL	BET	0.061
3	LL	2	DWFN-LL	Southern LL	ALB	0.115
4	LL	2	PICT-LL	Southern LL	ALB	0.355
5	LL	2	AZ-LL	Southern LL	ALB	0.004
6	LL	3	DWFN-LL	Southern LL	ALB	0.142
7	LL	3	PICT-LL	Southern LL	ALB	0.036
8	LL	3	AZ-LL	Southern LL	ALB	0.013
9	LL	4	DWFN-LL	Tropical & Southern LL	ALB & BET	0.075
10	LL	4	PICT.AZ-LL	Tropical & Southern LL	ALB & BET	0.044
11	LL	5	DWFN-LL	Southern LL	ALB	0.027
12	LL	5	PICT.AZ-LL	Southern LL	ALB	0.017
13	Troll	3	ALL TR	Southern Troll	ALB	0.037
14	Troll	5	ALL TR	Southern Troll	ALB	0.002

Table 6: Fisheries in the bigeye operating model, the associated WCPO fishery (from Table 1) and the proposed associated management procedure (MP). The *Catch prop.* column is the average proportion of total catches in biomass taken by that fishery in the years 2014 to 2016 (taken from the 2018 stock assessment). Fisheries operating in archipelagic waters of Papua New Guinea, Indonesia, Philippines and Vietnam are assumed to be managed through the skipjack MP but this may not necessarily be the case.

Model fishery	Gear	Region	Name	WCPO fishery	MP	Catch prop.
1	LL	1	L-ALL	Northern & Tropical LL	BET	0.039
2	LL	2	L-ALL	Northern & Tropical LL	BET	0.032
3	LL	2	L-US	Northern & Tropical LL	BET	0.032
4	LL	3	L-ALL	Tropical LL	BET	0.043
5	LL	3	L-OS	Tropical LL	BET	0.036
6	LL	7	L-OS	Tropical LL	BET	0.084
7	LL	7	L-ALL	Tropical LL	BET	0.009
8	LL	8	L-ALL	Tropical LL	BET	0.005
9	LL	4	L-ALL	Tropical LL	BET	0.185
10	LL	5	L-AU	Southern LL	ALB	0.003
11	LL	5	L-ALL	Southern LL	ALB	0.011
12	LL	6	L-ALL	Southern LL	ALB	0.028
13	PS	3	S-ASS-ALL	Tropical PS	SKJ	0.114
14	PS	3	S-UNA-ALL	Tropical PS	SKJ	0.028
15	PS	4	S-ASS-ALL	Tropical PS	SKJ	0.150
16	PS	4	S-UNA-ALL	Tropical PS	SKJ	0.009
17	DOM	7	Z-PH	ID/PH/VN	SKJ	0.011
18	DOM	7	Z-ID-PH	ID/PH/VN	SKJ	0.014
19	PS	1	S-JP	Northern PS	SKJ	0.004
20	PL	1	P-JP	PL	SKJ	0.012
21	PL	3	P-ALL	PL	SKJ	0.000
22	PL	8	P-ALL	PL	SKJ	0.000
23	DOM	7	Z-ID	ID/PH/VN	SKJ	0.062
24	PS	7	S-ID.PH	ID/PH/VN	SKJ	0.011
25	PS	8	S-ASS-ALL	Tropical PS	SKJ	0.031
26	PS	8	S-UNA-ALL	Tropical PS	SKJ	0.019
27	LL	9	L-AU	Southern LL	ALB	0.000
28	PL	7	P-ALL	PL	SKJ	0.017
29	LL	9	L-ALL	Southern LL	ALB	0.000
30	PS	7	S-ASS-ALL	Tropical PS	SKJ	0.000
31	PS	7	S-UNA-ALL	Tropical PS	SKJ	0.000
32	DOM	7	Z-VN	ID/PH/VN	SKJ	0.010

Table 7: Fisheries in the yellowfin operating model, the associated WCPO fishery (from Table 1) and the proposed associated management procedure (MP). The *Catch prop.* column is the average proportion of total catches in biomass taken by that fishery in the years 2014 to 2016 (taken from the 2017 stock assessment). Fisheries operating in archipelagic waters of Papua New Guinea, Indonesia, Philippines and Vietnam are assumed to be managed through the skipjack MP but this may not necessarily be the case.

Model fishery	Gear	Region	Name	WCPO fishery	MP	Catch prop.
1	LL	1	L-ALL	Northern & Tropical LL	BET	0.007
2	LL	2	L-ALL	Northern & Tropical LL	BET	0.002
3	LL	2	L-US	Northern & Tropical LL	BET	0.001
4	LL	3	L-ALL	Tropical LL	BET	0.019
5	LL	3	L-OS	Tropical LL	BET	0.013
6	LL	7	L-OS	Tropical LL	BET	0.096
7	LL	7	L-ALL	Tropical LL	BET	0.001
8	LL	8	L-ALL	Tropical LL	BET	0.009
9	LL	4	L-ALL	Tropical LL	BET	0.026
10	LL	5	L-AU	Southern LL	ALB	0.002
11	LL	5	L-ALL	Southern LL	ALB	0.012
12	LL	6	L-ALL	Southern LL	ALB	0.014
13	PS	3	S-ASS-ALL	Tropical PS	SKJ	0.077
14	PS	3	S-UNA-ALL	Tropical PS	SKJ	0.091
15	PS	4	S-ASS-ALL	Tropical PS	SKJ	0.071
16	PS	4	S-UNA-ALL	Tropical PS	SKJ	0.089
17	DOM	7	Z-PH	ID/PH/VN	SKJ	0.047
18	DOM	7	Z-ID-PH	ID/PH/VN	SKJ	0.064
19	PS	1	S-JP	Northern PS	SKJ	0.006
20	PL	1	P-JP	PL	SKJ	0.005
21	PL	3	P-ALL	PL	SKJ	0.000
22	PL	8	P-ALL	PL	SKJ	0.000
23	DOM	7	Z-ID	ID/PH/VN	SKJ	0.090
24	PS	7	S-ID.PH	ID/PH/VN	SKJ	0.032
25	PS	8	S-ASS-ALL	Tropical PS	SKJ	0.060
26	PS	8	S-UNA-ALL	Tropical PS	SKJ	0.115
27	LL	9	L-AU	Southern LL	ALB	0.000
28	PL	7	P-ALL	PL	SKJ	0.042
29	LL	9	L-ALL	Southern LL	ALB	0.000
30	PS	7	S-ASS-ALL	Tropical PS	SKJ	0.000
31	PS	7	S-UNA-ALL	Tropical PS	SKJ	0.001
32	DOM	7	Z-VN	ID/PH/VN	SKJ	0.009