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Progress update and technical challenges for the South Pacific albacore MSE framework

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Progress update and technical challenges for the South Pacific albacore MSE framework

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Contents

Executive Summary

Under the workplan for the development of harvest strategies for WCPO stocks and fisheries, SC18 is scheduled to agree the OM grid for south Pacific albacore. In this paper, options for the selection of OMs are considered along with an update on recent progress to develop MPs for south Pacific albacore.

Stock assessments for south Pacific albacore are subject to modeling challenges associated with uninformative data and data conflicts to a greater extent than other stock assessments for tunas and tuna fisheries in the WCPO and a substantial amount of work has been conducted to evaluate the performance of these models within an MSE framework. Attempts to select a reduced set of 'best performing' assessment models based on their diagnostics and prediction performance has proven unsuccessful.

Noting this, the full uncertainty grids from recent assessments represent the best available information on the status of the stock and fishery dynamics and currently provide the most appropriate basis for the OM grid reference set. Either the 2018 or the 2021 assessment could be considered for the basis for the OM grid. The spatial structure varies between them and therefore a choice must be made between selecting either the 2018 or the 2021 assessment models. This choice largely depends on whether EPO fishing activity is considered important and necessary to include in the MSE framework, which will require input from managers.

SC17 applied a weighted grid to the 2021 assessment which down weighted the SEAPODYM movement options. For the MSE analyses we would recommend that all models are equally weighted within the OM grid on the grounds that each one represents a plausible alternative scenario of stock and fishery dynamics.

Following guidance from SC17, recent work has investigated the use of model based MPs for south Pacific albacore. We illustrate an approach for implementing model based MPs that shows encouraging results along with HCR designs that manage the stock towards a target whilst constraining catch reductions over time. Additional work will be undertaken to further develop this approach.

To progress the development of harvest strategies for south Pacific albacore we seek feedback from SC on the following issues:

- advice on the preferred set of assessment models (2018 or 2021) to form the basis of the OM grid and any gaps that should be considered.
- input into candidate HCR designs;
- advice to SMD/WCPFC with regards the definition of fisheries and fishery controls within the harvest strategy;
- advice to SMD/WCPFC with regards the selection of either the 2018 or 2021 assessment models for the OM grid.

1 Introduction

The harvest strategy approach provides a framework for taking the best available information about a stock or fishery and applying an evidence- and risk-based approach to setting harvest levels. A key element of the harvest strategy approach is the management procedure (MP) that determines future fishing levels. Candidate MPs should be tested, prior to adoption, to determine the extent to which they achieve defined management objectives through simulation analysis (management strategy evaluation; MSE). The MSE simulation framework models two main components; the dynamics of the fish population and its associated fishery, i.e. the operating models (OMs), and the procedure by which the fishery will be managed, i.e. a candidate MP. In this paper we present options for the selection of OMs, and provide an update on recent progress to develop MPs for south Pacific albacore.

1.0.1 Operating models

Given our imperfect knowledge of the dynamics of populations and fisheries, OMs allow us to evaluate the consequences of this uncertainty by testing management performance against different hypotheses about those dynamics. A suite of different OMs should be identified, each one representing a plausible alternative hypothesis. This suite often includes a greater level of uncertainty than that considered within a stock assessment, so that all important sources of uncertainty affecting both the past and future states are included in the evaluation process.

The operating models are divided into two ”sets”. The first is the ”reference set”, comprising scenarios that are considered the most plausible hypotheses of alternative stock and fishery dynamics. These form the primary basis for evaluating candidate MPs and are the main focus of work at present. The second is the ”robustness set”, scenarios that are considered less likely though still plausible. These are the focus of ongoing work, and are used to give a secondary indication of the performance of a reduced subset of management procedures that have been selected on the basis of performance against the reference set.

An important requirement is that simulated data generated from the Operating Models (OMs) should have similar characteristics to historical observations. In this way, candidate MPs are evaluated under simulated conditions that sufficiently represent reality.

Ongoing discussions on the management of south Pacific albacore have focused upon economic management objectives (noted at WCPFC14 and the focus of discussions concerning the basis of the interim TRP during WCPFC15), specifically catch rates and fleet profitability. With this focus, recent work has concentrated on the ability of candidate OMs to generate realistic simulated CPUE data for use by MPs as the basis for estimating stock status. Diagnostic analyses including retrospective analyses (Yao et al., 2019, 2020a), hindcasting analyses (Yao et al., 2021) and likelihood profiles (Tremblay-Boyer et al., 2018) have been conducted across the grid of models within the 2018 South Pacific albacore stock assessment to determine whether they should be included in the

OM grid. The results indicated that, as recognised in recent assessment reports, assessments of south Pacific albacore suffer from data challenges and conflicts along with modelling challenges to a greater extent than other tuna stock assessments in the WCPO.

This recent work evaluating the performance of albacore assessment models using retrospective and hindcasting analyses has shown mixed results with some models performing relatively well and others quite poorly. Attempts to select a reduced set of 'best performing' assessment models based on their respective performance resulted in a very restricted grid with narrow confidence intervals that were unlikely to represent the full range of uncertainty in the dynamics of the stock and the fishery. The approach presented in Scott et al. (2021) has therefore been to use all models from the 2018 stock assessment in the OM grid as the basis for testing candidate management procedures.

In the longer term, initiatives including electronic monitoring for longline fisheries and the development of genetic tagging programmes for close kin mark recapture are expected to improve the information available to assess and manage the stock of south Pacific albacore. However, the issues that currently hinder the development of an improved assessment will not to be resolved in the short term.

1.0.2 Management procedures

Initial work to develop the management procedures for south Pacific albacore (Yao et al., 2019; Scott et al., 2019) focused on developing empirical procedures that used longline CPUE as the primary indicator of stock status, consistent with the noted management objectives. Results of those preliminary analyses (Yao et al., 2020b) highlighted the difficulty of using CPUE as the primary measure of stock status within empirical management procedures. Scott et al. (2021) noted that model-based approaches could address some of these problems. SC17 noted the difficulties with the use of CPUE to inform a management procedure for south Pacific albacore and supported the continuing investigation of simple model-based alternatives (SC17 Summary report, para 292).

Consequently, more recent work has focused on the development of model based management procedures that use estimates of total stock abundance from a relatively simple stock assessment model as a measure of stock status. While these model based approaches also depend on CPUE to estimate stock status, they typically provide more reliable and more stable estimates through the use of additional information (e.g. catches). An approach for developing model based MP for south Pacific albacore is outlined in Section 3 of this report.

2 Operating models for South Pacific albacore

The current OM grid for south Pacific albacore is based upon models used for the 2018 stock assessment (Tremblay-Boyer et al., 2018), which assessed the stock within the WCPFC-CA. The assessment comprised a grid of 72 models reflecting uncertainty in biological characteristics (stock recruitment relationship steepness, natural mortality and growth), fishery information (methods for standardising longline CPUE) and model settings (size frequency data weighting) (Table 1).

A new assessment, with some new areas of uncertainty (Table 1) and a different south Pacific-wide spatial structure, was agreed by SC17 in 2021 (Castillo Jordan et al., 2021). That assessment comprised 21 fisheries across 4 regions that spanned the whole of the south Pacific Ocean extending from the equator to 50°S (Figure 1b). Uncertainty was characterised by a grid of 72 models with varying assumptions for the spatial distribution of recruitment, steepness of the stock and recruitment relationship, the relative weighting to be applied to length composition data, the movement of fish between assessment regions, and the combined effects of growth and natural mortality (Table 1).

Ideally, when new information becomes available (e.g. updated information on growth) it should reduce the uncertainty required in the OM grid and not increase it. As such, it should not be necessary to update the OM grid each time a new assessment is conducted. The range of uncertainty considered in the OM grid should be sufficiently broad so as to encapsulate the results of new assessments. Where the results of new assessments lie outside the range of the OMs it may be necessary to consider additional sources of uncertainty or a wider range of plausible values. A comparison of recent assessments allows a review of whether the current ranges of uncertainty captured in the current OM grid remain sufficient and appropriate, or need updating.

Table 1: South Pacific albacore 2018 and 2021 stock assessment uncertainty grids .

Axis	**Code**	**Levels**	**Options**		
			0	**1**	**2**
2018					
Steepness	A	3	0.8	0.65	0.95
Natural mortality	B	2	0.3	0.4	
Growth	C	2	Estimated	Fixed (Chen-Wells)	
Size freq. wtg	D	3	20	50	80
CPUE	E	2	Geo-statistical	Traditional	
2021					
Steepness	A	3	0.8	0.65	0.95
Movement	B	2	Estimated	SEAPODYM	
Size freq. wtg	C	3	50 (low)	25 (medium)	10 (high)
Growth	D	2	Estimated	Fixed (Chen-Wells)	
Recruitment distbn.	E	2	SEAPODYM	Regions 3 and 4	

2.1 Selecting models for the OM grid

There are two main considerations when selecting models for inclusion in the OM grid. The first concerns the sources of uncertainty considered most important and most consequential for the assessment and management of the fishery, noting that some sources of uncertainty will be more influential than others and not all of them will need to be included.

The second consideration is the ability of the OMs to generate simulated data that adequately reflect reality. It is important to ensure that candidate MPs are tested against conditions that sufficiently resemble their likely operating environment. Therefore, the ability of the OM to provide reliable predictions of future conditions should be considered, particularly with regards to key quantities necessary for input to the management procedure (e.g. CPUE).

2.1.1 Sources of uncertainty

Summary plots of the model settings comprising the 2018 and 2021 stock assessment grids for alternative values of steepness of the stock and recruitment relationship (Figure 2); growth and natural mortality (Figure 4); alternative movement assumptions (Figure 3); and the alternative spatial distribution of recruitment (Figure 5) show the ranges of values considered and resulting model estimates. Note that some figures are presented only for the diagnostic case assessment model and that estimates will vary for other models of the grid.

There are marked differences in estimates of movement rates between model regions (Figure 3) both within the estimates of the models comprising the grids for 2018 and 2021 and also between the estimates of SEAPODYM (Spatial Ecosystem and Population Dynamics Model, Lehodey et al. (2008); Senina et al. (2020)). Due to a lack of tagging data MFCL has limited information with which to determine movement rates whereas SEAPODYM estimates movement rates from a combined physical and biological model that includes information on oceanographic variables and environmental forcing. The results of the 2021 assessment are strongly influenced by movement assumptions and some consideration of alternative movement rates in the OM grid is recommended.

Estimates of the spatial and temporal distribution of recruitment (Figure 5) are quite consistent between the 2018 and 2021 assessment and also with SEAPODYM estimates and the 2021 assessment was relatively insensitive to these alternative assumptions. However, the retention of options for the spatial and temporal distribution of recruitment in the OM grid is recommended pending further investigation of the impacts of climate change which may have important consequences for the assumed distribution of recruitment (Senina et al., 2020).

Growth and natural mortality (Figure 4) also show good consistency in both the model estimates determined from the 2018 and 2021 assessment and in the fixed values assumed in the assessment grids.

The 2018 assessment considered two alternative approaches for the standardisation of CPUE (a traditional approach and a novel geo-statistical approach). Based on the recommendations of SC, more recent assessments have moved away from the traditional approach and consider only geostatistical method for generating CPUE indices of abundance. As part of the work to develop the OM grid (using the 2018 models) an alternative geostatistical CPUE series was developed. Given the strong dependency of the assessments on CPUE and the sensitivity of CPUE indices to alternative assumptions and procedures for their development it is recommended that an axis of uncertainty for CPUE be retained in the OM grid.

2.1.2 Prediction performance

The ability of OMs to generate simulated data that have similar characteristics and dynamics to real data is an important consideration when developing the MSE framework. Methods for testing model consistency and the predictive power of models include retrospective analyses and hindcast analyses.

Retrospective patterns are systematic changes in estimates of population size, or other assessment model derived quantities, that occur as additional years of data are added to a stock assessment model. When model estimates display a persistent trend, in relation to previous estimates, for either under or over-estimation it suggests that something is misspecified in the model. Systematic error of this kind is referred to as retrospective bias (Sinclair et al., 1991). The mohn's rho statistic (Mohn, 1999) is used as a measure of retrospective bias. Hurtado-Ferro et al. (2015) propose, as a general rule of thumb, that for relatively short lived species acceptable levels of retrospective bias lie within the range of mohn's rho values between -0.22 to 0.3.

Yao et al. (2021) conducted extensive retrospective analyses on the 2018 south Pacific albacore assessment grid. These analyses included cluster analyses, used to identify targeted albacore fishing; CPUE standardisation approaches; as well as the assessment fitting. Of the 36 models tested, 29 displayed a persistent negative bias in the estimation of adult biomass with values for mohn's rho ranging between -0.21 and 0.

A complete analysis for the 2021 assessment has yet to be completed. Retrospective analyses conducted for 18 of the 72 models of the 2021 south Pacific wide albacore assessment showed a more persistent retrospective bias with Mohn's rho values of less than -0.3. The results from single model retrospective analyses for the 2018 and 2021 assessments are presented in Figure 7 for illustration.

Retrospective forecasting (Brooks and Legault, 2015), also known as hindcasting and backtesting, is a method for testing the prediction performance of an assessment model using existing historical data. The approach is based on a retrospective analysis with the additional step that each retrospective peel is projected through to the end of the original time series with observed catches and estimated recruitment fixed for the projection period. Prediction performance can be measured by how well the hindcast predictions compare to the model estimates for the full time series.

Hindcast analyses for projected CPUE (Yao et al., 2021) conducted for the models of the 2018 south Pacific albacore assessment showed that the index fisheries of the assessment had varying levels of ability to forecast accurate CPUE time series. Index fisheries for regions 2 and 3 showed the most promising results with projected CPUE showing little bias and being reasonably close to observed values (ca. 20% error). Hindcast analyses for the models of the 2021 assessment have not yet been conducted.

2.1.3 OM grid options

In spite of quite marked differences in model structure and settings both the 2018 and 2021 assessment provide relatively similar estimates for both the historical trajectory of the stock and current stock status (Figure 6). Median estimates of stock status show relatively good correspondence, while the 2018 assessment grid shows slightly wider confidence intervals throughout the time series. From the comparison of the estimates of stock status, either the 2018 or the 2021 assessment could be considered for the basis for the MSE uncertainty grid.

A choice must then be made whether to use the 2018 or 2021 assessment as the basis for the OM grid. The use of a combination of models across both assessments would not be feasible as the different spatial structures result in different fishery definitions leading to the inconsistent calculation of performance indicators. The 2018 assessment appears to show better retrospective performance than the 2021 assessment but does not take consideration of the stock and fisheries of the eastern Pacific Ocean (EPO). Whether the 2018 or 2021 assessment grid is to be used therefore largely depends on members' consideration of the importance of including the EPO in the MSE evaluations. Opting to include the EPO would be consistent with the current approach for WCPO skipjack for which archipelagic waters, that are outside the direct control of the MP, are included.

The current OM grid, based on the 2018 stock assessment, includes an additional axis of uncertainty for the approach used to generate standardised CPUE. As noted above, CPUE is a critical component of the MSE evaluation framework for south Pacific albacore and it will be important to consider any sources of uncertainty associated with it. If the 2021 assessment is selected it may be necessary to develop an additional axis for that grid to account for CPUE standardisation.

Similarly, the current OM grid does not include uncertainty in movement rates. If the 2018 assessment is selected it may be necessary to develop an additional axis for that grid to account for alternative movement scenarios within the WCPFC convention area.

SC17 applied a weighted grid to the 2021 assessment which down weighted the SEAPODYM movement options. For the MSE analyses we would recommend that all models are equally weighted within the OM grid on the grounds that each one represents a plausible alternative scenario of stock and fishery dynamics.

3 Management procedures for south Pacific albacore

Initial development of model based MPs for south Pacific albacore has been undertaken using relatively simple biomass dynamic models to provide an estimate of stock status to "drive" an HCR. Many implementations of biomass dynamic models exist. Initial trials have been conducted using JABBA (Just Another Bayesian Biomass Assessment, Winker et al. (2018)) and the SPiCT (Stochastic Production model in Continuous Time, Pedersen and Berg (2016)) R-package for fitting surplus production models to fisheries catch data and biomass indices.

We present preliminary results from a single analysis using SPiCT to demonstrate the approach and to highlight the potential implementation of an HCR that provides a progressive catch reduction approach to rebuilding the stock towards a biomass target. Tests have been conducted using OMs based on both the 2018 and 2021 assessments.

3.1 Methods for estimating stock status

In the first instance, models using only a single CPUE index have been employed, consequently stock status must be determined for a single assessment region. This estimate is then used to indicate the status of the stock as a whole. Assessment region 2 was selected since it contains the largest biomass of south Pacific albacore and has the largest catches.

A comparison of estimates of stock abundance in region 2 from SPiCT and that of the OM (Figure 8) shows generally good correspondence between the two. Note that the absolute levels of abundance estimated by SPiCT and MFCL differ and the two estimates must be re-scaled before comparison can be made. Total abundance estimates from both MFCL and SPiCT have been re-scaled using an arbitrarily selected historical baseline (average biomass for the period 2013-15). Successive estimates of abundance over an increasing time period (2022 to 2048) from SPiCT show good consistency indicating that it provides a reliable and relatively unbiased estimate of stock status.

3.2 Harvest control rule designs

The HCR examined (Figure 9) is of the standard form having two breakpoints to allow for a progressive change in fishing over a range of stock status between two constant levels. The HCR takes as input the scaled estimate of total abundance and outputs a scalar that increases or decreases fishing for all fisheries in equal measure. For the sake of this example, the baseline level of fishing has been set to average catches over the period 2014-16. The year ranges for catch and biomass re-scaling have been chosen arbitrarily.

Two implementations of the HCR were applied. The first used the scalar as determined directly from the HCR, the second applied a 5% constraint to changes in catch such that catches could not be reduced by more than 5% from one management period to the next, but were free to increase without restriction. The evaluations were run for 30 years with a 3 year management interval.

The trajectories for catch and biomass (Figure 10) resulting from the two HCR applications show the performance of the MP and highlight the effects of implementing the catch reduction constraint. Under the catch constraint, catches reduce at a slower and more progressive rate over time. However, the slower reduction in catches leads to a larger reduction in biomass in the short term. Ultimately under both scenarios the biomass rebuilds and both catches and biomass return to similar levels.

We note that this is just a single, illustrative example and that many aspects of the approach will require further development and testing. However, these initial results show promise for the development of model based MPs for south Pacific albacore.

4 Discussion

The work conducted to date to develop the MSE framework for south Pacific albacore has, to a large extent, been based on the 2018 stock assessment. Much of this work has focused on investigating the predictive capabilities of the assessment models, particularly with respect to CPUE, with a view to selecting the most appropriate models for inclusion in the OM grid. However, it has been difficult to identify a final OM grid from these analyses that adequately represents the full range of uncertainty in the dynamics of the stock and the fishery. Recent assessments therefore represent the best available information on the status of the stock and fishery dynamics and provide the most appropriate basis for the OM grid.

From the results obtained so far, the 2018 assessment shows better diagnostics with regards retrospective performance. Further work will be required to determine the full nature of the apparent poorer retrospective performance of the 2021 models and the extent to which this impacts their performance within the MSE framework. Overall, however, the two assessment grids provide comparable estimates of stock status and the choice of whether to use the 2018 or the 2021 assessment as the basis of the OM grid depends largely on whether EPO activity is considered to be important and necessary for inclusion in the MSE framework. We note that analyses to inform on a potential TRP for south Pacific albacore WCPFC-SC18-2022/MI-WP-04 also consider implications for WCPFC-CA management if the EPO is included/excluded from management action. Whilst this is a primarily a question for managers' consideration we seek input from SC18 with particular consideration of the OM grid.

Table 2: Advantages and disadvantages of selecting either the 2018 or the 2021 stock assessment grid as the basis for the OM grid for south Pacific albacore.

Assessment models	**Advantages**	**Disadvantages**
2018	Better retrospective performance	Excludes the EPO
	Includes CPUE axis	Excludes movement axis
2021	Includes the EPO	Poorer retrospective performance
	Includes movement axis	Excludes CPUE axis

Under the workplan for the development of harvest strategies for WCPO stocks and fisheries, SC18 is scheduled to agree the OM grid for south Pacific albacore. At this stage we seek guidance from SC18 on the basis of the OM grid and specifically the geographical area to be included in the MSE framework (i.e. the 2018 or 2021 assessment model grids). This will provide the basis for the further development of the MSE framework. We note that once the OM grid has been agreed there will still be opportunities to review and update it through the monitoring strategy as well as on the basis of discussions and recommendations from SC18.

5 Conclusions

To progress the development of harvest strategies for south Pacific albacore we seek feedback from SC on the following issues:

- advice on the preferred set of assessment models (2018 or 2021) to form the basis of the OM grid and any gaps that should be considered.
- input into candidate HCR designs;
- advice to SMD/WCPFC with regards the definition of fisheries and fishery controls within the harvest strategy;
- advice to SMD/WCPFC with regards the selection of either the 2018 or 2021 assessment models for the OM grid.

Acknowledgments

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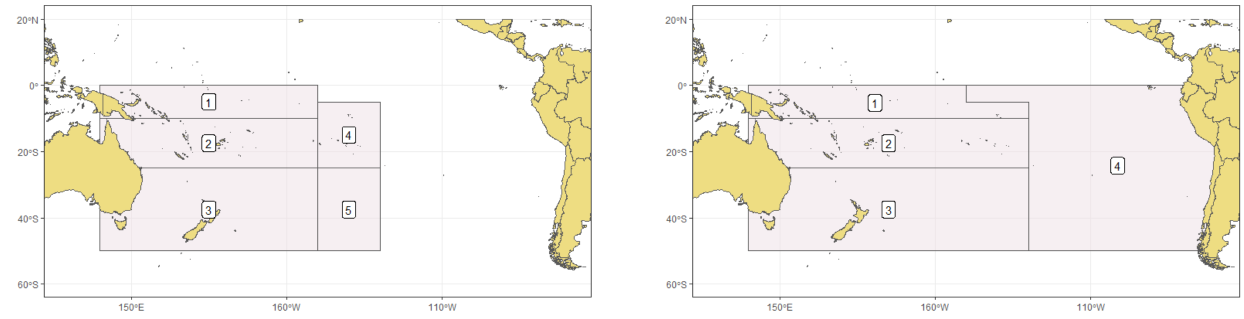
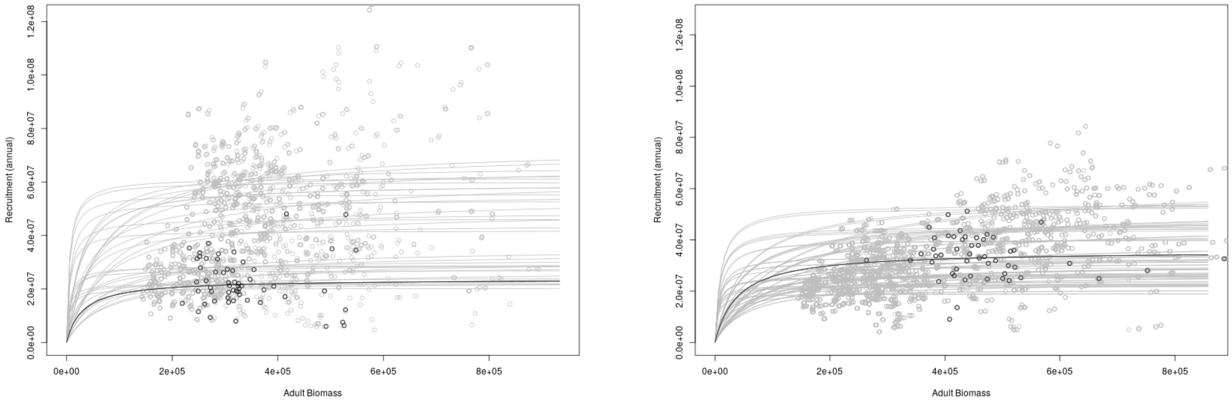
A Figures



(a) 2018

(b) 2021

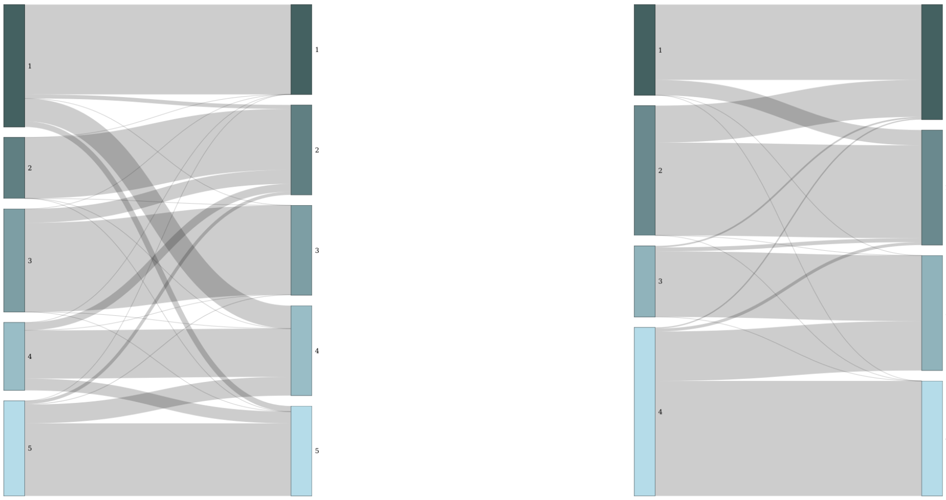
Figure 1: Regional structure of stock assessments conducted for south Pacific albacore in 2018 (WCPFC-CA only) and 2021 (south Pacific wide).



(a) 2018

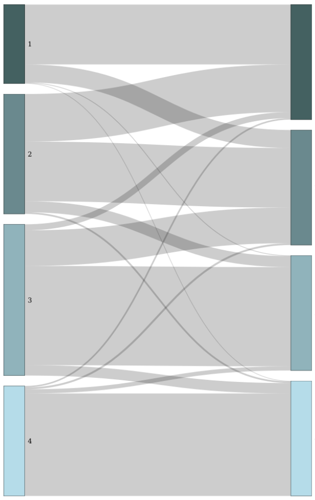
(b) 2021

Figure 2: Estimated stock and recruitment relationships across the 72 model grids for the 2018 and 2021 stock assessments of south Pacific albacore.



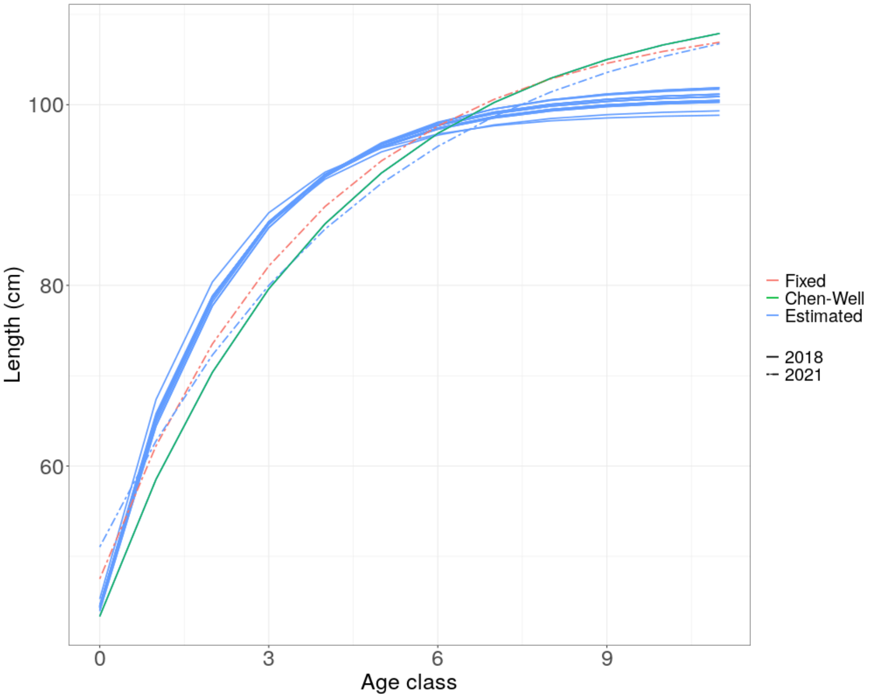
(a) 2018

(b) 2021 estimated

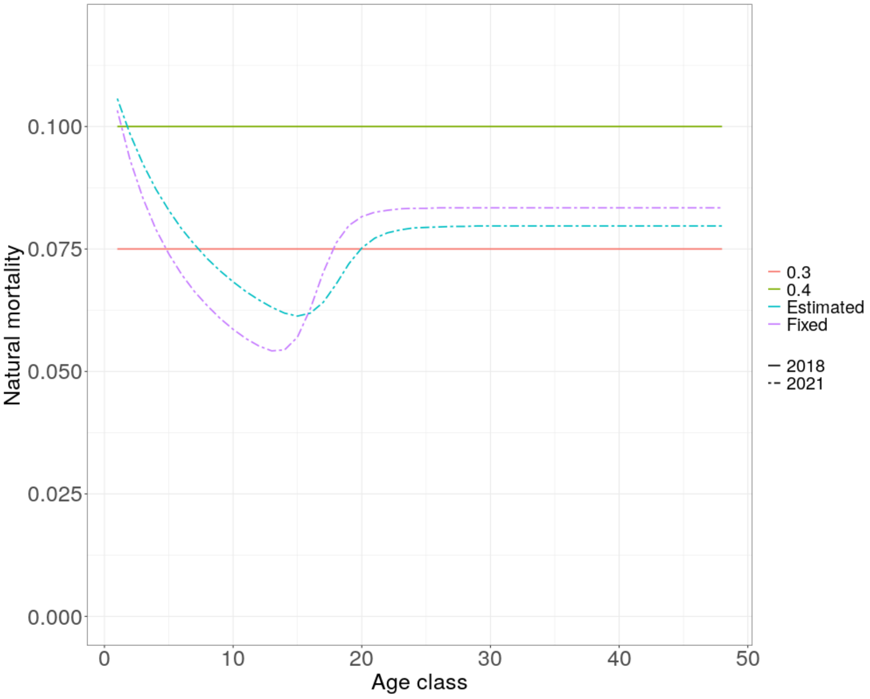


(c) 2021 SEAPODYM

Figure 3: Estimated movement rates for recent south Pacific albacore assessments from the diagnostic case assessment models for 2018 and 2021 and the externally estimated values from SEAPODYM used in the 2021 assessment. Each figure presents the movement rate from (left side of plot) to (right side of plot) respective regions of the stock assessment.

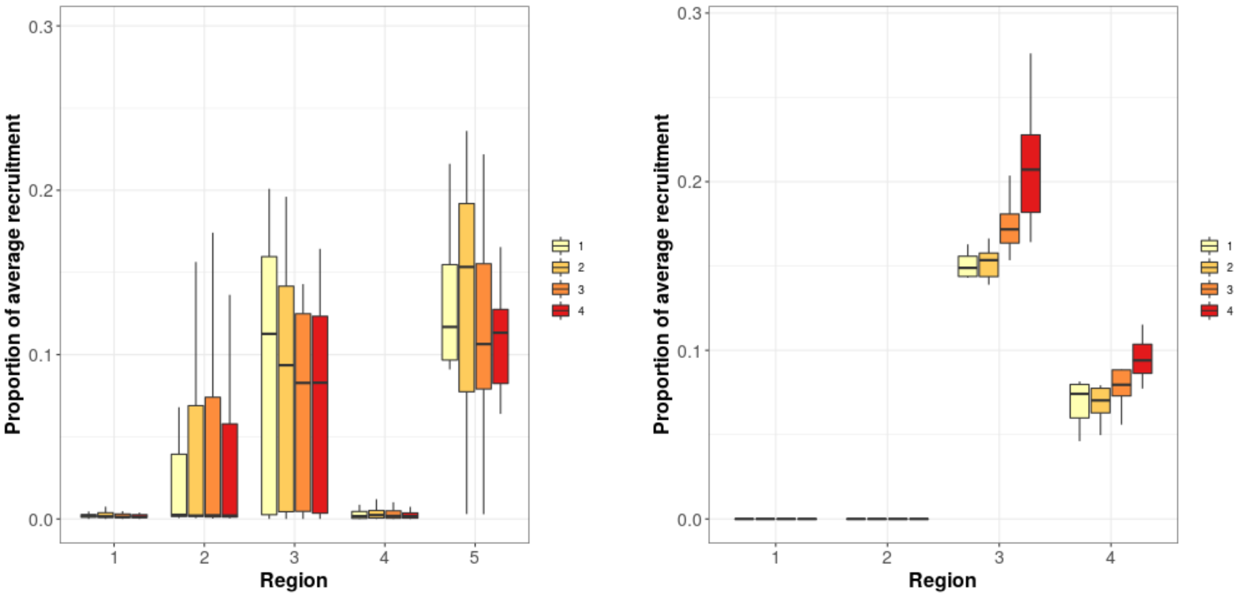


(a) Growth



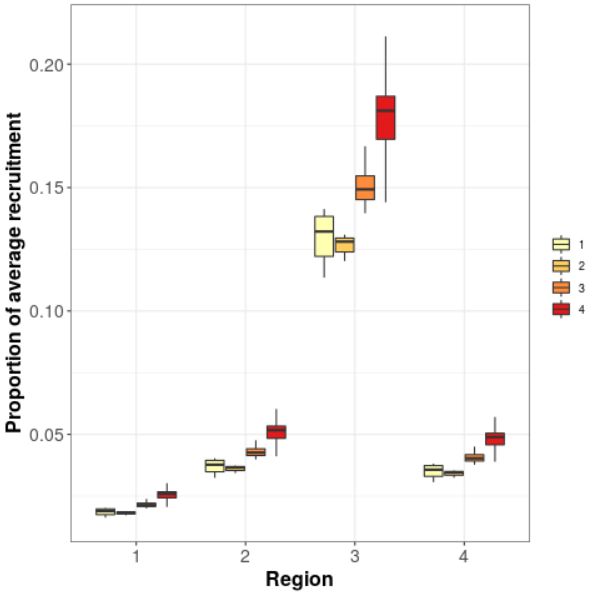
(b) Natural mortality

Figure 4: Estimated and fixed settings for growth and natural mortality in the 2018 (solid lines) and 2021 (dashed lines) stock assessments of south Pacific albacore



(a) 2018

(b) 2021 estimated



(c) 2021 SEAPODYM

Figure 5: Estimated spatial (regions) and temporal (quarterly) distribution of recruitment for recent south Pacific albacore assessments from the diagnostic case assessment models for 2018 and 2021 and the externally estimated values from SEAPODYM used in the 2021 assessment.

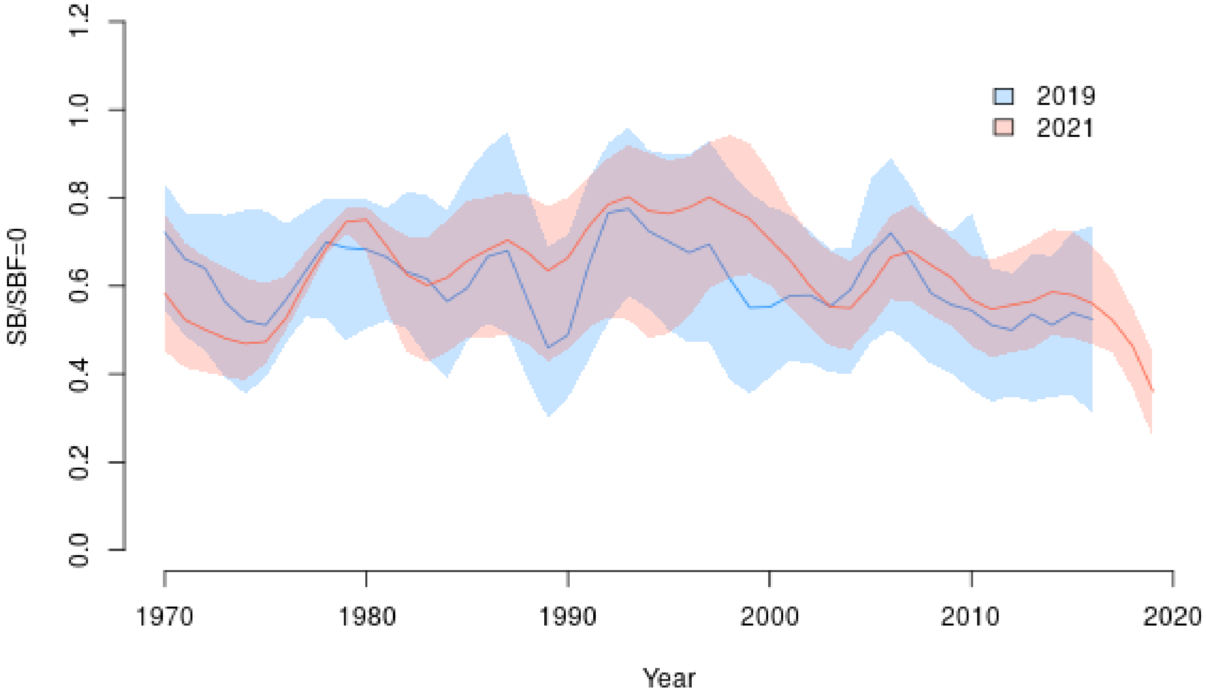
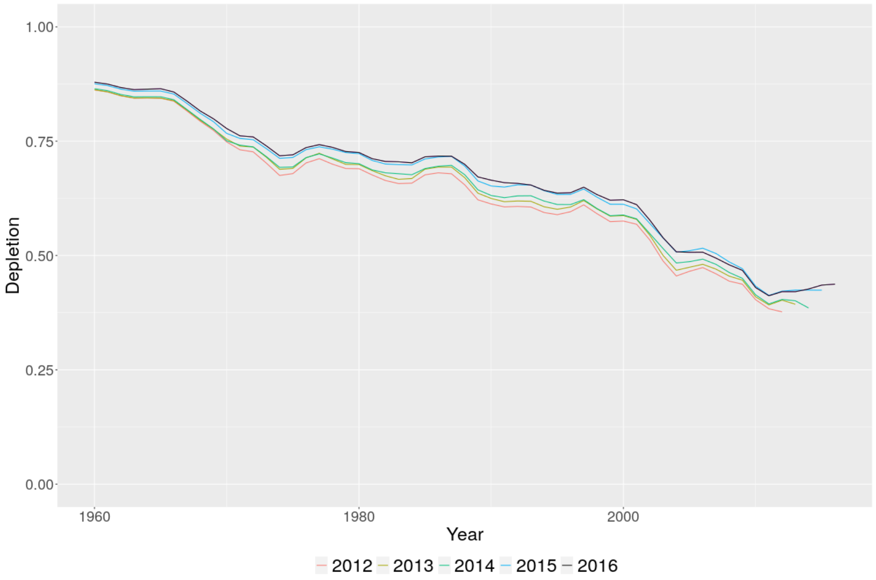
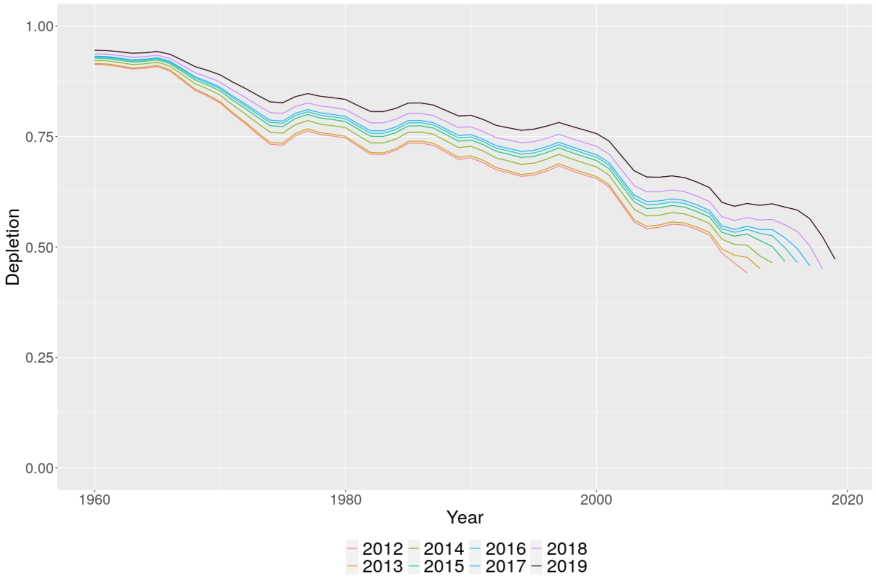


Figure 6: Estimated spawning potential depletion $SB_{latest}/SB_{F=0}$ for the 2018 and 2021 (regions 1,2 and 3, WCPFC-CA only) stock assessment model grids for south Pacific albacore. (all models equally weighted).



(a) 2018



(b) 2021

Figure 7: Illustrative example showing estimated instantaneous depletion ($SB/SB_{F=0}$) from retrospective analyses conducted for the 2018 and 2021 assessment models .

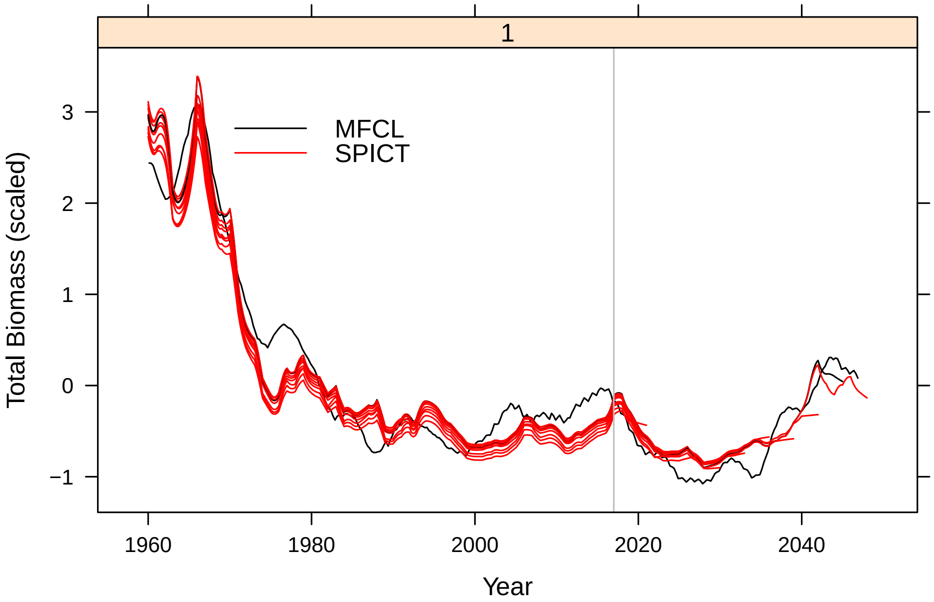


Figure 8: Estimated stock status (total biomass for region 2) determined from a single MFCL projection (black line) and multiple estimates of SPiCT to simulated data for progressively increasing time periods (red lines).

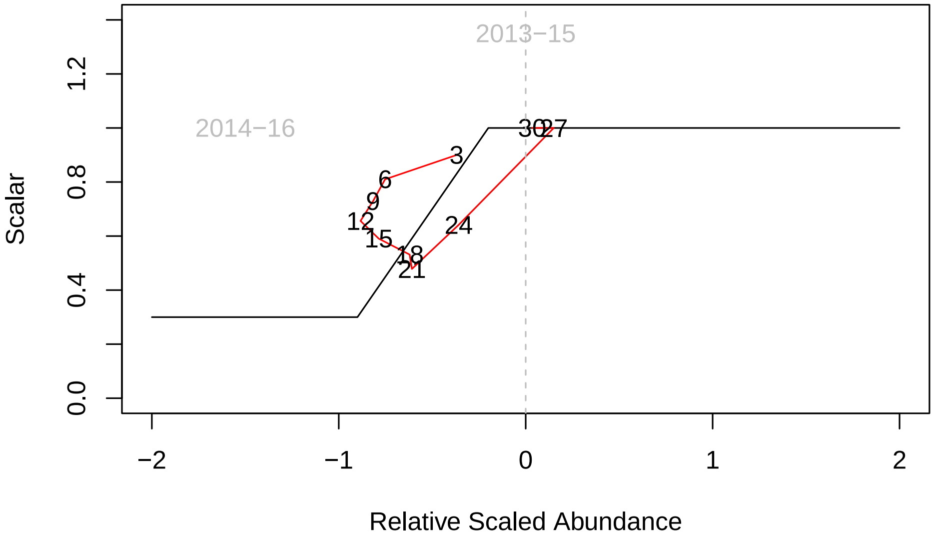
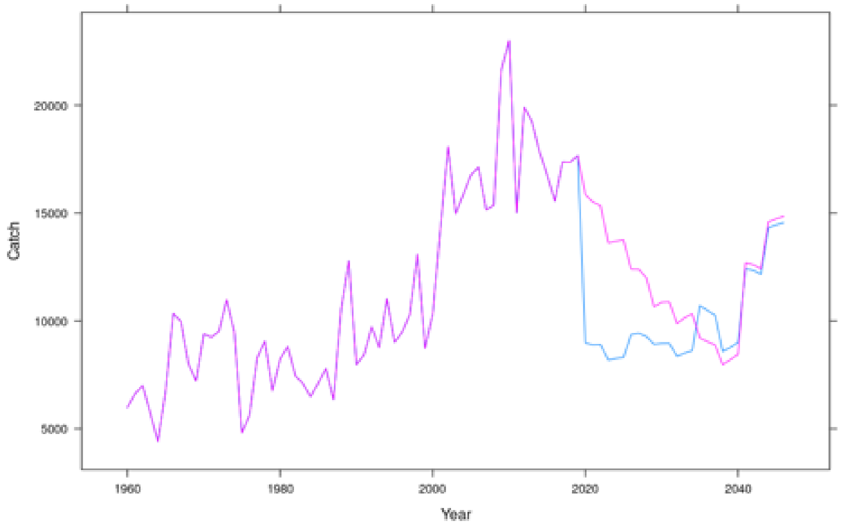
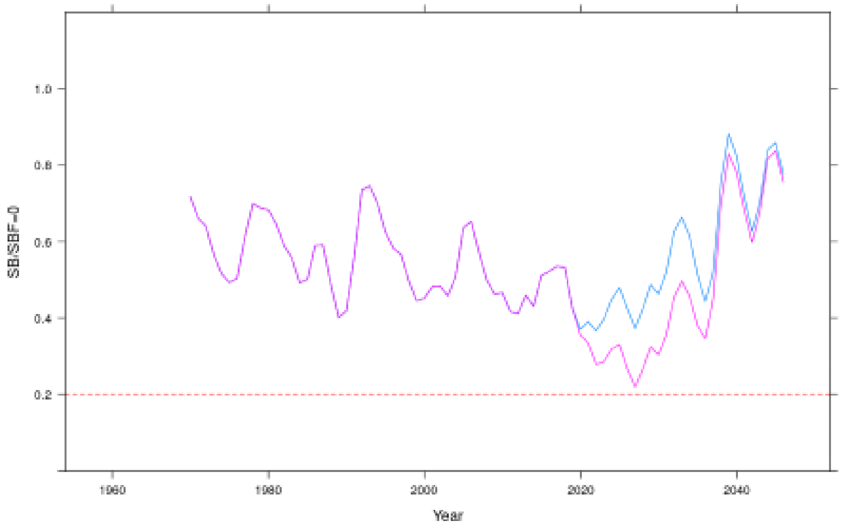


Figure 9: HCR used for the MP illustration. The red line shows the scalar values under the 5% catch constraint scenario where the constraint modifies the scalar values determined by the HCR. Numbers on the red line denote the year in which that scalar value was determined.



(a) Catch



(b) $SB_{latest}/SB_{F=0}$

Figure 10: Future catch and stock depletion ($SB_{latest}/SB_{F=0}$) under the illustration MP for the HCR with no constraint applied (blue line) and with the 5% constraint on catch reductions (red line).