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Selecting and Conditioning Operating Models for South Pacific Albacore

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Rev 1

- Abstract table updated with effort creep scenarios.
- Table 1 caption correted.

Rev 2

- Bigeye tables removed from the end of the document.

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Executive Summary

Under the WCPFC harvest strategy workplan, SC19 is scheduled to agree the operating models (OMs) for south Pacific albacore. In this paper we outline important sources of uncertainty that should be considered when conditioning OMs for south Pacific albacore and propose an initial OM reference set comprising 72 models and 144 scenarios, assuming a factorial design.

Axis	**Levels**		**Options**		
	Reference	Robustness	**0**	**1**	**2**
Process Error					
Rectmnt Variability	**1**		**1960-2017**		
Observation Error					
Catch and effort	**1**		**25%**		
Model Error					
Steepness ‡	**3**		**0.65**	**0.8**	**0.95**
Movement ‡	**2**		**Estimated**	**SEAPODYM**	
Growth ‡	**2**		**Estimated**	**fixed, Chen-Wells**	
Size comp. wtg ‡	**3**		**50 (low)**	**25 (medium)**	**10 (high)**
Rectmnt distbn	**2**		**SEAPODYM**	**Regions 3 & 4**	
Implementation Error					
Longline effort creep	**2**		**0%**	**2%**	

Table: SP albacore OM uncertainty grid. Scenarios shown in bold are proposed for the reference set. ‡ denotes those scenarios for which a dedicated fit of MULTIFAN-CL is required.

We note that several sources of uncertainty are not currently included in the OM grid. In particular for climate change scenarios, hyperstability in CPUE and assumptions for fisheries outside the control of the MP. These represent important sources of uncertainty and further work will be required to better understand these issues and to develop appropriate scenarios for them.

In addition some settings included in the OM grid might be considered preliminary estimates pending further analyses. Scenarios for recruitment distribution and effort creep are currently based either on the assumed dynamics of the south Pacific albacore population or have been selected to try to bound their level of uncertainty. We recommend that research continues into these, and other, sources of uncertainty to further develop the OM grid.

We view the current OM grid, which includes additional factors such as longline effort creep, as sufficient for initial development and exploration of albacore management procedures over the next 12 months. The OM grid should be reviewed as part of an ongoing monitoring strategy and in particular considering the results of the next assessment to ensure it is updated as necessary to capture additional uncertainties. That may include additional considerations identified in the development of the 2024 assessment and, if required, reconditioning of OMs.

We invite SC19 to consider the initial outline for the south Pacific albacore OM grid and to:

1. advise whether any additional sources of uncertainty should be considered;
2. advise whether current parameter values adequately reflect uncertainty in the dynamics of the stock and the fishery;
3. to note the ongoing development of scenarios to include in the OM grid and in particular the upcomming assessment scheduled for 2024.

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. An important benefit of the harvest strategy approach is the explicit consideration of uncertainty when designing, testing and selecting management procedures. Testing candidate management procedures before they are implemented against a range of alternative, yet plausible, scenarios that sufficiently reflect uncertainty in the status of the stock and the dynamics of the fishery increases the chance that defined management objectives will be achieved.

Under the WCPFC harvest strategy workplan, SC19 is scheduled to agree the operating models (OMs) for south Pacific albacore.

In this paper we focus on the process of developing and parameterising the operating models that represent the behaviour and dynamics of the fish populations and the fishing fleets that exploit them. This is a particularly important process in the development of the MSE framework and will require ongoing work to periodically re-evaluate the selection of OMs to use in the evaluations. Periodic review of the OMs (as part of a monitoring strategy) will ensure that any new data or updated information can be incorporated into the analyses and provides an opportunity to review the bounds and limits used to define exceptional circumstances. This paper presents the current suite of OMs for south Pacific albacore tuna.

1.1 Conditioning the operating model

Conditioning an operating model (Rademeyer et al., 2007) involves fitting the model to data in much the same way that a stock assessment model is fit to the available catch, size composition and tag recapture data. Because we do not have perfect knowledge of the dynamics of the resource, uncertainties will always be present. Our objective is to identify a suite of models that adequately characterises the range of uncertainty so that we can find the MP that performs best and is robust to that uncertainty.

In Section 2 we present an overview of the important issues to consider when designing the MSE. In Section 3 we draw on this general overview to provide specific recommendations on scenarios to be included in the suite of OMs. It may not be possible to examine all these scenarios due to technical limitations of the modelling framework or data deficiencies, and in Section 4 we consider what additional work will be required in order to address these issues.

2 Designing the MSE

Following a review of candidate tools for OM development, MULTIFAN-CL was identified as the most appropriate tool to use as the OM within the MSE simulation framework for WCPO stocks and fisheries (Scott et al., 2016, 2017) and a number of technical developments have been implemented to provide the software with the necessary functionality (Davies et al., 2017, 2018). The most recent stock assessment of south Pacific albacore (Castillo Jordan et al., 2021) was conducted using MULTIFAN-CL. This assessment and the data upon which it relies form the core of the OMs.

It would be impractical to try to account for every single source of uncertainty. Ideally, the inital range of uncertainties considered in an MSE should be sufficiently broad that new information collected after the management strategy is implemented should reduce rather than increase the range (Punt and Donovan, 2007). In practice, once the most important and most influential sources of uncertainty have been included, the influence of additional sources should have only a small impact on uncertainty bounds.

As a result, decisions need to be made on which alternative scenarios are the most important and consequential and therefore need to be included. In the following sections we address a number of potential sources of uncertainty. We consider their likely importance and review the available information on them with specific regard to south Pacific albacore and the southern longline fishery.

Stock assessments conducted by the Pacific Community (SPC) typically present a range of model configurations, termed the uncertainty grid, that explore the sensitivity of the assessment results to alternative assumptions about model settings for which data are often uninformative. Examples include the steepness of the stock recruitment relationship; assumed growth and maturity schedules, or the relative importance (weighting) that different data sources (size composition, CPUE) should be given in the assessment model.

The stock assessment uncertainty grids represent our current understanding of the biological processes of the fish stock, the quality of data and our ability to model those processes. However, the stock assessment uncertainty grid is concerned primarily with factors that impact the historical trajectory of the stock through to the present point in time. When projecting assessment results forwards in time, as performed by the MSE simulations, it may be necessary to consider a broader set of sensitivities in order to adequately capture the most important sources of uncertainty.

3 South Pacific albacore OM grid

Following the significant change in the spatial structure of the south Pacific albacore assessment in 2021 to a south Pacific wide assessment, spanning both the WCPFC and IATTC convention areas, SC18 expressed a preference that development of operating models for south Pacific albacore is based on that most recent assessment. In consideration of this, the proposed OM grid closely resembles the 2021 stock assessment uncertainty grid.

The OMs therefore cover the spatial extent of albacore in the south Pacific, from the equator to 50°S latitude, and the primary gears exploiting it: longliners (>90% of the catch in recent years) and the seasonal (November-April) troll fishery. Albacore tuna in the south Pacific Ocean are considered to comprise a single discrete stock (Murray, 1994). While some studies, using parasite faunal patterns (Jones, 1991) and genetic markers (Takagi et al., 2001; Montes et al., 2012) have suggested further stock structure exists within the south Pacific albacore population, tag recapture information, though limited, indicates wide scale mixing of adult albacore throughout the south Pacific Ocean. The Pacific-wide structure is therefore maintained within the current OM grid.

We note that albacore assessments suffer from a number of data related issues, including a paucity of usable tag release and recapture data, largely as a consequence of very low tag recapture rates and highly uncertain tag reporting estimates; highly variable length frequency data, resulting either from the aggregation of different fleets for the assessment or from seasonal variability in fishing practices; and from a general conflict between CPUE indices and size composition data. These and other issues are outlined in greater detail in an information paper to this SC on factors affecting recent and projected trends in albacore population abundance (Scott, 2023). Whilst some of the issues identified in that information paper pertain to the settings and underlying assumptions of the stock assessment model and may be addressed at the next stock assessment (scheduled for 2024), many of the issues represent persistent problems that cannot be easily fixed in the short term.

3.1 Sources of uncertainty

The major sources of uncertainty can be broadly categorised into process error, arising through natural variability in biotic and abiotic processes (affecting for example recruitment variability); observation error, arising largely from measurement error in quantities such as total catch, effort and biological sampling; model error, relating to model assumptions such as the form of the growth model, and implementation error where the management actions specified by the HCR do not correspond to what is acutally implemented for the fishery. Whilst this may include instances of non-compliance (e.g. catch or effort misreporting) we do not consider these in the MSE evaluations. When testing a candidate MP, we assume that management actions are applied as specified. Once an MP is adopted, any occurrence of non-compliance should be flagged under the monitoring strategy and highlighted for consideration under exceptional circumstances.

In this section we identify the different areas of uncertainty that may be considered in relation to both the 2021 stock assessment uncertainty grid, which focusses primarily on model error, and additional key uncertainties identified for South Pacific albacore.

3.1.1 Process error

Recruitment variability

A key source of future process error will be the level of recruitment, which is expected to be higher and more consistent with higher population abundance and lower, and potentially more variable, at low population abundance (see for example Figure 1). Recruitment levels for south Pacific albacore can also be highly variable at both annual and seasonal scales.

Long-term historical estimated trends indicate progressively increasing recruitment from around

1980 to 2010 with a marked dip in recent years (Figure 2). The true extent of this dip is unclear (see Scott (2023). Under current model settings the dip has a substantial yet transitory impact on predicted levels of population abundance. Once the very weak 2015 and 2016 cohorts have passed through, future population abundance re-stabilises around a new level of assumed average recruitment. The assumed level of average recruitment (1960 to 2017) is around 20% lower than average recruitment for the 2000 to 2010 period. On average, the CV of the annual recruitment deviates about the SRR is around 35%.

The general dynamics will be broadly captured through the assumption of a Beverton-Holt stock and recruitment relationship (see Section 3.1.3) with deviates about the relationship resampled from the historical time series. In turn, uncertainty in our knowledge of the spatial distribution of recruitment needs to be considered (see Section 3.1.3).

Future environmental drivers

The growth, distribution and abundance of albacore are known to be strongly influenced by ocean temperature, currents and dissolved oxygen (Briand et al., 2011; Brill, 1994; Domokos et al., 2007; Lehodey et al., 2013). Changes in these oceanographic variables at seasonal, inter-annual and multi-decadal time scales will likely affect albacore tuna distributions and may influence population dynamics processes such as recruitment (Lehodey et al., 2015). Oceanographic conditions can also affect the distribution and abundance of prey species that will also impact on the distribution and availability of albacore to fishing (Trenkel et al., 2014).

Several long-term changes in major oceanographic features in the tropical waters of the Pacific Ocean have been observed over the past 30 to 50 years (Ganachaud et al., 2011) including a strengthening of the south Pacific gyre which has altered the current system of the south west Pacific and changed the structure of water temperature in the region; a warming of the upper ocean layer leading to increased stratification with implications for nutrient supply to surface waters; decreasing concentrations of dissolved oxygen in sub-surface layers with potential detrimental impacts on biological production, and the absorption of increasing amounts of CO_2 leading to ocean acidification with negative impacts on shell formation and skeletal structure of calcareous organisms including crustacea that form a significant component of the diet of albacore tuna (Nickels et al., 2023; Williams et al., 2014). Climate simulation models predict that many of these observed changes will continue into the future and may strengthen.

The future impacts of climate change on the stock structure and movement rates of south Pacific albacore are uncertain. Ongoing work to better understand these impacts on tunas in the WCPO will allow further developement of climate change scenarios to be included in the OM grid.

3.1.2 Observation error

Observation error is applied to fishery-specific quarterly catch and effort through the application of log-normal error based on a user defined coefficient of variation (c.v.) (Davies et al., 2018). Separate coefficients can be applied for either catch or effort but cannot currently be applied to individual fisheries. A c.v. of 25% has been selected to simulate variability in future catch and effort observations that are consistent with historical observations.

3.1.3 Model error

As noted, the majority of the 2021 assessment uncertainty grid focussed on model error, covering biological uncertainty and issues with data weighting.

Steepness

The steepness of the stock and recruitment relationship (see Figure 1) is routinely included in the grid as there is often very little information to reliably inform its estimation. The assumed value of steepness may have less impact on historical estimates of stock status, but often has greater impact on projections of future stock status under alternative fishing scenarios as well as on management quantities such as MSY.

Growth and natural mortality

Albacore exhibit significant variation in length at age both between the sexes and also spatially (Williams et al., 2012). Growth trajectories are similar for both sexes up to around 4 years of age after which the males grow at a faster rate, reaching a maximum length that is more than 8cm larger than the females. In addition, length at age and growth parameters have been found to be greater at easterly longitudes for both males and females.

Further spatial variation in albacore population structure is apparent in the seasonal and spatial distribution of mature females. Females at more northerly latitudes (where spawning occurs) mature at smaller lengths and ages than females at more southerly latitudes, particularly during the spawning season (Farley et al., 2014). The predicted length at 50% maturity is around 87cm fork length (4.5 years).

The instantaneous rate of natural mortality is believed to be between 0.2 and 0.5 per year. The 2021 stock assessment assumed two scenarios for age specific rates of natural mortality, based on alternative growth rates and current understanding of maturity at length (Maunder et al., 2023). Both scenarios set natural mortality to values around 0.3 p/a.

Assumed rates of growth and natural mortality are therefore an area of uncertainty to be captured, since the assumed values can have a large impact on model fits and associated estimates of stock status. Within the 2021 assessment, two alternative growth models were determined, one from a fit to age at length observations from otolith readings, and a second model derived from the size frequency data included in the assessment. Both growth models were determined external to the stock assessment fit for given maturity and natural mortality schedules. The proposed OM grid includes these two growth and natural mortality scenarios (Figure 6).

Size composition weighting

Settings for the size frequency weighting effectively weight the relative importance of the different data sets in the assessment and are also commonly included in the stock assessment grid. For the 2021 south Pacific albacore assessment the two primary sources of information to the assessment are the standardised indices of CPUE and the size composition data. Consequently the weighting applied to the size composition data determines the relative influence that either the CPUE or the size frequencey data have. These size data weightings are retained for the proposed OM grid.

Recent analyses indicate that the settings assumed for the 2021 assessment potentially over-weight the size composition data and the values assumed in the OM grid may need to be modified pending further investigation of this at the next stock assessment.

Movement

Albacore in the south Pacific exhibit a marked seasonal migration between feeding grounds in the subtropical convergence zone in the south and spawning grounds in the sub-equatorial regions with movement models indicating relatively high adult advection rates of around 1.0 BL s^{-1} (Lehodey et al., 2013). Albacore spawning takes place during the austral summer in tropical and sub-tropical waters between latitudes 10°S and 25°S. The juveniles progressively move south towards the coastal waters of New Zealand and generally eastwards along the sub-tropical convergence zone (STCZ) (Murray, 1994) and are believed to move back into sub-tropical waters during the austral autumn. A seasonal migration between tropical and sub-tropical waters has been inferred from monthly trends in longline catch rates (Langley, 2004) although the true nature of albacore migration within the south Pacific remains somewhat obscure. Lehodey et al. (2013) suggest that two separate migration paths may exist with a north-south pattern in the Coral Sea and west Pacific and another following the border of the gyre in the east.

Movement appears to be characterised by two distinct patterns, the first being a seasonal north south migration between spawning and feeding habitats, and the second associated with an easterly movement along the south Pacific gyre (Lehodey et al., 2015).

The 2021 stock assessment of south Pacific albacore considered two alternative movement scenarios (Figure 5). The first, determined from model fits of MULTIFAN-CL, shows greater mixing between assessment regions 3 and 4, and, to a lesser extent, between regions 1, 2 and 4. This scenario emphasises east-west mixing and potential migration along the south Pacific gyre. The second movement scenario was based on fits to the SEAPODYM model, and shows stronger north south seasonal movement dynamics and less mixing with the EPO. This scenario gives more emphasis to the seasonal north-south migration pattern.

Given the uncertainty in albacore movement rates, both are considered plausible scenarios that capture our current understanding of likely spatial stock structure and movement dynamics for inclusion within the OM grid. Further work is recommended to better understand movement rates of south Pacific albacore and to better characterise uncertainty in those dynamics.

Recruitment distribution

Similar to movement rates, the distribution of recruitment throughout the region is also highly uncertain. It is generally accepted that albacore undergo seasonal migrations to summer spawning grounds in tropical and sub-tropical waters and that the juveniles progressively move south, eventually appearing in the surface fisheries around New Zealand. However, juvenile movement rates are poorly estimated and the resulting spatial distribution of recruitment is therefore also poorly understood. Two recruitment distribution scenarios were included in the 2021 assessment uncertainty grid, and are proposed for retention in the OM grid (Figure 3), the first derived from fits to a SEAPODYM model for south Pacific albacore, and the second based on the prior assumption that all recruitment occurs in the southerly regions (ie. assessment regions 3 and 4).

Hyperstability in CPUE

Catch per unit effort is often assumed to scale in strict proportion to population abundance. The higher the population abundance the higher the CPUE, and vice-versa. However, the strong schooling nature of tuna and the non-uniform spatial and temporal distribution of fishing can lead to a weak and potentially non-linear relationship between CPUE and abundance (Harley et al., 2001; Gaertner and Dreyfus-Leon, 2004; Maunder et al., 2006). Potential CPUE-abundance relationships under varying levels of hyperstability are illustrated in Figure 4.

The extent to which hyperstability in CPUE might be occurring in the south Pacific albacore fishery is unclear. Some fisheries at the northern and southern limits of the fishery show some variability in catches, catch rates and catch size composition that might be linked to population abundance. However, those in the core region of the fishery (assessment region 2) appear to maintain more consistent catch rates and catch size compositions regardless of estimated changes in population structure and abundance.

For the evaluations of candidate mangement procedures for WCPO skipjack, a range of hyperstability assumptions were considered with the intention to bound the level of uncertainty in the potential dynamics of the fishery. Assumptions of no hyperstability and moderate hyperstability were included in the reference set of OMs and a more severe assumption included in the robustness set. Ultimately, due to the relative stability of the skipjack stock within the evaluations, there were relatively small changes in the assumed CPUE relationship regardless of the extent of hyperstability assumed. In contrast, the population dynamics of south Pacific albacore are more variable. The stock is currently estimated to be in a depleted state, though the extent of depletion is uncertain, and the MP is required to rebuild the stock with the aim to achieve higher CPUE and improved economic conditions within the fishery.

The extent to which hyperstability is occurring in the south Pacific albacore fishery is highly uncertain and will be influenced by several factors including the schooling behaviour of albacore and the ability of fishers to find frontal systems and other oceanographic features associated with good albacore catch rates. Hyperstability in CPUE is not currently included in the OM grid for south Pacific albacore. The inclusion of hyperstability, if appropriate, could impact on MP performance, in particular with regard to achieving long-term increases in CPUE. It is proposed that further work be conducted to investigate the potential for hyperstability in longline fisheries in general and, with specific reference to south Pacific albacore, to determine what appropriate levels of hyperstability might be, for inclusion in the OM grid in the future.

3.1.4 Implementation error

Noting the discussion earlier on implementation error, some situations may occur that fall outside the control of the MP management actions. These may include substantial catch increases in archipelagic waters or in neighbouring regions, that fall outside the jurisdiction of the MP. Currently there are no scenarios included in the OM grid that consider this issue. However, following the approach for archipelagic waters in the WCPO skipjack evaluations, plausible scenarios for the behaviour of fleets in the EPO will need to be considered in the future.

Effort creep

Another potential source of implementation error is the occurrence of effort creep in commercial fishing operations. Where effort creep is occurring the efficiency of vessels increases as a result of, for example, technological developments and improvements, such that nominal fishing effort (e.g. days fished) no longer represents a consistent and reliable measure of fishing activity. The extent to which effort creep is occurring in longline fisheries is unclear, but could be important.

Therefore, two effort creep scenarios have been included within the OM grid. In the first, effort creep is assumed not to occur, and the second assumes a 2% annual increase in effective effort throughout the projection period. These values are selected to bound the uncertainty in potential levels of effort creep. Further work will be required to determine more appropriate estimates for longline fisheries, and we note recent discussions and developing studies related to longline effort creep.

3.2 Reference and robustness sets

It is considered best practice to divide the OM grid into a reference set of models, representing the most plausible and most influential scenarios to consider, and a robustness set of models representing

Axis	Levels		Options		
	Reference	Robustness	**0**	**1**	**2**
Process Error					
Recruitment variability	**1**		**1960-2017**		
Observation Error					
Catch and effort	**1**		**25%**		
Model Error					
Steepness ‡	**3**		**0.8**	**0.65**	**0.95**
Growth ‡	**2**		**otolith data**	**length freq data**	
Size comp. wtg ‡	**3**		**10**	**25**	**50**
Movement ‡	**2**		**MFCL**	**SEAPODYM**	
Recruitmnent distbn ‡	**2**		**SEAPODYM**	**fixed**	
Implementation Error					
Longline effort creep	**2**		**0%**	**2%**	

Table 1: South Pacific albacore OM uncertainty grid. Scenarios shown in bold are proposed for the reference set. ‡denotes those scenarios for which a dedicated fit of MULTIFAN-CL is required.

scenarios that, although still plausible, are more extreme (Rademeyer et al., 2007). The reference set is the primary set of models against which candidate MPs are tested and are the basis of the calculation of performance indices. The robustness set provides a set of more extreme scenarios that can used as an additional test once a subset of preferred MPs has been selected. For the current grid (Table 1) we consider only the reference set.

3.3 Model validation

The primary purpose of 'conditioning' the OMs is to ensure that all important sources of uncertainty have been appropriately accounted for. It is, therefore, particularly important to consider how accurately each of the models in the OM grid represents the real world and whether the type and scale of uncertainty generated from it represents a plausible future scenario against which candidate management procedures should be tested. There is no simple test to establish the validity of a model. Instead we rely on a collection of indicators, based on diagnostics of the fit of the model to data, and consideration of whether the quantities estimated from it are reasonable.

It would be impractical to present a comprehensive set of all model diagnostics in this report. Instead we present only a subset of the available diagnostic plots and tables. A full set of diagnostics is provided in an accompanying shiny app which can be accessed at `https://ofp-sam.shinyapps.io/spa-oms/`

3.3.1 Retrospective analyses

Retrospective analyses are an important diagnostic tool for determining the robustness of model estimates to varying quantities of data and in recent years have been routinely presented for each new stock assessment. Retrospective analyses were conducted across the OM grid, whereby the final assessment model was refitted to a progressively truncated time series of data over a 10 year period. Results are shown for 2 models from the OM grid (Figure 7). The full set of retrospectives can be viewed in the OM diagnostics shiny app. The results show a persistent retrospective bias occurring across the grid of models with two distinct patterns. Models based on MULTIFAN-CL estimates of movement rates show a progressive re-scaling of stock status with successive retrospective peels. Models based on SEAPODYM estimates of movement rates typically show less re-scaling but continue to show a marked retrospective bias in the terminal years.

Retrospective bias is a recurring feature of stock assessments for south Pacific albacore and potentially arises from conflicting signals in CPUE and size frequency data, although further work is required to better understand the underlying causes. The retrospective pattern has implications for the MSE analyses in that the terminal estimate of stock status (and the starting point for the MSE projections) may be underestimated, leading to more pessimistic outcomes, at least in the short term.

Given the uncertainty in terminal estimates of stock status arising from both retrospective bias and uncertain recruitment estimates for 2015 and 2016, we recommend that the MSE analyses employ a starting date of 2025 for the implementation of the management procedure (MP). This approach might be preferred, firstly because it is consistent with the current WCPFC workplan that schedules the adoption of an MP in 2024 and its first implementation in 2025, and secondly because by this time the population has had more time to stabilise around the assumed projection settings.

3.3.2 Likelihood profiles

Likelihood profiles show the relative influence that different data components have on the model. The likelihood profile for the 2021 diagnostic case assessment model (Figure 8) highlights the data conflict between the CPUE and size frequency data with CPUE data generally estimating higher biomass levels than the size frequency data. The overall model likelihood matches closely with that of the size frequency data which may reflect the higher weighting given to the size frequency data under the 2021 model configuration. Data weighting remains a key source of uncertainty when fitting models to south Pacific albacore and will be further investigated as part of the ongoing work to develop the OM grid as well as for the next stock assessment.

4 Future work areas

We note that several sources of uncertainty identified in Section 3.1 are not currently included in the OM grid. In particular for climate change scenarios, hyperstability in CPUE and assumptions for fisheries outside the control of the MP. These represent important sources of uncertainty and further work will be required to better understand these issues and to develop appropriate scenarios for them.

In addition some settings included in the OM grid might be considered preliminary estimates pending further analyses. Scenarios for recruitment distribution and effort creep are currently based either on the assumed dynamics of the south Pacific albacore population or have been selected to try to bound their level of uncertainty. We recommend that research continues into these, and other, sources of uncertainty to further develop the OM grid.

Additional information relevant to the development of OMs for south Pacific albacore are presented in information papers to this SC, specifically with regard to recent and predicted population trends (Scott, 2023) and CPUE standardisation (Yao et al., 2023). While no additional CPUE scenarios have been proposed for the initial OM grid as a result of this work, it remains an area for ongoing consideration.

We view the current OM grid, which includes additional factors such as longline effort creep, as sufficient for initial development and exploration of south Pacific albacore management procedures over the next 12 months. The OM grid should be reviewed as part of an ongoing monitoring strategy and in particular considering the results of the next assessment to ensure it is updated as necessary to capture additional uncertainties. That may include additional considerations identified in the development of the 2024 assessment and, if required, reconditioning of OMs.

5 Conclusions

Throughout this paper we have outlined the important sources of uncertainty that should be considered when conditioning OMs for south Pacific albacore. We propose an initial OM reference set comprising 72 models and 144 scenarios, assuming a factorial design.

We note that a number of important areas of uncertainty have been identified that have yet to be fully incorporated into either the reference or robustness sets. It is important that future work be undertaken to address these unresolved issues. In this respect, this paper presents the first round of conditioning the OMs and should be periodically reviewed to ensure that the range of OMs used in the analysis remains appropriate.

We invite SC19 to consider the initial outline for the south Pacific albacore OM grid and to:

1. advise whether any additional sources of uncertainty should be considered.
2. advise whether current parameter values adequately reflect uncertainty in the dynamics of the stock and the fishery.

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A Figures

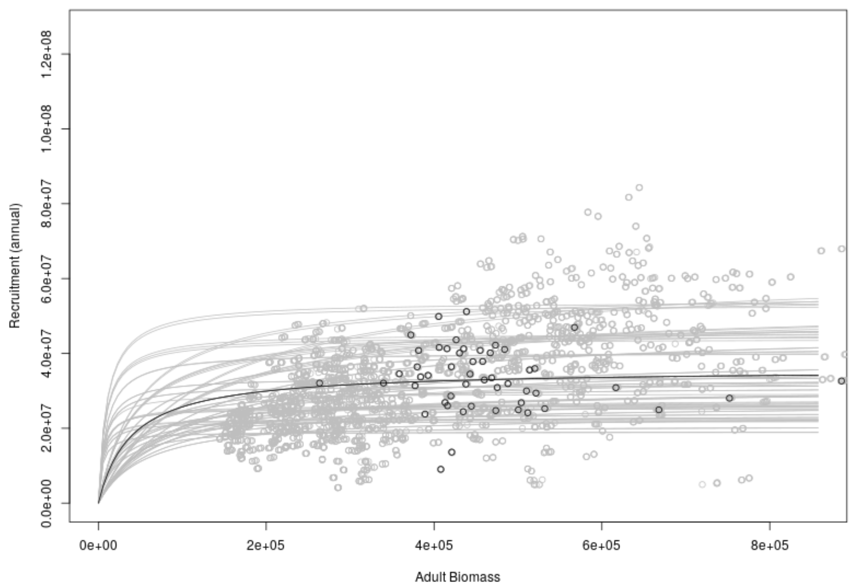


Figure 1: Stock and recruitment pairs and Beverton Holt SRR fits across the 72 models of the stock assessment grid. Diagnostic model shown in black.

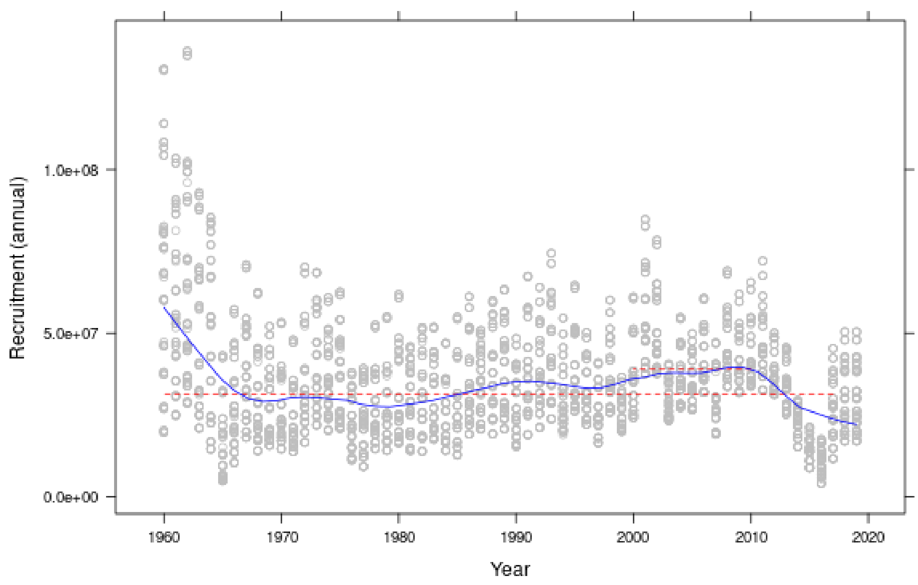


Figure 2: Recruitment time series across the 72 models of the stock assessment grid. Dotted red lines show the geometric mean recruitment (calculated across all models) for the periods 1960-2017 and 2000-2010. Blue line shows a loess smoother fitted to all data with a span of 1/5.

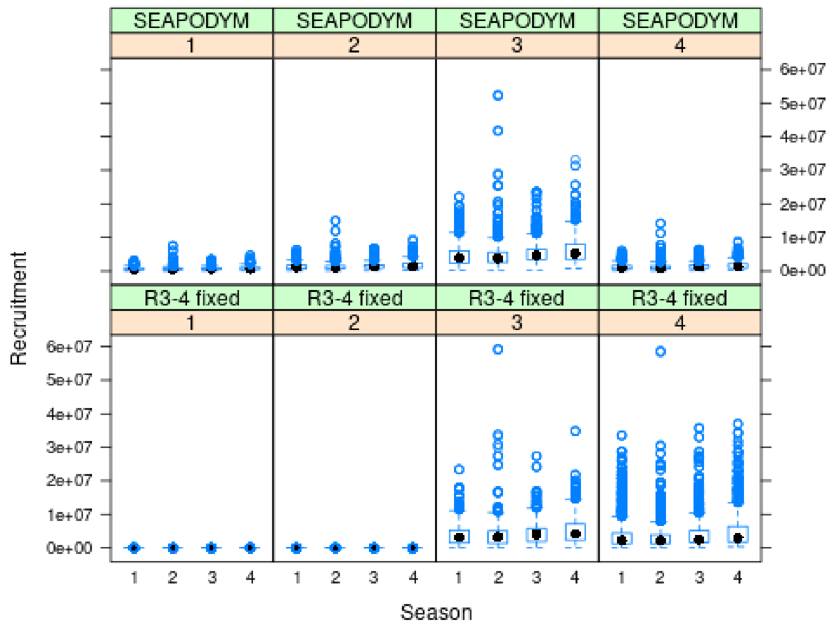


Figure 3: Regional recruitment distribution (all years and all models) by season for the two scenarios in the OM grid (SEAPODYM and regions 3 and 4 fixed) .

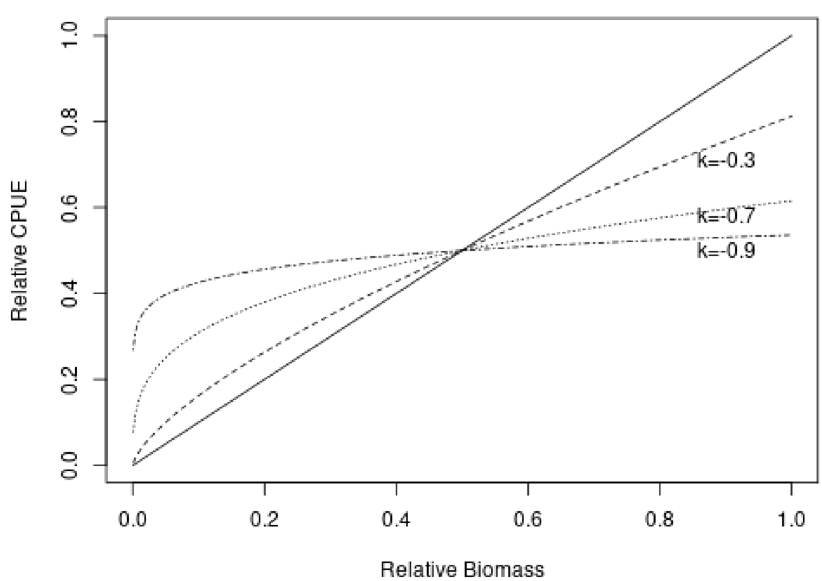
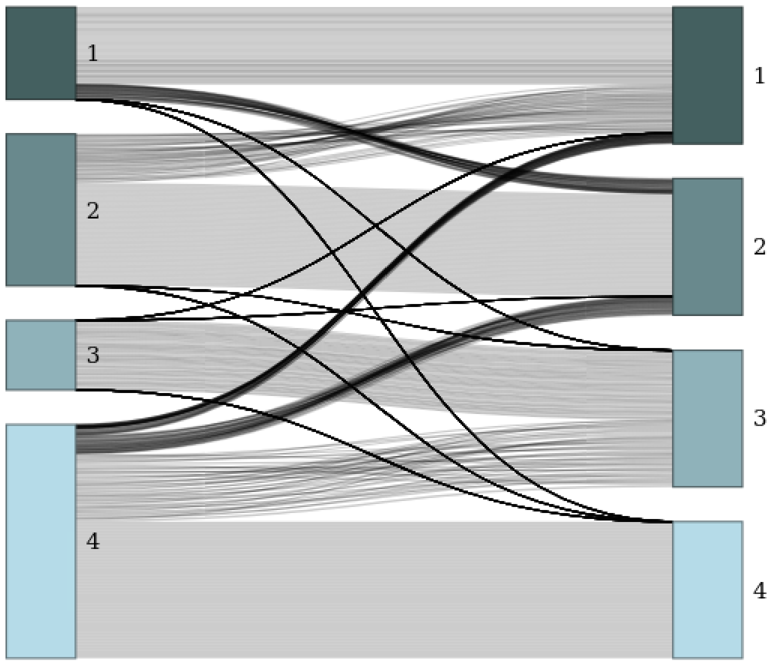
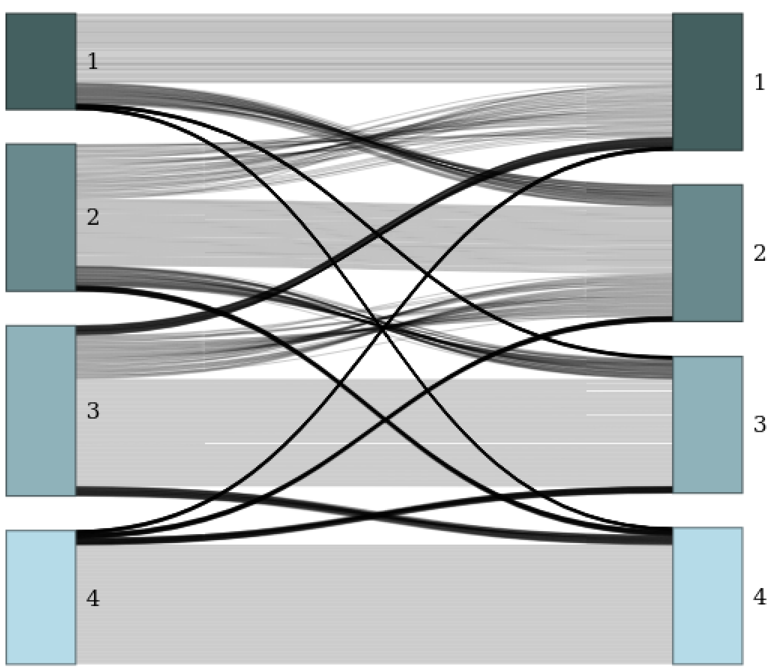


Figure 4: CPUE and abundance relationship under different levels of hyperstability in CPUE. k=-0.3 represents relatively weak hyperstability, k=-0.9 represents relatively severe levels of hyperstability.

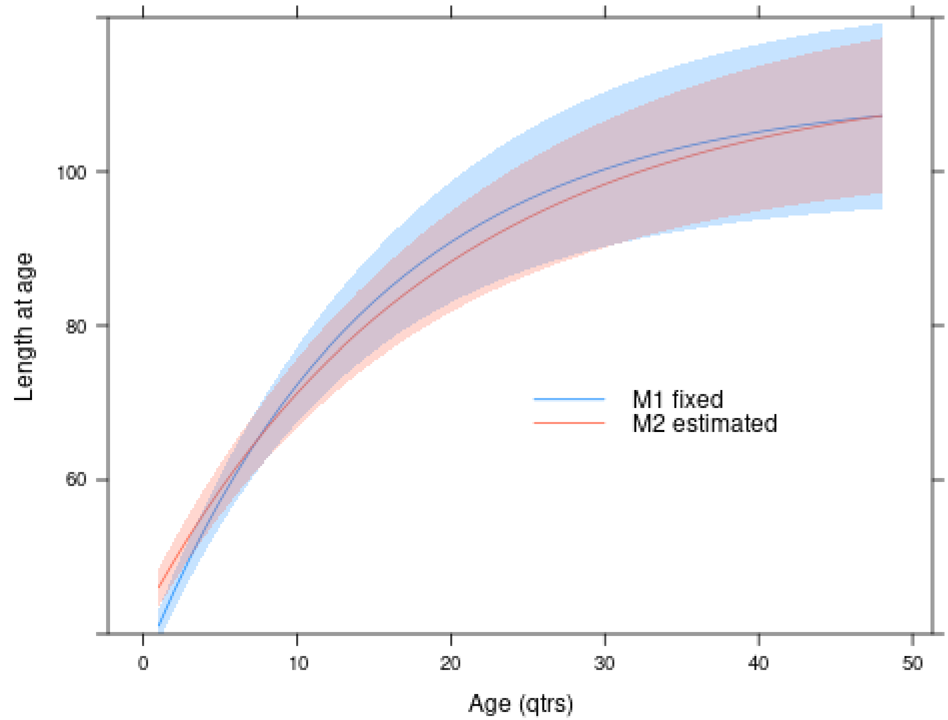


(a) MFCL

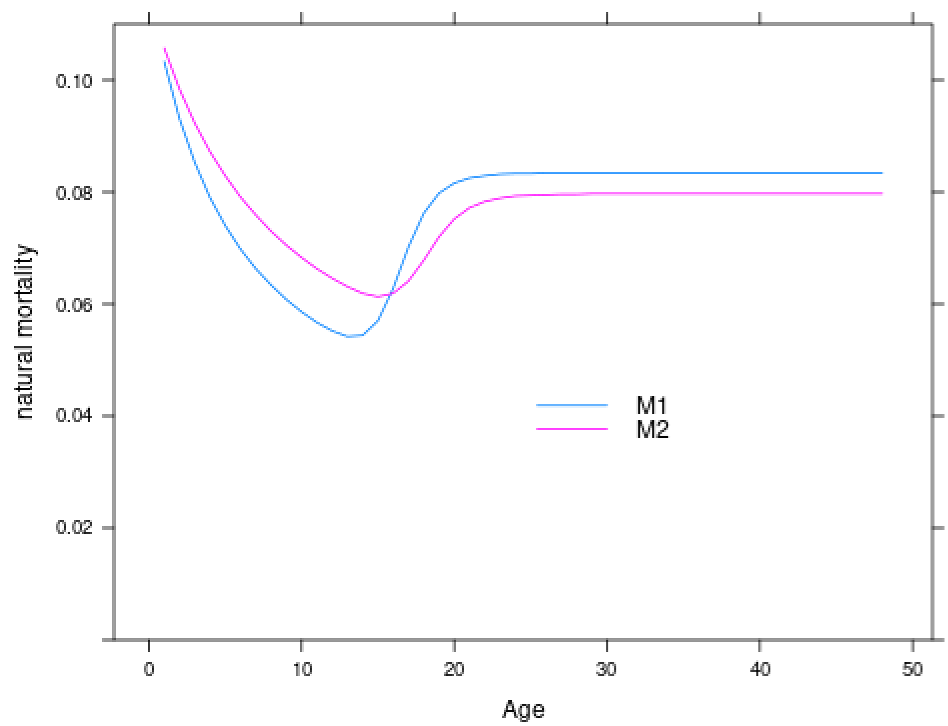


(b) SEAPODYM

Figure 5: Estimated movement rates between stock assessment regions (all ages and seasons) for MFCL (diagnostic case) and SEAPODYM. Estimated movement is shown from model regions on the left to model regions on the right.

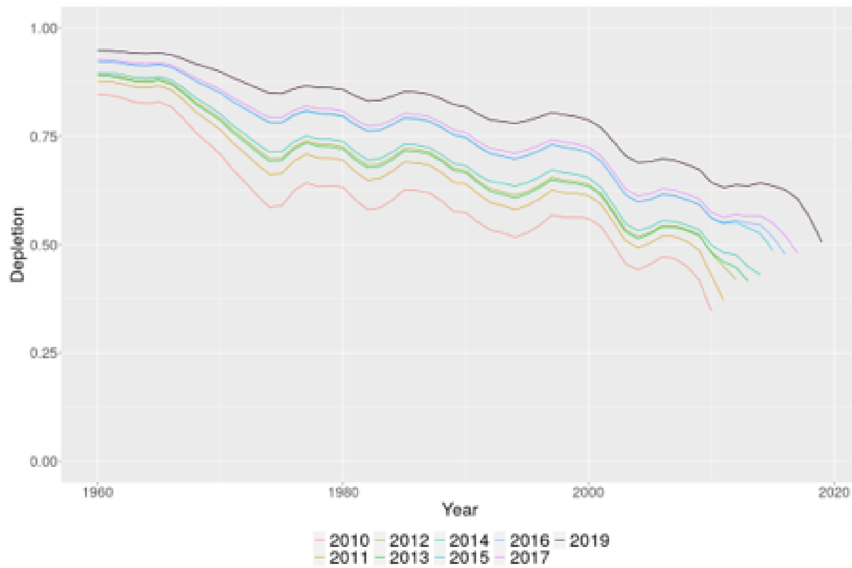


(a) Growth

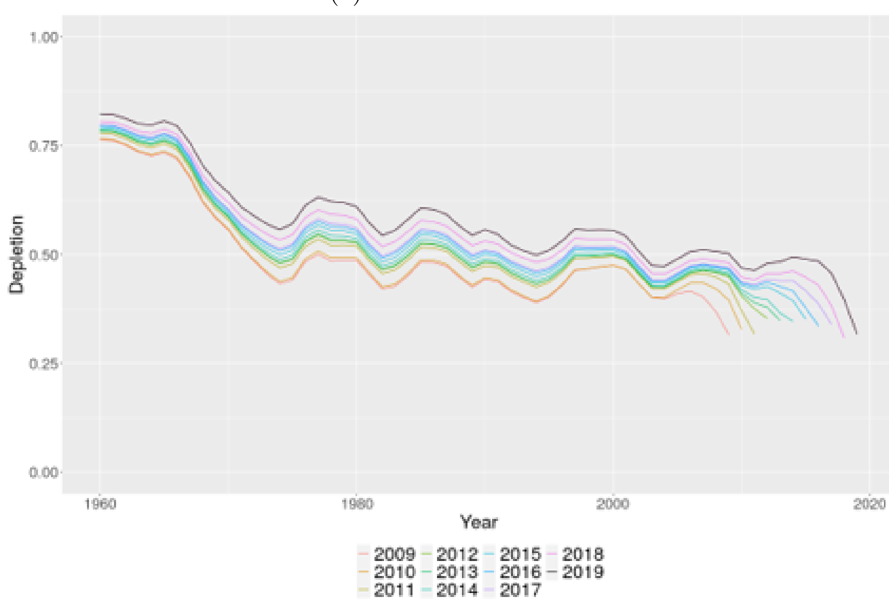


(b) Natural mortality

Figure 6: Alternative settings for growth and natural mortality under the OM grid.



(a) MFCL movement



(b) SEAPODYM movement

Figure 7: Estimates of stock status ($SB_{latest}/SB_{F=0}$) determined from retrospective analyses (10 peels between 2019 and 2009) conducted for two operating models. The first based on MULTIFAN-CL estimates of movement and the second based on SEAPODYM movement rates.

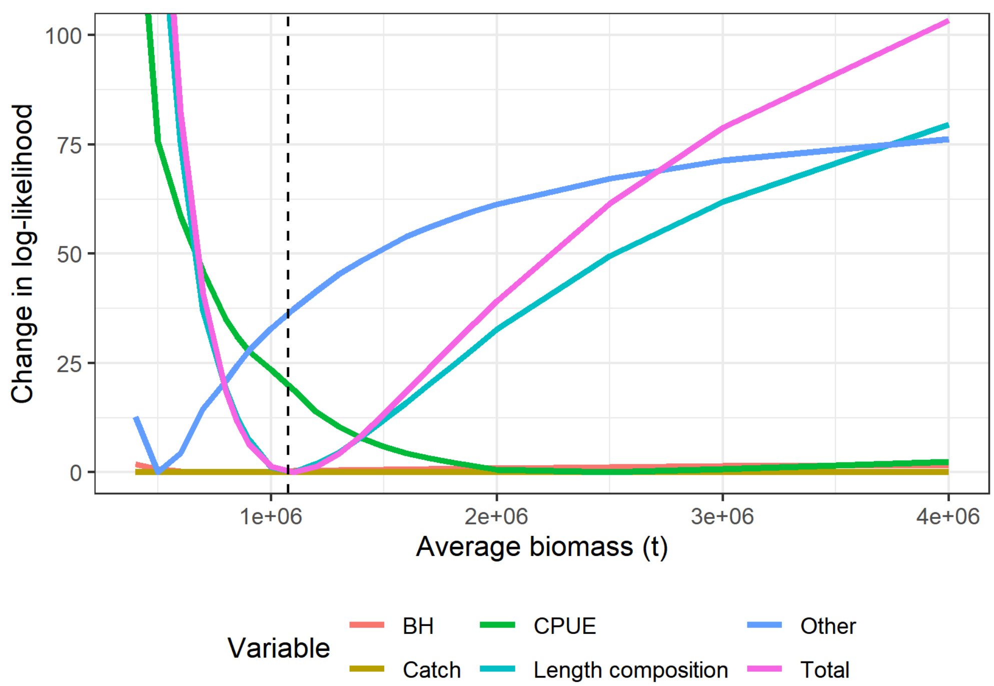


Figure 8: Likelihood profile for the 2021 diagnostic case assessment model.