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Factors contributing to recent and projected declines in south Pacific albacore stock status.

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Executive Summary

Recent assessments of south Pacific albacore show a decline in terminal stock abundance that continues into the future projected period. The extent of the decline is severe. Estimates vary across the 72 model assessment grid, but some model runs show a decrease in spawning potential ratio ($SB/SB_{F=0}$) from around 0.4 to less than 0.2 in the space of a few years. Given this considerable decline in stock status it might be expected that catches and catch rates in recent years would have declined. The absence of any indication of significantly reduced catch rates occurring as a result of this population decline (based on a combination of anecdotal information and updated catch and effort records to 2022) leads to two alternative possibilities:

- The decline in population abundance is real and driven by high fishing mortality and/or reduced recruitment.
- The decline in population abundance is not real and is an artifact of the modelling assumptions of the stock assessment and/or issues with the data.

In exploring these possibilities, we consider the dynamics of the fishery and the estimated population structure of south Pacific albacore in recent years as well as the potential impacts of environmental conditions and the data influences and modelling assumptions of the most recent (2021) stock assessment.

The analyses presented in this report suggest that there is some support for both possibilities. The decline in stock status is likely partly due to the evolving population structure under relatively high exploitation levels. There may also have been reduced recruitment in recent years, potentially as a result of recent environmental conditions. However, the assessed trend appears to be exacerbated by some of the modelling assumptions of the 2021 stock assessment that will require further consideration for the next assessment.

Given the uncertainty in the extent and the severity of the marked reduction in stock status estimated across the grid of the 2021 assessment we recommend that the MSE analyses employ a starting date of 2025 for the evaluation of candidate management procedures. As work develops on the next assessment (due in 2024) new information and updated analyses may feed into modifications of the MSE framework and analysis, consistent with the approach outlined in SC19-MI-WP-04.

We invite SC19 to consider:

- the recommendation for starting the MSE analyses in 2025 and provide advice accordingly;
- the potential impacts of long-term climate change and inter-annual climate variability on the population dynamics and catchability of south Pacific albacore and the potential to include these impacts in the MSE.

1 Introduction

The most recent stock assessment of south Pacific albacore (Castillo Jordan et al., 2021) shows a decline in stock status (spawning potential ratio, $SB/SB_{F=0}$) at the end of the time series. Projections conducted from this assessment (McKechnie et al., 2022) indicate a continued decline in stock status before the stock eventually increases again under the projection assumption of average recruitment. The scale of the decline is substantial and is consistently estimated across the grid of 72 models considered for the stock assessment, although the extent to which the stock declines varies, with some models estimating that spawning biomass depletion will fall below the limit reference point (LRP). On average, the stock is expected to fall to around 30% of unfished biomass levels for a brief period before increasing, although some models estimate a decline to less than 20%.

The decline in stock status was noted during the 2021 assessment and a number of analyses conducted to investigate the potential causes. These investigations comprised a series of sensitivity analyses in which data were sequentially removed from the terminal period of the assessment. The analysis found that both CPUE and size composition data for a number of fisheries and several years needed to be removed in order to reduce the scale of the decline in stock status. The assessment report concludes that the decline appears to be the result of a low period of recruitment estimated between 2015 and 2017, potentially as a consequence of unfavourable oceanographic and environmental conditions for albacore recruitment (Castillo Jordan et al., 2021). We also note that projections conducted from the 2018 stock assessment of south Pacific albacore (Tremblay-Boyer et al., 2018; Pilling, 2019) also predicted a decline in stock status during the period 2018 to 2021.

The last year of available data for the most recent stock assessment was 2019. The projections estimate stock status to reach its lowest point between 2020 and 2022. Given the substantial reduction in stock status, it might be expected that catch and CPUE in the fishery would be affected, however, recent anecdotal information suggests that no significant consistent reduction in catches or catch rates has been observed. For this reason it might be considered that the dip in stock status could be an artifact of the stock assessment model structure, or that a lack of data, or mis-specified data, in the terminal period of the assessment might be adversely affecting estimates of population abundance.

In this report we investigate the factors contributing to the decline in both recent estimates and projected stock status of south Pacific albacore. We consider the historical performance of the fishery; the temporal trend in recruitment over that period and the available fishery-specific size composition data to understand the population dynamics in the most recent time period. We also consider the modelling assumptions underlying both the stock assessment and the projections to try to understand the causes of the projected population decline. Based on the results of these investigations we make specific recommendations for the further development of harvest strategies for south Pacific albacore, in particular with respect to the further development of operating models and the structure of the MSE framework. In addition we highlight a number of factors pertaining to the stock assessment that should be considered prior to the next full assessment, scheduled for 2024.

2 Factors contributing to recent and projected declines in south Pacific albacore stock status

Inputs to the stock assessment comprise fishery-specific catch and size composition data along with area-specific standardised CPUE time series that are calculated from catch and effort data for a number of fisheries operating in each assessment region. Both the CPUE and size composition data provide information to the assessment on general trends in population abundance and fishing mortality.

Previous reports (Kendrick and Bentley, 2010) have argued that CPUE of troll-caught albacore in New Zealand waters is unlikely to be a useful index of abundance, but is rather an index of availability of juvenile fish to New Zealand and that there is probably no recruitment signal in these indices. Length frequency data from the troll fisheries on the other hand appear to show better correspondence with other data sources and may provide more reliable information on recruitment to the fishery. For this reason we focus initially on the size composition data as well as recent trends in catch and effort in the wider fishery to try to understand the factors influencing the recent estimated decline in recruitment and stock status.

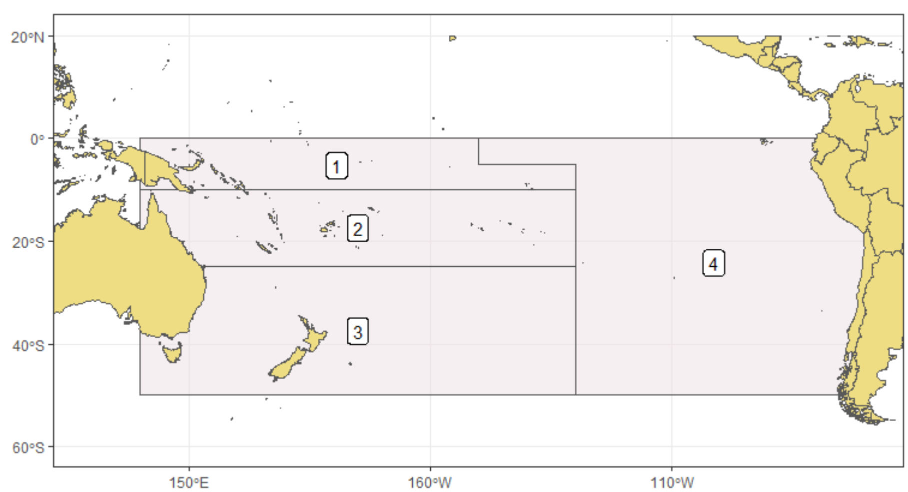


Figure 1: Spatial structure of the 2021 south Pacific albacore stock assessment .

2.1 Catches

Catches of south Pacific albacore (south Pacific wide) have increased progressively over the last 3 decades. Catches increased markedly between 2000 and 2010 and have since remained at high levels with catches peaking at around 95,500 mt in 2017 (Figure 2). The vast majority of these catches (around 91% in 2021, McKechnie et al. (2022)) are taken by longline vessels. Troll fisheries operate in the more southerly regions, predominantly in the New Zealand EEZ and on the high seas, and account for a smaller proportion of total catches (around 4,100 mt in 2021). Overall, catches of south Pacific albacore have been concentrated in EEZs and several high seas zones in the 10-20°S latitudinal band corresponding to region 2 of the 2021 stock assessment (McKechnie et al., 2022).

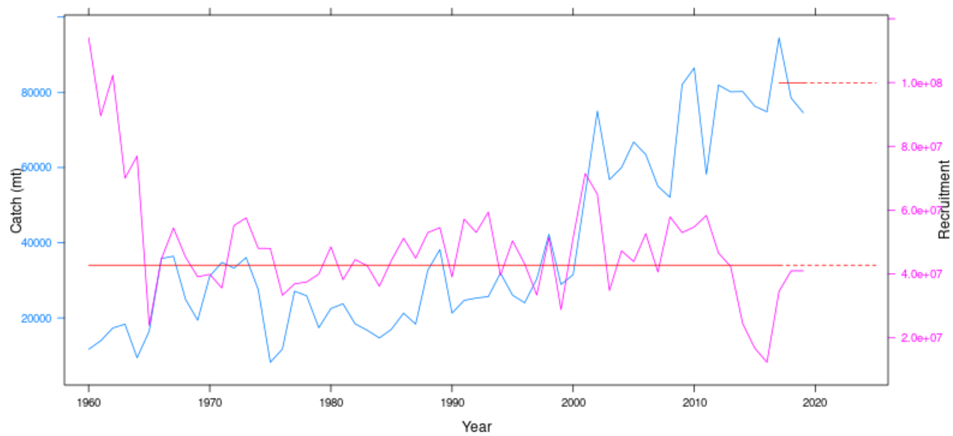


Figure 2: Catch in tonnes (blue) and recruitment (red) for south Pacific albacore for the period 1960 to 2019 (2021 diagnostic case assessment). Solid horizontal red lines show averge levels of recent catches (2017-19 mean) and recruitment (1960-2017 geometric mean) that are assumed for projections.

Longline caught albacore are typically in the range of 80-110cm although longline vessels may catch fish outside of this range depending on gear configuration and spatial location. This length range corresponds approximately to fish between 4 and 12 years of age and represents the proportion of the population contributing the most to spawning potential (Castillo Jordan et al., 2021). Troll fisheries target smaller fish with catches typically in the range of 50-80cm corresponding, approximately, to ages between 1 and 4. Consequently, the troll fishery length frequency data comprise the primary source of information to the assessment on recruitment trends. In Figure 3 we show the size composition data for the troll fishery and the longline index fishery in region 3 (Similar figures for all fisheries are shown in Appendix A). A number of apparent strong year-classes can be identified from the troll fishery length frequency data, identified as two or more successive periods of high catches of fish corresponding to the length range of the estimated growth curve. These apparent strong cohorts can also often be identified in region 3 longline length frequency data. This suggests that the year-class information provided by the troll fishery in region 3 is broadly consistent with that of the longline fisheries.

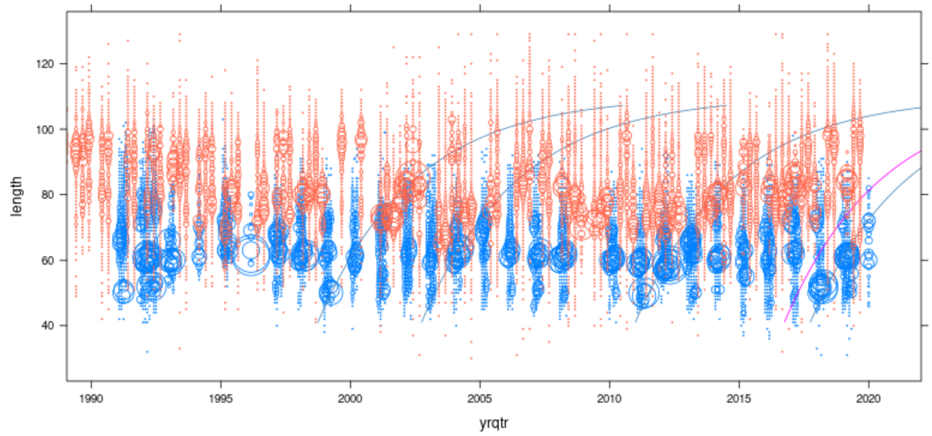


Figure 3: Composition of troll (All-TR, blue) and longline (Index-LL-3, red) catch at length in assessment region 3. Blue lines show estimated lengths for apparent strong cohorts. Pink line shows estimated length for the apparent weak 2016 cohort.

2.2 Population structure

The age structure of a population provides an indication of its response to fishing pressure. The estimated population age structure in assessment region 2 for assessed (1980-2019) and projected (2020-2049) time periods (Figure 4 and Figure 12, all WCPFC-CA regions) shows how the south Pacific albacore population is assessed to have evolved over time in response to changes in fishing. A progressive removal of large fish from the population is evident throughout the assessment time series with an initial marked reduction occurring in the late 1980's, followed by a more progressive and less severe decline until around 2000. The size of the plus group (the accumulation of fish aged 12 years and older) also shows a progressive decline throughout the assessment time period.

2.2.1 Recruitment

Estimated recruitment (Figure 2) has remained fairly consistent over the assessment time period with a notable period of very low recruitment occurring between 2014 and 2016 (see also Figure 4). Sustained periods of above average recruitments between 1985-1993 and 2000-2011 led initially to increased population abundance and have supported the increased catch levels observed since 2000. However, the recent period of below average estimated recruitments from 2013 onwards have not been sufficient to replenish the population given the continued high catches.

The reduction in predictions of large fish towards the end of the assessment time series, particularly in region 2, appears to be a consequence of recent below average estimated recruitment levels from 2013 onwards and continued high catches, and is further exacerbated by very poor estimated recruitment in 2015 and 2016. Moving into the projection period (post 2019), the assumption of median recruitment, which is generally lower than levels observed between 2000-2010 (Figure 2), leads to a further decline in adult biomass in the population.

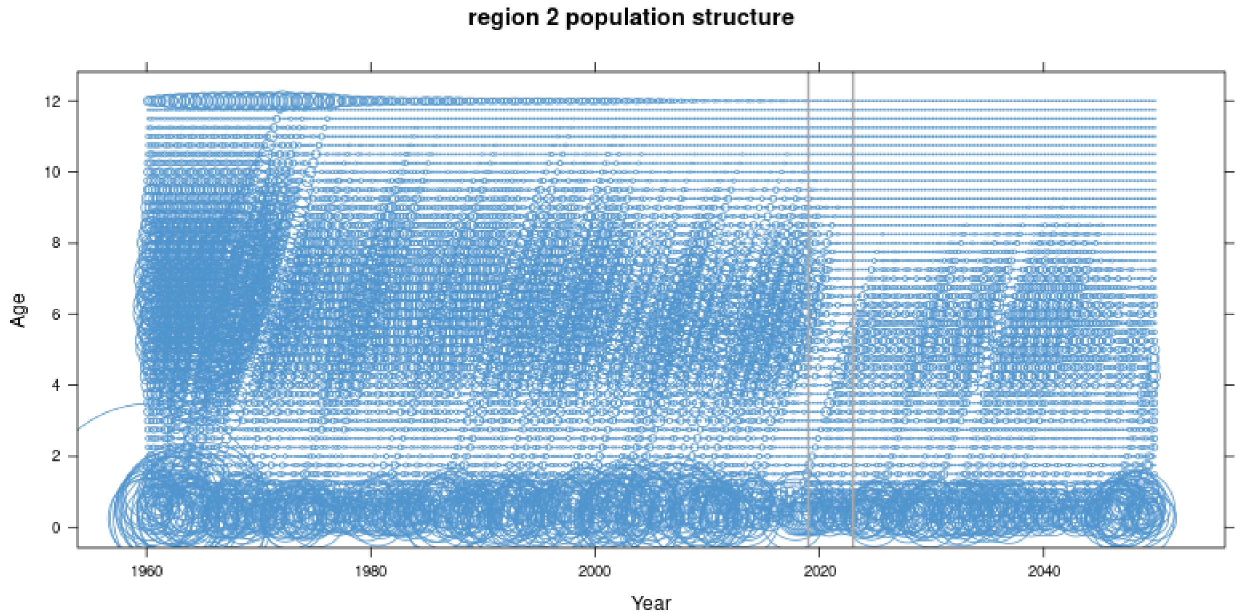


Figure 4: Estimated population age structure in assessment region 2 as predicted by a 30 year stochastic projection conducted for the diagnostic case stock assessment model. Large circles indicate high population numbers. Vertical lines show 2019, the last year of the assessment, and 2023, the proposed starting point for the MSE evaluations (2025) minus the 2 year data lag.

2.3 Environmental drivers of productivity for south Pacific albacore

For albacore in the south Pacific ocean, seasonal movement patterns appear to correspond with the seasonal shift in the 23-28°C sea surface temperature isotherm location and sea surface temperature and dissolved oxygen concentration appear to be important factors that determine optimum feeding habitat (Lehodey et al., 2013) and consequently growth. These oceanic variables will be impacted by long-term climate change patterns, but are also subject to shorter-term, inter-annual variation as a consequence of the El Niño Southern Oscillation (ENSO). El Niño and La Niña events have been shown to directly affect the horizontal movements and vertical distributions of tuna species in the WCPO (Lehodey et al., 2008). The variability in albacore CPUE in the EEZ of New Caledonia corresponds to seaonal and inter-annual ENSO events with high CPUEs recorded from 1986 to 1998 coincident with frequent El Niño events (Briand et al., 2011). The wider relationship across the Pacific, however, is less clear, with more easterly locations (Samoa and French Polynesia) showing an opposite relationship. Similarly the impact of ENSO events on albacore abundance is less clear, although a link between recruitment and El Niño phases has been proposed from population dynamics model simulations (Lehodey et al., 2006).

A relationship between south Pacific albacore tuna recruitment variability and ENSO has been proposed with La Niña being favourable and El Niño unfavourable (OFP, 2023). The low recruitment estimated in 2016 coincides well with the powerful 2015-16 El Niño event, while the period of apparent above average recruitment for south Pacific albacore (2000-2011) coincided with a period

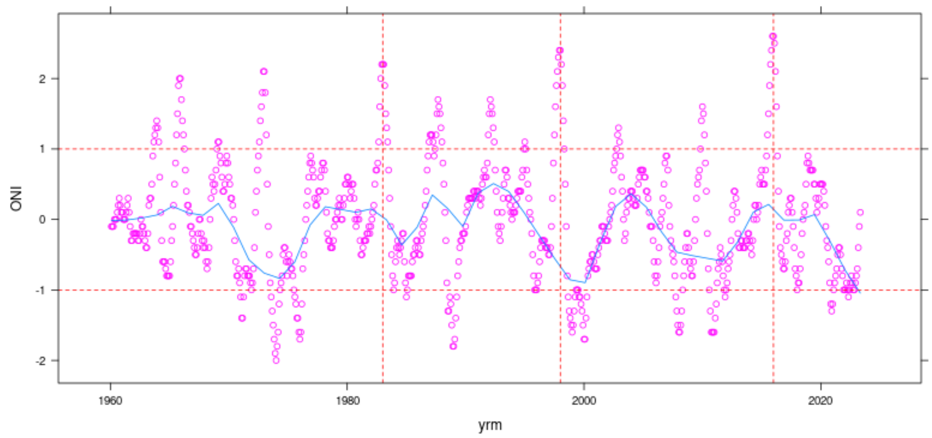


Figure 5: ENSO index (ONI, Oceanic El Niño index) for the period 1960 to 2022. Blue line shows a loess smoother fitted to the time series. Horizontal dotted lines indicate the boundary of ENSO neutral events (-1 to +1), La Niña events (less than -1) and El Niño events (greater than +1). Vertical dotted lines are shown for the strong El Niño events of 2015-16, 1997-98 and 1992-93.

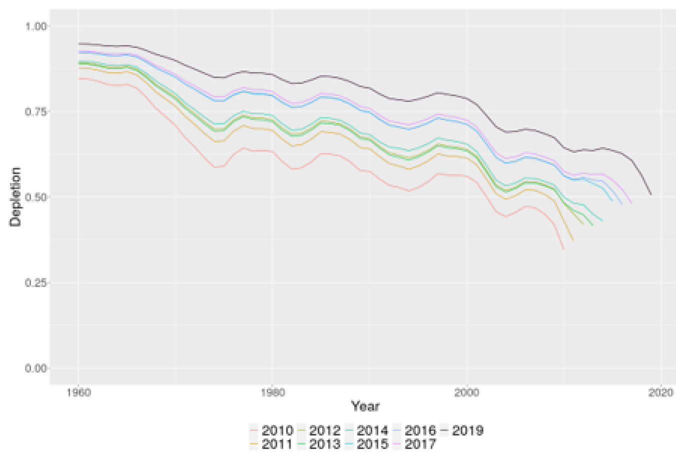
of frequent La Niña events. Senina et al. (2020) also identified a potential relationship between albacore spawning and ENSO events but noted that the doubling of longline catches since the early 2000s has had a stronger negative impact on the exploited stock than any predicted positive impacts of recent ENSO events. If the link between ENSO and south Pacific albacore is robust, the 2020-23 series of La Niña would be expected to be favourable to the recruitment of south Pacific albacore, and effects should be detected in the fisheries in the coming years.

2.4 Assessment model settings

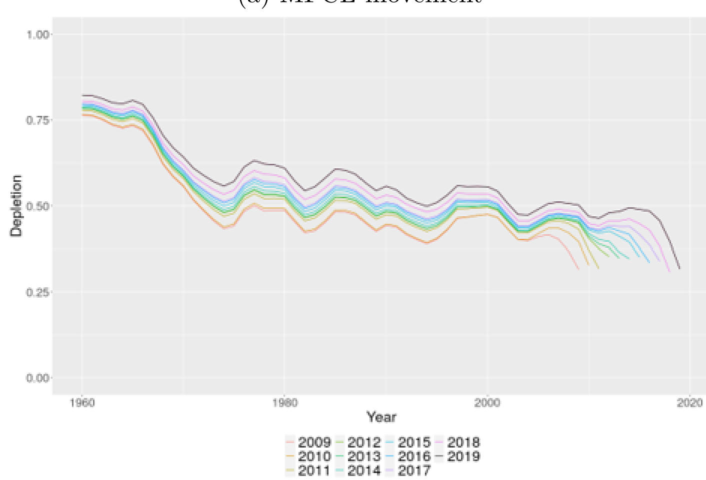
In addition to the dynamics of the fishery and underlying population structure, we also considered the model settings assumed for the most recent assessment. A large number of sensitivity analyses were conducted to investigate model assumptions and potential model mis-specification. There is evidence from the sensitivity analyses that modelling assumptions and settings are likely a contributing factor to the estimated sharp decline in recruitment and stock status. However, it remains unclear the degree to which the model assumptions and settings alone are driving the predicted declines. More work is required to fully resolve this issue. At this point, it is not possible to clearly discount that the low recruitment is, to some extent, real, although the extent of recruitment and stock decline predicted by the model may be greater than the true extent.

Conflicts in the information provided by size composition data and CPUE indices have been noted in all of the recent stock assessments for south Pacific albacore, and the relative weighting allocated to size composition data has been a recurring feature of the stock assessment model grid and associated sensitivity analyses. These data conflicts, amongst other factors, are a likely cause of the persistent retrospective pattern observed for recent assessments (Figure 6). It can be very difficult to discern the underlying causes of retrospective bias (Hurtado-Ferro et al., 2015) and further work will be required to better understand this issue. However, retrospective bias may be a further factor contributing to recent declines in estimates of stock status.

That said, preliminary analyses using a recently developed catch conditioned model, developed from the 2021 diagnostic model, with data extended through to 2021 (Figure 13) show a consistent, though slightly moderated, recruitment dip occurring in the same period to that seen in the 2021 assessment, with adult depletion stabilising after the sharp decline at the end of the 2021 assessment (Figure 14). These results are based on preliminary work and a more comprehensive analysis will form part of the 2024 scheduled assessment.



(a) MFCL movement



(b) SEAPODYM movement

Figure 6: Estimates of stock status ($SB/SB_{F=0}$) 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.

Over 40 sensitivity analyses were conducted to explore alternative model settings, focussing on the point in the stepwise development of the 2021 assessment at which the marked decline in stock status became apparent. From these analyses, a number of data weighting issues have been identified. The first relates to the practice of downweighting the size composition data to ensure that it is not over-represented in the assessment model. Size composition data are provided for the longline extraction fisheries and also for the longline index fisheries. These inputs are necessary to allow estimation of fishery-specific selection patterns but are often generated from the same data source. To prevent over-weighting arising from the duplication of data in the assessment the input sample sizes were reduced by half. However a setting of the assessment model rescales all size compositions greater than 1000 samples to a maximum sample size of 1000. As such, any size compositions of 1000 samples or more receive equal weighting in the model and the intended down-weighting is not applied [4]. An alternative run in which the size composition data were selectively downweighted to reduce the impact of double accounting [5] shows slightly increased recruitment estimates for 2015 and 2016 (Figure 7) and a more progressive reduction of stock status at the end of the stock assessment time series (Figure 8). Although the decline in stock status is more progressive, both model configurations estimate comparable stock status at the end of the time series.

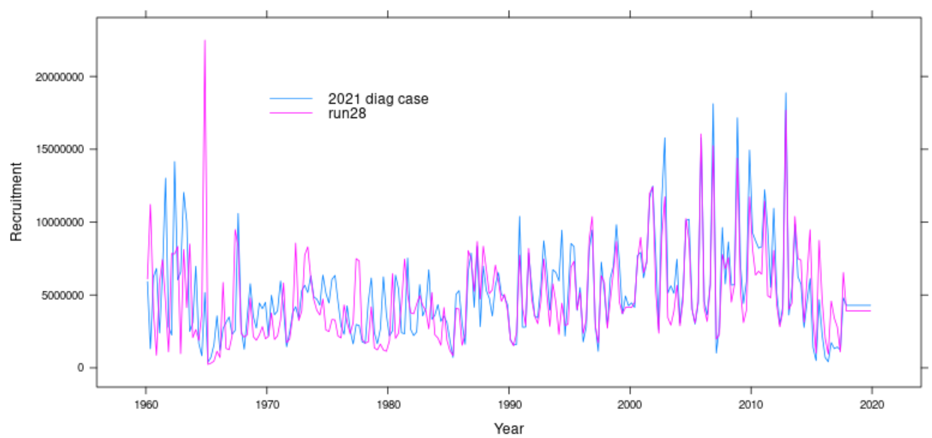


Figure 7: Estimated recruitment for the 2021 diagnostic case assessment model and an alternative run (run 28) for which length composition data have received lower weighting.

The size data in the 2021 assessment were substantially upweighted compared with the 2018 assessment. Biomass scaling was sensitive to size data weighting, and the sensitivity model run with highest weight on the size data (EES divisor of 10) scaled up the biomass and tended to exacerbate the biomass decline at the end of time series, although less so for estimates of depletion. For troll fisheries the size data were further upweighted by moving from quarterly to monthly time steps for this fishery. The data weighting is clearly influential on overall biomass scaling but it is unclear if or how alternative data weightings between assessments are implicated in the recently predicted declines.

[4]This issue can be resolved by down-weighting the size composition data using existing flag settings of MULTIFAN-CL rather than modifying the input files.

[5]fish flag 49 set to 150 for LL-DWFN; 75 for LL-PICT; 50 for DN and TR fisheries

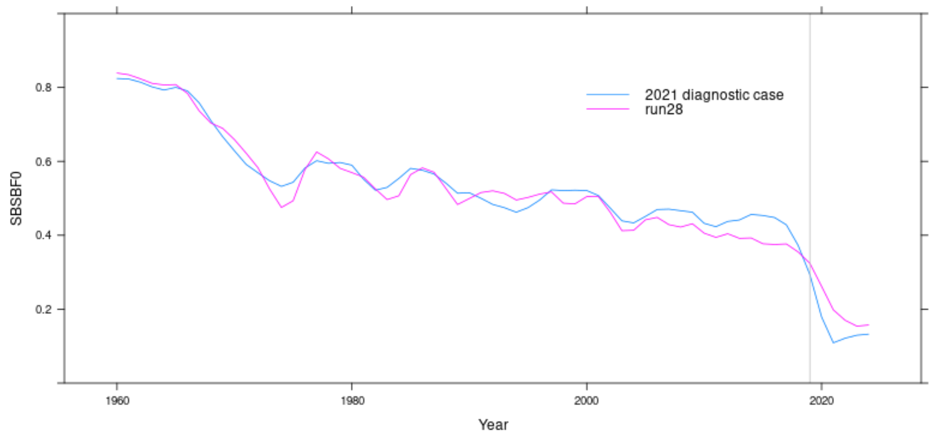


Figure 8: Projected stock status ($SB/SB_{F=0}$) for the 2021 diagnostic case assessment model and an alternative run (run 28) for which length composition data have received lower weighting. Vertical grey line denotes the end of the stock assessment and the start of the projections.

In addition to the data weighting options, it was noted that size composition data for some fisheries (e.g. fisheries 6, 7 and 8 in assessment region 3) are very noisy and show little temporal consistency. Although sample sizes for these fisheries are often smaller than 1000, they can still receive relatively high weighting in the model fit. This should be investigated as part of the next assessment.

Fits to size composition data are also poor for some of the individual fleets. The assssment assumes a shared (common) selection pattern for the longline index fisheries, and assumes asymptotic (i.e. non-decreasing) selectivity for all longline extraction fisheries. This is unlikely to provide a good fit to the size data and should be reviewed (Maunder et al., 2020; Sampson and Scott, 2012). We suggest that a thorough review of size composition data, fisheries definitions and selectivity should be an important part of the next assessment to try to improve the model fit to available data.

To explore the possible influence of size composition data and related settings on the recent declines a number of model runs have been conducted both as part of this exploration and in previous explorations as part of the 2021 assessment follow-up. For example, the model that down-weighted size composition data affected the rate and degree of the terminal declines in recruitment and stock status (Figure 8). These explorations require further analysis and interpretation, but provide some indication that model settings/misspecification are contributing to the predicted decline to a certain degree.

Further runs examined whether removal of the size composition data ameliorated the patterns observed in recruitment and spawning biomass. Reductions in the extent of the decline were only achieved by removing large quantities of size composition data at the end of the time series. In order to eliminate the decline altogether, size composition for all fisheries had to be removed.

The assumed growth rate is also an important consideration when interrogating model fits to size composition data. Growth rates of albacore are thought to vary both spatially and by sex (Williams et al., 2012) and the selection of an appropriate growth model to apply to stock assessments is challenging in these situations (Castillo Jordan et al., 2021). Alternative growth models have been a recurring feature in the uncertainty grids of recent assessments for south Pacific albacore, and the difficulty in appropriately specifying growth is a problem for fitting to size composition data. It is not possible to have spatially varying growth in the current MFCL, and exploration of alternative or newly developed length-age-structured modelling software is strongly encouraged. The recent peer review of the 2020 yellowfin assessment (Punt et al., 2023) was critical of the way external growth curves have been constructed by selecting otoliths according to size bins to ensure the full range of sizes were covered in the growth curve. It was noted that this approach likely introduces biases and it was strongly recommended that growth be estimated internally in the model using otolith data as conditional-age-at-length data. This will be attempted in the next assessment, however the same concerns around bias in growth curves are relevant for the previously published spatial comparisons of albacore growth and this issue needs further consideration. In this case of particular concern are the poor fits to the NZ troll fishery size composition data for the youngest cohort. Efforts to improve these fits, by separating the troll fishery information into monthly time steps and employing a modified von Bertalanffy growth model (Castillo Jordan et al., 2021) showed some improvement to model fits but further spatio-temporal analysis of growth is also required to understand how stable growth parameters are in space and time.

3 Is the recuitment dip real?

The estimated decline in stock status occurring at the end of the assessment time series and the initial years of the projections is severe. Stock status is estimated to fall to very low levels and in some model scenarios to fall below the LRP. The absence of any indication of severely reduced catch rates occurring as a result of this population decline (based on a combination of anecdotal information and updated catch and effort records to 2022) leads to two alternative schools of thought:

- The decline in population abundance is real and driven by a combination of high fishing mortality and reduced recruitment.
- The decline in population abundance is not real and is an artifact of the modelling assumptions of the stock assessment.

The analyses presented in this report suggest that there is evidence to support both scenarios and that the decline in stock status may be due to the evolving population structure under relatively high exploitation levels possibly coupled with reduced recruitment in recent years, potentially as a result of recent environmental conditions, but that the decline is likely exacerbated by some of the modelling assumptions. We note that the progressive decline in population abundance and the predicted poor recruitment events of 2015 and 2016, though less severe, remained apparent under alternative modelling assumptions that substantially downweighted the size composition data. The very steep decline in stock status observed at the end of the assessment time series is moderated under the alternative model settings, but the extent of the longer-term decline over the period 2000 to 2024 remains quite similar.

4 Implications for the south Pacific albacore MSE framework

A proposed grid of operating models (OMs) for the south Pacific albacore MSE is presented in SC19-MI-WP-04, developed from the 2021 stock assessment (Scott et al., 2023). The extent of the dip in estimated spawning ratio depletion for occurs on the cusp of the stock assessment and the first years of the projection period. The dip is consistently estimated across all 72 models of the proposed MSE grid and has a significant impact on the predicted performance of candidate management procedures in the short-term. Harvest control rules (HCRs) respond to the marked decline in population abundance by reducing catches at the fastest rate allowed (subject to any constraints on maximum change in catch). Where catches are not reduced sufficiently, there is a high probability ($> 20\%$) of the stock falling below the LRP.

The decline appears to result from a combination of factors, namely a progressive long-term decline in adult abundance due to high levels of fishing; reduced recruitment in recent years and in particular 2015 and 2016 for which very low recruitment is estimated, and the modelling assumptions of the 2021 stock assessment. The low recruitments of 2015 and 2016 have a pronounced impact on estimates of stock status, but their impact is relatively short term, with higher (though poorly estimated) recruitment occurring in subsequent years, and assumed average recruitment levels for the projection period. Given the uncertainty in the level of the decline we recommend that MSE evaluations of candidate management procedures for south Pacific albacore start in 2025, when the projected population has had time to rebuild after the impacts of the low recruitment events. This timing would also be consistent with the proposed implementation of the south Pacific albacore management procedure under the WCPFC harvest strategy workplan.

The next assessment of south Pacific albacore is scheduled for 2024. This will provide an opportunity to further investigate this issue and review data inputs, model settings and assumptions. The findings from the new assessment may be taken into consideration when reviewing the models selected for the OM grid as part of an ongoing monitoring strategy.

5 Conclusions

The estimated decline in the stock status of south Pacific albacore in recent years appears to be consistent with observed data including size frequency observations for surface fisheries targetting juvenile and sub-adult albacore as well as longer term trends in the fishery. In additon, low recruitment in 2015 and 2016 corresponds to the very strong El Nino event and is consistent with the hypothesised relationship between albacore spawning and ENSO events (OFP, 2023). However, it also appears likely that the declines are exacerbated by some of the modelling assumptions of the 2021 assessment. This requires further work to fully understand. This work will occur as part of the development of the 2024 stock assessment.

Given the uncertainty in the extent and the severity of the marked reduction in stock status estimated across the OM grid we recommend that the MSE analyses employ a starting date of 2025 for the implementation of the management procedure. 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 it's first implementation in 2025, and secondly because by this time the population has had more time to rebuild following the very low recruitment events of 2015 and 2016.

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A Additional figures

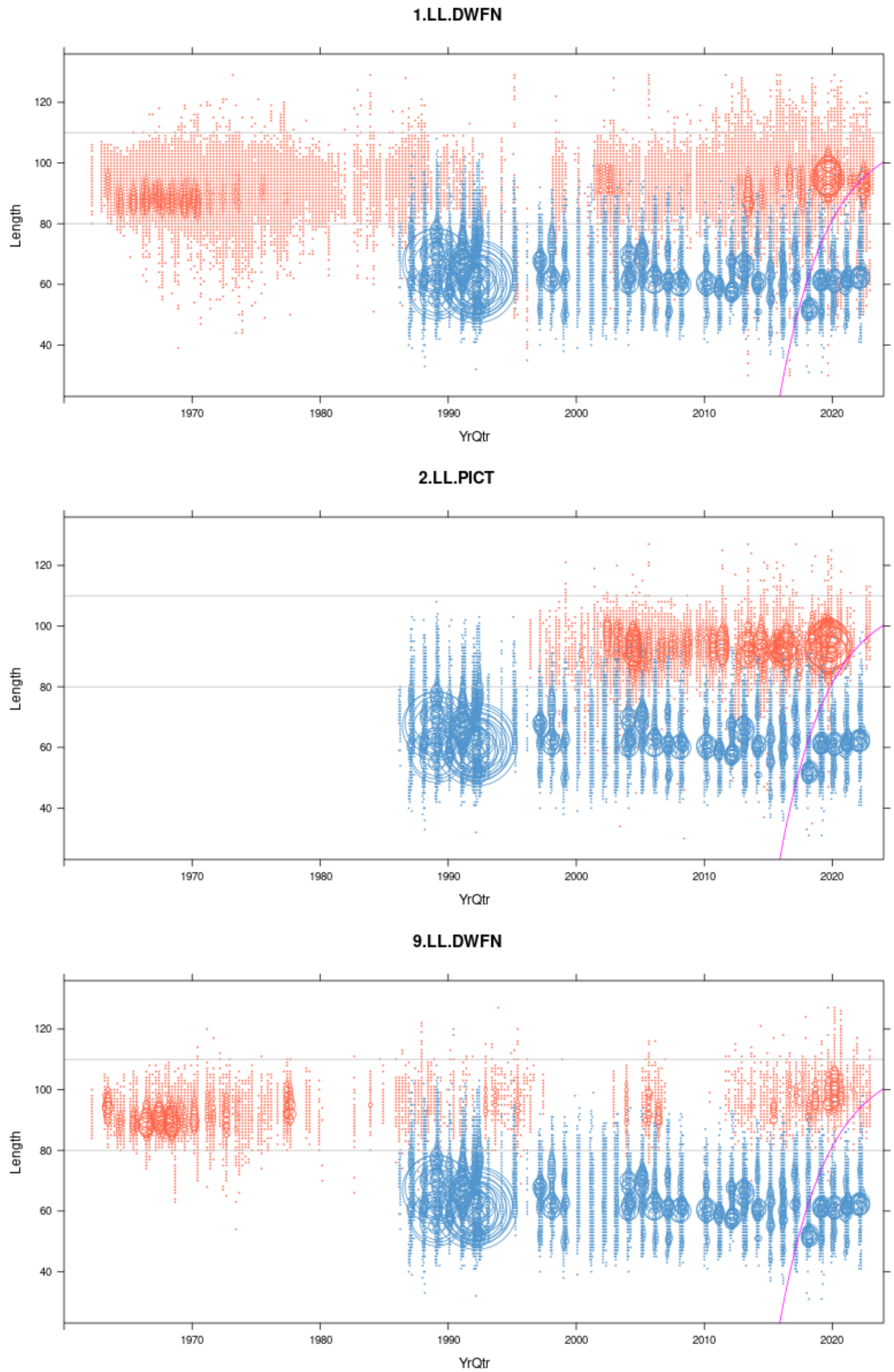

Figure 9: Size composition of longline catches for fisheries operating in assessment region 1 (red) and the NZ troll fishery in region 3 (blue). Blue line represents estimated length at age for the 2016 cohort. Compositions are scaled independently.

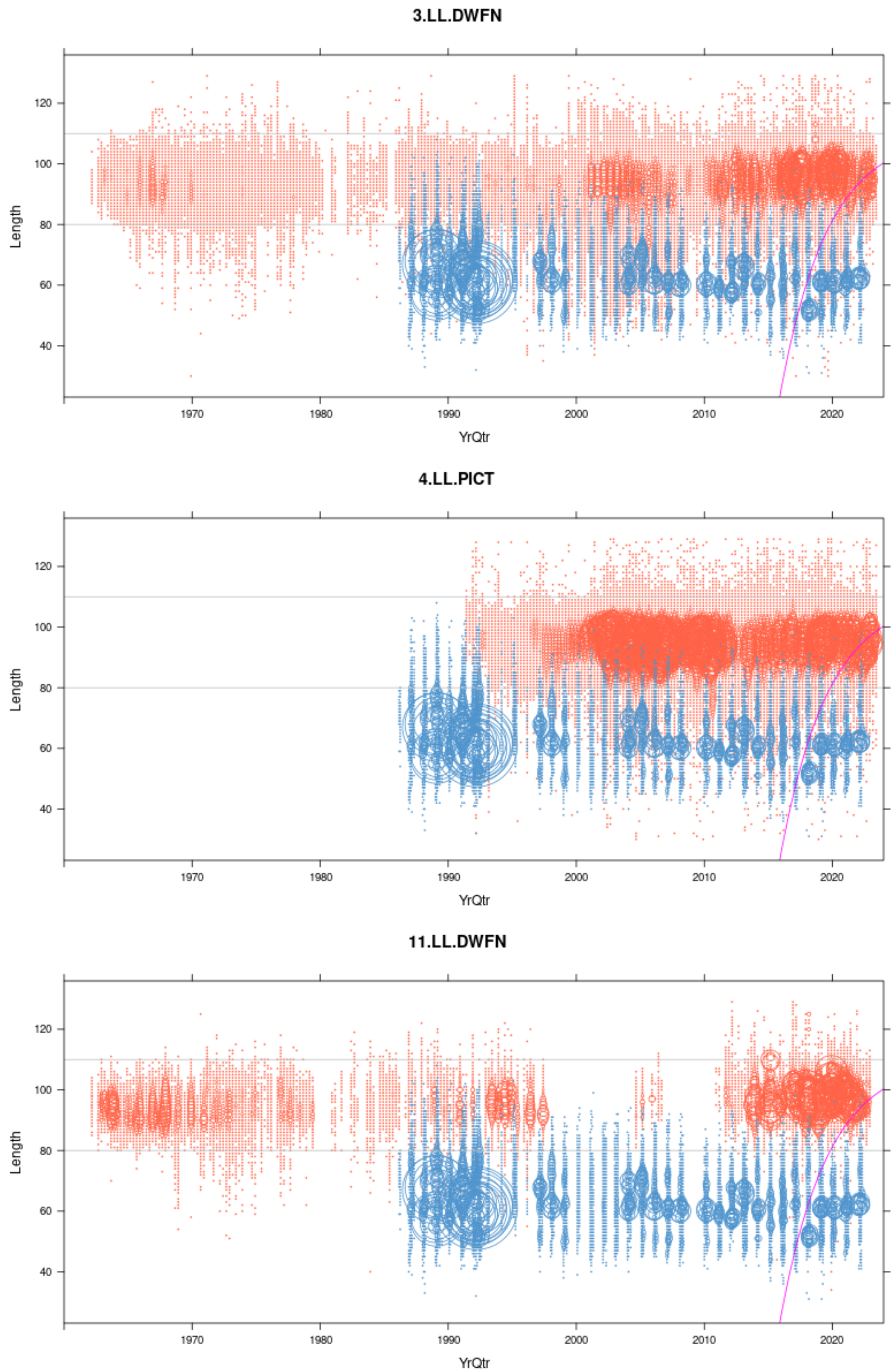

Figure 10: Size composition of longline catches for fisheries operating in assessment region 2 (red) and the NZ troll fishery in region 3 (blue). Blue line represents estimated length at age for the 2016 cohort. Compositions are scaled independently.

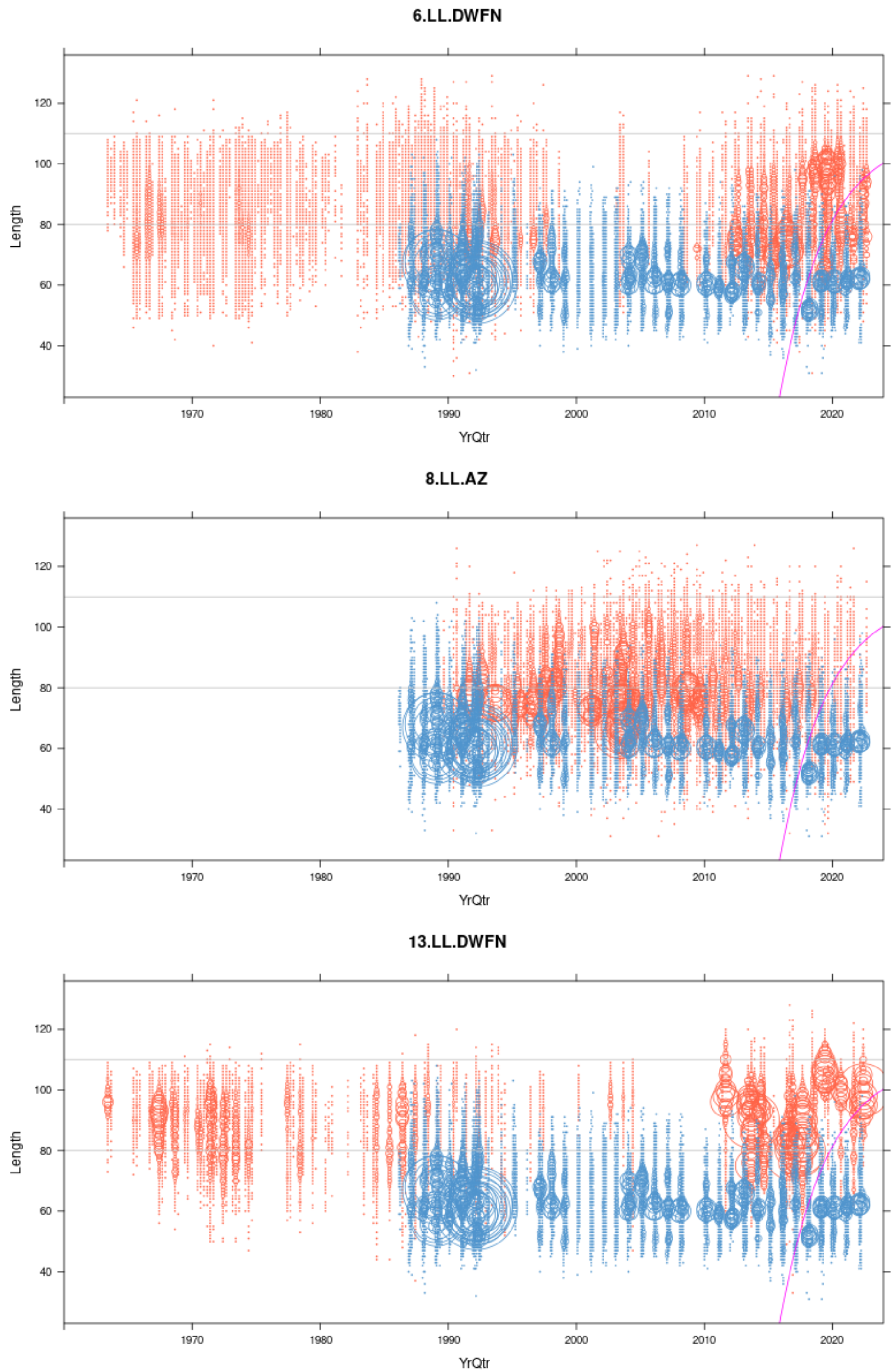

Figure 11: Size composition of longline catches for fisheries operating in assessment region 3 (red) and the NZ troll fishery in region 3 (blue). Blue line represents estimated length at age for the 2016 cohort. Compositions are scaled independently.

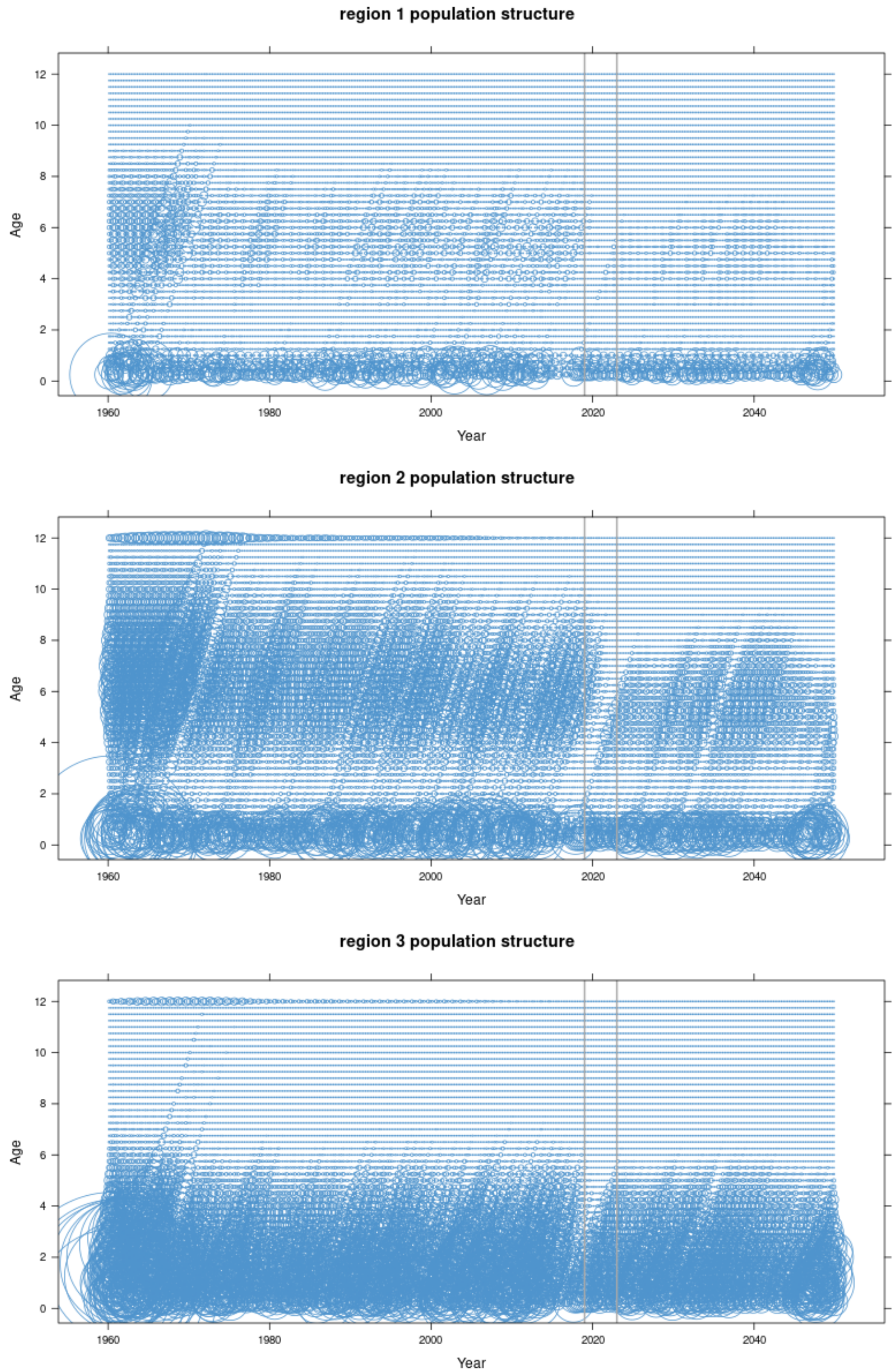

Figure 12: Population age structure in assessment regions 1,2 and 3.

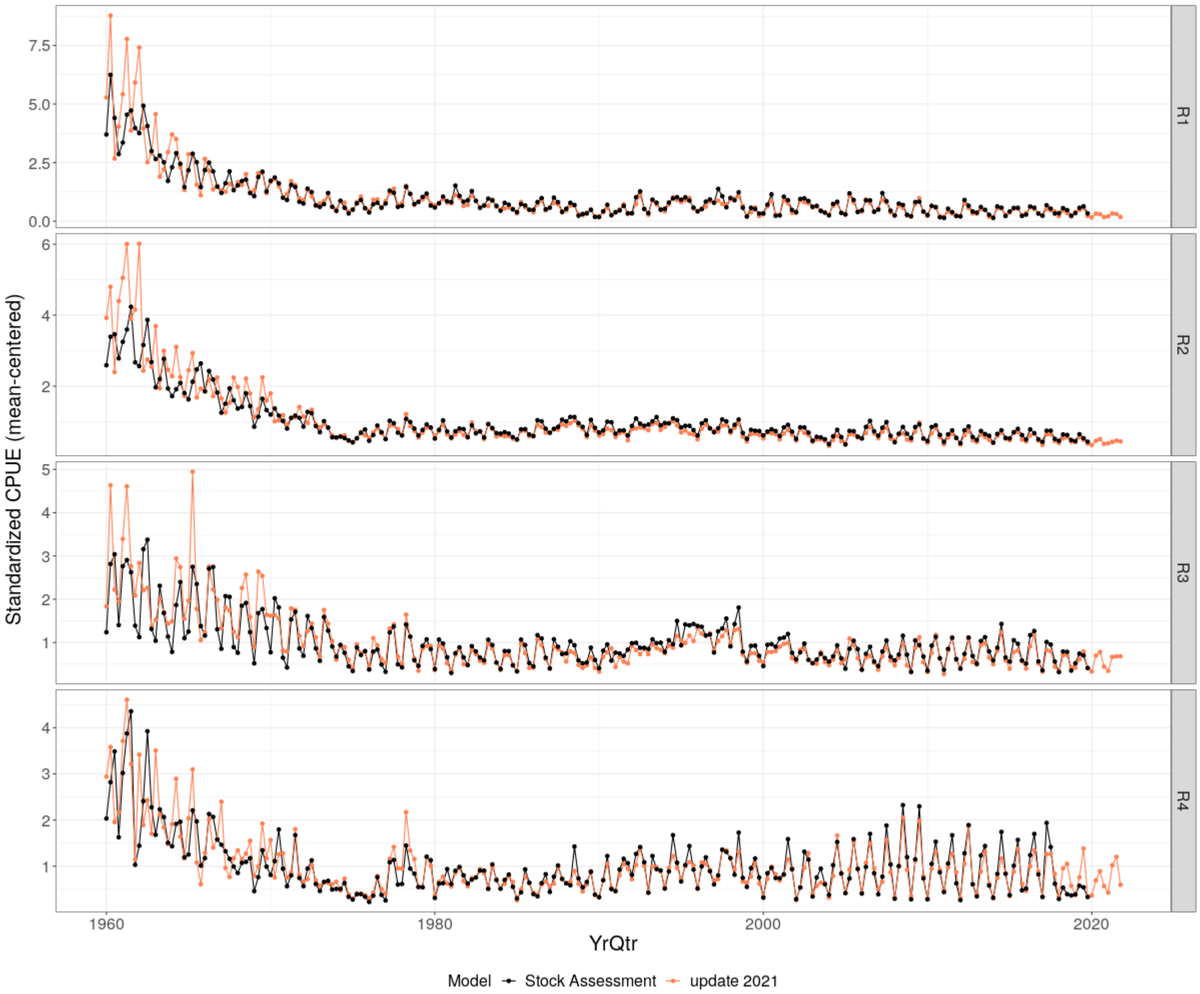

Figure 13: Standardised CPUE (quarterly) for south Pacific longline index fisheries in regions 1 to 4 for the 2021 stock assessment (black) and updated indices to 2021 (orange). Data updates were for 2020-21 for regions 1 to 3 and for 2018-21 for region 4.

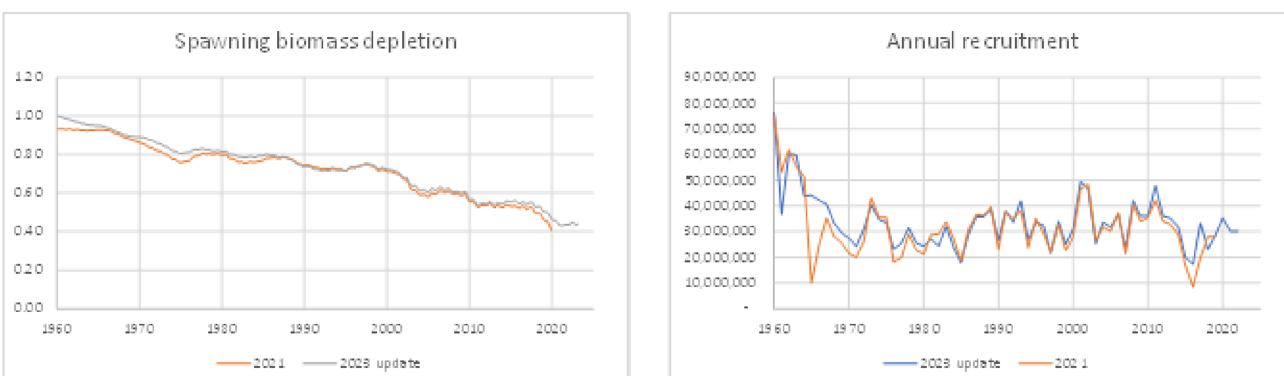

Figure 14: Comparative results of estimated spawning biomass depletion and recruitment from a recently developed catch conditioned MULTIFAN-CL model, based on the south Pacific albacore diagnostic case model, using data inputs to 2019 (2021 assessment, orange) and data inputs to 2021 (2023 update, grey, blue).