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Additional trajectories to achieve the South Pacific albacore interim TRP

WCPFC-SC16-2020/MI-IP-01
(Update of WCPFC-SC15-2019/MI-WP-02[A] and WCPFC16-2019-19[B])

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[A] In Appendix 1 of the paper, we detail the potential future total (longline + troll) annual catch levels under each of the scenarios examined. SC15 noted that the scenario examining the consequences of continued fishing at recent levels assumes a constant level of catch would be taken into the future. As the South Pacific albacore population declines under this scenario, it implies greater levels of fishing effort are required to maintain that specified catch. Noting this, SC15 requested that the Science Service Provider undertake a similar set of analyses based on fishing effort-based projections. In this paper we also present the results of equivalent analyses to the "consequences of continued fishing at recent levels for the South Pacific albacore stock" and "achieve the TRP in 20 years minimising overshoots" scenarios, using effort-based projections.

[B] Fiji as Chair of the South Pacific albacore roadmap working group, requested three additional management scenario options to be examined that achieved the TRP within 20 years, but also reduced 'overshoots' of the TRP. The results of those scenarios are described herein.

Executive Summary

WCPFC15 adopted an interim target reference point (TRP) for South Pacific albacore of 56% $SB_{F=0}$ and tasked the scientific services provider to identify: "*a range of alternative catch pathways and timeframes that achieve [the interim TRP] no later than 20 years. … information from all fisheries will be included while noting… management measures must take account of the impact of different gear types." (paras. 209-210)*.

We perform stochastic stock projections across the grid of 72 assessment models under future fishery scenarios to examine their performance in recovering the stock to the TRP, including:

A. *consequences of continued fishing at recent levels for the South Pacific albacore stock*. Under 2014-16 average catch conditions, the stock declines to 42% $SB_{F=0}$ on average by 2040, with a 21% risk of falling below the LRP (Figure 1). If effort levels in the South Pacific albacore fishery remain at 2014-16 average levels, the stock will decline in the future, but to a lesser extent than the scenario where catch is assumed to be maintained despite a reduction in stock size. In the effort-based projections, the stock declined slightly to 50% $SB_{F=0}$ on average by 2040, with a 1% risk of falling below the LRP. The stock therefore declined and remained below the agreed TRP under both status quo scenarios.

B. *alternative stock trajectories to achieving the candidate TRP, specifically*:
   '<u>Close the fishery</u>', representing the fastest recovery to the TRP. The stock recovers to the TRP in 3 years, with recovery strongly supported by relatively positive recent estimated recruitments.

   '<u>Achieve the TRP in 20 years</u>': a specific fixed year-on-year reduction off the 2014-16 average level in both longline and troll catch (a step-by-step reduction). An annual reduction equivalent to 1.6% of the 2014-16 average catch (approximately 1,000 mt per annum) achieves the TRP in 20 years (a reduction of approximately 19,700 mt over that period) (Figure 2).

   '<u>Achieve the TRP sooner</u>': alternative larger fixed annual percentage catch reductions. A 2% equivalent annual reduction recovers the stock in 17 years, while a 3% equivalent annual reduction achieves recovery in 12 years. The impact of increasing reductions on recovery time is not linear as larger annual reductions limit initial stock declines, leading to recovery from a larger 'minimum' stock level.

   '<u>Achieve the TRP in 20 years minimising overshoots</u>': All previous scenarios achieve the TRP in a given time period, but lead to the stock overshooting the TRP after that time. This scenario aims to reduce catches in both longline and troll fisheries in the first 10 years to allow the stock to recover toward the TRP, but then allows smaller year-on-year increases in catch for the next 10 years to transition to maintaining the stock at the TRP. A 3.75% reduction for the first 10 years, followed by a 2.75% catch increase for the following 10 years, approximately achieves this (Figure 3).

C. *Examine the impact of the different South Pacific albacore fishery components (longline and troll) on stock recovery*. If the troll fishery were maintained at 2014-16 average catch levels, an additional 0.1% reduction in longline catch in each year (to approximately 1,000 mt per annum, a longline-specific additional catch reduction of under 100 mt) would be required to compensate and recover the stock to the TRP in 20 years.

D. *Additional scenarios requested by the South Pacific albacore roadmap working group Chair*. Three alternative scenarios were tested, to achieve the same aim as the last scenario of B above, to minimize overshoots of the TRP:

'Reduce catch for 10 years then maintain catch at that level for the remaining 10 years': This scenario aims to reduce catches in both longline and troll fisheries in the first 10 years to allow the stock to recover toward the TRP, and then holds catches at that level for the remaining 10 years to achieve equilibrium at the TRP. A 2.4% reduction each year for the first 10 years (approximately 1,500 mt per annum), holding the catch at 76% of the 2014-16 average for the remaining 10 years, achieves this.

'Reduce catch for 5 years, then increase catch for 15 years': By reducing catch by 7% per year for the first 5 years (approximately 4,300 mt per annum), the impact on the stock is reduced sufficiently in the short term to allow a 1% increase in catch for the remaining 15 years (approximately 600 mt per annum).

'Reduce catch for 15 years, then increase catch for 5 years': By extending the period over which catch is reduced, a 2% annual decrease in catch for 15 years (approximately 1,200 mt per annum) can be followed by a 1.5% increase for the remaining 5 years (approximately 900 mt per annum).

A wide range of management scenarios can be applied and a small sub-set have been examined here. A recovery period of 20 years, the longest time period specified by WCPFC15, implies lower short-term impacts on fisheries compared to shorter recovery periods. However, the stock declines in the short term if catch reductions are insufficient or management action is delayed. Overall management interventions will then need to be greater as stock recovery will be from a lower biomass level. The corresponding economic implications of candidate recovery programmes should be evaluated to inform managers.

Simple annual catch reductions will achieve the TRP, but dependent upon the scenario will lead to TRP overshoots unless catch reductions are ceased, or notable catch is allowed back into the system relatively rapidly to maintain the stock at the TRP once it is approached. A range of scenarios are presented here than minimize overshoots, and demonstrate the more complex management approaches that can be considered. The harvest strategy approach could identify management procedures that achieve this, although it is a challenging process. Furthermore, all options should be evaluated through management strategy evaluation to ensure they are robust to uncertainty.

We invite WCPFC-SC16 to:

- Consider the results previously presented to SC15 and WCPFC16, as well as the new catch pathways that are projected to achieve the South Pacific albacore interim TRP within 20 years, while minimising overshoots.

Introduction

WCPFC15 adopted an interim target reference point (TRP) for South Pacific albacore of 56% $SB_{F=0}$, with the objective of achieving an 8% increase in catch per unit of effort (CPUE) for the southern longline fishery as compared to 2013 levels (WCPFC, 2019; para. 207). The 2018 stock assessment provided a median estimate of stock status in 2016 of 52% $SB_{F=0}$, implying recovery to the adopted interim TRP was required. WCPFC15 agreed that the timeline for achieving this recovery to the interim TRP should be no later than 20 years (para. 209). WCPFC15 tasked the scientific services provider to identify:

"*a range of alternative catch pathways and timeframes that achieve [the interim TRP], for consideration in 2019. In undertaking [this work] information from all fisheries will be included while noting that any management measures must take account of the impact of different gear types." (paras. 209 and 210)*.

As noted in Pilling et al. (2016a), the recovery of a stock to a target reference point (or rebuilding to an LRP[2]) within a given timeframe can be achieved through many different trajectories. Those different trajectories may have very different economic and social implications for the fisheries exploiting the stock (e.g. FAO, 2003).

To support discussions on potential management plans to recover the South Pacific albacore stock to the adopted TRP, this paper:

1. Examines the potential consequences of continued fishing at recent levels for the South Pacific albacore stock, to provide a baseline scenario;
2. Examines alternative stock trajectories to achieving the candidate TRP at or before 2040 (a 20 year recovery period from 2020);
3. Examines the impact of the different South Pacific albacore fishery components (longline and troll) on stock recovery.

In addition, the Chair of the South Pacific albacore roadmap working group requested the SSP examine three additional scenarios. These are described within this paper and aim to demonstrate further management options that can achieve the South Pacific albacore interim TRP within the timeframe specified by WCPFC15. The overall aim is to provide scientific analyses to address WCPFC15's requests, and to support management discussions on recovery timescales and the features of any desired recovery plan for South Pacific albacore. The paper also discusses the implications of the work for the development of harvest strategies for this stock.

Methods

Comparable to Pilling et al. (2016b), we define alternative fishery scenarios and use stock projections to identify trajectories that achieve the TRP within specified timelines.

[2] Most fisheries literature talks about 'rebuilding' fisheries in relation to depleted stocks. We therefore reserve that description for stocks below the LRP, and use recovery to describe returning a stock to the TRP that is currently above the LRP but below that TRP.

Definition of fishery scenarios for the evaluation

We defined six fishery scenarios to help examine pathways for South Pacific albacore recovery to the TRP to meet the request of WCPFC15. Future fishing levels are generally defined in terms of catch, specifically as scalars from a baseline of the average of 2014-16 catch levels (the last 3 years of assessment[3]). In specific scenarios, effort-based approaches were also modelled, at the request of SC15. Scenarios were:

1. '2014-2016 average conditions': a) longline and troll catch continued at the average of levels seen across 2014-2016; b) longline effort and troll catch continued at the average of levels seen across 2014-2016.
2. 'Close the fishery': the fastest recovery to the TRP would be achieved through closure of the fishery. Future longline and troll fishery catch was reduced to zero.
3. 'Achieve the TRP in 20 years': a fixed year-on-year reduction in longline and troll catch (a fixed stepped reduction) was identified that achieved the TRP in exactly 20 years[4], consistent with the request of WCPFC15. The annual catch reduction is constant (i.e. not a compound reduction).
4. 'Achieve the TRP sooner': similar to (3), but alternative larger fixed annual catch reductions off the 2014-16 average level were applied, achieving a faster recovery to the TRP.
5. 'Achieve the TRP in 20 years minimising overshoot': The previous scenarios achieve recovery to the TRP in 20 years or less, with sufficient catch being removed to achieve recovery at that specified time. However, the stock will then overshoot the TRP unless significant catch is allowed back into the fishery to maintain the stock at the TRP. Scenario 5 attempts to a) reduce catches to allow the stock to recover toward the TRP, but then allows catch increases to transition from recovery to maintaining the stock at the TRP. The scenario is therefore similar to (3) but year-on-year reductions in longline and troll catch were applied for the first 10 years, followed by smaller year-on-year *increases* in catch for the second 10 years; b) reduce longline effort (rather than catch) to recover toward the TRP, then allow effort to increase to transition from recovery to maintaining the stock at the TRP. Year-on-year reductions in longline effort and troll catch were applied for the first 10 years, followed by smaller year-on-year *increases* in effort/catch for the second 10 years.
6. 'Achieve the TRP in 20 years with longline management only': to evaluate the sensitivity of recovery to exclusion of the troll fishery from management, scenario 3 was re-evaluated assuming future troll catch was maintained at 2014-16 average levels, and catch reductions applied to longline fleets only.

As noted, for the first 5 scenarios, catch (or effort) scalars were applied equally across all longline and troll fleets within the stock assessment. The 6th scenario applied catch scalars to the longline fishery only.

In addition, the Chair of the South Pacific albacore roadmap working group requested three additional scenarios be examined. The objective of those scenarios was to provide alternative pathways that achieve

[3] Combined longline and troll average catch was approximately 61,500 mt.

[4] An iterative approach was used to identify the exact percentage of catch that needed to be removed from the fishery each year to achieve the candidate TRP by 2040.

the TRP within 20 years, but have similar dynamic catch-based management approaches to scenario 5 above, with the aim of minimizing overshoots of the TRP. These were:

7. 'Reduce catch for 10 years then maintain catch at that level for the remaining 10 years'. This scenario aims to reduce catches in both longline and troll fisheries in the first 10 years to allow the stock to recover toward the TRP, and then holds catches at that level for the remaining 10 years to achieve equilibrium at the TRP.
8. 'Reduce catch for 5 years, then increase catch for 15 years'. A comparable approach to scenario 5, but with larger initial catch reductions over a shorter time period, and a longer period of catch increases.
9. 'Reduce catch for 15 years, then increase catch for 5 years'. A comparable approach to scenario 5, but with smaller initial catch reductions over a longer time period, and a shorter period of catch increases.

Scalars on longline and troll catch (or effort) in the years immediately following the end of the assessment were estimated based upon existing data; actual catch levels in 2017 and 2018 were calculated and applied as scalars for those years. For 2019, catch levels in 2018 were assumed to continue. In 2020, catch levels were assumed to return to the baseline average 2014-16 catches and the management scenario applied from 2021[5]. A 20 year time period following the implementation of management interventions (i.e. after 2020) was therefore 2040.

Projection approach

All projections were based upon the 2018 assessment for South Pacific albacore (Tremblay-Boyer et al., 2018). Stochastic projections were performed which allowed a probabilistic view of recovery to be taken. Key features of the projections were:

- Stochastic projections for a 30 year period from 2017 were run for each of the scenarios described above, and relevant years within that 30 year projection period were selected for each scenario.
- Projections were run across the grid of 72 assessment runs selected by SC14 to capture uncertainty in our knowledge of South Pacific albacore.
- For each future fishery scenario, one hundred projections were run from each of the 72 assessment models (7,200 projections in total).
- Future recruitment in the projections was determined by randomly sampling from the recruitment deviations from the stock-recruitment relationship estimated in each model, from the period 1970 to 2015.
- Catchability (which can have a trend in the historical component of the model for some fisheries) was assumed to remain constant in the projection period at the level estimated in the terminal year of the assessment model.

Recovery was defined as the year in which the target reference point was achieved on average. The year (*y*) in which the median biomass depletion ($SB_y/SB_{F=0,\, y-1 \text{ to } y-10}$) trajectory of the 7,200 runs for each recovery

[5] 2014-2016 average catch levels imply approximate scalars of 0.85 on total longline catch, and 0.69 on total troll catch compared to 2019 levels (overall scalar = 0.85).

scenario reached the interim TRP level was identified. The recovery period (to year *y*) was calculated as the number of years following implementation of the management intervention (after 2020).

Results

Results are considered for each scenario and are summarised in Table 1.

'2014-2016 average conditions'

If South Pacific albacore catch levels in the southern longline and troll fisheries remain at 2014-16 average levels (which is lower than in the most recent period; see footnote 4), the stock will decline into the future (Figure 1). By 2040 the stock declines to 42% $SB_{F=0}$, and there is a 21% risk of the stock falling below the LRP.

If effort levels in the South Pacific albacore fishery remain at 2014-16 average levels, the stock will decline in the future, but to a lesser extent than the previous scenario where catch is assumed to be maintained despite a reduction in stock size. In the effort-based projections, the stock declined slightly to 50% $SB_{F=0}$ on average by 2040, with a 1% risk of falling below the LRP. The stock therefore remains below the agreed TRP.

'Close the fishery'

This scenario indicates the fastest possible recovery time for the stock, as defined by its biology and patterns of recent recruitment. Recent estimated recruitments have been relatively positive, and removal of fishing allows the stock to reach the interim TRP in 2023 (3 years after the closure was implemented).

'Achieve the TRP in 20 years'

An annual reduction in total catch equal to 1.6% of the average 2014-2016 annual catch in each of the 20 years allows the stock to recover on average to the interim TRP at the end of that period. This equates to an annual catch reduction of approximately 1,000 mt or approximately 19,700 mt in total over 20 years from those levels. The stock first declines since catch levels initially remain high enough to drive the stock down, until the cumulative annual catch reductions are sufficient to allow the stock to recover (Figure 2).

'Achieve the TRP sooner'

Two alternative percentage annual catch reductions were examined. An annual catch reduction equivalent to 2% of the average 2014-16 annual catch (1,200 mt) achieves recovery in 17 years (2037), while an annual catch reduction equivalent to 3% of the average 2014-16 catch (1,800 mt) achieves recovery in 12 years (2032). The shortening of recovery time is not linear with increasing annual percent catch reductions, since faster catch reductions early in the time series limits the initial decline in stock biomass and hence recovery occurs from a higher 'minimum' level.

'Achieve the TRP in 20 years minimising overshoot'

An annual catch reduction equivalent to 3.75% of the average 2014-16 annual catch (2,300 mt) for the first 10 years, followed by a catch increase equivalent to 2.75% of the average 2014-16 annual catch (1,700 mt) for the subsequent 10 years leads to the stock beginning to fluctuate around the TRP. In this preliminary scenario, the stock reaches the TRP in approximately 11 years on average, overshoots slightly before declining back to just below the TRP level (Figure 3).

When managing fishing effort, a successful scenario was: an annual reduction in longline effort and troll catch by the equivalent of 4.75% of the average 2014-16 effort for the first 10 years (for longliners, approximately 21 million hooks each year); followed by an annual increase in effort/catch equivalent to 3% of the average 2014-16 effort for the second 10 years (approximately 13 million hooks each year; Figure 4). In this preliminary scenario, the stock reaches the TRP in approximately 10 years on average, overshoots slightly before declining back to just above the TRP level in 2040.

'Achieve the TRP in 20 years with longline management only'

If the troll fishery were to maintain its catch at 2014-16 average catch levels, the longline fishery would need to take a 1.7% reduction in catch each year (approximately 20,100 mt in total over 20 years) to compensate and achieve recovery to the TRP in 20 years. This implies an additional catch reduction of under 100 mt per annum by the longline fishery compared to the combined longline and troll catch reduction described above.

'Reduce catch for 10 years then maintain catch at that level for the remaining 10 years'.

An annual catch reduction equivalent to 2.4% reduction of the average 2014-16 annual catch (1,500 mt) for the first 10 years, holding the catch at 76% of the 2014-16 average for the remaining 10 years (46,700 mt), achieves recovery in 20 years (Figure 5, Appendix 1).

'Reduce catch for 5 years, then increase catch for 15 years'.

Reducing catch annually by 7% of the average 2014-16 annual catch (4,300 mt) for the first 5 years, the impact of fishing on the stock is reduced sufficiently in the short term to allow catch to increase by 1% of the average 2014-16 annual catch (600 mt) for the remaining 15 years. The stock recovers to the TRP in 10 years on average (Figure 6).

'Reduce catch for 15 years, then increase catch for 5 years.'

By extending the period over which catch is reduced, an annual decrease by 2% of the average 2014-16 annual catch (1,200 mt) for the first 15 years can be followed by annual increases in catch of 1.5% of the average 2014-16 annual catch (900 mt) for the remaining 5 years. The stock recovers to the TRP in 19 years on average (Figure 7).

Note that for those scenarios that achieve the TRP within the 20 year period, the risk of falling below the LRP in 2040 varies (Table 1). This is due to the impact of management action on those runs that represent the less productive stock assumptions within the model grid. Greater catch cuts early in the time series lead to a positive stock response in these runs and reduces the overall risk.

Discussion

This analysis aims to support discussions on potential management actions to recover the South Pacific albacore stock to the interim TRP, by evaluating alternative fishery management scenarios that achieve recovery in 20 years or less. Within these scenarios, we have assumed that the fishery in 2020 is at catch levels seen on average over the period 2014-16, which implies some management action is necessary to achieve that starting point (2019 catch being 18% higher than the 2014-16 average; see Hare et al., 2020). Further reductions are taken from that level in subsequent years. These can be related to the scenario where no further action is taken ('2014-16 average conditions'), which leads to stock declines under both 'status quo' (catch or effort) assumptions.

While closure of the fishery may be an unlikely management response, it is included here to provide a baseline for the minimum recovery time as defined by the stock's biological characteristics and the distance the stock is from the TRP when the fishery closure is implemented. Results of the current analysis suggest a 50% probability of achieving the TRP within 3 years in the absence of fishing. The assessment model includes some recent positive recruitments that are 'burned into' the population prior to the projection period. These are particularly notable in some assessment models and result in the positive 'spike' of $SB/SB_{F=0}$ after 2016 that is seen in the upper tail of the stock status distribution in Figure 1. These contribute significantly to the short recovery period and influence recovery times under all scenarios. Results are therefore sensitive to these recruitment estimates.

The maximum timeframe for recovery to the TRP specified by WCPFC15 is 20 years. This analysis suggests that an annual reduction in catch equivalent to 1.6% of the average 2014-16 annual catch (i.e. an annual reduction of approximately 1,000 mt) will achieve the TRP in 20 years, on average.

Managers may decide that a faster recovery period is warranted, for example for economic and/or social reasons. To inform those considerations, we examined the sensitivity of recovery times to slightly larger annual catch reductions. Reducing catch annually by the equivalent of 2% of the average 2014-16 annual catch (approximately 1,200 mt per annum) decreases the time to recovery to 17 years following management implementation, while reducing catch annually by the equivalent of 3% of the average 2014-16 annual catch (approximately 1,800 mt) decreases the time of recovery to 12 years after management is applied.

A recovery period of 20 years implies smaller short-term impacts on fisheries. However, initial cumulative catch reductions are insufficient to stop the early decline in the population. Reducing immediate fishery impacts, or having a longer period before management action is taken, generally implies greater overall management interventions as the stock will be recovering from a lower biomass level. In turn, it will often lead to extended periods of lower profitability when compared to making larger reductions in fishing impact in the short term (see Skirtun et al., 2019).

The length of the recovery period comes with scientific and management implications. As the length of time for recovery increases, the biological advice that can be provided becomes increasingly uncertain, given, for example, uncertainty in future recruitment levels and the form of the stock recruitment relationship (e.g. Powers, 1999).

Once recovery to the TRP has been achieved, there needs to be a transition to a fishery management regime that maintains the stock around the agreed TRP. While the management interventions described above achieve the TRP within particular timescales, the catch reductions are greater than that needed to maintain the stock at the TRP. The stock will therefore 'overshoot' unless significant catch is rapidly allowed back into the fishery to maintain the stock around the TRP. Allowing catch back into the fishery over a short time period may be difficult in practice, and may lead to issues for the industry. Scenarios 5, 7, 8 and 9 attempt to develop plans that reduce catches by different percentages over different periods to allow the stock to recover toward the TRP, and then either stabilize catch or allow catch levels to increase by a smaller amount in the second period to transition from recovery to maintenance at the TRP. They demonstrate the more complex management approaches that can be considered within a recovery programme. Clearly, the periods of catch (or effort) reduction and increase can be adjusted. In turn, the harvest strategy approach could potentially identify individual management procedures that allow recovery of the stock to the TRP within identified overall timescales and subsequent maintenance of the stock at the TRP within a single management procedure.

WCPFC15 noted that any management measures must take account of the impact of different gear types. While managers must decide which fishery component should be included within any procedure, we evaluated the potential implications of excluding the troll fishery from the management regime. As the longline fishery takes the majority of the total South Pacific albacore catch (Hare et al., 2020), exclusion of the troll fishery requires a 1.7% reduction in annual longline catch to compensate (implying a longline-only catch reduction of approximately 20,100 mt in total over 20 years). We note that as the longline fishery catch reduces over time, the proportion of the troll catch will, of course, increase in this scenario.

A further step for this evaluation would be to include for manager consideration the economic consequences of candidate recovery programmes for the fishing fleet (e.g. Skirtun et al., 2019). In general, given that longer-term gains are financially discounted more than gains earlier in the process, those interventions that recover the stock faster would often perform financially better than those calling for slower, longer term reductions. However, the inclusion of the potential costs incurred from any vessels exiting the fishery need to be included within these calculations, which may change the perceived benefits across scenarios.

In this evaluation, most management interventions are based upon catch, consistent with the request of WCPFC15. Specific effort-based scenarios have also been performed as requested by SC15. It is important to note that the percentage reduction in fishing effort required to achieve the specified catch reduction under the catch-based projection will be greater than the percentage catch reduction identified here, since CPUE recovers as catch levels are reduced.

We note that the scenarios examined are not exhaustive. All options should preferably be evaluated for performance through Management Strategy Evaluation to ensure they are robust to uncertainty (Scott *et al.*, 2016). In practical terms, strategies will also require monitoring during the recovery period to ensure that they are performing adequately in the face of future recruitment levels (both good and bad), unforeseen shifts in fishing strategies, and implementation issues.

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Tables

Table 1. Summary of stock consequences under status quo catch scenario, and the average (median) recovery times to the interim TRP (56% $SB_{F=0}$) under alternative stock recovery scenarios. Results are summarised for the catch-based analyses only.

Scenario number	Scenario	% per annum catch reduction after 2020	Time period to achieve TRP (56% $SB_{F=0}$)	$SB_{2040}/SB_{F=0}$	Risk $SB_{2040}/SB_{F=0}$ < LRP
1	'2014-2016 average catch conditions'	0%	-	42% $SB_{F=0}$	21%
2	'Close the fishery'	-100%	3 years	-	0%
3	'Achieve TRP in 20 years'	-1.6%	20 years	56% $SB_{F=0}$	5%
4	'Achieve TRP sooner'	-2%	17 years	-	2%
		-3%	12 years	-	0%
5	'Active TRP in 20 years without overshoot'	-3.75%/+2.75%	11 years	54% $SB_{F=0}$	3%
6	'Achieve TRP in 20 years with longline management only'	-1.7%	20 years	56% $SB_{F=0}$	5%
7	'Reduce catch for 10 years then maintain catch at that level for the remaining 10 years'	-2.4%/Constant	20 years	56% $SB_{F=0}$	4%
8	'Reduce catch for 5 years, then increase catch for 15 years'	-7%/+1%	10 years	56% $SB_{F=0}$	2%
9	'Reduce catch for 15 years, then increase catch for 5 years'	-2%/+1.5%	19 years	56% $SB_{F=0}$	4%

Figures

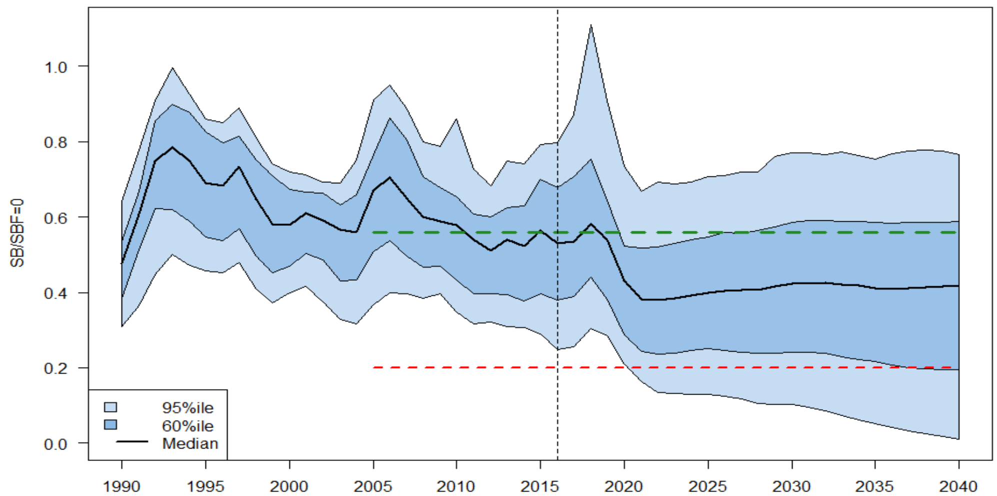

Figure 1. Time series of South Pacific albacore tuna spawning biomass ($SB/SB_{F=0}$) from the uncertainty grid of assessment model runs for the period 1990 to 2016 (the vertical dotted line at 2016 represents the last year of the assessment), and stochastic projection results for the period 2017 to 2040 assuming 2014-2016 <u>average catch levels</u> continue from 2020 onwards in both longline and troll fisheries. During the projection period (2017-2040) levels of recruitment variability are related to those over the time period used to estimate the stock-recruitment relationship (1970-2015). The red horizontal dashed line represents the agreed limit reference point, the green horizontal dashed line represents the agreed interim target reference point.

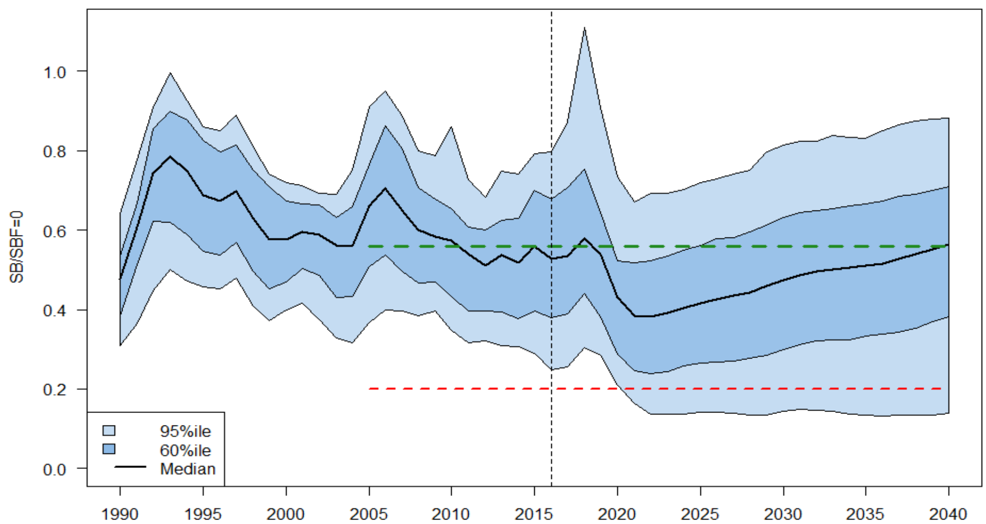

Figure 2. Time series of South Pacific albacore tuna spawning biomass ($SB/SB_{F=0}$) assuming a year-on-year catch reduction equivalent to 1.6% of 2014-2016 average catch levels (applied from 2021 onwards) in both longline and troll fisheries (Scenario 3). See Figure 1 for further description of the figure.

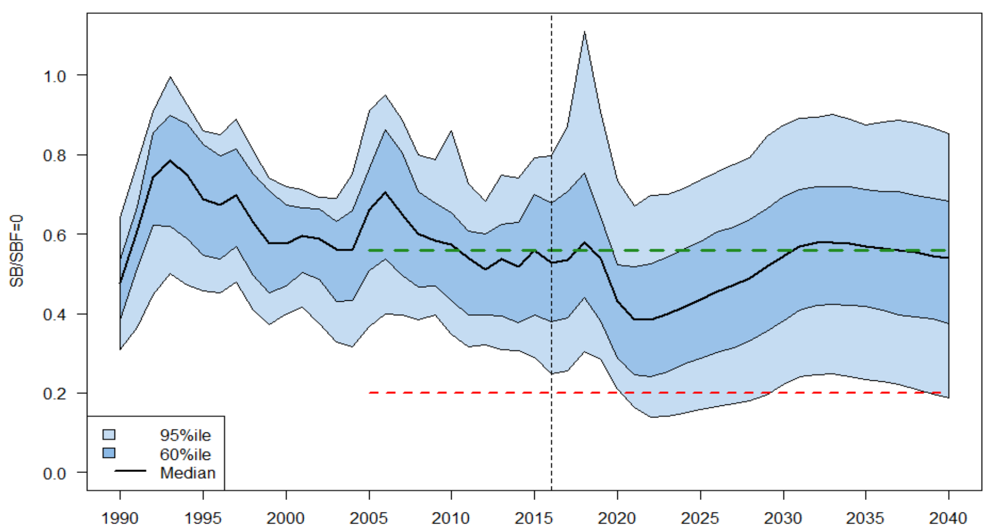

Figure 3. Time series of South Pacific albacore tuna spawning biomass ($SB/SB_{F=0}$) assuming a year-on-year catch reduction equivalent to 3.75% of 2014-2016 average catch levels from 2021 to 2030, and a 2.75% increase from 2031 to 2040 in both longline and troll fisheries (Scenario 5). See Figure 1 for further description of the figure.

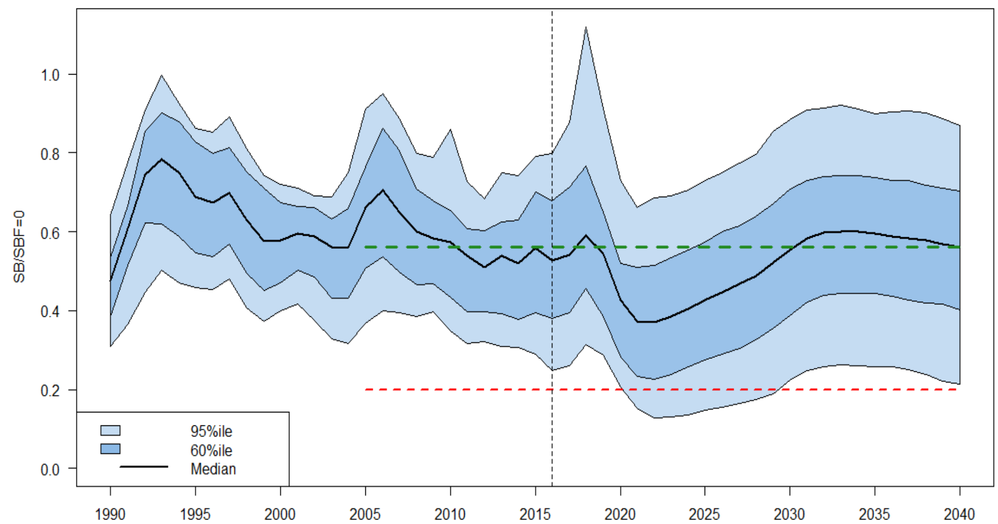

Figure 4. Time series of South Pacific albacore tuna spawning biomass ($SB/SB_{F=0}$) assuming a year-on-year effort (longline) or catch (troll) reduction equivalent to 4.75% of the 2014-16 average effort/catch levels from 2021 to 2030, and a 3% increase from 2031-2040. See Figure 1 for further description of the figure.

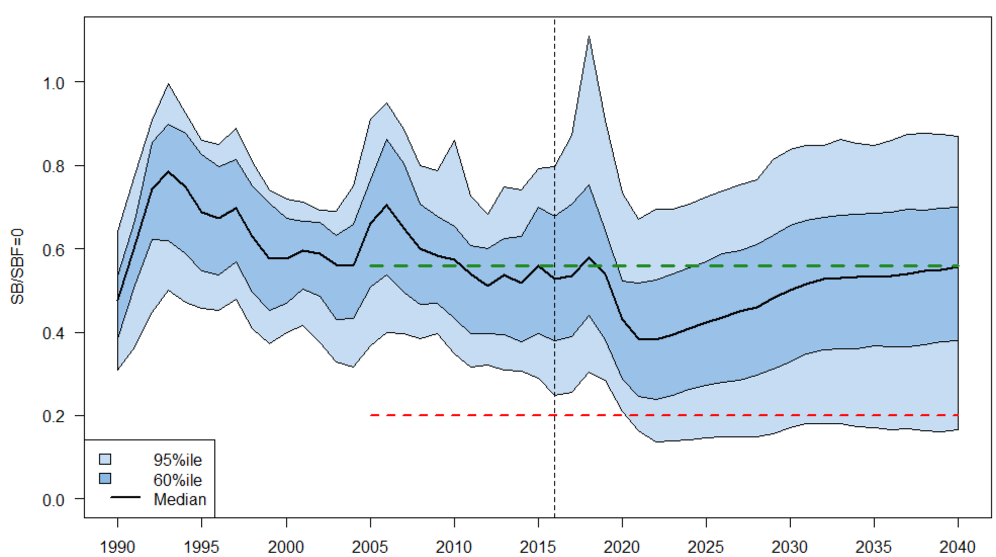

Figure 5. Time series of South Pacific albacore tuna spawning biomass ($SB/SB_{F=0}$) assuming a 10 year catch <u>reduction</u> equivalent to 2.4% of 2014-2016 average catch levels from 2021 to 2030, with catch held at the 2030 level from 2031 to 2040 in both longline and troll fisheries (Scenario 7). See Figure 1 for further description of the figure.

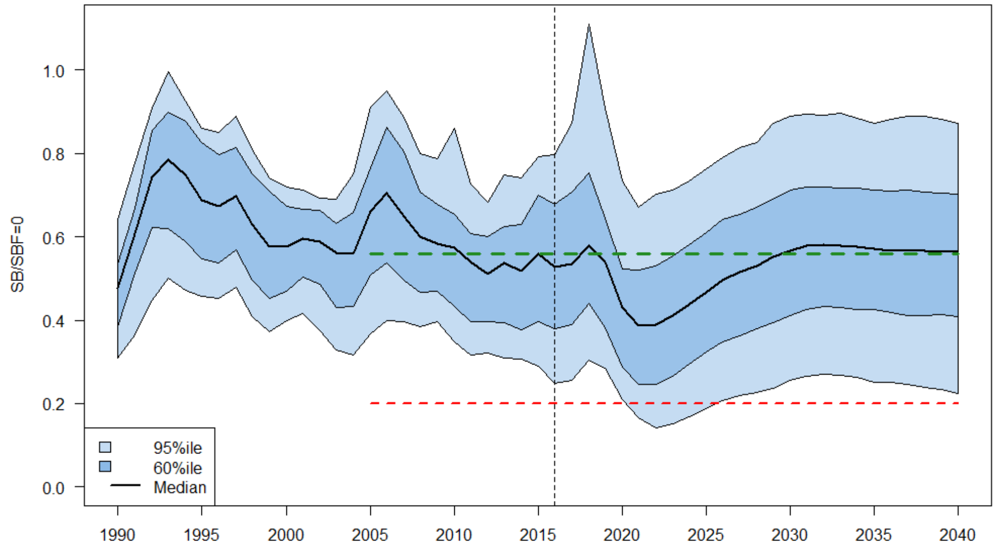

Figure 6. Time series of South Pacific albacore tuna spawning biomass ($SB/SB_{F=0}$) assuming a 5 year catch ***reduction*** *equivalent to 7% of 2014-2016 average catch levels from 2021 to 2025, and a 1%* ***increase*** *from 2026 to 2040 in both longline and troll fisheries (Scenario 8). See Figure 1 for further description of the figure.*

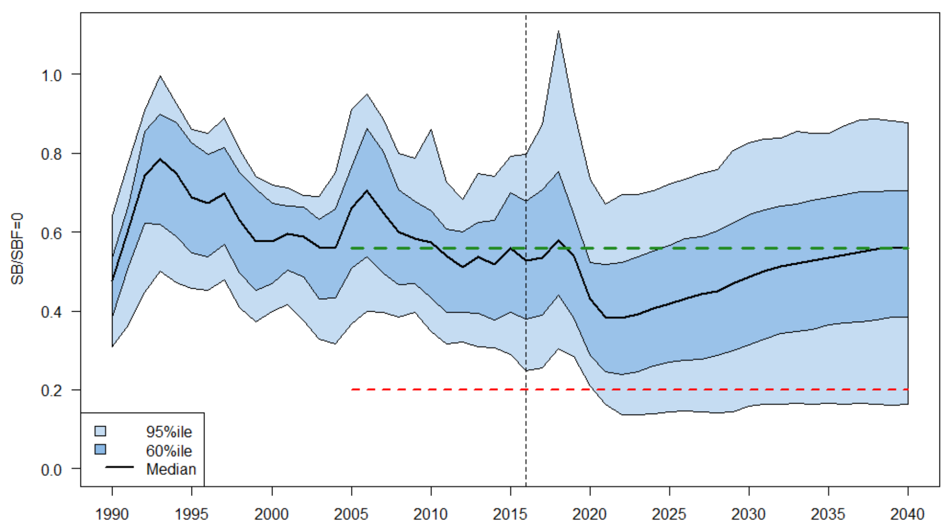

Figure 7. Time series of South Pacific albacore tuna spawning biomass ($SB/SB_{F=0}$) assuming a 15 year catch ***reduction*** *equivalent to 2% of 2014-2016 average catch levels from 2021 to 2035, and a 1.5%* ***increase*** *from 2036 to 2040 in both longline and troll fisheries (Scenario 9). See Figure 1 for further description of the figure.*

Appendix 1. Total South Pacific albacore catch (longline + troll) trajectory over time under the scenarios examined

Scenario	Achieve TRP							
	in 20yrs	with 2% redn	with 3% redn	minimise overshoots	with LL only	decrease 10yrs, maintain	decrease 5 yrs, increase 15	decrease 15yrs, increase 5
2020[1]	61,500	61,500	61,500	61,500	61,500	61,500	61,500	61,500
2021	60,500	60,300	59,600	59,200	60,500	60,000	57,200	60,300
2022	59,500	59,000	57,800	56,900	59,500	58,500	52,900	59,000
2023	58,500	57,800	56,000	54,600	58,500	57,100	48,600	57,800
2024	57,600	56,600	54,100	52,300	57,500	55,600	44,300	56,600
2025	56,600	55,300	52,300	50,000	56,500	54,100	40,000	55,300
2026	55,600	54,100	50,400	47,700	55,500	52,600	40,600	54,100
2027	54,600	52,900	48,600	45,400	54,500	51,200	41,200	52,900
2028	53,600	51,700	46,700	43,000	53,500	49,700	41,800	51,700
2029	52,600	50,400	44,900	40,700	52,400	48,200	42,400	50,400
2030	51,700	49,200	43,000	38,400	51,400	46,700	43,000	49,200
2031	50,700	48,000	41,200	40,100	50,400	46,700	43,700	48,000
2032	49,700	46,700	39,400	41,800	49,400	46,700	44,300	46,700
2033	48,700	45,500		43,500	48,400	46,700	44,900	45,500
2034	47,700	44,300		45,200	47,400	46,700	45,500	44,300
2035	46,700	43,000		46,900	46,400	46,700	46,100	43,000
2036	45,800	41,800		48,600	45,400	46,700	46,700	44,000
2037	44,800	40,600		50,300	44,400	46,700	47,400	44,900
2038	43,800			52,000	43,400	46,700	48,000	45,800
2039	42,800			53,700	42,400	46,700	48,600	46,700
2040	41,800			55,300	41,400	46,700	49,200	47,700

[1] average 2014-2016 from SC16-MI-IP-11

NOTE: catches are rounded to the nearest median estimated 100 mt.