SCIENTIFIC COMMITTEE
TWELFTH REGULAR SESSION

Bali, Indonesia
3-11 August 2016

Biological and economic consequences of alternative trajectories to achieve a candidate south Pacific albacore target reference point

WCPFC-SC12-2016/ MI-WP-01

Graham Pilling[1], Maggie Skirtun[2], Chris Reid[2] and John Hampton[1]

[1] Pacific Community (SPC), Oceanic Fisheries Programme
[2] Pacific Islands Forum Fisheries Agency (FFA)

Abstract

Using deterministic projections, biological and economic consequences of status quo (2013) effort and catch scenarios were examined for the south Pacific albacore stock and longline fishery. Three alternative management interventions recovering the stock to a candidate Target Reference Point (TRP; 45% $_{SBF=0}$) over 20 years were also examined:

1. 'Take the reduction early': an immediate one-off effort cut;
2. 'Delay the reduction': making a one-off effort cut in 2024;
3. 'Spread the reduction': reduce effort every year by a fixed annual percentage.

Status quo conditions led to both stock and CPUE declines, and significantly reduced profits over the next 20 years. The stock was reduced to 32% $SB_{F=0}$ with effort at 2013 levels, and to 23%$SB_{F=0}$ with catch at 2013 levels. Achieving constant catch from a declining stock biomass required over a doubling of fishing effort by 2033, led to economic losses under all economic conditions, a 41% risk of falling below the limit reference point, and a risk of stock collapse. Economic performance was much improved under the effort reduction scenarios:

1. 'take the reduction early': the stock equilibrated at the TRP within 5 years after an immediate cut in effort to 53% of 2013 levels. Annual fishery profit and total net present value were the highest of all effort scenarios examined, under base case economic conditions.
2. 'delay the reduction': a slightly larger cut in effort in 2024, to 49% of 2013 levels was required following initial stock declines. The TRP was then achieved within 10 years. Economically, this was the worst performing scenario.
3. 'spread the reduction': an annual 3% effort cut was required to achieve the TRP in 2033 exactly. Effort was reduced to 43% of 2013 effort levels over the 20 year period. This was the second best performing scenario, economically.

Displacement cost to vessels exiting the fishery was not included in this analysis. These are likely to strongly influence results. The three economic conditions examined provide some sensitivity around prices and costs, but remain fixed over the 20 years. Economic indicator analyses of the fishery suggest the likelihood of optimistic conditions occurring is likely to decrease over time. Managers should consider the likelihood of good and bad economic conditions, and resulting tradeoffs and risks, when selecting a robust management strategy. The choice of management scenario will also be influenced by the time horizon used by managers, and the value operators place on their investment. The effort reduction needed is clearly dependent upon the target, when and how effort is reduced, and the defined timescale for recovery.

SC12 is invited to:

- Consider the approach taken to evaluate the biological and economic consequences of alternative scenarios for future southern longline fishery effort;
- Note the biological and economic consequences of status quo fishing levels;
- Note the economic consequences of the alternative recovery strategies examined;
- Note the importance of assumptions on key bycatch species catch levels for economic estimates;
- Suggest approaches for modelling the economic losses due to the exit of vessels from the fishery;
- Consider the implications of these analyses when providing advice to WCPFC13.

Introduction

For the south Pacific albacore stock, the 11th Scientific Committee meeting report noted that "Despite the fact that the stock is not overfished and overfishing is not occurring, SC11 reiterates the advice of SC10 recommending that longline fishing mortality and longline catch be reduced to avoid further decline in the vulnerable biomass so that economically viable catch rates can be maintained".

Based upon biological and economic objectives for the south Pacific albacore fishery proposed at the WCPFC 2nd Management Objectives Workshop (WCPFC, 2013), work identifying candidate target reference points (TRPs) that achieve desired longline fishery economic performance was presented to both SC11 (Pilling et al., 2015) and the 2015 WCPFC Harvest Strategy Workshop meeting (SPC-OFP, 2015a). Based upon those analyses, a delegation paper (FFA members, 2015) was submitted to WCPFC12 proposing an interim TRP for the south Pacific albacore stock of 45% $SB_{F=0,\ 2003\text{-}2012}$[1]. This proposal was based upon the positive consequences that increases in stock biomass would have for catch rates, a primary driver of profitability and economic viability in the fishery. The proposed TRP represented a stock size approximately 10% larger than identified within the most recent stock assessment (SB_{2013} = 41%$SB_{F=0}$ when averaged across the model runs used to capture uncertainty in the south Pacific albacore assessment; Harley et al., 2015).

As noted in Pilling et al. (2016a), the recovery/rebuilding of a stock to a specified level (be it a target or limit reference point) within a given timeframe can be achieved through many different trajectories. Those different trajectories can have very different implications for the fisheries exploiting the stock. To support further discussions of candidate target reference points for the south Pacific albacore stock and southern longline fishery, and to develop scientific approaches to examine the biological and economic consequences of alternative stock pathways to desired levels, this paper:

1. Examines the potential consequences of continued fishing at recent levels for the south Pacific albacore stock, to provide baseline scenarios;
2. Examines the biological and economic consequences of alternative trajectories to achieving the candidate TRP by 2033 (a 20 year recovery period).

Ultimately, the aim is to develop scientific outputs to support management discussions on desirable target levels, recovery timescales and features of any desired recovery plan for south Pacific albacore.

Methods

The analysis was undertaken in two phases. In the first, deterministic stock projections were performed under different southern longline fishery scenarios to identify stock trajectories that achieved the candidate TRP by 2033. In the second, catch estimates developed from those projections were used to assess the consequences of the different interventions for the profitability of southern longline fleets.

South Pacific albacore stock projections

All projections were performed based upon the 2015 assessment for south Pacific albacore (Harley et al., 2015). Deterministic 20 year projections were run for five scenarios. The first two scenarios

[1] $SB_{F=0,\ 2003\text{-}2012}$ will be termed $SB_{F=0}$ for the remainder of this paper.

examined the consequences of status quo conditions, assuming effort or catch would remain unchanged into the future:

1. No change in effort levels (2013 longline effort kept constant into the future), regardless of the likelihood that at least some effort would become unprofitable;
2. No change in catch levels (2013 longline catch kept constant into the future; this scenario assumes effort will increase if the stock declines, in order for the same annual catch to be taken). This scenario also assumes that additional effort would be possible in spite of the deteriorating profitability that would occur with such stock declines.

The final three scenarios recovered the south Pacific albacore stock to the candidate TRP over a 20 year timescale by manipulating longline effort. Although there are many different scenarios through which the stock could be managed to achieve the candidate TRP over that time period, the following three scenarios attempt to bracket the possibilities:

3. 'Take the reduction early': Achieve the TRP in 2033 through an immediate one-off cut in fishing effort;
4. 'Delay the reduction': Achieve the TRP in 2033 by maintaining status quo effort until 2023 (10 years), then making a one-off cut in fishing effort in 2024 sufficient to recover the stock to the TRP over the final 10 years;
5. 'Spread the reduction': Achieve the TRP in 2033 by reducing effort every year from 2015 to 2033 by a fixed annual percentage (a step-by-step reduction). This approach aims to minimize shocks to the system; given the potential implications for markets, industry etc. of a sudden reduction in effort, this may represent a more practical management intervention.

In each scenario, an iterative approach was taken to identify the exact amount of effort that needed to be removed from the southern longline fishery to achieve the candidate TRP by 2033 under each scenario.

Stock projections were deterministic, with future recruitment assumed to represent the average level defined by the stock recruitment relationship for a given underlying adult biomass. Projections were run across the subset of assessment runs selected by SC11 to capture existing uncertainty in our knowledge of south Pacific albacore. Results were weighted according to the decisions of SC11. This is described in more detail within the annex to this paper.

From each of the scenarios, the annual south Pacific albacore catch taken in the southern longline fishery was estimated, here defined as the longline fishery operating south of 10°S and excluding the overlap area (attempting to minimise the impact of longline activity frequently focussed on other species on the high seas), i.e. within regions 2, 3, 5 and 6 of the assessment model (see Figure 1). Key fishery parameters (albacore catch and vulnerable biomass (a CPUE proxy)) were also evaluated in this study. For the economic analysis, the amount of key bycatch was estimated to underpin the calculation of fishery profits. In previous analyses, a regression approach has been used to estimate the catch of non-target species (e.g. Pilling et al., 2016b). This approach was maintained for the estimation of equivalent billfish, shark and other species catches. For yellowfin and bigeye, an approach consistent with the regional bioeconomic model was used (Kirchner et al., 2014). This is described in detail within the annex.

Economic outcomes

Economic outcomes were evaluated based on two measures of performance: undiscounted annual real profits earned in the southern longline fishery, and discounted cumulative Net Present Value (NPV) of these profits over the 20 year projection period. Annual real profits illustrate the economic implications for the fishery *along* the path of each scenario, and were not discounted to assist comparison across scenarios at a particular point in time. In contrast, NPV of these profits were discounted and cumulated to show the accrued profit or loss up to that point in time, taking into account the opportunity cost of capital. More specifically, NPV demonstrates the relative overall costs of transition under each scenario, with the discount rate giving more weight to profits/losses made earlier in the projection period, and less weight to those earned later on. In other words, a dollar of profit next year is valued more highly than a dollar made in twenty years' time.

As noted above, while the biological stock projections look at the biological consequences for the whole of the albacore stock assessment area (Figure 1), the economic analysis concentrated only on the outputs for the southern longline fishery (assessment regions 2, 3, 5 and 6, excluding the overlap area with IATTC). Catches of albacore and bycatch species were therefore estimated for those regions only and used to estimate revenue based upon the average ex-vessel price for each species. Economic costs, not including payments for access fees, were estimated based upon annual effort in number of hooks defined by the different scenarios, and a specified cost per hook.

The general steps taken in this analysis were:

- Obtain 20 year deterministic projections for south Pacific albacore catch and key bycatch species under the 5 scenarios by assessment area;
- Calculate real annual fishery revenue by multiplying long-term average price for each species (US$/mt) with the corresponding catch (mt). Also calculate alternative real annual fishery revenue under different price conditions (±20% of base prices);
- Estimate real cost of fishing using 3 different costs per hook ($0.90, $1.10 and $1.30) for effort (annual number of hooks used) associated with each of the 5 scenarios; and
- Calculate annual economic profits (fishery rent) over the projection period. Compute the cumulative NPV under discount rates of 3%, 5% and 7% per annum, across the 5 stock trajectories and 3 different economic scenarios.

The 'base case' economic scenario is estimated using the long-term real price and a cost per hook of US$1.10 taken from Pilling *et al.* (2015). However there is considerable uncertainty and fleet-specific variability in prices received and costs incurred, including the effects of subsidies within specific fleets and economic conditions beyond the control of governments or management. Therefore results for two alternative economic scenarios ('optimistic' and 'pessimistic') were also estimated to provide an analysis of the sensitivity of results to these uncertainties. The optimistic case uses prices that are 20% higher than the long-term real price for species and a lower cost per hook of US$0.90, while the pessimistic case is calculated based on prices that are 20% lower and a cost per hook of $1.30. Fish prices used reflect ex-vessel prices to key markets, and represent 'real term' 2014 USD prices. For details on the methodology and values used, see the annex.

Although sensitivity is built around prices and costs, prices and costs are not assumed to vary within each economic scenario. This is less of a concern for prices as long-run elasticity analyses do not suggest a strong relationship between catch and price for the southern longline fishery. However, keeping cost per hook constant relies on the assumption that the fleet size (number of vessels) declines proportionately to declines in effort, which may not be the case. For example, if the fleet size reduces by proportionally less than the number of hooks (i.e. vessels each deploy fewer hooks, rather than leaving the fishery), then cost per hook will be higher (i.e. relatively more fixed capital costs will need to be included per hook).

It is also important to note that the economic profits calculated reflect those earned by the harvest sector alone. Costs therefore cover only those incurred in the operation of the vessel (i.e. vessel operating costs, other cash costs and fixed capital costs of remaining vessels), and the opportunity cost of capital. Displacement cost for vessels that exit the fishery and other wider economic benefits to national economics from the fishery, such as employment, on-shore processing and government taxes received etc. are not considered. It is intended in future work to examine this two part cost effect on industry: the displacement cost of vessels that exit, and the cost implications on the vessels which remain in the fishery resulting from disproportionate reductions in vessels numbers to reductions in effort.

Results

South Pacific albacore stock projections

To provide context, across the nine stock assessment models used within the analysis, the average stock status in 2013 (the last year of the assessment) was 41%$SB_{F=0}$.

Status quo conditions

If effort remained at 2013 levels, the stock is predicted to continue to decline, falling to an average of $SB/SB_{F=0}$ = 0.32 in 2033 (Table 1, Figure 2). The overall CPUE in the longline fishery (vulnerable biomass) is estimated to decline by 14% from 2013 levels over the projection period.

If catch remains at 2013 levels, the stock decline is greater (in the status quo effort scenario, catch reduces as stock size declines). The stock is predicted to fall to $SB/SB_{F=0}$ = 0.23 in 2033, close to the limit reference point (Table 1). Separately run stochastic projections under this status quo catch scenario indicated a 41% risk of the stock falling below the limit reference point by 2033, and in some individual runs the stock size was reduced to zero (11% of runs). As the stock declines, achieving the same annual catch requires considerably more effort, approximately 120% more than 2013 levels (i.e. more than double) by 2033. As a result, CPUE in 2033 is reduced by 32% relative to 2013 levels.

Alternative approaches to achieving the TRP

'Take the reduction early': Cutting effort immediately to 53% of 2013 levels (i.e. cut effort by 47%) is projected to recover the stock to the TRP by 2033 (Figure 2). Indeed, under the deterministic projections the stock would recover to the TRP within 5 years of the significant management intervention, after which point the stock was in equilibrium with the level of effort at the TRP.

'Delay the reduction': Under this scenario status quo effort is maintained for 10 years, and a slightly larger cut in effort in 2024, to 49% of 2013 levels (i.e. cut effort by 51%), is necessary to recover the stock to the TRP by 2033. This larger cut is necessary since the stock continues to decline over the first 10 years. The trajectory of the stock is very different to the previous scenario (Figure 2), and the TRP is achieved in 2032, within 10 years of the significant management intervention.

‘Spread the reduction’: To achieve the TRP by 2033, a cut in effort of 3% per annum is required. This implies effort is reduced to 43% of 2013 effort levels by the end of the 20 year period. The stock recovers to the TRP in 2033.

Under each scenario, the vulnerable biomass in 2033 is comparable, but the catch level in 2033 is influenced by the different levels of effort implied under the scenarios in the final year. This is explained in the discussion section below.

Economic implications

A summary of undiscounted annual real profit and cumulative net present value of discounted profit (NPV) for the base case economic conditions are summarized in Table 1, along with profits under the two alternative economic conditions. Detailed results and figures under all three economic conditions are provided in the Annex.

Status quo conditions

For the effort status quo scenario, undiscounted fishery profit is predicted to follow a declining trend for the first 10 years before increasing slightly to $4.5 million per year under base case economic conditions (Figure 4). Under optimistic conditions, the median annual fishery profit over the 20 year projection period is estimated to be $118 million, compared to -$110 million under pessimistic conditions (Table 1). In fact, fishery profitability is expected to fall to below -$100 million annually, 1 year into the projection period under pessimistic conditions. Discounted cumulative NPV is projected to sum to a total of $186 million over the 20 years to 2033 under base case conditions and a 5% discount rate (Figure 3).

In contrast, if catch is maintained at 2013 levels, undiscounted annual profit for the fishery is projected to fall below -$265 million annually from 2022 onwards under the base case, attaining a minimum profit of -$323 million over the projection period (Figure 4, Table 1). Total discounted economic loss (negative NPV) in the fishery is expected to be in excess of $2.5 billion for the 20 year period to 2033. This is exacerbated under the pessimistic scenario, with median annual fishery profit estimated at -$471 million and a total discounted NPV of $5.0 billion over the 20 year projection period (Table **A4**). Even under optimistic conditions, median annual profit and total discounted NPV are estimated at -$96 million and -$159 million.

Alternative approaches to achieving the TRP

The final year profits when the TRP of 45% $SB_{F=0}$ has been achieved are the same under all approaches. However, profits earned in each year of the transition period, and hence NPV, vary considerable between scenarios. In examining the results it is important to recall that future costs borne by operators of vessels that exit the fishery are not accounted for, nor is any increase in cost per hook that may result if effort reductions result in annual effort levels per vessel declining.

‘Take the reduction early’: Cutting effort immediately to 53% of 2013 levels is projected to reduce annual fishery profit to $42 million in the first year after the cut (2015). This gradually recovers to above $50 million by 2018 under base case economic conditions (Figure 4). Over the projection period, the NPV is estimated to reach $735 million, which is the highest out of the 5 scenarios (Figure 3). Under optimistic economic conditions, median annual fishery profit is estimated to be $123 million over the majority of the projection period, while pessimistic conditions lead to a median annual loss of $18 million (Table 1). There are therefore still some risks of economic loss at the TRP level under pessimistic economic conditions (Table A3). This is consistent with results from SPC-OFP (2016; Table A5) where breakeven under pessimistic conditions was estimated to be at 49% $SB_{F=0}$, a stock size greater than the proposed TRP.

'Delay the reduction': cutting effort to 49% of 2013 levels in 2024 yields a lower median annual fishery profit compared to 'take the reduction early' ($33 million compared to $53 million) under base case conditions, and also a lower NPV of $384 million by 2033. Similarly, median annual profit under optimistic conditions is also lower at $117 million than the corresponding profit under the 'take the reduction early' scenario, as is the case under pessimistic conditions with median profit at -$55 million annually.

'Spread the reduction': cutting effort by 3% per annum is estimated to result in a median annual profit that is lower compared to 'take the reduction early' but higher than 'delay the reduction' scenario, at $35 million under base case conditions. Over the projection period, the scenario is expected to yield a total discounted NPV of $465 million, which is also in between 'take the reduction early' and 'delay the reduction' (Table 1, Figure 3).

The absolute value of undiscounted annual fishery profit varied significantly due to the assumed economic conditions ('optimistic', 'base case' and 'pessimistic'; Figure A1, Table A3). While the relative ranking of annual profits achieved under the different effort cut options did not change for the majority of years in the projection period, ranking was affected at different stages of the time series. For instance, under optimistic economic conditions, 'spread the reduction' and 'delay the reduction' generated higher annual profits than 'take the reduction early' for the first 5 years of the projection (Table A3). Under pessimistic conditions, in contrast, 'take the reduction early' yielded significantly better (albeit still negative) annual profits, but did not remain the best option for the entire 20 years. Annual profits under the other two effort cut scenarios gradually improved and outperformed the 'take the reduction early' scenario in the last 5 years. Nevertheless, on the whole 'take the reduction early' remains the best performing effort option in terms of annual fishery profit achieved.

Cumulative NPVs also varied substantially across the effort options under different assumed economic conditions (Figure A2). Under optimistic conditions, the effort status quo scenario performed better than all effort cut options. This was mostly the result of significantly higher annual revenue made under favourable prices, especially for yellowfin and bigeye, but also the discounting of future profits (i.e. putting more weight on the higher initial profits made under effort status quo). Conversely, 'take the reduction early' performed substantially better than all other scenarios under pessimistic conditions in terms of cumulative NPV. This was followed by 'spread the reduction' and 'delay the reduction'.

Discussion

The status quo effort scenario, reflecting 'stable' vessel numbers, is estimated to result in a decline in both stock status and CPUE over the 20 year projection period. From previous work (e.g. SPC-OFP, 2015b) if effort remains at 2013 levels, the risk of falling below the agreed Limit Reference Point (LRP) will reach 20% by 2033. We note that while there have been some reductions in effort within the longline fishery south of 10°S (Pilling et al., 2016c), this has had little impact on the overall projected state of the stock or the risk of falling below the LRP, and hence the analyses performed here remain valid. We also note that the small effort reductions seen are not close to the approximately 33% reduction from 2013 levels Pilling et al. (2015) identified as required to halt declines in adult stock biomass.

The risk of the stock falling below the LRP is greater under the status quo catch projection, with average stock status falling to just above the LRP in 2033, and a 41% risk of the stock falling below the LRP. In some stochastic projection trajectories, particularly where the assessment model assumed the stock had lower productivity, the stock collapsed (11% of all runs). The assumption of constant catch at 2013 levels implies a considerable increase in effort to maintain it in the face of a declining stock, and required over a doubling of fishing effort within the 20 year period. It is therefore a 'worst case' scenario and results in considerable economic losses under all economic conditions and a danger of stock collapse.

To achieve the candidate TRP of 45% $SB_{F=0}$ by 2033, reductions in effort are required. Three alternative scenarios to recover the stock were examined here to 'bracket' alternative management approaches that could be taken. Although all three scenarios achieved the TRP by 2033, they implied different stock trajectories, and hence have different economic implications in the short and long term.

Making a significant effort cut immediately, the 'take the reduction early' scenario, led to a relatively rapid stock recovery, with the fishery recovering to the TRP level (on average) within 5 years. This approach minimized short term reductions in biomass (Figure 2). In doing so, the fishery was able to achieve the highest real annual profit in all years of the projection period following the cut under base case economic conditions. Therefore, it is not surprising that the 'take the reduction early' scenario was able to achieve the highest cumulative NPV among the 3 alternative management options. However, this is partly driven by the non-inclusion of costs associated with vessels that exit the fishery as a result of the large cut in effort, and the assumption that the fleet declines proportionately to the decline in effort. The latter assumption implies that cost per hook remains constant after any cuts in effort, which may not be the case if the fleet size does not decline proportionally (i.e. individual vessels use fewer hooks, increasing the cost per hook).

Allowing effort to remain at status quo levels before initiating a significant effort cut in 2024 led to initial stock declines, following the pathway of the status quo effort scenario, and hence required a slightly greater cut in effort to achieve the TRP by 2033 from that lower stock size. In turn, this resulted in a slower recovery time to the TRP of around 10 years (Figure 2). This also led to very low annual fishery profit (less than $10 million) between 2016 and 2023 under base case economic conditions (Table A3), and hence yielded the lowest NPV at the end of the projection period out of the three effort cut scenarios.

In order to achieve the TRP in 2033 through year-on-year cuts in effort across the 20 year period, effort had to be reduced by 3% per annum (Table 1). This resulted in a slow but steady recovery to the TRP. While annual fishery profits were significantly above 'delay the reduction' for the first 10 years of the projection period, profit did fall in the initial years as the stock recovered at a much slower pace compared to 'take the reduction early'. Moreover, once the cut was taken under 'delay the reduction', the annual profits in that scenario recovered rapidly and exceeded 'spread the reduction' by 2026. Nevertheless, the gradual but steady reductions in effort under 'spread the reduction' supported consistent improvements in fishery profitability year on year, and in turn, accumulated a higher discounted NPV at the end of the projection period compared to the 'delay the reduction' scenario.

The most profitable scenario was clearly influenced by the economic conditions assumed, with very different results under 'optimistic' economic conditions in particular. While the three economic conditions provide some sensitivity around prices and costs, the resulting economic conditions (price per species and cost per hook) remain fixed over the 20 years. However, the indicator analysis of economic conditions (Skirtun and Reid, 2016) suggests that the likelihood of optimistic conditions occurring will decrease over time if the identified declining trends continue. Therefore, managers need to consider the possibility of both good and bad economic conditions and the resulting tradeoffs and risks, when selecting a robust management strategy for the fishery. In turn, the choice of management scenario will be influenced by the time horizon used by managers, and the value operators place on their investment in the fishery; i.e. the discount rate. Performance of an implemented scenario should also be monitored to allow adjustment in the face of future recruitment levels (both good and bad), unforeseen shifts in fishing strategies, implementation issues, and changes in catch levels, prices and operating conditions that can have potentially unexpected implications for the scenario's economic consequences.

The level of effort reduction is clearly dependent upon both when and how effort is reduced, and the timescale over which managers wish the stock to recover to the TRP. While a recovery time of 20 years has been used here, the time of recovery is a decision for managers, who must trade off the biological and economic consequences of alternative stock trajectories (Pilling et al., 2016a). Many alternative scenarios could be examined, but guidance would be required from managers to frame that analysis.

Once the target has been achieved, some adjustment to the level of fishing may be required. For the last two scenarios ('delay the reduction', 'spread the reduction'), the reductions in effort that transition the stock to the TRP in 2033 are greater than that required to maintain the stock at the TRP at equilibrium. In those two cases, the stock size would continue to increase after 2033. Once the stock has recovered to the desired level within the specified timescale, therefore, management may need to adjust the level of fishing. This may involve alternative Harvest Control Rules that maintain the stock at the TRP.

Comments on the analysis

In an improvement of previous analyses, the stock dynamics of key economic bycatch species (bigeye and yellowfin) have been incorporated as realistically as possible through the use of the regional bioeconomic modelling approach. This meant they were no longer directly related to changes in albacore catch rates. The change in approach to estimating bigeye and yellowfin catch levels influenced the performance of fleet profitability under the status quo effort scenario. In particular, it resulted in lower declines in valuable yellowfin catches compared to previous analyses. The use of the regional bioeconomic model for tropical tuna catch estimation does require assumptions on future levels of tropical purse seine and longline fishing, which are important drivers of overall bigeye and yellowfin stock sizes. While a status quo assumption was made in the current analysis, changes in tropical fishing levels will have influences on southern longline fishery profitability.

Obtaining realistic bigeye and yellowfin catch estimates for 'albacore targeting' longliners from the regional bioeconomic model approach proved challenging. Catch estimates were strongly influenced by fleets operating at those latitudes targeting other species. This positively biased profitability to levels that industry feedback suggested were highly unlikely. As the 2015 albacore stock assessment modelled an amalgamated longline fleet for each region, it was not possible to segregate catches effectively. Therefore a pragmatic approach was used taking the regional bioeconomic model estimated trends in yellowfin and bigeye catches under each management scenario, and applying to the catch levels estimated for 2013 through the original regression approach. While this is a step forward from previous analyses, the considerable contribution to revenue from bigeye and yellowfin catches remains an area of uncertainty.

The economic analysis is focused only on the profitability of the harvesting sector. Economic losses incurred by those vessels that are forced to exit the industry and from the reduction in other wider economic benefits, such as employment, on-shore processing and government taxes received etc. are not considered. However, if fishing is to continue at the current levels of effort or catch, declines in fleet profits may reduce wider economic benefits regardless. In addition, the analysis assumes that effort reductions will result in proportional reductions to the size of the fleet which may affect the results presented. Nonetheless, while the analysis can be improved by addressing these issues, it clearly illustrates that the different transition paths to achieving the same TRP will result in significantly different economic outcomes.

We also note that this evaluation does not consider whether vessels leaving the fishery move, for example, into the tropical longline fishery rather than being decommissioned. The potential wider effects of management interventions on other fisheries and hence fish stocks, would need to be considered within a framework such as the regional bio-economic model.

In the absence of WCPFC decisions on a candidate target reference point for south Pacific albacore, SC12 is invited to:

- Consider the approach taken to evaluate the biological and economic consequences of alternative scenarios for future southern longline fishery effort;
- Note the biological and economic consequences of status quo fishing levels;
- Note the economic consequences of the alternative recovery strategies examined;
- Note the importance of assumptions on key bycatch species catch levels for economic estimates;
- Suggest approaches for modelling the economic losses due to the exit of vessels from the fishery;
- Consider the implications of these analyses when providing advice to WCPFC13.

Acknowledgements

The study was carried out with financial support from program funding to SPC Fisheries, Aquaculture and Marine Ecosystems (FAME) through the Australian Government DFAT Partnership for Pacific Regionalism and Enhanced Development, and financial support from the Environmental Defense Fund. Thanks also go to Alex Tidd for helpful comments on an earlier version of this paper.

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Table 1 Average stock and fishery status under i) status quo conditions, and ii) using alternative approaches to achieve the candidate TRP by 2033, from deterministic projections. Minimum, median and maximum annual fishery profit and cumulative NPV discounted at 5% under the three economic scenarios (across the 20 year period) are also presented.

	LL effort scalar (2013)	Median $SB_{2033}/SB_{F=0}$	Median longline VB_{2033}/VB_{2013}	Median albacore catch ($Catch_{2033}/Catch_{2013}$)	NPV base case (US$ mils)		Fishery profit base case	Fishery profit optimistic	Fishery profit pessimistic
Status quo effort	1	0.32	0.86	0.72	185.6	Min	2.3	115.6	-111.0
						Med	4.1	117.8	-109.5
						Max	71.8	199.1	-55.4
Status quo catch	-	0.23	0.68	1	-2562.8	Min	-323.1	-134.7	-512.4
						Med	-283.5	-96.4	-470.6
						Max	71.8	199.1	-55.4
Cut effort in 2014	0.53	0.45	1.17	0.59	734.7	Min	41.8	110.0	-55.4
						Med	52.9	123.2	-18.0
						Max	71.8	199.1	-15.5
Status quo effort to 2023, cut effort in 2024	0.49	0.45	1.17	0.55	384.2	Min	2.3	79.6	-111.0
						Med	32.7	117.4	-55.4
						Max	71.8	199.1	-11.3
Cut effort by 3% per annum, starting 2015	0.43 in 2033	0.45	1.17	0.50	465.1	Min	8.8	110.3	-99.1
						Med	34.9	117.0	-55.4
						Max	71.8	199.1	-7.4

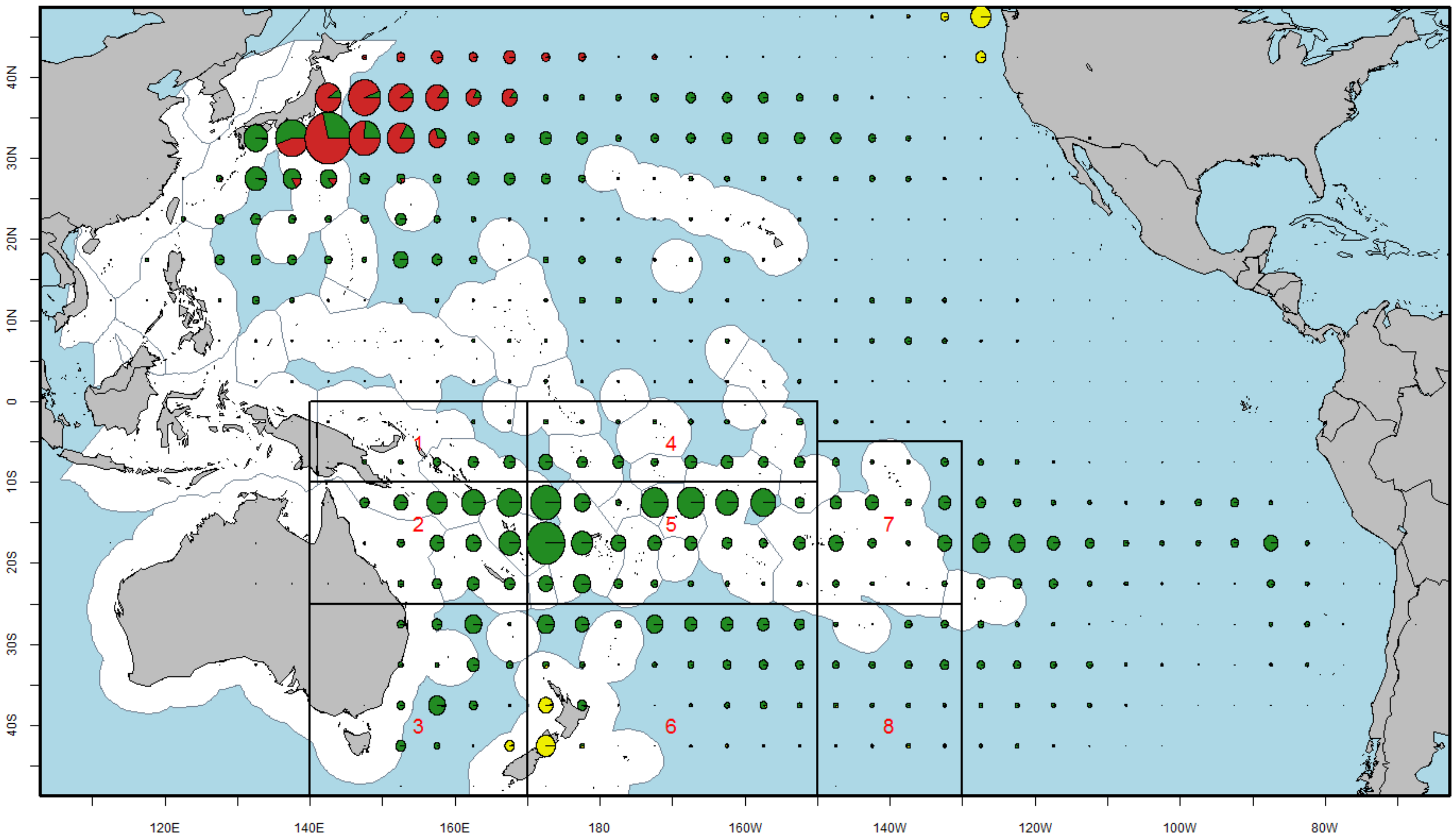

Figure 1. Regions of the albacore stock assessment overlaying catch distribution (2004-2013). Catch distribution is by 5° square and fishing method: longline (green), pole-and-line (red), and other (yellow) for the entire Pacific Ocean.

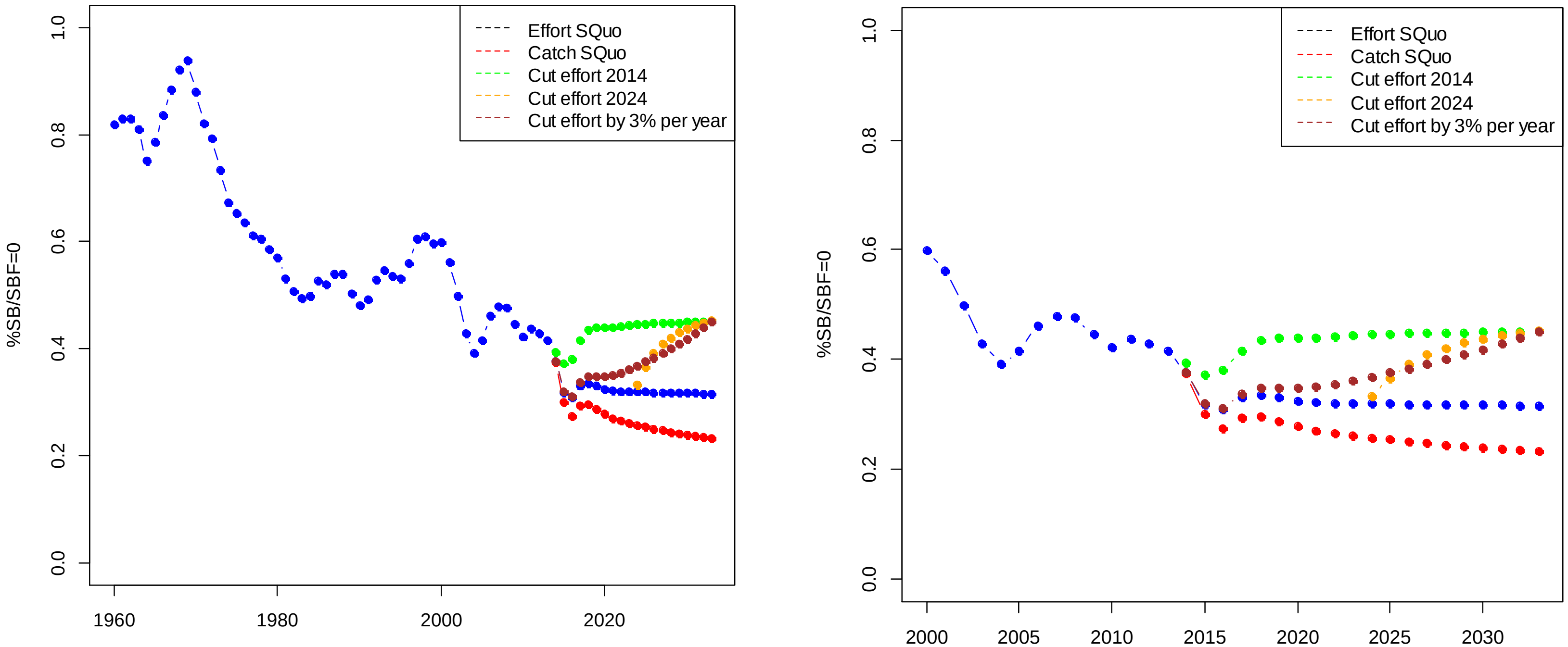

Figure 2. Deterministic stock status trajectories under alternative management scenarios; left: full time series; right: shortened time series.

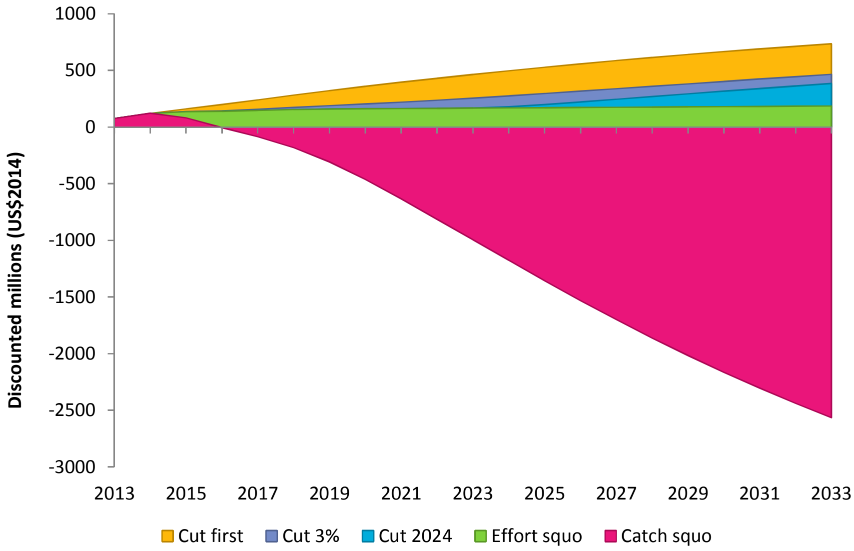

Figure 3. Discounted cumulative net present value of profits for the southern longline fishery under the 5 scenarios, using 'base case' cost and prices. Real discount rate is set at 5% to reflect opportunity cost of capital investment.

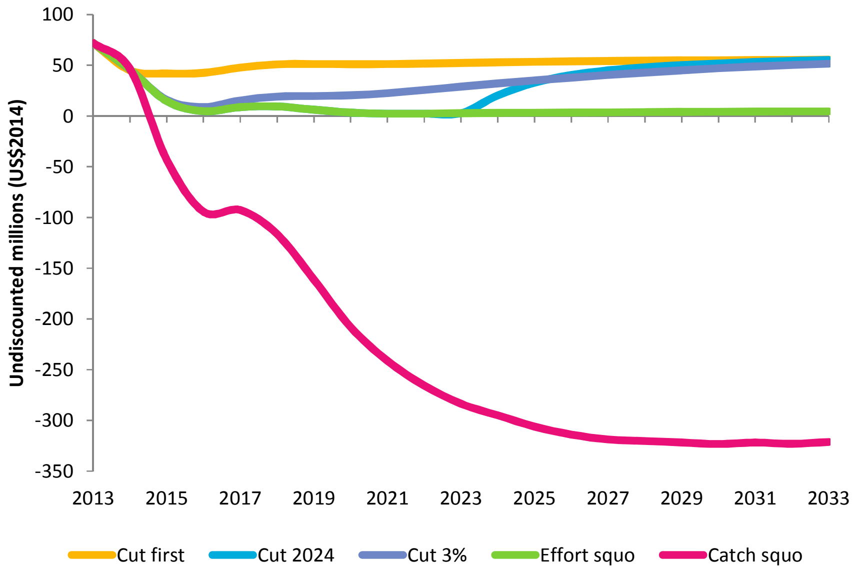

Figure 4. Undiscounted annual profits for the southern longline fishery under the 5 scenarios, in USD millions, using 'base case' cost and prices.

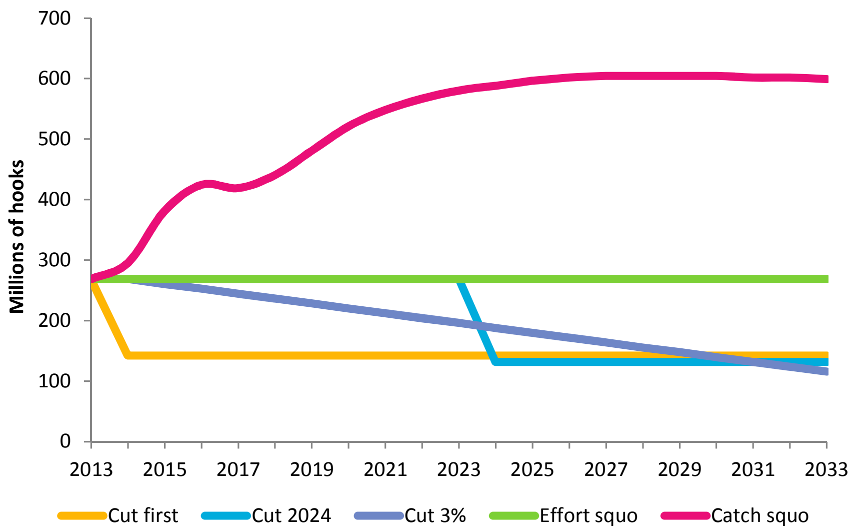

Figure 5. Effort required in the southern longline fishery under the 5 scenarios, in millions of hooks.

Annex: Methods

Uncertainty within deterministic projections

Within the deterministic south Pacific albacore projections, SC9's recommendations on capturing uncertainty (WCPFC SC9, 2013) were incorporated. The main assumptions made within the projections were:

- Nine alternative assessment runs from the 2015 south Pacific albacore stock assessment uncertainty grid (Harley et al., 2015) were used to capture uncertainty in 'current' stock status and biological characteristics. These runs were a subset of the runs specified by SC11 for reporting stock assessment advice, and covered alternative stock recruitment relationship steepness assumptions and assumed values of the natural mortality rate (see Table below);
- Future recruitment at a given adult biomass level was defined by the stock-recruitment relationship;
- Catchability (which can have a trend in the historical component of the model) was assumed to remain constant in the projection period at the level estimated in the terminal year of the assessment model;
- Projections were run for twenty years from 2013;
- Levels of activity in the troll fishery were kept constant at 2013 levels.

When examining results, those from each of the nine models were weighted as in the table below, consistent with the approach taken at SC10; the run SC considered most biologically plausible was given the most weight, and results from runs considered less biologically plausible were 'down-weighted'.

Table A1. Nine stock assessment model runs from the 2015 assessment selected to capture uncertainty in current conditions and knowledge of south Pacific albacore biology, and weighting values assigned to each run for analysis of results.

Run #	Settings	Weighting
500	M = 0.30, Steepness 0.80 (ref case)	1
504	M = 0.25, Steepness 0.80	0.8
508	M = 0.40, Steepness 0.80	0.8
512	M = 0.30, Steepness 0.65	0.8
513	M = 0.30, Steepness 0.95	0.8
520	M = 0.25, Steepness 0.65	0.64
521	M = 0.25, Steepness 0.95	0.64
528	M = 0.40, Steepness 0.65	0.64
529	M = 0.40, Steepness 0.95	0.64

The unfished biomass level ($SB_{F=0}$, calculated as the average of the spawning biomass over the period 2003-12 that would have occurred in the absence of fishing) was calculated within each of the nine assessment model runs to ensure consistency with the underlying biological assumptions. The agreed Limit Reference Point was 20% of that unfished level.

Estimating bycatch levels

Two approaches were taken to estimate bycatch levels within the southern longline fishery:

- For yellowfin and bigeye, an approach consistent with the regional bioeconomic model was taken;
- For billfish, sharks and other species, the regression approach described in Pilling et al. (2016b) was used.

Yellowfin and bigeye

The yellowfin and bigeye stock assessments (Davies et al., 2014 and Harley et al., 2014) were used to underpin the modelling of future southern longline fishery catches of these species.

As the last year in the bigeye and yellowfin assessments was 2012, all fisheries were projected through to 2013 with the relevant catch or effort multiplier to ensure the stocks were being projected from the same starting year as that for albacore. From the updated 2013 status, scalars were applied to the effort in fisheries equivalent to the southern longline fishery (specifically fisheries 11, 12, 13, 28 and 30) consistent with each scenario examined for south Pacific albacore. The annual species catches within those fisheries under the different scenarios was then estimated.

One feature of the tropical tuna assessments in the southern region is that they include significant catches from longline fleets targeting tropical tunas. As a result, at the regional scale they do not directly represent the southern longline fleet targeting albacore. Inflated tropical tuna catch levels result. Therefore, the bigeye and yellowfin stock assessments were used to capture stock dynamics resulting from the southern longline fishery management interventions identified, and estimate the resulting 20 year time series of catches of these species. To ensure results were consistent with the catch levels from the albacore targeting fleet, the relative annual change in each of yellowfin and bigeye catch levels from 2013 was calculated for the 20 year projection period. Those relative changes were then applied to the regression-based estimate of yellowfin and bigeye catch in 2013 derived from the south Pacific albacore catch level (as for the other species, below). The resulting time series of bigeye and yellowfin catches were used within the economic calculations.

Other species

Annual albacore catch levels from logsheet information over the period 1990–2012 by longline fleet were related to annual catches of combined billfish, sharks, and a combined 'other species' category, through linear regression. These regressions were used to calculate annual bycatch levels of each species based upon the annual south Pacific albacore catch by fleet estimated within the deterministic stock projections. Linear regressions were fitted to the natural logarithms of the catch data using the *lm*() function in R. Where diagnostics indicated that there was no clear relationship between the level of albacore catch taken by a fleet and the corresponding bycatch species level, a constant catch of that species or group was assumed, being the average over the time period. Oceanic whitetip and silky sharks were excluded from the shark catch data to mimic the future impact of recent non-retention CMMs.

Economic analysis

Cost per hook estimates were based on an 'average' cost of putting a hook in the southern waters of the WCPFC-CA for a 'typical' longline vessel (USD 1.10 per hook). Sensitivity analyses were conducted with a cost structure of ±USD 0.20 per hook. The lower range is generally consistent with other cost estimates of a heavily fuel-subsidized fleet. The cost of putting a hook in the water is assumed to be constant throughout the projection period. The number of hooks used in the analysis corresponds to the 5 candidate effort scenarios selected.

Three price structures were used (low, base, and high prices) to capture recent market fluctuations. The 'base' price reflects the long term average price at key regional markets, while the low and high levels were calculated ±20% from that level. Revenues were based on an average price received for an average metric ton of fish caught by species category. Market prices are assumed to be constant (in real terms) throughout the projection period, invariant to the landing location and total catch, and do not take into account any size-based market differences. The lower and higher price structures were designed to examine uncertainties around these assumptions. These prices were applied to the estimated annual catch of albacore from the deterministic projection under each of the 5 effort scenarios, and corresponding catches of other species estimated as defined above.

The use of constant price (in real terms) is justified by the fact that, despite some short-term fluctuations, the long-term real price trend for albacore imports into Thailand since 1997 has been relatively flat (Reid and Raubani, 2015). Furthermore, a statistical analysis using price, catch and other macroeconomic data from 2000 to 2014 was conducted to examine the short and long run relationship between the volume and price for albacore tuna landed in the WCPO. The results showed that there is insufficient evidence to suggest any co-integrated/sustainable long run price dependence on albacore catch (i.e. no statistically significant price elasticity was detected). Therefore, it is assumed in this analysis that real long-term price is constant and invariant to changes in effort.

Table A2. Real prices and cost used in the economic analysis

Scenario	**Optimistic**	**Base case**	**Pessimistic**
Real costs	**Low**	**Med**	**High**
Per hook (US$2014)	0.9	1.1	1.3
Real prices in US$2014/mt	**20% higher**	**Base**	**20% lower**
Albacore	3480	2900	2320
Yellowfin	11760	9800	7840
Bigeye	13620	11350	9080
Billfish	5400	4500	3600
Shark	1860	1550	1240
Others	2957	2464	1971

In contrast, using a constant cost per hook relies on a less realistic assumption that the fleet declines proportionately to declines in effort. Depending on which vessels exit the fishery (e.g. inefficient vessels or efficient but unsubsidized vessels) to exit the fishery, the cost per hook would vary. For example, if the fleet reduces by proportionally less than the number of hooks (efficient but unsubsidized vessels exit), then cost per hook will be higher as each remaining vessel is implied to be deploying less hooks (i.e. relatively more fixed capital costs will need to be included per hook). On the other hand, if less efficient vessels exit the fishery and each remaining vessel is able to deploy more hooks, then the cost per hook should decline.

This issue is also closely linked with the exclusion of wider economic costs such as costs to displaced vessels. For more efficient vessels that are forced to exit the fishery, the cost is likely to be greater compared to inefficient vessels. This is likely to distort the economic outcomes under the 5 effort scenarios, especially under different discount rates. Therefore, further work is planned to look at this two part cost assumption: displacement cost to vessels that exit and cost implications regarding to the change in fleet size compared with changes in effort.

Net present value (NPV) was calculated as: $NPV = \sum_{1}^{N} \frac{P_y}{(1+d)^y}$ where N is the total number of years (y), P_y is the profit in year y and d is the discount rate applied.

Detailed table of results for effort scenarios under alternative economic conditions and discounting

Table A3. Real annual economic profit of the southern longline fishery under the 5 effort scenarios, not discounted for opportunity cost of capital. Prices and costs for each economic scenario are as in Table A2. All values are expressed in real millions US$2014.

	Base case					Optimistic case					Pessimistic case				
Year	Effort squo	Catch squo	Cut first	Cut 2024	Cut 3%	Effort squo	Catch squo	Cut first	Cut 2024	Cut 3%	Effort squo	Catch squo	Cut first	Cut 2024	Cut 3%
2013	71.8	71.8	71.8	71.8	71.8	199.1	199.1	199.1	199.1	199.1	-55.4	-55.4	-55.4	-55.4	-55.4
2014	45.6	46.4	44.8	45.6	45.6	167.6	179.9	113.6	167.6	167.6	-76.4	-87.0	-23.9	-76.4	-76.4
2015	14.6	-43.1	41.8	14.6	15.8	130.4	108.5	110.0	130.4	128.5	-101.2	-194.8	-26.4	-101.2	-96.8
2016	4.8	-94.3	42.4	4.8	8.8	118.6	65.1	110.7	118.6	116.6	-109.0	-253.8	-25.9	-109.0	-99.1
2017	8.8	-92.7	47.6	8.8	15.3	123.4	64.8	116.9	123.4	121.1	-105.9	-250.2	-21.7	-105.9	-90.5
2018	9.3	-116.4	50.8	9.3	19.1	124.1	45.4	120.8	124.1	122.2	-105.4	-278.2	-19.2	-105.4	-84.1
2019	6.2	-161.1	51.2	6.2	19.6	120.3	8.7	121.3	120.3	119.4	-107.9	-330.9	-18.8	-107.9	-80.3
2020	3.4	-208.0	50.9	3.4	20.3	116.9	-30.6	120.9	116.9	117.0	-110.1	-385.3	-19.1	-110.1	-76.3
2021	2.3	-241.2	51.0	2.3	22.5	115.6	-59.2	121.1	115.6	116.1	-111.0	-423.2	-19.0	-111.0	-71.2
2022	2.4	-265.6	51.6	2.4	25.6	115.7	-80.6	121.7	115.7	116.5	-111.0	-450.6	-18.5	-111.0	-65.3
2023	2.7	-283.5	52.3	2.7	28.9	116.1	-96.4	122.5	116.1	117.0	-110.7	-470.6	-18.0	-110.7	-59.3
2024	3.0	-294.9	52.9	20.3	32.0	116.5	-106.8	123.2	79.6	117.4	-110.4	-483.1	-17.5	-39.1	-53.4
2025	3.2	-306.0	53.3	32.7	34.9	116.7	-116.7	123.8	94.5	117.5	-110.3	-495.3	-17.1	-29.1	-47.7
2026	3.4	-313.8	53.8	40.3	37.7	116.9	-123.8	124.3	103.7	117.5	-110.2	-503.9	-16.8	-23.0	-42.1
2027	3.6	-318.7	54.1	45.0	40.3	117.2	-128.5	124.7	109.3	117.2	-110.0	-508.9	-16.5	-19.3	-36.6
2028	3.8	-320.2	54.4	48.0	42.8	117.4	-130.4	125.1	112.8	116.8	-109.8	-510.1	-16.3	-16.9	-31.3
2029	4.0	-321.6	54.7	50.1	45.0	117.6	-132.0	125.5	115.4	116.1	-109.7	-511.2	-16.0	-15.2	-26.1
2030	4.1	-323.1	54.9	51.8	47.0	117.8	-133.8	125.7	117.4	115.1	-109.5	-512.4	-15.9	-13.9	-21.1
2031	4.3	-321.7	55.1	53.1	48.8	118.0	-133.2	126.0	119.0	113.8	-109.4	-510.2	-15.7	-12.8	-16.3
2032	4.4	-323.0	55.3	54.2	50.2	118.2	-134.7	126.2	120.3	112.2	-109.3	-511.2	-15.6	-12.0	-11.7
2033	4.5	-321.1	55.4	55.0	51.5	118.3	-133.6	126.3	121.3	110.3	-109.2	-508.5	-15.5	-11.3	-7.4

Table A4. Discounted cumulative net present value of the southern longline fishery under the 5 effort scenarios. Prices and costs for each economic scenario are as in Table A2. All values are expressed in real millions US$2014. All values are expressed in real millions US$2014.

	Base case					Optimistic case					Pessimistic case				
Year	Effort squo	Catch squo	Cut first	Cut 2024	Cut 3%	Effort squo	Catch squo	Cut first	Cut 2024	Cut 3%	Effort squo	Catch squo	Cut first	Cut 2024	Cut 3%
2013	75.4	75.4	75.4	75.4	75.4	209.0	209.0	209.0	209.0	209.0	-58.2	-58.2	-58.2	-58.2	-58.2
2014	121.0	121.9	120.3	121.0	121.0	376.6	388.9	322.6	376.6	376.6	-134.5	-145.2	-82.1	-134.5	-134.5
2015	134.9	80.8	160.1	134.9	136.1	500.8	492.2	427.4	500.8	498.9	-230.9	-330.7	-107.2	-230.9	-226.7
2016	139.3	-4.8	198.6	139.3	144.0	608.3	551.3	527.8	608.3	604.7	-329.8	-560.8	-130.7	-329.8	-316.6
2017	146.8	-84.9	239.7	146.8	157.3	714.9	607.3	628.8	714.9	709.3	-421.2	-777.0	-149.5	-421.2	-394.7
2018	154.5	-180.6	281.5	154.5	172.9	817.0	644.6	728.2	817.0	809.8	-507.9	-1005.8	-165.2	-507.9	-463.9
2019	159.4	-306.8	321.6	159.4	188.3	911.2	651.4	823.2	911.2	903.3	-592.5	-1265.1	-180.0	-592.5	-526.8
2020	161.9	-462.0	359.6	161.9	203.5	998.4	628.6	913.4	998.4	990.6	-674.7	-1552.6	-194.2	-674.7	-583.7
2021	163.5	-633.4	395.9	163.5	219.4	1080.6	586.5	999.4	1080.6	1073.1	-753.6	-1853.4	-207.7	-753.6	-634.3
2022	165.1	-813.2	430.8	165.1	236.7	1158.9	531.9	1081.8	1158.9	1152.0	-828.7	-2158.4	-220.3	-828.7	-678.5
2023	166.9	-995.9	464.5	166.9	255.3	1233.8	469.8	1160.8	1233.8	1227.4	-900.0	-2461.7	-231.9	-900.0	-716.7
2024	168.7	-1177.0	496.9	179.3	275.0	1305.3	404.3	1236.5	1282.6	1299.5	-967.8	-2758.3	-242.7	-924.0	-749.5
2025	170.6	-1355.9	528.1	198.4	295.4	1373.5	336.0	1308.9	1337.9	1368.2	-1032.3	-3047.9	-252.7	-941.0	-777.4
2026	172.5	-1530.7	558.0	220.9	316.4	1438.6	267.1	1378.1	1395.7	1433.6	-1093.6	-3328.5	-262.0	-953.9	-800.8
2027	174.4	-1699.7	586.7	244.7	337.8	1500.7	199.0	1444.2	1453.6	1495.8	-1152.0	-3598.3	-270.8	-964.1	-820.2
2028	176.3	-1861.4	614.2	269.0	359.4	1560.0	133.1	1507.4	1510.6	1554.8	-1207.4	-3856.0	-279.0	-972.7	-836.0
2029	178.2	-2016.1	640.5	293.0	381.0	1616.6	69.6	1567.8	1566.1	1610.6	-1260.2	-4101.9	-286.7	-980.0	-848.5
2030	180.1	-2164.2	665.7	316.8	402.6	1670.6	8.3	1625.4	1619.9	1663.3	-1310.4	-4336.6	-294.0	-986.4	-858.2
2031	182.0	-2304.5	689.7	339.9	423.9	1722.1	-49.8	1680.3	1671.8	1713.0	-1358.1	-4559.2	-300.9	-991.9	-865.3
2032	183.8	-2438.7	712.7	362.5	444.7	1771.2	-105.8	1732.8	1721.8	1759.6	-1403.5	-4771.6	-307.3	-996.9	-870.1
2033	185.6	-2565.8	734.7	384.2	465.1	1818.0	-158.7	1782.8	1769.8	1803.2	-1446.8	-4972.8	-313.5	-1001.4	-873.1

Table A5. Sensitivity analysis of cumulative net present value for the southern longline fishery under the 5 effort scenarios, assuming base case economic conditions (Table A2). All values are expressed in real millions US$2014.

	5% discount rate					3% discount rate					7% discount rate				
Year	**Effort squo**	**Catch squo**	**Cut first**	**Cut 2024**	**Cut 3%**	**Effort squo**	**Catch squo**	**Cut first**	**Cut 2024**	**Cut 3%**	**Effort squo**	**Catch squo**	**Cut first**	**Cut 2024**	**Cut 3%**
2013	75.4	75.4	75.4	75.4	75.4	74.0	74.0	74.0	74.0	74.0	76.9	76.9	76.9	76.9	76.9
2014	121.0	121.9	120.3	121.0	121.0	119.6	120.4	118.8	119.6	119.6	122.5	123.3	121.7	122.5	122.5
2015	134.9	80.8	160.1	134.9	136.1	133.8	78.5	159.4	133.8	135.0	136.1	83.0	160.8	136.1	137.3
2016	139.3	-4.8	198.6	139.3	144.0	138.3	-10.4	199.4	138.3	143.2	140.3	0.6	197.8	140.3	144.9
2017	146.8	-84.9	239.7	146.8	157.3	146.3	-95.2	243.0	146.3	157.2	147.4	-75.1	236.7	147.4	157.4
2018	154.5	-180.6	281.5	154.5	172.9	154.6	-198.6	288.1	154.6	174.2	154.6	-163.9	275.4	154.6	171.9
2019	159.4	-306.8	321.6	159.4	188.3	159.9	-337.6	332.3	159.9	191.0	159.0	-278.7	311.9	159.0	185.9
2020	161.9	-462.0	359.6	161.9	203.5	162.7	-511.8	374.9	162.7	208.1	161.2	-417.3	345.9	161.2	199.4
2021	163.5	-633.4	395.9	163.5	219.4	164.6	-707.9	416.4	164.6	226.3	162.6	-567.5	377.7	162.6	213.4
2022	165.1	-813.2	430.8	165.1	236.7	166.5	-917.5	457.1	166.5	246.5	164.0	-722.1	407.7	164.0	228.3
2023	166.9	-995.9	464.5	166.9	255.3	168.6	-1134.8	497.2	168.6	268.7	165.5	-876.3	436.1	165.5	244.0
2024	168.7	-1177.0	496.9	179.3	275.0	170.8	-1354.3	536.5	183.6	292.5	167.0	-1026.2	463.0	175.8	260.3
2025	170.6	-1355.9	528.1	198.4	295.4	173.1	-1575.3	575.0	207.3	317.7	168.6	-1171.6	488.3	191.3	276.9
2026	172.5	-1530.7	558.0	220.9	316.4	175.5	-1795.4	612.7	235.6	344.2	170.1	-1311.0	512.2	209.3	293.6
2027	174.4	-1699.7	586.7	244.7	337.8	178.0	-2012.4	649.6	266.2	371.6	171.6	-1443.2	534.6	227.9	310.4
2028	176.3	-1861.4	614.2	269.0	359.4	180.5	-2224.1	685.6	297.9	399.9	173.0	-1567.4	555.7	246.5	327.0
2029	178.2	-2016.1	640.5	293.0	381.0	183.0	-2430.6	720.7	330.0	428.8	174.5	-1683.9	575.6	264.7	343.3
2030	180.1	-2164.2	665.7	316.8	402.6	185.6	-2632.0	754.9	362.3	458.1	175.9	-1793.4	594.2	282.2	359.2
2031	182.0	-2304.5	689.7	339.9	423.9	188.2	-2826.6	788.3	394.4	487.6	177.2	-1895.2	611.6	299.0	374.6
2032	183.8	-2438.7	712.7	362.5	444.7	190.8	-3016.3	820.8	426.3	517.1	178.5	-1990.8	628.0	315.0	389.5
2033	185.6	-2565.8	734.7	384.2	465.1	193.4	-3199.4	852.4	457.6	546.4	179.8	-2079.6	643.3	330.3	403.7

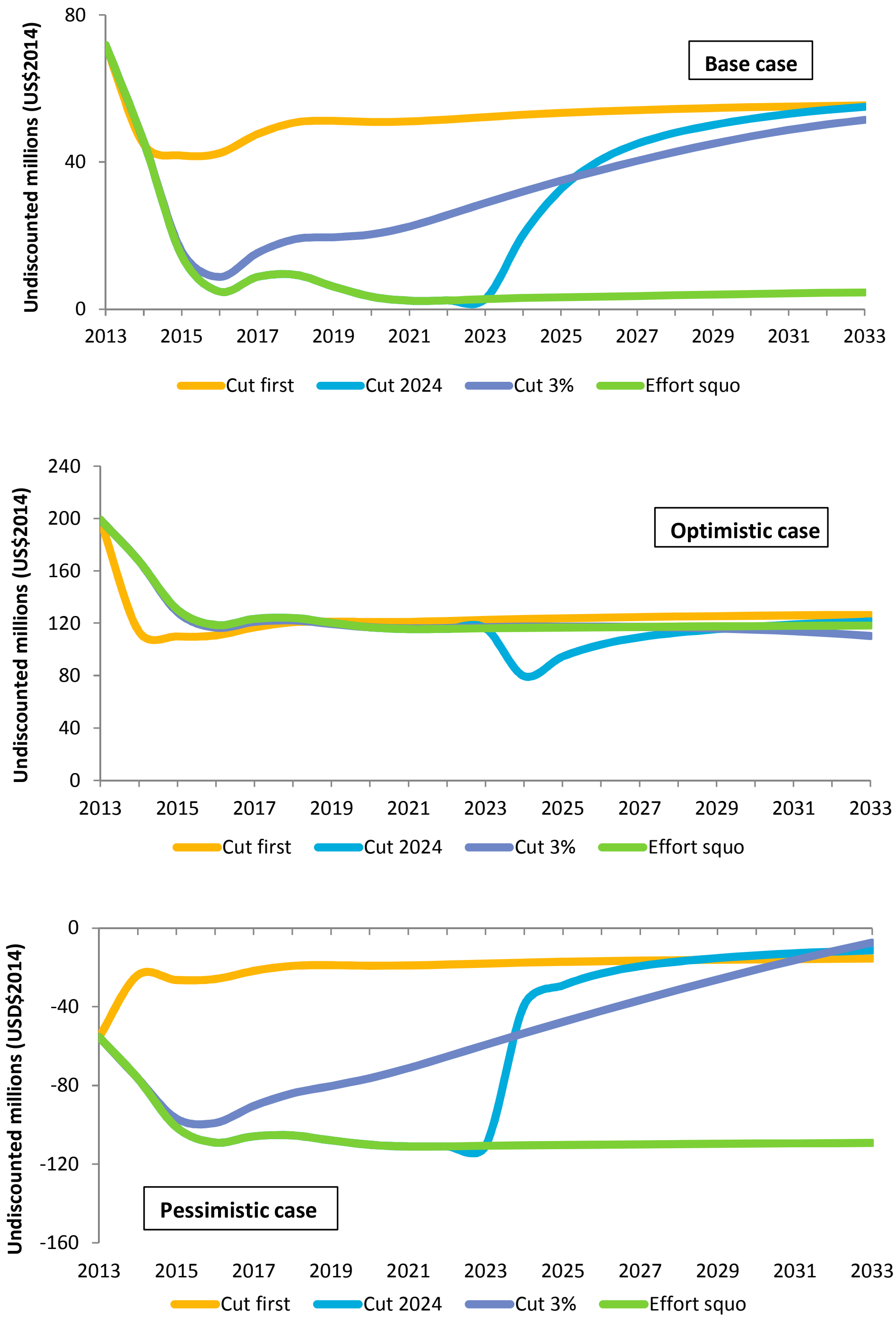

Figure A1. A comparison of undiscounted real annual profit in the southern longline fishery under different economic conditions (see Table A2).

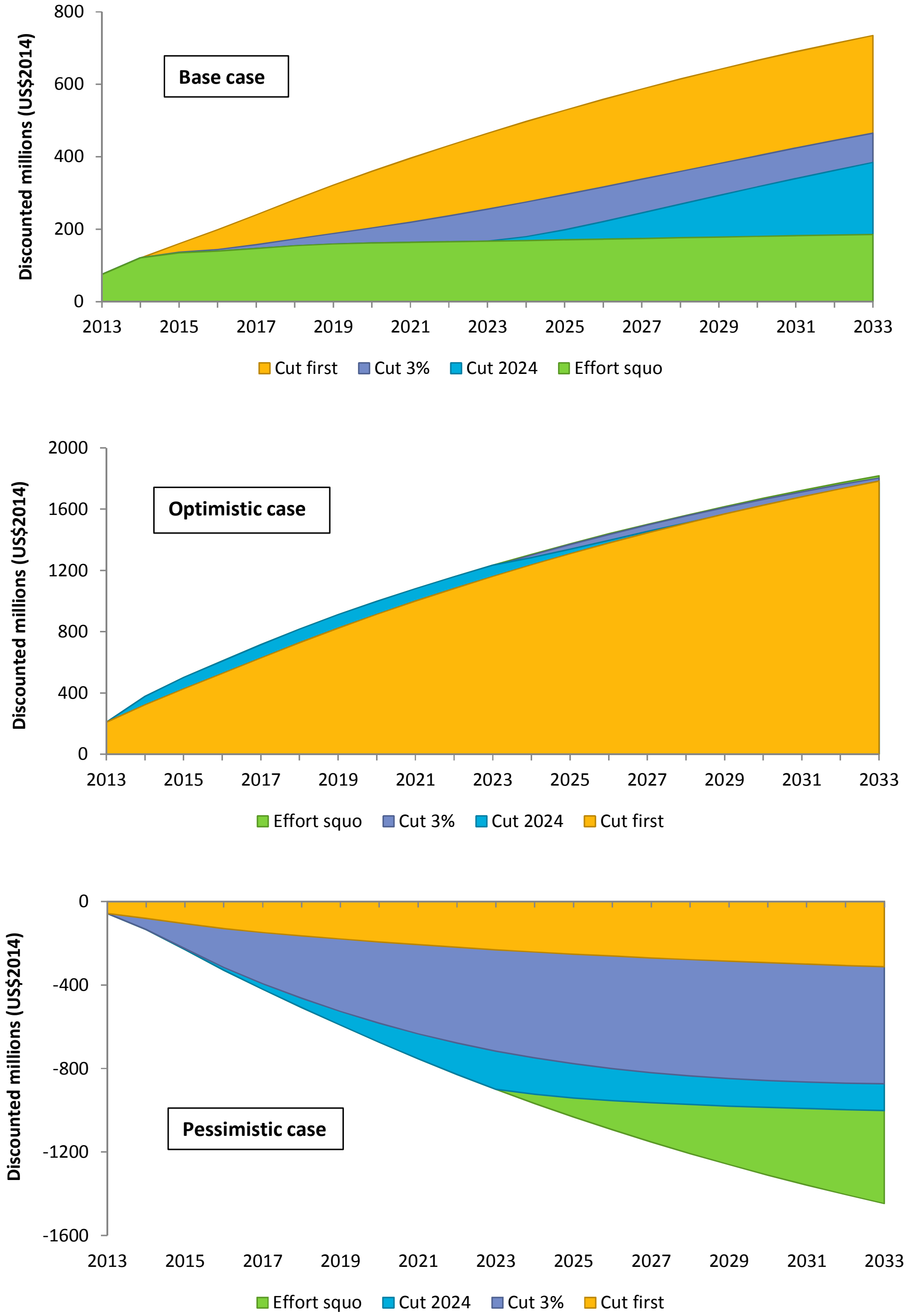

Figure A2. A comparison of net present values for the southern longline fishery under different economic conditions using a discount rate of 5% (see Table A2).