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Further consideration of candidate target reference points for bigeye and yellowfin tuna in the WCPO

WCPFC-SC16-2020/MI-WP-01

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Executive Summary

WCPFC16 requested SC16 to provide advice on the formulation of TRPs for bigeye and yellowfin tuna for candidate TRP indicators other than depletion ratio, such as longline CPUE. WCPFC16 further requested the Scientific Services Provider to conduct an analysis for bigeye and yellowfin tuna similar to that undertaken in WCPFC16-2019-14 for skipjack that could be presented to TCC16 and WCPFC17.

Where TRPs are selected to represent favourable conditions that may have occurred in the past (e.g. in CPUE), an important consideration is which sectors of the fishery should be represented in the TRP calculation. Both bigeye and yellowfin tuna are caught throughout the WCPO by a range of different fisheries and gear types. TRPs can be designed based on a combination of all of these gear types and fisheries or on some subset depending on how the stocks are intended to be managed and the preferences of managers. When identifying desirable fishery conditions based on CPUE, the short-term variability; the relationship between CPUE and stock abundance and the impact of recent management measures must all be taken into account.

Subject to the acceptance of the stock assessments for both bigeye and yellowfin, guidance is requested from SC16 on the range of settings that should be considered for the analyses. In particular:

- The model settings that should be considered for the stock assessment uncertainty grid and any preferential weighting that should be applied to the grid.
- The range of additional scenarios (if any) that should be considered for the future projections (e.g. alternative recruitment regimes).
- The range of target stock depletion levels that should be considered in the analysis (e.g. 30%, 40%, 50%).
- The time period(s) of the projections over which the depletion levels should be computed for comparison to candidate TRPs.
- Which fisheries should be projected on catch and which on effort.
- The baseline catch and effort values to which the scalers should be applied (e.g. average of the recent period 2016-2018).
- Noting that targets can be achieved across a range of different catch and effort scalers for the different gear categories, it would be useful if SC16 could provide guidance on limits for the relative scalers to apply to purse seine, longline and other fishery components.
- The outputs that should be reported from the analysis. The same outputs as the skipjack analysis are initially proposed.

1 Introduction

Reference points are benchmarks that allow managers to compare the current status of a stock, or performance of a fishery, to desirable (target), or undesirable (limit), levels. Often they are defined in terms of stock biomass or some level of biomass depletion. Limit reference points (LRPs) identify conditions, such as very low stock biomass levels at which recruitment can become impaired, that should be avoided with high probability. Target reference points (TRPs) are more closely associated with the defined management objectives for a fishery. They identify scenarios corresponding to desirable conditions in, for example, catches, revenue, or catch rates, and if achieved, result in a low probability of breaching the LRP.

Reference points are an important tool for fisheries management and a key component of the harvest strategy approach. Under CMM 2014-06 the Commission shall, taking into account advice from the Scientific Committee and other relevant subsidiary bodies, as appropriate, establish stock specific reference points that identify:

- targets intended to meet management objectives (target reference points, TRPs), and
- limits intended to constrain harvesting within safe biological limits (limit reference points, LRPs).

WCPFC has agreed an LRP of 20% of unfished biomass ($SB_{F=0}$) for all four tuna stocks based on the guidelines outlined in Preece et al. (2011). Acceptable levels of risk of breaching the LRP have not been agreed. However, WCPFC13 agreed that risk levels greater than 20% should be considered inconsistent with the LRP related principle in UNFSA and that, for the purpose of harvest strategy analyses, a range between 0% and 20% should be considered when determining the acceptability of potential HCRs (WCPFC13, paragraph 296). Ultimately, the choice of an acceptable level of risk may need to be informed by the associated trade-offs in other performance indicators from the results of MSE analyses (see below). In addition, interim TRPs have previously been agreed for skipjack tuna (50% SBF=0, CMM 2015-06[2]) and for South Pacific albacore tuna (56% SBF=0, WCPFC15, paragraph 207). However, TRPs have not yet been agreed for bigeye or yellowfin tuna.

To support discussions on TRP options, evaluations have previously been presented to WCPFC that determine minimum TRPs for bigeye and yellowfin tuna associated with given risk levels of breaching the LRP (SPC-OFP, 2019). These minimum TRPs were expressed in terms of stock depletion ($SB/SB_{F=0}$) and were determined solely from biological considerations. WCPFC16 requested SC16 to provide advice on the formulation of TRPs for bigeye and yellowfin tuna for candidate TRP indicators other than depletion ratio, such as longline CPUE. WCPFC16 further requested the Scientific Services Provider to conduct an analysis for bigeye and yellowfin tuna similar to that undertaken in WCPFC16-2019-14 for skipjack.

[2] We note that given the changed understanding of the stock's biology and perception of stock status provided by the 2019 assessment, discussions on the appropriate TRP value for skipjack tuna continue.

Recognising that new stock assessments for WCPO bigeye and yellowfin tuna will be presented to SC16, WCPFC16 tasked SC16 in 2020 to review the bigeye and yellowfin assessments, advise on the uncertainty grid and provide advice on the range of depletion for analysis. With regard to the range of depletion, the Commission tasked the Scientific Services Provider to conduct the analysis (based on the new assessments) and present their outcomes in 2020 to the TCC16 and WCPFC17.

In this paper, we provide an overview of the factors to consider when selecting TRPs for bigeye and yellowfin tuna in the WCPO. We consider a number of analyses and approaches that might inform TRP selection and we request advice from SC16 on the range of inputs and settings that should be applied.

2 Candidate target reference points

Candidate reference points for the management of fish stocks in the WCPO have previously been considered by the WCPFC (Norris, 2009; Harley et al., 2009) In 2009 a workshop of the WCPFC Methods Specialist Working Group reviewed various technical options for both target and limit reference points and noted the difficulty of identifying reference points based on socio-economic factors.

Many of the more traditional reference points used in fisheries management are based on the assumption of equilibrium conditions which assumes that the biological characteristics of the stock, such as recruitment, growth, maturity and natural mortality, as well as the overall selection pattern of the fishery remain fixed through time. Within WCPFC, TRPs have more often been expressed as levels of stock depletion associated with favourable conditions in the fishery and have therefore included consideration of social and economic factors. Both of these approaches depend on estimates of either fishing mortality or stock abundance from a stock assessment. TRPs can also be based on purely empirical measurements. Here we focus on the use of empirical quantities to inform TRP selection. Further details of TRPs based on depletion and equilibrium dynamics are provided in Appendix A.

2.1 TRPs based on empirical quantities

TRPs based on empirical quantities can have some clear benefits over those calculated from more theoretical assumptions. They can be expressed in terms of routinely measured quantities (catch, CPUE, etc.) which makes them easier to understand and more directly related to management actions. In addition, the metrics upon which they are based can often be calculated more easily, than those from, for example, a stock assessment, which means that monitoring progress against them can be conducted more frequently.

Empirical TRPs have, however, had mixed success. Whilst their simplicity can be appealing, it is often difficult to find empirical quantities that relate closely to stock status or that show consistent and reliable trends over time. Direct measurements of CPUE, for example, are rarely used in stock assessments and must be standardised beforehand to remove the effect of factors that can bias their measurement over time. Recent implementations of interim TRPs for WCPO skipjack and south Pacific albacore have instead been based on depletion levels corresponding to the expected status of the stock under desired catch, effort and associated economic conditions.

Specific to the request from WCPFC16, the design of TRPs based on CPUE will vary depending on the characteristics of the fishery in question, but will, by definition, comprise some measure of catch for a given amount of effort. Measurements of effort may include days fished; distance steamed; number of sets etc. depending on the type of information that can be collected from the fishery. Besides CPUE, TRPs can be informed by other metrics including, for example, the mean size of fish caught or the proportion of mature individuals in the catch.

3 Factors to consider when selecting a TRP

Several factors must be taken into consideration both when selecting a particular type of TRP to use, and when determining an appropriate value for it. Many of the more theoretical approaches for defining a TRP (outlined briefly in Appendix A) consider only the biological dynamics of the fishery and take little or no account of social or economic factors. For this reason, TRPs that have been implemented within WCPFC (often as interim measures) have been set to alternative values that include some consideration of the broader set of social, economic and ecosystem objectives associated with the management of the fishery.

Where TRPs are selected to represent favourable conditions that may have occurred in the past (e.g. in CPUE), an important consideration is which sectors of the fishery should be represented in the TRP calculation. Both bigeye and yellowfin tuna are caught throughout the WCPO by a range of different fisheries and gear types. TRPs can be designed based on a combination of all of these gear types and fisheries or on some subset depending on how the stocks are intended to be managed and the preferences of managers.

Time series plots of bigeye and yellowfin CPUE for a range of purse seine, longline and pole and line fisheries are presented in SC16-SA-WP-01. These figures and their accompanying descriptions give some indication of the recent trends and variability in CPUE that would be an important consideration when using this information to develop TRPs. For example bigeye CPUE for the tropical purse seine drifting FAD fishery has shown a general decline since 2013 which is likely related to FAD management measure that have been in force since that date. Conversely, bigeye CPUE for the tropical longline fishery has been more stable with recent trends showing a slight decline for the main distant water fisheries. When identifying desirable fishery conditions based on a target CPUE level, the short-term variability; the relationship between CPUE and stock abundance and the impact of recent management measures must all be taken into account.

3.1 Key sources of uncertainty with respect to TRPs

All three types of TRP, whether they are based on depletion estimates, equilibrium calculations, or empirical data, can be subject to uncertainty. Uncertainty can exist both in estimating the reference point itself and in the estimation of where the stock is in relation to it. Key sources of uncertainty that impact on the estimation of TRPs include the biological processes of growth, maturation and recruitment, as well as the characteristics of the fishery, specifically with regard to selection patterns. The sensitivity of reference points to these processes and in particular to steepness of the stock and recruitment relationship is well documented. The risk posed by this uncertainty can be mitigated to some extent by calculating TRPs across the range of scenarios in the stock assessment uncertainty grid. Uncertainty can also be reduced by expressing the TRP in terms of ratio estimators (e.g. $SB/SB_{F=0}$, SB/SB_{MSY}).

Particular care should be taken where these processes and characteristics might change over time. For example, management measures that modify the allocation of effort amongst different gear types can result in changes to the overall fishery selection pattern and may have consequences when comparing the current status of the fishery to some previously calculated TRP (Scott and Sampson, 2011). As such, identification of an appropriate TRP can be particularly difficult in complex multi-species and mixed-fishery situations. Reference points based on estimates of stock biomass, or depletion, are often more robust to uncertainty in fishery selectivity than reference points based on fishing mortality, CPUE or MSY.

4 Further analyses to be conducted

To progress the work to explore potential TRPs for bigeye and yellowfin tuna, WCPFC16 has requested that the Scientific Services Provider conduct an analysis of depletion based TRPs similar to that undertaken in WCPFC16-2019-14 for skipjack. This work is to be undertaken using the new assessments for bigeye and yellowfin that will be considered by SC16. We also note that ongoing work to develop harvest strategies for the four tuna stocks can also inform on potential TRPs.

4.1 Projections of stock status to inform TRP considerations

The requested analysis explores the consequences for future fishing opportunities of adopting different TRPs. It involves conducting a series of stochastic projections across the grid of assessment models to identify the fishery specific catch and effort multipliers that achieve a given stock status. This analysis has not yet been conducted pending the completion of stock assessments for WCPO bigeye and yellowfin tuna and the review of those assessments by SC16.

Subject to the acceptance of the stock assessments for both bigeye and yellowfin, guidance is requested from SC16 on the range of settings that should be considered for the analyses. In particular:

- The model settings that should be considered for the stock assessment uncertainty grid and any preferential weighting that should be applied to the grid.
- The range of additional scenarios (if any) that should be considered for the future projections (e.g. alternative recruitment regimes).
- The range of target stock depletion levels that should be considered in the analysis (e.g. 30%, 40%, 50% $SB_{F=0}$) and the time period(s) of the projections over which the depletion levels should be computed for comparison to candidate TRPs.
- Which fisheries should be projected on catch and which on effort (in general, purse seine fisheries have been projected on effort and longline and other fisheries on catch).
- The baseline catch and effort values to which the scalers should be applied (e.g. average of the recent period 2016-2018). While the baseline does not affect results, use of a more recent baseline is often more easily interpreted by managers, and more closely relates recent management decisions for the fishery.
- Noting that targets can be achieved across a range of different catch and effort scalers for the different gear categories, it would be useful if SC16 could provide guidance on limits for the relative scalers to apply to purse seine, longline and other fishery components.
- The outputs that should be reported from the analysis. The same outputs as the skipjack analysis are initially proposed (see SC16-MI-WP02).

With so many factors and potential scalers, the analysis outlined above can quickly become very large. The range of options to consider should, to the extent possible, be constrained to ensure the analysis is tractable and reflect realistic management alternatives. Time permitting, the results of these analyses can be presented to TCC16 and WCPFC17.

4.2 Management strategy evaluations

Although a management target may be defined in terms of achieving a given stock abundance, or depletion, fishery managers are more often concerned with achieving a broader set of management objectives that satisfy a range of social, economic and ecosystem considerations. The TRP is used to identify the stock and fishery conditions under which these various objectives might best be achieved. For example, to identify the stock size that would support a given catch, or catch rate, that would ensure profitability of the fishery. If all of the management objectives could be achieved simultaneously then the identification of an appropriate TRP would be straight forward. Unfortunately, management objectives often conflict and cannot be achieved simultaneously.

Under the MSE approach it is possible to evaluate the relative performance of different harvest strategies in meeting defined management objectives before they are implemented. Performance indicators calculated from the MSE evaluations allow the comparison of alternative management procedures and the identification of trade-offs in meeting objectives. Based on these results a TRP can be identified that specifies the fishery conditions that best achieve those objectives. Under this framework the identification of a TRP becomes less critical for management provided that the performance indicators give a reliable indication of likely outcomes. This is not to say that the identification of a TRP is unnecessary. Having a single clearly defined management target helps to focus negotiations and provides an important benchmark for evaluating performance. It also allows several performance indicators to be encapsulated in a single measurement.

We note that this approach is similar to the concept of PGY (pretty good yield) (Hilborn, 2010) which aims to identify a broad range of stock sizes at which acceptable, though perhaps not maximum, levels of yield can be achieved, thereby allowing other management objectives to be realised. This concept has been extended to include multi-species and mixed fishery considerations, PGMY (pretty good multi-species yield) (Rindorf et al., 2016), to try to provide a way to manage a complex mix of stocks and fisheries for which management objectives may be in conflict.

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A A brief description of equilibrium based TRPs

Target reference points can be formulated in many different ways, each one requiring different types of data and making different assumptions about the dynamics of the fishery and the biology of the stock. At the broadest level they can be grouped into 3 categories. Depletion based TRPs specify a given level of impact that a fishery should have on the stock; TRPs based on equilibrium assumptions define the likely conditions under constant fishery dynamics; and TRPs based on empirical quantities use measurable quantities as proxies for stock status.

A.1 TRPs based on depletion

Depletion is a relatively simple measure of the impact that fishing has on the population. It is defined as the estimated population state at a point in time (or averaged over a period of time) relative to the population state that would have occurred in the absence of fishing[3]. It is often calculated in terms of spawning biomass ($SB/SB_{F=0}$). For the definition of reference points, WCPFC employs two slightly different formulations of depletion that use either the population state in the last year of available data, t (Eqn 1) or the average population state in the recent period (Eqn 2). In both cases the unfished population is calculated as the average over the recent 10 year period with a lag of 1 year.

$$\frac{SB_{latest}}{SB_{F=0}} = \frac{SB_t}{SB_{F=0,\ t-10\ to\ t-1}} \tag{1}$$

$$\frac{SB_{recent}}{SB_{F=0}} = \frac{SB_{t-3\ to\ t}}{SB_{F=0,\ t-10\ to\ t-1}} \tag{2}$$

Metrics based on depletion can be more robust to some of the main sources of uncertainty that impact on TRPs, such as the steepness of the stock and recruitment relationship and changes in the fishery selection pattern. However, the estimation of depletion relies on a stock assessment which may be conducted only once every three years and, where time lags in data availability occur, may not provide estimates for the most recent years.

A.2 TRPs based on equilibrium dynamics

The term equilibrium conditions describes a fishery for which key the processes of mortality, growth, recruitment and fishing are constant from one year to the next. Under these hypothetical conditions the age structure of the population, the quantity of catch and the fishing effort required to

[3] For the determination of reference points, absence of fishing typically refers to the absence of all fishing. Depletion can also be calculated based on the absence of just one fishery, or fishery group, allowing the relative impact of different fishing sectors to be determined.

take that catch do not change over time. Because external drivers such as environmental and economic conditions are both highly influential and highly variable in tuna fisheries, true equilibrium conditions are rarely, if ever, achieved.

A relatively simple measure of the effect of fishing on a population can be calculated as the yield per recruit (YPR), which measures the amount of yield that can generated from a single recruit for a given level of fishing. The calculation of YPR assumes fixed, time invariant values of growth, maturity and natural mortality of the stock and size selectivity of the fishery. Since it is computed as a relative "per recruit" measure, YPR is insensitive to changes in recruitment due to environment or stock size. Alternative fishing mortality rates can then be investigated to explore the trade-off between the processes of biomass increase through growth and biomass decrease through natural mortality and fishing. The point at which this trade-off is optimised, in terms of yield, is the maximum YPR and the corresponding fishing mortality rate is F_{MAX}. A slightly more conservative measure, based on similar calculations, is $F_{0.1}$ which is calculated as the fishing mortality rate corresponding to a slope of the YPR curve of 10% of its slope at the origin. This point will always imply a fishing mortality rate lower than F_{MAX}. F_{MAX} is considered potentially useful as a limit reference point in some situations and $F_{0.1}$ has been widely used as target. Both are relatively easy to calculate, but neither takes account of changes that may occur in recruitment with changing stock size and therefore provides little information with regards recruitment overfishing.

Another very similar measure can be calculated as the spawning biomass per recruit (i.e. the spawning biomass that would occur for each individual fish that recruits to the population). This can also be expressed as a ratio relative to the spawning biomass, per recruit, that would be expected to occur in the absence of fishing. This metric is termed the spawner-per-recruit or the spawning potential ratio (SPR) and is typically expressed as the level of fishing mortality that achieves a given ratio ($F_{x\%SPR}$).

A.2.1 MSY and MEY

Perhaps the most widely used equilibrium based reference point is the maximum sustainable yield (MSY), which is defined as the maximum catch that can be sustained by the fishery under equilibrium conditions. Similar to the calculation of SPR, the assumption of equilibrium conditions implies that the biological characteristics of the stock, such as growth, maturity and natural mortality, as well as the overall selection pattern of the fishery remain fixed through time. Alternative fishing mortality rates can then be investigated to explore the trade-off between the processes of population increase (recruitment and fish growth) and the processes of population decline (natural mortality and fishing). The point at which this trade-off is optimised, in terms of yield, is the MSY and the corresponding fishing mortality rate and stock biomass represent F_{MSY} and B_{MSY} respectively.

Recognising that the priority management objective may be to maximise revenue from a fishery rather than simply achieve the maximum yield, the concept of maximum economic yield (MEY) has been proposed. MEY represents the catch level where the difference between total fishing costs and total revenue is greatest and profits are maximised. Similar to MSY, it is calculated under the assumption of equilibrium conditions. Although MEY is relatively simple in concept, its calculation and practical application can be very difficult since it relies not just on good information on stock structure, biology and fishing patterns, but also on detailed information on the fishery specific fixed and variable costs of fishing[4].

[4]The FFA is working with WCPFC members to establish guidelines for the voluntary submission of economic data to the Commission. Intersessional work is required to further develop such guidelines and any associated documents required with regard to the confidentiality and use of any economic data provided under this process