CCSBT-ESC/2108/Info 01
(ESC Agenda item 16)

Oceans & Atmosphere
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Developing a Point of Recruitment Impairment (PRI) for Southern Bluefin tuna

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Abstract

The Marine Stewardship Council (MSC) defines its Principle 1 sustainability criterion in terms of the concept of a Point of Recruitment Impairment (PRI). In the MSC guidelines a decision tree applies to the definition of a default PRI when an analytical estimate is not available - in the CCSBT case that default PRI is at 20% of the unfished adult population abundance. The CCSBT Management Procedure is defined in terms of meeting *future* relative adult abundance targets, not current ones. This paper outlines the calculation of a candidate analytic PRI for SBT using the steepness and relative adult abundance level. We also calculated the probability being above the MSC-defined risk criteria for historical population abundance estimates from the most recent stock assessment.

1 Background

The Commission for the Conservation of Bluefin Tuna (CCSBT) has, since 2011, used a fully simulation tested Management Procedure (MP) as the method of providing management advice. In 2011 [1] the MP was driven by long-line CPUE and juvenile biomass indices; in 2020 [2] a new MP was adopted and implemented using long-line CPUE alongside a gene tagging index of 2 year old SBT and Close-Kin Mark-Recapture data to estimate the adult abundance and mortality. In 2011 the interim rebuilding target was 20% of the unfished SSB, B_0, to be attained by 2035 with a probability of 0.7. In 2020, given more favourable recruitment and recent SSB depletion estimates, the rebuilding criterion was adjusted to achieve a depletion level of 30% by 2035 with probability 0.5. The key point is that the CCSBT uses fully evaluated MPs tuned to meet specific risk criteria for SSB depletion levels **at pre-specified points in the future** as a basis for management advice. The CCSBT Scientific Committee and Commission doesn't use *current* stock status to provide management advice - it does use current status to report on the progress of the rebuilding strategy over time but not in setting quotas [2]. The reasons for the CCSBT taking this approach are well documented and supported by nearly two decades of research [1, 2]. They do differ, however, with how the Marine Stewardship Council (MSC) approaches the concept of sustainability in its Principle 1 guidelines: MSC standards. For the MSC the primary sustainability condition for the target species of interest is couched in terms of a Point of Recruitment Impairment (PRI) - a limit reference point for the reproductive part of the stock (using which ever proxy is applied e.g. spawning stock biomass). Given the variable way in which stock status metrics are derived and reported across various fisheries around the world the MSC defines a type of decision tree for how to define the PRI for a particular stock. From the MSC's documentation the conditional sequence, in relation to SBT, is:

1. The *analytical* estimate of $B_{\mathrm{msy}}/B_0 < 0.4$
2. There is no *analytical* estimate of the PRI
3. The default PRI is that $\mathbb{P}\left(TRO/TRO_0 > 0.2\right) \geq 0.7$

We interpret the use of the word "analytical" above to mean derived from estimated, measured, and assumed variables in the stock assessment, which in the case of CCSBT, is TRO, the Total Reproductive Output of the stock in a given year (with TRO_0 being what we would expect in the absence of fishing).

The CCSBT, and indeed arguably most of the other tuna RFMOs, have not focussed on deriving what could be interpreted as an analytical PRI for their stocks. Indeed most of the tuna RMFOs limit reference points are expressed in terms of 20% of the unfished state with a variety of different risk criteria attached to that - this is probably why the MSC uses a specific condition relating to this status level in its default PRI. In the past, the CCSBT has outlined some more empirical historical reference points which could be related to the concept of the PRI. Many years ago the spawning stock biomass (SSB - used prior to the inclusion of the CKMR data) depletion in 1980 (REFS) was discussed as the point in time where estimated mean recruitment began to decrease as the SSB decreased further; as a result it is used as the basis for the interim rebuilding target. So, this was a more empirical type of PRI and would arguably not be considered *analytic*. Also, while some features of the SSB and recruitment estimates from more recent stock assessments still display that trend in the 1990s and through the early 2000s, the more recent better estimates of average recruitment (comparable with the lower end of the estimates from the 1960s through to 1980) complicates that observation. Given this, our main observation is that historical empirical PRI-like observations are not likely to prove a robust and defensible proxy for an analytical PRI for SBT. In this paper we provide a derivation of PRI that we consider consistent with the intent of the MSC guidelines that can be calculated with the available output from the CCSBT Operating Models used for the regular assessment of stock status and testing on MPs.

2 Methods

This section outlines an approach to deriving an analytical PRI for SBT based on the available (and agreed) stock status and productivity information for the stock. The key reference in this specific space is Myers *et al.* (1994) [3]. Since publication, this paper has informed a lot of the progression from "what is a good SSB depletion level?" to "what depletion levels correspond to bad levels with respect to recruitment overfishing?". This is the key focus of the PRI. Below is the full abstract for [3]:

"*In this study we consider the problem of estimating, for management purposes, a minimum biomass reference level at which recruitment to a fish stock is seriously reduced. We take an empirical, comparative approach to the problem by examining observations on a wide range of fish stocks. Eight methods for estimating spawning stock biomass thresholds for recruitment overfishing are investigated. Their behaviour is tested using stock and recruitment data for 72 finfish populations, each with at least 20 years of data. We considered three classes of thresholds defined by: (1) the stock size corresponding to 50% of the maximum predicted average recruitment; (2) the minimum stock size that would produce a good year class when environmental conditions are favourable; and (3) the stock size corresponding to 20% of various estimates of virgin stock size. The estimators of the first type are generally preferable because they are easily understood, relatively robust if only data at low stock sizes are available, and almost always result in higher levels of recruitment above the threshold.*"

The high-level conclusion from Myers *et al.* [3] is that, specifically in relation to thresholds for recruitment overfishing (i.e. PRI), a better approach than defaulting to 20% of the mature biomass depletion for the PRI would be the mature biomass depletion at which the mean recruitment level is at 50% of the *maximum* recruitment. The maximum recruitment condition requires some interpretation through whatever the particular stock-recruitment curve is assumed. For the Beverton-Holt model used in the SBT assessment model there are two potential interpretations:

1. With an expected relationship between mean recruitment, R, and mature biomass, S, as

follows:

$$R = \frac{\alpha S}{\beta + S}$$

then the maximum recruitment occurs at $S = \infty$ and the value is $R = \alpha$. This interpretation doesn't really follow logically because $S = \infty$ is not attainable without some sort of consistently increasing recruitment trend, which is impossible given the formulation of the model where dR/dS monotonically decreases as S increases.

2. For the Beverton-Holt model the maximum long-term average recruitment would be at $F = 0$ and would effectively be $R_0 = \alpha S_0/(\beta + S_0)$, where S_0 is the unfished equilibrium mature biomass (an estimated parameter of the SBT assessment model). This interpretation makes more sense in terms of what constitutes an attainable maximum long-term average recruitment level to be used in the calculation of a PRI.

Proceeding using this definition (R_0) for maximum recruitment, what we need to calculate to get the PRI reference point, $\mathcal{R}$, is the following:

$$\mathcal{R} = \frac{R}{R_0} = \frac{\alpha S}{\beta + S} \times \frac{\beta + S_0}{\alpha S_0} \tag{2.1}$$

Given that both α and β depend on steepness (the key recruitment resilience parameter in the assessment) in a moderately complex way, the details of the derivation of the key PRI statistic are moved to the Appendix. In the SBT assessment we use the concept of Total Reproductive Output (TRO), rather than the mature biomass proxies often used. The final formula depends on two key stock assessment outputs: relative TRO for each year (i.e. $\Delta_y = TRO_y/TRO_0$) and the steepness value of that particular grid cell, h:

$$\mathcal{R} = \frac{4h\Delta}{h\,(5\Delta - 1) + 1 - \Delta} \tag{2.2}$$

which, at a high level, behaves as one would intuit: at $h = 1$ when recruitment is independent of TRO, $\mathcal{R} = 1$; when $h = 0.2$ where recruitment is linearly related to TRO, $\mathcal{R} = \Delta$. Therefore we argue that an analytic estimate of a PRI that is consistent with the recommendations of [3], as opposed to the proxy used in the absence of an analytic PRI, is readily calculable from two pieces of information: the steepness in the uncertainty grid and the relative TRO. Both these pieces of information have been agreed and approved within the CCSBT Scientific Committee and Commission and are provided in CCSBT reports [2].

If one follows the same risk requirements as used for the PRI proxy (i.e. probability of 0.7 of exceeding the PRI) then the full requirement is that $\mathbb{P}\,(\mathcal{R} > 0.5) \geq 0.7$. The risk level would be calculated across the full uncertainty grid used within the reference set of OMs employed in the most recent CCSBT stock assessment [2].

3 Results

Figure 1 shows the probability of exceeding the PRI - i.e. $\mathcal{R} > 0.5$ - as defined in Eq. (2) over time, given the most recent estimates of both steepness and relative TRO. The probability of exceeding the PRI falls below 0.7 by around 1996 and only increases above 0.7 in 2015 increasing to a probability of just below 0.9 by 2020

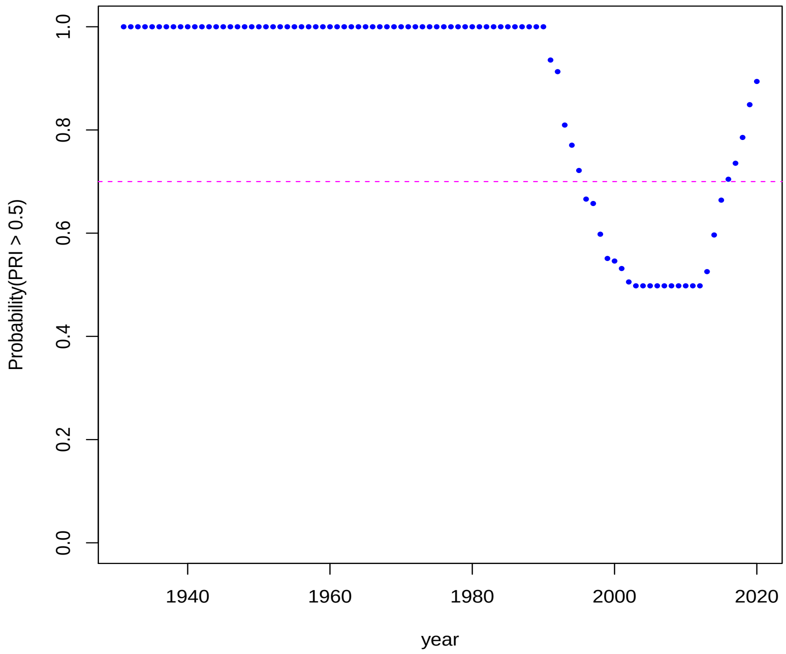

Figure 3.1: *Probability of exceeding the PRI over time (blue dots) with the critical threshold of 0.7 the dotted magenta horizontal line.*

While coincidental, the default PRI condition ($\mathbb{P}\left(TRO/TRO_0 > 0.2\right) \geq 0.7$), was embedded within the performance requirements of the Bali Procedure implemented in 2011 [1] as the interim rebuilding objective and key tuning criterion. In the Cape Town Procedure (CTP) implemented in 2020 [2] it was a performance statistic to be met (or exceeded) alongside the tuning criterion of reaching 30% relative TRO in 2035 with probability 0.5. Specifically for the reference set of Operating Models (on which the stock assessment was based) Figure 2 shows $\mathbb{P}\left(\Delta > 0.2\right)$ over time for the adopted CTP projecting forward in time from 2020 to 2050. The stock is projected to exceed the 70% risk level between 2022 and 2023. The main point of comparing these two is to demonstrate that, qualitatively speaking, they broadly agree in terms of trends - especially recently (and into the future for the MP).By deriving an analytical PRI we are not creating an alternative to the default proxy of $\mathbb{P}\left(TRO/TRO_0 > 0.2\right)$, we are simply looking to derive a statistic that is consistent with the intent of the PRI concept specified in the MSC guidelines.

4 Discussion

In this document we have outlined the rationale for, and calculation of, a suitable Point of Recruitment Impairment (PRI) for Southern Bluefin Tuna, which we consider consistent with the MSC guidelines, as well as an assessment of the recent status of the stock relative to the specified PRI. The purpose is purely focussed on the calculation of an analytical PRI consistent with requirement of the Marine Stewardship Council's Principle 1 sustainability criteria based on readily accessible outputs from the regular CCSBT stock assessment. This work is has no bearing on

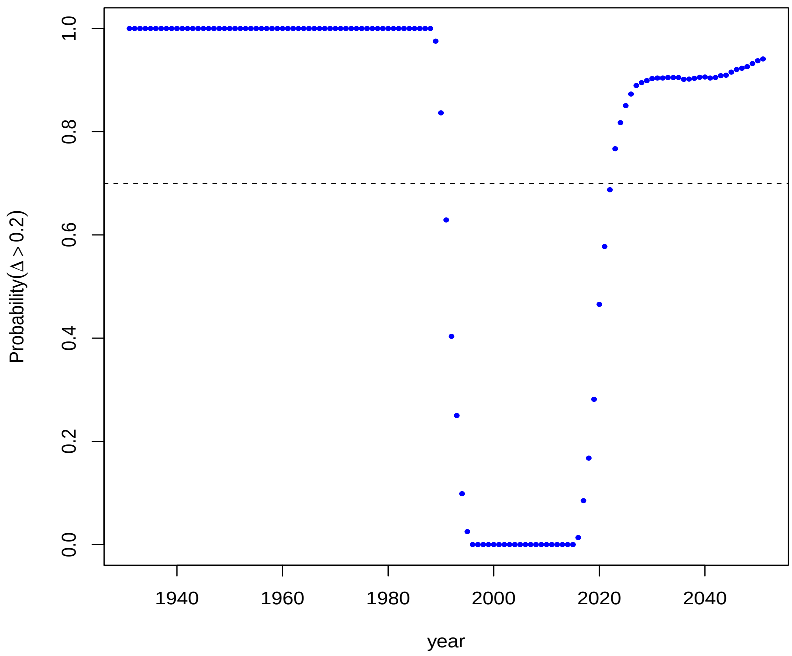

Figure 3.2: *Probability of exceeding a relative TRO of 0.2 historically and projected out to 2050 for the CTP as implemented by the CCSBT. The dotted line denotes the 70% probability level.*

the Management Procedure work recently completed in 2019 and then implemented in 2020 [2] and is not presented as an alternative reference point for consideration within the CCSBT Scientific Committee and Commission.

Broadly speaking, tuna RFMOs have not focussed on deriving analytical PRIs for the various stocks they manage, so there were no existing examples from which to base an assessment against this MSC criterion. The work herein instead focussed on the recommendations of the key paper in this area [3] which concluded, using data across 72 different stocks with at least 20 years of data per stock, that the PRI is best defined in terms of the relative reproductive potential that results in a mean recruitment of 50% of the unfished level. We outlined how this PRI can be derived and readily calculated using only the estimates of the distribution steepness and relative TRO over time from the most recent SBT stock assessment [2].

Using the analytical PRI we assessed the historical and recent status of the SBT stock relative to the derived PRI, given the pre-specified critical risk criteria of a probability of 0.7 from the MSC guidelines. The SBT stock fell below the 0.7 level by around 1996 and did not rise above that level until around 2015, after which it continued to increase as the stock slowly rebuilt to a probability of just below 0.9 by 2020. The qualitative trends in the calculated PRI mirrored those of the CCSBT-focussed probability of being above 20% of the unfished TRO, indicating a level of qualitative consistency between the two measures, from the most recent assessment of stock status. The overarching conclusion is that, for the specified derivation of an analytical PRI for SBT, based on the most recent CCSBT stock assessment, the current status of the stock (as of 2020) is well above the 0.7 risk criterion with an increasing trend both recently and into the future based on projections under the current MP.

5 Acknowledgements

This work was funded by the Australian Fisheries Research and Development Corporation and CSIRO.

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Appendix

We need to get a definition for the PRI variable, $\mathcal{R}$:

$$\mathcal{R} = \frac{R}{R_0} = \frac{\alpha S}{\beta + S} \times \frac{\beta + S_0}{\alpha S_0}$$

in terms of the steepness, h, and the relative adult biomass, $\Delta = S/S_0$. The parameters α and β are defined as follows:

$$\alpha = \frac{4hR_0}{S_0(1-h)},$$
$$\beta = \frac{5h-1}{S_0(1-h)}.$$

If we now replace these relationships in Eq. (1) we get the following:

$$\mathcal{R} = \frac{\frac{4hR_0 S}{S_0(1-h)}}{R_0\left(1 + \frac{5h-1}{S_0(1-h)}S\right)}$$

and multiplying the numerator and denominator by $1-h$ we obtain

$$\mathcal{R} = \frac{4h\Delta}{5h\Delta - h + 1 - \Delta} = \frac{4h\Delta}{h(5\Delta - 1) + 1 - \Delta}$$

which is now defined only in terms of h and Δ as required $\square$.

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