Selection of acceptable levels of risk for South African small pelagics: the probability of dropping below pre-defined risk thresholds

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This document considers alternative methods to define acceptable risk levels – or acceptable probabilities of dropping below limit-like reference or "risk" thresholds - for use in tuning Candidate Management Procedures for the South African sardine and anchovy resources. The document focuses on the sardine resource only and is written to provide background information to the key question to the panel "How do we best select the acceptable probability of dropping below a risk threshold?"

Background

The control parameters of the joint Operational Management Procedures (OMPs) for South African sardine and anchovy have historically been tuned so that the simulated future biomass avoids a pre-defined risk threshold with a selected probability.

de Moor (2017) has provided information regarding the selection of appropriate risk thresholds. This document considers alternative "risk levels", or the acceptable probability of dropping below a pre-defined risk threshold, and focusses only on sardine. For the past three OMPs the risk levels have been:

> $risk_S$ - the probability that simulated total sardine 1+ biomass falls below the average total sardine 1+ biomass between November 1991 and 1994 at least once during the projection period of 20 years

with the risk levels being 0.1 for OMP-04 (de Moor et al. 2011), 0.18 for OMP-08 (de Moor and Butterworth 2016), 0.21 for OMP-14 (de Moor and Butterworth 2014).

A pre-defined risk level has not previously been deemed acceptable for South African small pelagics given changes in the Operating Model (OM) from one OMP to another. In particular, increases or decreases in the estimated natural variability of the resource (closely linked to increases or decreases in the estimate of σ_R given the short-lived nature of this species) could result in an expected increase or decrease in the resilience of the resource to reduction to a low level. For example, given a higher σ_R, the resource would be expected to be simulated to drop below the risk threshold more frequently, even under a no catch scenario. Changes in natural mortality assumptions from one OM to another also impact the extent to which biomass fluctuates with or without fishing.

An objective method (described below) has previously been sought to assist in calculating the acceptable risk level for new OMPs. It is expected that this method may not be straightforwardly applied to sardine in changing from OMP-14 to OMP-18 given, in particular, the focus on risk to the west component instead of risk to the total sardine resource, and a probable change to the risk threshold (de Moor 2017).

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Previous Method

The method previously used to inform on appropriate risk levels has considered the distribution of simulated sardine total biomass at the end of the 20 year projection period. Comparison was then made of the "leftward shift" in this distribution from a no future catch scenario, to that under a catch scenario, with the biomass distribution being moved further to the left for higher risk levels. The difference in these distributions at the lower percentiles were considered quantitatively. Higher percentiles were not considered given their lower importance to resource risk. One could argue to consider the extreme lower percentiles of these distributions (e.g. 5 or 10%ile) given risk is considering the probability of "something bad" happening to the resource. However, given these a-symmetrical distributions were only calculated from 1000 draws from the posterior distribution, it was previously decided that the risk level should be adjusted such that the ratio of catch to no catch under a new OMP be the same as that under the previous OMP at the 20%ile of these distributions, while being similar at the 10, 30, 40 and 50%iles. Figure 1 and Table 1 demonstrate this.

Discussion

- In evaluating whether a Harvest Control Rule (HCR) for a management plan conforms with the Precautionary Approach, ICES (2013) requires the probability that the (spawning) stock biomass is below the limit biomass reference point (B_{lim}) should not exceed 5%. ICES (2013) acknowledges the influence of the choice of OM on this probability and advises that such OMs should consist of realistic assumptions and encompass the range of situations considered plausible in reality. The Management Strategy Evaluation should include robustness testing to plausible uncertainties including alternative structural models. ICES (2013) however fails to clarify whether in the case of multiple OMs, they consider that the 5% probability criterion should apply for every OM, or for some weighted integration over the OMs.
- For some short-lived species ICES management involves an "escapement strategy" with the TAC being set such that there is a sufficiently high probability of $SSB>SSB_{lim}$. No catch is allowed unless this escapement can be achieved. This strategy is naturally highly dependent on incoming year classes and requires a good early indicator of recruitment (ICES 2013).
- ICES (2013) note that for short lived species the risk of falling below B_{lim} even in the absence of fishing may be higher than 5% and caution if B_{lim} has been appropriately defined in these cases. In these cases they recommend "Prob1" (see below) to be a more adequate measure of risk than "Prob2" (see below) and in cases where risk is >5% even in the absence of fishing they recommend allowing a risk which is some multiple (> 1) higher than that in the absence of fishing, but lower than a maximum level that should not be exceeded.
- The most recent computations have evaluated each risk threshold in three ways:

i) The probability of being below the risk threshold at least once during the projection period of 20 years - this very stringent risk criterion has been used for previous OMPs for South African sardine and anchovy

- given the current relatively low (spawner) biomass level for the sardine west component this probability is rather high compared to what would result for the resource starting from closer to its average historical abundance[1]
- doesn't take any probability of recovery into account
- corresponds to ICES (2013) "Prob2".

ii) The probability of being below the risk threshold during the projection period of 20 years
- this considers the average risk over the projection period
- corresponds to ICES (2013) "Prob1".

iii) The probability of being below the risk threshold at the end of the projection period of 20 years
- this considers the risk once the transient influence of the starting point has dissipated, and together with i) or ii) can help inform between candidate MPs which allow for some recovery over time.

- Risk evaluated using i) can be considerably larger than that from ii) for stocks with low autocorrelation in spawner biomass, typical of short-lived species (ICES 2013).
- Ideally one would want HCRs to be sufficiently flexible that should future biomass drop below a risk threshold, there is a high probability of the biomass 'rapidly' increasing above the threshold. In past OMPs, this has been implicitly considered by ensuring that the poorest (in terms of minimum biomass) simulations result in a short-term increase in biomass once Exceptional Circumstances components of HCRs come into play, with the Exceptional Circumstances rules (functional shape, thresholds) adjusted during MP development to ensure this.
- When performance in terms of medians and of lower 5%-iles differs substantially in terms of acceptability, how best can one rationalise any specific choice of %-ile as the basis for recommendations?

Discussion Points

Discussion (including drawing from examples in fisheries where the panel have worked) and recommendations towards the following questions are sought:

i) How should we best define an acceptable risk level, where risk level is defined in terms of the probability of dropping below (once off or on average) a pre-defined risk threshold.

ii) In particular, how does one "sell" a high risk level. Should one continue fishing if the (currently estimated) risk to the resource is high even under a no fishing scenario. For example, is it better to focus on the difference in risk compared to the zero catch case?

It is worth noting that while an objective method to define a risk level would be best, following substantial changes (in stock recruitment relationship and natural mortality) in the anchovy baseline operating model from that used to develop OMP-08 to that used to develop OMP-14, the method outlined in Figure 1 and Table 1 didn't provide a satisfactory result for anchovy. The Small Pelagic Scientific Working Group subsequently selected a risk level of 0.25 for OMP-14 on a more *ad hoc* basis after considering the results for a range of risk levels (e.g. de Moor and Butterworth 2014).

[1] For anchovy this risk is higher for longer term projections due to the wide uncertainty in simulated future biomass over time.

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Table 1. The ratio of the percentiles of the distribution of sardine biomass at the end of the projection period under an OMP to a no catch scenario. The risk level, $risk_S$, is defined as the probability that simulated total sardine 1+ biomass falls below the average total sardine 1+ biomass between November 1991 and 1994 at least once during the projection period of 20 years. A comparison is made to the ratio of the percentiles for previous OMPs to inform the appropriate level of risk for a new OMP. In general, higher levels of risk result in higher ratios (greater depletion) and lower levels of risk result in lower ratios (lower depletion). Shaded cells represent cases for which the predicted ratio (depletion) is more pessimistic than that used for the immediately preceding OMP.

	OMP-04/No catch	OMP-08/No catch	OMP-14/No catch
	$risk_S$<0.10	$risk_S$<0.18	$risk_S$<0.21
10%ile	0.59	0.50	0.59
20%ile	**0.68**	**0.68**	**0.68**
30%ile	0.69	0.72	0.73
40%ile	0.71	0.73	0.76
50%ile	0.72	0.72	0.78

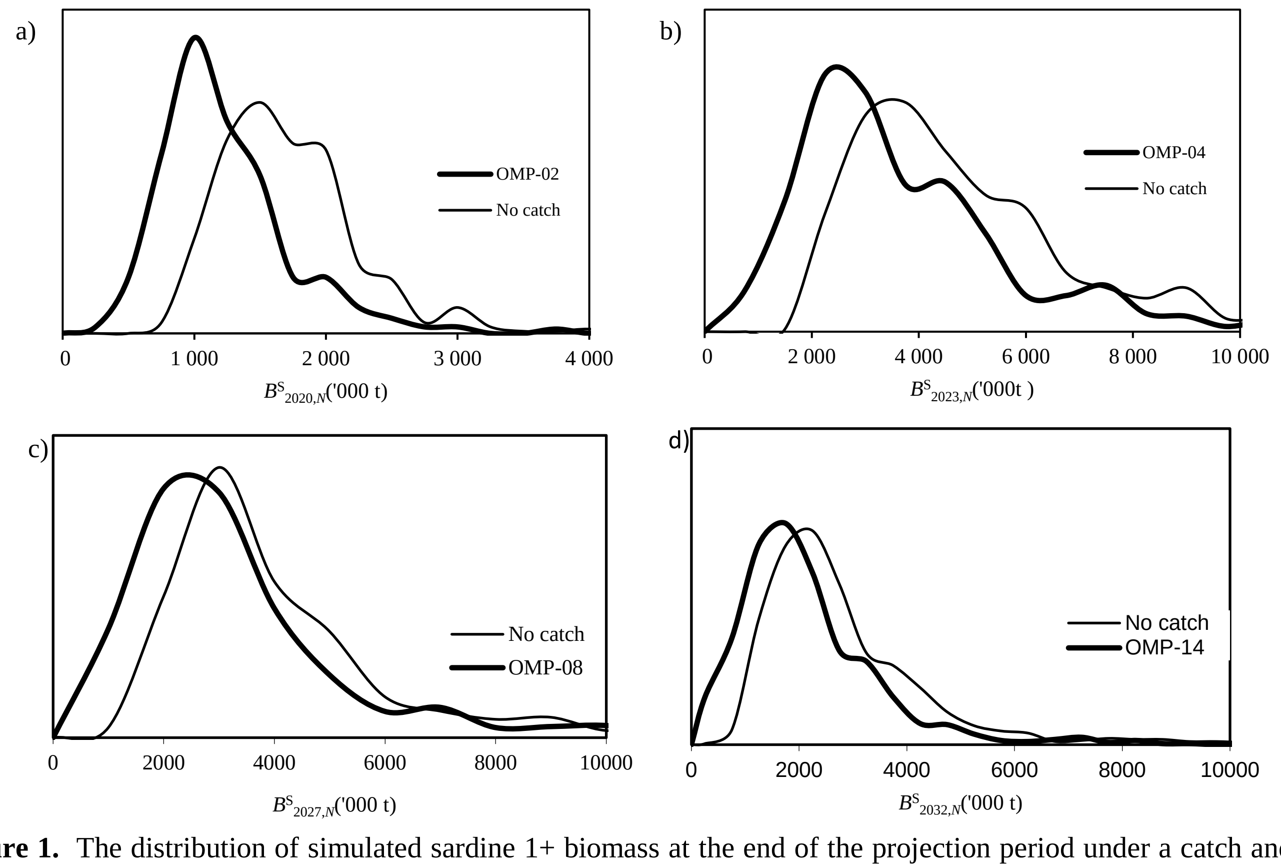

Figure 1. The distribution of simulated sardine 1+ biomass at the end of the projection period under a catch and no-catch scenario. Comparisons are shown for a) OMP-02 (projections to 2020 based on an OM developed using data up to November 1999, from de Moor et al. (2011)), b) OMP-04 (projections to 2023 based on an OM developed using data up to November 2003, from de Moor et al. (2011)), c) OMP-08 (projections to 2027 based on an OM developed using data up to November 2006, from de Moor and Butterworth (2016)), and d) OMP-14 (projections to 2032 based on an OM developed using data up to November 2011, from de Moor and Butterworth (2014)). The previous method involved trying to match the "leftward shift" from a no catch to a catch scenario in these distributions when moving from one OMP to the next. This was quantitatively evaluated at the 20%ile (see Table 1).