An example contrasting TAC behaviour under target- and slope-based empirical management procedures

R.A. Rademeyer and D.S. Butterworth

The current OMP for South African hake is, at basis, an empirical MP using a **target-**based approach, i.e. the TAC is adjusted up or down each year in relation to the extent to which the recent average of a composite index of abundance is above or below a target level (see MARAM/IWS/2017/BG9). That level is a control parameter of the MP which is tuned to provide the desired performance in terms of the trade-off between average catch and risk of undesired biomass reduction.

Previously a basically **slope**-based procedure was used, where the TAC was adjusted up or down depending on the sign and magnitude of the recent trend in that composite index. The target-based approach was preferred for the current OMP because of the lesser variability in the resultant TACs.

Table 1 and Figure 1 show results from the recent revision process for the MP for Greenland halibut used by NAFO, with Appendix 1 providing the specifications for the target- and slope-based candidate MPs considered, together with those for a combination of the two. Table 1 compares performance statistics, while Figure 1 contrasts TAC and spawning biomass worm plots for the three CMPs, which were all tuned to achieve the same target median exploitable biomass level of Bmsy in 20 years.

The larger AAV statistic for the slope- compared to the target-based procedure evident in Table 1 was as expected. Some features which were, however, not anticipated were:

- the higher average catch for the slope-based CMP, and
- the lower AAV for the combination CMP compared to the target-based CMP,

but perhaps more importantly:

- the qualitative difference between the target- and slope-based worm plots for the TAC – the former seldom change direction, whereas the latter can "bounce-around" to a much greater extent.

With a little thought this difference in behaviour is readily understood – e.g. an averaged index currently above the target will tend to stay above for the following applications of the MP, so that the TAC continues to increase, whereas an estimate of slope tends to have high variance even if a larger number of years are taken into account, and so may more frequently change sign (and hence likewise the direction of the TAC adjustment). The larger AAV is of course also a reflection of this, but the greater directional consistency provided by the target-based approach may be of pertinence for industry stakeholders for their future planning.

Table 1: Performance measures for three CMPs for OM1.

CMP	$B^{5\text{-}9}{}_{2037}/B^{5\text{-}9}{}_{msy}$	$B^{5\text{-}9}{}_{2037}/B^{5\text{-}9}{}_{2018}$	$B^{sp}{}_{2037}/B^{sp}{}_{2018}$	avC: 2018-2037	AAV: 2018-2037
CMP15_t	**1.00**	1.59	1.76	18.80	4.53
CMP15_s	**1.00**	1.54	1.34	20.53	7.48
CMP15_s+t	**1.00**	1.59	1.64	18.89	3.14

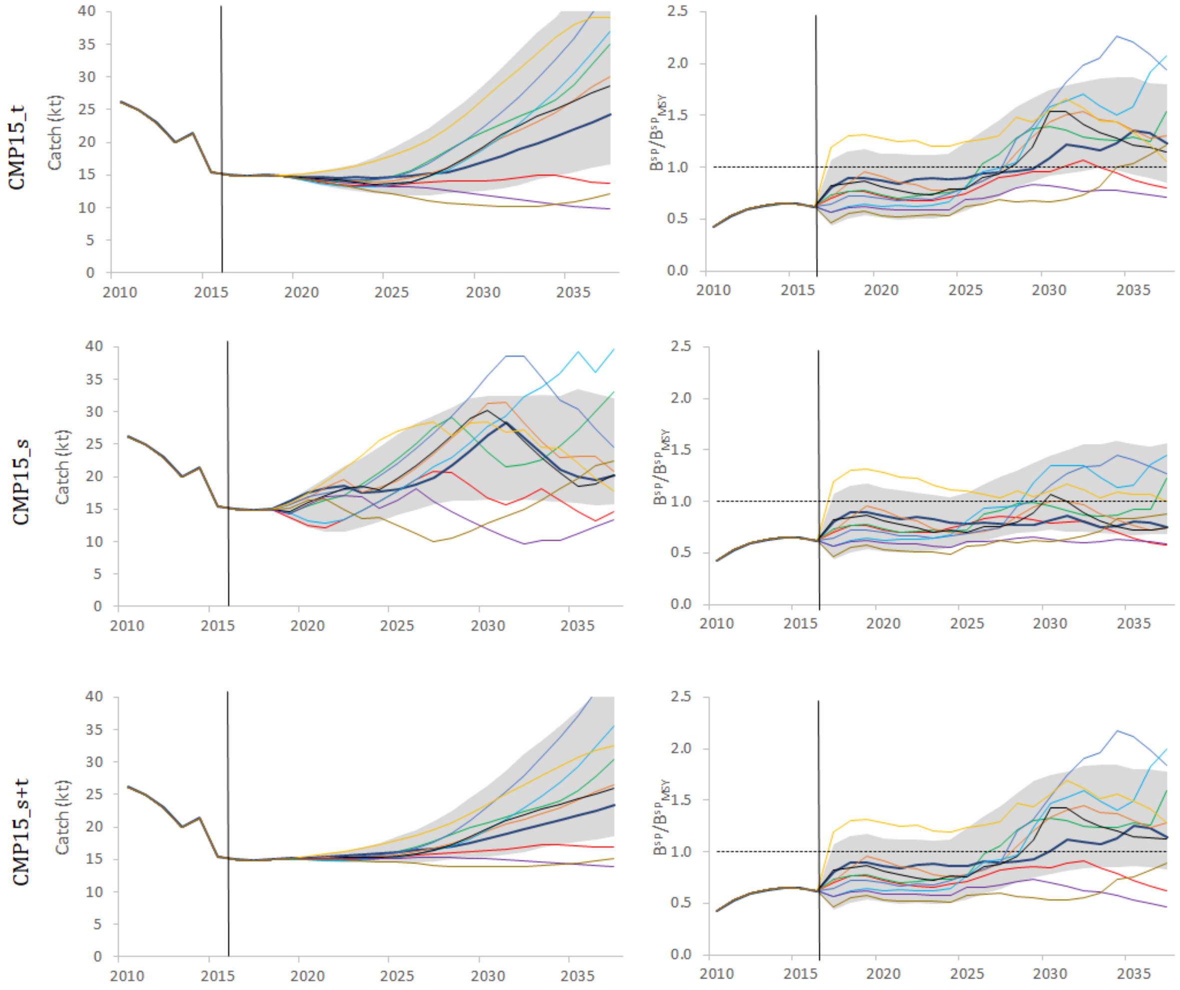

Figure 1: "Worm" plots showing individual trajectories as well as the 80% probability envelopes (grey shading) for catch and spawning biomass (relative to B_{MSY}), for the baseline OM (OM1) under CMP15_t, CMP15_s and CMP15_s+t.

Appendix 1: Definitions of the CMPs

The CMPs considered here are either target based, slope based or a combination of the two:

Target based:

$$TAC_{y+1} = TAC_y\left(1 + \gamma(J_y - 1)\right) \quad (1)$$

where

TAC_y is the TAC recommended for year *y*,

γ is the "response strength" tuning parameter

J_y is a composite measure of the immediate past level in the abundance indices that are available to use for calculations for year *y*; for this base case CMP five series have been used, with *i* = 1, 2, 3, 4 and 5 corresponding respectively to Canada Fall 2J3K, EU 3M 0-1400m, Canada Spring 3LNO, EU 3NO and Canada Fall 3LNO:

$$J_y = \sum_{i=1}^{5} \frac{1}{(\sigma^i)^2} \frac{J_{curr,y}^i}{J_{target}^i} \Big/ \sum_{i=1}^{5} \frac{1}{(\sigma^i)^2} \quad (2)$$

with

$(\sigma^i)^2$ being the estimated variance for index *i* (estimated in the model fitting procedure)

$$J_{curr,y}^i = \frac{1}{q}\sum_{y'=y-q}^{y-1} I_{y'}^i \quad (3)$$

$$J_{target}^i = \alpha\frac{1}{5}\sum_{y'=2011}^{2015} I_{y'}^i \qquad \text{(where } \alpha \text{ is a control/tuning parameter for the CMP)} \quad (4)$$

Note the assumption that when a TAC is set in year *y* for year *y*+1, indices will not at that time yet be available for the current year y.

Slope based:

$$TAC_{y+1} = TAC_y\left[1 + \lambda_{up/down}(s_y - X)\right] \quad (5)$$

where

$\lambda_{up/down}$ and X are tuning parameters,

s_y is a measure of the immediate past trend in the survey-based abundance indices, computed by linearly regressing lnI_y^i vs year y' for $y' = y - 5$ to $y' = y - 1$, for each of the five surveys considered, with

$$s_y = \sum_{i=1}^{5} \frac{1}{(\sigma^i)^2} s_y \Big/ \sum_{i=1}^{5} \frac{1}{(\sigma^i)^2} \quad (6)$$

with the standard error of the residuals of the observed compared to model-predicted logarithm of survey index *i* (σ^i) estimated in the operating model.

When a combination is used, rather than either approach alone, each year these initial TACs are evaluated according to each rule separately, and then an arithmetic average is taken before applying the constraints below.

Constraints on the maximum allowable annual change in TAC are then applied, viz.:

if $TAC_{y+1} > TAC_y\left(1+\Delta_{up}\right)$ then $TAC_{y+1} = TAC_y\left(1+\Delta_{up}\right)$ (7)

and

if $TAC_{y+1} < TAC_y(1-\Delta_{down})$ then $TAC_{y+1} = TAC_y(1-\Delta_{down})$ (8)

Combination Target and Slope based:

For the target and slope based combination:

1) TAC_{y+1}^{target} is computed from equation (1),
2) TAC_{y+1}^{slope} is computed from equation (5) (the option with λ_{down}=2.0 is used), and
3) $TAC_{y+1} = \left(TAC_{y+1}^{target} + TAC_{y+1}^{slope}\right)/2$
4) The constraints (equations 7 and 8) are then applied to obtain a final value for TAC_{y+1}.