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Examples of Management Procedure Outputs for Greenland Halibut

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Summary

The results of some variants of a simple target-based Management Procedure (MP) are provided purely as examples to illustrate the performance trade-offs and robustness considerations involved in selecting an MP, and also to illustrate the various performance statistics put forward at the April Scientific Council meeting in Vigo.

Introduction

This document intends to provide a few results for some example Candidate Management Procedures (CMPs) simply to illustrate the process and the form of outputs from which a final choice of an MP will ultimately need to be made. The performance statistics put forward by the April Scientific Council meeting in Vigo are also reported for these CMPs for the baseline SCAA Operating Model (OM); this is intended to assist assimilate what information these suggestions would see provided, and in particular in the hope that agreement can be reached to reduce what is currently a rather substantial number of outputs.

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Example Candidate Management Procedures

The algorithm for the example Candidate Management Procedures (CMPs) presented here is empirical. It calculates an increase or decrease of the TAC as a function of the difference between a biomass index and a target level for that index. The basis for the associated computations is set out below, with the tuning parameters for the examples reported given in Table 1; these parameters have deliberately been chosen so that results reflect the trade-off between the amount of catch to be taken and the extent of recovery of the resource, as the choice of a point on this trade-off axis will be a key component of the final MP selection process.

$$TAC_{y+1} = \omega TAC_y \left(1 + \gamma_{up/down}(J_y - 1)\right) \tag{1}$$

where

TAC_y is the TAC recommended for year y,

ω, γ_{up} and γ_{down} are tuning parameters (γ_{down}if $J_y < 1$ and γ_{up} if $J_y \geq 1$)

J_y is a measure of the immediate past level in the abundance indices that are available to use for calculations for year y; for this example three series have been used, with i = 1, 2 and 3 corresponding respectively to Canada Fall 2J3K, EU 3M 0-1400m and Canada Spring 3LNO surveys:

$$J_y = \frac{1}{3}\sum_{i=1}^{3} \frac{J^i_{curr}}{J^i_{target}} \tag{2}$$

with

$$J^i_{curr} = \frac{1}{5}\sum_{y'=y-5}^{y-1} I^i_{y'} \tag{3}$$

$$J^i_{target} = \alpha \frac{1}{5}\sum_{y'=2011}^{2015} I^i_{y'} \tag{4}$$

where a is a further tuning parameter.

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

Constraints on the maximum allowable annual change in TAC can be applied, i.e.:

$$\text{if } TAC_{y+1} > TAC_y(1 + \Delta_{up}) \text{ then } TAC_{y+1} = TAC_y(1 + \Delta_{up}) \tag{5}$$

and

$$\text{if } TAC_{y+1} < TAC_y(1 - \Delta_{down}) \text{ then } TAC_{y+1} = TAC_y(1 - \Delta_{down}) \tag{6}$$

Table 1: Tuning parameters for the example CMPs considered here.

	⍰	⍰	⍰$_{up}$	⍰$_{down}$	⍰$_{up}$	⍰$_{down}$
CMP1$_{0.6}$	1	0.6	0.05	0.05	0.15	0.15
CMP1$_{0.8}$	1	0.8	0.05	0.05	0.15	0.15
CMP1$_{1.0}$	1	1.0	0.05	0.05	0.15	0.15
CMP1$_{1.2}$	1	1.2	0.05	0.05	0.15	0.15
CMP1$_{1.4}$	1	1.4	0.05	0.05	0.15	0.15
CMP1$_{5\%}$	1	1.0	0.05	0.05	0.05	0.05

For the projections into the future under a specific CMP, the details of the computations are as set out in Rademeyer and Butterworth (2017), Appendix 1, except that random error is now also included to reflect the uncertainty in the numbers-at-age vector at the start of 2016. In particular, future random error in the recruitment is also included, with autocorrelation of 0.5 as agreed during the Vigo Scientific Council meeting (NAFO, 2017), and predicted values for survey indices of abundance in future years are computed with observation error.

Results

Results are presented here for the various CMPs applied to SCAA baseline and a few further Operating Models (OMs). The SCAA baseline corresponds to scenario NBf in the Vigo Scientific Council meeting report (NAFO, 2017), but using the weight-at-age matrix agreed subsequently by email.

Figure 1 plots projected catch and spawning and exploitable biomass for the baseline OM for management under $CMP1_{1.0}$ (the "central" CMP). Median and 90% PIs are shown as well as 10 actual trajectories ("worm plots").

Figure 2 compares medians and 90% PI for a series of catch and biomass related performance statistics for the baseline OM under constant catch of 0t and 20000t and the six example CMPs to illustrate the trade-offs amongst these performance statistics across the CMPs. Note that the average annual catch variation (AAV) is not zero for the constant catch case because the constant 20000t catch starts in 2018, while the AAV is computed from 2017 (for which a TAC and catch of 14 799t is assumed).

As in Figure 2, Figure 3 compares medians and 90% PIs for a series of performance statistics, but this time across a selection of four OMs under the "central" CMP to provide some indication of the robustness of that CMP to alternative underlying resource dynamics. The four OMs selected for this illustration are the baseline ("BC"), "h=0.7", M increasing at older ages ("M incr") and using the alternative survey data set ("O3") (see NAFO, 2017, for further details).

Figure 4 presents the median trajectory for the fishery for the "central" CMP applied to the baseline OM in the form of a Kobe plot.

Performance statistics results (medians and 90%iles) are given in Table 2 for the baseline OM under the series of CMPs considered. These performance statistics are detailed in Appendix 1 and correspondence to the suggestions made by the Scientific Council meeting (NAFO, 2017).

Discussion

It is first important to stress that the results here are **examples** shown for the purpose of providing **illustrations** of the concepts and comparisons involved in the process of developing and selecting an MP. They are **not** put forward at this time as serious candidates for a final MP – the development and testing of such candidates will occur in the next step of the overall process.

It is important to realise that the Probability Interval (PI) envelope plots in Figure 1 for the central CMP under the baseline OM are not trajectories (nor is the median), but reflect a series of values of statistics for distributions simulated for each year. This becomes clear when considering the individual trajectories ("worm plots") shown, which each exhibit considerable variability.

Figure 2 is intended to illustrate trade-offs between performance statistics under the baseline OM across the different CMPs. As the value of the control parameter α is increased (i.e. the target for the combined abundance index is raised), both spawning and exploitable biomass increase, but catch and inter-annual catch variability decrease. For about the same average catch, either decreasing the maximum variation of the TAC allowed from year to year, or fixing the TAC at 20000 t, lead to very little increase in risk as reflected by the lower percentiles of the biomass distributions.

Figure 3 relates to robustness: given uncertainty about the true dynamics of the resource, there needs to be a check that the anticipated performance of any MP potentially selected does not vary substantially across the different OMs which reflect that uncertainty. Only four OMs have been included in Figure 3, given that it is intended to be no more than illustrative. The results indicate almost surprisingly strong robustness of performance for the central CMP for the OMs that differ from the baseline. The only difference of note is lower depletion at the 5% level under the OM that allows for an increase in natural mortality *M* at older ages.

Figure 4 shows that under the “central” CMP after 20 years the resource is expected to be virtually at B_{MSY} with fishing mortality at F_{MSY}, though the ranges about these expectations are fairly wide.

The main take home point from the wide range of performance statistics reported in Table 2 is how voluminous they are (and these are for the baseline OM only). Some “culling” seems desirable to reduce the quantity of output to be reported in future analyses (remembering that these will need to be reported for multiple OMs) to a level that renders such results and their implications easier to assimilate.

References

NAFO. 2017, Report of the meeting of the Scientific Council., Vigo, Spain – 3-7 April, 2017,

Rademeyer, RA and Butterworth, DS. 2017. Management procedures for Greenland halibut. NAFO SCR Doc. 17/003. 13pp.

Table 2: Medians and 90% PIs for a series of performance statistics for the baseline OM with management under constant catch options of 0t (to provide bounding values) and 20000t, and six CMPs.

	$B^{5\text{-}9}_{2022}/B^{5\text{-}9}_{2018}$		$B^{5\text{-}9}_{2027}/B^{5\text{-}9}_{2018}$		$B^{5\text{-}9}_{2037}/B^{5\text{-}9}_{2018}$		$B^{5\text{-}9}_{low}/B^{5\text{-}9}_{2018}$		$B^{5\text{-}9}_{low}/B^{5\text{-}9}_{min}$		$B^{5\text{-}9}_{2037}/B^{5\text{-}9}_{target}$		$B^{5\text{-}9}_{2037}/B^{5\text{-}9}_{msy}$	
CMP$1_{0.6}$	1.09	(0.79; 1.44)	0.89	(0.47; 1.54)	0.23	(0.11; 0.85)	0.20	(0.11; 0.57)	0.47	(0.31; 1.20)	0.26	(0.15; 0.77)	0.28	(0.16; 0.81)
CMP$1_{0.8}$	1.10	(0.80; 1.46)	0.96	(0.52; 1.65)	0.67	(0.15; 1.37)	0.57	(0.15; 0.94)	1.31	(0.38; 2.04)	0.72	(0.19; 1.39)	0.76	(0.20; 1.46)
CMP$1_{1.0}$	1.11	(0.81; 1.47)	0.99	(0.54; 1.71)	0.91	(0.39; 1.57)	0.71	(0.36; 0.97)	1.63	(0.87; 2.13)	0.97	(0.43; 1.67)	1.02	(0.46; 1.76)
CMP$1_{1.2}$	1.12	(0.81; 1.47)	1.01	(0.55; 1.74)	1.04	(0.50; 1.72)	0.76	(0.42; 0.98)	1.74	(1.15; 2.19)	1.09	(0.61; 1.81)	1.15	(0.65; 1.90)
CMP$1_{1.4}$	1.12	(0.82; 1.48)	1.03	(0.57; 1.75)	1.09	(0.62; 1.80)	0.80	(0.47; 0.98)	1.81	(1.19; 2.29)	1.16	(0.71; 1.93)	1.22	(0.74; 2.04)
CMP$1_{1.0}$ - 5% constr.	1.11	(0.81; 1.47)	0.99	(0.57; 1.71)	0.97	(0.45; 1.64)	0.73	(0.40; 0.98)	1.68	(1.03; 2.17)	1.02	(0.54; 1.81)	1.07	(0.57; 1.91)
C=0t	1.28	(0.94; 1.63)	1.19	(0.70; 2.00)	1.36	(0.80; 2.20)	0.94	(0.58; 1.00)	2.05	(1.51; 2.71)	1.48	(0.99; 2.40)	1.56	(1.04; 2.53)
C=20 000t	1.07	(0.75; 1.41)	0.97	(0.49; 1.65)	1.00	(0.58; 1.69)	0.74	(0.43; 0.95)	1.72	(1.03; 2.29)	1.13	(0.54; 1.89)	1.19	(0.57; 1.99)

	$B^{sp}_{2022}/B^{sp}_{2018}$		$B^{sp}_{2027}/B^{sp}_{2018}$		$B^{sp}_{2037}/B^{sp}_{2018}$		$B^{sp}_{low}/B^{sp}_{2018}$		$B^{sp}_{low}/B^{sp}_{min}$		$B^{sp}_{2037}/B^{sp}_{target}$		$B^{sp}_{2037}/B^{sp}_{msy}$	
CMP$1_{0.6}$	1.25	(1.06; 1.62)	1.34	(0.98; 1.82)	0.54	(0.30; 1.01)	0.54	(0.30; 0.92)	1.56	(0.85; 2.31)	0.35	(0.19; 0.55)	0.68	(0.37; 1.09)
CMP$1_{0.8}$	1.27	(1.07; 1.64)	1.48	(1.07; 1.98)	0.99	(0.41; 2.03)	0.97	(0.41; 1.00)	2.32	(1.49; 3.22)	0.57	(0.39; 0.98)	1.13	(0.77; 1.93)
CMP$1_{1.0}$	1.28	(1.07; 1.65)	1.55	(1.13; 2.12)	1.36	(0.60; 2.52)	1.00	(0.60; 1.00)	2.66	(1.57; 3.90)	0.82	(0.55; 1.21)	1.62	(1.08; 2.37)
CMP$1_{1.2}$	1.29	(1.08; 1.66)	1.60	(1.16; 2.21)	1.60	(0.74; 2.83)	1.00	(0.73; 1.00)	2.74	(1.57; 4.47)	0.99	(0.64; 1.41)	1.94	(1.26; 2.76)
CMP$1_{1.4}$	1.30	(1.08; 1.67)	1.63	(1.19; 2.27)	1.75	(0.85; 3.11)	1.00	(0.81; 1.00)	2.79	(1.57; 4.86)	1.08	(0.70; 1.54)	2.12	(1.37; 3.02)
CMP$1_{1.0}$ - 5% constr.	1.28	(1.07; 1.65)	1.56	(1.14; 2.12)	1.38	(0.66; 2.76)	1.00	(0.66; 1.00)	2.69	(1.57; 4.02)	0.86	(0.55; 1.44)	1.69	(1.08; 2.82)
C=0t	1.63	(1.26; 2.17)	2.31	(1.59; 3.37)	2.95	(1.52; 4.99)	1.00	(1.00; 1.00)	2.81	(1.57; 5.12)	1.79	(1.31; 2.44)	3.51	(2.58; 4.80)
C=20 000t	1.19	(1.01; 1.50)	1.38	(1.04; 1.87)	1.45	(0.76; 2.65)	1.00	(0.76; 1.00)	2.73	(1.57; 4.64)	0.92	(0.42; 1.61)	1.81	(0.83; 3.17)

Table 2: continued

	C_{2018}		C_{2019}		C_{2020}		avC:2018-2027		avC:2018-2037		AAV:2018-2022		AAV:2018-2037	
$CMP1_{0.6}$	15.44	(15.28; 15.69)	16.24	(15.80; 17.04)	17.35	(16.50; 18.94)	22.85	(19.00; 27.73)	37.48	(24.78; 56.72)	0.07	(0.04; 0.11)	0.07	(0.04; 0.11)
$CMP1_{0.8}$	15.10	(14.98; 15.28)	15.49	(15.17; 16.08)	16.09	(15.48; 17.22)	19.08	(16.64; 22.11)	26.78	(19.54; 39.28)	0.04	(0.02; 0.07)	0.05	(0.03; 0.09)
$CMP1_{1.0}$	14.89	(14.79; 15.04)	15.05	(14.80; 15.51)	15.37	(14.89; 16.24)	17.14	(15.38; 19.27)	21.42	(16.72; 29.45)	0.02	(0.00; 0.04)	0.04	(0.01; 0.06)
$CMP1_{1.2}$	14.75	(14.67; 14.87)	14.76	(14.55; 15.14)	14.90	(14.51; 15.61)	15.96	(14.60; 17.60)	18.40	(15.04; 23.84)	0.01	(0.00; 0.03)	0.02	(0.01; 0.05)
$CMP1_{1.4}$	14.65	(14.58; 14.76)	14.56	(14.38; 14.88)	14.57	(14.24; 15.17)	15.17	(14.06; 16.49)	16.52	(13.96; 20.51)	0.01	(0.00; 0.02)	0.02	(0.01; 0.03)
$CMP1_{1.0}$ - 5% constr.	14.89	(14.79; 15.04)	15.05	(14.80; 15.51)	15.37	(14.89; 16.24)	17.04	(15.38; 18.54)	20.94	(16.74; 24.05)	0.02	(0.00; 0.04)	0.04	(0.01; 0.05)
C=0t	0.00	(0.00; 0.00)	0.00	(0.00; 0.00)	0.00	(0.00; 0.00)	0.00	(0.00; 0.00)	0.00	(0.00; 0.00)	0.20	(0.20; 0.20)	0.05	(0.05; 0.05)
C=20 000t	20.00	(20.00; 20.00)	20.00	(20.00; 20.00)	20.00	(20.00; 20.00)	20.00	(20.00; 20.00)	20.00	(20.00; 20.00)	0.07	(0.07; 0.07)	0.02	(0.02; 0.02)

	F_{2022}/F_{MSY}		F_{2027}/F_{MSY}		F_{2037}/F_{MSY}		$\max(F_{2023-2027})/F_{MSY}$		$\max(F_{2028-2037})/F_{MSY}$		P>15%	
$CMP1_{0.6}$	0.53	(0.35; 0.73)	1.15	(0.70; 2.50)	5.00	(1.65; 5.00)	1.15	(0.74; 2.50)	25.66	(3.99; 25.66)	0.00	(0.00; 0.00)
$CMP1_{0.8}$	0.44	(0.30; 0.61)	0.71	(0.43; 1.23)	3.05	(0.64; 25.66)	0.71	(0.48; 1.23)	3.22	(1.20; 25.66)	0.00	(0.00; 0.00)
$CMP1_{1.0}$	0.40	(0.27; 0.55)	0.54	(0.34; 0.89)	1.01	(0.40; 5.78)	0.55	(0.38; 0.89)	1.21	(0.72; 5.78)	0.00	(0.00; 0.00)
$CMP1_{1.2}$	0.37	(0.25; 0.51)	0.46	(0.29; 0.77)	0.66	(0.30; 1.67)	0.48	(0.35; 0.77)	0.79	(0.53; 1.76)	0.00	(0.00; 0.00)
$CMP1_{1.4}$	0.36	(0.24; 0.49)	0.41	(0.26; 0.66)	0.49	(0.26; 0.97)	0.42	(0.30; 0.66)	0.64	(0.43; 1.24)	0.00	(0.00; 0.00)
$CMP1_{1.0}$ - 5% constr.	0.40	(0.27; 0.55)	0.52	(0.31; 0.87)	0.89	(0.40; 2.39)	0.54	(0.37; 0.87)	1.07	(0.68; 2.78)	0.00	(0.00; 0.00)
C=0t	0.00	(0.00; 0.00)	0.00	(0.00; 0.00)	0.00	(0.00; 0.00)	0.00	(0.00; 0.00)	0.00	(0.00; 0.00)	3.33	(3.33; 3.33)
C=20 000t	0.53	(0.33; 0.82)	0.57	(0.30; 1.02)	0.54	(0.31; 1.24)	0.60	(0.38; 1.02)	0.75	(0.44; 1.72)	3.33	(3.33; 3.33)

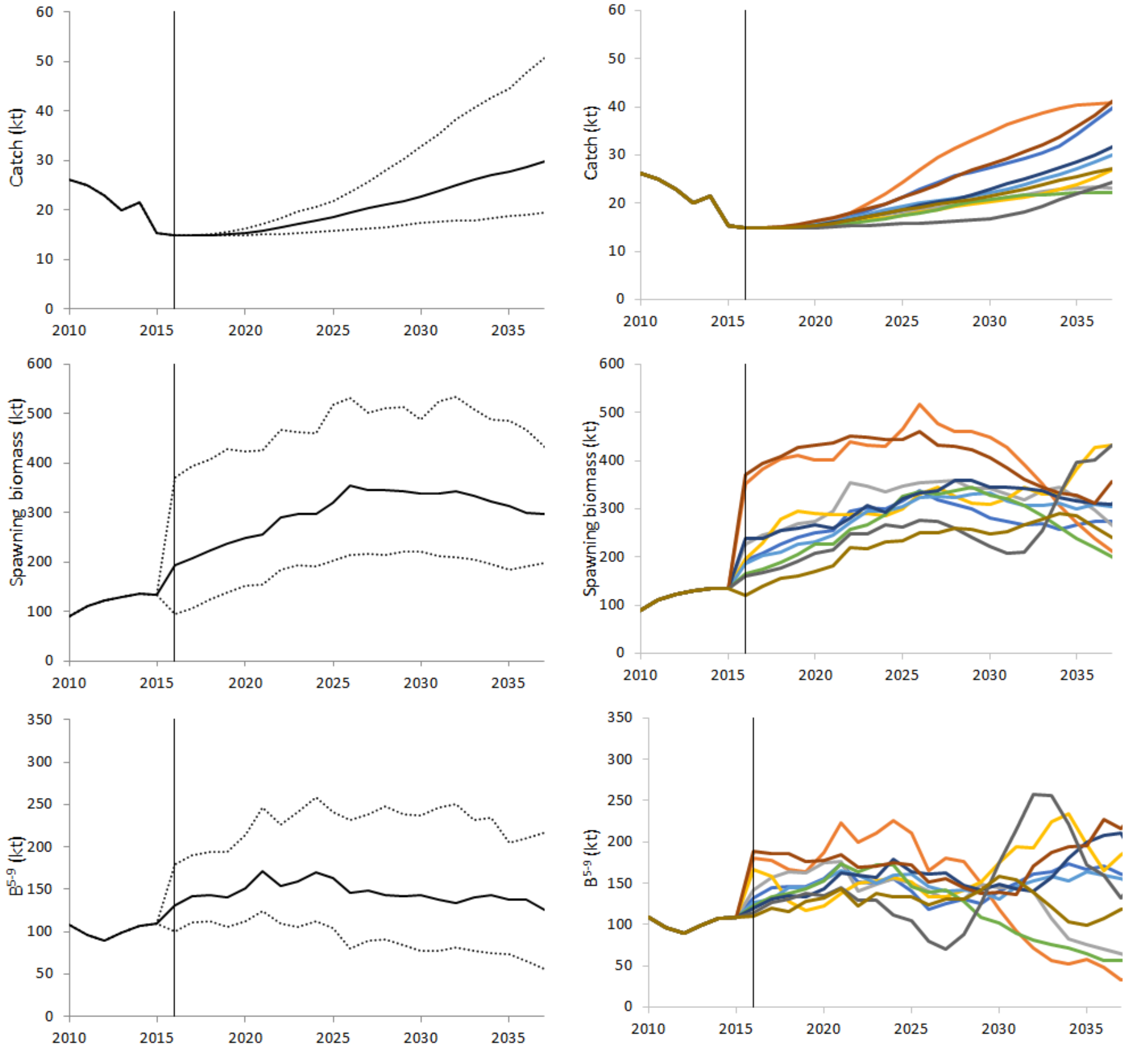

Fig. 1. Median and 90% PI envelopes (left side) and worm plots (right side) for projected catch, spawning biomass and exploitable biomass under **CMP1$_{1.0}$** (the “central” CMP) for the **baseline** OM.

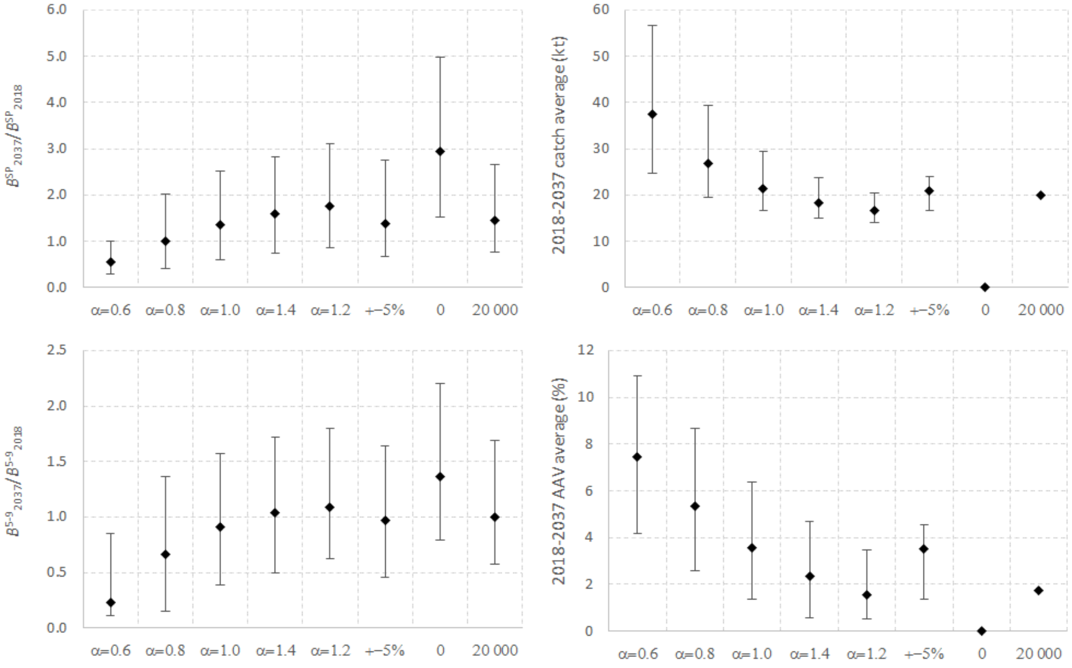

Fig. 2. Medians and 90% PIs for a series of performance statistics for the **baseline** OM managed under constant catch of 0 and 20000t constant catch scenario, and the six illustrative CMPs.

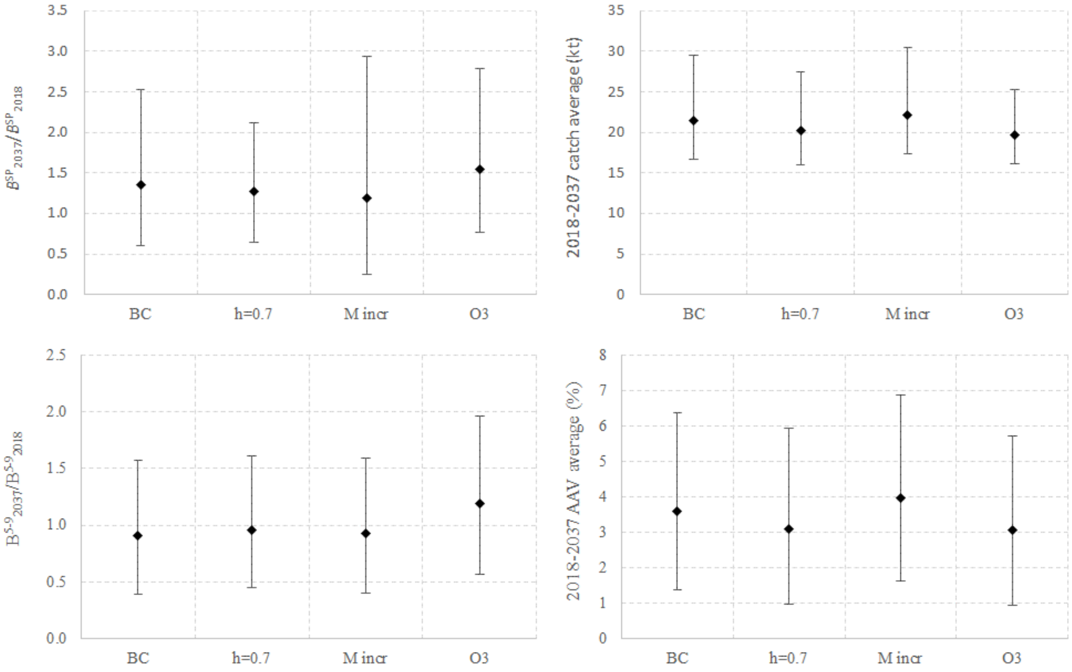

Fig. 3. Medians and 90% PIs for a series of performance statistics for four OMs with management under **CMP1$_{1.0}$**. The four OMs are the baseline ("BC"), "*h*=0.7", M increasing at older ages ("M incr") and using the alternative survey data set ("O3").

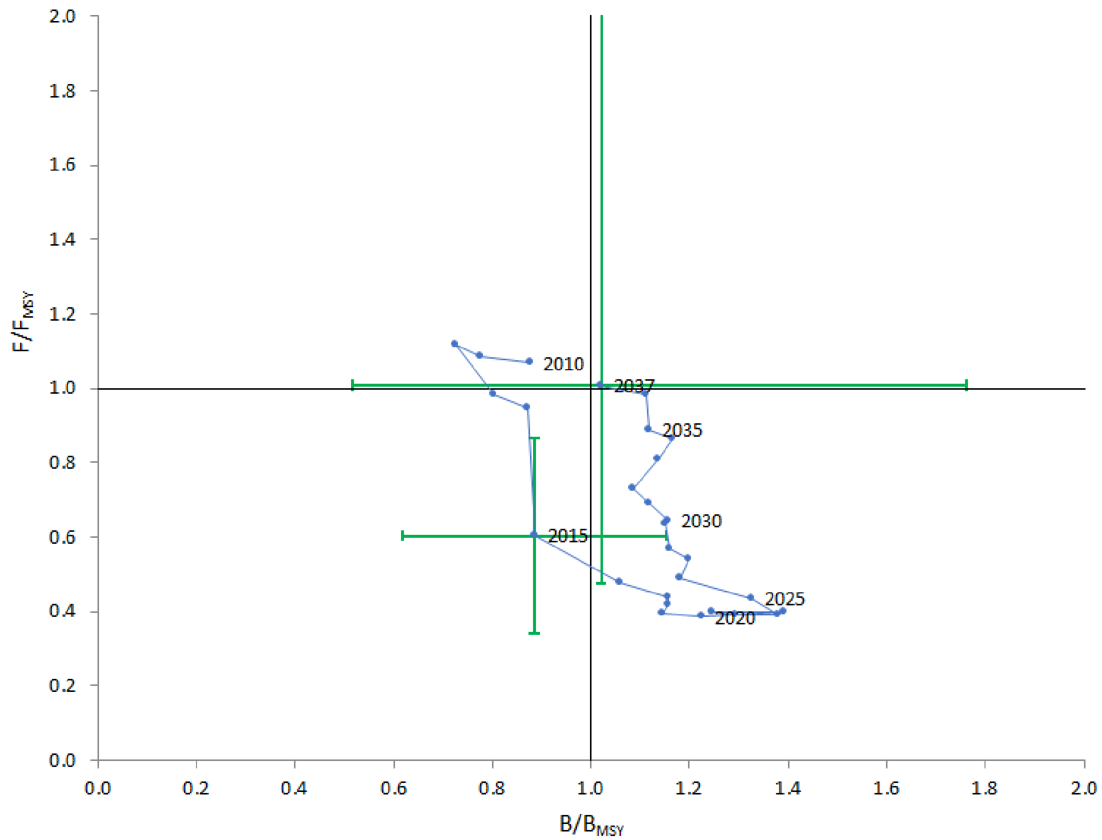

Fig. 4. Kobe plot for the baseline OM projected under the central CMP. Error bars (90%) are included for the 2015 (most recent year of assessment) and 2037 (final year of projection) points. B refers to the exploitable component of the biomass.

Appendix 1: Performance Targets and Statistics

NAFO/FC-SC Doc. 17-xx lists the following general management objectives:

1. Restore to within a *prescribed period of time* or maintain at B_{msy}
2. The risk of failure to meet the B_{msy} target and interim biomass targets within a *prescribed period of time* should be kept moderately low
3. Low risk of exceeding F_{msy}
4. Very Low risk of going below an established threshold (e.g. B_{lim}* or B_{lim} proxy)
5. Maximize yield in the short, medium and long term
6. The risk of steep decline of stock biomass should be kept moderately low
7. Keep inter annual TAC variation below established thresholds

A number of mathematical expressions (Performance Statistics) are proposed here to capture these objectives:

(a) P_{2022}/P_{2018}, P_{2027}/P_{2018} and P_{2037}/P_{2018}, where P_y is the population size in year y;

(b) P_{lowest}/P_{2018}, where P_{lowest} is the lowest population size during evaluation period (2018-2037);

(c) P_{lowest}/P_{min}, where P_{min} is the lowest population size during the assessment period (1975-2015);

(d) P_{2037}/P_{target}, where P_{target} is pre-defined recovery target population size, for which the average value over the period 1975 to 1999 for the assessment/operating model concerned will be used for the moment pending further discussions;

(e) P_{2037}/P_{MSY} where P_{MSY} is the population level when maximum sustainable yield is achieved;

(f) F_{2022}/F_{MSY} and F_{2027}/F_{MSY} F_{2037}/F_{MSY} where F_{MSY} is the fishing mortality rate needed to achieve maximum sustainable yield.

In each of them, population can be measured as total numbers (N_y^{tot}), total biomass (B_y^{tot}), exploitable numbers (ages 5 – 9) (N_y^{5-9}), exploitable biomass (B_y^{5-9}), survey index (B_y^i) or spawning biomass (B_y^{sp}), (though with primary focus on exploitable biomass for P_{target}) where:

$$N_y^{tot} = \sum_{a=0}^{m} N_{y,a} \tag{1}$$

$$B_y^{tot} = \sum_{a=0}^{m} w_{y,a}^{st} N_{y,a} \tag{2}$$

$$N_y^{5-9} = \sum_{a=5}^{9} N_{y,a} \tag{3}$$

$$B_y^{5-9} = \sum_{a=5}^{9} w_{y,a}^{mid} N_{y,a} \tag{4}$$

$$B_y^{i} = \sum_{a=0}^{m} w_{y,a}^{i} S_a^i N_{y,a} e^{-Z_{y,a}T^i/12} \tag{5}$$

$$B_y^{sp} = \sum_{a=1}^{m} f_a\, w_{y,a}^{strt} N_{y,a} \tag{6}$$

The fishing mortality rate refers to the apical fishing mortality rate (age at which selectivity is 1 – age 8 for the baseline OMs).

The catch-related objectives can be captured by:

(g) (Average) annual catch over short, medium and long terms:

C_{2018}, C_{2019}, C_{2020}, $\sum_{y=2018}^{2022} C_y/5$, $\sum_{y=2018}^{2027} C_y/10$, $\sum_{y=2018}^{2037} C_y/20$

(h) Average annual variation in catch over short and long terms:

$AAV_{2018-2022} = \frac{1}{5}\sum_{y=2018}^{2022}\left|C_y - C_{y-1}\right|/C_{y-1}$ and

$AAV_{2018-2037} = \frac{1}{20}\sum_{y=2018}^{2037}\left|C_y - C_{y-1}\right|/C_{y-1}$

$P > 15\%$ being the proportion of years during the projection period where $\frac{|C_y - C_{y-1}|}{C_{y-1}} > 0.15$. Catch constraints as part of the control rule or as a performance statistic to be determined.

(i) $F_{highest}/F_{msy}$, where $F_{highest}$ is the highest F during each evaluation period (2018-2022, 2023-2027 and 2028-2037);

A total of 100 forward projections will be run for each trial, with results presented as the 5th, average of 50th and 51st and 96th in an ordered set (i.e. median with 90% probability intervals).

Plots of annual catch and B^{5-9} may be produced for each trial, the first showing the median and 90% probability envelopes, and the second showing the first 5 realisations ("worm plots").