Northwest Atlantic Fisheries Organization

FCWGMSE WP 10/13

FC Working Group on Greenland Halibut Management
Strategy Evaluation (WGMSE) – September 2010

Greenland Halibut MSE Results for Updated SCAA Reference Case and Robustness Test Operating Models

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September 2010

ABSTRACT

This paper reports the results of the application of 18 potential Management Procedures (MPs) to the Base Case and seven robustness test operating models based on SCAA assessments of the Greenland halibut resource. One of these MPs is selected as a preferred candidate (subject to its performance for XSA-based operating models) on the basis of satisfying virtually all performance targets identified at the May NAFO WGMSE meeting and achieving relatively high catches. The one drawback for this MP (and also all others considered) is failure to meet the specified resource recovery target under robustness test SCAA5 (a lower stock-recruitment steepness), and suggestions are made in that regard. Suggestions are also made in relation to "exceptional circumstances" provisions where over-riding the TAC recommendation output by the MP becomes scientifically justified, and for catering for possible future TAC over-runs. Following discussions of these analyses with our EU principals, results for four further variants of these MPs have been added for consideration.

INTRODUCTION

This document reports results of testing of candidate Management Procedures (MPs) for Greenland halibut for a set of SCAA operating models for the population dynamics which have been updated using the most recent data for the resource as considered at the 2010 NAFO SC meeting (Butterworth and Rademeyer, 2010a). This set includes a Reference Case (SCAA0) and seven robustness tests (SCAA1 to SCAA7).

The projection methodology utilised for these tests is detailed in Butterworth and Rademeyer (2010b), which also lists the performance statistics agreed at the May NAFO WGMSE meeting (NAFO, 2010). Results for 18 alternative MPs are contrasted below in terms in line with the forms and the performance targets and statistics agreed at that meeting.

RESULTS AND DISCUSSION

All the MPs follow the form of the NAFO (2010) default control rule:

$$TAC_{y+1} = \begin{cases} TAC_y \times (1+\lambda_u \times slope) & if \quad slope \geq 0 \\ TAC_y \times (1+\lambda_d \times slope) & if \quad slope < 0 \end{cases} \tag{1}$$

Three factors/tuning parameters are varied, with the alternatives reflected here culled from a wider set investigated:

1) the λ_u and λ_d control parameters: a) λ_u=1.0 and λ_d=1.25; b) λ_u=1.0 and λ_d=2.0;

2) the starting TAC control parameter: a) 16 000t; b) 17 500t; c) 19 000t;

3) the inter-annual TAC change constraints: a) +10%, -10%; b) +10%; -5%; c) +15%, -5%.

Note that our earlier Greenland halibut MSE analyses (e.g. Rademeyer and Butterworth, 2010) had imposed inter-annual TAC constraints of 20% and later 15%. These relatively large values were necessitated by the poor status of the resource indicated by earlier XSA assessments, so that sufficient adaptive TAC adjustment could be achieved if these reflected the actual underlying resource situation. However the updated XSA assessment from the 2010 NAFO SC meeting reflects notably improved results as regards resource status (which is now also closer to SCAA results), motivating consideration of tighter constraints in the interests of enhanced industrial stability.

A full cross of the factors/parameters listed above is reported, yielding 18 candidate MPs (mp01 to mp18) in all. The linkage between MP names and factor/parameter values is provided in Table 1a, which lists results in terms of a format corresponding to the performance targets agreed in NAFO (2010), with results for a 16 000 t constant catch MP also add to provide a convenient benchmark for comparisons. Note that in this Table, statistics that do not meet the targets specified in NAFO (2010) are shown shaded.

These same results are shown in Fig. 1 in the form of graphical projections for the annual catch (assumed equal to the TAC in projections under MPs) and exploitable biomass (*B*5-9), with both medians and lower 2.5%iles of probability distributions plotted. In this Figure, the 18 MPs are grouped by the starting TAC control parameter value.

In the authors' view, mp14 provides the best trade-off amongst the performance statistics under SCAA0, satisfying all performance targets, and yielding the highest catches amongst the other MPs which do likewise. It is thus used as a "baseline" MP in Figure 2, which illustrates the sensitivity of the results for mp14 to single factor variations of the starting TAC control parameter (Fig. 2a), the inter-annual TAC change constraints (Fig. 2b) and the λ control parameters (Fig. 2c). Note that the impact of variation of the first two of these factors on results is much greater than the third. It is possible to "mimic" TAC change constraints by decreasing λ values, but for reasons of longer-term stability of abundance projections (i.e. adequate feedback), λ_d values in particular should preferably not be set less than 1.

The performance of the Baseline mp14 across the SCAA Base Case and robustness tests is shown in Table 1b and Fig. 3. Performance targets are met in all cases except for a marginal failure for

$P_{\text{achieved}}/P_{\text{milestone}}$ (resource recovery) for SCAA4 (increasing natural mortality at larger ages), and a much greater extent of failure for SCAA5 (stock-recruitment steepness $h = 0.6$ in contrast to the $h = 0.9$ preferred for SCAA0 because of a much better fit to the data). Fig. 3 shows that behavior for SCAA5 is qualitatively different to that for the other robustness tests which manifest quite similar behavior to that of the Base Case SCAA0. In contrast to increases in both catches and exploitable biomasses for these other scenarios, for SCAA5 these both remain fairly steady into the future. Table 1c shows results for SCAA5 across all 18 of the MPs considered, and demonstrates that the failure to meet recovery targets for this scenario is general and not peculiar to mp14. Further comments on this are made below.

In response to a suggestion from Canadian scientists for selection of the three best performing MPs, our selections in addition to the Baseline mp14 are mp12 and mp16 (it must be stressed that these constitute the authors' selections, and do not necessarily reflect the views of the EU). These choices are seen by the authors to provide the best balances between achieving recovery targets, maximizing catches, and minimising TAC variations. We do not consider the marginal failure of mp16 to meet certain TAC change performance targets to be critical, both because these particular targets were chosen primarily with TAC decrease being the concern whereas it is TAC increases that are resulting in these "failures", and further because if such targets are considered critical, they could readily be hard-wired into the control rules without any great impact on other performance statistics. Results for these three MPs applied to the Base Case SCAA operating model (SCAA0) are given in Table 2 in a format different from Table 1, with the statistics for mp14 under robustness test SCAA5 also added there. Graphical comparisons are shown in Figs 4 and 5. Except for the earliest years mp14 achieves the highest catches for only marginal lesser recovery, and also shows appreciably less TAC variation.

An alternative graphical form for contrasting performance statistics for the various MPs applied to SCAA0 is shown in Fig 6a, with comparisons restricted to the authors' three preferred MP choices shown in Fig. 6b.

SUMMARY AND RELATED CONSIDERATIONS

Subject to showing satisfactory performance also under the various XSA based operating models, mp14 appears to the authors to be a strong candidate for adoption as the MP to provide TAC recommendations for Greenland halibut. It meets all the performance targets set at the May WGMSE meeting (NAFO, 2010) while also being likely to achieve relatively high catches. It provides a good example of a major strength of the MSE approach that has been evident in its application to other fisheries, *viz.* that of being able to provide a scientifically defensible basis to constrain inter-annual TAC variation in a manner that nevertheless secures adequate safeguards for the risk of unintended resource depletion. Thus in the first few future years in this case, the TAC change constraints imposed prevent unnecessary reduction of the TAC as a consequence of following more of the noise than the signal in the survey data (nearly all recent residuals in the assessment fits to the survey indices of abundance are positive), and in a manner which does not compromise resource recovery.

The one concern is the failure of mp14 (or indeed any of the other MPs considered) to secure the desired level of resource recovery under robustness test SCAA5 (lower steepness). The lower 2.5%ile plot for exploitable biomass shown in Fig. 3 for this situation does at least indicate that application of mp14 would prevent any continuing deterioration. This is a manifestation of a potential problem with derivative-control-based MP approaches such as that of equation (1), which arises because their targets are emergent properties which cannot be pre-specified and therefore may turn out to be different to what is desired. The simplest solution to this problem is to include a target-based term as an extension of equation (1). This might better secure some recovery under SCAA5 while not compromising the desirable performance achieved under mp14 for the other SCAA scenarios.

Two other more general issues merit attention in moving towards agreement of an MSE approach for Greenland halibut with its associated decision rule in the form of a TAC formula. The first is that it is usual to pre-agree some guidance concerning "exceptional circumstances" – unexpected future events which provide scientific justification for over-riding the TAC recommendation provided by an MP's control rule. A customary criterion for what need to be compelling reasons to take such action is future data falling outside the range considered in the MSE process, thus indicating that circumstances have arisen outside the range for which the control rule has been tested to show adequate robustness. To aid consideration of this possible approach, Fig. 7 shows probabilistic projections of future survey results expected under SCAA0 (and implementation of mp14).

A second concern is TAC over-runs, given an empirical MP (equation 1) which takes no explicit account of any mismatch between the TAC set and the catch subsequently taken (as, in contrast, a population model based MP would do). The feedback nature of MPs ensures that they do react to this, but typically slower than needed to make fully compensatory TAC adjustments in the short term. Furthermore, none of the robustness tests considered for these evaluations have considered the impact of possible future catch over-runs. Ideally there should be pre-agreement, as part of any Management Procedure of this type that is adopted, on how to make appropriate adjustments for such over-runs to recommendations output by an MP for TACs.

ADDENDUM

In discussion of the above with our EU principals, suggestions were made that the following further options warranted analysis to allow consideration of the results:

mp14*: this MP is as mp14 (i.e. starting TAC control parameter of 17 500t; λ_u=1 and λ_d =2; and constraints on the inter-annual TAC changes of +10% and -5%), but the 2011 MP output is over-ridden by a pre-set TAC of 16 000t. To compute the TAC in 2012 the original 2011 MP output (17 182t) is used in the control rule (equation 1).

mp14**: as mp14*, but the 2012 MP output is also over-ridden by a pre-set TAC of 16 000t.

mp14***: as mp14* but with a pre-set TAC of 14 500t instead of 16 000t in 2011.

mp19: starting TAC control parameter of 14 500t; λ_u=1 and λ_d =2; and constraints on the inter-annual TAC changes of +10% and -5%.

Results for these four further MPs are compared to mp14 and mp11 (starting TAC of 16 000t) in Tables 3 and 4, while the exploitable biomass and TAC are plotted in Fig. 8. In terms of the biomass projections (Fig. 8), the original mp14 and its three variants are virtually indistinguishable. The catches over time for all the mp14's (starting TAC control parameter of 17 500t) are appreciably higher than for mp11 (starting TAC control parameter of 16 000t) and mp19 (starting TAC control parameter of 14 500t) without compromising mp14 reaching the specified biomass recovery targets.

REFERENCES

Butterworth DS and Rademeyer RA. 2010a. Greenland halibut updated SCAA Reference Case and robustness tests. NAFO document, 13 pp.

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NAFO. 2010. Report of the Working Group on Greenland Halibut Management Strategy Evaluation (WGMSE), 2 – 4 May 2010, Halifax, Nova Scotia, Canada. NAFO/FC Doc. 10/5, 11 pp.

Rademeyer RA and Butterworth DS. 2010. Overview of progress with Management Strategy Evaluation (MSE) for Greenland halibut. NFO document NAFO FCWGMSE WP 10/6, 18 pp.

Table 1a: Performance statistics for a series of MPs for the Base Case SCAA operating model (SCAA0), where these are reported in a format that relates to specified targets in NAFO (2010). Instances where those targets are not met are shown shaded.

				1	2a				2b	2c					3			4
SCAA0				Prob	Prob*	Prob*	Prob	Prob	Prob	Prob	Prob	Prob	Prob	Prob	$C_{2011\text{-}2015}$	$C_{2016\text{-}2020}$	$C_{2011\text{-}2030}$	Prob
	λ_{up}; λ_{down}	starting TAC	bounds	$B^{5\text{-}9}$	(2011-2015)	(2010-2014)	(2011-2030)	(2010-2029)	(2010-2027)	2011	2012	2013	2014	2015				$P_{achieved}$ / $P_{milestone}$
cteC	1; 1.25	16000t		3%	0%	20%	0%	5%	0%	0%	0%	0%	0%	0%	16000	16000	16000	4%
mp01	1; 1.25	16000t	+10%; -10%	0%	0%	20%	0%	5%	25%	0%	0%	0%	0%	0%	13413	13800	14329	2%
mp02	1; 1.25	16000t	+10%; -5%	2%	0%	20%	0%	5%	17%	0%	0%	0%	0%	0%	14628	16093	16882	12%
mp03	1; 1.25	16000t	+15%; -5%	2%	0%	20%	0%	5%	22%	0%	0%	0%	0%	0%	14628	16425	17795	19%
mp04	1; 1.25	17500t	+10%; -10%	1%	0%	0%	0%	0%	28%	0%	0%	0%	0%	0%	14638	14953	15497	2%
mp05	1; 1.25	17500t	+10%; -5%	2%	0%	0%	0%	0%	17%	0%	0%	0%	0%	0%	15988	17461	18367	21%
mp06	1; 1.25	17500t	+15%; -5%	2%	0%	0%	0%	0%	22%	0%	0%	0%	0%	0%	15988	17726	19180	30%
mp07	1; 1.25	19000t	+10%; -10%	2%	0%	0%	0%	0%	22%	0%	0%	0%	0%	0%	15884	16079	16634	8%
mp08	1; 1.25	19000t	+10%; -5%	4%	0%	0%	0%	0%	11%	0%	0%	0%	0%	0%	17333	18717	19736	31%
mp09	1; 1.25	19000t	+15%; -5%	4%	0%	0%	0%	0%	17%	0%	0%	0%	0%	0%	17333	18959	20579	33%
mp10	1; 2	16000t	+10%; -10%	0%	0%	20%	0%	5%	28%	0%	0%	0%	0%	0%	13283	13437	13713	1%
mp11	1; 2	16000t	+10%; -5%	1%	0%	20%	0%	5%	17%	0%	0%	0%	0%	0%	14513	15855	16674	11%
mp12	1; 2	16000t	+15%; -5%	1%	0%	20%	0%	5%	22%	0%	0%	0%	0%	0%	14513	16211	17485	17%
mp13	1; 2	17500t	+10%; -10%	1%	0%	20%	0%	5%	28%	0%	0%	0%	0%	0%	14517	14511	14869	2%
mp14	1; 2	17500t	+10%; -5%	2%	0%	20%	0%	5%	14%	0%	0%	0%	0%	0%	15857	17218	18102	20%
mp15	1; 2	17500t	+15%; -5%	2%	0%	20%	0%	5%	22%	0%	0%	0%	0%	0%	15857	17545	18916	28%
mp16	1; 2	19000t	+10%; -10%	2%	0%	0%	0%	0%	28%	0%	0%	0%	0%	0%	15746	15561	15930	3%
mp17	1; 2	19000t	+10%; -5%	4%	0%	0%	0%	0%	11%	0%	0%	0%	0%	0%	17203	18570	19466	27%
mp18	1; 2	19000t	+15%; -5%	4%	0%	0%	0%	0%	17%	0%	0%	0%	0%	0%	17203	18797	20240	33%

Table 1b: Performance statistics formulated as in Table 1a for mp14 for the Base Case SCAA operating model (SCAA0) and its associated robustness tests.

	1	2a				2b	2c						3		4
mp14	Prob $B^{5\text{-}9}$	Prob* (2011-2015)	Prob* (2010-2014)	Prob (2011-2030)	Prob (2010-2029)	Prob (2010-2027)	Prob 2011	Prob 2012	Prob 2013	Prob 2014	Prob 2015	$C_{2011\text{-}2015}$	$C_{2016\text{-}2020}$	$C_{2011\text{-}2030}$	Prob $P_{achieved}/P_{milestone}$
SCAA0	2%	0%	20%	0%	5%	14%	0%	0%	0%	0%	0%	15857	17218	18102	20%
SCAA1	4%	0%	20%	0%	5%	17%	0%	0%	0%	0%	0%	15756	16314	17816	22%
SCAA2	2%	0%	20%	0%	5%	22%	0%	0%	0%	0%	0%	15765	16676	19198	1%
SCAA3	2%	0%	20%	0%	5%	17%	0%	0%	0%	0%	0%	16016	18306	18329	17%
SCAA4	2%	0%	20%	0%	5%	17%	0%	0%	0%	0%	0%	15812	17310	18776	27%
SCAA5	14%	0%	20%	0%	5%	11%	0%	0%	0%	0%	0%	15579	14355	15366	100%
SCAA6	2%	0%	20%	0%	5%	17%	0%	0%	0%	0%	0%	15923	17636	18598	6%
SCAA7	2%	0%	20%	0%	5%	17%	0%	0%	0%	0%	0%	15847	17450	18849	16%

Table 1c: Performance statistics formulated as in Table 1a for a series of MPs for SCAA5.

				1	2a				2b	2c						3		4
SCAA5	$\lambda_{up}; \lambda_{down}$	starting TAC	bounds	Prob $B^{5\text{-}9}$	Prob* (2011-2015)	Prob* (2010-2014)	Prob (2011-2030)	Prob (2010-2029)	Prob (2010-2027)	Prob 2011	Prob 2012	Prob 2013	Prob 2014	Prob 2015	$C_{2011\text{-}2015}$	$C_{2016\text{-}2020}$	$C_{2011\text{-}2030}$	Prob $P_{achieved}/P_{milestone}$
cteC	1; 1.25	16000t		16%	0%	20%	0%	5%	0%	0%	0%	0%	0%	0%	16000	16000	16000	100%
mp01	1; 1.25	16000t	+10%; -10%	5%	0%	20%	0%	5%	28%	0%	0%	0%	0%	0%	13153	11020	11820	97%
mp02	1; 1.25	16000t	+10%; -5%	11%	0%	20%	0%	5%	17%	0%	0%	0%	0%	0%	14381	13448	14465	100%
mp03	1; 1.25	16000t	+15%; -5%	11%	0%	20%	0%	5%	19%	0%	0%	0%	0%	0%	14381	13596	14801	100%
mp04	1; 1.25	17500t	+10%; -10%	8%	0%	0%	0%	0%	28%	0%	0%	0%	0%	0%	14364	11891	12687	99%
mp05	1; 1.25	17500t	+10%; -5%	14%	0%	0%	0%	0%	11%	0%	0%	0%	0%	0%	15715	14564	15597	100%
mp06	1; 1.25	17500t	+15%; -5%	14%	0%	0%	0%	0%	17%	0%	0%	0%	0%	0%	15715	14594	15950	100%
mp07	1; 1.25	19000t	+10%; -10%	13%	0%	0%	0%	0%	22%	0%	0%	0%	0%	0%	15574	12816	13596	100%
mp08	1; 1.25	19000t	+10%; -5%	21%	0%	0%	0%	0%	11%	0%	0%	0%	0%	0%	17039	15672	16714	100%
mp09	1; 1.25	19000t	+15%; -5%	21%	0%	0%	0%	0%	11%	0%	0%	0%	0%	0%	17039	15680	17116	100%
mp10	1; 2	16000t	+10%; -10%	4%	0%	20%	0%	5%	33%	0%	0%	0%	0%	0%	13025	10706	11273	94%
mp11	1; 2	16000t	+10%; -5%	11%	0%	20%	0%	5%	17%	0%	0%	0%	0%	0%	14243	13281	14239	100%
mp12	1; 2	16000t	+15%; -5%	11%	0%	20%	0%	5%	19%	0%	0%	0%	0%	0%	14243	13288	14590	100%
mp13	1; 2	17500t	+10%; -10%	8%	0%	20%	0%	5%	33%	0%	0%	0%	0%	0%	14209	11568	12130	98%
mp14	1; 2	17500t	+10%; -5%	14%	0%	20%	0%	5%	11%	0%	0%	0%	0%	0%	15579	14355	15366	100%
mp15	1; 2	17500t	+15%; -5%	14%	0%	20%	0%	5%	17%	0%	0%	0%	0%	0%	15579	14394	15752	100%
mp16	1; 2	19000t	+10%; -10%	12%	0%	0%	0%	0%	33%	0%	0%	0%	0%	0%	15398	12329	12990	100%
mp17	1; 2	19000t	+10%; -5%	20%	0%	0%	0%	0%	11%	0%	0%	0%	0%	0%	16914	15420	16472	100%
mp18	1; 2	19000t	+15%; -5%	20%	0%	0%	0%	0%	14%	0%	0%	0%	0%	0%	16914	15420	16772	100%

Table 2: Performance statistics for mp12, mp14 and mp16 for the Base Case SCAA operating model (SCAA0) and for mp14 for SCAA5.

Performance target:		1	2a				2b		2c					3				4
SCAA0		B^{5-9} $P_{2016}/$ P_{2011}	Prob* (2010-2014)	Prob* (2011-2015)	Prob (2010-2029)	Prob (2011-2030)	Prob (2010-2027)	Prob (2011-2028)	C_{2011}	C_{2012}	C_{2013}	C_{2014}	C_{2015}	$C_{2011-2015}$	$C_{2016-2020}$	$C_{2011-2030}$	AAV_{2011_2029}	B^{5-9} $P_{achieved}/$ $P_{milestone}$
constant catch	median	1.15	20%	0%	5%	0%	0%	0%	16000	16000	16000	16000	16000	16000	16000	16000	1.1%	1.22
	low 2.5%	0.75	20%	0%	5%	0%	0%	0%	16000	16000	16000	16000	16000	16000	16000	16000	0.9%	0.98
	high 2.5%	1.52	20%	0%	5%	0%	6%	0%	16000	16000	16000	16000	16000	16000	16000	16000	1.6%	1.53
mp12	median	1.18	20%	0%	5%	0%	22%	17%	15709	14939	14207	13511	14165	14513	16211	17485	6.8%	1.17
	low 2.5%	0.81	20%	0%	5%	0%	6%	0%	15709	14939	14207	13511	12849	14243	12249	14993	5.1%	0.81
	high 2.5%	1.54	20%	0%	5%	0%	42%	36%	15709	14939	14207	15043	16767	15303	21124	22118	8.5%	1.48
mp14	median	1.16	20%	0%	5%	0%	14%	11%	17182	16340	15539	14778	15420	15857	17218	18102	5.9%	1.17
	low 2.5%	0.78	0%	0%	0%	0%	0%	0%	17182	16340	15539	14778	14054	15579	13253	15683	4.6%	0.85
	high 2.5%	1.53	20%	0%	5%	0%	33%	28%	17182	16340	15539	16407	17840	16627	20785	21741	7.1%	1.46
mp16	median	1.17	0%	0%	0%	0%	28%	22%	18655	16808	15144	13645	14279	15746	15561	15930	7.2%	1.23
	low 2.5%	0.80	0%	0%	0%	0%	6%	3%	18655	16808	15144	13645	12294	15309	11197	13422	5.5%	1.00
	high 2.5%	1.53	20%	0%	5%	0%	53%	47%	18655	16808	15325	16015	17510	16837	19399	19696	8.6%	1.51
SCAA5																		
mp14	median	0.96	20%	0%	5%	0%	11%	11%	17182	16340	15539	14778	14054	15579	14355	15366	5.7%	0.61
	low 2.5%	0.57	0%	0%	0%	0%	0%	0%	17182	16340	15539	14778	14054	15579	12118	12880	4.6%	0.39
	high 2.5%	1.34	20%	0%	5%	0%	25%	22%	17182	16340	15539	14868	15658	15937	18261	19299	6.7%	0.86

Table 3: Performance statistics for a series of further MPs for the Base Case SCAA operating model (SCAA0) requested for addition by our EU principals, where these are reported in a format that relates to specified targets in NAFO (2010). All MP options shown meet all the NAFO (2010) performance targets.

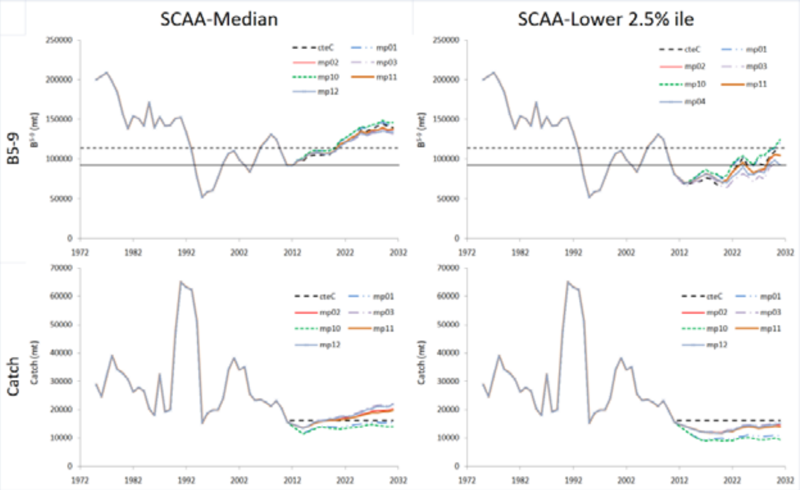
			1	2a				2b	2c					3			4
SCAA0			Prob	Prob*	Prob*	Prob	Prob	Prob	Prob	Prob	Prob	Prob	Prob	$C_{2011-2015}$	$C_{2016-2020}$	$C_{2011-2030}$	Prob
	starting TAC	override of MP recommendation	B^{5-9}	(2011-2015)	(2010-2014)	(2011-2030)	(2010-2029)	(2010-2027)	2011	2012	2013	2014	2015				$P_{achieved}/P_{milestone}$
mp11	16000t		1%	0%	20%	0%	5%	17%	0%	0%	0%	0%	0%	14513	15855	16674	11%
mp14	17500t		2%	0%	20%	0%	5%	14%	0%	0%	0%	0%	0%	15857	17218	18102	20%
mp14*	17500t	C_{2011}=16000t	2%	0%	20%	0%	5%	17%	0%	0%	0%	0%	0%	15625	17252	18045	20%
mp14**	17500t	C_{2011} and C_{2012}=16000t	2%	0%	20%	0%	5%	17%	0%	0%	0%	0%	0%	15559	17260	18026	20%
mp14***	17500t	C_{2011}=14500t	2%	0%	20%	0%	5%	17%	0%	0%	0%	0%	0%	15334	17295	17960	20%
mp19	14500		0%	0%	20%	0%	5%	17%	0%	0%	0%	0%	0%	13405	14765	15520	5%

Table 4: Performance statistics for a series of further MPs (as in Table 3) for the Base Case SCAA operating model (SCAA0).

			Performance target	1	2a				2b		2c					3				4
SCAA0				B^{5-9}	Prob*	Prob*	Prob	Prob	Prob	Prob										B^{5-9}
	starting TAC	override of MP recommendation		P_{2016}/P_{2011}	(2010-2014)	(2011-2015)	(2010-2029)	(2011-2030)	(2010-2027)	(2011-2028)	C_{2011}	C_{2012}	C_{2013}	C_{2014}	C_{2015}	$C_{2011-2015}$	$C_{2016-2020}$	$C_{2011-2030}$	AAV_{2011_2029}	$P_{achieved}/P_{milestone}$
mp11	16000t		median	1.18	0.20	0.00	0.05	0.00	0.17	0.11	15709	14939	14207	13511	14165	14513	15855	16674	6.3%	1.21
			low 2.5%	0.81	0.20	0.00	0.05	0.00	0.06	0.00	15709	14939	14207	13511	12849	14243	12249	14532	5.1%	0.91
			high 2.5%	1.54	0.20	0.00	0.05	0.00	0.33	0.28	15709	14939	14207	15043	16359	15221	19038	20096	7.4%	1.48
mp14	17500t		median	1.16	0.20	0.00	0.05	0.00	0.14	0.11	17182	16340	15539	14778	15420	15857	17218	18102	5.9%	1.17
			low 2.5%	0.78	0.00	0.00	0.00	0.00	0.00	0.00	17182	16340	15539	14778	14054	15579	13253	15683	4.6%	0.85
			high 2.5%	1.53	0.20	0.00	0.05	0.00	0.33	0.28	17182	16340	15539	16407	17840	16627	20785	21741	7.1%	1.46
mp14*	17500t	C_{2011}=16000t	median	1.16	0.20	0.00	0.05	0.00	0.17	0.11	16000	16340	15539	14778	15443	15625	17252	18045	6.0%	1.17
			low 2.5%	0.78	0.20	0.00	0.05	0.00	0.00	0.00	16000	16340	15539	14778	14054	15342	13273	15615	4.8%	0.85
			high 2.5%	1.53	0.20	0.00	0.05	0.00	0.33	0.28	16000	16340	15539	16435	17876	16403	20791	21686	7.2%	1.46
mp14**	17500t	C_{2011}=16000t C_{2012}=16000t	median	1.16	0.20	0.00	0.05	0.00	0.17	0.11	16000	16000	15539	14778	15449	15559	17260	18026	5.8%	1.17
			low 2.5%	0.78	0.20	0.00	0.05	0.00	0.00	0.00	16000	16000	15539	14778	14054	15274	13282	15605	4.6%	0.85
			high 2.5%	1.53	0.20	0.00	0.05	0.00	0.33	0.28	16000	16000	15539	16436	17872	16335	20792	21669	7.0%	1.46
mp14***	17500t	C_{2011}=14500t	median	1.16	0.20	0.00	0.05	0.00	0.17	0.11	14500	16340	15539	14778	15474	15334	17295	17960	6.9%	1.17
			low 2.5%	0.78	0.20	0.00	0.05	0.00	0.00	0.00	14500	16340	15539	14778	14054	15042	13311	15583	5.7%	0.85
			high 2.5%	1.53	0.20	0.00	0.05	0.00	0.33	0.28	14500	16340	15539	16470	17911	16127	20799	21615	8.0%	1.46
mp19	14500t		median	1.21	0.20	0.00	0.05	0.00	0.17	0.14	14500	13790	13114	12471	13128	13405	14765	15520	6.6%	1.23
			low 2.5%	0.84	0.20	0.00	0.05	0.00	0.06	0.00	14500	13790	13114	12471	11860	13147	11458	13557	5.4%	0.96
			high 2.5%	1.56	0.20	0.00	0.05	0.00	0.33	0.28	14500	13790	13114	13918	15141	14082	17599	18712	7.7%	1.51

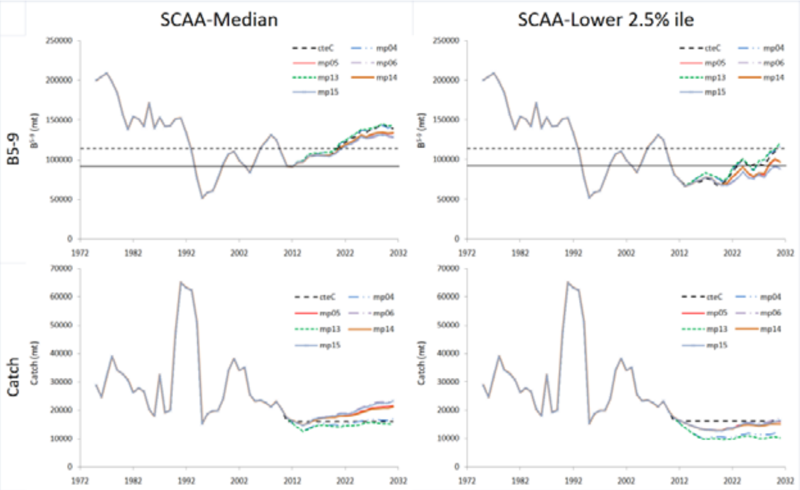
Starting TAC:

16 000t



Starting TAC:

17 500t



Starting TAC:

19 000t

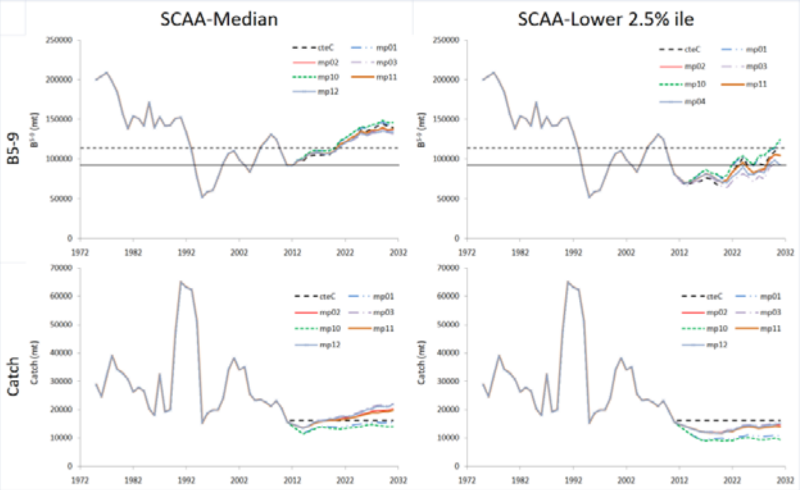


Fig. 1: Medians (left) and lower 2.5%iles (right) TAC and exploitable biomass for a series of MPs for the **Base Case SCAA** operating model (SCAA0). Here and in subsequent biomass plots the full horizontal line represents the 2011 median level while the dashed horizontal line represents the target level (1985-1999 average).

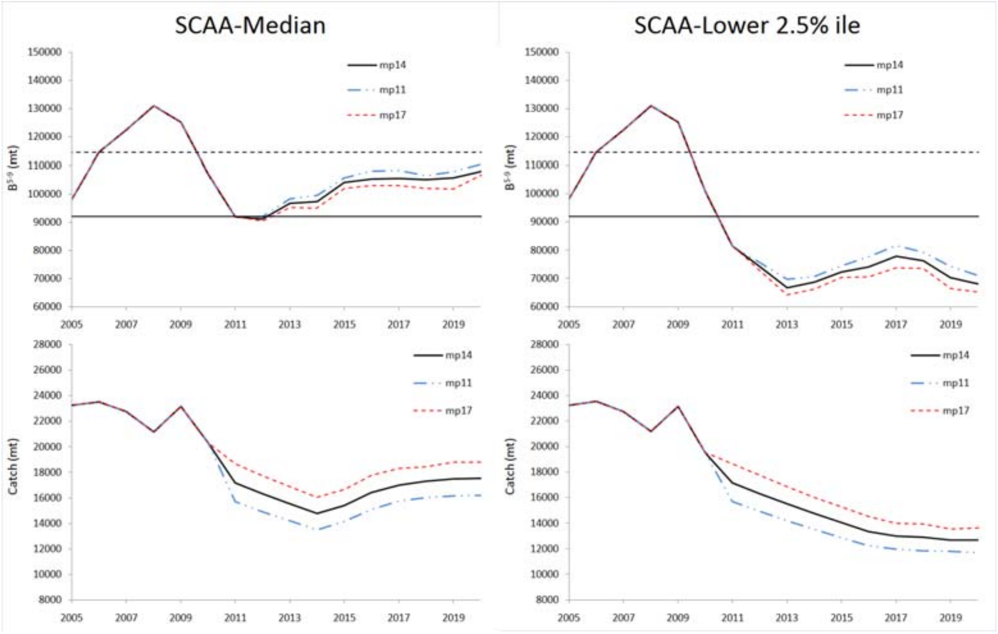


Fig. 2a: Medians (left) and lower 2.5%iles (right) TAC and exploitable biomass for three MPs with different starting TAC control parameters (mp14: 17 500t; mp11: 16 000t and mp17: 19 000t) for SCAA0. Note that here and below to magnify around where most differences are evident, the axes no longer intersect at a zero value on the vertical axis.

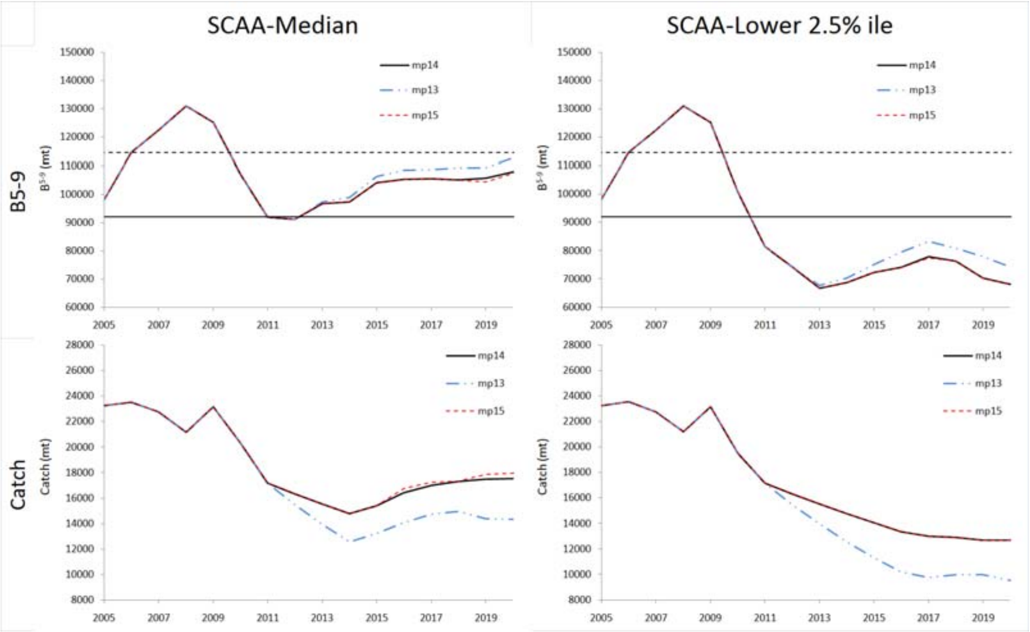


Fig. 2b: Medians (left) and lower 2.5%iles (right) TAC and biomass for three MPs with different bounds on maximum annual TAC change (mp14: +10%, -5%; mp13: +10%, -10% and mp15: +15%, -5%) for SCAA0.

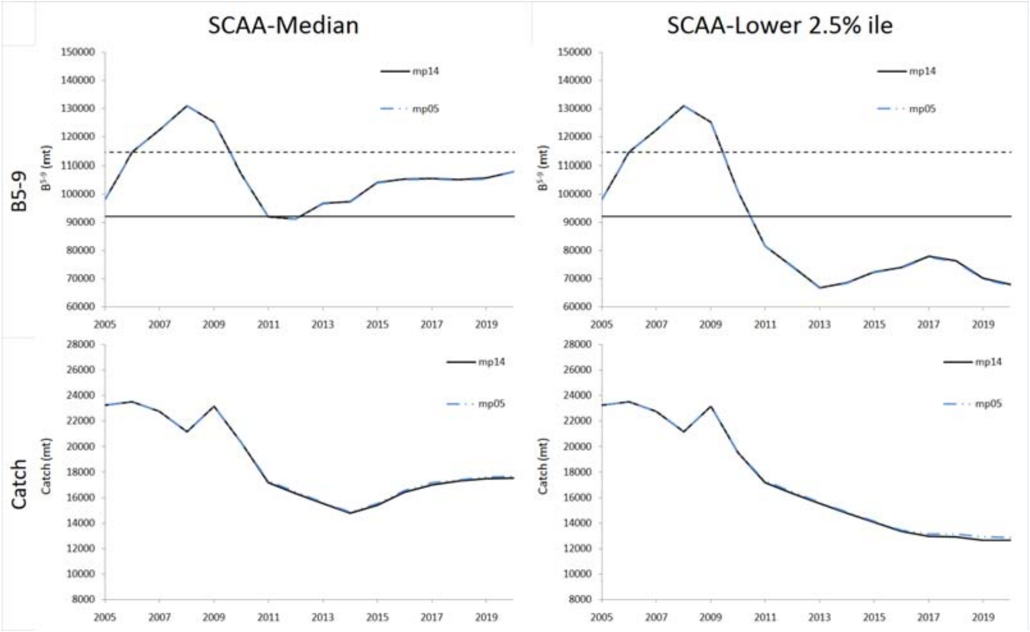


Fig. 2c: Medians (left) and lower 2.5%iles (right) TAC and exploitable biomass for three MPs with different values for λ_{down} (mp14: 1.25 and mp05: 2.0) for SCAA0.

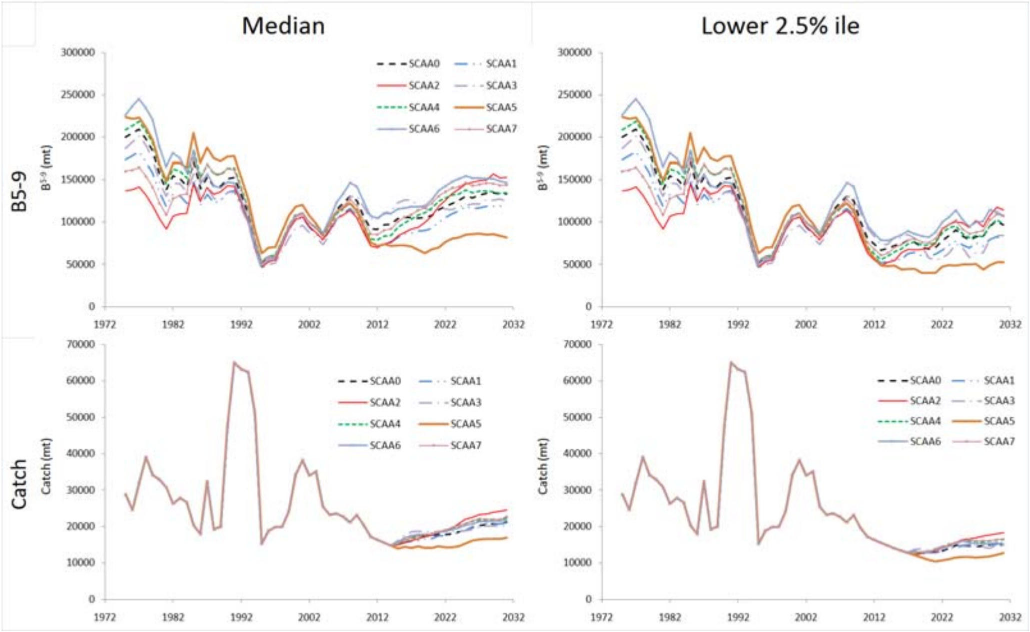


Fig. 3: Medians (left) and lower 2.5%iles (right) TAC and exploitable biomass for the SCAA Base Case operating model (SCAA0) and a series of robustness tests (SCAA1 – SCAA7) for mp14.

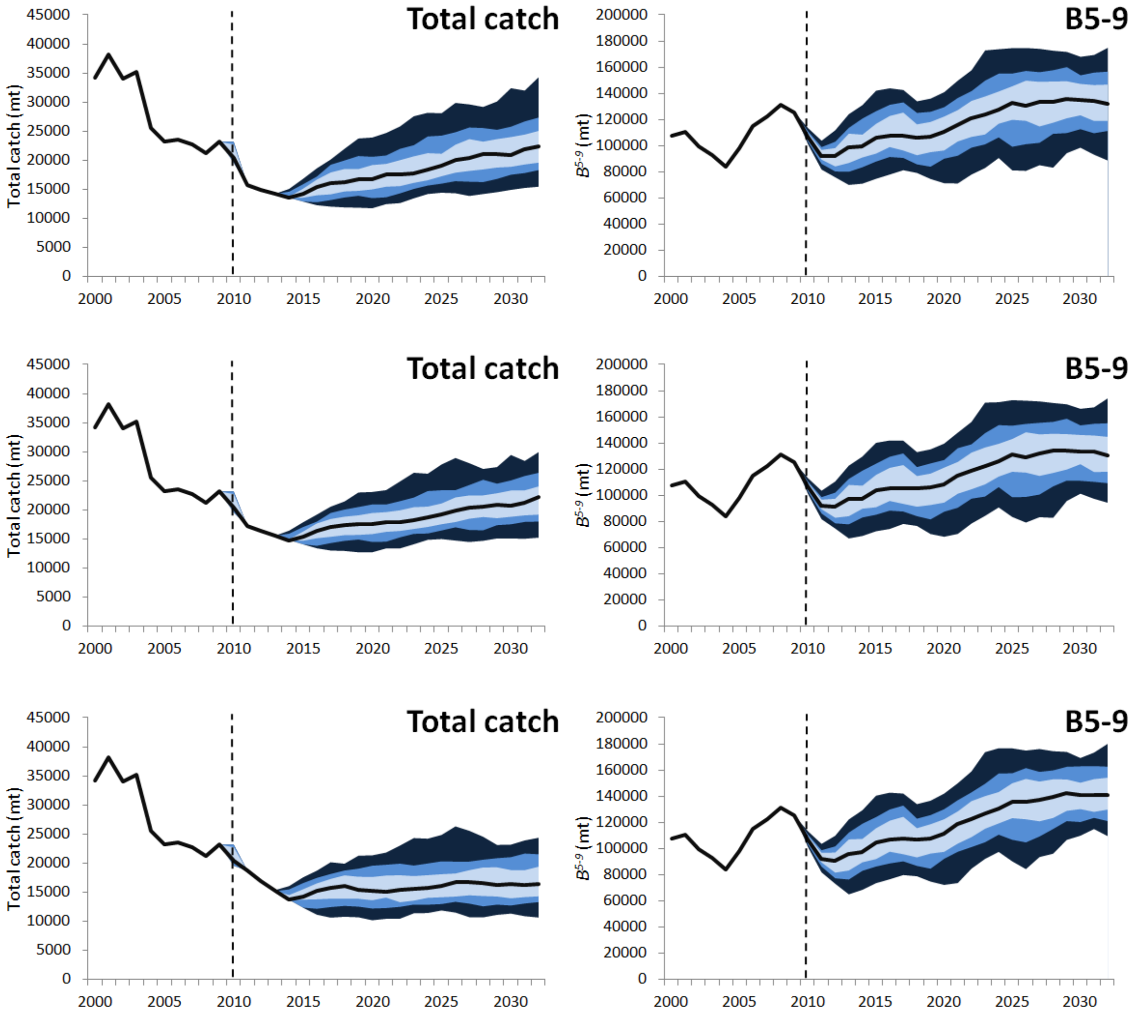


Fig. 4: 95, 75 and 50% PIs and medians for the total catch and exploitable biomass projections for mp12 (top), mp14 (middle) and mp16 (bottom) for SCAA0.

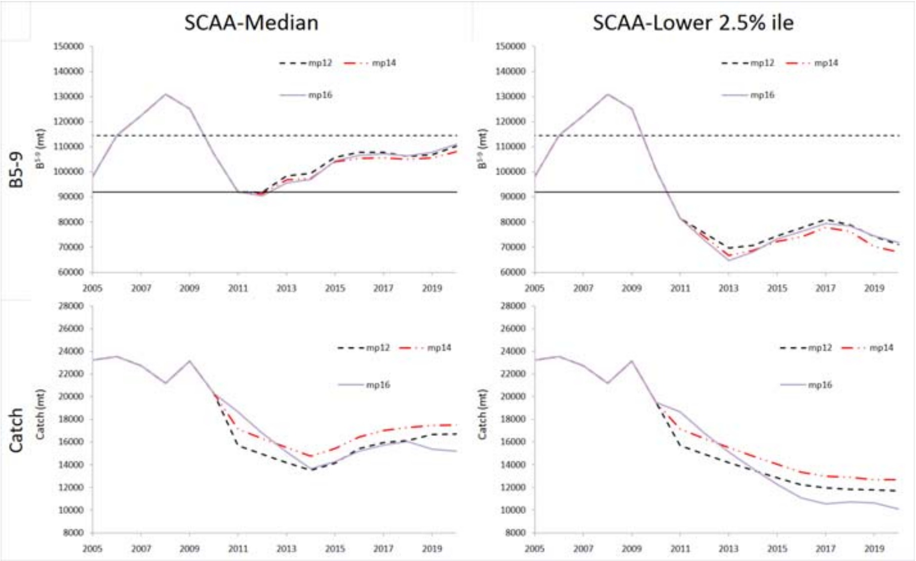


Fig. 5: Medians (left) and lower 2.5%iles (right) TAC and exploitable biomass for the SCAA Base Case for mp12, mp14 and mp16.

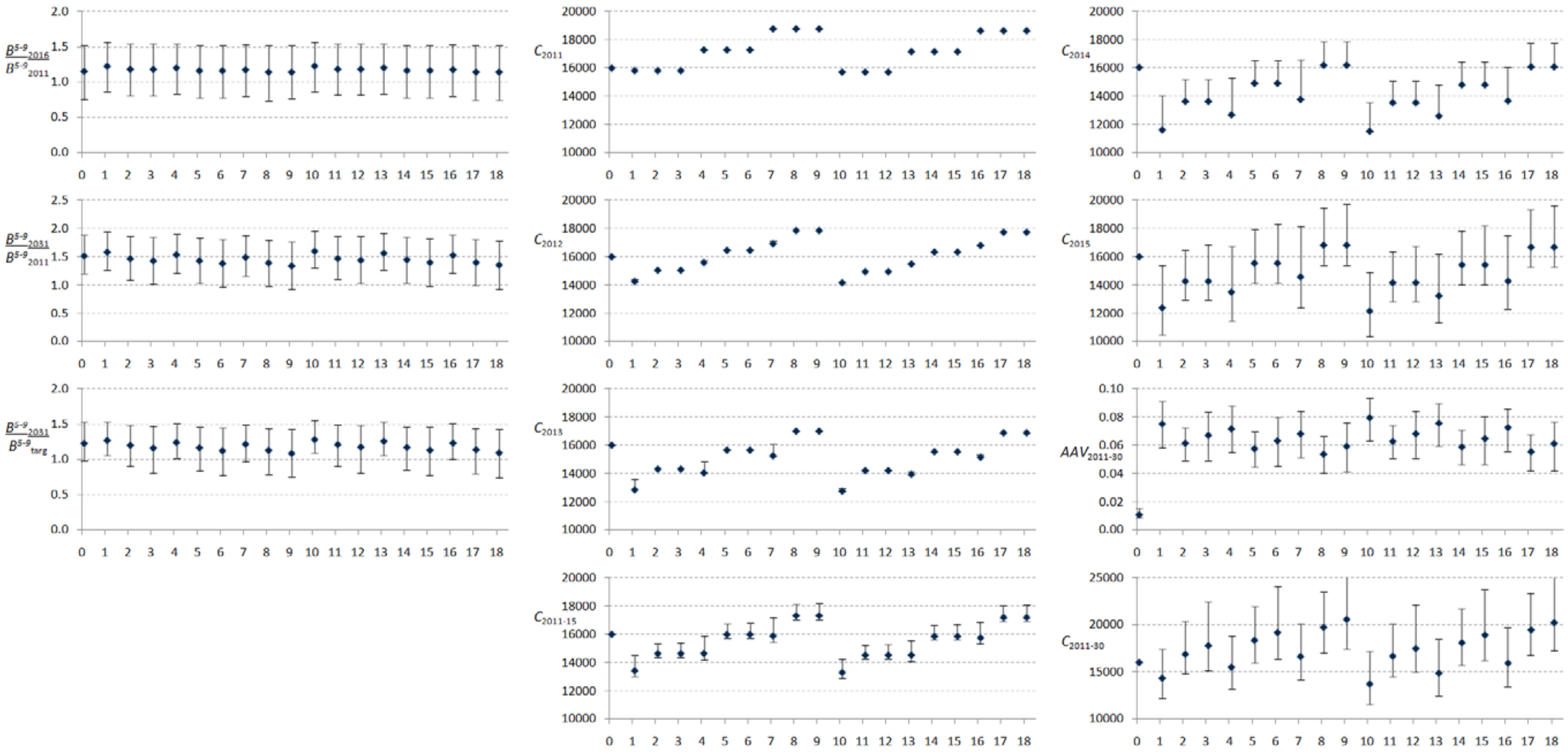


Fig. 6a: Median and 95%-iles for a series of performance statistics for the Base Case SCAA under a series of MPs (0=cteC; 1=mp1, 2=mp2...).

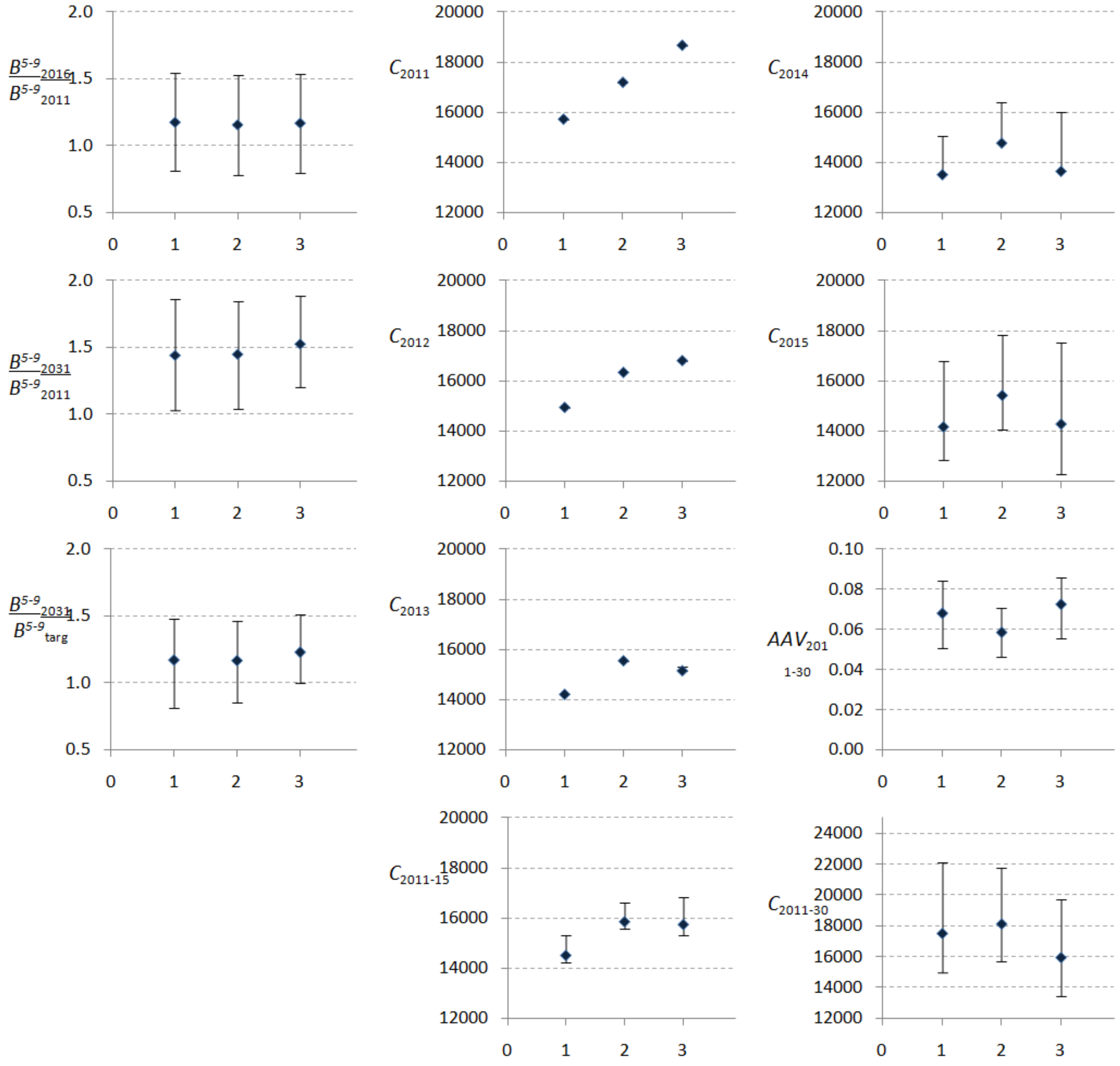


Fig. 6b: Median and 95%-iles for a series of performance statistics for the Base Case SCAA under mp12, mp14 and mp16 (in that order).

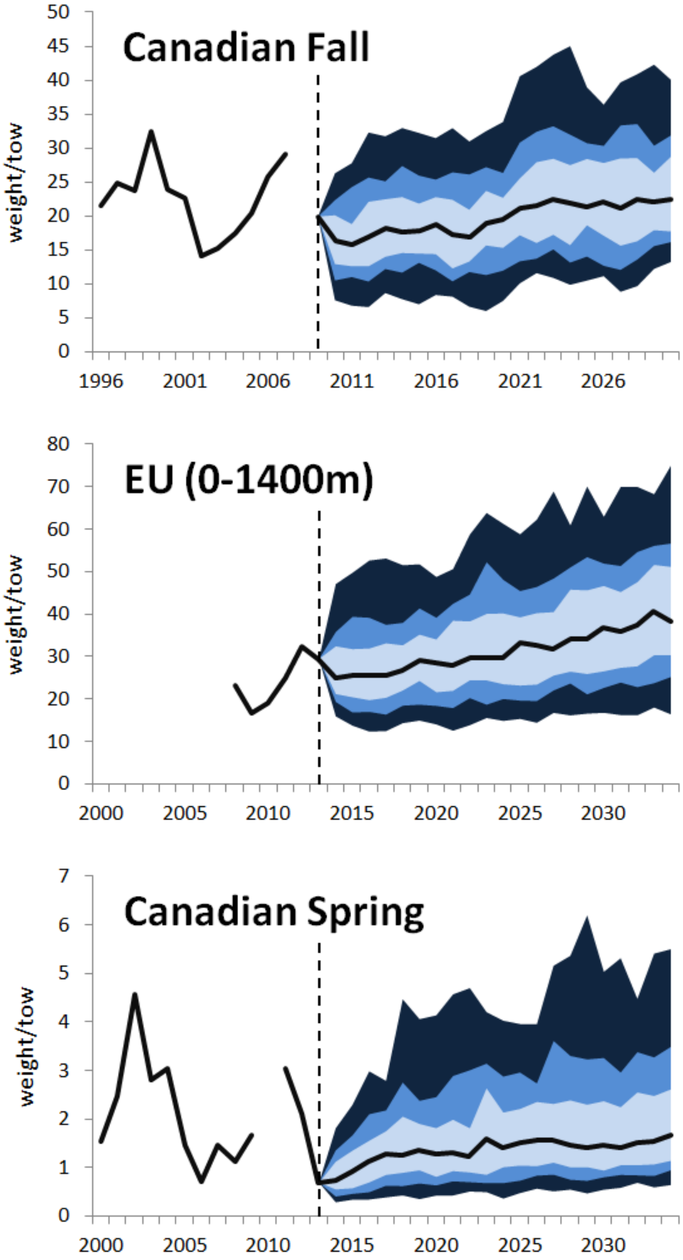


Fig. 7: 95, 75 and 50% PIs and medians for the survey projections for SCAA0 under implementation of mp14.

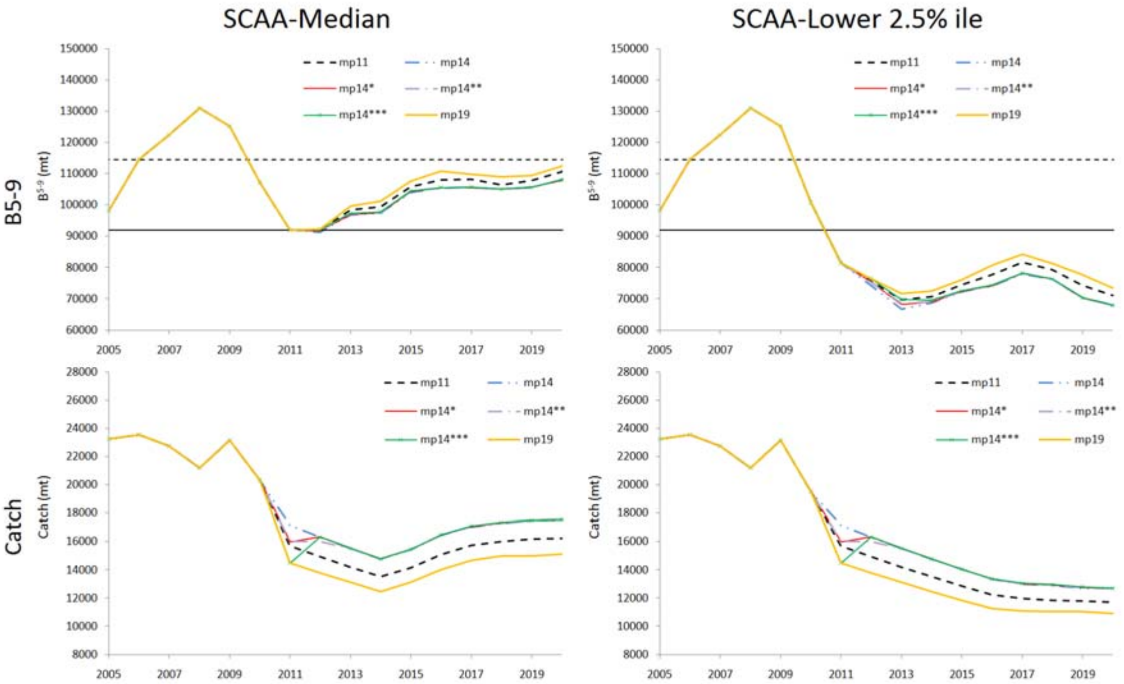


Fig. 8: Medians (left) and lower 2.5%iles (right) TAC and exploitable biomass for some further MPs (requested for addition by our EU principals) for the **Base Case SCAA** operating model (SCAA0). Here and in subsequent biomass plots the full horizontal line represents the 2011 median level while the dashed horizontal line represents the target level (1985-1999 average).