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ABSTRACT

The final trial specifications for the North Atlantic common minke whales as tailored to evaluate *Strike Limit Algorithms* (*SLA*s) for aboriginal subsistence whaling hunts off West and East Greenland are implemented and used to test the common *SLA* (G-Common minke SLA') based on the agreed *Evaluation* and *Robustness Trials*. Previous evaluations of carryover provisions and the interim allowance approach are extended to make use of the new trials and to account for hunts off East as well as West Greenland.

INTRODUCTION

The Scientific Committee adopted a *Strike Limit Algorithm* (*SLA*) for the aboriginal subsistence whaling operation for common minke whales[1] off West Greenland in 2018 and one for the operation off East Greenland in 2019 (IWC, 2019a, In-press-a). The same *SLA* is applied for the two regions (the 'G-Common minke SLA' - see Witting [2019] and Appendix A for details). The Sub-committee on *Implementation Reviews* and *Simulations Trials* (IWC, In-press-b) recommended that a single simulation testing framework be developed for the North Atlantic minke whales and that the 2020 Scientific Committee meeting be provided with a synthesis paper that includes results for all *Evaluation* and *Robustness Trials*, as well as an evaluation of carryover and interim allowance for East and West Greenland minke whales.

The steps to conduct this consolidated testing are:

- finalize the technical description of the simulation trials framework, including specification of the final *Evaluation* and *Robustness Trials*;
- condition the resulting trials and summarize the results of the conditioning using standard diagnostic plots;
- use the trials structure to provide a summary of the performance of the G-Common minke SLA*;*
- evaluate the conservation consequences of carryover provisions; and
- evaluate the conservation and need satisfaction consequences of the interim allowance approach.

This document does not include all possible results and summary statistics, in particular the results of the conditioning are not provided in full detail (although the authors examined these, and they are available from the Secretariat). Similarly, and in common with past evaluations of carryover provisions and interim allowance (e.g. IWC, 2019b), the evaluations of carryover provisions and the interim allowance approach are based on the *Evaluation Trials* among those that led to the highest conservation risk.

TECHNICAL DESCRIPTION, TRIALS, AND PERFORMANCE STATISTICS

The final technical description of the trial structures is provided in IWC (In press-b). Figure 1 shows the sub-areas on which the trials are based and Figure 2 shows the two stock structure hypotheses on which these trials are based. The *Implementation Review* for the North Atlantic minke whales (IWC, 2018) included four stock structure hypotheses, but the trials to evaluate *SLA*s for the West and East Greenland consider only the stock hypotheses with 4 or 5 stocks and focus on uncertainties pertinent to the western North Atlantic.

Table 1 lists the factors considered in the trials and Table 2 the final set of trials divided into *Evaluation* and *Robustness Trials.* IWC (In press-b) lists many performance statistics (Table 3). However, most of these provide very similar information so the results in this document are limited to five performance statistics:

- D1: Final depletion (population size at the end of the 100-years; 1+ population component);
- D10: Relative increase (population size at the end of the 100-years relative to that at the start of the projection period; 1+ population component);
- N9: Average need satisfaction over 20 years (N9-20);

[1] Henceforth "minke whales"

- N9: Average need satisfaction over 100 years (N9-100); and
- N12: Mean down step.

The conservation performance statistics are shown for the stocks that are primarily found in the sub-areas in which aboriginal subsistence whaling occurs (W or W-2 for hunts off West Greenland; C for hunts off East Greenland; Figure 2) and the need satisfaction statistics are presented separately for the two hunts (West and East Greenland). The analyses assume commercial catches are based on RMP Variant 5[2] (IWC, 2018), but with catches in the CIC sub-areas restricted to 100 whales because catches in the this sub-area have the most impact on stocks in the WG and CG sub-areas, and the RMP catch being set is much higher than the current takes (the highest annual catch in the CIC sub-area since 1986 is 81 whales) (IWC, 2019b). As noted by IWC (2019b), the RMP catch limits are pre-specified, with trial-specific catch limits by year based on the two Baseline Hypothesis 1 trials (M01-1 and M01-4). If the RMP catch limit for the *Combination Area* or *Small Area* containing the CG sub-area is less than or equal to the aboriginal strike limit (as set by the *SLA*), the catch limit for that *Combination Area* or *Small Area* is set to zero and the aboriginal catch is equal to the strike limit; or if the RMP catch limit is larger than aboriginal strike limit, the catch limit for that *Combination* Area or *Small Area* is set to the RMP catch limit less the aboriginal strike limit (IWC, In-press-b).

CONDITIONING

Conditioning is the process of setting the values for the parameters of the operating model. The operating model is fitted to four sources of information: (a) estimates of absolute abundance, (b) mixing proportions, (c) average sex ratios (‘survey’/’original’[3] and ‘fishery’ sex ratios separately) and (d) time-series of sex ratios for West Greenland (operating models M11 and M12 only). The *Robustness Trials* had not previously been conditioned when the *Evaluation Trials* had been conditioned and the conditioning was examined by the Scientific Committee for these trials (e.g. IWC 2019b,c). As for previous conditioning exercises, the simulated data set for each simulation (of each trial) is fitted multiple times from different starting points for the parameters and the best fit (lowest value for the objective function) selected. This is because, given the complex log-likelihood surface, it is possible for the non-linear minimization algorithm to converge to a local (rather than the global) minimum.

Table 4 lists diagnostics used to evaluate the conditioning. These diagnostics include statistics used during the last *Implementation Review* for the North Atlantic minke whales (IWC, 2018) as well as diagnostic statistics developed specifically for the evaluation of *SLA*s for West and East Greenland (e.g. 2019b,c).

The operating model is able to mimic the data used for conditioning adequately (see, for examples, Figures 3-9, which shows the diagnostics for the four ‘base-case’ trials M01-1, M01-2, M02-1, and M02-2; the remaining plots are available from the Secretariat). As expected, the operating model matches the central tendency of the abundance estimates well (Figures 3-6). There are some cases where the deterministic and median stochastic time-trajectories of mature female numbers differ (e.g. the C stock for trials M01-1 and M02-1; Figure 3), but this behaviour is not evident for the 1+ trajectories. There is no evidence for outlying trajectories (Figures 5 and 6), which might indicate convergence to a local minimum of the objective function for the data.

The fits to the sex-ratio data are good (Figure 7), with the fits to the fishery sex-ratios better (as expected) than those to the original (or ‘survey’) sex-ratios. This is because the operating model includes an estimable parameter for each sub-area to allow it to match the fishery sex-ratios almost exactly. In contrast, the fits to the ‘original’ sex-ratios are poorer because the operating model imposes constraints on overall sex-ratios due to its population dynamics equations. The fits to mixing proportions are, as expected, almost exact given the high weight assigned to these data.

The operating model matches the sex ratios for West Greenland in general. The model predictions generally capture the central tendency of the observations. The trials that allow for density-dependent mixing (M11 and M12) exhibit lesser among-simulation variation than those that assume time-invariant mixing proportions (e.g. M01 and M02). All eight operating models in Figure 9 predict stable (or near stable) sex-ratios off West Greenland. None of the operating models are able to mimic the increase in the proportion of females in catches in recent years.

Overall, the trials were successfully conditioned and there were no obvious concerns evident in the diagnostic plots.

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[2] Sub-areas CIP+CIC+CG+CM, EN, EB, ESW+ESE and EW are *Small Areas*, with the catch limits for the E *Small Areas* based on catch cascading from the E *Combination Area*. All the catches from CIP+CIC+CG+CM *Small* Area are taken in sub-area CIC (after taking the Aboriginal catch from CG) and those for the ESW+ESE *Small Area* are taken in sub-area ESE.

[3] The original sex ratios apply to the populations when they are at unexploited equilibrium.

TRIAL RESULTS

Table 5 lists the values for conservation-related performance statistics (D1 and D10) for the stocks most impacted by the aboriginal subsistence hunts off West and East Greenland, and Table 6 lists the values for need satisfaction and strike limit stability statistics (N9 and N12) for the West and East Greenland hunts. There are no thresholds for what constitutes adequate performance for an *SLA* (unlike the situation for the Revised Management Procedure [IWC, 2005]). However, to identify which trials are the most challenging, Table 5 highlights cases in which the D1 statistic is less than 0.6 (MSYL) and the D10 statistic is less than 0.99 (no increase compared to the population size in the first year), while Table 6 highlights cases in which need satisfaction is less than 80%. Cases in which the W/W-2 stock is below the MSYL at the end of the projection period and did not increase might warrant additional consideration.

As expected, conservation performance is adequate for all the $MSYR_{mat}$=4% trials. The poorest conservation performance occurs for trial M05-1, a trial with $MSYR_{1+}$=1% and the "A4" mixing hypothesis, which has the highest proportion of the animals in the WG sub-area being from the W-2 stock (75%), along with only 25% of the animals in the (more abundant) WC sub-area being from this stock. This is the only trial for which the median final depletion is less than 0.6 (0.440; Table 5). Other trials in which the lower 5th percentile of the D1 statistic is less than 0.6 and the lower 5% percentile of the D10 statistic is less than 0.99 are M01-1, M03-1, M04-1, M07-1, M11-1, M23-1, and M27-1 (the latter two being *Robustness Trials*). These trials involve stock hypothesis I (five stocks, including W-1 and W-2 stocks). The value of the D1 statistic for trials M01-1, M07-1, and M11-1 is close to 0.6 (0.574, 0.557, and 0.576).

80% need satisfaction is achieved for all trials for the aboriginal subsistence hunt off East Greenland, whereas this is never achieved with more than 95% probability over 100 years for the hunt off West Greenland. The poorest performance in terms of need satisfaction occurs for trial M12 (four stocks with density-dependent mixing into West Greenland) and trials M25 and M26 (*Robustness Trials* with longer survey intervals).

CARRYOVER

At its March 2018, meeting, the AWMP Working Group received a joint request from the US Acting Commissioner and the Danish Commissioner for assessment by the Scientific Committee of the conservation performance and other scientific issues associated with a specific carryover scheme. The request related to a period of accumulation (three blocks), a time until expiration (greater than three blocks), and a limit on usage (total strikes not exceeding 150% of the annual strike limit). The March 2018 Workshop (IWC, 2019b) developed an approach using the simulation testing framework to compare alternative carryover schemes and applied it to the Bering-Chukchi-Beaufort Seas bowhead whales and humpback whales off West Greenland. The comparison was based on five cases in addition to "no carryover":

- The "frontloaded" scheme assumes that strikes are taken as quickly as possible within a block, subject to the 150% limit. It serves as a bounding case for evaluating a non-accumulating scheme.
- The scheme "3@67%, 2@≤150%" refers to a scheme with three accumulation six-year blocks (with 67% strike limit usage) followed by two carryover usage blocks (using up to 150% of the baseline strike limit).
- The "3@80%, 2@≤150%" scheme resembles the previous one, but 80% of the strike limit is taken during the accumulation blocks.
- The scheme "1@67%, 1@≤150%" alternates between carryover accumulation and usage blocks: first only 67% of the strike limit is taken, then up to 150% of the strike limit is used.
- The scheme "1@80%, 1@≤150%" resembles the previous, but it assumes that 80% of the strike limit is taken in the accumulation block.

The trials for which results are reported in relation to the conservation consequences of carryover (M01, M02, M04, and M08) are *Evaluation Trial*s that are amongst those that provide the most severe (conservation) challenges to the *SLA*s (e.g. 1% MSY rates) and the reported results should therefore not be considered to be representative of those of the full set of *Evaluation Trials*, but rather likely to over-estimate the negative effects of carryover provisions. Following IWC (2019b), the trials are based on 5-year rather than 6-year blocks. The conservation-related performance statistics are listed in Table 7.

None of the lower 5th percentiles for final depletion (D1) for the carryover scenarios exceed those for the scenario with no carryover. This confirms previous conclusions by the Scientific Committee that carryover provisions are unlikely to lead to poorer conservation performance.

INTERIM ALLOWANCE APPROACH

Most of the trials assume that estimates of abundance become available every 10 years. However, surveys may not occur as frequently due to logistical constraints. The AWMP includes a provision that strike limits are reduced by 50% (the 'grace period') once a recent abundance estimate has not been available for 10 years (the 'phase out' approach). IWC (2016) considered a proposal for the Bering-Chukchi-Beaufort Seas stock of bowhead whales that the 'phase out' approach be replaced by an 'interim allowance' approach in which the 50% phase-out during the grace period would not apply. Simulations are undertaken for 10-, 15- and 20-year inter-survey intervals, in which either the original or interim approach is applied.

Tables 8 and 9 list the results of the trials. As expected, there is no impact of adopting an interim allowance approach if the survey interval is 10 years. The conservation performance statistics for a 15-year survey interval are lower for the interim allowance approach but only for trial M04-1 - the D1 statistic is lower than for the 10-year survey period. In contrast to the 10- and 15-year survey periods, a 20-year survey period leads to several instances in which conservation performance statistics are poorer than was the case for a 10-year survey interval.

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Table 1
Factors considered in the *Evaluation and Robustness Trials*.

Factor	Values
MSYR	1% (1+), 4% (1+)
Need envelope (West Greenland)[1]	A: constant 164; B: 164 to 250 over 100 years; C: 164 to 350 over 100 years
Need envelope (East Greenland)	Constant 20
Number of W-sub-stocks	2 (stock hypothesis I); 1 (stock hypothesis II)
Scenarios regarding mixing proportions	A1, A2, A3, A4, A5, A6, B1, B2, B3
Mixing	Density-independent[1], density-dependent
Survey bias	0.8, 1, 1.2
Survey period	10, 15
Survey CV (difference from the average CV)	-0.05, 0, 0.05

1: trials are only conducted for need envelope A (IWC, 2019c).

Table 2
The final set of trials.

Trial	*MSYR*	Stock Hypothesis	Mixing Proportions	Mixing	Survey Bias	Survey period	Survey CV	Condition
Evaluation Trials								
M01	1% (1+) & 4 % (mat)	1	A1	Independent	1	10	Base	Yes
M02	1% (1+) & 4 % (mat)	2	B1	Independent	1	10	Base	Yes
M03	1% (1+) & 4 % (mat)	1	A2	Independent	1	10	Base	Yes
M04	1% (1+) & 4 % (mat)	1	A3	Independent	1	10	Base	Yes
M05	1% (1+) & 4 % (mat)	1	A4	Independent	1	10	Base	Yes
M06	1% (1+) & 4 % (mat)	1	A5	Independent	1	10	Base	Yes
M07	1% (1+) & 4 % (mat)	1	A6	Independent	1	10	Base	Yes
M08	1% (1+) & 4 % (mat)	2	B2	Independent	1	10	Base	Yes
M09	1% (1+) & 4 % (mat)	2	B3	Independent	1	10	Base	Yes
~~M10~~	~~1% (1+) & 4 % (mat)~~	~~2~~	~~B4~~	~~Independent~~	~~1~~	~~10~~	~~Base~~	Yes
M11	1% (1+) & 4 % (mat)	1	A1	Density-dependent	1	10	Base	Yes
M12	1% (1+) & 4 % (mat)	2	B1	Density-dependent	1	10	Base	Yes
Robustness Trials								
M21	1% (1+) & 4 % (mat)	1	A1	Independent	0.8	10	Base	Yes
M22	1% (1+) & 4 % (mat)	2	B1	Independent	0.8	10	Base	Yes
M23	1% (1+) & 4 % (mat)	1	A1	Independent	1.2	10	Base	Yes
M24	1% (1+) & 4 % (mat)	2	B1	Independent	1.2	10	Base	Yes
M25	1% (1+) & 4 % (mat)	1	A1	Independent	1	15	Base	
M26	1% (1+) & 4 % (mat)	2	B1	Independent	1	15	Base	
M27	1% (1+) & 4 % (mat)	1	A1	Independent	1	10	Base + 0.05	
M28	1% (1+) & 4 % (mat)	2	B1	Independent	1	10	Base + 0.05	
M29	1% (1+) & 4 % (mat)	1	A1	Independent	1	10	Base - 0.05	
M30	1% (1+) & 4 % (mat)	2	B1	Independent	1	10	Base - 0.05	
M31	4% (1+)	1	A1	Independent	1	10	Base	Yes
M32	4% (1+)	2	B1	Independent	1	10	Base	Yes

Table 3
The performance statistics

ID	Name	Mandatory	Optional	Time Periods	Use to explain performance to layperson	Use to evaluate performance for SC	Details
D1	Final Depletion	1+, mature		100	Yes	Yes	P_T / K
D2	Lowest Depletion		mature	100	Yes	Yes	$\min(P_t / K): t = 0,1,...,T$
D6	Trajectories 1 and 2		1+, mature	100	Yes	No	
D7	Pointwise Quantile Trajectories		1+, mature	100	Yes	No	
D8	Rescaled final Depletion	Yes		100		No	P_T / P_T^*
D9	Minimum number of whales		1+, mature	100		No	$\min(P_t): \ t = 0,1,\ldots,T$
D10	Relative Increase	Yes		100		Yes	P_T / P_0
N1	Total Need Satisfaction		Yes	20, 100	Yes	Yes	$\sum_{t=0}^{T-1} C_t / \sum_{t=0}^{T-1} Q_t$
N2	Longest Shortfall		Yes	20, 100	Yes, after rescaling	Yes	(negative of the greatest number of consecutive years in which $C_t < Q_t$) / T
N4	Fraction of years in which catch = quota		Yes	20, 100	Yes	Yes	
N7	Percent Need Satisfaction Pointwise Quantile Trajectory Plot		Yes	100	No	Yes	
N8	Percent Need Satisfaction Trajectories 1 and 2 Plot		Yes	100	No	Yes	
N9	Average need satisfaction	Yes		20, 100	Yes	Yes	$\frac{1}{T}\sum_{t=0}^{T-1}\frac{C_t}{Q_t}$
N10	Average Annual Variation in Catch		Yes	100	No	Yes	
N11	Anti-curvature Catch Variation Statistic		Yes	100	No	Yes	
N12	Mean downstep	Yes					
R1	Relative Recovery	1+		100	Yes	Yes	$P_{t_r^*} / P_{t_r^*}^*$ where t_r^* = 1st year in which P_t^* passes through *MSYL*
R3	Time Frequency in Recovered State after Recovery		1+, mature	100	Yes	Yes	
R4	Relative Time to Recovery		1+,mature	100	Yes	Yes	

Table 4
Summary of the diagnostic plots and statistics used to evaluate conditioning

Plot/statistic	Description	Factors in the evaluation
Fit of the operating model by sub-area to the estimates of abundance	The plot for each sub-area shows the abundance estimates and their 90% confidence intervals, the fit of the model to the actual data ('deterministic'; solid red lines), and the median and 90% intervals from the 100 replicates (solid black and dashed lines respectively).	Adequate performance for these plots is that (i) the 'deterministic' trajectory passes through the centroid of the data points, (ii) the 'deterministic' and median trajectories are not markedly different, (iii) the 90% interval for the 1+ abundance in a year with data matches the sampling distribution for the data when there is only one data point, and (iv) the 90% intervals for 1+ abundance for years with data are narrower than the sampling distributions when there are multiple abundance estimates for a sub-area.
Annual numbers of mature females by stock	This plot shows the median and 90% intervals for the annual numbers of mature females.	This plot is examined qualitatively to check that the model has not converged to an "unrealistic" situation)
Individual trajectories of 1+ numbers by sub-area	The plot for each sub-area shows the 100 trajectories of 1+ numbers by sub-area and the abundance estimates and their 90% confidence intervals	This plot is examined qualitatively to ensure that there are no 'unexpected' trajectories that would be missed by simply looking at overall 90% limits only. Such trajectories could suggest convergence to a local minimum
Annual numbers of mature females expressed relative to the unfished numbers by stock	This plot shows the median and 90% intervals for the annual numbers of mature females expressed relative to carrying capacity.	This plot is examined qualitatively to check that the model has not converged to an "unrealistic" situation.
Fit of the operating model to the mean sex ratios ('original' and 'fishery').	The plots for each sex ratio type show the data points by sub-area and their assumed (normal) sampling distributions, along with the model-predictions from the fit to the actual data, and the median and 90% intervals for the model predictions.	For these plots, the 'deterministic' estimates should match the data almost exactly, and the 95% intervals from the stochastic replicates should closely match the sampling distributions. The model should mimic the original sex ratios fairly closely, but should not match them as well as the fishery sex ratios because the model imposes relationships among the abundances by sub-area, in particular that the overall sex ratio is 1:1 across the spatial domain of the model.
Fit to the mixing proportions	This plot shows the observed proportion of the W and C stocks in sub-areas WC, WG, CIP, CG and CIC (black dots), and the median and the 90% intervals for the model predictions (red dots and lines; the lines are usually too small to be seen).	The black and red dots should match very closely. The fits should be very good and the intervals very narrow because high weight is assigned to fitting the pre-specified mixing proportions.
Time-series of observed and operating model predicted sex-ratios for West Greenland (trials M11 and M12 only)	This plot shows the target (observed) sex-ratios and the distributions (medians and 90% intervals) from the 100 replicates.	The observed sex-ratios should fall randomly above and below the values in the operating model.

Table 5

Conservation performance statistics for the *Evaluation* and *Robustness Trials*. Values for the D1 statistic less than 0.6 and for the D10 statistic less than 0.99 are highlighted in bold underline typeface.

Trial	D1 (W/W-2)			D 1(C)			D10 (W/W-2)			D10 (C)		
	5%	Median	96%	5%	Median	96%	5%	Median	96%	5%	Median	96%
Evaluation Trials												
M01-1A	**0.574**	0.689	0.785	0.908	0.933	0.949	**0.857**	0.958	1.093	1.006	1.021	1.042
M01-4A	0.871	0.904	0.940	0.967	0.973	0.979	1.007	1.034	1.091	0.997	0.999	1.005
M02-1A	0.728	0.833	0.894	0.910	0.932	0.949	**0.970**	1.012	1.084	1.013	1.026	1.045
M02-4A	0.917	0.944	0.967	0.967	0.974	0.979	1.000	1.011	1.043	0.997	0.999	1.005
M03-1A	**0.451**	0.605	0.714	0.900	0.928	0.941	**0.734**	**0.877**	1.026	0.999	1.014	1.036
M03-4A	0.843	0.885	0.913	0.966	0.972	0.977	1.013	1.041	1.106	0.996	0.999	1.004
M04-1A	**0.443**	0.592	0.724	0.919	0.940	0.952	**0.734**	**0.890**	1.082	1.000	1.012	1.030
M04-4A	0.835	0.883	0.925	0.970	0.975	0.979	1.024	1.067	1.135	0.993	0.996	1.000
M05-1A	**0.279**	**0.440**	0.623	0.909	0.934	0.945	**0.498**	**0.724**	**0.937**	**0.988**	1.006	1.026
M05-4A	0.787	0.849	0.899	0.969	0.974	0.979	1.031	1.071	1.163	0.993	0.995	0.999
M06-1A	0.642	0.744	0.819	0.901	0.927	0.946	**0.900**	**0.982**	1.079	1.009	1.027	1.048
M06-4A	0.890	0.918	0.947	0.965	0.972	0.979	0.999	1.018	1.060	0.999	1.002	1.008
M07-1A	**0.557**	0.679	0.763	0.892	0.922	0.934	**0.826**	**0.935**	1.026	1.006	1.021	1.039
M07-4A	0.871	0.902	0.926	0.963	0.971	0.976	1.000	1.018	1.055	0.998	1.001	1.006
M08-1A	0.695	0.823	0.890	0.921	0.941	0.953	**0.961**	1.008	1.089	1.007	1.020	1.036
M08-4A	0.906	0.943	0.964	0.970	0.975	0.979	1.004	1.018	1.061	0.994	0.996	1.000
M09-1A	0.767	0.845	0.902	0.903	0.928	0.947	**0.978**	1.012	1.075	1.016	1.030	1.052
M09-4A	0.925	0.947	0.967	0.965	0.972	0.979	0.996	1.006	1.030	0.999	1.002	1.009
M11-1A	**0.576**	0.693	0.806	0.908	0.934	0.953	**0.851**	**0.963**	1.118	1.007	1.024	1.042
M11-4A	0.879	0.917	0.956	0.967	0.975	0.982	1.003	1.040	1.101	0.997	1.002	1.009
M12-1A	0.725	0.872	0.946	0.916	0.942	0.965	**0.980**	1.059	1.161	1.013	1.039	1.061
M12-4A	0.923	0.954	0.978	0.968	0.976	0.982	1.002	1.021	1.050	0.997	1.003	1.009
Robustness Trials												
M21-1A	0.681	0.766	0.823	0.929	0.946	0.956	**0.930**	**0.982**	1.054	1.006	1.015	1.029
M21-4A	0.899	0.924	0.943	0.974	0.978	0.982	1.001	1.014	1.042	0.996	0.998	1.002
M22-1A	0.786	0.860	0.906	0.930	0.945	0.956	**0.986**	1.006	1.053	1.009	1.018	1.029
M22-4A	0.931	0.952	0.968	0.973	0.978	0.982	0.998	1.003	1.022	0.996	0.998	1.001
M23-1A	**0.457**	0.621	0.750	0.889	0.920	0.942	**0.755**	**0.924**	1.119	1.005	1.027	1.057
M23-4A	0.844	0.886	0.933	0.962	0.969	0.975	1.021	1.069	1.156	0.998	1.002	1.010
M24-1A	0.660	0.800	0.886	0.890	0.920	0.941	**0.964**	1.021	1.118	1.014	1.034	1.062
M24-4A	0.908	0.936	0.967	0.961	0.969	0.976	1.003	1.026	1.076	0.998	1.002	1.010
M25-1A	0.697	0.775	0.834	0.930	0.945	0.955	1.035	1.081	1.170	1.022	1.036	1.052
M25-4A	0.910	0.929	0.948	0.972	0.976	0.980	1.031	1.059	1.112	0.999	1.002	1.009
M26-1A	0.832	0.873	0.918	0.929	0.943	0.954	1.050	1.072	1.134	1.026	1.038	1.055
M26-4A	0.942	0.955	0.970	0.971	0.975	0.980	1.012	1.024	1.065	0.999	1.002	1.009

M27-1A	**0.576**	0.694	0.793	0.909	0.933	0.950	**0.868**	**0.959**	1.102	1.006	1.021	1.043
M27-4A	0.872	0.907	0.940	0.967	0.974	0.979	1.007	1.035	1.094	0.997	1.000	1.005
M28-1A	0.728	0.834	0.896	0.911	0.933	0.949	**0.971**	1.013	1.088	1.013	1.026	1.045
M28-4A	0.917	0.944	0.967	0.967	0.974	0.979	1.000	1.012	1.044	0.997	0.999	1.005
M29-1A	0.563	0.689	0.784	0.906	0.932	0.949	**0.852**	**0.957**	1.080	1.006	1.021	1.042
M29-4A	0.871	0.904	0.939	0.967	0.973	0.979	1.007	1.033	1.090	0.997	0.999	1.005
M30-1A	0.728	0.830	0.894	0.910	0.932	0.948	**0.967**	1.010	1.080	1.013	1.025	1.044
M30-4A	0.917	0.944	0.966	0.967	0.973	0.979	1.000	1.010	1.042	0.997	0.999	1.005
M31-4A	0.996	1.007	1.015	0.994	0.998	1.002	**0.979**	0.990	0.996	**0.985**	0.989	0.993
M32-4A	0.998	1.006	1.012	0.996	0.999	1.003	**0.984**	0.992	0.997	**0.986**	0.990	0.993

Table 6
Need satisfaction and strike limit stability performance statistics for the *Evaluation* and *Robustness Trials*. Values for need satisfaction less than 0.8 are indicated using underline typeface.

Trial	N9-20 (WG)			N9-100 (WG)			N12 (WG)			N9-20 (EG)			N9-100 (EG)			N12 (EG)		
	5%	Median	96%	5%	Median	96%	5%	Median	96%	5%	Median	96%	5%	Median	96%	5%	Median	96%
Evaluation Trials																		
M01-1A	0.889	1.000	1.000	**0.620**	0.908	1.000	0	0.032	0.091	1.000	1.000	1.000	0.882	1.000	1.000	0	0	0.071
M01-4A	0.889	1.000	1.000	**0.679**	0.915	1.000	0	0.028	0.090	1.000	1.000	1.000	0.908	1.000	1.000	0	0	0.067
M02-1A	0.886	1.000	1.000	**0.622**	0.895	1.000	0	0.035	0.090	1.000	1.000	1.000	0.853	1.000	1.000	0	0	0.081
M02-4A	0.885	1.000	1.000	**0.596**	0.904	1.000	0	0.033	0.089	1.000	1.000	1.000	0.862	1.000	1.000	0	0	0.081
M03-1A	0.905	1.000	1.000	**0.679**	0.944	1.000	0	0.024	0.073	1.000	1.000	1.000	0.868	1.000	1.000	0	0	0.074
M03-4A	0.905	1.000	1.000	**0.734**	0.956	1.000	0	0.021	0.070	1.000	1.000	1.000	0.899	1.000	1.000	0	0	0.072
M04-1A	0.895	1.000	1.000	**0.635**	0.906	1.000	0	0.032	0.089	1.000	1.000	1.000	0.860	1.000	1.000	0	0	0.071
M04-4A	0.895	1.000	1.000	**0.698**	0.942	1.000	0	0.024	0.084	1.000	1.000	1.000	0.893	1.000	1.000	0	0	0.063
M05-1A	0.914	1.000	1.000	**0.668**	0.944	1.000	0	0.024	0.081	1.000	1.000	1.000	0.823	1.000	1.000	0	0	0.077
M05-4A	0.917	1.000	1.000	**0.781**	0.968	1.000	0	0.016	0.065	1.000	1.000	1.000	0.892	1.000	1.000	0	0	0.065
M06-1A	0.888	1.000	1.000	**0.611**	0.900	1.000	0	0.033	0.086	1.000	1.000	1.000	0.872	1.000	1.000	0	0	0.079
M06-4A	0.888	1.000	1.000	**0.628**	0.911	1.000	0	0.030	0.084	1.000	1.000	1.000	0.882	1.000	1.000	0	0	0.079
M07-1A	0.913	1.000	1.000	**0.705**	0.954	1.000	0	0.021	0.060	1.000	1.000	1.000	0.871	1.000	1.000	0	0	0.079
M07-4A	0.911	1.000	1.000	**0.729**	0.961	1.000	0	0.019	0.061	1.000	1.000	1.000	0.886	1.000	1.000	0	0	0.077
M08-1A	0.889	1.000	1.000	**0.645**	0.907	1.000	0	0.033	0.090	1.000	1.000	1.000	0.865	1.000	1.000	0	0	0.076
M08-4A	0.888	1.000	1.000	**0.625**	0.924	1.000	0	0.029	0.085	1.000	1.000	1.000	0.885	1.000	1.000	0	0	0.077
M09-1A	0.882	0.999	1.000	**0.613**	0.892	1.000	0	0.035	0.090	1.000	1.000	1.000	0.848	1.000	1.000	0	0	0.081
M09-4A	0.884	1.000	1.000	**0.589**	0.892	1.000	0	0.036	0.094	1.000	1.000	1.000	0.861	1.000	1.000	0	0	0.081
M11-1A	0.857	0.990	1.000	**0.589**	0.882	0.998	0.002	0.042	0.111	1.000	1.000	1.000	0.872	1.000	1.000	0	0	0.080
M11-4A	0.810	0.975	1.000	**0.514**	0.837	1.000	0	0.049	0.123	1.000	1.000	1.000	0.907	1.000	1.000	0	0	0.068
M12-1A	**0.660**	0.908	1.000	**0.304**	**0.743**	0.997	0.003	0.071	0.193	1.000	1.000	1.000	0.874	1.000	1.000	0	0	0.075
M12-4A	**0.731**	0.920	1.000	**0.424**	**0.752**	0.964	0.018	0.073	0.159	1.000	1.000	1.000	0.878	1.000	1.000	0	0	0.081
Robustness Trials																		
M21-1A	0.895	1.000	1.000	**0.733**	0.961	1.000	0	0.019	0.065	1.000	1.000	1.000	0.937	1.000	1.000	0	0	0.058
M21-4A	0.898	1.000	1.000	**0.731**	0.965	1.000	0	0.018	0.069	1.000	1.000	1.000	0.942	1.000	1.000	0	0	0.055
M22-1A	0.895	1.000	1.000	**0.716**	0.957	1.000	0	0.021	0.071	1.000	1.000	1.000	0.928	1.000	1.000	0	0	0.065
M22-4A	0.894	1.000	1.000	**0.721**	0.957	1.000	0	0.022	0.074	1.000	1.000	1.000	0.915	1.000	1.000	0	0	0.062
M23-1A	0.882	1.000	1.000	**0.562**	0.848	1.000	0	0.045	0.104	1.000	1.000	1.000	0.809	1.000	1.000	0	0	0.094
M23-4A	0.880	1.000	1.000	**0.570**	0.868	1.000	0	0.041	0.101	1.000	1.000	1.000	0.855	1.000	1.000	0	0	0.077
M24-1A	0.878	1.000	1.000	**0.559**	0.851	1.000	0	0.044	0.102	1.000	1.000	1.000	0.832	1.000	1.000	0	0	0.100
M24-4A	0.881	1.000	1.000	**0.566**	0.854	1.000	0	0.043	0.105	1.000	1.000	1.000	0.832	1.000	1.000	0	0	0.098
M25-1A	**0.718**	**0.722**	**0.722**	**0.480**	**0.657**	0.688	0.311	0.343	0.385	1.000	1.000	1.000	0.892	1.000	1.000	0	0	0.069
M25-4A	**0.722**	**0.722**	**0.722**	**0.474**	**0.655**	0.688	0.311	0.343	0.386	1.000	1.000	1.000	0.908	1.000	1.000	0	0	0.066
M26-1A	**0.716**	**0.722**	**0.722**	**0.448**	**0.654**	0.688	0.306	0.343	0.384	1.000	1.000	1.000	0.879	1.000	1.000	0	0	0.080
M26-4A	**0.720**	**0.722**	**0.722**	**0.444**	**0.652**	0.688	0.307	0.343	0.387	1.000	1.000	1.000	0.876	1.000	1.000	0	0	0.081

M27-1A	0.894	1.000	1.000	**0.613**	0.905	1.000	0	0.032	0.092	1.000	1.000	1.000	0.882	1.000	1.000	0	0	0.071
M27-4A	0.895	1.000	1.000	**0.673**	0.911	1.000	0	0.029	0.088	1.000	1.000	1.000	0.908	1.000	1.000	0	0	0.067
M28-1A	0.889	1.000	1.000	**0.611**	0.888	1.000	0	0.037	0.093	1.000	1.000	1.000	0.853	1.000	1.000	0	0	0.081
M28-4A	0.892	1.000	1.000	**0.576**	0.897	1.000	0	0.037	0.091	1.000	1.000	1.000	0.862	1.000	1.000	0	0	0.081
M29-1A	0.882	1.000	1.000	**0.641**	0.915	1.000	0	0.030	0.087	1.000	1.000	1.000	0.882	1.000	1.000	0	0	0.071
M29-4A	0.883	1.000	1.000	**0.678**	0.924	1.000	0	0.026	0.086	1.000	1.000	1.000	0.908	1.000	1.000	0	0	0.067
M30-1A	0.879	1.000	1.000	**0.625**	0.901	1.000	0	0.032	0.088	1.000	1.000	1.000	0.853	1.000	1.000	0	0	0.081
M30-4A	0.879	1.000	1.000	**0.615**	0.906	1.000	0	0.031	0.089	1.000	1.000	1.000	0.862	1.000	1.000	0	0	0.081
M31-4A	0.886	1.000	1.000	**0.635**	0.913	1.000	0	0.031	0.090	1.000	1.000	1.000	0.871	1.000	1.000	0	0	0.070
M32-4A	0.886	1.000	1.000	**0.609**	0.898	1.000	0	0.034	0.090	1.000	1.000	1.000	0.844	1.000	1.000	0	0	0.083

Table 7

Simulation results comparing carryover schemes for West and East Greenland minke whales. The cases are no carryover, within-block frontloading, two cases with accumulation from one prior block, and two cases with accumulation from three prior blocks. The statistics, pertaining to the age 1+ population, are D1 (final depletion), and D10 (relative increase). The results are shown for four *Evaluation Trials*.

Trial	Scenario	D1 (W/W-2)			D 1(C)			D10 (W/W-2)			D10 (C)		
		5%	Median	96%	5%	Median	96%	5%	Median	96%	5%	Median	96%
M01-1A	No carryover	0.574	0.690	0.785	0.909	0.933	0.949	0.861	0.956	1.091	1.006	1.021	1.042
	Frontloaded	0.580	0.695	0.789	0.910	0.934	0.949	0.866	0.961	1.101	1.007	1.022	1.042
	1@67%, 1@≤150%	0.609	0.717	0.809	0.916	0.937	0.951	0.914	0.994	1.118	1.012	1.026	1.046
	1@80%, 1@≤150%	0.596	0.706	0.800	0.914	0.936	0.950	0.890	0.981	1.109	1.011	1.025	1.044
	3@67%, 2@≤150%	0.589	0.701	0.792	0.911	0.934	0.949	0.875	0.969	1.098	1.007	1.022	1.042
	3@80%, 2@≤150%	0.584	0.697	0.791	0.910	0.934	0.949	0.869	0.965	1.099	1.006	1.022	1.041
M02-1A	No carryover	0.731	0.834	0.892	0.910	0.932	0.948	0.972	1.011	1.084	1.013	1.026	1.045
	Frontloaded	0.734	0.837	0.895	0.911	0.934	0.949	0.979	1.018	1.085	1.015	1.027	1.046
	1@67%, 1@≤150%	0.754	0.849	0.903	0.915	0.937	0.950	1.003	1.034	1.100	1.018	1.031	1.047
	1@80%, 1@≤150%	0.746	0.844	0.899	0.914	0.935	0.949	0.997	1.028	1.093	1.017	1.029	1.046
	3@67%, 2@≤150%	0.736	0.838	0.895	0.912	0.933	0.949	0.987	1.018	1.085	1.014	1.027	1.046
	3@80%, 2@≤150%	0.732	0.837	0.894	0.911	0.933	0.948	0.982	1.017	1.084	1.014	1.027	1.046
M04-1A	No carryover	0.448	0.590	0.721	0.918	0.940	0.952	0.733	0.894	1.075	1.000	1.013	1.029
	Frontloaded	0.452	0.596	0.729	0.921	0.940	0.952	0.742	0.902	1.071	1.002	1.014	1.030
	1@67%, 1@≤150%	0.494	0.629	0.749	0.927	0.943	0.954	0.808	0.951	1.102	1.004	1.016	1.031
	1@80%, 1@≤150%	0.476	0.611	0.741	0.925	0.941	0.953	0.778	0.931	1.090	1.003	1.015	1.030
	3@67%, 2@≤150%	0.458	0.607	0.729	0.922	0.940	0.952	0.749	0.922	1.075	1.001	1.014	1.029
	3@80%, 2@≤150%	0.454	0.601	0.729	0.921	0.940	0.952	0.742	0.910	1.074	1.001	1.014	1.029
M08-1A	No carryover	0.575	0.696	0.803	0.908	0.934	0.952	0.851	0.964	1.117	1.007	1.023	1.041
	Frontloaded	0.595	0.706	0.810	0.911	0.936	0.952	0.872	0.983	1.133	1.010	1.025	1.043
	1@67%, 1@≤150%	0.624	0.730	0.828	0.916	0.940	0.954	0.917	1.015	1.144	1.014	1.028	1.046
	1@80%, 1@≤150%	0.610	0.720	0.822	0.914	0.938	0.953	0.898	1.001	1.133	1.013	1.027	1.045
	3@67%, 2@≤150%	0.606	0.717	0.811	0.911	0.936	0.952	0.887	0.995	1.131	1.010	1.025	1.043
	3@80%, 2@≤150%	0.598	0.711	0.811	0.911	0.936	0.952	0.876	0.988	1.132	1.011	1.025	1.043

Table 8
Conservation performance statistics for the trials to compare the performance of the 'phase out' ('original') and 'interim allowance' ('interim') options for the North Atlantic minke whales. Values in bold typeface indicate cases in which the D1 statistic is less than 0.6, and lower than under 'original' option when surveys occur every 10 years.

Trial	Option	D1 (W/W-2)			D 1(C)			D10 (W/W-2)			D10 (C)		
		5%	Median	96%	5%	Median	96%	5%	Median	96%	5%	Median	96%
10-year surveys													
M01-1A	Original	0.574	0.689	0.785	0.908	0.933	0.949	0.857	0.958	1.093	1.006	1.021	1.042
	Interim	0.574	0.689	0.785	0.908	0.933	0.949	0.857	0.958	1.093	1.006	1.021	1.042
M02-1A	Original	0.728	0.833	0.894	0.910	0.932	0.949	0.970	1.012	1.084	1.013	1.026	1.045
	Interim	0.728	0.833	0.894	0.910	0.932	0.949	0.970	1.012	1.084	1.013	1.026	1.045
M04-1A	Original	0.443	0.592	0.724	0.919	0.940	0.952	0.734	0.890	1.082	1.000	1.012	1.030
	Interim	0.443	0.592	0.724	0.919	0.940	0.952	0.734	0.890	1.082	1.000	1.012	1.030
M11-1A	Original	0.576	0.693	0.806	0.908	0.934	0.953	0.851	0.963	1.118	1.007	1.024	1.042
	Interim	0.576	0.693	0.806	0.908	0.934	0.953	0.851	0.963	1.118	1.007	1.024	0.963
15-year surveys													
M01-1A	Original	0.697	0.775	0.834	0.930	0.945	0.955	1.035	1.081	1.170	1.022	1.036	1.052
	Interim	0.578	0.679	0.775	0.911	0.930	0.947	0.847	0.950	1.076	1.005	1.021	1.043
M02-1A	Original	0.832	0.873	0.918	0.929	0.943	0.954	1.050	1.072	1.134	1.026	1.038	1.055
	Interim	0.757	0.820	0.891	0.914	0.932	0.947	0.978	1.010	1.083	1.010	1.025	1.047
M04-1A	Original	0.608	0.709	0.798	0.935	0.948	0.958	1.007	1.078	1.202	1.010	1.024	1.036
	Interim	0.444	**0.574**	0.708	0.922	0.938	0.951	0.707	0.879	1.042	0.996	1.013	1.028
M11-1A	Original	0.699	0.772	0.851	0.928	0.945	0.957	1.032	1.080	1.185	1.023	1.036	1.053
	Interim	0.586	0.679	0.795	0.910	0.932	0.950	0.859	0.947	1.102	1.004	1.021	1.044
20-year surveys													
M01-1A	Original	0.766	0.828	0.879	0.941	0.952	0.963	1.112	1.155	1.238	1.032	1.044	1.055
	Interim	**0.552**	0.681	0.785	0.910	0.932	0.953	0.840	0.945	1.108	1.006	1.021	1.043
M02-1A	Original	0.860	0.908	0.939	0.939	0.951	0.962	1.074	1.111	1.171	1.035	1.047	1.062
	Interim	0.738	0.834	0.900	0.910	0.932	0.953	0.966	1.007	1.093	1.013	1.026	1.047
M04-1A	Original	0.698	0.782	0.854	0.943	0.954	0.963	1.137	1.188	1.302	1.019	1.030	1.041
	Interim	**0.418**	**0.568**	0.729	0.921	0.939	0.954	0.683	0.870	1.107	0.999	1.013	1.030
M11-1A	Original	0.761	0.829	0.880	0.940	0.954	0.964	1.103	1.158	1.256	1.032	1.045	1.056
	Interim	**0.565**	0.686	0.803	0.909	0.935	0.956	0.832	0.948	1.130	1.006	1.022	1.046

Table 9
Need satisfaction and limit stability performance statistics for the trials to compare the performance of the ‘phase out’ (‘original’) and ‘interim allowance’ (‘interim’) options for the North Atlantic minke whales.

Trial	Option	N9-20 (WG)			N9-100 (WG)			N12 (WG)			N9-20 (EG)			N9-100 (EG)			N12 (EG)		
		5%	Median	96%	5%	Median	96%	5%	Median	96%	5%	Median	96%	5%	Median	96%	5%	Median	96%
10-year surveys																			
M01-1A	Original	0.889	1.000	1.000	0.620	0.908	1.000	0	0.032	0.091	1.000	1.000	1.000	0.882	1.000	1.000	0	0	0.071
	Interim	0.889	1.000	1.000	0.620	0.908	1.000	0	0.032	0.091	1.000	1.000	1.000	0.853	1.000	1.000	0	0	0.081
M02-1A	Original	0.886	1.000	1.000	0.622	0.895	1.000	0	0.035	0.090	1.000	1.000	1.000	0.853	1.000	1.000	0	0	0.081
	Interim	0.886	1.000	1.000	0.622	0.895	1.000	0	0.035	0.090	1.000	1.000	1.000	0.860	1.000	1.000	0	0	0.071
M04-1A	Original	0.895	1.000	1.000	0.635	0.906	1.000	0	0.032	0.089	1.000	1.000	1.000	0.860	1.000	1.000	0	0	0.071
	Interim	0.895	1.000	1.000	0.635	0.906	1.000	0	0.032	0.089	1.000	1.000	1.000	0.872	1.000	1.000	0	0	0.08
M11-1A	Original	0.857	0.990	1.000	0.589	0.882	0.998	0.002	0.042	0.111	1.000	1.000	1.000	0.872	1.000	1.000	0	0	0.08
	Interim	0.857	0.990	1.000	0.589	0.882	0.998	0.002	0.042	0.111	1.000	1.000	1.000	0.892	1.000	1.000	0	0	0.069
20-year surveys																			
M01-1A	Original	0.718	0.722	0.722	0.480	0.657	0.688	0.311	0.343	0.385	1.000	1.000	1.000	0.882	1.000	1.000	0	0	0.07
	Interim	0.993	1.000	1.000	0.677	0.947	1.000	0	0.022	0.062	1.000	1.000	1.000	0.879	1.000	1.000	0	0	0.08
M02-1A	Original	0.716	0.722	0.722	0.448	0.654	0.688	0.306	0.343	0.384	1.000	1.000	1.000	0.860	1.000	1.000	0	0	0.081
	Interim	0.991	1.000	1.000	0.638	0.938	1.000	0	0.024	0.065	1.000	1.000	1.000	0.881	1.000	1.000	0	0	0.069
M04-1A	Original	0.721	0.722	0.722	0.489	0.658	0.688	0.312	0.343	0.382	1.000	1.000	1.000	0.860	1.000	1.000	0	0	0.071
	Interim	0.999	1.000	1.000	0.693	0.934	1.000	0	0.023	0.060	1.000	1.000	1.000	0.893	1.000	1.000	0	0	0.071
M11-1A	Original	0.680	0.720	0.722	0.418	0.640	0.687	0.305	0.343	0.387	1.000	1.000	1.000	0.882	1.000	1.000	0	0	0.08
	Interim	0.957	0.994	1.000	0.594	0.917	0.998	0.001	0.029	0.075	1.000	1.000	1.000	0.893	1.000	1.000	0	0	0.069
20-year surveys																			
M01-1A	Original	0.551	0.556	0.556	0.336	0.491	0.521	0.471	0.509	0.515	1.000	1.000	1.000	0.878	1.000	1.000	0	0	0.075
	Interim	0.993	1.000	1.000	0.625	0.937	1.000	0	0.019	0.060	1.000	1.000	1.000	0.879	1.000	1.000	0	0	0.08
M02-1A	Original	0.549	0.556	0.556	0.337	0.488	0.521	0.47	0.507	0.519	1.000	1.000	1.000	0.853	1.000	1.000	0	0	0.081
	Interim	0.991	1.000	1.000	0.629	0.934	1.000	0	0.020	0.060	1.000	1.000	1.000	0.898	1.000	1.000	0	0	0.068
M04-1A	Original	0.555	0.556	0.556	0.345	0.520	0.521	0.471	0.509	0.512	1.000	1.000	1.000	0.856	1.000	1.000	0	0	0.078
	Interim	0.999	1.000	1.000	0.625	0.946	1.000	0	0.017	0.056	1.000	1.000	1.000	0.886	1.000	1.000	0	0	0.076
M11-1A	Original	0.524	0.556	0.556	0.321	0.484	0.521	0.472	0.505	0.517	1.000	1.000	1.000	0.868	1.000	1.000	0	0	0.081
	Interim	0.957	0.994	1.000	0.596	0.911	0.999	0.001	0.026	0.070	1.000	1.000	1.000	0.882	1.000	1.000	0	0	0.071

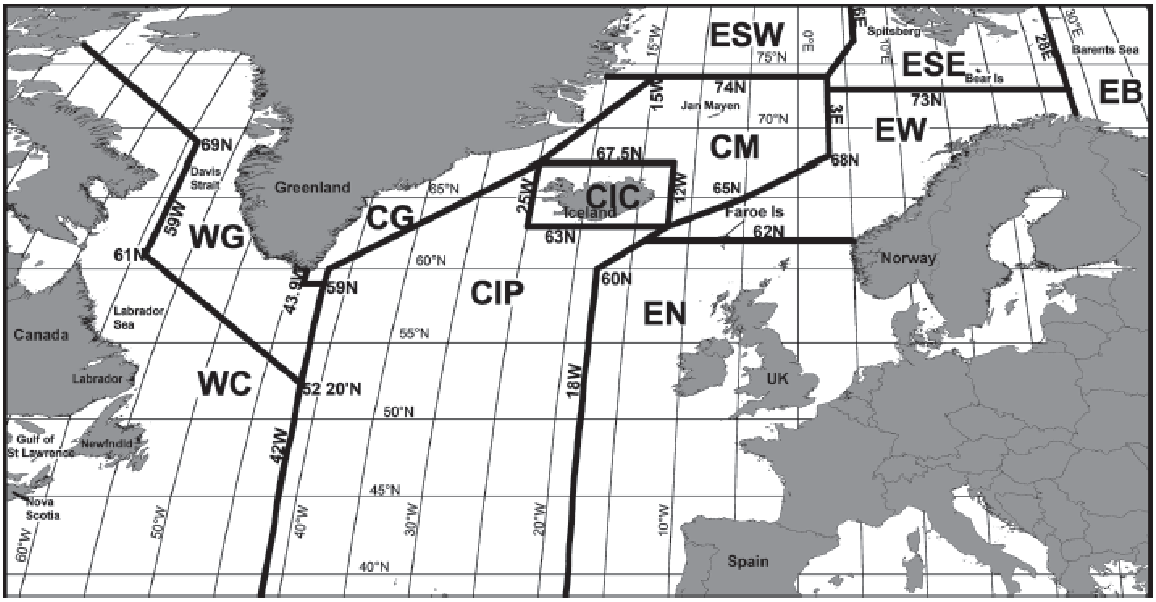

Figure 1. Sub-areas used in the *Implementation Simulation Trials* for the North Atlantic minke whales.

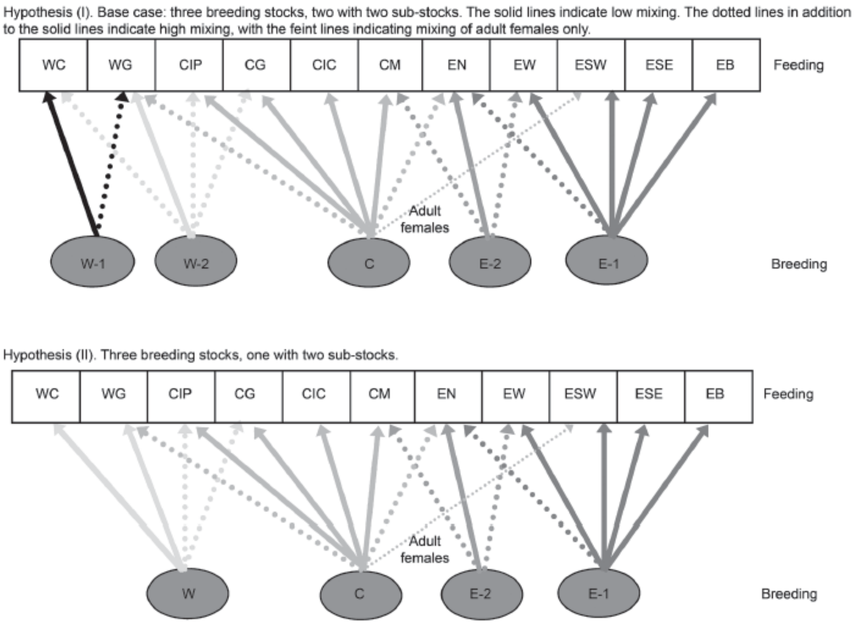

Figure 2. Stock hypotheses in the *Implementation Review* for the North Atlantic common minke whales on which the trials in this document are based.

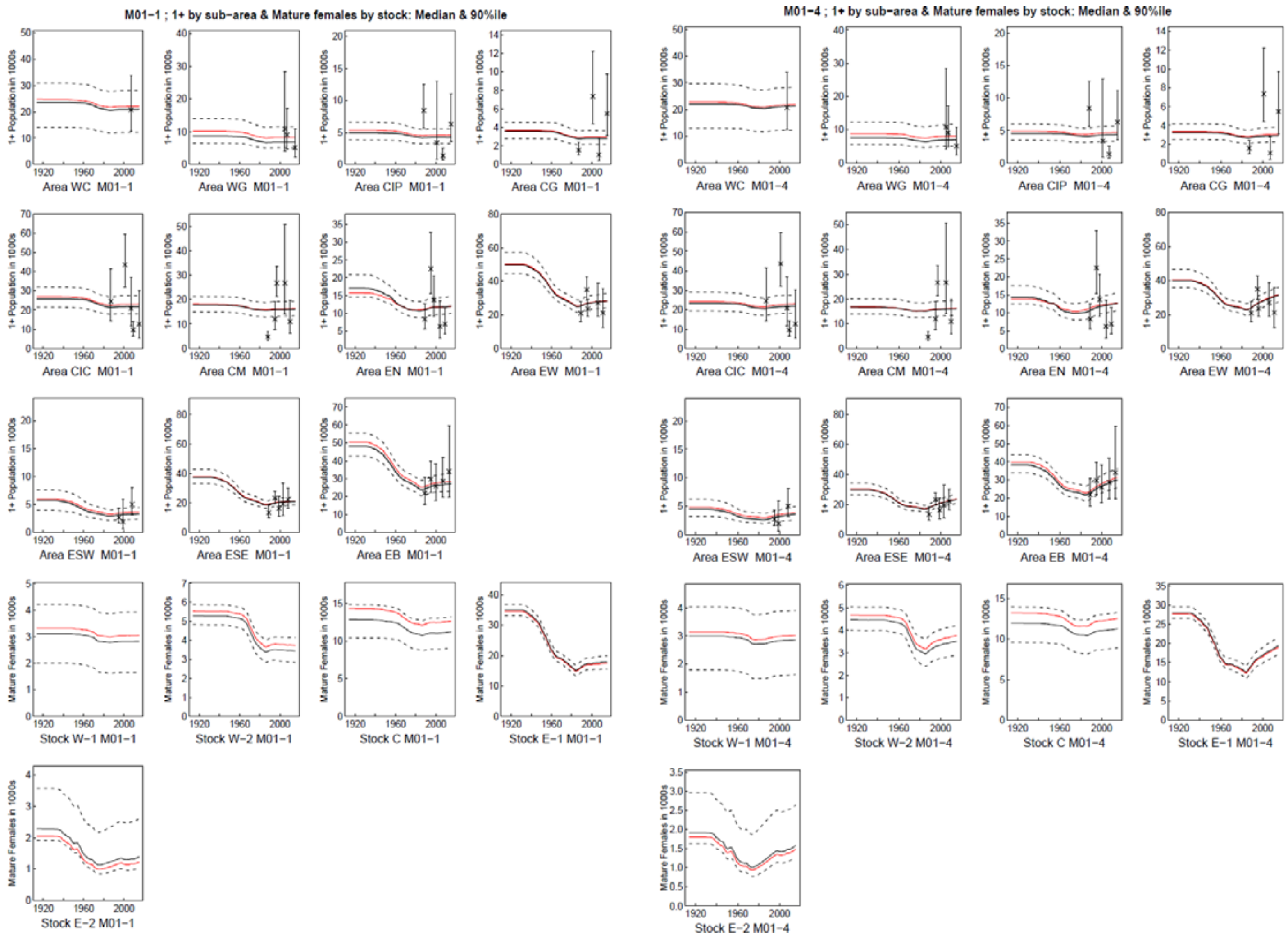

Figure 3. For trials M01-1, and M01-4, the fit of the operating model to the actual data ('deterministic'; solid red lines), and the median and 90% intervals from the 100 replicates (solid black and dashed lines respectively), together with the abundance estimates and their 90% confidence intervals for each sub-area and the numbers of mature females by stock, again the median and 90% intervals from the 100 replicates and the 'deterministic' trajectory.

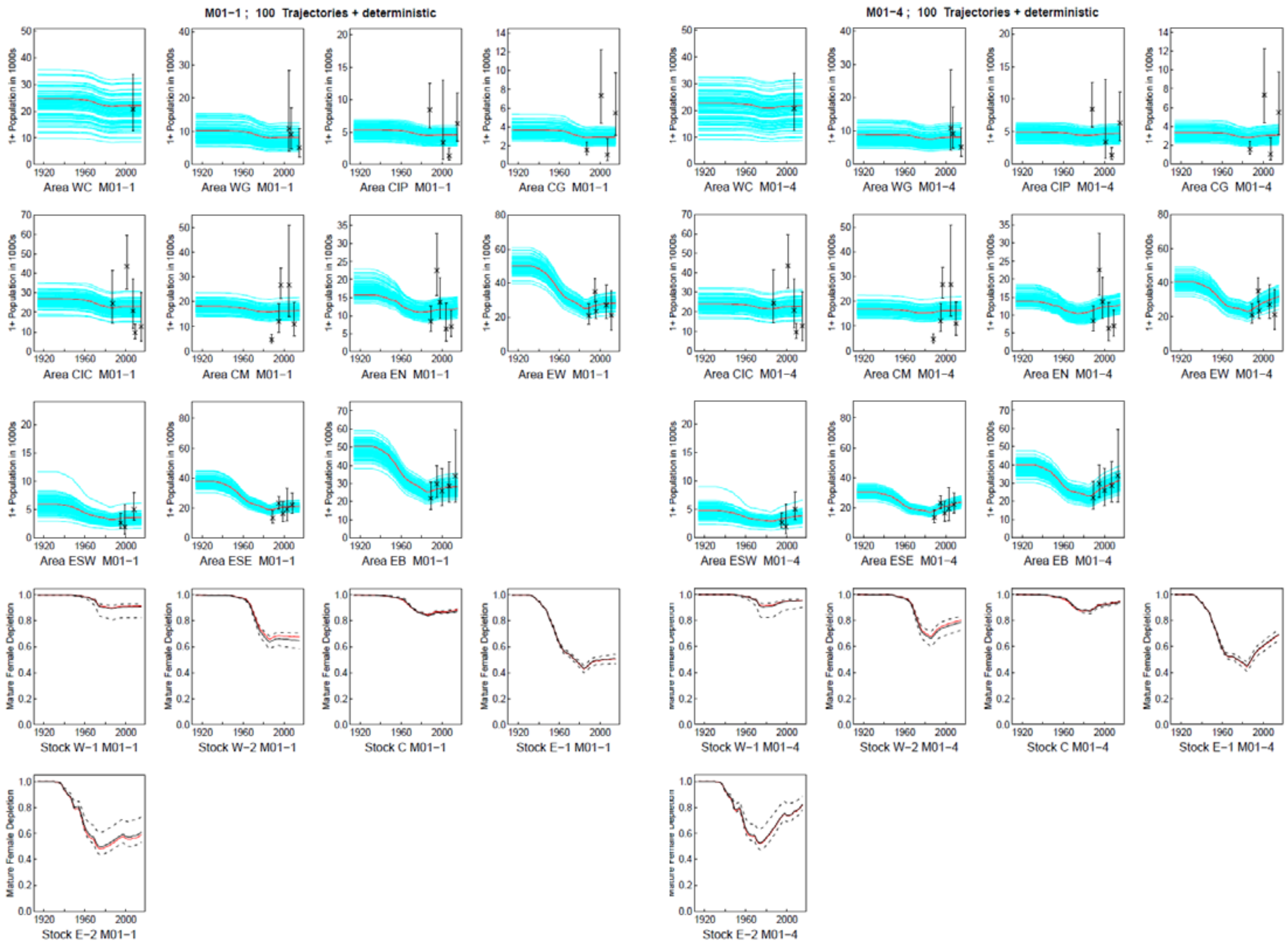

Figure 4. For trials M01-1, and M01-4, the 100 trajectories of 1+ populations, together with the abundance estimates and their 90% confidence intervals for each sub-area and the numbers of mature females by stock expressed relative to carrying capacity, the median and 90% intervals from the 100 replicates and the 'deterministic' trajectory.

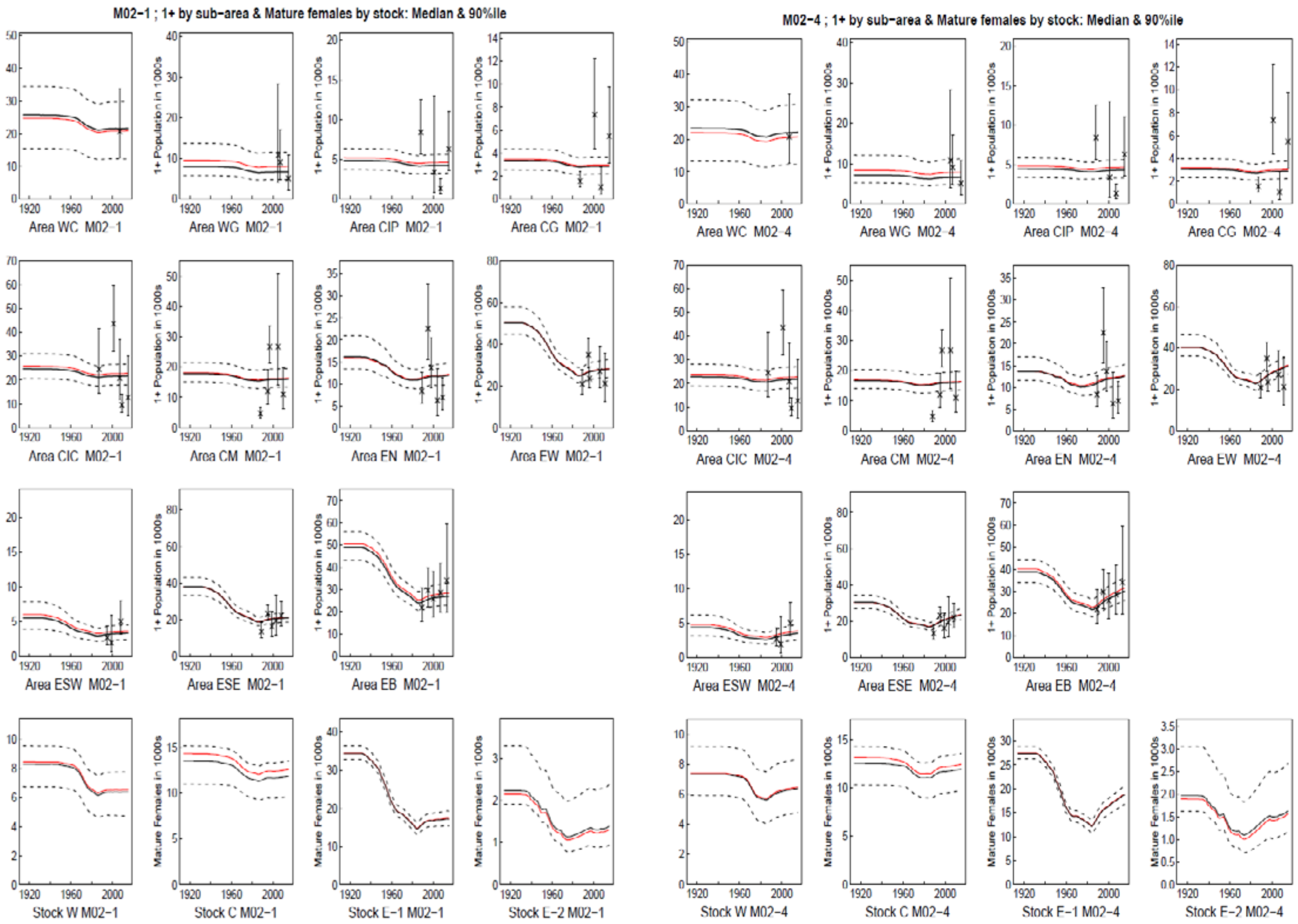

Figure 5. For trials M02-1, and M02-4, the fit of the operating model to the actual data (‘deterministic’; solid red lines), and the median and 90% intervals from the 100 replicates (solid black and dashed lines respectively) together with the abundance estimates and their 90% confidence intervals for each sub-area and the numbers of mature females by stock, again the median and 90% intervals from the 100 replicates and the ‘deterministic’ trajectory.

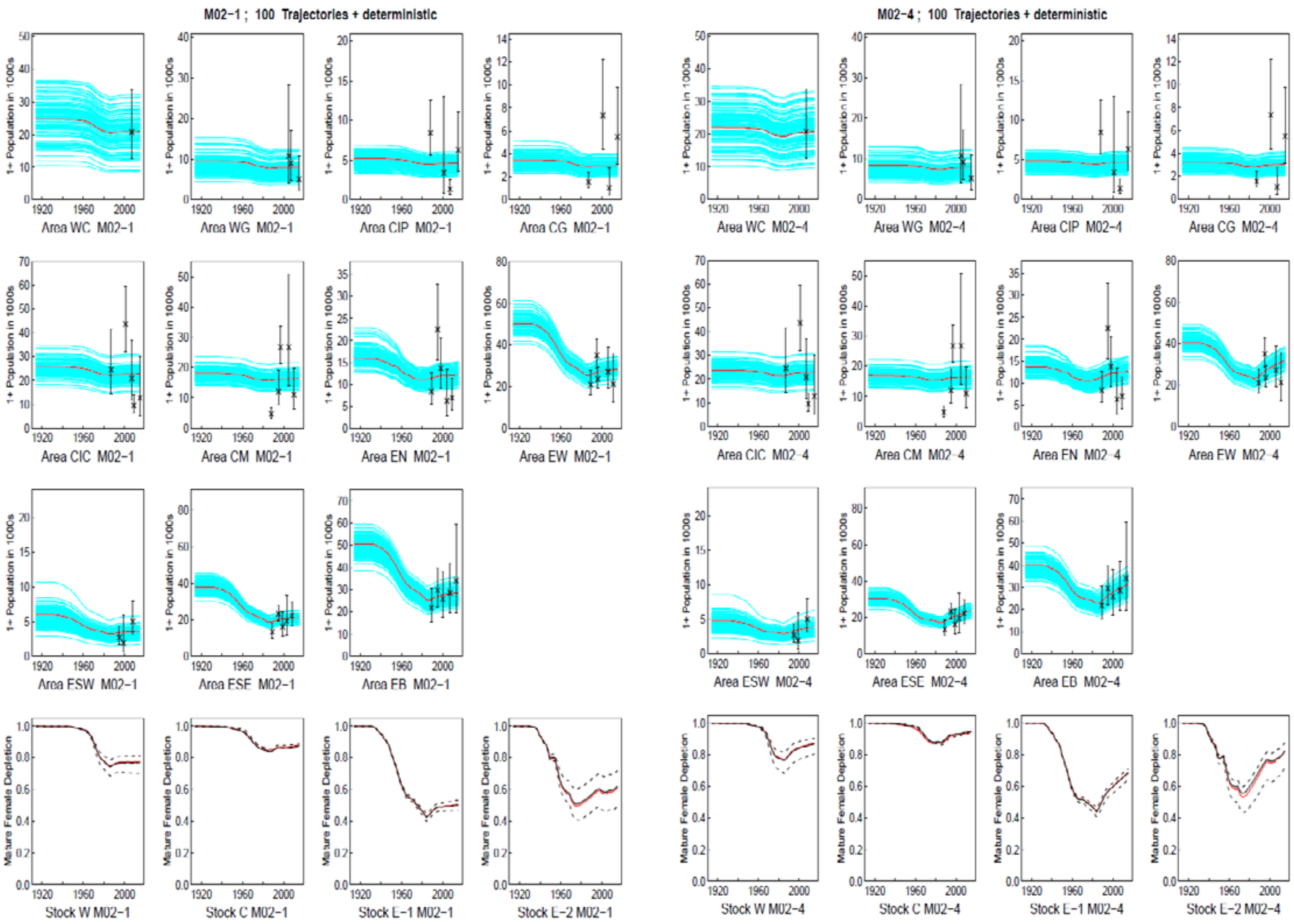

Figure 6. For trials M02-1, and M02-4, the 100 trajectories of 1+ populations, together with the abundance estimates and their 90% confidence intervals for each sub-area and the numbers of mature females by stock expressed relative to carrying capacity, the median and 90% intervals from the 100 replicates and the 'deterministic' trajectory.

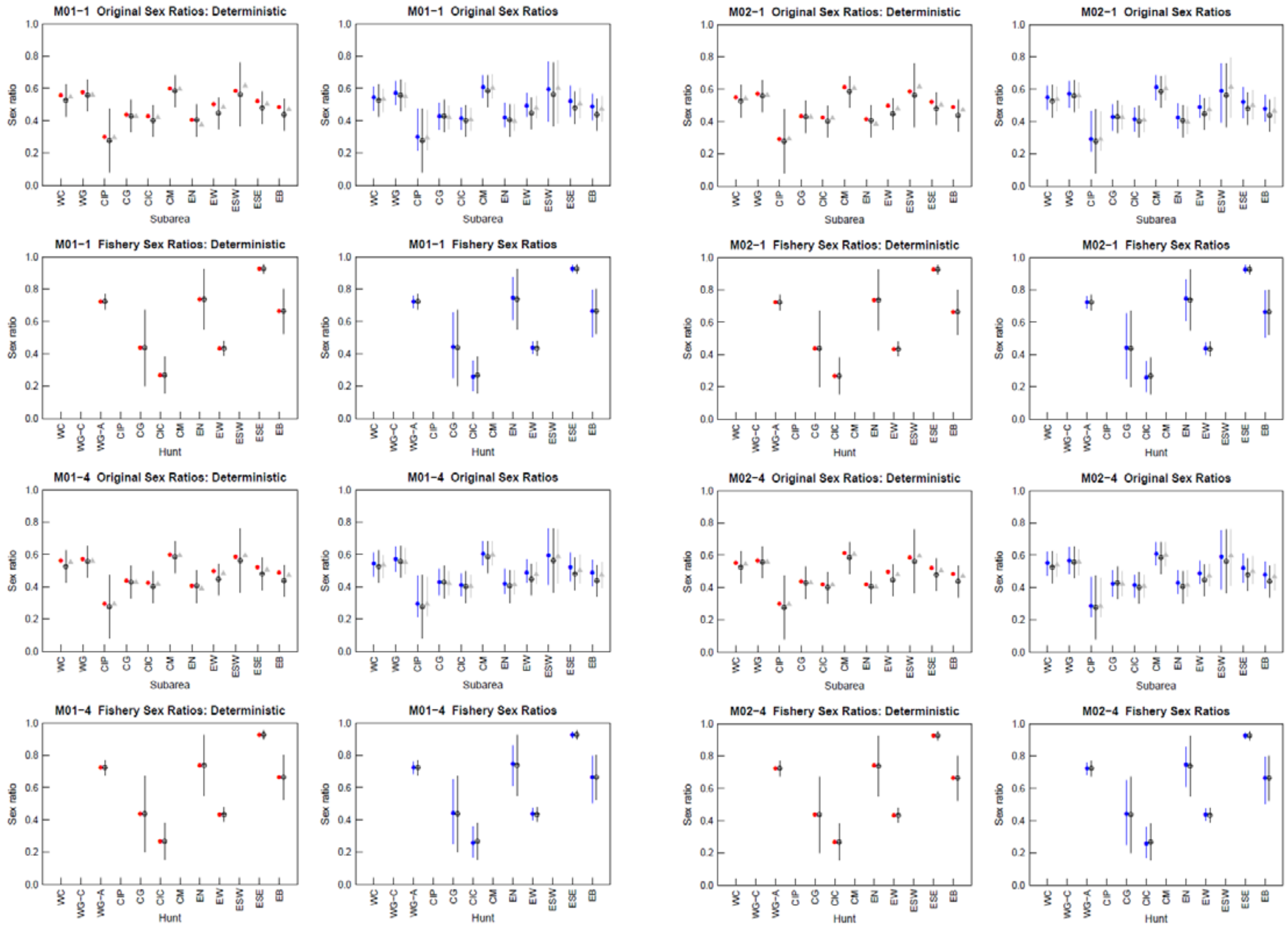

Figure 7. Proportions of females by sub-area in the pristine population (the ‘original’ sex ratios) and the fishery proportions. The plots on the left for each set of two trials show the model-predictions from the fit to actual data by sub-area (red dots) together with the data points (black dots) and their assumed (normal) sampling distributions. The plots on the right for each set of two trials show the median operating model predictions (blue dots) and the 90% intervals for each sex ratio type together with the data points and their assumed sampling distributions. The grey triangles show the sex ratio in the 2016 population for comparison with the pristine values.

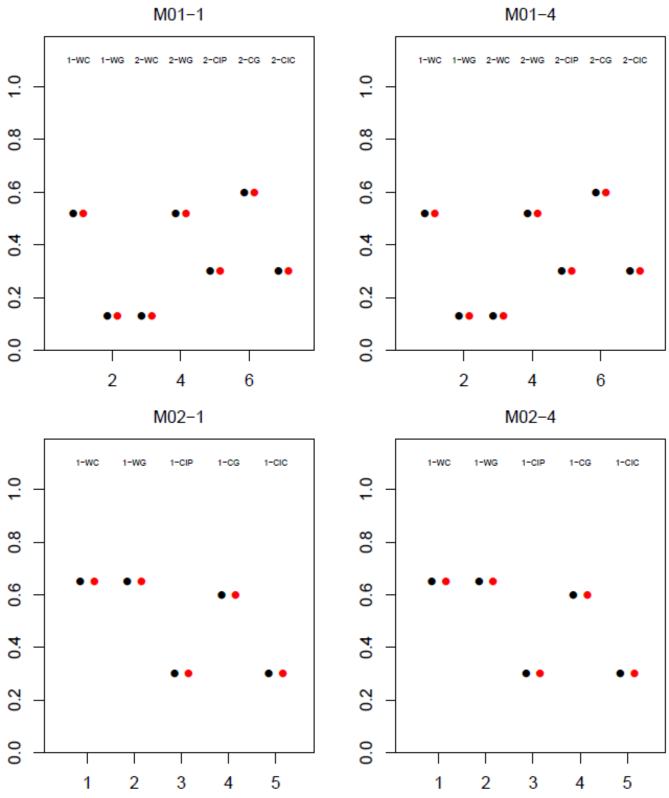

Figure 8. Plots of the specified mixing proportions (i.e. the target proportion of the total (1+) numbers in a given sub-area that belong to a particular stock (stock 1 or stock 2) averaged over the years 2008-2013), together with the distribution over replicates for the model predictions.

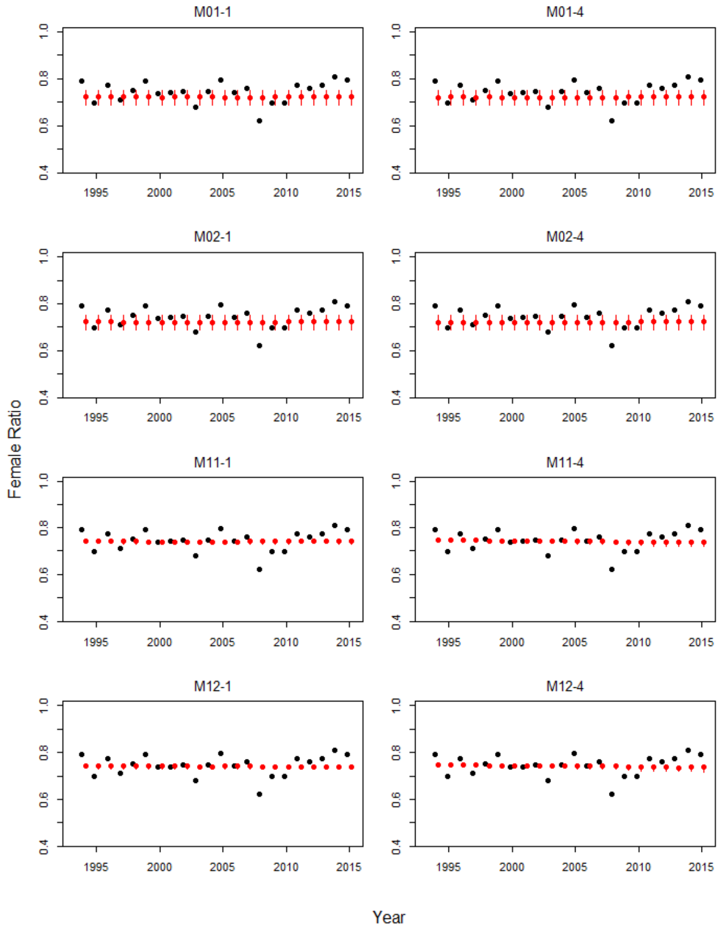

Figure 9. Plots of the observed and operating model-predicted sex-ratios for trials M01, M02, M11 and M12 (MSYR = 1% and 4%). The black dots show the observed sex ratios for the years 1994-2015. The red dots and lines show the mean and 90-%iles of the modelled values over these years.

Appendix A
The G-Common minke *SLA* (Witting, 2019)

With τ being the year of a strike limit calculation, the *SLA* makes an interim-*SLA*-like calculation based on an estimate of abundance (N_τ) with an associated coefficient of variation (cv_τ). This estimate

$$N_\tau = \exp\left(\frac{\sum_{i=-2}^{0} \ln N_i \,/\, cv_i^2}{\sum_{i=-2}^{0} 1/cv_i^2} \right) \tag{A.1}$$

and its uncertainty

$$cv_\tau = \left(\frac{1}{\sum_{i=-2}^{0} 1/cv_i^2} \right)^{1/2} \tag{A.2}$$

is an inverse variance weighted average of the last three abundance estimates (ignoring zero estimates), with *i* = 0 denoting the most recent positive estimate, and *cv* being the error coefficient of variation.

The strike limit S_τ is calculated as:

$$\tilde{S}_\tau = rN_\tau e^{-q\,cv_\tau} \tag{A.3}$$

$$\dot{S}_\tau = \begin{cases} \tilde{S}_\tau & \text{if } \tilde{S}_\tau < s\,\text{need}_\tau \\ \text{need}_\tau & \text{otherwise} \end{cases} \tag{A.4}$$

$$S_\tau = \begin{cases} \dot{S}_\tau & \text{if } N_\tau > 2n \\ \frac{N_\tau - n}{n}\dot{S}_\tau & \text{if } n < N_\tau \le 2n \\ 0 & \text{if } N_\tau \le n \end{cases} \tag{A.5}$$

with the total number of strikes for a six year block period being 6 S_τ . The parameters of the *SLA* are *r*=0.0353, q=1.65, *s*=0.8, and *n*=500.