Annex D

Report of the Sub-Committee on the Revised Management Procedure

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1. INTRODUCTORY ITEMS

1.1 Convenor's opening remarks
As Convenor, Bannister welcomed the participants.

1.2 Election of Chair and appointment of rapporteurs
Bannister was elected Chair. Butterworth, Johnson, McKinlay and Punt acted as rapporteurs.

1.3 Adoption of Agenda
The adopted Agenda is shown in Appendix 1.

1.4 Available documents
The documents considered by the sub-committee were SC/66b/RMP01-RMP06, SC/66b/IA18, Hakamada *et al.* (2016), Hakamada and Matsuoka (2016), SC/66b/Rep04-Rep05, and relevant extracts from past reports of the Scientific Committee.

2. GENERAL ASSESSMENT ISSUES WITH A FOCUS ON THOSE RELATED TO THE REVISED MANAGEMENT PROCEDURE

2.1 Relationship between $MSYR_{mat}$ and $MSYR_{1+}$: evaluate energetics-based model
SC/66b/RMP04 reports progress on using an individual based energetics model to examine the relationship between the MSY (maximum sustainable yield) rates applicable to the population aged one year and above (1+) compared with that from the mature component of the population. The results presented are for a 'like minke' energetics model. Comparing the results from the individual based model (IBM) with those from Baleen II show that the ratio between $MSYR_{mat}$ and $MSYR_{1+}$ is higher for the energetics model than for Baleen II. However, the proportion of the 1+ population that is mature is substantially lower from the IBM than for Baleen II, with the consequence that using Baleen II to calculate MSY_{mat} from $MSYR_{1+}$ leads to a numeric MSY that is larger than would be obtained from the energetics model for the same 1+ population size. Averaged over the cases, the numerical MSY from applying the Baleen II model is too large by about 42%. The results for the 'like minke' dynamics are qualitatively different from previous results based on humpbacks. In the latter, the ratios of $MSYR_{1+}$ to $MSYR_{mat}$ are less than those from the Baleen II model, and they are also more dependent on $MSYR_{1+}$.

In discussion, it was noted that the relationship between $MSYR_{1+}$ and $MSYR_{mat}$ is consequential to the work of the Committee. MSYR is defined in terms of the 1+ component of the population when specifying trials because the MSYR review, which was completed in 2013, was based on rates of increase from survey estimates of abundance, which tend to be estimates of 1+ abundance. In contrast, selectivity during actual whaling operations usually pertains to older animals and hence MSYR as it applies to the selected population will determine the performance of RMP variants. The relationship between $MSYR_{1+}$ and $MSYR_{mat}$ will depend on the age-specificity of natural mortality as well as whether density-dependence pertains to the calving/calf survival rate or to natural mortality.

The sub-committee noted that limited progress had been made in relation to the work plan for this item developed last year. This is partially due to the computational demands associated with modifying the individual based energetics model to capture the dynamics of minke whales and conducting projections using this based model. It updated its work plan for the 2017 Annual Meeting to include reviewing how the individual based model was parameterised for 'like minke' whales, as well as how well a population model can capture the behaviour of the individual-based model. The sub-committee **agreed** that the results in SC/66b/RMP04 would not impact the *Implementation Reviews* currently being undertaken for the North Atlantic fin and minke whales, but that future *Implementations* and *Implementation Reviews* should take the results into account during sensitivity tests which explore density-dependence on natural mortality as well as fecundity. The upcoming *Implementation Review* for the North Pacific Bryde's whales should be the first to include these sensitivity tests.

2.2 Requirements and Guidelines for Conducting Surveys: model based abundance estimates
The Committee's existing Requirement and Guidelines were written for design-based surveys only. Recently, the Committee recognised a need to consider what circumstances might require approval when the survey and analysis are conducted based on spatial modelling or quasi design-based approaches. The Committee agreed in 2012 (IWC, 2013) that a review of this issue should take place intersessionally.

The sub-committee obtained an update on progress by Bravington and colleagues towards developing guidelines and software for developing model-based abundance estimates. A planned meeting prior to SC/66b to develop software for model-based estimation did not occur, and will be unlikely to be conducted until 2017. The sub-committee **agreed** that a demonstration of the software implementing the analysis method should occur, preferably during a Workshop held as a pre-meeting to SC/67a. This Workshop would test the guidelines against several test cases of model-based abundance estimation.

The sub-committee re-established a Steering Group under Butterworth (Chair) with members Bravington, Cooke, Kitakado and Miller, to co-ordinate intersessional work, develop an agenda for the Workshop and facilitate preparations for the Workshop.

2.3 Implications of *ISTs* for consideration of 'status'

The *Implementation Simulation Trials* used by the Committee can provide information on the current status of populations using metrics such as current population size, current population size relative to carrying capacity, recent past trends, and expected short-term future trends. The sub-committee highlights that there are usually many *Implementation Simulation Trials* for any given *Implementation*, which means that metrics of status may need to be given as ranges based on plausible trials rather than as point estimates. It was also noted that the number of stocks in a region often differs among *Implementation Simulation Trials*. Thus, it may be necessary to provide metrics of status for a region or perhaps some smaller areas such as '*Medium Area*'.

The sub-committee **agreed** that this issue would be best addressed intersessionally and established a Steering Group consisting of Donovan (Chair) and members Butterworth, Cooke, Punt, and Walløe to provide advice on how to develop and present metrics of status at the 2017 meeting.

2.4 Work plan

See text table below.

Before the 2017 Annual Meeting	During the 2017 Annual Meeting
(1) Conduct work to evaluate the energetics-based model and hence the relationship between MSYR$_{1+}$ and MSYR$_{mat}$ (Item 2.1): (a) write a paper documenting how the individual-based model was parametersised for 'like minke' whales (De la Mare); (b) develop emulator models (de la Mare, Butterworth, Punt, Cooke)[1]; (c) conduct simulations of the *CLA* for the energetics-based model (De la Mare); and (d) conduct simulations of the *CLA* for the emulator models (De la Mare, Butterworth, Punt, Cooke).	(1) Review intersessional progress on evaluating the energetics-based model (Item 2.1).
(2) Develop simple-to-use diagnostic software that uses model-based analysis to assist in evaluating design based estimates (Bravington and Miller, Item 2.2).	(2) Hold a pre-meeting Workshop with Terms of Reference: (i) to test proposed new Guidelines against several test cases of model-based abundance estimates developed specifically for and during the Workshop; and (ii) to demonstrate and discuss the proposed diagnostic software. There will be costs involved for travel and subsistence (Item 2.2).
(3) Further develop ways to integrate results from *Implementation Simulation Trials* to assess status (Item 2.3).	(3) Review the proposed approaches for determining status and apply them to some example species and regions.
Before the 2018 Annual Meeting	**During the 2018 Annual Meeting**
(1) Continue to work to evaluate the energetics-based model and hence the relationship between MSYR$_{1+}$ and MSYR$_{mat}$ (Item 2.1).	(1) Review intersessional progress on evaluating the energetics-based model (Item 2.1).

[1]This is a multi-year process – completion of these tasks depends on progress relative to issue (a).

Table 1

The agreed final *Implementation Simulation Trials* for North Atlantic fin whales. All trials assume the following unless otherwise stated: the 'Best' catch series; future surveys will occur in sub-areas EG, WI and EI/F; and *g*(0) is taken to be equal to 1. Trial weightings are also shown (H=high and M=medium). Trials assigned 'low' plausibility during the current meeting and not included in the final evaluation are indicated as strike-through font.

Trial no.	Stock hypothesis	*MSYR* [1]	No. of stocks	Trial description	Weight 1%	Weight 4%
Baseline						
NF-B1	I	1, 4%	4	4 stocks, separate feeding areas	M	H
NF-B2	II	1, 4%	4	4 stocks; 'W' and 'E' feed in central sub-areas	M	H
NF-B3	III	1, 4%	4	4 stocks; 'C1' and 'C3' feed in adjacent sub-areas	M	H
NF-B5	V	1, 4%	4	4 stocks as in Hypothesis I but stock 'S' in adjacent sub-areas	M	H
NF-B6	VI	4%	3	3 stocks (no 'E' stock)	N/A	H
Sensitivity						
NF-H2	II	1, 4%	4	High historical catch series	M	M
NF-H3	III	1, 4%	4	High historical catch series	M	M
NF-Q3	III	1, 4%	4	Future WI and EI/F surveys exc. strata S 60°N	M	M
NF-A2	II	1, 4%	4	Pro-rate abundance data for conditioning	M	M
NF-A3	III	1, 4%	4	Pro-rate abundance data for conditioning	M	M
NF-U3	III	~~1~~,4%	4	Selectivity decreases by 4%/year for age 8+; *M*=0.04	~~M~~	M
NF-G2	II	1, 4%	4	C2 sub-stock enters EG beginning year 1985 (opt. a)	M	M
NF-G3	III	1, 4%	4	C2 sub-stock enters EG beginning year 1985 (opt. a)	M	M
NF-F2	II	1, 4%	4	C2 sub-stock enters EG 1985-2025 (opt. b)	M	M
NF-F3	III	1, 4%	4	C2 sub-stock enters EG 1985-2025 (opt. b)	M	M
NF-S3	III	1, 4%	4	Selectivity estimated for pre and post 2000 and use all age data	M	M
NF-Y1	I	1, 4%	4	8 year future survey interval	M	H
NF-Y1	II	1, 4%	4	8 year future survey interval	M	H
NF-Y3	III	1, 4%	4	8 year future survey interval	M	H
NF-Y5	V	1, 4%	4	8 year future survey interval	M	H
NF-Y6	VI	1, 4%	3	8 year future survey interval	n/a	H
NF-E2	II	1, 4%	4	Exclude 1987/9 abundance in WI, EG and EI/F	M	M
NF-E3	III	1,4%	4	Exclude 1987/9 abundance in WI, EG and EI/F	M	~~M~~
NF-D1	I	1%	4	Dispersal: max bound of 20%	M	-
NF-D3	III	1%	4	Dispersal: max bound of 20%	M	-
NF-J1	II	1, 4%	4	Assume *g*(0) = 0.8 (all estimates)	M	H
NF-J2	III	1, 4%	4	Assume *g*(0) = 0.8 (all estimates)	M	H

[1]MSYR in terms of 1^+ on 1% and mature on 4%.

3. RMP – *IMPLEMENTATION*-RELATED MATTERS

3.1 North Atlantic fin whales (*Implementation Review*)

3.1.1 Report of intersessional Workshop

Donovan reported on the intersessional Workshop on the *Implementation Review* of North Atlantic fin whales, held in Copenhagen from 19-23 March 2016. The *Implementation Review* process began during a pre-meeting at the 2013 Annual Meeting of the Scientific Committee (IWC, 2014) and continued with a first intersessional Workshop in 2014 (IWC, 2015b) and a second Workshop in 2015 (IWC, 2016a). The original *Implementation* was completed in 2009 (IWC, 2010).

The main tasks of the Workshop were to: (1) review the results of the conditioning and finalise the trial specifications; (2) provide recommendations to the Scientific Committee related to plausibility weighting of trials; and (3) take forward work to enable the Scientific Committee to complete the *Implementation Review* at SC/66b.

The Workshop was a technical Workshop and a considerable part of the time was spent reviewing conditioning results. This is a substantial task given the complexity of the trials structure (eight stock structure hypotheses – see fig. 2 in Appendix 3). Satisfactory conditioning was based upon the consideration of three data sources: abundance estimates; *Discovery* mark (tag) data; and age data. Initial focus of the Workshop was to examine these data sources in light of whether all or subsets were suitable for use in conditioning.

With respect to abundance estimates, discussion focussed on the '1988' surveys for sub-areas EG, WI and EI/F, and the 1995 estimate for sub-area EG. The Workshop concluded that despite some difficulties, the available information was not sufficient to exclude use of those '1988' and 1995 estimates from the conditioning. However, the Workshop agreed that the information provided above was valuable for interpreting whether the fit to the abundance data was acceptable when examining the conditioning results (i.e. how close a fit to the 'trend' was acceptable).

Following on from discussions at SC/66a (IWC, 2016c), the Workshop considered the appropriate weighting to be given to the tagging data and the role of those data in conditioning. It agreed that the 43 recoveries from sub-area WI allowed for meaningful comparisons across different hypotheses and assumptions – in particular, predicted recapture values of less than 24[1] did not provide an adequate fit to the data.

In summary, after careful consideration the Workshop recommended:

(a) to discontinue consideration of stock structure Hypotheses IV, VII and VIII, and those involving tag loss, because of incompatibility with the tag-recapture data for sub-area WI (in effect, this is equivalent to giving trials with these hypotheses a 'low' plausibility weighting – see Item 4 of SC/66b/Rep05); and
(b) to maintain a downweighting (by a multiplicative 0.1 factor) of the age data in the objective function only for those $MSYR_{1+}$=1% scenarios that had at best marginal acceptability under full weighting of the age data (full weighting of the age data should be used for all other trials).

After work to address issues identified at SC/66a (IWC, 2016c), the Workshop agreed that the fits to the age data whilst not good, were adequate for conditioning purposes. Nevertheless, noting the lack of fit to the post-2000 age data that reflects larger/older whales being caught than in the past - see discussion in (IWC, 2016c) - the Workshop agreed to omit these data from the conditioning of the baseline trials but also agreed that the sensitivity tests should include a scenario allowing for a change in selectivity post-2000 that included the post-2000 age data in the conditioning (trial NF-S3). The Workshop noted that work is in progress to check the recent age readings and recommended that the results from this work are considered during the next *Implementation Review* (scheduled for around 2021).

The final list of agreed trials is provided as Table 1.

The Workshop then reviewed the conditioning results. The full set of results for the baseline trials were available and were agreed to be acceptable. This was also true for those sensitivity trials for which results were available but it was agreed that review of the remaining trials would be undertaken intersessionally.

The final important task of the Workshop was to assign plausibility to the trials following the Requirements and Guidelines. The resultant weightings are indicated in Table 1. A work plan was developed to facilitate completion of the *Implementation Review* at SC/66b.

In concluding his report, Donovan thanked Elvarsson, Allison, Punt and de Moor for their tireless computing work and the Greenland Representation for its excellent facilities.

The sub-committee thanked Donovan for chairing the Intersessional Workshop and the participants for their work during the Workshop and subsequently, in particular Elvarsson, Allison and de Moor. It **endorsed** the Workshop recommendations, including the weights assigned provisionally to the trials.

Elvarsson reported that an error had been discovered in the way the trials were conditioned (the 2003 abundance estimate for sub-area EC was assumed to pertain to 2007), which has led to the need for all of the trials to be re-conditioned. A small group (Allison, de Moor, Elvarsson, Gunnlaugsson, Johnson, Punt, Walløe) was established to review the revised conditioning results (see Appendix 2 for the full set of conditioning diagnostics and Appendix 3 for the final trial specifications). The small group recommended that trials NFU-1 and NFE-4 be assigned 'low' plausibility because of their poor fits to the tagging data (and for NFU-1 for its poor fit to the aging data) and hence dropped from further consideration. The sub-committee **agreed** with this recommendation. Table 1 lists the final set of trials and their associated weights.

3.1.2 Completion of Implementation Review

3.1.2.1 OVERVIEW AND PROCEDURE TO FOLLOW

The procedure for defining 'acceptable', 'borderline' and 'unacceptable' performance agreed by the Committee (IWC, 2007) involves conducting the following steps for each stock (or sub-stock) in an *Implementation Simulation Trial*.

(1) Construct a single stock trial, which is 'equivalent' to the stock. For example, if a particular stock in the *Implementation Simulation Trial* involved carrying capacity halving over the 100-year projection period, the 'equivalent single stock trial' will also involve carrying capacity halving over the next 100 years.
(2) Conduct two sets of 100 simulations based on this single stock trial in which future catch limits are set by the *CLA*. The two sets of simulations correspond to the 0.60 and 0.72 tunings of the *CLA*. Rather than basing these calculations on a single initial depletion, the simulations for each stock shall be conducted for the distribution of initial depletions for the stock concerned in the *Implementation Simulation Trial* under consideration.

[1]Approximately the lower 95% confidence interval about the observed number of recaptures under the assumption of a Poisson-like recapture process.

(3) The cumulative distributions for the final depletion and for the minimum depletion ratio (the minimum over each of the 100-year projections of a trial of the ratio of the population size to that when there are only incidental catches) shall be constructed for each of these two tunings of the *CLA*.
(4) The lower 5%-ile of these distributions shall form the basis for determining whether the performance of the RMP (i.e., the RMP variant under consideration) for the *Implementation Simulation Trial* is 'acceptable' - A, 'borderline' - B or 'unacceptable' - U, as follows:
    (a) if the 5%-ile of the final depletion or the 5%-ile of the minimum depletion ratio for the *Implementation Simulation Trial* is greater than for the equivalent single stock trial with the 0.72 tuning of the *CLA* (or the 5%-ile of the minimum depletion ratio for the *Implementation Simulation Trial* is greater than 0.999), the performance of the RMP variant shall be classified as 'acceptable';
    (b) if performance is not 'acceptable' and either the 5%-ile of the final depletion or the 5%-ile of the minimum depletion ratio for the *Implementation Simulation Trial* is greater than for the equivalent single stock trial with 0.60 tuning of the *CLA*, the performance of the RMP variant shall be classified as 'borderline'; and
    (c) if performance is neither 'acceptable' nor 'borderline' and if the 5%-ile of the final depletion and the 5%-ile of the minimum depletion ratio for the *Implementation Simulation Trial* are less than those for the equivalent single stock trial with 0.60 tuning of the *CLA*, then performance of the RMP variant shall be classified as 'unacceptable'.

If the performance for a small number of medium weight trials is 'borderline' but close to 'acceptable', then performance of the variant can be considered 'acceptable' without research. A flow chart summarising the decision process that should be followed is given as Fig. 1.

The sub-committee reviewed the results of the *Implementation Simulation Trials* based on the experience gained during recent *Implementations* and *Implementation Reviews*. The purposes of the following tables range from providing a quick summary of conservation performance to listing many of the performance statistics for each trial and RMP variant. The master set of plots and tables is archived by the Secretariat and available to members of the Scientific Committee on request.

(1) A table showing for each RMP variant: the average over the trials of the lower 5%-ile, median and upper 95%-ile of catch in sub-areas WI and E/IF for the first 10 and final 10 years of the projection period and a summary of the application of the procedure for defining 'acceptable' - A, 'borderline' - B and 'unacceptable' - U performance. Results are shown separately for the 'high' and 'medium' plausibility trials.
(2) A table showing the detailed results for each trial and RMP variant. The following information is included in this table:
    (a) median catch over the entire projection period and median, lower 5%-ile and upper 5%-ile over the first 10 years;
    (b) lower 5%-ile and median of the final depletion distribution (by stock);
    (c) lower 5%-ile and median of the minimum depletion ratio distribution (by stock); and
    (d) lower 5%-ile and median of the initial depletion distribution (by stock).

This table also includes the values for the thresholds for each performance statistic and stock for the trials and the outcomes of the application of the procedure for defining 'acceptable', 'borderline' and 'unacceptable' performance.

3.1.2.2 REVIEW TRIALS RESULTS

The seven management variants to be considered were as follows:

(1) sub-area WI is a *Small Area*;
(2) sub-area (WI+EG) is a *Small Area*. All of the catch is taken in sub-area WI;
(3) sub-area (WI+EG+EI/F) is a *Small Area*. All of the catch is taken in sub-area WI;
(4) sub-area WI is a *Small Area*. Catch limits will be set based on survey estimates for sub-area WI north of 60°N (both historical and future surveys);
(5) sub-areas WI and EG are taken to be *Small Areas* and sub-area WI+EG is taken to be a *Combination Area*. The catch limits set for the EG *Small Area* are not taken;
(6) sub-areas WI, EI/F and EG are taken to be *Small Areas* and sub-area WI+EI/F+EG is taken to be a *Combination Area*. The catch limits set for the EG and EI/F *Small Areas* are not taken; and
(7) sub-areas WI+EG and EI/F are taken to be *Small Areas* and sub-area WI+EI/F+EG is taken to be a *Combination Area*. The catch limits set for the WI+EG *Small Area* are taken in sub-area WI. The catch limit for sub-area EI/F is taken there.

The simulated application of the RMP is always based on using the 'best' catch series.

There are a number of possible scenarios to consider when evaluating the trials, and it is at this stage that a degree of judgement is required, including consideration of the overall balance of the trials and the characteristics of the specific trials for which performance is questionable. Tables 2 and 3 summarise the application of the rules for evaluating conservation performance.

In relation to conservation performance:

(1) Variants 1, 4, 5 and 6. These variants did not have 'unacceptable' or 'borderline' conservation performance for any trials and are hence 'acceptable without research'.
(2) Variant 2. This variant had 'borderline' conservation performance for 16 of the 'medium' plausibility trials. Given the large number of trials in which conservation performance was not 'acceptable', there was no justification to consider the conservation performance of this variant to be 'acceptable'.
(3) Variant 3. This variant had 'unacceptable' conservation performance for four of the 'medium' plausibility trials, 'borderline' performance for six of the 'high' plausibility trials and 'borderline' conservation performance for 19 of the 'medium' plausibility trials. Given the large number of trials in which conservation performance was not 'acceptable', there was no justification to consider the conservation performance of this variant to be 'acceptable'.
(4) Variant 7. This variant had 'borderline' conservation performance for three of the 'medium' plausibility trials (A2-1, E2- and E3-1). The performance statistics for this variant for trial A2-1 are marginally below the thresholds for 'acceptable' performance (Fig. 2). The performance statistics for stocks C1 and C2 are halfway

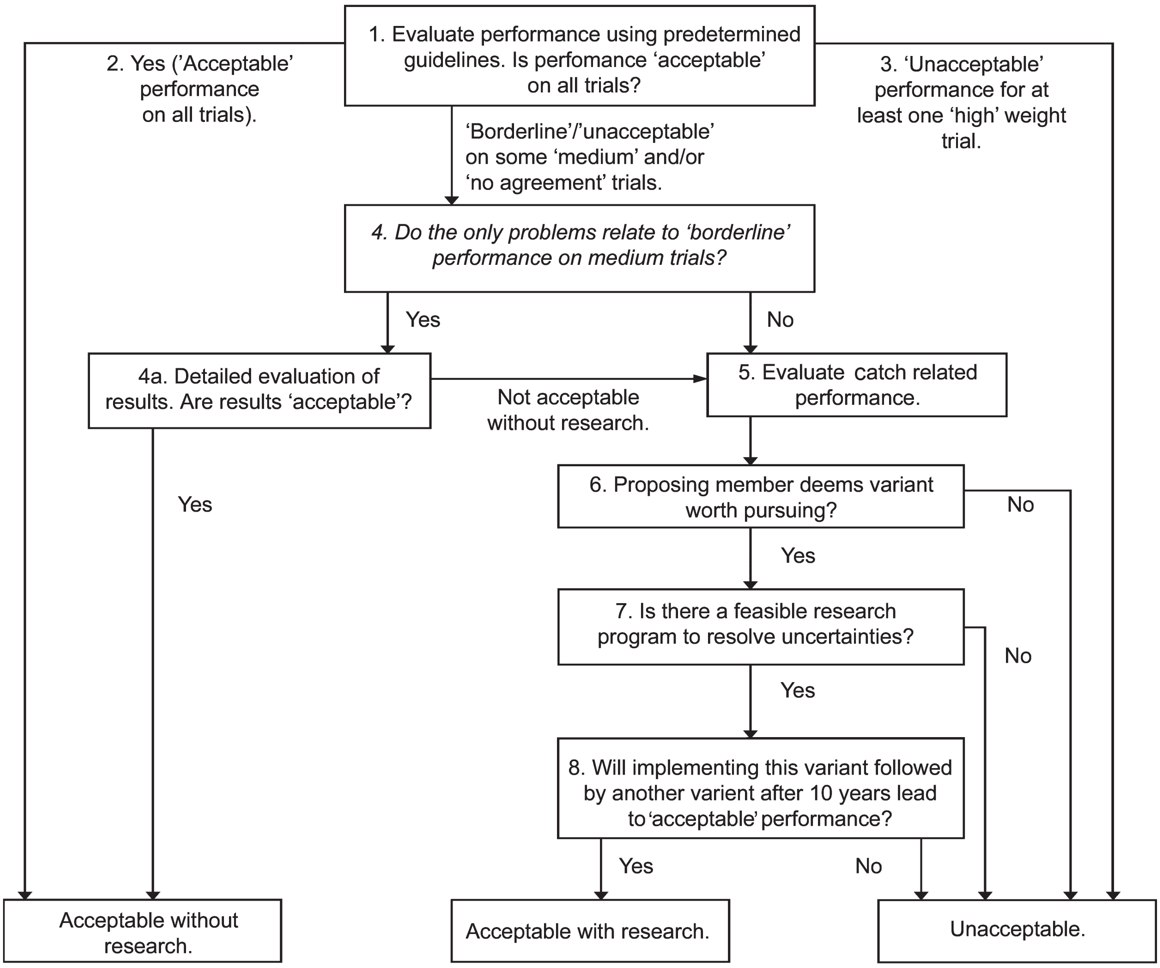


Fig. 1. Flowchart summarising the procedure for the review of *IST*s. Figure taken from IWC (2005).

between 'acceptable' and 'unacceptable' thresholds for trials E2-1 and E3-1 (trials that involve ignoring the 1987/9 abundance estimates in sub-areas WI, EG & EI/F). However, overall performance was considered sufficiently close to 'acceptable' that the sub-committee considered this variant 'acceptable without research'.

Variant 7 outperforms variants 1, 4, 5 and 6 in terms of catch performance (Table 3).

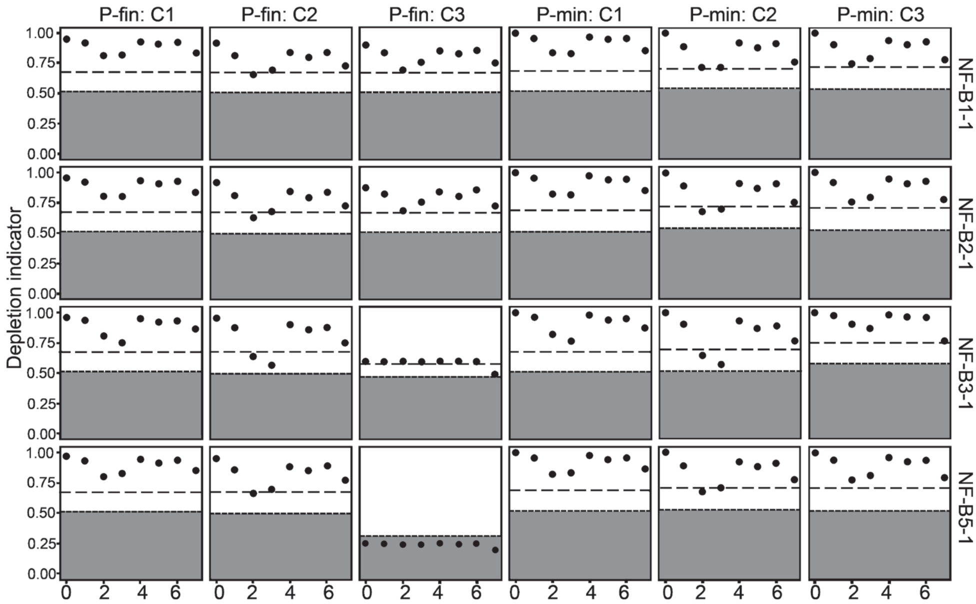
3.1.3 New information

SC/66b/IA18 presented the sixth North Atlantic Sightings Survey (NASS) conducted in June-July 2015. Three vessels surveyed 7,027 nautical miles in a large area of the northern North Atlantic during 102 vessel days. The effort was similar to the earlier NASSs, but for the first time a fully independent double platform observer mode was applied. A contiguous area north and east of Iceland around Jan-Mayen Island was covered simultaneously by a Norwegian vessel as a part of an annual cyclic mosaic survey and is not presented here. One of the Icelandic survey vessels was conducting coincident fisheries surveys and collecting accompanying environmental data. Transects for the other two vessels, fully dedicated to cetacean surveying, were designed using the program Distance. A plot of the designed and initially planned tracks is given in SC/66b/RMP02. A plot of realised effort in BSS<=5 is given in SC/66b/RMP01. Observers included foreign scientists and students. Surveys were generally successful, and sightings per mile appear similar to earlier surveys, while there were more sightings in the Faroese survey area south of Iceland and around the Faroes than anticipated. Fin, common minke and long-finned pilot whales were the primary target species, but emphasis was made to identify as many sightings as possible to the species level. Consequently, 15 cetacean species were identified. During an 18 day capelin survey north of Iceland to East Greenland in September-October 2015, the same set-up was again used for cetacean surveying and resulted in only 423 nautical miles covered. A point estimate for this area was 4,923 fin whales and 7,083 humpback whales. A few minke whales were seen near the coast of Iceland while sightings of other species were few.

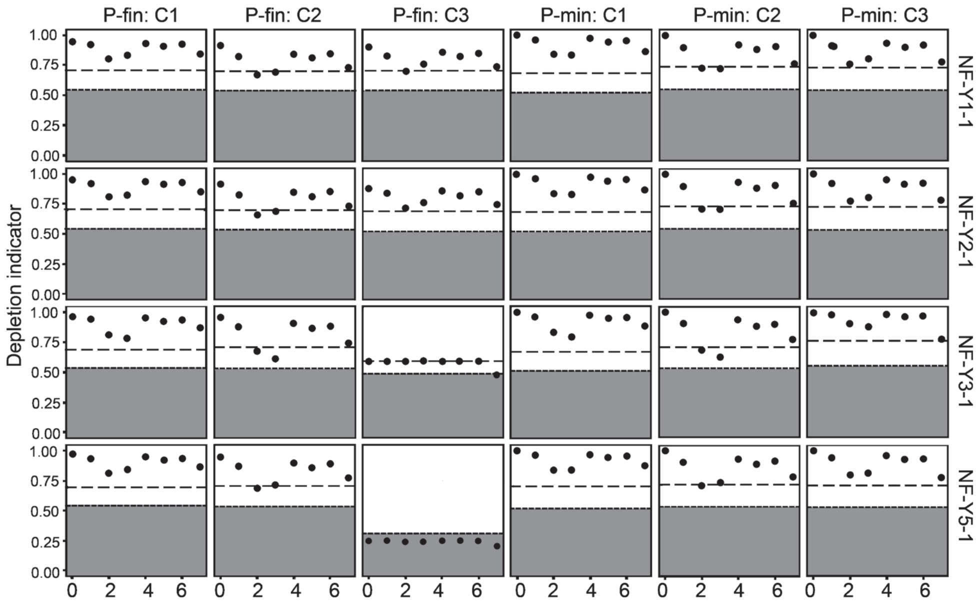
The sub-committee discussed the usefulness of collecting still images of sightings over video recordings, and the potential for this technology to be incorporated into observer binoculars. The sub-committee expressed interest in learning more about this technology and **recommended** that the authors of SC/66b/IA18 provide advice about the technology and its potential for use in surveys at the next meeting.

SC/66b/RMP01 provided abundance estimates for fin whales from the Icelandic and Faroese survey blocks from the NASS 2015 survey. The survey areas were further stratified to match the IWC *RMP Implementation* areas. Estimates were obtained using stratified mark-recapture distance sampling techniques in the DISTANCE 6.2 software package. Covariates were retained only if the resultant Akaike Information Criterion value was lowered. The estimate of perception bias ($g(0) = 0.86$) for the combined platforms for fin whales at perpendicular distance 0 was used. The perception bias provides a correction for missed

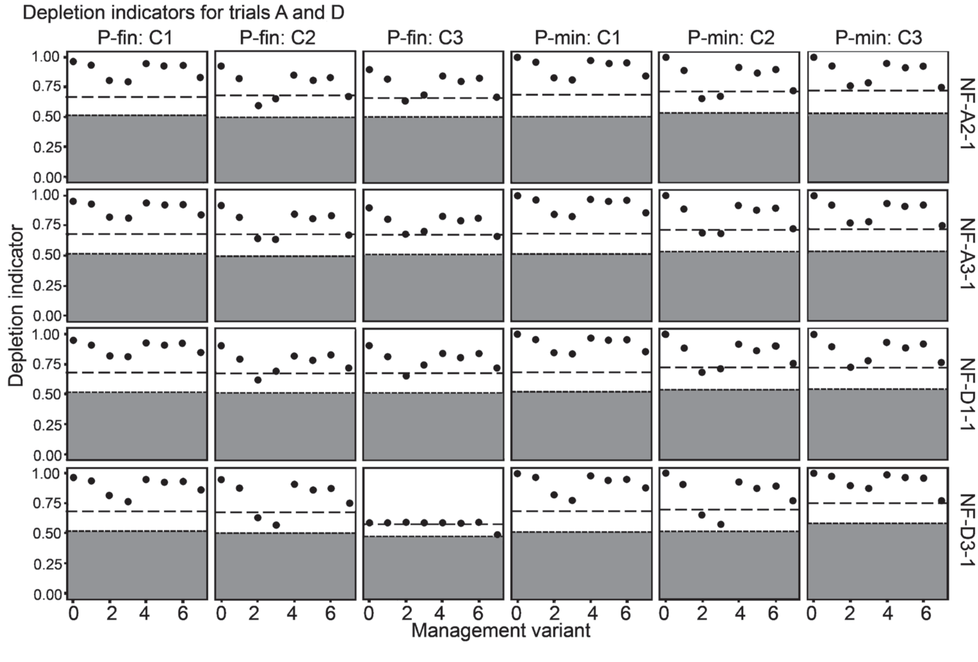
Depletion indicators for the Baseline trials



Depletion indicators for the Baseline trials with 8 year survey interval



Depletion indicators for trials A and D



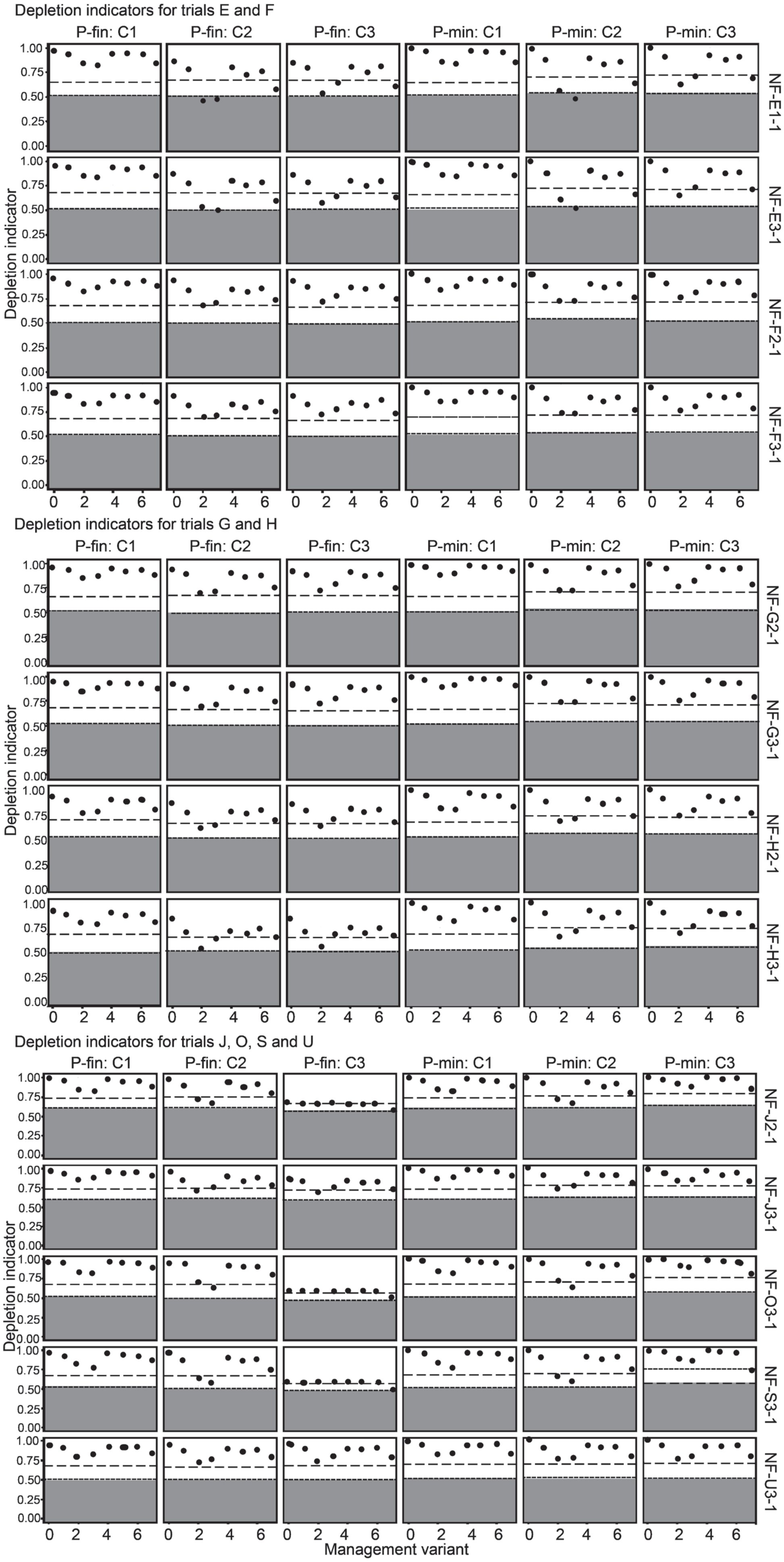


Fig. 2. A plot showing the performance of each of the seven RMP variants for each of the $MSYR_{1+}$=1% trials. Results are presented for the C1, C2 and C3 sub-stocks and the two performance statistics on which the thresholds are based (P-fin: the lower 5th percentile of the final depletion distribution and P-min: the lower 5th percentile of the minimum depletion ratio distribution). The values for the performance statistics for each variant (and the no-catch scenario, labelled 'Variant 0') are represented as dots, and horizontal lines indicate the thresholds (upper line: 'acceptable'; lower line: 'borderline'). The shaded area in this plot indicates 'unacceptable' performance.

Table 2

Summary of the 'high' and 'medium' plausibility trials on which each of the variants failed to achieve 'acceptable' performance. None of the variants were 'unacceptable' on 'high' plausibility trials.

	High plausibility	Medium plausibility		
Variant	Borderline	Unacceptable	Borderline	Recommendation
1	None	None	None	Acceptable
2	None	None	A2-1, A3-1, B1-1, B2-1, B3-1, B5-1, D1-1, D3-1, 2-1, E2-4, E3-1, H2-1, H3-1, S3-1, Y2-1, Y3-1	Unacceptable
3	B1-4, B2-4, B3-4, Y1-4, Y2-4, Y3-4,	E2-1, E2-4, H2-4, H3-4	A2-1, A3-1, A3-4, B2-1, B3-1, D1-4, D3-1, D3-4, E3-1, E3-4, F2-4, H2-1, H3-1, J2-1, Q3-1, S3-1, S3-4, U3-4, Y3-1	Unacceptable
4	None	None	None	Acceptable
5	None	None	None	Acceptable
6	None	None	None	Acceptable
7	None	None	A2-1, E2-1, E3-1	Acceptable

Table 3

Summary of the conservation and catch performance of the seven RMP variants.

					Catch first 10 years			Catch last 10 years		
Variant	Trial weight	Acceptable	Borderline	Unacceptable	Mean 5%	Mean med	Mean 95%	Mean 5%	Mean med	Mean 95%
1	H	12	0	0	15	18	22	0	6	34
2	H	12	0	0	83	86	89	42	90	121
3	H	6	6	0	120	127	135	64	103	144
4	H	12	0	0	4	7	11	0	1	16
5	H	12	0	0	31	33	36	10	25	45
6	H	12	0	0	34	36	40	11	20	34
7	H	12	0	0	121	128	135	64	104	145
1	M	40	0	0	15	18	23	7	30	54
2	M	24	16	0	84	87	90	80	115	144
3	M	17	19	4	118	127	135	64	115	161
4	M	36	0	0	4	8	12	2	16	39
5	M	40	0	0	31	33	37	24	42	60
6	M	40	0	0	33	36	41	18	31	46
7	M	37	3	0	118	127	136	63	114	161

sightings, but not for whales missed where one platform sees a smaller group than the other platform. In strata covered by the coincident cetacean/fisheries research vessel, some cetacean survey effort was maintained while ferrying between transects, resulting in some transects running parallel to the Greenland or Iceland coast. These transects were aligned with expected high fin whale density gradients observed in previous surveys. Rejecting this compromised effort and using effort conducted in Beaufort sea state of less than five, the total corrected estimate for the survey area using all fin whale sightings is 40,788 (CV 0.17; 95% CI 28,476 to 58,423). Estimates are also provided including the compromised effort or excluding low confidence sightings. The estimated densities were higher than estimates from earlier surveys in the area between West Iceland and East Greenland and in the Faroese survey area south of Iceland.

The sub-committee **endorsed** the estimate of abundance for use in the *CLA*.

3.1.4 Conclusions

Based on the results of the *Implementation Simulation Trials*, variants 1, 4, 5, 6, and 7 are acceptable in terms of conservation performance. Of these variants, variant 7 achieves the best performance in terms of catch. This completes the *Implementation Review*.

3.2 North Atlantic common minke whale (*Implementation Review*)

3.2.1 Report of intersessional Workshop

Donovan reported on the intersessional Workshop on the *Implementation Review* of North Atlantic common minke whales, held in Copenhagen from 19-23 March 2016. The *Implementation Review* process began with a joint AWMP/RMP Workshop in 2014 (IWC, 2015a) followed by a pre-meeting in 2014 (IWC, 2015c) and continued with a first intersessional Workshop in 2015 (IWC, 2016b) and discussions at the 2015 Annual Meeting. In addition, aspects of the work identified at the 2015 Annual Meeting were considered during the AWMP Workshop reported in SC/66b/Rep03.

The main tasks of the Workshop were to: (1) review the results of the conditioning and finalise the trial specifications; (2) provide recommendations to the Scientific Committee related to plausibility weighting of trials; and (3) take forward work to enable the Scientific Committee to complete the *Implementation Review* at SC/66b.

The Workshop was a technical Workshop and much of the time was spent on improving the conditioning results. This is a substantial task given the complexity of the trials structure and considerable time was spent on improving the mixing matrices. Satisfactory conditioning was based primarily upon the consideration of factors associated with abundance estimates and sex ratio data.

The final list of agreed trials is provided as Table 4.

The Workshop then reviewed the conditioning results. After considerable work the Workshop agreed that conditioning had been satisfactorily achieved for providing advice on catches by Norway and Iceland, but that aspects of the conditioning for West Greenland would need to be taken into account when developing a *Strike Limit Algorithm* for the West Greenland hunt.

The final important task of the Workshop was to assign plausibility to the trials following the Requirements and Guidelines. The resultant weightings are indicated in

Table 4

The *Implementation Simulation Trials* for North Atlantic minke whales.

Trial no.	Stock hypothesis	MSYR	No. of stocks	Boundaries	Catch sex-ratio for selectivity	Trial weight	Notes
NM01-1	I	1%[1]	3	Baseline	2008-13	M	3 stocks, E and W with sub-stocks
NM01-4	I	4%[2]	3	Baseline	2008-13	H	3 stocks, E and W with sub-stocks
NM02-1	II	1%[1]	2	Baseline	2008-13	M	2 stocks, E with sub-stocks
NM02-4	II	4%[2]	2	Baseline	2008-13	H	2 stocks, E with sub-stocks
NM03-1	III	1%[1]	1	Baseline	2008-13	M	1 stock
NM03-4	III	4%[2]	1	Baseline	2008-13	M	1 stock
NM04-1	IV	1%[1]	2	Baseline	2008-13	M	2 cryptic stocks
NM04-4	IV	4%[2]	2	Baseline	2008-13	M	2 cryptic stocks
NM05-1	I	1%[1]	3	Stock C not in ESW	2008-13	M	3 stocks, E and W with sub-stocks
NM05-4	I	4%[2]	3	Stock C not in ESW	2008-13	M	3 stocks, E and W with sub-stocks
NM06-1	II	1%[1]	2	Stock C not in ESW	2008-13	M	2 stocks, E with sub-stocks
NM06-4	II	4%[2]	2	Stock C not in ESW	2008-13	M	2 stocks, E with sub-stocks
NM07-1	I	1%[1]	3	Baseline	2002-07	M	Alternative years to adjust selectivity-at-age
NM07-4	I	4%[2]	3	Baseline	2002-07	M	Alternative years to adjust selectivity-at-age
NM09-1	I	1%	3	Baseline	2008-13	M	E-2 stock in EN 10%
NM09-4	I	4%	3	Baseline	2008-13	M	E-2 stock in EN 10%
NM10-1	I	1%	3	Baseline	2008-13	M	E-2 stock in EN 90%
NM10-4	I	4%	3	Baseline	2008-13	M	E-2 stock in EN 90%
NM12-1	I	1%[1]	3	Stock E1 not in ESW	2008-13	M	3 stocks, E and W with sub-stocks
NM12-4	I	4%[2]	3	Stock E1 not in ESW	2008-13	M	3 stocks, E and W with sub-stocks
NM13-1	II	1%[1]	2	Stock E1 not in ESW	2008-13	M	2 stocks, E with sub-stocks
NM13-4	II	4%[2]	2	Stock E1 not in ESW	2008-13	M	2 stocks, E with sub-stocks
NM01-1v	I	1%[1]	3	Baseline	2008-13	M	CV of future abundance = ½ basecase value
NM01-4v	I	4%[2]	3	Baseline	2008-13	H	Ditto
NM02-1v	II	1%[1]	2	Baseline	2008-13	M	Ditto
NM02-4v	II	4%[2]	2	Baseline	2008-13	H	Ditto
NM03-1v	III	1%[1]	1	Baseline	2008-13	M	Ditto
NM03-4v	III	4%[2]	1	Baseline	2008-13	M	Ditto
NM04-1v	IV	1%[1]	2	Baseline	2008-13	M	Ditto
NM04-4v	IV	4%[2]	2	Baseline	2008-13	M	Ditto

[1] 1+; [2]mature.

Table 4. A work plan was developed to facilitate completion of the *Implementation Review* at SC/66b.

In concluding his report, Donovan thanked Allison, Punt and de Moor for their tireless computing work and the Greenland Representation for its excellent facilities.

The sub-committee thanked Donovan for chairing the intersessional Workshop and the participants for their work during the Workshop and subsequently, in particular Allison and de Moor. It **endorsed** the Workshop recommendations, including the weights assigned to the trials (Table 4). Appendix 4 lists the final trial specifications for the North Atlantic minke whales.

Allison reported that, as recommended by the Workshop, she and de Moor has developed a method for setting the variation in spatial distribution to mimic the observed variation (see Section E of Appendix 4). She reported that the conditioning of the trials has been completed. A small group (Allison, de Moor, Elvarsson, Gunnlaugsson, Johnson, Punt, Walløe) was established to review the revised conditioning results (see Annex D of SC/66b/Rep04 for the full set of conditioning diagnostics). The small group agreed that conditioning had been successfully achieved and this conclusion was **endorsed** by the sub-committee.

3.2.2 Completion of Implementation Review

The sub-committee followed the same process for evaluating the results of the *Implementation Simulation Trials* it applied when interpreting the results of the *Implementation Simulations Trials* for the North Atlantic minke whales (see Items 3.1.2.1 and 3.1.2.2).

The five management variants to be considered were as follows.

(1) Sub-areas CIC, CM, CG, CIP, EN, EB, ESW+ESE and EW are *Small Areas*, with the catch limits for these *Small Areas* based on catch cascading from the C and E *Combination Areas*. The catch from the ESW+ESE *Small Area* is all taken in sub-area ESE. The catch limits set for the CM, CG and CIP *Small Areas* are not taken (except that the Aboriginal catch is taken from CG).

(2) Sub-areas CIC, CM, CG, CIP, EN and EB+ESW+ESE+EW are *Small Areas*, with the catch limits for these *Small Areas* based on catch cascading from the C and E *Combination Areas*. The catch from the EB+ ESW+ESE +EW *Small Area* is all taken in sub-area EW. The catch limits set for the CM, CG and CIP *Small Areas* are not taken (except that the Aboriginal catch is taken from CG).

(3) Sub-areas CIC, CM, CG, CIP, EN, ESW+ESE, and EB+EW are *Small Areas*, with the catch limits for these *Small Areas* based on catch cascading from the C and E *Combination Areas*. The catch from the EB+ EW *Small Area* is all taken in sub-area EW and the catch from the ESW+ESE *Small Area* is taken in the ESE sub-area. The catch limits set for the CM, CG and CIP *Small Areas* are not taken (except that the Aboriginal catch is taken from CG).

(4) As for variant 1, except that sub-areas CIC+CIP+CM are a single *Small Area* and all of the catches from this *Small Area* are taken in sub-area CIC. The catch limits set for the CG *Small Area* are not taken (except that the Aboriginal catch is taken).

(5) 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.

3.2.2.1 REVIEW TRIAL RESULTS

The trials were conducted. However, there was insufficient time to finalise interpretation of the results before the end of the sub-committee. The sub-committee **agreed** that work to finalise the analyses should continue and the results reported to the Plenary. In the event that it is not possible to complete the *Implementation Review* during the Plenary, the work can be continued during a two-day pre-meeting before the planned AWMP Workshop (see Annex E, Item 3).

3.2.3 New information

SC/66b/RMP02 provided abundance estimates for common minke whales from the NASS 2015 Iceland-Faroese survey blocks that were further stratified according to the IWC *RMP Implementation* areas. Covariates were retained only if the resultant Akaike Information Criterion value was lowered. The estimate of perception bias ($g(0) = 0.51$) for the combined platforms for minke whales at perpendicular distance 0 was used for the first time to produce abundance estimates from NASS shipboard surveys. In strata covered by the coincident cetacean/fisheries research vessel some cetacean survey effort was maintained while ferrying between transects, resulting in some transects running parallel to the Greenland or Iceland coast. These transects were aligned with expected high whale density gradients observed in previous surveys. Rejecting this compromised effort and using only effort in conducted in a Beaufort sea state of less than four, the total corrected estimate for the survey area using all minke whale sightings is 36,185 (CV 0.31; 95% CI 19,942 to 65,658). The highest densities were, as in earlier surveys, observed in Icelandic coastal waters, close to the east coast of Greenland, and around the Faroes. Notably, in 2015 no minke whales were seen to the north of Iceland, an area of high density in previous years. However, realised effort in this area was very low in 2015 due to unfavourable weather, which impacted the estimate for the coastal Iceland area of 12,710 (CV 0.53; 95% CI 4,498 to 35,912). The estimate is in the low range of recent corrected aerial survey estimates for this area. An aerial survey in this area was unsuccessful in 2015 due to the poor weather conditions. The uncorrected estimate is similar to earlier vessel survey estimates generated for this area, and estimated densities are also similar in most other areas, while the estimated minke whale density around the Faroes has varied considerably.

The sub-committee **endorsed** the abundance estimates for use in the *CLA*.

The sub-committee discussed the distinction between availability and perception bias for ship and aerial surveys. The sub-committee **agreed** that the distinction between availability and detection bias for ship-board surveys was somewhat arbitrary and dependent on the exact analysis method employed. It **recommended** that a footnote be added to the table in Item 4 to define how $g(0)$ should be interpreted for different estimates.

SC/66b/RMP03 presented preliminary abundance estimates of common minke whales in Northeast Atlantic areas covered by Norwegian surveys over the two years 2014-15. These areas comprise the RMP *Small Management Areas* ES (2014), EW (2015) and part of CM (2015). Cetaceans were searched for by naked eye from two independent platforms, each manned with two observers following the protocols established for these surveys and used in previous survey cycles. The analyses have followed the same lines as in previous analyses. However, the estimated abundance of 48,232 minke whales is given as point estimates only because the final variance estimation calculations remain uncalculated. The 40% drop in abundance in the Jan Mayen area, which was observed in the survey cycle 2008-13, as compared to the abundances estimated for the two foregoing survey cycles, seems to have been reversed in 2015. The abundance in 2015 was three times that of 2011 in one major survey block (CM3) in the Jan Mayen area. The minke whale abundance attributed to the Norwegian Sea is apparently stable. The minke whale abundance in the Svalbard area (ES) in 2014 decreased to 45% of the abundance from 2008, indicating a distributional shift. The authors of SC/66b/RMP03 suggest that understanding the scale of the shifts is important for estimating population abundance.

The sub-committee discussed issues related to the likely effect of systematic variation of multi-year surveys on estimated variances, which are currently combined using random effects modelling, the effect of differential yearly patterns of re-sighting, and the effect of changing strip half-widths among years. The sub-committee **recommended** that results from analyses regarding effect strip half-width be presented in 2017, that the abundance estimates not be accepted and the abundance estimates be re-submitted after further work.

SC/66b/RMP06 summarised a sighting survey conducted in the eastern Norwegian Sea in the Small Management Area (EW) and at Jan Mayen within the Small Management Area (CM) during the summer 2015. This was the second year of the ongoing six-year survey program (2014-19) for minke whales in the northeast Atlantic with EW as the target area. In addition, an extension was made to the Jan Mayen area as part of the NASS-2015 survey effort. One vessel covered these areas over the period 22 June to 30 August 2016. Three designed survey blocks within EW and two survey blocks within CM were covered during the period. In total, 4,343 nautical miles were conducted in primary search mode. During the primary search, the established sightings procedures, including double platform and tracking of minke whales, were followed as in previous surveys in which minke whales have been the primary target species. The most common species sighted were minke whales, fin whales and sperm whales. In addition, sightings were made of white-beaked dolphins, killer whales, humpback whales, blue whales, harbour porpoises, white-sided dolphins and Northern bottlenose whales.

Øien advised the sub-committee that next year the plan is to survey the Barents Sea which will require access to Russian EEZ. Without such access the final abundance estimates will be compromised and not complete. The sub-committee **recommends** that the Commission request the relevant authorities in Russia to grant permission to a Norwegian vessel to survey the planned areas in Russian EEZ of the Barents Sea. The sub-committee appointed Øien to provide oversight on its behalf.

3.2.4 Conclusions and recommendations

Conclusions and recommendations may be drawn during the Plenary should final results be available, but see Item 3.2.2.1.

3.3 North Pacific common minke whales

3.3.1 Review new information

The sub-committee considered Hakamada *et al.* (2016) and Hakamada and Matsuoka (2016), which were submitted to the Final Review of JARPN II Expert Panel in 2016. Hakamada *et al.* (2016) presented estimates of common minke whales distributed in JARPN II coastal survey areas.

The sub-committee noted that the abundance estimates were not for the whole of the stock, but rather for the sub-areas that were surveyed. Further, it was noted that estimates

Before the 2017 Annual Meeting	During the 2017 Annual Meeting
	(1) North Atlantic fin whales: Review new abundance estimates (Item 3.1). (2) North Atlantic minke whales: Review new abundance estimates (Item 3.2). (3) Western North Pacific minke whales: (a) review stock structure hypotheses in light of the new information submitted; and (b) agree the estimates of abundance for use in actual applications of the RMP (Item 3.3).
(1) Western North Pacific Bryde's whales: (a) conduct the First Intersessional Workshop[1] (Item 3.4); and (b) code the resulting trials and condition the trials (Item 3.4).	(4) Western North Pacific Bryde's whales: Conduct the work required for the First Annual Meeting (Item 3.4).
Before the 2018 Annual Meeting	**During the 2018 Annual Meeting**
	(1) North Atlantic fin whales: Review new abundance estimates (Item 3.1). (2) North Atlantic minke whales: Review new abundance estimates (Item 3.2). (3) Western North Pacific minke whales: Review new abundance estimates (Item 3.2): (a) Plan for the *Implementation Review.*
(1) Western North Pacific Bryde's whales: (a) conduct the Second Intersessional Workshop (Item 3.4).	(4) Western North Pacific Bryde's whales: Conduct the work required for the Second Annual Meeting (Item 3.4).

were not corrected for $g(0)$ and as such should be noted under item 4 as classification 2 (indicating some reservations about the estimates). The estimate of $g(0)$ is 0.798. The sub-committee **recommended** that confidence intervals for $g(0)$ be developed using the Scealy approach. In addition, it was noted that this information could be considered in a future *Implementation Review,* particularly if the data could be used to estimate additional variance.

SC/66b/RMP05 described a survey plan for a 2017 survey in Korean waters. The sub-committee noted that ideally surveys should be conducted taking the migration patterns of the surveyed animals into account (if these are known). It noted that one block will be surveyed north to south and another south to north. Park was appointed to provide oversight on behalf of the Committee.

Japanese scientists advised that they had decided not to proceed with a 'variant with research' plan. In their view research results reported from the JARPN II research programme indicated that some of the stock structure hypotheses for the previous *Implementation Simulation Trials* were no longer compatible with the data. Accordingly they considered those *Implementation Simulation Trials* flawed and in need of revision, so that development of the research plan linked to those *Implementation Simulation Trials* should be put on hold until an *Implementation Review* is conducted, and perhaps leads to different RMP variants requiring such attention.

Therefore there is no plan by Japan to submit a 'variant with research' plan in 2017.

The sub-committee noted discussion of stock structure for western North Pacific minke whales by the Working Group on Stock Definition (see Item 3.2.2.1 of Annex I). It thanked the Working Group and **agreed** that the information provided did not change its plan for the next *Implementation Review* to start in 2018 as anticipated.

3.4 Western North Pacific Bryde's whales

Regular *Implementation Reviews* are required under the RMP. The Committee is initiating the first *Implementation Review* for North Pacific Bryde's whales since the original *Implementation* was completed in 2007. This *Implementation Review* was originally scheduled for 2013. However, in 2012, the Committee postponed the *Implementation Review* until 2016 to allow additional sightings and genetics data to be available and analysed (IWC, 2013). The Committee has agreed that this will be a full *Implementation Review* given there is considerable new information on stock structure and abundance.

The sub-committee established a Steering Group: Donovan (Chair), Allison, Butterworth, Kitakado, Miyashita, Pastene and Punt to guide the *Implementation Review* and to plan for an Intersessional Workshop for next year.

3.5 Work plan

See text table above.

4. ABUNDANCE ESTIMATES

The sub-committee provided an updated list of abundance estimates (see Annex S).

5. BUDGET ISSUES

Three intersessional Workshops are proposed:

(1) a Workshop held as a pre-meeting before SC/67a to test the proposed new Guidelines against several test cases of model-based abundance estimates made specifically for and during the Workshop and to demonstrate and discuss the proposed diagnostic software with a wider Committee audience involved in basic line-transect abundance estimation (Convenor: Butterworth) (already funded; Item 2.2); and

(2) two intersessional Workshops (one in early 2017 and another in early 2018) to conduct the *Implementation Review* for North Pacific Bryde's whales (Convenor: Donovan) (£20,000 over two years; Item 3.5).

The sub-committee supported the proposal for computing support, without which it will be impossible to conduct all the computing tasks required to complete the upcoming *Implementation Reviews*.

6. ADOPTION OF REPORT

The Report was adopted at 17:34 on 15 June 2016. The sub-committee thanked Bannister for his excellent Chairmanship, and Punt for his indefatigable rapporteuring.

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Appendix 1

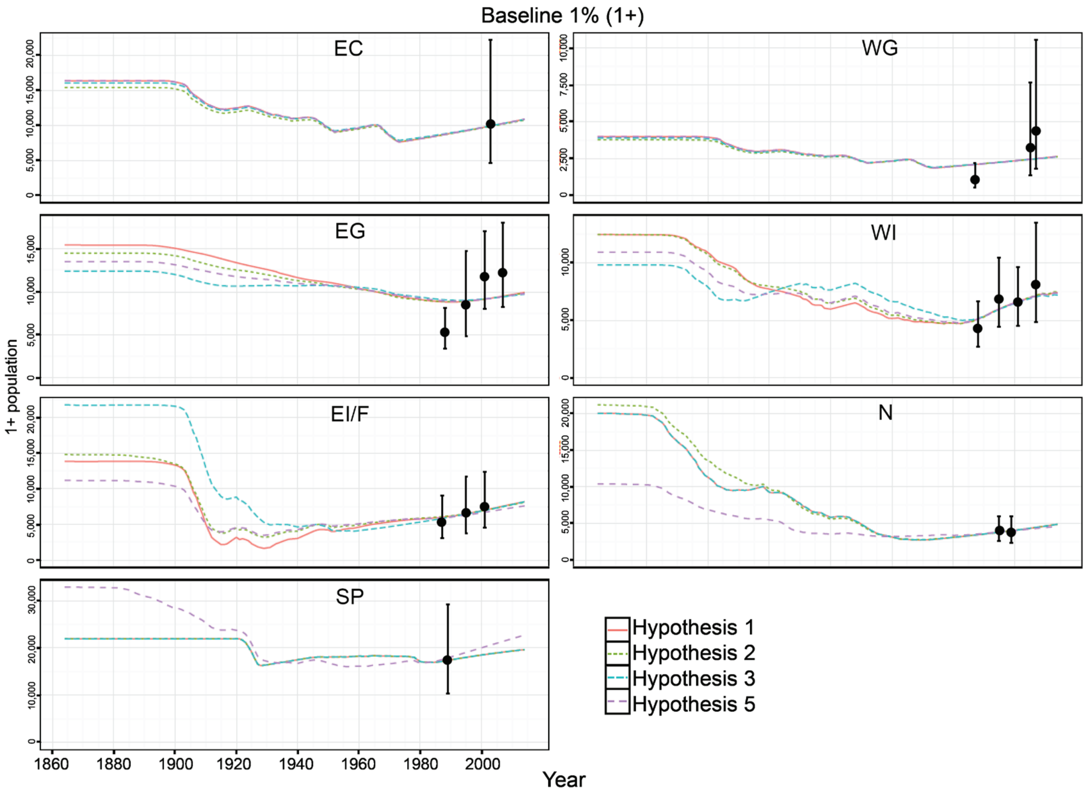
AGENDA

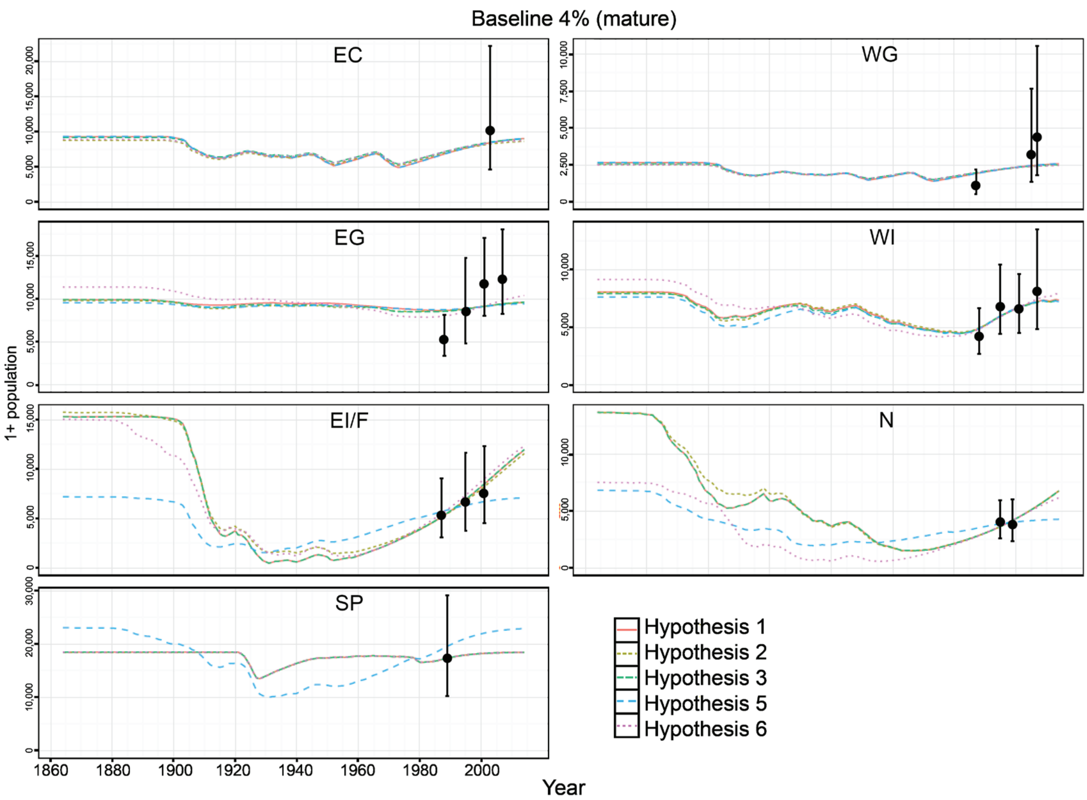
1. Introductory items
   - 1.1 Convenor's opening remarks
   - 1.2 Election of Chair and appointment of rapporteurs
   - 1.3 Adoption of Agenda
   - 1.4 Available documents
2. General assessment issues with a focus on those related to the Revised Management Procedure
   - 2.1 Relationship between $MSYR_{mat}$ and $MSYR_{1+}$: evaluate energetics-based model
   - 2.2 Requirements and guidelines for conducting surveys: model based abundance estimates
   - 2.3 Implications of *IST*s for consideration of 'status'
   - 2.4 Work plan
3. RMP – *Implementation*-related matters
   - 3.1 North Atlantic fin whales (*Implementation Review*)
     - 3.1.1 Report of the intersessional Workshop
     - 3.1.2 Completion of *Implementation Review*
       - 3.1.2.1 Overview and procedure to follow
     - 3.1.3 New information
     - 3.1.4 Conclusions and recommendations
   - 3.2 North Atlantic common minke whales (*Implementation Review*)
     - 3.2.1 Report of the intersessional Workshop
     - 3.2.2 Completion of *Implementation Review*
     - 3.2.3 New information
     - 3.2.4 Conclusions and recommendations
   - 3.3 North Pacific common minke whales
     - 3.3.1 Review of new information
     - 3.3.2 Conclusions and recommendations
   - 3.4 Western North Pacific Bryde's whales
   - 3.5 Work plan
4. Abundance estimates
5. Budget issues
6. Adoption of Report

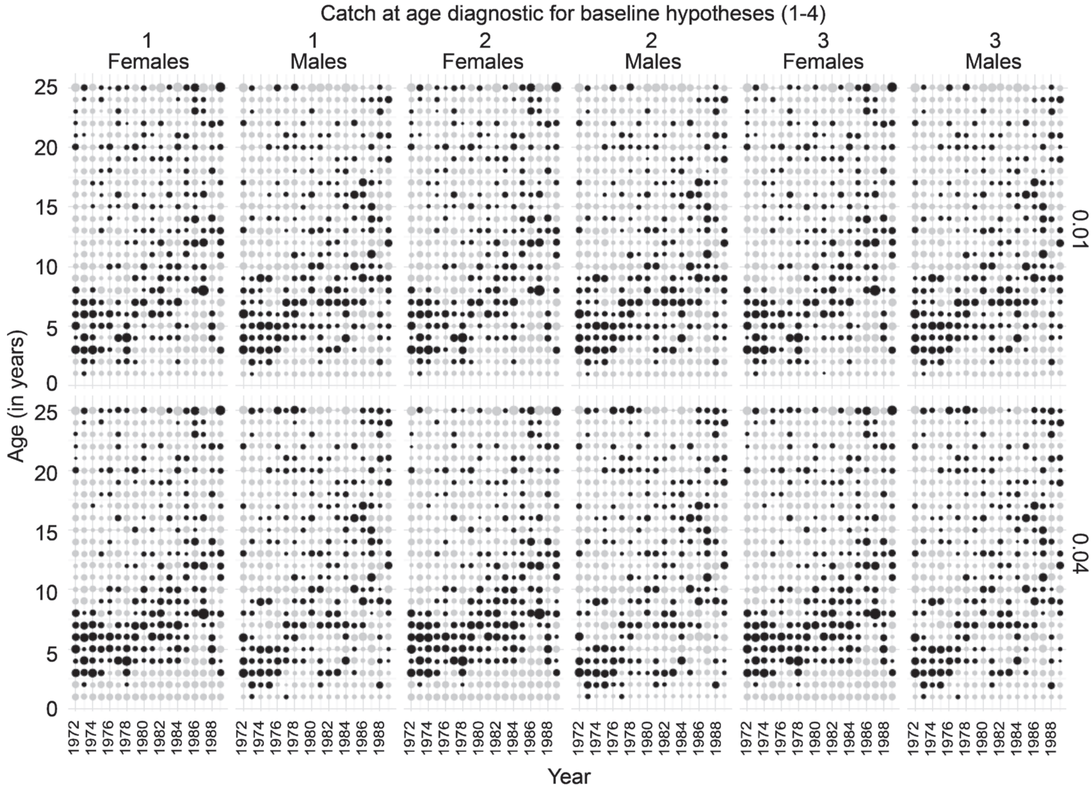
Appendix 2

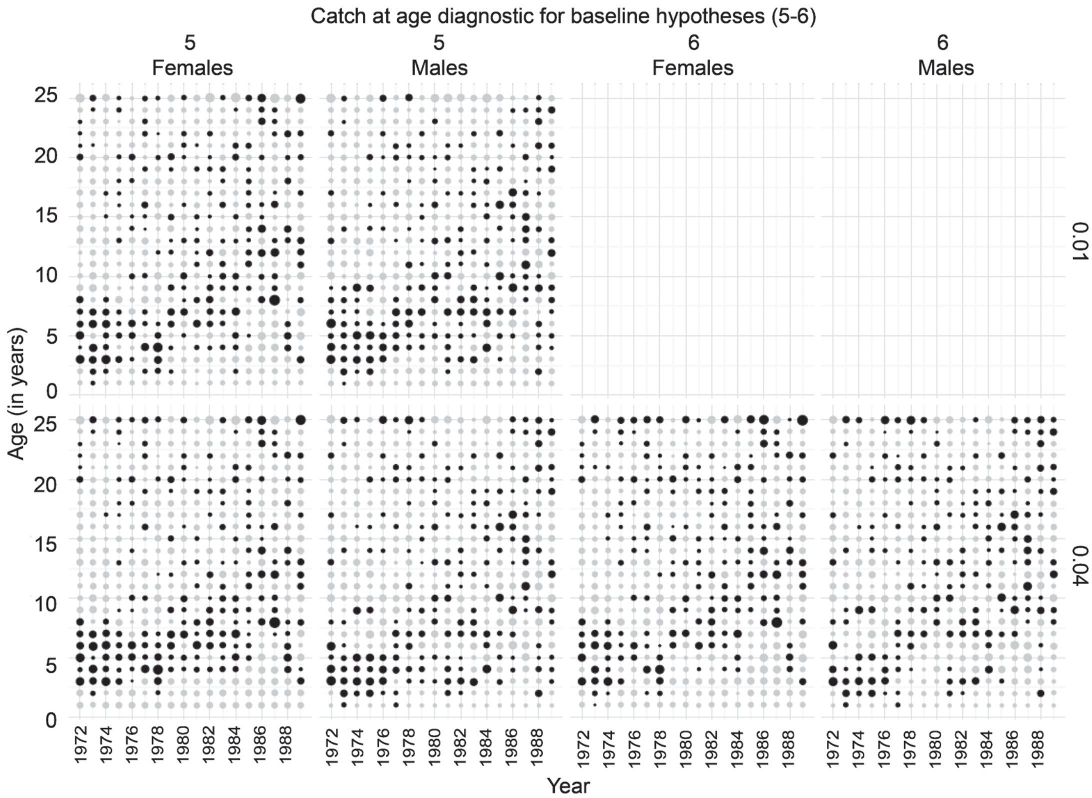
FULL CONDITIONING RESULTS FOR THE NORTH ATLANTIC FIN WHALES

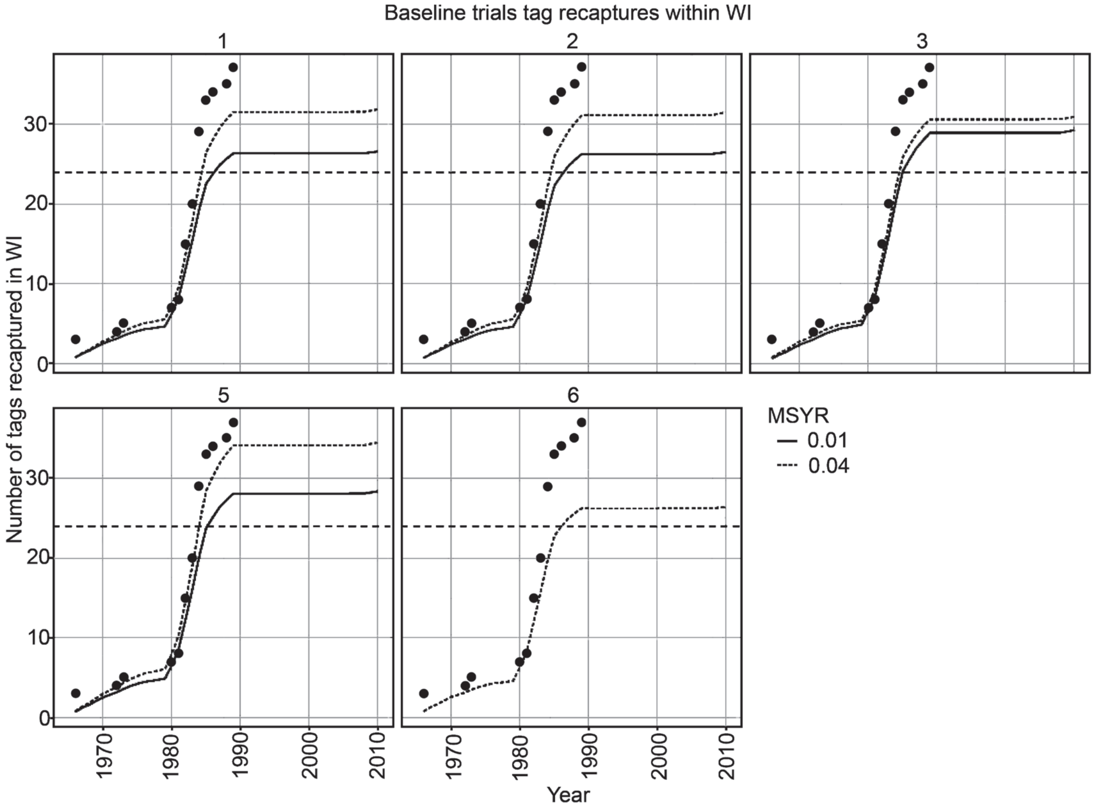
Examples are given here - full results are available online at: *http://archive.iwc.int/?c=29*






Catch at age diagnostic for baseline hypotheses (1-4)
1 Females
1 Males
2 Females
2 Males
3 Females
3 Males
Age (in years)
0.01
0.04
Year


Catch at age diagnostic for baseline hypotheses (5-6)
5 Females
5 Males
6 Females
6 Males
Age (in years)
0.01
0.04
Year



[Appendix 3 is overleaf]

Appendix 3

IMPLEMENTATION SIMULATION TRIAL SPECIFICATIONS FOR NORTH ATLANTIC FIN WHALES

A. Basic concepts and stock-structure

The objective of these trials is to examine the performance of the RMP when managing a fishery for North Atlantic fin whales off West Iceland. The underlying dynamics model allows for multiple stocks and sub-stocks and incorporates dispersal (permanent transfer of animals between stocks or sub-stocks). The model is age- and sex-structured.

The region to be managed (the Northern North Atlantic) is divided into 7 sub-areas (see Fig. 1). The term 'stock' refers to a group of whales from the same breeding ground. The model assumes there is a central 'C' stock (which feeds at least in the area between East Greenland and the Faroe Islands and possibly more widely), which is divided into two or three sub-stocks ('C1' and 'C2' or 'C1', 'C2' and 'C3'). In addition, there is a Spain stock 'S', and under most hypotheses an Eastern stock 'E' and/or a Western stock 'W' are assumed. There are six or seven feeding areas, namely Canada (EC); West Greenland (WG), East Greenland (EG) and West Iceland (WI) or EG/WI combined, East Iceland + Faroes (EI/F); North and West Norway (N) and Spain (Sp). There is no interchange (dispersion) of animals between stocks, but there is dispersion between sub-stocks 'C1' and 'C2' and between sub-stocks 'C2' and 'C3' for most trials. The rationale for the position of the sub-area boundaries is given in Item 3.1 of IWC (2009).

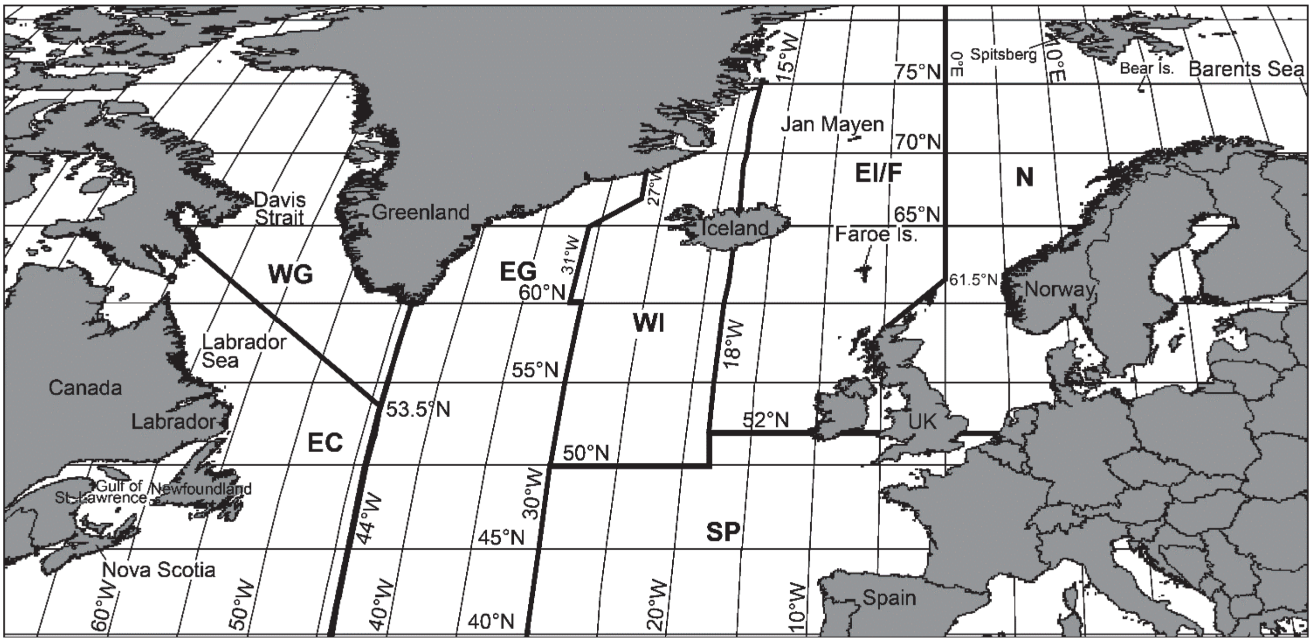


Fig. 1. Map of the North Atlantic showing the sub-areas defined for the North Atlantic Fin whales.
Sub-areas EG and WI are combined for Hypotheses VII and VIII.

There are seven general hypotheses regarding stock structure, as illustrated in Fig. 2:

(I) *Four stocks with separate feeding areas*. There are 4 stocks, with the central 'C' stock divided into 3 sub-stocks. The 'W' stock feeds in the EC and WG sub-areas, sub-stock 'C1' in the EG sub-area, sub-stock 'C2' in the WI sub-area, sub-stock 'C3' in the EI/F sub-area, stock 'E' in the N sub-area, and stock 'S' in the Sp sub-area.

(II) *Four stocks with 'W' and 'E' feeding in the central sub-areas.* There are 4 stocks, with the central stock divided into 3 sub-stocks. The 'W' stock feeds in sub-areas EC, WG, EG and WI, sub-stock 'C1' in sub-area EG, sub-stock 'C2' in sub-area WI, sub-stock 'C3' in sub-area EI/F, stock 'E' in sub-areas WI, EI/F and N, and stock 'S' in sub-area Sp.

(III) *Four stocks with 'C' feeding in adjacent sub-areas*. There are 4 stocks, with the central stock divided into 3 sub-stocks. The 'W' stock feeds in sub-areas EC and WG, sub-stock 'C1' in sub-areas EC, WG and EG, sub-stock 'C2' in sub-area WI, sub-stock 'C3' in sub-areas EI/F and N, stock 'E' stock in sub-area N, and stock 'S' in sub-area Sp.

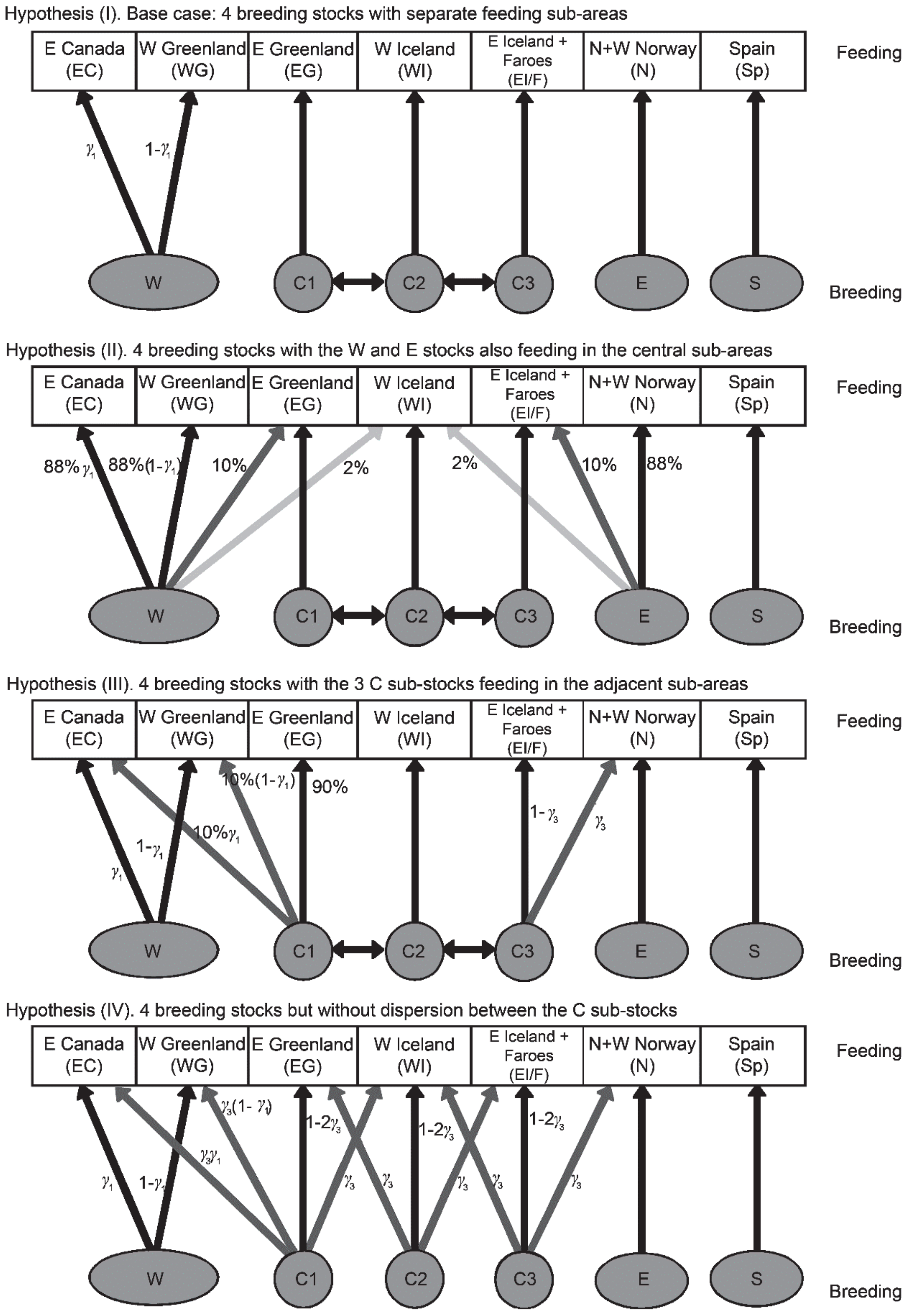
(IV) *Four stocks without sub-stock dispersion*. There are 4 stocks, with the central stock divided into 3 sub-stocks, but there is no dispersion between the sub-stocks. The 'W' stock feeds in sub-areas EC and WG; sub-stock 'C1' feeds in sub-areas EC, WG, EG and WI, sub-stock 'C2' in sub-areas EG, WI and EI/F, sub-stock 'C3' in sub-areas WI, EI/F and N, stock 'E' in sub-area N, and stock 'S' in sub-area Sp.

(V) *Four stocks with 'S' feeding in adjacent sub-areas*. There are 4 stocks, with the central 'C' stock divided into 3 sub-stocks. The stocks/sub-stocks feed as in hypothesis I except that stock 'S' feeds in sub-areas N and EI/F in addition to sub-area Sp.

(VI) *Three stocks*. There are 3 stocks, with the central 'C' stock divided into 3 sub-stocks. The 'W', 'C1', 'C2' and 'S' stock/sub-stocks feed as in hypothesis II. Sub-stock 'C3' feeds in sub-areas EI/F and N.

(VII) *As for hypothesis III (four stocks with 'C' feeding in adjacent sub-areas) except sub-areas EG and WI are combined and the central 'C' stock is divided into 2 sub-stocks.* Sub-stock 'C1' feeds in sub-areas EC, WG and EG/WI and sub-stock 'C2' in sub-areas EI/F and N.

(VIII) *As for hypothesis IV (four stocks without sub-stock dispersion) except sub-areas EG and WI are combined and the central 'C'stock is divided into 2 sub-stocks.* Sub-stock 'C1' feeds in sub-areas EC, WG, EG/WI and EI/F and sub-stock 'C2' in sub-areas EG/WI, EI/F and N.



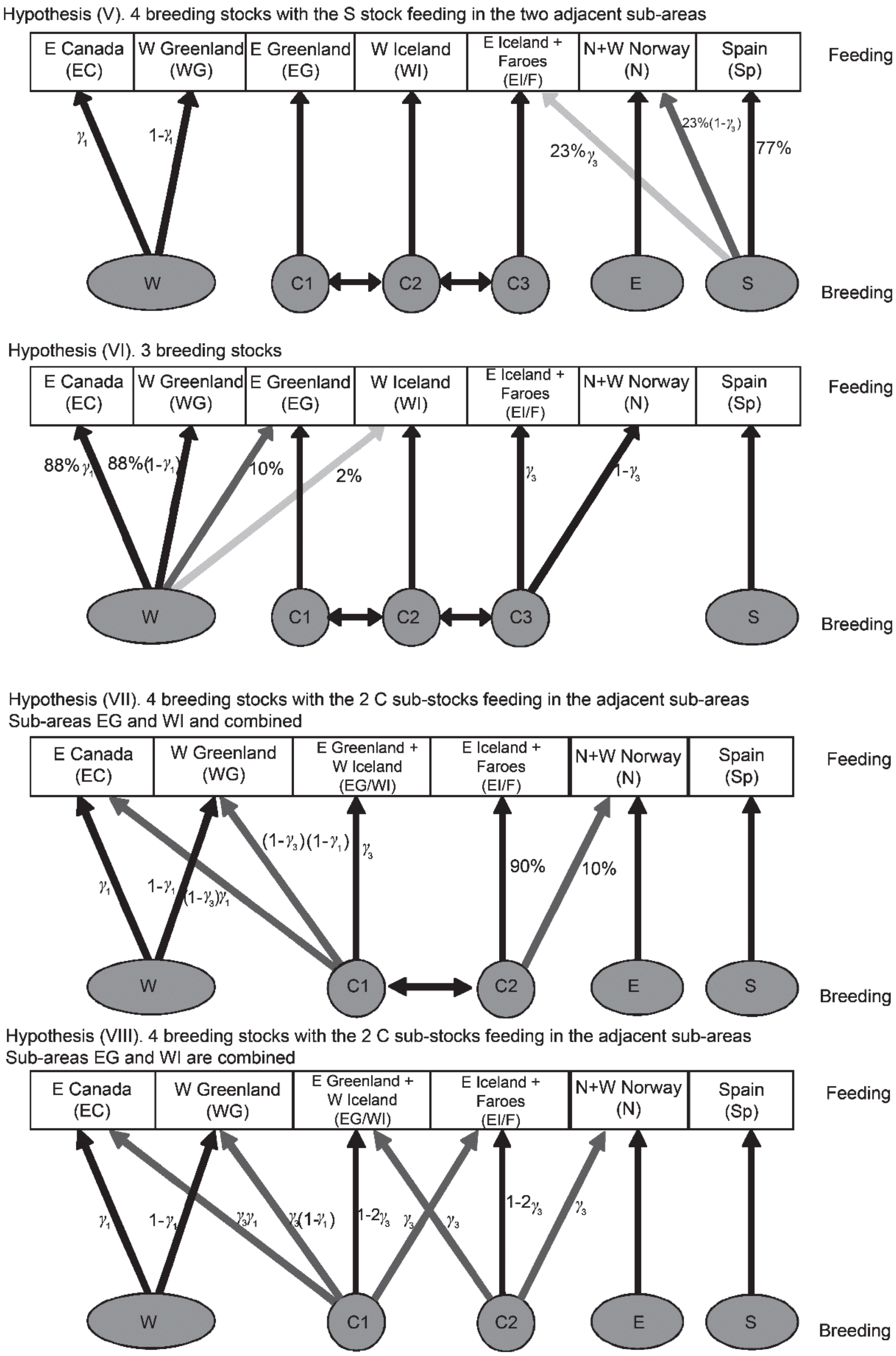


Fig. 2. Stock structure hypotheses for North Atlantic fin whales.

Possible sub-structure in the westernmost and easternmost regions has not been modelled (except as required by the nature of the abundance data) as the primary aim of these trials is not to investigate the full stock structure of fin whales in the North Atlantic, but rather to develop a broad set of hypotheses consistent with the data that will allow the conservation implications of future catches from the West Iceland sub-area to be examined.

B. Basic dynamics

The dynamics of the animals in stock/sub-stock *j* are governed by equations B.1(a) for the 'W', 'E' and 'S' stocks for which there is no dispersal (permanent movement) between stocks and by Equations B.1(b) for the 'C1', 'C2' and 'C3' sub-stocks:

$$N^{g,j}_{t+1,a} = \begin{cases} 0.5 b^j_{t+1} & \text{if } a=0 \\ (N^{g,j}_{t,a-1} - C^{g,j}_{t,a-1})\tilde{S} & \text{if } 1 \le a < x \\ (N^{g,j}_{t,x} - C^{g,j}_{t,x})\tilde{S} + (N^{g,j}_{t,x-1} - C^{g,j}_{t,x-1})\tilde{S} & \text{if } a = x \end{cases} \quad \text{(B.1a)}$$

$$N^{g,j}_{t+1,a} = \begin{cases} 0.5 b^j_{t+1} & \text{if } a=0 \\ \left(1-\sum_{j'\ne j} D^{j,j'}\right)(N^{g,j}_{t,a-1} - C^{g,j}_{t,a-1})\tilde{S} + \sum_{j \ne j'} D^{j',j}(N^{g,j'}_{t,a-1} - C^{g,j'}_{t,a-1})\tilde{S} & \text{if } 1 \le a < x \\ \left(1-\sum_{j'\ne j} D^{j,j'}\right)(N^{g,j}_{t,x} - C^{g,j}_{t,x} + N^{g,j}_{t,x-1} - C^{g,j}_{t,x-1})\tilde{S} + \sum_{j \ne j'} D^{j',j}(N^{g,j'}_{t,x} - C^{g,j'}_{t,x} + N^{g,j'}_{t,x-1} - C^{g,j'}_{t,x-1})\tilde{S} & \text{if } a = x \end{cases} \quad \text{(B.1b)}$$

where:

$N^{g,j}_{t,a}$ is the number of animals of gender *g* and age *a* in stock/sub-stock *j* at the start of year *t* (before any catch is taken);

$C^{g,j}_{t,a}$ is the catch (in number) of animals of gender *g* and age *a* in stock/sub-stock *j* during year *t* (whaling is assumed to take place in a pulse at the start of each year);

b^j_t is the number of calves born to females from stock/sub-stock *j* at the start of year *t*;

$\tilde{S}$ is the survival rate = e^{-M} where *M* is the instantaneous rate of natural mortality (assumed to be independent of stock, time, age and sex);

x is the maximum age (treated as a plus-group); and

$D^{j,j'}$ is the dispersal rate (i.e. the probability of an animal moving permanently) from sub-stock *j* to *j'* (note: there is only dispersal between the C1 and C2 sub-stocks and between the C2 and C3 sub-stocks [when C3 is defined]).

Note that *t*=0, the year for which catch limits might first be set, corresponds to 2014.

Density-independent dispersal between stocks

The model allows density-independent dispersal (i.e. diffusion) between sub-stocks C1 and C2 and sub-stocks C2 and C3. Dispersal is assumed to occur after tagging, but prior to births and survey sightings.

The rates of dispersal between sub-stocks are constant over time, and selected so that at carrying capacity there is no net dispersal among sub-stocks. The values for the dispersal parameters are determined primarily by the mark-recapture data.

To ensure equilibrium in the pristine population:

$$K^{1+,C1}D^{C1,C2} = K^{1+,C2}D^{C2,C1} \quad \text{and} \quad K^{1+,C2}D^{C2,C3} = K^{1+,C3}D^{C3,C2} \quad \text{(B.2a)}$$

where $$K^{1+,j} = \sum_{a=1}^{x}(N^{m,j}_{-\infty,a} + N^{f,j}_{-\infty,a}) \quad \text{(B.2b)}$$

In other words, given the estimated mean rate of dispersal between sub-stocks C1 and C2, $\alpha^{C1,C2}$, and sub-stocks C2 and C3, $\alpha^{C2,C3}$, the dispersal parameters are:

$$D^{C1,C2} = \alpha^{C1,C2}\frac{K^{1+,C1}+K^{1+,C2}}{0.5K^{1+,C1}} \quad \text{and} \quad D^{C2,C1} = D^{C1,C2}\frac{K^{1+,C1}}{K^{1+,C2}}$$

$$D^{C2,C3} = \alpha^{C2,C3}\frac{K^{1+,C2}+K^{1+,C3}}{0.5K^{1+,C2}} \quad \text{and} \quad D^{C3,C2} = D^{C2,C3}\frac{K^{1+,C2}}{K^{1+,C3}}$$

For this option the population dynamics are governed by equation B.1b.

Dispersal rates may not exceed 40% except in trials NF-D1 and NF-D3 in which the rates may not exceed 20%.

C.1. Births

Density-dependence is assumed to act on the female component of the 'mature' population. The convention of referring to the mature population is used here, although this actually refers to animals that have reached the age of first parturition.

$$b^j_t = B^j N^{f,j}_t \{1 + A^j(1-(N^{f,j}_t / K^{f,j})^{z^j})\} \quad \text{(C.1)}$$

where:

B^j is the average number of births (of both sexes) per year for a mature female in stock/sub-stock *j* in the pristine population;

A^j is the resilience parameter for stock/sub-stock *j*;

z^j is the degree of compensation for stock/sub-stock *j*;

$N_t^{f,j}$ is the number of 'mature' females in stock/sub-stock *j* at the start of year *t*:

$$N_t^{f,j} = \sum_{a=a_m}^{x} N_{t,a}^{f,j} \tag{C.2}$$

a_m is the age-at-first-parturition; and

$K^{f,j}$ is the number of mature females in stock/sub-stock *j* in the pristine (pre-exploitation, written as t=-∞) population:

$$K^{f,j} = \sum_{a=a_m}^{x} N_{-\infty,a}^{f,j} \tag{C.3}$$

The values of the parameters A^j and z^j for each stock/sub-stock are calculated from the values for $MSYL^j$ and $MSYR^j$ (Punt, 1999). Their calculation assumes harvesting equal proportions of males and females.

D. Catches

It is assumed that whales are homogeneously distributed across a sub-area. The catch limit for a sub-area is therefore allocated to stocks/sub-stocks by sex and age relative to their true density within that sub-area and a mixing matrix *V*, i.e.:

$$C_{t,a}^{g,j} = \sum_k F_t^{g,k} V_t^{j,k} S_a^g N_{t,a}^{g,j} \tag{D.1}$$

$$F_t^{g,k} = \frac{C_t^{g,k}}{\sum_{j'} V_t^{j',k} \sum_{a'} S_{a'}^g N_{t,a'}^{g,j'}} \tag{D.2}$$

where:

$F_t^{g,k}$ is the exploitation rate in sub-area *k* on fully recruited ($S_a^g \rightarrow 1$) animals of gender *g* during year *t*;

S_a^g is the selectivity on animals of gender *g* and age *a* :

$$S_a^g = (1 + e^{-(a - a_{50}^g)/\delta^g})^{-1} \tag{D.3}$$

a_{50}^g, δ^g are the parameters of the (logistic) selectivity ogive for gender *g*;

$C_t^{g,k}$ is the observed catch of animals of gender *g* in sub-area *k* during year *t*; and

$V_t^{j,k}$ is the fraction of animals in stock/sub-stock *j* that is in sub-area *k* during year *t*.

In these trials the mixing matrix (*V*) is independent of year, sex and age (although the control program retains the option for dependency on year and age).

The catches by sub-area and year are set to one of two historical (pre-2013) series ('best' and 'high'[1]) as listed in Adjunct 1. The 'best' series includes an estimated lost whale rate of 30% in the early period (up to 1916) and allocates whales not identified to species based on the species proportions for the nearest group of years by operation or by sub-area depending on the available data. All of the unspecified whales are taken to be fin whales and a lost whale rate of 50% applied in the 'high' series. Further details of the assumptions used are included in Adjunct 1. Trials NF-H1, 3 and 4 use the 'high' catch series; all other trials use the 'best' series.

Future catches in the WI sub-area are determined using the RMP. A constant future annual catch of 19 whales, corresponding to the current aboriginal request for fin whales, is assumed to be taken in the WG sub-area. There are no future incidental catches. The sex ratio for historical catches of unknown sex and for future catches is assumed to be 50:50.

Trials NF-S3 and 4 test the sensitivity to the assumption of a time-invariant selectivity pattern, allowing the selectivity parameters to differ pre- and post-2007.

E. Mixing

The entries in the mixing matrix *V* are selected to model the distribution of each stock/sub-stock at the time when the catch is removed / when the surveys are conducted. Mixing is deterministic in all the North Atlantic fin whale trials. Table 1 lists the mixing matrices for each of the stock structure hypotheses. (The problem of a mismatch between survey area and model sub-area, and the issue of surveyed whales moving out of the area before catching occurs is addressed in trials with process error due to boundary mis-specification (NF-X3) and alternative survey strategies (trials NF-P3 and NF-Q3)).

Trials NF-G1, NF-G3, NF-F1 and NF-F3 examine the possibility that the increase in abundance off East Greenland reflected in the recent abundance estimates is caused by changes in distribution. In these trials the rate of mixing of WI animals in *sub-area* EG increases from 1985 to 2005 [by linearly increasing the proportion of the C2 sub-stock in EG from 0% to 30%] and then: (a) either remains at this level; or (b) declines to the 1985 level by 2025.

[1]In the 2007 trials, an additional, 'low' catch series was tested in which none of the unspecified whales were considered fin whales and a lost whale rate of 20% was applied. These trials are omitted in the current *Implementation*.

Table 1

The mixing matrices. The γs indicate that the entry concerned is to be estimated during the conditioning process.

	Feeding area	Stock W	Sub-stock C1	Sub-stock C2	Sub-stock C3	Stock E	Stock S
Hypothesis I	EC	γ_1	-	-	-	-	-
	WG	$1-\gamma_1$	-	-	-	-	-
	EG	-	1	-	-	-	-
	WI	-	-	1	-	-	-
	EI/F	-	-	-	1	-	-
	N	-	-	-	-	1	-
	SP	-	-	-	-	-	1
Hypothesis II	EC	$0.88\gamma_1$	-	-	-	-	-
	WG	$0.88(1-\gamma_1)$	-	-	-	-	-
	EG	0.10	1	-	-	-	-
	WI	0.02	-	1	-	0.02	-
	EI/F	-	-	-	1	0.10	-
	N	-	-	-	-	0.88	-
	SP	-	-	-	-	-	1
Hypothesis III	EC	γ_1	$0.10\gamma_1$	-	-	-	-
	WG	$1-\gamma_1$	$0.10(1-\gamma_1)$	-	-	-	-
	EG	-	0.90	-	-	-	-
	WI	-	-	1	-	-	-
	EI/F	-	-	-	γ_3	-	-
	N	-	-	-	$1-\gamma_3$	1	-
	SP	-	-	-	-	-	1
Hypothesis IV	EC	γ_1	$\gamma_3\gamma_1$	-	-	-	-
	WG	$1-\gamma_1$	$\gamma_3(1-\gamma_1)$	-	-	-	-
	EG	-	$1-2\gamma_3$	γ_3	-	-	-
	WI	-	γ_3	$1-2\gamma_3$	γ_3	-	-
	EI/F	-	-	γ_3	$1-2\gamma_3$	-	-
	N	-	-	-	γ_3	1	-
	SP	-	-	-	-	-	1
Hypothesis V	EC	γ_1	-	-	-	-	-
	WG	$1-\gamma_1$	-	-	-	-	-
	EG	-	1	-	-	-	-
	WI	-	-	1	-	-	-
	EI/F	-	-	-	1	-	$0.23\gamma_3$
	N	-	-	-	-	1	$0.23(1-\gamma_3)$
	SP	-	-	-	-	-	0.77
Hypothesis VI	EC	$0.88\gamma_1$	-	-	-	n/a	-
	WG	$0.88(1-\gamma_1)$	-	-	-	n/a	-
	EG	0.10	1	-	-	n/a	-
	WI	0.02	-	1	-	n/a	-
	EI/F	-	-	-	γ_3	n/a	-
	N	-	-	-	$1-\gamma_3$	n/a	-
	SP	-	-	-	-	n/a	1
Hypothesis VII	EC	γ_1	$(1-\gamma_3)\gamma_1$	-	n/a	-	-
	WG	$1-\gamma_1$	$(1-\gamma_3)(1-\gamma_1)$	-	n/a	-	-
	EG/WI	-	γ_3	-	n/a	-	-
	EI/F	-	-	0.90	n/a	-	-
	N	-	-	0.10	n/a	1	-
	SP	-	-	-	n/a	-	1
Hypothesis VIII	EC	γ_1	$\gamma_3\gamma_1$	-	n/a	-	-
	WG	$1-\gamma_1$	$\gamma_3(1-\gamma_1)$	-	n/a	-	-
	EG/WI	-	$1-2\gamma_3$	γ_3	n/a	-	-
	EI/F	-	γ_3	$1-2\gamma_3$	n/a	-	-
	N	-	-	γ_3	n/a	1	-
	SP	-	-	-	n/a	-	1

n/a denotes that the stock/sub-stock concerned is not included in the trial.

F. Generation of data

The actual historical estimates of absolute abundance (and their associated CVs) provided to the RMP are listed in Table 2. The proposed plan for future surveys is given in Table 3. The trials assume that it takes two years for the results of a sighting survey to become available for use by the management procedure, i.e. a survey conducted in 2015 could first be used for setting the catch limit in 2017. Trials NF-Y3 and 4 examine the possibility that future surveys would be conducted with longer intervals, with no application of the phase out rule.

Table 2

The estimates of abundance and their sampling standard errors (see IWC, 2009, Annex H and Adjunct 2). An abundance estimate of 1,613 in EI/F in 2007 (cv 0.26) is not used (IWC, 2016a).

Sub-area	Year	Estimate	Sampling CV
EG	1988	5,269	0.221
EG	1995	8,412	0.288
EG	2001	11,706	0.194
EG	2007	12,215	0.20
WI	1988	4,243	0.229
WI	1995	6,800	0.218
WI	2001	6,565	0.194
WI	2007	8,118	0.26
EI/F	1987	5,261	0.277
EI/F	1995	6,647	0.288
EI/F	2001	7,490	0.255

Table 3

Sighting survey plan.
The years in which catch limits are set are also shown.

	Sub-area			
Season	EG	WI	EI/F	Set catch limits
2013-14	-	-	-	-
2015	Yes	Yes	Yes	Yes
2016-20	-	-	-	-
2021	Yes	Yes	Yes	Yes
2022-26	-	-	-	-
2027	Yes	Yes	Yes	Yes
	And so on in this pattern			

The future estimates of abundance for a survey area (a sub-area for these trials) (say survey area *K*) are generated using the formula developed for the first stage screening trials for a single stock (IWC, 1991, p.109):

$$\hat{P} = P\,Y\,w\,/\,\mu = P^*\,\beta^2\,Y\,w \qquad \text{(F.1)}$$

where:

Y is a lognormal random variable $Y = e^{\varepsilon}$ where $\varepsilon \sim N(0;\sigma_\varepsilon^2)$ and $\sigma_\varepsilon^2 = \ell n(1+\alpha^2)$;

w is a Poisson random variable with $E(w) = \text{var}(w) = \mu = (P/P^*)/\beta^2$, *Y* and *w* are independent;

P is the current total (1+) population size in survey area *K*:

$$P = P_t^K = \sum_{k\in K}\sum_j V_t^{j,k} \sum_g \sum_{a\geq 1} N_{t,a}^{g,j} \qquad \text{(F.2)}$$

P^* is the reference population level, and is equal to the total (1+) population size in the survey area prior to the commencement of exploitation in the area being surveyed; and

F is the set of sub-areas making up survey area *E*.

Note that under the approximation $CV^2(ab) \cong CV^2(a) + CV^2(b)$, $E(\hat{P}) \cong P$ and $CV^2(\hat{P}) \cong \alpha^2 + \beta^2 P^* / P$.

For consistency with the first stage screening trials for a single stock (IWC, 1991, p.109; 1994, pp.85-86), the ratio $\alpha^2 : \beta^2 = 0.12 : 0.025$, so that:

$$CV(\hat{P}) = \tau(0.12 + 0.025P^* / P)^{1/2} \qquad \text{(F.3)}$$

The value of τ is calculated from the survey sampling CV's of earlier surveys in sub-area *E*. If $\overline{CV^2}$ is the average value of CV^2 estimated for each of these surveys, and $\overline{P}$ is the average value of the total (1+) population sizes in area *E* in the years of these surveys, then:

$$\tau = \overline{CV^2} / \left(0.12 + 0.025P / \overline{P}\right) \qquad \text{(F.4)}$$

and the CV of a survey estimate prior to the commencement of exploitation in the area being surveyed would be:

$$\sqrt{(\alpha^2 + \beta^2)} = 0.38\tau \qquad \text{(F.5)}$$

The above equations apply in the absence of additional variance. If this is present with a *CV* of CV_{add}, then the following adjustment is made:

$$\sigma_\varepsilon^2 = \ell n\left(1+\alpha^2+CV_{add}^2\right) \qquad \text{(F.6)}$$

An estimate of the *CV* is generated for each sighting survey estimate of abundance $\hat{P}$:

$$CV\left(\hat{P}\right)_{est}^2 = \sigma^2\chi^2/n \qquad \text{(F.7)}$$

where $\sigma^2 = \ell n\left(1+\alpha^2+\beta^2 P^*/\hat{P}\right)$, and

χ^2 is a random number from a Chi-square distribution with *n* degrees of freedom (where *n*=10 as used for NP minke trials; IWC, 2004).

Three alternative survey strategies will be investigated in the *Robustness Trials*:

(1) In trials NF-P3 future surveys will cover only the WI sub-area, but with greater survey sampling intensity. This is implemented by changing $n \to 3n$, $\alpha^2 \to \alpha^2/3$ and $\beta^2 \to \beta^2/3$ corresponding to a tripling of this intensity. The additional variance contribution to the estimate (CV_{add}) is unchanged[2].

(2) In trials NF-Q3 future surveys in the WI and EI/F sub-areas do not cover the strata to the south of 60°N. The generated abundance estimates are a proportion of the estimates for the full sub-area. In order to incorporate inter-annual variation, the proportion is drawn annually from a beta distribution with mean (0.78 for WI and 093 for EI/F) and variance (SE=0.162 for WI and 0.085 for EI/F) based on the actual proportions from the NASS surveys. The same proportions are used in setting future abundance estimates under management variant V4 (see section I).

(3) The effects of an 8-year period for abundance estimation are studied, without the phase-out rule being applied, in trials NF-Y3 and 4 to evaluate the maximum conservation risk associated with an 8-year inter-survey period.

G. Parameters and conditioning

The values for the biological and technological parameters are listed in Table 4.

Table 4

The values for the biological and technological parameters that are fixed.

Parameter	Value
Plus group age, *x*	25 years
Natural mortality, *M*	0.08yr^{-1} (see also below)
Age-at-first-parturition, a_m	Knife-edged at age 6
Maximum Sustainable Yield Level, *MSYL*	0.6 in terms of mature female component of the population

The natural mortality rate *M* is initially set to 0.08yr^{-1} for most trials, including the baseline. However, in the NF-U1 trials *M*=0.04yr^{-1}and the selectivity decreases by 4% per year geometrically for ages above 8 (see Item 4.5 of IWC, 2009) to allow for the possibility of dome-shaped selectivity, and noting that the Comprehensive Assessment meeting (IWC, 1992) used a value of *M*=0.04yr^{-1}.

The 'free' parameters of the above model are the initial (pre-exploitation) sizes of each of the sub-stocks/stocks, the values that determine the mixing matrices (i.e. the γ parameters), the dispersion rates between C1 and C2 and between C2 and C3, and the parameters for the gender specific selectivity ogive.

The process used to select these 'free' parameters is known as conditioning. The conditioning process involves first generating 100 sets of 'target' data as detailed in steps (a) to (d) below, and then fitting the population model to each (in the spirit of a bootstrap). The number of animals in sub-area *k* at the start of year *t* is calculated starting with guessed values of the initial population sizes and projecting the operating model forward to 2013 to obtain values of abundance etc. for comparison with the generated data[3].

The information used in the conditioning process is as follows.

(a) The 'target' values for the historical abundance by sub-area are generated using the formula:

$$P_t^k = O_t^k \exp[\mu_t^k - (\sigma_t^k)^2/2];\ \mu_t^k \sim N[0;(\sigma_t^k)^2] \qquad \text{(G.1)}$$

where

P_t^k is the abundance for sub-area *k* in year *t*;

O_t^k is the actual survey estimate for sub-area *k* in year *t* (Table 5); and

σ_t^k is the CV of O_t^k .

Additional variance was introduced for the surveys for the WG, EG, WI and EI/F sub-areas as described in IWC (2010b). Table 5 lists both the original sampling CV's associated with each estimate of abundance together with the conditioning CVs incorporating sub-area specific additional variance.

[2]These trials were given low plausibility as they were not considered practical by Icelandic scientists.

[3]Plots such as those shown in Allison and Punt (2003) will be examined, together with time-trajectories of the fraction of each stock in each sub-area to check that the conditioning exercise has been successfully achieved.

As some historical abundance estimates do not cover the full sub-area, the data used in conditioning robustness trials NF-A3 are pro-rated upwards. The revised estimates are listed in Table 5 (see also Adjunct 2). (These revised estimates will not be available to the *CLA*).

Table 5

The actual estimates of abundance, their sampling standard errors (see IWC, 2009, Annex H for details), and the CV's including additional variance used in conditioning (see IWC, 2010b). The pro-rated abundance estimates used in trials NF-A3 are also shown (see Adjunct 2 for details).

Sub-area	Year	Abundance estimate	Sampling CV	CV inc. additional variance	Pro-rated abundance (trials NF-A3)
EC	2003	10,105*	0.40	0.40	-
WG	1987	1,096	0.35	0.532	-
WG	2005	3,234	0.44	0.595	-
WG	2007	4,359	0.45	0.602	-
EG	1988^	5,269	0.221	0.334	5,269
EG	1995	8,412	0.288	0.381	10,152
EG	2001	11,706	0.194	0.316	14,225
EG	2007	12,215	0.20	0.32	15,847
WI	1988^	4,243	0.229	0.229	4,243
WI	1995	6,800	0.218	0.218	7,363
WI	2001	6,565	0.194	0.194	7,430
WI	2007	8,118	0.26	0.26	8,898
EI/F	1987^	5,261	0.277	0.707	5,261
EI/F	1995	6,647	0.288	0.711	7,170
EI/F	2001	7,490	0.255	0.698	9,555
EI/F	2007	1,613	0.26	0.70	2,466
N	1995	3,964	0.21	0.21	-
N	1999	3,749	0.24	0.24	-
Sp	1989	17,355	0.265	0.265	-

*the 2007 EC estimate (2,808, CV 0.302) is uncorrected and so is not used; the estimate of 10,105 from the IWC/NAMMCO 2006 Workshop (IWC, 2007) is used instead. ^trials NF-E2 and NF-E3 test the sensitivity of results to the exclusion of these abundance estimates.

(b) A 'target' for the numbers of animals tagged and recaptured is generated by selecting records at random and with replacement from the tag-recapture data (see Table 6). The objective function used to include the tagging data when conditioning is given below. The tag recapture data are assumed to be negative binomially (rather than Poisson) distributed to account for possible non-randomness in the tagging/recapture process. The dynamics of tagged animals are essentially the same as those of untagged animals, except that account needs to be taken of tagging. The following equations are used to determine the number of tagged animals of age *a* (for ages less than *x*) and gender *g* in stock/sub-stock j at the start of year *t*+1 originally tagged in sub-area *k*, $T^{g,j,k}_{t+1,a}$ (tagging is assumed to take place halfway through the fishing season):

For stocks with no dispersal:

$$T^{g,j,k}_{t+1,a} = T^{g,j,k}_{t,a-1}(1-\sum_{k'} V^{j,k'}_t S^g_{a-1} F^{g,k'}_t)\Omega_{2+} e^{-M} + Q^{g,j,k}_{t,a-1}(\Omega_1 \; e^{-M})^{1/2} \qquad \text{(G.2a)}$$

For stocks with dispersal:

$$T^{g,j,k}_{t+1,a} = \tilde{T}^{g,j,k}_{t+1,a} + \sum_{j\neq j'}\left\{D^{j',j}\tilde{T}^{g,j'}_{t+1,a} - D^{j,j'}\tilde{T}^{g,j,k}_{t+1,a}\right\} \qquad \text{(G.2b)}$$

where:

$Q^{g,j,k}_{t,a}$ is the number of animals of age *a* and gender *g* in stock/sub-stock *j* that were tagged in sub-area *k* during year *t*:

$$Q^{g,j,k}_{t,a} = \frac{(Q^k_t - SS^k_t / \Psi^k)C^{g,k}_t}{C^{f,k}_t + C^{m,k}_t} \; \frac{V^{j,k}_t N^{g,j}_{t,a}}{\sum_{j'} V^{j',k}_t \sum_{a'} N^{g,j'}_{t,a'}} \qquad \text{(G.2c)}$$

Q^k_t is the number of releases during year *t* in sub-area *k*;

SS^k_t is the number of whales recovered in the same season as the tags were released in sub-area *k*;

$\tilde{T}^{g,j,k}_{t+1,a}$ is defined as for $T^{g,j,k}_{t+1,a}$ in the no dispersion case (i.e. is set using equation G.4a);

Ψ^k is the reporting rate parameter (usually set to 1); and

Ω_1 and Ω_2 are unity less the rates of tag-loss in year 1 and years 2 on (both are assumed to be unity for the baseline analyses).

The number of 'recruits' by age, sex and sub-stock to the tagged population therefore depends on the actual number tagged, assuming that an animal to be tagged is selected at random from the catch. Account is taken in Equation G.2 of mortality (both natural and fishing) from the time of tagging until the end of the year. If there is no catch in a sub-area *k* and year *t* when tagging takes place, then the tags are allocated using a 50:50 male:female ratio.

The model-predicted number of animals recaptured during year t in sub-area k that were originally tagged in sub-area k', $U_t^{k,k'}$ is given by:

$$U_t^{k,k'} = \Psi^k \left(\sum_g \sum_j \sum_a T_{t,a}^{g,j,k} V_t^{j,k} S_a^g F_t^{g,k} \right) \tag{G.3}$$

Same season recoveries are removed from the population, accounting for tag-reporting, but are not included in the likelihood function (i.e. they are included in Eqn G.2 but not G.3). Trials NF-R3 and 4 test the effect of excluding tags recaptured after one year (in addition to the same season recoveries) from the likelihood.

The mark reporting rate Ψ^k is taken to equal 1 in the base case except for tags released in Canada where it is treated as estimable. A loss rate of 0 is assumed in the base case. A loss rate of 0.2yr^{-1} in year 1 (i.e. $\Omega_1 = e^{-0.2}$), and 0.1 thereafter (i.e. $\Omega_{2+} = e^{-0.1}$) is tested in trials NF-T1-3.

(c) In the base case, CPUE data will be used qualitatively to compare with model output rather than being included directly in the likelihood calculation. In addition trials NF-C3 will investigate the effect of including all the CPUE series (West Iceland 1962-87, East Iceland 1904-13 (see Punt, 2009) and West Iceland 1902-14 (Gunnlaugsson series 2)) in the likelihood calculation. The CPUE series are listed in Table 7.

Table 6a

Summary of the fin whales marked (recorded as 'hits') and recovered in the North Atlantic. The following marks are excluded: 9 off Africa in 1950, 1 off Nova Scotia in 1960; 2 in EC in 1965 and 2 in the Mediterranean in 1969, 3 marks not recorded as 'hits' but which were recovered; 1 whale marked by Canada in 1968 and recovered the same day.

Year	EC	WG	EG	WI	EI/F	No	Sp
1965	0	0	0	13	0	0	0
1966	78	0	0	0	0	0	0
1967	53	5	8	0	0	0	0
1968	0	0	15	2	0	0	0
1969	46[1]	0	0	0	0	0	0
1970	3	0	3	1	0	0	0
1971	19	0	2	0	0	0	0
1972	59	0	0	3	0	0	0
1973	12	3	3	0	0	0	0
1974	0	0	0	0	0	0	0
1975	0	0	0	0	0	0	0
1976	2	0	0	0	0	0	0
1977	0	0	0	0	0	0	0
1978	0	0	0	0	0	24	0
1979	27	3	0	33	0	0	0
1980	0	8	0	11	0	0	0
1981	0	4	26	62	0	0	3
1982	0	0	0	52	14	0	2
1983	0	0	5	10	0	0	17
1984	0	0	31	0	7	0	0
1985	0	0	0	0	0	0	0
1986	0	1	0	0	0	0	0
Total	299	24	93	187	21	24	22

[1]including 1 whale marked between Oct68-Jan69.

(d) A 'target' for the numbers of animals caught at age in the WI whaling grounds is generated using the formula:

$$P_{t,a}^{g,k} = P_{t,a}^{\hat{g},k} \Big/ \sum_{a'} P_{t,a'}^{\hat{g},k}$$

where:

$P_{t,a}^{g,k}$ the proportion of animals of age a and sex g caught during year t in sub-area k. $P_{t,a}^{\hat{g},k}$ is given by the formula:

$$P_{t,a}^{\hat{g},k} = O_{t,a}^{g,k} e^{\varepsilon_{t,a}^{g,k}}; \quad \varepsilon_{t,a}^{g,k} \sim N\left(0, \sigma_{t,a}^{g,k}\right)$$

where $O_{t,a}^{g,k}$ is the observed proportion of animals of age a and sex g caught during year t in sub-area k derived from tables 1 and 2 in adjunct 3,

$$\sigma_{t,a}^{g,k} = \sqrt{\frac{\sigma^2}{O_{t,a}^{g,k}}} \quad \text{and}$$

σ^2 is given in equation G.12 below, using the original observed and deterministic model predicted catch at age.

Table 6b

Summary of the fin whales mark recovered in the North Atlantic.

	Release		Recovery				
Mark no.	Area	Year	Area	Year	Sex	Years to rec.	Note:
34	EC	1966	EC	1966	F	0	
67	EC	1966	EC	1966	M	0	
16/410	EC	1966	EC	1966	M	0	
5/410	EC	1966	EC	1966	M	0	
C 177	EC	1966	EC	1967	F	1	
C 319	EC	1966	EC	1967	M	1	
94	EC	1966	EC	1967	M	1	
3/410	EC	1966	EC	1967	M	1	
63	EC	1966	EC	1967	M	1	
86	EC	1966	EC	1967		1	1
72	EC	1966	EC	1968	F	2	
15456	EC	1966	EC	1968	F	2	
89	EC	1966	EC	1968	M	2	
C 164	EC	1966	EC	1968	M	2	
15466	EC	1966	EC	1968	M	2	
70	EC	1966	EC	1968	F	2	
56	EC	1966	EC	1968		2	2
C 154	EC	1966	EC	1968		2	
73	EC	1966	EC	1968		2	
10/410	EC	1966	EC	1968		2	3
97	EC	1966	EC	1969	M	3	4
85	EC	1966	EC	1969	F	3	
3	EC	1966	EC	1969	M	3	
55	EC	1966	EC	1969	M	3	5
48	EC	1966	EC	1970	F	4	
58	EC	1966	EC	1970	F	4	
C 318	EC	1966	EC	1970	M	4	
C 183	EC	1966	EC	1971	M	5	
809	EC	1967	EC	1967	F	0	
816	EC	1967	EC	1968	F	1	
753	EC	1967	EC	1971	M	4	6
807	EC	1967	EC	1972	F	5	
912	EC	1967	EC	1969	M	2	4
~~15481~~	~~EC~~	~~1968~~	~~EC~~	~~1968~~	~~F~~	0	7
1083	EC	1969	EC	1971	F	2	
926	EC	1970	EC	1970	F	0	
1756	EC	1971	EC	1972	F	1	
1296	EC	1972	EC	1972	M	0	
1291	EC	1972	EC	1972	M	0	8
c1866	EC	1979	WI	1988	F	9	
16144	EG	1968	WI	1969	M	1	
16150	EG	1968	WI	1968	F	0	
15565	EG	1968	WI	1977	F	9	
15600	EG	1973	WI	1983	F	10	
38254	EG	1981	WI	1989	F	8	
39875	EG	1984	WI	1986		2	9
39876	EG	1984	WI	1988	M	4	10
~~39881~~	~~EG~~	~~1984~~	~~WI~~	~~1988~~	~~M~~	4	10
16110	WI	1965	WI	1966	M	1	11
16131	WI	1965	WI	1966	M	1	
16132	WI	1965	WI	1973	M	8	
16133	WI	1965	WI	1966	M	1	
16135	WI	1965	WI	1972	M	7	
15815	WI	1972	WI	1972	M	0	
36282	WI	1979	WI	1980	F	1	12
36289	WI	1979	WI	1979	F	0	
36298	WI	1979	WI	1982	F	3	
36310	WI	1979	WI	1980	M	1	
X74	WI	1979	WI	1981	?	2	
~~36226~~	~~WI~~	~~1979~~	~~WI~~	~~1979~~	~~F~~	0	13
29436	WI	1979	WI	1983	M	4	
36389	WI	1980	WI	1982	F	2	
36392	WI	1980	WI	1980	M	0	
36221	WI	1980	WI	1984	F	4	
29465	WI	1981	WI	1982	F	1	
38176	WI	1981	WI	1984	M	3	
38182	WI	1981	WI	1982	F	1	14
38184	WI	1981	WI	1981	F	0	
~~38220~~	~~WI~~	~~1981~~	~~WI~~	~~1981~~	~~M~~	0	15
38320	WI	1981	WI	1985	M	4	
38202	WI	1981	WI	1984	?	3	
38195	WI	1981	WI	1981	M	0	16
38199	WI	1981	WI	1984	F	3	
38201	WI	1981	WI	1985	F	4	
38204	WI	1981	WI	1982	M	1	
38316	WI	1981	WI	1981	F	0	
38193	WI	1981	WI	1982	M	1	
38217	WI	1981	WI	1983	?	2	
38213	WI	1981	WI	1984	F	3	
~~38214~~	~~WI~~	~~1981~~	~~WI~~	~~1981~~	~~M~~	0	17
38216	WI	1981	WI	1981	M	0	
38241	WI	1981	WI	1983	M	2	
38255	WI	1981	WI	1983	F	2	
38261	WI	1981	WI	1985	M	4	
40796	WI	1981	WI	1982	F	1	
24824	WI	1982	WI	1984	M	2	
24826	WI	1982	WI	1982	M	0	
24828	WI	1982	WI	1982	M	0	
24834	WI	1982	WI	1984	F	2	
24842	WI	1982	WI	1984	M	2	
24851	WI	1982	WI	1984	M	2	
24868	WI	1982	WI	1982	M	0	
24865	WI	1982	WI	1986	M	4	18
39794	WI	1982	WI	1983	M	1	
39806	WI	1982	WI	1989	F	7	19
39815	WI	1982	WI	1985	M	3	
39829	WI	1983	WI	1988	F	5	
39837	WI	1983	WI	1989	M	6	
~~39838~~	~~WI~~	~~1983~~	~~WI~~	~~1983~~	~~F~~	~~0~~	20
40278	EI/F	1982	EI/F	1982	F	0	

Notes:

1. Recovery date given as ‘before Jun 1968’ (in cooker?) and elapsed time as ~11 months so recovery year set as 1967.
2. Mitchell (1977) says found before 10/08/68 and elapsed time 24-26 months but letter from Mitchell to Brown dated April 1968 says recovered from kvæner (cooker) 1967.
3. Recovery date given as ‘before 3 July 1969’ (in cooker?) and elapsed time as ~23 months so recovery year set as 1968.
4. Tags 97 (fired in 1966) and 912 (fired in 1967) were recovered from the same whale.
5. Also recovered 1966 tag 11/410 in this whale.
6. Tagging date given as 29/07/1967 and recovery date as 09/05/1971 but elapsed time as 9⅓ months.
7. 1 mark only, recovered on the same/next day. Not used in conditioning.
8. Mark 1293 fired during the same cruise was recovered in the same whale.
9. Found in cooking pot; prior to this season.
10. 39876 and 39881 recovered in same whale but not thought to be same whale on firing. Only one used in conditioning.
11. Whale double tagged; 2nd tag (16111) also recovered.
12. Whale double tagged; 2nd tag (36283) also recovered.
13. Recorded as protruding hit, recovered 1 month later. Not used in conditioning.
14. Whale double tagged; 2nd tag (38179) also recovered.
15. Recorded as protruding hit, recovered 3 days later and found to be permanent. Not used in conditioning.
16. Tag no. uncertain. 38195 and 6 both fired in 1981. Discrepancy re: which was recovered.
17. Recorded as miss, recovered same day. Not used in conditioning.
18. Recovery date given as 1986 in Icelandic data (with 1986 whale number) but as 1987 in Icelandic Progress Report.
19. Female in IMS records but male in Icelandic data.
20. Recorded as protruding hit, recovered 2 months later. Not used in conditioning.

Table 7

CPUE series for North Atlantic fin whales.

	Earlier period			Later period			
	East Iceland	West Iceland		West Iceland			
Year	CPUE i=5	CPUE i=6	Year	CPUE i=1	CPUE i=2	CPUE i=3	CPUE i=4
1902	-	24.8	1962	0.1398	0.1512	0.1048	-
1903	-	21.2	1963	0.1363	0.0841	0.0671	-
1904	1.195	22.9	1964	0.0770	0.0551	0.0492	-
1905	1.621	28.3	1965	0.1979	0.1519	0.1204	-
1906	0.894	18.2	1966	0.1150	0.1083	0.0863	0.1310
1907	1.122	16.0	1967	0.1040	0.1280	0.1798	0.1350
1908	0.971	16.5	1968	0.1548	0.0990	0.1314	0.1672
1909	1.228	25.4	1969	0.0541	0.0880	0.0691	0.0495
1910	0.733	18.4	1970	0.1040	0.1596	0.1466	0.1282
1911	0.739	16.9	1971	0.0824	0.0591	0.0523	0.0703
1912	-	9.9	1972	0.0836	0.0718	0.0648	0.0601
1913	0.496	5.8	1973	0.0785	0.0853	0.0708	0.0791
1914	-	7.4	1974	0.0810	0.1134	0.0861	0.1132
			1975	0.1115	0.0958	0.0779	0.1011
			1976	0.1067	0.0909	0.0993	0.0779
			1977	0.0296	0.0651	0.0443	0.0390
			1978	0.0507	0.0583	0.0732	0.0675
			1979	0.1817	0.1494	0.1389	0.1276
			1980	0.0891	0.0933	0.1317	0.1220
			1981	0.1572	0.1134	0.1333	0.1271
			1982	0.1677	0.1190	0.1094	0.0974
			1983	0.0804	-	0.0597	0.0837
			1984	0.1169	-	0.1233	0.1283
			1985	0.1170	-	0.0777	0.0857
			1986	-	-	0.0744	0.0856
			1987	-	-	0.1792	0.0990

Table 8

The variance-covariance matrix for the late CPUE series obtained by quadratically de-trending the log-transformed data (Butterworth and Punt, 1992).

	1	2	3	4
1	0.171	0.089	0.102	0.118
2	0.089	0.103	0.105	0.076
3	0.102	0.105	0.156	0.104
4	0.118	0.076	0.104	0.127

Calculation of likelihood

The likelihood function consists of up to five components (depending on whether the CPUE data are used when conditioning trials). Equations G.4-G.5, G.9, G.11 and G.12 list the negative of the logarithm of the likelihood for each of these components so the objective function minimised is L_1+L_2+L_3+L_4+L_5. An additional penalty is added to the likelihood if the full historic catch is not removed.

(a) Abundance estimates

$$L_1 = 0.5\sum_n \frac{1}{(\sigma_n)^2}\ell n\left(P_n / \hat{P}_n\right)^2 \quad \text{(G.4)}$$

where $\hat{P}_n$ is the model estimate of the 1+ abundance in the same year and sub-area as the n^{th} estimate of abundance P_n.

(b) Tagging data

$$L_2 = \sum_t\sum_{k'}\sum_k \ell n\left(\frac{\Gamma(U_t^{k,k'}+\tilde{U}_t^{k,k'})}{\Gamma(\tilde{U}_t^{k,k'}+1)\Gamma(U_t^{k,k'})}\right)+U_t^{k,k'}\ell n\left(\frac{\lambda}{1+\lambda}\right)+\tilde{U}_t^{k,k'}\ell n\left(\frac{1}{1+\lambda}\right) \quad \text{(G.5)}$$

where $\tilde{U}_t^{k,k'}$ is the observed number of animals recaptured during year t in sub-area k that were originally tagged in sub-area k'; and λ is an over-dispersion parameter.

In order to investigate the trade-off between fitting the tags recovered in the EC sub-area from tagging in that sub-area and tags recovered in sub-area WI from tagging conducted there, trials NF-W1 weight the contribution of all the tagging data to the objective function by a factor of 10.

(c) CPUE data

The ith CPUE series is assumed to be proportional to the selected abundance in the corresponding area k and year t.

$$CPUE_t^{k,i} = q^i N_t^{k,e} \quad \text{(G.6)}$$

$$N_t^{k,e} = \sum_j V_t^{j,k}\sum_g\sum_a S_a^g N_{t,a}^{g,j} \quad \text{(G.7)}$$

The catchability coefficient q^i for CPUE series i is set to its maximum likelihood value, which is given by:

$$\ell n\hat{q}^i = \frac{1}{n^i}\sum_t \left(\ell nCPUE_t^{k,i} - \ell nN_t^{k,e}\right) \tag{G.8}$$

where n^i is the number of data points for CPUE series i.

The negative log-likelihood for the later period CPUE series (i=1 to 4) over 1966 to 1982 is given by:

$$L_3 = -\ell nL^{CPUE1} = 0.5\sum_t \eta_t\left[V^{-1}\right]\eta_t^T \tag{G.9}$$

where V^{-1} is the inverse of the variance-covariance matrix V (Table 8) for the late series CPUE indices, and η_t is a vector comprised of four elements, the ith element of which is:

$$\eta_t^i = \ell nCPUE_t^{k,i} - \ell nq^iN_t^{k,e} \tag{G.10}$$

This method applies to the years in which values from all four series are available (1966-82). Where there are values available from only three (1962-65 and 1983-85) or two (1986-87) of the series, the contributions to $-\ell nL^{CPUE1}$ are similar but V and η_t are reduced by removing the row(s) and column(s) for which no values are available.

For the earlier period CPUE series (i=5 or 6) the negative log-likelihoods are:

$$L_4 = -\ell nL^{CPUE2} = \sum_{i=5}^{6}\left(\frac{1}{2\sigma_i^2}\sum_t\left[\ell nCPUE_t^{k,i} - \ell n\left(q^iN_t^{k,e}\right)\right]^2\right) \tag{G.11}$$

where values of $\sigma_5 = 0.228$ and $\sigma_6 = 0.251$ were obtained by quadratic de-trending of these data.

(d) Catch at age data

The log-likelihood function follows the approach of Punt and Kennedy (1997):

$$L_5 = \sum_{g,t,k,a}\left\{0.5\ell n\left(\sigma^2 / p_{t,a}^{g,k}\right) + \frac{p_{t,a}^{g,k}}{2\sigma^2}\left(\ell n\left(p_{t,a}^{g,k}\right) - \ell n\left(\pi_{t,a}^{g,k}\right)\right)^2\right\} \tag{G.12}$$

where $\pi_{t,a}^{g,k} = \dfrac{S_a^g\sum_j V_t^{j,k}N_{t,a}^{g,j}}{\sum_{a'}S_{a'}^g\sum_{j'}V_t^{j',k}N_{t,a'}^{g,j'}}$, $p_{t,a}^{g,k} = C_{a,t}^{\text{obs},g,k} / \sum_{a'}C_{a',t}^{\text{obs},g,k}$ i.e. the predicted and observed proportions in sub-area k,

and $\sigma^2 = \sum_{g,t,k,a}\left\{p_{t,a}^{g,k}\left(\ell n\left(p_{t,a}^{g,k}\right) - \ell n\left(\pi_{t,a}^{g,k}\right)\right)^2\right\} / \sum_{g,t,k,a}(1)$

$C_{a,t}^{\text{obs},g,k}$, the observed catches by age and sex, are listed in Adjunct 3, except that the early age-compositions are excluded (IWC, 2016a). In trials for which MSYR=1%, L_5 is downweighted by a factor of 10.

H. Trials

The *Implementation Simulation Trials* for the North Atlantic fin whales are listed in Table 9. See IWC (2016b) for a comparison of the trial numbers used here with those used in the previous *Implementation* (IWC, 2010a).

In these trials density dependence and MSYL are defined on the 1+ population; MSYR is defined in terms of 1^+ on 1% and mature on 4%.

I. Management options

The following management variants will be considered.

Management variants based on calculating catch limits by *Small Area*:

V1 Sub-area WI is a *Small Area*.

V2 Sub-area (WI+EG) is a *Small Area*. All of the catch is taken in the WI sub-area.

V3 Sub-area (WI+EG+EI/F) is a *Small Area*. All of the catch is taken in the WI sub-area.

V4 Sub-area WI is a *Small Area*. Catch limits will be set based on survey estimates for the WI sub-area north of 60°N (both historical and future surveys). The same proportions are used in setting future abundance estimates as for trials NF-Q3 (see Item F). The catch series is unchanged as all historical catches in the WI sub-area were taken north of 60°N.

Management variants based on applying catch cascading:

V5 Sub-areas WI and EG are taken to be *Small Areas* and sub-area WI+EG is taken to be a *Combination area*. The catch limits set for the EG *Small Area* are not taken.

V6 Sub-areas WI, EI/F and EG are taken to be *Small Areas* and sub-area WI+EI/F+EG is taken to be a *Combination area*. The catch limits set for the EG and EI/F *Small Areas* are not taken.

V7 Sub-areas WI+EG and EI/F are taken to be *Small Areas* and sub-area WI+EI/F+EG is taken to be a *Combination area*. The catch limits set for the WI+EG *Small Area* are taken in the WI sub-area. The catch limit for the EI/F sub-area is taken there.

The simulated application of the RMP is based on using the 'best' catch series (see Adjunct 1).

Table 9

The *Implementation Simulation Trials* for North Atlantic fin whales. All trials assume the following unless otherwise stated: the 'Best' catch series; future surveys will occur in sub-areas EG, WI and EI/F; and $g(0)$ is taken to be equal to 1. Trials shown in grey were assigned low weight and are omitted from the final set of trials.

Trial no.	Stock hypothesis	*MSYR* [4]	No. of stocks	Weight 1%	Weight 4%	Trial description
Baseline						
NF-B1	I	1, 4%	4	M	H	Base case: 4 stocks, separate feeding areas
NF-B2	II	1, 4%	4	M	H	4 stocks; 'W' and 'E' feed in central sub-areas
NF-B3	III	1, 4%	4	M	H	4 stocks; 'C1' and 'C3' feed in adjacent sub-areas
NF-B4	IV	1, 4%	4	L	L	4 stocks without sub-stock dispersion (i.e. no interchange)
NF-B5	V	1, 4%	4	M	H	4 stocks as in hypothesis I but stock 'S' in adjacent sub-areas
NF-B6	VI	1, 4%	3	L	H	3 stocks (no 'E' stock)
NF-B7	VII	1, 4%	4	L	L	4 stocks as in hypothesis III but WI/EG are combined; 2 'C' sub-stocks
NF-B8	VIII	1, 4%	4	L	L	4 stocks as in hypothesis IV but WI/EG are combined; 2 'C' sub-stocks (no dispersal)
Other factors						
NF-H2	II	1, 4%	4	M	M	High historical catch series
NF-H3	III	1, 4%	4	M	M	High historical catch series
NF-H4	IV	2.5, 4%	4	L	L	High historical catch series
NF-X3	III	1, 4%	4	L	L	N Iceland catch including in WI sub-area
NF-P3	III	1, 4%	4	L	L	Survey WI only with greater precision
NF-Q3	III	1, 4%	4	M	M	Future WI and EI/F surveys exc. strata S 60ºN
NF-A2	II	1, 4%	4	M	M	Pro-rate abundance data for conditioning
NF-A3	III	1, 4%	4	M	M	Pro-rate abundance data for conditioning
NF-C3	III	1, 4%	4	L	L	Inc. CPUE data in the likelihood calculation
NF-T1	I	1, 4%	4	L	L	Tag loss =20% in year 1; 10%/year thereafter
NF-T3	III	1, 4%	4	L	L	Tag loss =20% in year 1; 10%/year thereafter
NF-T4	IV	1, 4%	4	L	L	Tag loss =20% in year 1; 10%/year thereafter
NF-U3	III	1, 4%	4	Ls	M	Selectivity decreases by 4%/year for age 8+; M=0.04
NF-W1	I	1, 4%	4	L	L	Weight tag likelihood by factor of 10
NF-G2	II	1, 4%	4	M	M	C2 sub-stock enters EG beginning year 1985 (opt. a)
NF-G3	III	1, 4%	4	M	M	C2 sub-stock enters EG beginning year 1985 (opt. a)
NF-F2	II	1, 4%	4	M	M	C2 sub-stock enters EG 1985-2025 (opt. b)
NF-F3	III	1, 4%	4	M	M	C2 sub-stock enters EG 1985-2025 (opt. b)
NF-S3	III	1, 4%	4	M	M	Selectivity estimated for pre and post 2007
NF-S4	IV	1, 4%	4	L	L	Selectivity estimated for pre and post 2007
NF-Y1	I	1, 4%	4	M	H	8 year future survey interval
NF-Y2	II	1, 4%	4	M	H	8 year future survey interval
NF-Y3	III	1, 4%	4	M	H	8 year future survey interval
NF-Y4	IV	1, 4%	4	L	L	8 year future survey interval
NF-Y5	V	1, 4%	4	M	H	8 year future survey interval
NF-Y6	VI	1, 4%	3	L	H	8 year future survey interval
NF-R3	III	1, 4%	4	L	L	Only use tags recaptured after one year
NF-R4	IV	1, 4%	4	L	L	Only use tags recaptured after one year
NF-E2	II	1, 4%	4	M	M	Exclude 1987/89 abundance in WI, EG & EI/F
NF-E3	III	1, 4%	4	M	L	Exclude 1987/89 abundance in WI, EG & EI/F
NF-D1	I	1%	4	M	-	Dispersal: max bound of 20%
NF-D3	III	1%	4	M	-	Dispersal: max bound of 20%
NF-J2	II	1, 4%	4	M	H	Assume $g(0)$=0.8 (all estimates)
NF-J3	III	1, 4%	4	M	H	Assume $g(0)$=0.8 (all estimates)

J. Output statistics

Population-size and continuing catch statistics are produced for each stock/sub-stock and catch-related statistics for each sub-area.

(1) Total catch (TC) distribution: (a) median; (b) 5^{th} value; (c) 95^{th} value.

(2) Initial mature female population size ($P_{initial}$) distribution: (a) median; (b) 5^{th} value; (c) 95^{th} value.

(3) Final mature female population size (P_{final}) distribution: (a) median; (b) 5^{th} value; (c) 95^{th} value.

(4) Lowest mature female population size (P_{lowest}) distribution: (a) median; (b) 5^{th} value; (c) 95^{th} value.

(5) Average catch by sub-area over the first ten years of the 100-year management period: (a) median; (b) 5^{th} value; (c) 95^{th} value.

(6) Average catch by sub-area over the last ten years of the 100-year management period: (a) median; (b) 5^{th} value; (c) 95^{th} value.

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Adjunct 1

The Catch Series

The Catch Series used in the trials are given in tables 1 (the 'best' series) and 2 (the 'high' series). The 'best' series includes an estimated lost whale rate of 30% in the early period (up to 1916) and allocates whales not identified to species based on the species proportions for the nearest group of years by operation or by sub-area depending on the available data. In the 'high' catch series all the unspecified whales are taken to be fin whales and a lost whale rate of 50% in the period up to 1916 is applied.

Table 3 lists the catches known by sex. A sex ratio of 50:50 is assumed for all other catches.

Table 1

'Best' Catch Series (total 95,975 whales). Catches from land-stations by area are listed followed by pelagic catches. Catches from the UK are allocated to the EI/F sub-area as Thompson 1928 showed that most fin whales were taken there. Pelagic catches of unknown area are allocated as follows: [a]WI sub-area; [b]N sub-area; [c]167:52 WI:N; [d]50:50 WI:N sub-areas.

Year	Canada (EC)	WGrnl. (WG)	EGrnl. (EG)	WIcel. (WI)	E.Icel. (EI/F)	Faroe (EI/F)	UK (EI/F)	Spitsb. (N)	N.Norw (N)	W.Norw (N)	Spain (Sp)	Pelag. WG	Pelag. EG	Pelag. WI	Pelag. EI/F	Pelag. N	Pelag. ?Area
1864	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0
1865	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0
1866	0	0	0	0	24	0	0	0	0	0	0	0	0	0	0	0	0
1867	0	0	0	0	19	0	0	0	1	0	0	0	0	0	0	0	0
1868	0	0	0	0	2	0	0	0	10	0	0	0	0	0	0	0	0
1869	0	0	0	0	0	0	0	0	17	0	0	0	0	0	0	0	0
1870	0	0	0	0	0	0	0	0	36	0	0	0	0	0	0	0	0
1871	0	0	0	0	5	0	0	0	20	0	0	0	0	0	0	0	0
1872	0	0	0	0	0	0	0	0	17	0	0	0	0	0	0	0	0
1873	0	0	0	0	0	0	0	0	16	0	0	0	0	0	0	0	0
1874	0	0	0	0	0	0	0	0	22	0	0	0	0	0	0	0	0
1875	0	0	0	0	0	0	0	0	17	0	0	0	0	0	0	0	0
1876	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0
1877	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0
1878	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0
1879	0	0	0	0	0	0	0	0	52	0	0	0	0	0	0	0	0
1880	0	0	0	0	0	0	0	0	65	0	0	0	0	0	0	0	0
1881	0	0	0	0	0	0	0	0	68	0	0	0	0	0	0	0	0
1882	0	0	0	0	0	0	0	0	366	0	0	0	0	0	0	0	0
1883	0	0	0	0	0	0	0	0	316	0	0	0	0	0	0	0	0
1884	0	0	0	3	0	0	0	0	338	0	0	0	0	0	0	0	0
1885	0	0	0	18	0	0	0	0	612	0	0	0	0	0	0	0	0
1886	0	0	0	14	0	0	0	0	867	0	0	0	0	0	0	0	0
1887	0	0	0	28	0	0	0	0	627	0	0	0	0	0	0	0	0
1888	0	0	0	47	0	0	0	0	509	0	0	0	0	0	0	0	0
1889	0	0	0	86	0	0	0	0	509	0	0	0	0	0	0	0	0
1890	0	0	0	105	0	0	0	4	481	0	0	0	0	0	0	0	0
1891	0	0	0	119	0	0	0	2	393	0	0	0	0	0	0	0	0

Cont.

Year	Canada (EC)	WGrnl. (WG)	EGrnl. (EG)	WIcel. (WI)	E.Icel. (EI/F)	Faroe (EI/F)	UK (EI/F)	Spitsb. (N)	N.Norw (N)	W.Norw (N)	Spain (Sp)	Pelag. WG	Pelag. EG	Pelag. WI	Pelag. EI/F	Pelag. N	Pelag. ?Area
1892	0	0	0	164	5	0	0	0	530	0	0	0	0	0	0	0	0
1893	0	0	0	403	4	0	0	0	735	0	0	0	0	0	0	0	0
1894	0	0	0	273	0	18	0	0	710	0	0	0	0	0	0	0	0
1895	0	0	0	372	0	10	0	0	592	0	0	0	0	0	0	0	0
1896	0	0	0	235	0	26	0	0	1,051	0	0	0	0	0	0	0	0
1897	0	0	0	329	0	33	0	0	608	0	0	0	0	0	0	0	0
1898	106	0	0	249	0	49	0	0	670	0	0	0	0	0	0	0	0
1899	116	0	0	389	0	61	0	0	379	0	0	0	0	0	0	0	0
1900	123	0	0	425	0	86	0	0	388	0	0	0	0	0	0	0	0
1901	148	0	0	532	23	181	0	0	497	0	0	0	0	0	0	0	0
1902	237	0	0	485	121	174	0	0	640	0	0	0	0	0	0	0	0
1903	449	0	0	322	338	345	152	9	228	0	0	0	0	0	0	0	0
1904	897	0	0	255	383	260	575	62	256	0	0	0	0	0	0	0	0
1905	651	0	0	202	457	413	613	329	0	0	0	0	0	0	0	0	0
1906	407	0	0	151	296	243	426	132	0	0	0	0	0	0	0	0	0
1907	518	0	0	131	595	304	689	170	0	0	0	0	0	0	0	0	0
1908	514	0	0	138	594	282	520	76	0	0	0	0	0	0	0	0	0
1909	524	0	0	261	731	315	621	58	0	0	0	0	0	0	0	0	0
1910	384	0	0	198	460	334	564	149	0	0	0	0	0	0	0	0	0
1911	364	0	0	153	369	333	589	131	0	0	0	0	0	0	0	0	0
1912	325	0	0	97	105	142	428	53	0	28	0	0	0	0	0	0	0
1913	296	0	0	49	56	144	452	0	0	42	0	0	0	0	0	0	0
1914	242	0	0	26	0	152	516	0	0	0	0	0	0	0	0	0	0
1915	171	0	0	59	0	346	0	0	0	0	0	0	0	0	0	0	0
1916	59	0	0	0	0	208	0	0	0	0	0	0	0	0	0	0	0
1917	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1918	84	0	0	0	0	0	0	0	305	302	0	0	0	0	0	0	0
1919	40	0	0	0	0	0	0	0	194	283	0	0	0	0	0	0	22[a]
1920	0	0	0	0	0	272	409	15	44	106	0	0	0	0	0	0	36[a]
1921	0	0	0	0	0	174	0	0	0	37	323	0	0	0	0	0	0
1922	0	14	0	0	0	155	282	0	0	117	571	0	0	0	0	0	0
1923	66	20	0	0	0	193	312	0	0	147	1,080	0	0	0	0	0	0
1924	144	94	0	0	0	245	501	0	0	272	1,218	0	0	0	0	0	0
1925	270	30	0	0	0	225	315	0	0	332	1,592	0	0	0	0	0	0
1926	329	24	0	0	0	156	400	24	0	376	1,312	0	0	0	0	0	0
1927	249	22	0	0	0	171	263	44	0	333	369	0	0	0	0	0	0
1928	358	24	0	0	0	280	139	0	0	427	0	0	0	0	0	0	0
1929	333	24	0	0	0	160	73	0	0	148	0	0	0	0	0	0	192[b]
1930	281	27	0	0	0	233	0	196	0	101	0	0	0	0	5	162	219[c]
1931	0	16	0	0	0	0	0	164	0	69	0	285	0	8	0	0	0
1932	0	25	0	0	0	0	0	0	0	190	0	41	3	191	0	0	208[b]
1933	226	17	0	0	0	90	0	148	0	197	0	7	57	290	5	51	0
1934	328	23	0	0	0	74	0	0	0	132	66	0	0	98	0	32	0
1935	156	23	0	25	0	75	0	0	0	106	0	0	0	0	0	0	0
1936	146	15	0	72	0	82	0	0	0	147	0	0	0	0	0	0	0
1937	439	9	0	56	0	142	0	0	0	224	0	0	8	158	32	0	263[d]
1938	0	7	0	113	0	183	0	0	0	261	0	0	0	0	0	0	0
1939	118	3	0	109	0	153	0	0	0	282	0	0	0	0	0	0	0
1940	64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1941	65	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0
1942	62	0	0	0	0	0	0	0	0	58	0	0	0	0	0	0	0
1943	141	0	0	0	0	0	0	0	0	110	0	0	0	0	0	0	0
1944	231	0	0	0	0	0	0	0	0	112	38	0	0	0	0	0	0
1945	346	0	0	0	0	30	0	0	0	159	36	0	0	0	0	0	0
1946	502	47	0	0	0	94	0	0	0	392	42	0	0	0	0	0	0
1947	413	51	0	0	0	196	0	0	0	285	111	0	0	0	0	0	0
1948	670	21	0	195	0	223	0	0	41	219	178	0	0	0	0	0	0
1949	425	21	0	249	0	222	0	0	138	204	69	0	0	0	0	0	0
1950	408	36	0	226	0	376	33	0	90	252	82	0	0	0	0	0	0
1951	483	15	0	312	0	156	13	0	70	251	72	0	0	0	0	0	0
1952	1	16	0	224	0	20	0	0	83	291	141	0	0	0	0	0	0
1953	1	15	0	207	0	87	0	0	60	215	58	0	0	0	0	0	0
1954	0	22	0	177	0	17	0	0	58	212	126	0	0	0	0	0	0
1955	2	22	0	236	0	80	0	0	95	115	134	0	0	0	0	0	0
1956	7	28	0	265	0	43	0	0	63	69	34	0	0	0	0	0	0
1957	23	21	0	348	0	141	0	0	47	92	63	0	0	0	0	0	0
1958	55	8	0	289	0	16	0	0	70	53	37	0	0	0	0	0	0
1959	14	0	0	178	0	0	0	0	82	98	54	0	0	0	0	0	0
1960	1	0	0	160	0	0	0	0	51	77	124	0	0	0	0	0	0
1961	0	0	0	142	0	0	0	0	43	119	159	0	0	0	0	0	0
1962	0	0	0	303	0	6	0	0	76	69	50	0	0	0	0	0	0
1963	0	0	0	283	0	3	0	0	21	21	19	0	0	0	0	0	0
1964	57	1	0	217	0	13	0	0	32	6	59	0	0	0	0	0	0
1965	141	1	0	288	0	10	0	0	101	5	155	0	0	0	0	0	0
1966	427	0	0	310	0	4	0	0	54	0	107	0	0	0	0	0	0
1967	745	0	0	239	0	0	0	0	28	6	99	0	0	0	0	0	0
1968	700	3	0	202	0	6	0	0	68	8	106	0	0	0	0	0	0

Cont.

Year	Canada (EC)	WGrnl. (WG)	EGrnl. (EG)	WIcel. (WI)	E.Icel. (EI/F)	Faroe (EI/F)	UK (EI/F)	Spitsb. (N)	N.Norw (N)	W.Norw (N)	Spain (Sp)	Pelag. WG	Pelag. EG	Pelag. WI	Pelag. EI/F	Pelag. N	Pelag. ?Area
1969	533	0	0	251	0	0	0	0	14	2	116	0	0	0	0	0	0
1970	578	0	19	272	0	0	0	0	44	0	181	0	0	0	0	0	0
1971	418	0	0	208	0	0	0	0	37	0	98	0	0	0	0	0	0
1972	360	1	0	238	0	0	0	0	0	0	97	0	0	0	0	0	0
1973	0	2	0	267	0	0	0	0	0	0	112	0	0	0	0	0	0
1974	0	5	0	285	0	0	0	0	0	0	120	0	0	0	0	0	0
1975	0	1	0	245	0	0	0	0	0	0	137	0	0	0	0	0	0
1976	0	9	0	275	0	0	0	0	0	0	234	0	0	0	0	0	0
1977	0	13	0	144	0	0	0	0	0	0	151	0	0	0	0	0	0
1978	0	8	0	236	0	7	0	0	0	0	668	0	0	0	0	0	0
1979	0	7	0	260	0	11	0	0	0	0	562	0	0	0	0	0	0
1980	0	13	0	237	0	0	0	0	0	0	218	0	0	0	0	0	0
1981	0	7	0	254	0	3	0	0	0	0	146	0	0	0	0	0	0
1982	0	9	0	194	0	3	0	0	0	0	150	0	0	0	0	0	0
1983	0	8	0	144	0	5	0	0	0	0	120	0	0	0	0	0	0
1984	0	10	0	167	0	2	0	0	0	0	102	0	0	0	0	0	0
1985	0	9	0	161	0	0	0	0	0	0	48	0	0	0	0	0	0
1986	0	9	0	76	0	0	0	0	0	0	0	0	0	0	0	0	0
1987	0	9	0	80	0	0	0	0	0	0	0	0	0	0	0	0	0
1988	0	9	0	68	0	0	0	0	0	0	0	0	0	0	0	0	0
1989	0	14	0	68	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1992	0	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1993	0	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1994	0	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1995	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1996	0	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1997	0	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1998	0	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1999	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2000	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2001	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2002	0	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2003	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2004	0	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2005	0	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2006	0	10	1	7	0	0	0	0	0	0	0	0	0	0	0	0	0
2007	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2008	0	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2009	0	10	0	125	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	0	6	0	148	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	0	9	0	134	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	17,971	1,181	20	16,287	4,595	9,296	8,885	1,766	14,770	8,165	11,944	333	68	745	42	245	940

Table 2

'High' Catch Series. Catches from land-stations by area are listed followed by pelagic catches. Pelagic catches of unknown area are allocated as follows: [a]WI sub-area; [b]N sub-area; [c]167:52 WI:N; [d]50:50 WI:N sub-areas.

Year	Canada	Greenl. W	Greenl. E	Icelnd W	Icelnd E	Faroe	UK	Spitsb.	Norwy N	Norwy W	Spain	Pelag. WG	Pelag. EG	Pelag. WI	Pelag. EI	Pelag. N	Pelag. ?Area
1864	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0
1865	0	0	0	0	40	0	0	0	0	0	0	0	0	0	0	0	0
1866	0	0	0	0	145	0	0	0	0	0	0	0	0	0	0	0	0
1867	0	0	0	0	133	0	0	0	1	0	0	0	0	0	0	0	0
1868	0	0	0	0	16	0	0	0	10	0	0	0	0	0	0	0	0
1869	0	0	0	0	3	0	0	0	25	0	0	0	0	0	0	0	0
1870	0	0	0	0	3	0	0	0	52	0	0	0	0	0	0	0	0
1871	0	0	0	0	26	0	0	0	29	0	0	0	0	0	0	0	0
1872	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0
1873	0	0	0	0	0	0	0	0	18	0	0	0	0	0	0	0	0
1874	0	0	0	0	0	0	0	0	25	0	0	0	0	0	0	0	0
1875	0	0	0	0	0	0	0	0	19	0	0	0	0	0	0	0	0
1876	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0
1877	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0	0
1878	0	0	0	0	0	0	0	0	152	0	0	0	0	0	0	0	0
1879	0	0	0	0	0	0	0	0	60	0	0	0	0	0	0	0	0
1880	0	0	0	0	0	0	0	0	77	0	0	0	0	0	0	0	0
1881	0	0	0	0	0	0	0	0	83	0	0	0	0	0	0	0	0
1882	0	0	0	0	0	0	0	0	441	0	0	0	0	0	0	0	0
1883	0	0	0	0	2	0	0	0	498	0	0	0	0	0	0	0	0
1884	0	0	0	3	0	0	0	0	488	0	0	0	0	0	0	0	0

Cont.

Year	Canada	Greenl. W	Greenl. E	Icelnd W	Icelnd E	Faroe	UK	Spitsb.	Norwy N	Norwy W	Spain	Pelag. WG	Pelag. EG	Pelag. WI	Pelag. EI	Pelag. N	Pelag. ?Area
1885	0	0	0	48	0	0	0	0	707	0	0	0	0	0	0	0	0
1886	0	0	0	38	0	0	0	0	1,011	0	0	0	0	0	0	0	0
1887	0	0	0	72	0	0	0	0	741	0	0	0	0	0	0	0	0
1888	0	0	0	123	0	0	0	0	656	0	0	0	0	0	0	0	0
1889	0	0	0	153	0	0	0	0	708	0	0	0	0	0	0	0	0
1890	0	0	0	168	0	0	0	5	555	0	0	0	0	0	0	0	0
1891	0	0	0	177	0	0	0	5	563	0	0	0	0	0	0	0	0
1892	0	0	0	267	37	0	0	0	902	0	0	0	0	0	0	0	0
1893	0	0	0	528	27	0	0	0	1,145	0	0	0	0	0	0	0	0
1894	0	0	0	479	0	50	0	0	993	0	0	0	0	0	0	0	0
1895	0	0	0	680	0	35	0	0	767	0	0	0	0	0	0	0	0
1896	0	0	0	711	0	75	0	0	1,220	0	0	0	0	0	0	0	0
1897	0	0	0	896	0	117	0	0	702	0	0	0	0	0	0	0	0
1898	132	0	0	521	0	174	0	0	774	0	0	0	0	0	0	0	0
1899	134	0	0	789	0	173	0	0	485	0	0	0	0	0	0	0	0
1900	168	0	0	732	0	294	0	0	495	0	0	0	0	0	0	0	0
1901	270	0	0	1,221	27	300	0	0	621	0	0	0	0	0	0	0	0
1902	591	0	0	920	636	381	0	0	786	0	0	0	0	0	0	0	0
1903	518	0	0	642	837	516	176	11	311	0	0	0	0	0	0	0	0
1904	1,035	0	0	294	641	300	663	78	342	0	0	0	0	0	0	0	0
1905	794	0	0	248	731	506	723	380	0	0	0	0	0	0	0	0	0
1906	516	0	0	174	348	356	492	275	0	0	0	0	0	0	0	0	0
1907	837	0	0	152	687	471	795	299	0	0	0	0	0	0	0	0	0
1908	633	0	0	159	689	326	600	168	0	0	0	0	0	0	0	0	0
1909	683	0	0	302	855	381	717	96	0	0	0	0	0	0	0	0	0
1910	521	0	0	263	542	386	651	200	0	0	0	0	0	0	0	0	0
1911	485	0	0	191	435	384	680	152	0	0	0	0	0	0	0	0	0
1912	431	0	0	144	131	168	494	87	0	45	0	0	0	0	0	0	0
1913	344	0	0	57	102	167	522	0	0	48	0	0	0	0	0	0	0
1914	330	0	0	30	0	176	596	0	0	0	0	0	0	0	0	0	0
1915	171	0	0	68	0	438	0	0	0	0	0	0	0	0	0	0	0
1916	61	0	0	0	0	240	0	0	0	0	0	0	0	0	0	0	0
1917	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1918	101	0	0	0	0	0	0	0	305	302	0	0	0	0	0	0	0
1919	41	0	0	0	0	0	0	0	194	283	0	0	0	0	0	0	29[a]
1920	0	0	0	0	0	272	409	15	44	106	0	0	0	0	0	0	36[a]
1921	0	0	0	0	0	174	0	0	0	37	323	0	0	0	0	0	0
1922	0	14	0	0	0	155	282	0	0	117	571	0	0	0	0	0	0
1923	66	20	0	0	0	193	312	0	0	147	1,080	0	0	0	0	0	0
1924	144	94	0	0	0	245	501	0	0	272	1,218	0	0	0	0	0	0
1925	270	30	0	0	0	225	315	0	0	332	1,592	0	0	0	0	0	0
1926	329	24	0	0	0	156	400	24	0	376	1,312	0	0	0	0	0	0
1927	249	22	0	0	0	171	263	44	0	359	369	0	0	0	0	0	0
1928	358	24	0	0	0	280	139	0	0	427	0	0	0	0	0	0	0
1929	333	24	0	0	0	160	73	0	0	148	0	0	0	0	0	0	192[b]
1930	281	27	0	0	0	233	0	196	0	101	0	0	0	0	5	162	219[c]
1931	0	16	0	0	0	0	0	164	0	69	0	285	0	8	0	0	0
1932	0	25	0	0	0	0	0	0	0	190	0	41	3	191	0	0	208[b]
1933	295	17	0	0	0	90	0	148	0	197	0	7	57	290	5	51	0
1934	418	23	0	0	0	74	0	0	0	132	66	0	0	98	0	32	0
1935	156	23	0	25	0	75	0	0	0	106	0	0	0	0	0	0	0
1936	146	15	0	72	0	82	0	0	0	147	0	0	0	0	0	0	0
1937	439	9	0	56	0	142	0	0	0	224	0	0	8	158	32	0	263[d]
1938	0	7	0	113	0	183	0	0	0	261	0	0	0	0	0	0	0
1939	118	3	0	109	0	153	0	0	0	282	0	0	0	0	0	0	0
1940	64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1941	65	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0
1942	62	0	0	0	0	0	0	0	0	58	0	0	0	0	0	0	0
1943	141	0	0	0	0	0	0	0	0	110	0	0	0	0	0	0	0
1944	231	0	0	0	0	0	0	0	0	112	38	0	0	0	0	0	0
1945	346	0	0	0	0	35	0	0	0	159	36	0	0	0	0	0	0
1946	502	47	0	0	0	94	0	0	0	392	42	0	0	0	0	0	0
1947	413	51	0	0	0	196	0	0	0	285	111	0	0	0	0	0	0
1948	670	21	0	195	0	223	0	0	41	219	178	0	0	0	0	0	0
1949	425	21	0	249	0	222	0	0	138	204	69	0	0	0	0	0	0
1950	408	36	0	226	0	376	33	0	90	252	82	0	0	0	0	0	0
1951	483	15	0	312	0	156	13	0	70	251	72	0	0	0	0	0	0
1952	1	16	0	224	0	20	0	0	83	291	141	0	0	0	0	0	0
1953	1	15	0	207	0	87	0	0	60	215	58	0	0	0	0	0	0
1954	0	22	0	177	0	17	0	0	58	212	126	0	0	0	0	0	0
1955	2	22	0	236	0	80	0	0	95	115	134	0	0	0	0	0	0
1956	7	28	0	265	0	43	0	0	63	69	34	0	0	0	0	0	0
1957	23	21	0	348	0	141	0	0	47	92	63	0	0	0	0	0	0
Catches from 1958-2012 are the same as those in the 'Best' series listed in Table 1.																	
Total	272	1,181	20	21,219	7,093	11,256	9,849	2,347	18,514	8,214	11,944	333	68	745	42	245	947

Table 3
Catches known by sex.

Subarea:	EC	EC	WG	WG	EG	EG	WI	WI	EI/F	EI/F	N	N	Sp	Sp
Year	Male	Fem.	Male	Fem.	Male	Fem.	Male	Fem.	Male	Fem.	Male	Fem.	Male	Fem.
1864	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1865	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1866	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1867	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1868	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1869	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1870	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1871	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1872	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1873	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1874	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1875	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1876	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1877	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1878	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1879	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1880	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1881	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1882	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1883	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1884	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1885	0	0	0	0	0	0	0	0	0	0	12	8	0	0
1886	0	0	0	0	0	0	0	0	0	0	15	22	0	0
1887	0	0	0	0	0	0	0	0	0	0	6	14	0	0
1888	0	0	0	0	0	0	0	0	0	0	11	10	0	0
1889	0	0	0	0	0	0	0	0	0	0	10	7	0	0
1890	0	0	0	0	0	0	0	0	0	0	17	19	0	0
1891	0	0	0	0	0	0	0	0	0	0	9	21	0	0
1892	0	0	0	0	0	0	0	0	0	0	22	22	0	0
1893	0	0	0	0	0	0	0	0	0	0	20	9	0	0
1894	0	0	0	0	0	0	0	0	0	0	10	12	0	0
1895	0	0	0	0	0	0	0	0	0	0	1	4	0	0
1896	0	0	0	0	0	0	0	0	0	0	20	16	0	0
1897	0	0	0	0	0	0	0	0	0	0	8	5	0	0
1898	0	0	0	0	0	0	0	0	0	0	10	11	0	0
1899	0	0	0	0	0	0	0	0	0	0	4	4	0	0
1900	0	0	0	0	0	0	0	0	0	0	1	2	0	0
1901	0	0	0	0	0	0	0	0	0	0	13	10	0	0
1902	0	0	0	0	0	0	0	0	0	0	13	7	0	0
1903	0	0	0	0	0	0	0	0	0	0	10	10	0	0
1904	0	0	0	0	0	0	6	15	238	210	0	0	0	0
1905	0	0	0	0	0	0	0	0	291	262	0	0	0	0
1906	0	0	0	0	0	0	0	0	101	121	0	0	0	0
1907	0	0	0	0	0	0	0	0	91	93	0	0	0	0
1908	0	0	0	0	0	0	0	0	428	416	0	0	0	0
1909	0	0	0	0	0	0	0	0	528	601	0	0	0	0
1910	0	0	0	0	0	0	10	11	474	507	0	0	0	0
1911	0	0	0	0	0	0	10	10	410	437	0	0	0	0
1912	0	0	0	0	0	0	0	0	209	225	0	0	0	0
1913	0	0	0	0	0	0	0	0	237	225	0	0	0	0
1914	0	0	0	0	0	0	10	10	283	231	0	0	0	0
1915	0	0	0	0	0	0	20	24	131	101	0	0	0	0
1916	0	0	0	0	0	0	0	0	48	39	0	0	0	0
1917	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1918	0	0	0	0	0	0	0	0	0	0	11	10	0	0
1919	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1920	0	0	0	0	0	0	0	0	46	68	0	0	0	0
1921	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1922	0	0	0	0	0	0	0	0	23	21	0	0	0	0
1923	0	0	0	0	0	0	0	0	55	41	32	29	0	0
1924	0	0	34	32	0	0	0	0	59	63	0	0	0	0
1925	0	0	0	0	0	0	0	0	114	110	165	167	16	8
1926	0	0	0	0	0	0	0	0	17	21	160	136	103	129
1927	92	96	0	6	0	0	0	0	168	163	190	143	83	89
1928	134	135	0	0	0	0	0	0	166	166	230	197	0	0
1929	164	169	0	4	0	0	0	0	89	144	137	143	0	0
1930	153	128	0	3	0	0	91	76	102	130	246	247	0	0
1931	0	0	154	132	0	0	1	7	0	0	130	103	0	0
1932	0	0	32	34	1	2	101	90	0	0	205	191	0	0
1933	0	0	13	11	25	23	159	130	52	43	211	181	0	0
1934	0	0	0	0	0	0	48	50	34	40	70	94	41	25
1935	44	53	9	14	0	0	0	0	36	38	45	58	0	0
1936	78	68	6	9	0	0	26	46	40	42	72	75	0	0
1937	0	0	2	7	6	2	185	160	91	83	173	182	0	0
1938	0	0	4	3	0	0	55	58	108	74	139	122	0	0
1939	62	56	1	2	0	0	66	43	73	80	134	148	0	0
1940	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1941	26	39	0	0	0	0	0	0	0	0	5	1	0	0

Cont.

Subarea:	EC	EC	WG	WG	EG	EG	WI	WI	EI/F	EI/F	N	N	Sp	Sp
Year	Male	Fem.	Male	Fem.	Male	Fem.	Male	Fem.	Male	Fem.	Male	Fem.	Male	Fem.
1942	30	32	0	0	0	0	0	0	0	0	33	25	0	0
1943	65	76	0	0	0	0	0	0	0	0	67	43	0	0
1944	115	116	0	0	0	0	0	0	0	0	55	57	0	0
1945	139	207	0	0	0	0	0	0	0	0	80	79	0	0
1946	280	222	26	21	0	0	0	0	53	39	207	185	0	0
1947	224	189	29	22	0	0	0	0	107	89	138	147	0	0
1948	374	295	10	11	0	0	92	103	112	111	133	127	21	25
1949	210	215	5	16	0	0	108	141	101	121	191	151	0	0
1950	195	213	18	18	0	0	96	130	228	179	185	156	45	37
1951	217	266	8	7	0	0	123	189	81	87	174	147	23	22
1952	0	1	4	12	0	0	100	124	15	5	193	181	6	6
1953	0	1	6	9	0	0	101	106	43	44	125	150	4	5
1954	0	0	17	5	0	0	70	107	6	11	137	132	6	6
1955	0	2	14	8	0	0	119	117	46	34	118	92	0	0
1956	3	4	17	11	0	0	114	151	22	21	62	70	0	0
1957	12	10	11	10	0	0	152	196	71	70	68	71	12	12
1958	37	18	2	6	0	0	141	148	7	9	58	65	10	15
1959	6	8	0	0	0	0	96	82	0	0	94	86	17	19
1960	1	0	0	0	0	0	82	78	0	0	62	66	22	17
1961	0	0	0	0	0	0	65	77	0	0	83	79	19	20
1962	0	0	0	0	0	0	164	139	5	1	80	65	1	2
1963	0	0	0	0	0	0	151	132	0	3	23	19	1	3
1964	20	36	0	0	0	0	111	106	4	9	18	20	30	11
1965	69	69	0	0	0	0	157	131	5	5	63	43	37	28
1966	188	235	0	0	0	0	161	149	2	1	23	31	58	49
1967	303	438	0	0	0	0	111	128	0	0	17	17	54	45
1968	312	388	0	0	0	0	101	101	4	2	39	37	60	46
1969	216	316	0	0	0	0	117	134	0	0	8	8	73	43
1970	288	288	0	0	14	5	140	132	0	0	17	27	97	84
1971	190	227	0	0	0	0	97	111	0	0	18	19	57	41
1972	177	183	0	0	0	0	122	116	0	0	0	0	41	56
1973	0	0	0	0	0	0	135	132	0	0	0	0	57	54
1974	0	0	0	0	0	0	142	143	0	0	0	0	65	55
1975	0	0	0	0	0	0	127	118	0	0	0	0	77	60
1976	0	0	0	0	0	0	132	143	0	0	0	0	113	121
1977	0	0	0	0	0	0	64	80	0	0	0	0	81	70
1978	0	0	1	0	0	0	104	132	5	2	0	0	253	207
1979	0	0	0	0	0	0	127	133	4	7	0	0	255	197
1980	0	0	0	0	0	0	117	119	0	0	0	0	113	105
1981	0	0	0	0	0	0	121	132	2	1	0	0	78	68
1982	0	0	0	0	0	0	96	98	1	2	0	0	58	91
1983	0	0	0	0	0	0	70	74	1	4	0	0	62	58
1984	0	0	0	0	0	0	66	100	2	0	0	0	33	69
1985	0	0	1	2	0	0	74	87	0	0	0	0	18	30
1986	0	0	2	1	0	0	27	49	0	0	0	0	0	0
1987	0	0	1	2	0	0	38	42	0	0	0	0	0	0
1988	0	0	4	5	0	0	31	37	0	0	0	0	0	0
1989	0	0	3	3	0	0	23	45	0	0	0	0	0	0
1990	0	0	9	6	0	0	0	0	0	0	0	0	0	0
1991	0	0	5	6	0	0	0	0	0	0	0	0	0	0
1992	0	0	4	9	0	0	0	0	0	0	0	0	0	0
1993	0	0	2	11	0	0	0	0	0	0	0	0	0	0
1994	0	0	10	10	0	0	0	0	0	0	0	0	0	0
1995	0	0	9	3	0	0	0	0	0	0	0	0	0	0
1996	0	0	8	10	0	0	0	0	0	0	0	0	0	0
1997	0	0	5	5	0	0	0	0	0	0	0	0	0	0
1998	0	0	1	8	0	0	0	0	0	0	0	0	0	0
1999	0	0	3	4	0	0	0	0	0	0	0	0	0	0
2000	0	0	3	3	0	0	0	0	0	0	0	0	0	0
2001	0	0	3	4	0	0	0	0	0	0	0	0	0	0
2002	0	0	5	8	0	0	0	0	0	0	0	0	0	0
2003	0	0	2	4	0	0	0	0	0	0	0	0	0	0
2004	0	0	5	6	0	0	0	0	0	0	0	0	0	0
2005	0	0	1	11	0	0	0	0	0	0	0	0	0	0
2006	0	0	2	6	0	0	3	4	0	0	0	0	0	0
2007	0	0	6	4	0	0	0	0	0	0	0	0	0	0
2008	0	0	8	3	0	0	0	0	0	0	0	0	0	0
2009	0	0	1	7	0	0	67	58	0	0	0	0	0	0
2010	0	0	0	5	0	0	74	68	0	0	0	0	0	0
2011	0	0	0	5	0	0	0	0	0	0	0	0	0	0
2012	0	0	0	4	0	0	0	0	0	0	0	0	0	0
2013	0	0	3	5	0	0	58	71	0	0	0	0	0	0
M total:	4,424		529		46		5,375		5,669		5,136		2,200	
F total:		4,799		573		32		5,723		5,652		4,835		2,028

Adjunct 2

Survey abundance pro-rating

Rebecca Rademeyer

Some historical abundance estimates from the NASS surveys used in the North Atlantic fin trial conditioning do not cover the full sub-areas (East Greenland, West Iceland and East Iceland/Faroes). *Robustness Trials* (NF-A3) have been included in which the data used in conditioning are pro-rated for these sub-areas only. The abundance indices have simply been pro-rated by assuming the same density in and out of the surveyed region. Table 1 gives the NASS region estimates used to compute the final sub-areas estimates. The original and pro-rated estimates are given. Table 2 compares the final estimates used in the conditioning trials which are calculated as described in Wade (2009).

Table 1

The NASS region estimates used to compute the final sub-areas estimates (Pike and Gunnlaugsson, 2006; Pike *et al.*, 2008).

Year	Region	*N*	Pro-rated *N*	Area covered	Pro-rated by
East Greenland					
1987	B-West	1,750		82,331	
1989	B-West	2,329		82,331	
1995	B-West	7,812		77,682	
2001	B-West	7,736		88,694	
2007	B-West	7,185		101,893	
1989	A-West	3,274		263,980	1.00
1995	A-West	600	2,340	67,706	3.90
2001	A-West	3,970	6,489	161,551	1.63
2007	A-West	1,396	5,029	111,854	3.60
West Iceland					
1987	B-East	1,857		109,971	
1989	B-East	3,677		92,854	
1995	B-East	5,915		101,081	
2001	B-East	6,285		102,740	
2007	B-East	4,557		111,854	
1989	A-East	1,595		213,039	1.00
1995	A-East	885	1,448	130,217	1.64
2001	A-East	280	1,145	52,131	4.09
2007	A-East	2,781	3,561	135,878	1.28
East Iceland/Faroe Islands					
1987	EGI	1,050		145,783	
1995	EGI	4,145		127,219	
2001	EGI	5,405		254,076	
2007	EGI	981		125,767	
1987	WN-SPB	675		271,255	1.00
1995	WN-SPB	1,594	1,709	204,222	1.33
2001	WN-SPB	2,085	3,353	136,278	1.99
2007	WN-SPB	632	1,485	112,121	2.35

Table 2

The final estimates used in the conditioning trials which are calculated as described in Wade (2009).

Year	*N*	Pro-rated *N*
East Greenland		
1988	5,269	5,269
1995	8,412	10,152
2001	11,706	14,225
2007	12,215	15,847
West Iceland		
1988	4,243	4,243
1995	6,800	7,363
2001	6,565	7,430
2007	8,118	8,898
East Iceland/Faroe Islands		
1987	5,261	5,261
1995	6,647	7,170
2001	7,490	9,555
2007	1,613	2,466

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Adjunct 3

Catch at age in the West Iceland (WI) catches

Table 1

Males known by age.

Age	1967	1969	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	2006	2009	2010
1	-	-	-	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
2	-	2	2	3	2	-	-	2	3	2	1	2	1	-	2	-	-	-	-	-	-	-	-
3	1	-	7	6	9	6	4	1	7	1	2	2	2	1	-	-	-	-	-	2	-	1	-
4	2	3	3	8	5	4	5	8	12	5	5	8	6	5	5	1	-	-	3	1	-	1	-
5	1	-	8	3	6	7	10	4	7	5	7	7	4	4	7	5	-	1	4	-	-	-	-
6	2	3	6	9	9	6	12	5	5	9	4	16	10	6	4	5	1	1	3	1	-	2	-
7	3	-	5	7	7	6	3	5	4	10	12	7	10	6	10	4	1	2	2	-	-	-	-
8	1	3	6	3	5	1	5	1	2	4	6	11	11	3	4	4	3	9	2	2	-	-	-
9	3	2	1	-	2	4	5	2	1	7	6	6	9	5	5	5	1	3	1	1	-	1	-
10	-	1	2	-	1	3	7	4	-	3	9	4	5	6	6	3	2	3	1	-	-	2	-
11	2	1	2	1	2	3	3	2	2	3	2	7	2	5	3	6	1	1	1	2	-	1	-
12	2	-	2	1	1	2	3	1	3	4	2	5	8	-	1	5	3	5	1	2	-	3	1
13	1	1	-	1	-	4	1	-	2	3	5	6	3	3	3	3	-	2	2	2	-	1	-
14	2	1	-	1	1	2	4	2	2	-	3	4	1	2	-	4	3	1	3	-	-	3	1
15	-	2	1	1	2	1	3	2	-	5	1	5	3	2	3	-	1	1	1	-	-	-	1
16	-	-	-	1	1	2	2	4	-	2	3	1	2	4	1	3	1	3	-	-	1	2	1
17	-	-	-	-	2	2	2	-	1	-	1	2	3	-	1	3	-	1	-	1	-	4	1
18	-	-	1	-	-	2	3	-	-	-	1	1	2	2	1	3	-	-	2	-	-	1	2
19	-	-	-	-	-	1	1	2	-	2	-	4	3	3	1	2	-	-	-	-	-	2	2
20	-	-	3	-	-	2	5	1	2	5	2	2	2	-	4	-	1	-	1	1	-	-	4
21	-	1	1	1	1	1	-	-	1	-	3	2	1	1	3	3	-	-	-	-	-	2	-
22	1	-	1	-	-	-	-	2	1	1	3	-	3	-	-	1	-	1	2	1	-	6	3
23	-	-	1	-	-	1	-	2	-	-	1	-	-	-	-	-	2	1	-	-	-	1	1
24	-	-	-	1	-	2	1	-	-	-	-	1	-	-	1	-	1	1	-	-	-	3	3
25	-	2	-	-	-	1	-	-	1	-	-	2	-	3	-	1	-	1	-	1	-	1	3
26	1	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	1	-	-	-	1	3	2
27	-	-	-	-	1	-	-	1	-	-	1	1	-	-	-	-	2	-	-	-	-	1	5
28	-	1	-	-	2	2	2	-	-	2	-	-	-	-	-	-	-	-	-	1	-	-	5
29	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	2
30	-	1	-	-	-	-	2	1	-	-	-	1	-	-	-	1	-	-	-	-	-	6	5
31	1	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-	1	-	3	1
32	-	1	-	1	-	1	-	-	1	1	1	-	-	1	-	-	-	-	-	-	-	4	5
33	-	-	-	-	-	-	1	-	1	-	-	-	-	1	-	-	-	-	-	-	-	-	2
34	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	3
35	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	1	-	-	-	-	-	2	-
36	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	6
38	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	2
39	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-	-	1	-
40	1	-	-	1	-	-	-	-	1	-	1	1	-	-	-	-	-	-	-	-	-	-	2
41	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
42	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
43	-	-	-	-	-	1	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
44	-	-	-	-	-	1	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
45	-	-	-	1	-	1	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
46	-	-	-	1	-	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-	2	1
47	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
48	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
49	1	-	1	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
50	1	2	1	2	-	1	1	-	-	-	2	1	-	-	1	-	-	-	-	-	-	-	-
51	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	1
52	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
53	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-
55	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
56	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
58	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-
59	-	-	-	-	-	2	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-
60	-	1	-	-	-	-	-	1	-	2	-	-	-	-	-	-	-	-	-	-	-	1	-
61	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
62	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
63	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
64	-	-	-	-	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
65	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
66	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-	-	-	-
67	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	2	-	-	-	-	-	-	-
68	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
70	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
73	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
74	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-
75	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-
83	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
94	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-

Table 2

Females known by age.

Age	1967	1969	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	2006	2009	2010
1	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	-	1	4	4	2	4	1	1	-	-	-	4	1	-	-	-	-	-	2	-	-	-	-
3	4	1	9	4	7	6	8	1	2	2	2	7	6	6	1	3	-	-	-	1	-	-	-
4	1	1	8	4	5	4	10	6	5	6	3	9	4	1	11	1	2	-	2	2	-	1	-
5	3	3	5	5	10	9	10	7	5	7	7	9	6	4	2	6	3	-	2	3	-	-	-
6	2	3	12	5	5	5	6	7	10	5	6	7	6	3	10	3	-	1	3	2	-	-	-
7	2	4	5	4	5	1	5	10	9	12	4	16	11	8	11	8	5	2	2	3	-	1	-
8	1	2	6	5	5	3	3	6	3	5	10	7	11	8	6	3	1	3	1	4	-	1	1
9	2	2	4	4	10	7	5	2	6	9	7	7	3	6	5	5	7	3	4	4	-	-	-
10	2	3	-	3	2	2	1	2	1	4	10	14	2	3	2	11	3	3	2	-	-	2	-
11	3	3	1	1	2	3	3	2	7	5	3	8	5	2	5	1	1	6	-	2	-	-	-
12	-	1	1	2	2	-	4	3	3	4	4	3	6	4	3	1	2	-	-	5	1	-	-
13	-	3	5	1	-	-	2	3	1	4	7	9	4	2	5	2	2	3	1	3	-	1	-
14	-	3	-	3	2	3	4	1	3	3	2	3	5	1	3	4	1	4	2	1	-	2	-
15	1	-	-	-	1	2	2	1	-	4	1	3	2	1	5	2	2	4	-	-	-	2	1
16	1	-	-	1	2	2	1	3	1	3	6	3	2	3	3	9	3	-	-	-	-	2	-
17	-	-	3	-	1	1	3	-	-	2	1	4	3	2	1	2	5	2	1	-	-	-	-
18	-	-	1	1	-	1	1	1	2	-	3	-	2	2	4	1	-	1	-	-	-	4	4
19	-	-	1	-	-	1	1	-	-	1	2	1	1	2	2	3	1	-	1	3	-	6	1
20	-	-	-	-	1	3	2	3	2	3	2	5	1	-	-	1	-	2	-	1	1	2	3
21	-	1	-	-	-	1	1	3	2	1	1	3	2	-	1	1	1	-	2	2	-	4	-
22	-	1	3	-	-	-	3	1	-	3	1	1	-	2	-	4	-	-	-	-	-	3	1
23	-	1	-	1	-	-	-	-	-	1	3	-	1	-	1	-	-	-	2	-	-	2	1
24	-	1	-	-	-	-	1	-	1	-	1	-	-	-	-	-	1	1	1	3	-	1	5
25	1	-	-	-	-	-	3	-	1	1	1	-	-	3	2	1	-	2	-	-	-	2	1
26	2	-	-	-	1	-	1	1	-	-	-	1	1	-	1	1	1	-	-	1	-	1	4
27	-	-	-	1	1	-	-	-	1	-	-	2	-	1	-	-	1	-	-	-	-	1	3
28	1	-	-	-	-	-	-	-	-	2	-	-	1	-	-	2	-	1	-	-	-	2	2
29	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	1	-	2	2
30	-	-	-	-	2	-	1	-	-	3	1	-	-	-	-	-	-	-	-	-	-	2	7
31	-	-	-	-	-	-	-	1	-	-	1	-	1	-	-	-	-	-	-	-	1	-	2
32	-	2	-	1	-	1	1	-	-	1	-	-	-	-	-	1	-	-	-	-	-	2	8
33	-	2	-	-	-	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1
34	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-	-	-	1	2	5
35	1	-	-	1	-	-	2	1	1	-	-	-	1	-	-	-	1	1	-	-	-	1	-
36	-	-	-	-	-	-	1	1	-	-	1	-	-	1	-	-	-	-	1	-	-	1	6
37	-	-	-	-	-	-	-	1	1	-	1	1	-	-	-	-	-	1	-	-	-	-	-
38	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	2	1
39	-	-	-	-	1	-	-	-	1	-	-	-	2	-	-	-	1	-	1	-	-	-	1
40	1	1	-	1	2	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	2
41	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
42	-	-	-	-	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	2
43	-	-	-	-	-	-	-	-	3	-	-	1	-	-	-	-	-	-	-	1	-	-	-
44	-	-	-	-	-	-	-	1	2	-	-	-	-	1	-	-	-	-	-	-	-	-	-
45	1	-	-	-	-	-	2	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1
46	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
47	-	1	-	-	-	-	1	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-
48	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
49	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
50	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-
51	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
52	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
53	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
54	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
55	-	-	1	1	-	-	1	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-
57	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-
59	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
60	-	-	-	-	-	1	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-
61	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
64	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
65	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
68	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
70	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
73	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
77	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Appendix 4

THE AWMP/RMP *IMPLEMENTATION SIMULATION TRIALS* FOR THE NORTH ATLANTIC MINKE WHALES

A. Basic concepts and stock-structure

The objective of these trials is to examine the performance of the RMP and AWMP when managing a fishery for North Atlantic minke whales. Allowance is made for both commercial and aboriginal subsistence catches. The underlying dynamics model allows for multiple stocks and sub-stocks, and is age- and sex-structured. The trials capture uncertainty regarding stock structure and MSYR, as well as uncertainty regarding selectivity.

The region to be managed (the Northern North Atlantic) is divided into 11 sub-areas (see Fig. 1). The term 'stock' refers to a group of whales from the same (putative) breeding ground. The 3-stock models assume there is western 'W' stock (which feeds at least in the 'WG' and 'WC' sub-areas), a central 'C' stock (which feeds at least in the 'CG', 'CIC', 'CIP', and 'CM' sub-areas), and an eastern 'E' stock (which feeds at least in the 'EN', 'EB', 'ESW', 'ESE', and 'EW' sub-areas). The 'E' and 'W' stocks are divided into sub-stocks for some of trials (sub-stocks 'E-1' and 'E-2' for the 'E' stock; sub-stocks 'W-1' and 'W-2' for the 'W' stock). There is no interchange between stocks, or sub-stocks. The rationale for the position of the sub-area boundaries is given in IWC (1993, p.194; 2004a, pp.12-13; 2009, p.138).

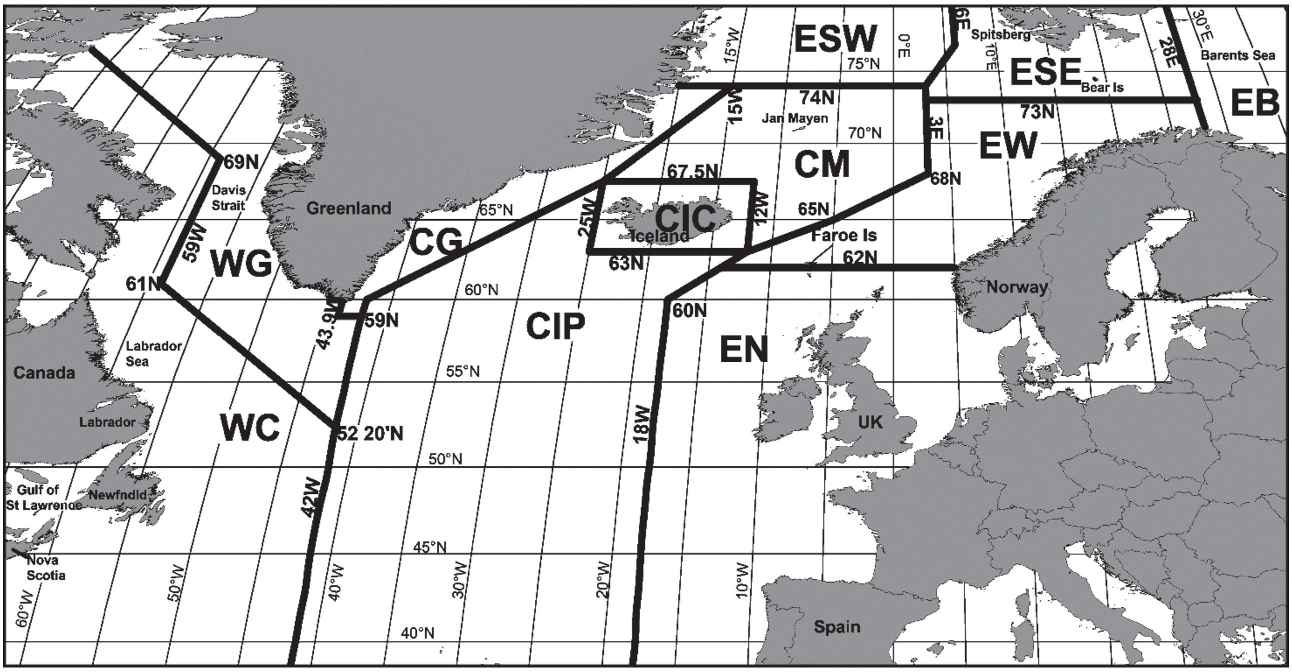

Fig. 1. Map of the North Atlantic showing the sub-areas defined for the North Atlantic minke whales.

There are three general hypotheses regarding stock structure (see IWC, 2015 for the rationale for these hypotheses):

(I) *Three stocks*. There are three stocks 'W', 'C', and 'E'. The 'W' stock consists of two sub-stocks ('W-1' and 'W-2') and the 'E' stock consists of two sub-stocks ('E-1' and 'E-2').

(II) *Two stocks.* There are two stocks 'W*', and 'E'. The 'W*' stock consists of two sub-stocks ('W' and 'C*') where the C* stock is the same as the 'C' stock for stock hypothesis I, except that the whales that occur primarily in the 'WG' sub-area are also part of this stock. The 'E' stock is defined as for stock hypothesis I.

(III) *One stock*. There is only a single ('O') stock of minke whales in the North Atlantic.

(IV) *Two cryptic stocks*. There are two stocks ('O-1' and 'O-2') of minke whales in the North Atlantic. The two stocks are found in all 11 sub-areas[1].

The trials (see Section H) include variants of these general hypotheses to capture further aspects of uncertainty regarding stock structure. The trials also allow for the difference in the catch sex-ratios between the primary catching season (i.e. before July) and the time when surveys are conducted (July onwards) (see details in Section G).

[1]This stock structure hypothesis was discussed by the April 2014 Joint AWMP/RMP North Atlantic Minke Whale Stock Structure Workshop, though it was not included in the final report of that meeting (IWC, 2015).

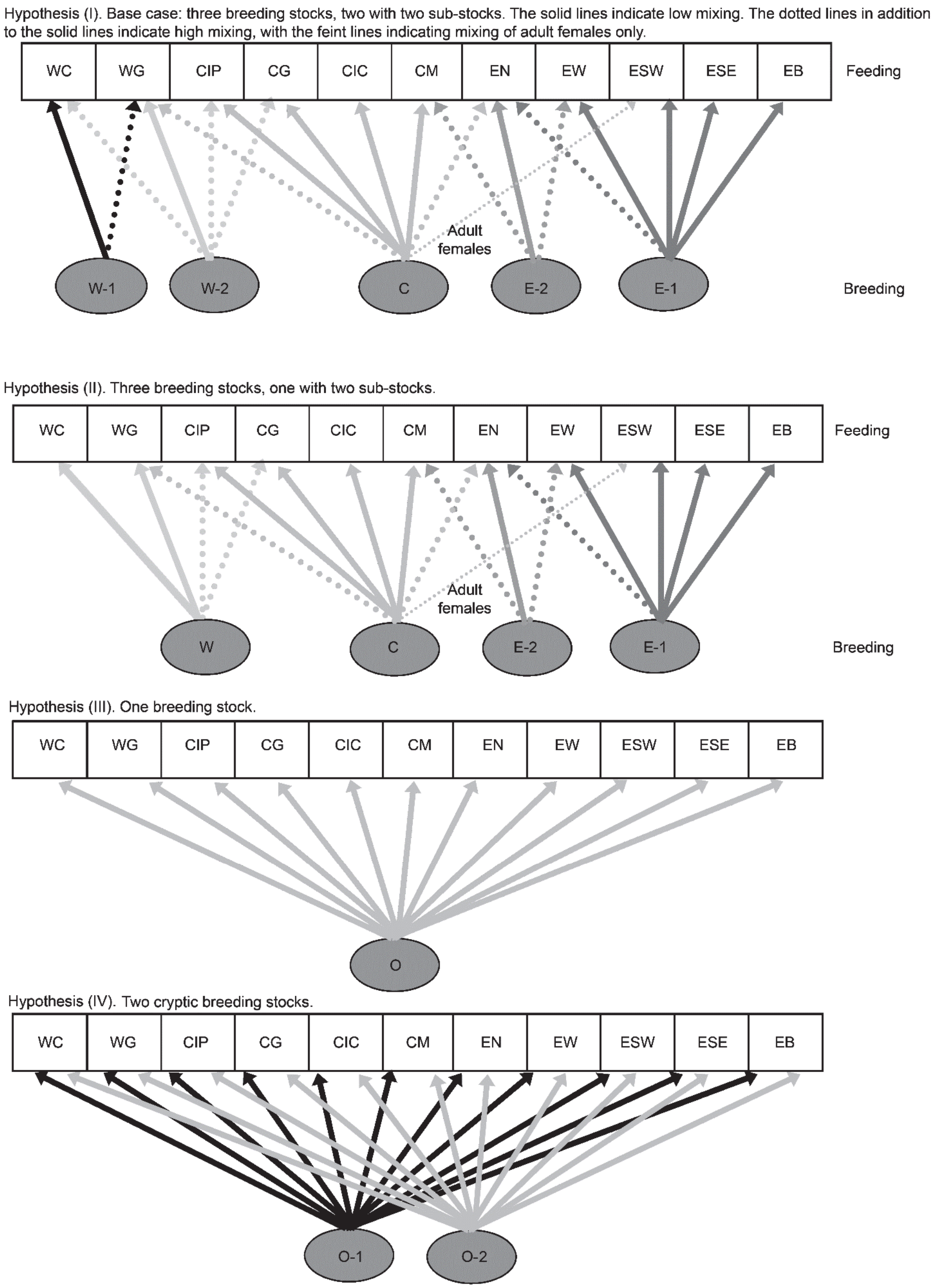

Fig. 2. Stock structure hypotheses for North Atlantic minke whales.

B. Basic dynamics

The dynamics of the animals in stock/sub-stock *j* are governed by equation B.1:

$$N_{t+1,a}^{g,j} = \begin{cases} 0.5\, b_{t+1}^{j} & \text{if } a=0 \\ (N_{t,a-1}^{g,j} - C_{t,a-1}^{g,j})\tilde{S}_{a-1} & \text{if } 1 \le a < x \\ (N_{t,x}^{g,j} - C_{t,x}^{g,j})\tilde{S}_{x} + (N_{t,x-1}^{g,j} - C_{t,x-1}^{g,j})\tilde{S}_{x-1} & \text{if } a = x \end{cases} \tag{B.1}$$

where

$N_{t,a}^{g,j}$ is the number of animals of gender *g* and age *a* in stock/sub-stock *j* at the start of year *t*;

$C_{t,a}^{g,j}$ is the catch (in number) of animals of gender *g* and age *a* in stock/sub-stock *j* during year *t* (whaling is assumed to take place in a pulse at the start of each year);

b_t^j is the number of calves born to females from stock/sub-stock *j* at the start of year *t*;

$\tilde{S}_a$ is the survival rate = e^{-M_a} where M_a is the instantaneous rate of natural mortality (assumed to be independent of stock, time, and gender); and

x is the maximum age (treated as a plus-group);

Note that *t*=0, the year for which catch limits might first be set, corresponds to 2015.

C. Births

Density-dependence is assumed to act on the 1+ population. The convention of referring to the mature population is used here, although this actually refers to animals that have reached the age of first parturition.

$$b_t^j = B^j N_t^{\mathrm{f},j}\{1 + A^j(1-(N_t^{\mathrm{f},j}/K^{\mathrm{f},j})^{z^j})\} \tag{C.1}$$

where

B^j is the average number of births (of both sexes) per year for a mature female in stock/sub-stock *j* in the pristine population;

A^j is the resilience parameter for stock/sub-stock *j*;

z^j is the degree of compensation for stock/sub-stock *j*;

$N_t^{\mathrm{f},j}$ is the number of 'mature' females in stock/sub-stock *j* at the start of year *t*:

$$N_t^{\mathrm{f},j} = \sum_{a=3}^{x} \beta_a N_{t,a}^{\mathrm{f},j} \tag{C.2}$$

β_a is the proportion of females of age *a* that have reached the age-at-first partition; and

$K^{\mathrm{f},j}$ is the number of mature females in stock/sub-stock *j* in the pristine (pre-exploitation, written as *t*=-∞) population:

$$K^{\mathrm{f},j} = \sum_{a=3}^{x} \beta_a N_{-\infty,a}^{\mathrm{f},j} \tag{C.3}$$

The values of the parameters A^j and z^j for each stock/sub-stock are calculated from the values for $MSYL^j$ and $MSYR^j$ (Punt, 1999). Their calculation assumes harvesting equal proportions of males and females.

D. Catches

The historical (pre-2015) catch series used is listed in adjunct 1 of IWC (2016, pp.165-168) and includes commercial, special permit and incidental catches. The numbers of incidental catches are small so these are not modelled into the future.

Catch limits are set by *Small Area*. It is assumed that whales are homogeneously distributed across a sub-area. The catch/strike limit for a sub-area is therefore allocated to stocks/sub-stocks by sex and age relative to their true density within that sub-area and a catch mixing matrix V.

The catch mixing matrix for these trials is based on the sightings mixing matrix, with the selectivity pattern by sex adjusted for each sub-area. Two fishing selectivity patterns are modelled in the WG sub-area to reflect the different sex ratio shown in different hunts: the recent aboriginal hunt in this area compared to that in the earlier commercial catches. All other sub-areas have just one hunt type and thus a single fishing selectivity per sub-area. Details of how the catch mixing matrix is set up is given in Section G.

$$C_{t,a}^{g,j} = \sum_{k}\sum_{h\in k} F_t^{g,h} V_{t,a}^{g,j,k} \tilde{S}_a^{g,h} N_{t,a}^{g,j} \tag{D.1}$$

$$F_t^{g,h} = \frac{C_t^{g,h}}{\sum_{j'}\sum_{a'} V_{t,a'}^{g,j',k} \tilde{S}_{a'}^{g,h} N_{t,a'}^{g,j'}} \tag{D.2}$$

where

$F_t^{g,h}$ is the exploitation rate in hunt *h* (within sub-area *k)* on fully recruited ($S_a^g \rightarrow 1$) whales of gender *g* during year *t*;

$V_{t,a}^{g,j,k}$ is the fraction of animals in stock/sub-stock *j* of gender *g* and age *a* that is in sub-area *k* during year *t*;

$\tilde{S}_a^{g,h}$ is the fishing selectivity on animals of gender *g* and age *a* by the hunt *h* (within sub-area *k*) which is based on the reference selectivity $R_a^{g,h}$ (see Equation G.5):

$C_t^{g,h}$ is the observed catch of animals of gender *g* in hunt *h* (within sub-area *k*) during year *t*. See adjunct 1 of IWC (2016, pp.165-168) for the historical catches. Future catches are allocated to sex using the modelled fishery sex ratio $\hat{\lambda}^{2,h}$ (see equation G.7).

E. Mixing

The entries in the mixing matrix *V* are selected to model the distribution of each stock/sub-stock at the time when the catch is removed/when the surveys are conducted. Mixing is stochastic.

For the two and three stock hypotheses (Hypotheses I and II), the default mixing matrix for each year is the average of the 'hi' and 'low' matrices (matrices A and B in Table 2).

In the high mixing option for Hypotheses I and II, three sub-stocks (C, E-1 and E-2) are found in sub-area EN. There are no data on which to condition the proportions of these sub-stocks in the sub-area so the trials assume 50% of the whales in sub-area EN in the pristine state are from the E-2 sub-stock, with trials NM09 and NM10 testing sensitivity to this assumption.

The historical variation in abundance estimates is due both to spatial variation in abundance, and also to sampling error. In future years, additional variance is added to the mixing matrices, in order to model the hypothesis that in any one year, some subareas are more attractive to minke whales than others (e.g. due to prey availability)[2]. To account for this hypothesised difference in annual distribution, the CV used for a sub-area when determining the extent of variation in mixing is the square root of the difference between the CV^2 of the abundance estimates for that sub-area and the corresponding median of the sampling error CV^2s (see Table 1a).

For the two and three stock hypotheses (Hypotheses I and II), this variation in future abundance is implemented by applying a power parameter to the mixing matrix entries for each subarea and year. The power parameters are generated every year from $U[\max(0,1-\chi_k),1+\chi_k]$, where the χ_k parameters defining the power parameter distributions are selected such that the realized variability of future populations over years 50-100 for the NM01-4 trial are close to the adjusted (target) CVs listed in Table 1a.

Trials NM-0x"v" test the alternative assumption that this future variability is half that of the baseline trials.

For the one stock and two cryptic stocks (Hypotheses III and IV), the additional variance is implemented by multiplying the elements of the mixing matrix (just for the O-1 matrix for trials NM04-1 and NM04-4) by lognormal random variables $=\exp(\xi_k)$ where $\xi_k \sim N(0;\sigma_k^2)$. The values of σ_k^2 are listed in Table 1b and are selected such that the realized variability of future populations over years 50-100 are close to the adjusted (target) CVs listed in Table 1a.

Table 1a

Statistics related to the validation of the method used to generate spatial variation in abundance by sub-area (see Punt, 2016, for the derivation of the basic approach). χ is the parameter that defines the distribution for the power parameter for each year (by sub-area). The power parameter is generated from $U[\max(0,1 - \chi),1 + \chi$. 'Actual CVs' are the CVs of the point estimates of abundance for each sub-area, except that the longer series of relative abundance indices reported in Heide-Jørgensen and Laidre (2008) is used for the WG subarea. 'Adjusted' CVs equal the square root of the difference between the CV^2 of the abundance estimates for that subarea and the corresponding median of the sampling error CV^2s.

	WC	WG	CIP	CG	CIC	CM	EN	EW	ESW	ESE	EB
Actual CVs		0.6981	0.8301	1.0553	0.5747	0.6138	0.5905	0.2274	0.4993	0.2188	0.1623
Adjusted CVs		0.5951	0.7380	1.0087	0.5018	0.5462	0.5349	0.1510	0.4064	0.1085	0.1623[1]
Baseline χ	1.72	0.97	0.78	0.77	3.60	1.20	0.65	0.31	0.22	0.07	0.30
'v' trials χ	0.90	0.63	0.44	0.37	1.40	0.37	0.36	0.16	0.107	0.04	0.166

[1]value would be < 0 so the actual CV is used here.

Table 1b

The additional variances used for Hypotheses III and IV.

Hypothesis	WC	WG	CIP	CG	CIC	CM	EN	EW	ESW	ESE	EB
III	0.48	1.19	1.48	2.02	1.00	1.09	1.07	0.30	0.81	0.22	0.32
IV	0.62	2.3	4	6	1.7	2	1.85	0.31	1.1	0.15	0.36

In Hypothesis IV, the ratio of the two pristine stocks is set equal to 4.

[2]It is unnecessary to model this variability in the past, as the purpose of the trials is to assess the effect of future catches.

Table 2

The mixing matrices. The γs and Ωs indicate that the entry concerned is estimated during the conditioning process. Note that the values for the γs and Ωs are the same for the high and low mixing matrices within each trial replicate.

	WC	WG	CIP	CG	CIC	CM	EN	EW	ESW	ESE	EB
Stock structure hypothesis I (matrix Ai) [high mixing]											
Adult females (ages 10+)											
W-1	1	γ_{10}	-	-	-	-	-	-	-	-	-
W-2	0.2	0.45	0.15	0.2	-	-	-	-	-	-	-
C	-	0.1	γ_2	γ_3	0.5 γ_4	γ_5	0.05	-	γ_6	-	-
E-1	-	-	-	-	-	-	0.1	γ_7	$0.1\gamma_6$	γ_8	γ_9
E-2	-	-	-	-	-	0.1	0.8	0.1	-	-	-
Adult males (ages 10+) and juveniles											
W-1	Ω_{11}	$\gamma_{10}\Omega_{12}$	-	-	-	-	-	-	-	-	-
W-2	0.2 Ω_{11}	0.45 Ω_{12}	0.15 Ω_{13}	$0.2\Omega_{14}$	-	-	-	-	-	-	-
C	-	0.1 Ω_{12}	$\gamma_2\,\Omega_{13}$	$\gamma_3\,\Omega_{14}$	$\gamma_4\,\Omega_{15}$	$\gamma_5\,\Omega_{16}$	0.05 Ω_{17}	-	-	-	-
E-1	-	-	-	-	-	-	0.1 Ω_{17}	$\gamma_7\,\Omega_{18}$	$0.1\gamma_6\,\Omega_{19}$	$\gamma_8\,\Omega_{20}$	$\gamma_9\,\Omega_{21}$
E-2	-	-	-	-	-	$0.1\Omega_{16}$	0.8 Ω_{17}	0.1 Ω_{18}	-	-	-
Stock structure hypothesis I (matrix Bi) [low mixing]											
Adult females (ages 10+)											
W-1	1	-	-	-	-	-	-	-	-	-	-
W-2	-	1	-	-	-	-	-	-	-	-	-
C	-	-	γ_2	γ_3	γ_4	γ_5	-	-	-	-	-
E-1	-	-	-	-	-	-	-	γ_7	$5\gamma_6$	5 γ_8	γ_9
E-2	-	-	-	-	-	-	1	-	-	-	-
Adult males (ages 10+) and juveniles											
W-1	1		-	-	-	-	-	-	-	-	-
W-2	-	1	-	-	-	-	-	-	-	-	-
C	-	-	$\gamma_2\,\Omega_{13}$	$\gamma_3\,\Omega_{14}$	2 $\gamma_4\,\Omega_{15}$	$\gamma_5\,\Omega_{16}$	-	-	-	-	-
E-1	-	-	-	-	-	-	-	$\gamma_7\,\Omega_{18}$	$5\gamma_6\,\Omega_{19}$	5 $\gamma_8\,\Omega_{20}$	$\gamma_9\,\Omega_{21}$
E-2	-	-	-	-	-	-	1	-	-	-	-
Stock structure hypothesis II (matrix Aii) [high mixing]											
Adult females (ages 10+)											
W	0.55	0.2	0.1	0.15	-	-	-	-	-	-	-
C	-	γ_1	γ_2	γ_3	0.5 γ_4	γ_5	0.05	-	γ_6	-	-
E-1	-	-	-	-	-	-	0.1	γ_7	$0.1\gamma_6$	γ_8	γ_9
E-2	-	-	-	-	-	0.1	0.8	0.1	-	-	-
Adult males (ages 10+) and juveniles											
W	0.2 Ω_{11}	Ω_{12}	0.1 Ω_{13}	0.2 Ω_{14}	-	-	-	-	-	-	-
C	-	0.1 $\gamma_1\Omega_{12}$	$\gamma_2\,\Omega_{13}$	$\gamma_3\,\Omega_{14}$	$\gamma_4\,\Omega_{15}$	$\gamma_5\,\Omega_{16}$	0.05 Ω_{17}	-	-	-	-
E-1	-	-	-	-	-	-	0.1 Ω_{17}	$\gamma_7\,\Omega_{18}$	$0.1\gamma_6\Omega_{19}$	$\gamma_8\,\Omega_{20}$	$\gamma_9\,\Omega_{21}$
E-2	-	-	-	-	-	$0.1\Omega_{16}$	0.8 Ω_{17}	0.1 Ω_{18}	-	-	-
Stock structure hypothesis II (matrix Bii) [low mixing]											
Adult females (ages 10+)											
W	1	-	-	-	-	-	-	-	-	-	-
C	-	γ_1	γ_2	γ_3	γ_4	γ_5	-	-	-	-	-
E-1	-	-	-	-	-	-	-	γ_7	$5\gamma_6$	5 γ_8	γ_9
E-2	-	-	-	-	-	-	1	-	-	-	-
Adult males (ages 10+) and juveniles											
W	1	-	-	-	-	-	-	-	-	-	-
C	-	$\gamma_1\,\Omega_{12}$	$\gamma_2\,\Omega_{13}$	$\gamma_3\,\Omega_{14}$	2 $\gamma_4\,\Omega_{15}$	$\gamma_5\,\Omega_{16}$	-	-	-	-	-
E-1	-	-	-	-	-	-	-	$\gamma_7\,\Omega_{18}$	$5\gamma_6\,\Omega_{19}$	5 $\gamma_8\,\Omega_{20}$	$\gamma_9\,\Omega_{21}$
E-2	-	-	-	-	-	-	1	-	-	-	-
Stock structure hypotheses III [high mixing]											
Adult females (ages 10+)											
O	γ_1	γ_2	γ_3	γ_4	γ_5	γ_6	γ_7	γ_8	γ_9	γ_{10}	1
Adult males (ages 10+) and juveniles											
O	$\gamma_1\,\Omega_{11}$	$\gamma_2\,\Omega_{12}$	$\gamma_3\,\Omega_{13}$	$\gamma_4\,\Omega_{14}$	$\gamma_5\,\Omega_{15}$	$\gamma_6\,\Omega_{16}$	$\gamma_7\,\Omega_{17}$	$\gamma_8\,\Omega_{18}$	$\gamma_9\,\Omega_{19}$	$\gamma_{10}\,\Omega_{20}$	Ω_{21}
Stock structure hypotheses IV [high mixing]											
Adult females (ages 10+)											
O-1	γ_1	γ_2	γ_3	γ_4	γ_5	γ_6	γ_7	γ_8	γ_9	γ_{10}	1
O-2	γ_1	γ_2	γ_3	γ_4	γ_5	γ_6	γ_7	γ_8	γ_9	γ_{10}	1
Adult males (ages 10+) and juveniles											
O-1	$\gamma_1\,\Omega_{11}$	$\gamma_2\,\Omega_{12}$	$\gamma_3\,\Omega_{13}$	$\gamma_4\,\Omega_{14}$	$\gamma_5\,\Omega_{15}$	$\gamma_6\,\Omega_{16}$	$\gamma_7\,\Omega_{17}$	$\gamma_8\,\Omega_{18}$	$\gamma_9\,\Omega_{19}$	$\gamma_{10}\,\Omega_{20}$	Ω_{21}
O-2	$\gamma_1\,\Omega_{11}$	$\gamma_2\,\Omega_{12}$	$\gamma_3\,\Omega_{13}$	$\gamma_4\,\Omega_{14}$	$\gamma_5\,\Omega_{15}$	$\gamma_6\,\Omega_{16}$	$\gamma_7\,\Omega_{17}$	$\gamma_8\,\Omega_{18}$	$\gamma_9\,\Omega_{19}$	$\gamma_{10}\,\Omega_{20}$	Ω_{21}
Stock structure hypothesis I, with no C stock in sub-area ESW (Trial NM05) (matrix A05) [high mixing]											
Adult females (ages 10+)											
W-1	1	γ_{10}	-	-	-	-	-	-	-	-	-
W-2	0.2	0.45	0.15	0.2	-	-	-	-	-	-	-
C	-	0.1	γ_2	γ_3	0.5 γ_4	γ_5	0.05	-	-	-	-
E-1	-	-	-	-	-	-	0.1	γ_7	$0.1\gamma_6$	γ_8	γ_9
E-2	-	-	-	-	-	0.1	0.8	0.1	-	-	-
Adult males (ages 10+) and juveniles											
W-1	Ω_{11}	$\gamma_{10}\Omega_{12}$	-	-	-	-	-	-	-	-	-
W-2	0.2 Ω_{11}	0.45 Ω_{12}	0.15 Ω_{13}	$0.2\Omega_{14}$	-	-	-	-	-	-	-
C	-	0.1 Ω_{12}	$\gamma_2\,\Omega_{13}$	$\gamma_3\,\Omega_{14}$	$\gamma_4\,\Omega_{15}$	$\gamma_5\,\Omega_{16}$	0.05 Ω_{17}	-	-	-	-
E-1	-	-	-	-	-	-	0.1 Ω_{17}	$\gamma_7\,\Omega_{18}$	$0.1\gamma_6\,\Omega_{19}$	$\gamma_8\,\Omega_{20}$	$\gamma_9\,\Omega_{21}$
E-2	-	-	-	-	-	$0.1\Omega_{16}$	0.8 Ω_{17}	0.1 Ω_{18}	-	-	-

Cont.

	WC	WG	CIP	CG	CIC	CM	EN	EW	ESW	ESE	EB
Stock structure hypothesis I (matrix Bi) [low mixing]											
Adult females (ages 10+)											
W-1	1	-	-	-	-	-	-	-	-	-	-
W-2	-	1	-	-	-	-	-	-	-	-	-
C	-	-	γ_2	γ_3	γ_4	γ_5	-	-	-	-	-
E-1	-	-	-	-	-	-	-	γ_7	$5\gamma_6$	$5\ \gamma_8$	γ_9
E-2	-	-	-	-	-	-	1	-	-	-	-
Adult males (ages 10+) and juveniles											
W-1	1	-	-	-	-	-	-	-	-	-	-
W-2	-	1	-	-	-	-	-	-	-	-	-
C	-	-	$\gamma_2\ \Omega_{13}$	$\gamma_3\ \Omega_{14}$	$2\ \gamma_4\ \Omega_{15}$	$\gamma_5\ \Omega_{16}$	-	-	-	-	-
E-1	-	-	-	-	-	-	-	$\gamma_7\ \Omega_{18}$	$5\gamma_6\ \Omega_{19}$	$5\ \gamma_8\ \Omega_{20}$	$\gamma_9\ \Omega_{21}$
E-2	-	-	-	-	-	-	1	-	-	-	-
Stock structure hypothesis II, with no C stock in sub-area ESW (Trial NM06) (matrix A06) [high mixing]											
Adult females (ages 10+)											
W	0.55	0.2	0.1	0.15	-	-	-	-	-	-	-
C	-	γ_1	γ_2	γ_3	$0.5\ \gamma_4$	γ_5	0.05	-	-	-	-
E-1	-	-	-	-	-	-	0.1	γ_7	$0.1\gamma_6$	γ_8	γ_9
E-2	-	-	-	-	-	0.1	0.8	0.1	-	-	-
Adult males (ages 10+) and juveniles											
W	$0.2\ \Omega_{11}$	Ω_{12}	$0.1\ \Omega_{13}$	$0.2\ \Omega_{14}$	-	-	-	-	-	-	-
C	-	$0.1\ \gamma_1\Omega_{12}$	$\gamma_2\ \Omega_{13}$	$\gamma_3\ \Omega_{14}$	$\gamma_4\ \Omega_{15}$	$\gamma_5\ \Omega_{16}$	$0.05\ \Omega_{17}$	-	-	-	-
E-1	-	-	-	-	-	-	$0.1\ \Omega_{17}$	$\gamma_7\ \Omega_{18}$	$0.1\gamma_6\Omega_{19}$	$\gamma_8\ \Omega_{20}$	$\gamma_9\ \Omega_{21}$
E-2	-	-	-	-	-	$0.1\Omega_{16}$	$0.8\ \Omega_{17}$	$0.1\ \Omega_{18}$	-	-	-
Stock structure hypothesis II (matrix Bii) [low mixing]											
Adult females (ages 10+)											
W	1	-	-	-	-	-	-	-	-	-	-
C	-	γ_1	γ_2	γ_3	γ_4	γ_5	-	-	-	-	-
E-1	-	-	-	-	-	-	-	γ_7	$5\gamma_6$	$5\ \gamma_8$	γ_9
E-2	-	-	-	-	-	-	1	-	-	-	-
Adult males (ages 10+) and juveniles											
W	1	-	-	-	-	-	-	-	-	-	-
C	-	$\gamma_1\ \Omega_{12}$	$\gamma_2\ \Omega_{13}$	$\gamma_3\ \Omega_{14}$	$2\ \gamma_4\ \Omega_{15}$	$\gamma_5\ \Omega_{16}$	-	-	-	-	-
E-1	-	-	-	-	-	-	-	$\gamma_7\ \Omega_{18}$	$5\gamma_6\ \Omega_{19}$	$5\ \gamma_8\ \Omega_{20}$	$\gamma_9\ \Omega_{21}$
E-2	-	-	-	-	-	-	1	-	-	-	-
Stock structure hypothesis I, without E-1 stock in sub-area ESW (Trial NM12) (matrix A12) [high mixing]											
Adult females (ages 10+)											
W-1	1	γ_{10}	-	-	-	-	-	-	-	-	-
W-2	0.2	0.45	0.15	0.2	-	-	-	-	-	-	-
C	-	0.1	γ_2	γ_3	$0.5\ \gamma_4$	γ_5	0.05	-	γ_6	-	-
E-1	-	-	-	-	-	-	0.1	γ_7	-	γ_8	γ_9
E-2	-	-	-	-	-	0.1	0.8	0.1	-	-	-
Adult males (ages 10+) and juveniles											
W-1	Ω_{11}	$\gamma_{10}\Omega_{12}$	-	-	-	-	-	-	-	-	-
W-2	$0.2\ \Omega_{11}$	$0.45\ \Omega_{12}$	$0.15\ \Omega_{13}$	$0.2\Omega_{14}$	-	-	-	-	-	-	-
C	-	$0.1\ \Omega_{12}$	$\gamma_2\ \Omega_{13}$	$\gamma_3\ \Omega_{14}$	$\gamma_4\ \Omega_{15}$	$\gamma_5\ \Omega_{16}$	$0.05\ \Omega_{17}$	-	$\gamma_6\ \Omega_{19}$	-	-
E-1	-	-	-	-	-	-	$0.1\ \Omega_{17}$	$\gamma_7\ \Omega_{18}$	-	$\gamma_8\ \Omega_{20}$	$\gamma_9\ \Omega_{21}$
E-2	-	-	-	-	-	$0.1\Omega_{16}$	$0.8\ \Omega_{17}$	$0.1\ \Omega_{18}$	-	-	-
Stock structure hypothesis I, without E-1 stock in sub-area ESW (Trial NM12) (matrix B12) [low mixing]											
Adult females (ages 10+)											
W-1	1	-	-	-	-	-	-	-	-	-	-
W-2	-	1	-	-	-	-	-	-	-	-	-
C	-	-	γ_2	γ_3	γ_4	γ_5	-	-	$5\gamma_6$	-	-
E-1	-	-	-	-	-	-	-	γ_7	-	$5\ \gamma_8$	γ_9
E-2	-	-	-	-	-	-	1	-	-	-	-
Adult males (ages 10+) and juveniles											
W-1	1	-	-	-	-	-	-	-	-	-	-
W-2	-	1	-	-	-	-	-	-	-	-	-
C	-	-	$\gamma_2\ \Omega_{13}$	$\gamma_3\ \Omega_{14}$	$2\ \gamma_4\ \Omega_{15}$	$\gamma_5\ \Omega_{16}$	-	-	$5\gamma_6\ \Omega_{19}$	-	-
E-1	-	-	-	-	-	-	-	$\gamma_7\ \Omega_{18}$	-	$5\ \gamma_8\ \Omega_{20}$	$\gamma_9\ \Omega_{21}$
E-2	-	-	-	-	-	-	1	-	-	-	-
Stock structure hypothesis II, without E-1 stock in sub-area ESW (Trial NM13) (matrix A13) [high mixing]											
Adult females (ages 10+)											
W	0.55	0.2	0.1	0.15	-	-	-	-	-	-	-
C	-	γ_1	γ_2	γ_3	$0.5\ \gamma_4$	γ_5	0.05	-	γ_6	-	-
E-1	-	-	-	-	-	-	0.1	γ_7	-	γ_8	γ_9
E-2	-	-	-	-	-	0.1	0.8	0.1	-	-	-
Adult males (ages 10+) and juveniles											
W	$0.2\ \Omega_{11}$	Ω_{12}	$0.1\ \Omega_{13}$	$0.2\ \Omega_{14}$	-	-	-	-	-	-	-
C	-	$0.1\ \gamma_1\Omega_{12}$	$\gamma_2\ \Omega_{13}$	$\gamma_3\ \Omega_{14}$	$\gamma_4\ \Omega_{15}$	$\gamma_5\ \Omega_{16}$	$0.05\ \Omega_{17}$	-	$\gamma_6\Omega_{19}$	-	-
E-1	-	-	-	-	-	-	$0.1\ \Omega_{17}$	$\gamma_7\ \Omega_{18}$	-	$\gamma_8\ \Omega_{20}$	$\gamma_9\ \Omega_{21}$
E-2	-	-	-	-	-	$0.1\Omega_{16}$	$0.8\ \Omega_{17}$	$0.1\ \Omega_{18}$	-	-	-
Stock structure hypothesis II, without E-1 stock in sub-area ESW (Trial NM13) (matrix B13) [low mixing]											
Adult females (ages 10+)											
W	1	-	-	-	-	-	-	-	-	-	-
C	-	γ_1	γ_2	γ_3	γ_4	γ_5	-	-	$5\gamma_6$	-	-
E-1	-	-	-	-	-	-	-	γ_7	-	$5\ \gamma_8$	γ_9
E-2	-	-	-	-	-	-	1	-	-	-	-
Adult males (ages 10+) and juveniles											
W	1	-	-	-	-	-	-	-	-	-	-
C	-	$\gamma_1\ \Omega_{12}$	$\gamma_2\ \Omega_{13}$	$\gamma_3\ \Omega_{14}$	$2\ \gamma_4\ \Omega_{15}$	$\gamma_5\ \Omega_{16}$	-	-	$5\gamma_6\ \Omega_{19}$	-	-
E-1	-	-	-	-	-	-	-	$\gamma_7\ \Omega_{18}$	-	$5\ \gamma_8\ \Omega_{20}$	$\gamma_9\ \Omega_{21}$
E-2	-	-	-	-	-	-	1	-	-	-	-

Table 3

The estimates of abundance and their sampling standard errors.

Year	Sub-Area	Abundance	CV	Year	Sub-Area	Abundance	CV
2007	WC	20,741	0.3	1989	EN	8,318	0.25
1987	WG*	3,266	0.31	1995	EN	22,536	0.23
1993	WG*	8,371	0.43	1998	EN	13,673	0.25
2005	WG	10,792	0.59	2004	EN	6,246	0.47
2007	WG	16,609	0.428	2009	EN	6,891	0.31
1988	CIP	8,431	0.245	1989	EW	20,991	0.17
2001	CIP	3,391	0.82	1995	EW	34,986	0.12
2007	CIP	1,350	0.38	1996	EW	23,522	0.13
1995	CIP+CG*	4,854	0.27	2006	EW	27,152	0.218
1987	CG	1,555	0.26	2011	EW	21,218	0.32
2001	CG	7,349	0.31	1995	ESW	2,691	0.29
2007	CG	1,048	0.6	1999	ESW	1,932	0.68
1987	CIC	24,532	0.32	2008	ESW	5,009	0.29
2001	CIC	43,633	0.19	1989	ESE	13,370	0.19
2007	CIC	20,834	0.35	1995	ESE	23,278	0.11
2009	CIC	9,588	0.24	1999	ESE	16,241	0.25
1988	CM	4,732	0.23	2003	ESE	19,377	0.33
1995	CM	12,043	0.28	2008	ESE	22,281	0.18
1997	CM	26,718	0.14	1989	EB	21,868	0.21
2005	CM	26,739	0.39	1995	EB	29,712	0.18
2010	CM	10,991	0.36	2000	EB	25,885	0.24
				2007	EB	28,625	0.23
				2013	EB	34,125	0.34

*Only used when applying the *CLA* to *Small* or Combination Areas consisting of both CIP and CG, and not used for CIP or CG sub-areas separately (e.g. when allocating a catch limit for a Combination Area to its component *Small Areas*).

F. Generation of data

The actual historical estimates of absolute abundance (and their associated CVs) provided to the RMP are listed in Table 2. The proposed plan for future surveys is given in Table 4. The trials assume that it takes two years for the results of a sighting survey to become available for use by the RMP and *SLA*, e.g. a survey conducted in 2015 could first be used for setting the catch limit in 2017.

The future estimates of abundance for a survey area (a sub-area for these trials) (say survey area K) are generated using the formula (IWC, 1991).

$$\hat{P} = PYw / \mu = P * \beta^2 Yw \qquad \text{(F.1)}$$

where

Y is a lognormal random variable $Y=e^{\delta}$ where $\varepsilon \sim N(0;\sigma_\varepsilon^2$ and $\sigma_\varepsilon^2 = \ell\text{n}(1+\alpha^2)$;

w is a Poisson random variable with $E(w) = \text{var}(w) = \mu = (P/P^*)/\beta^2$, Y and w are independent;

P is the current total (1+) population size in survey area K:

$$P = P_t^K = \sum_{k\in K}\sum_j\sum_g\sum_{a\geq 1} V_{t,a}^{g,j,k} N_{t,a}^{g,j} \qquad \text{(F.2)}$$

P^* is the reference population level, and is equal to the total (1+) population size in the survey area prior to the commencement of exploitation in the area being surveyed; and

F is the set of sub-areas making up survey area K.

Note that under the approximation $CV^2(ab)=CV^2(a)+CV^2(b)$, $E(\hat{P}) = P$ and $\text{CV}^2(\hat{P}) = \alpha^2 + \beta^2 P^*/P$. For consistency with the first stage screening trials for a single stock (IWC, 1991, p.109; 1994, p.85), the ratio $\alpha^2 : \beta^2 = 0.12 : 0.025$, so that:

$$CV^2(\hat{P}) = \tau(0.12 + 0.025P^*/P) \qquad \text{(F.3)}$$

The value of τ is calculated from the survey sampling CV's of earlier surveys in area K. If $\overline{CV^2}$ is the average value of CV^2 estimated for each of these surveys, and $\overline{P}$ is the average value of the total (1+) population sizes in area K in the years of these surveys, then:

$$\tau = \overline{CV^2} / (0.12 + 0.025P/\overline{P}) \qquad \text{(F.4)}$$

Note therefore that:

$$\alpha^2 = 0.12\tau \qquad \beta^2 = 0.025\tau \qquad \text{(F.5)}$$

The above equations apply in the absence of additional variance. If this is present with a *CV* of CV_{add}, then the following adjustment is made:

$$\sigma_\varepsilon^2 = \ell n(1 + \alpha^2 + CV_{add}^2 \qquad \text{(F.6)}$$

An estimate of the *CV* is generated for each sighting survey estimate of abundance $\hat{P}$:

$$CV(\hat{P})^2_{est} = \sigma^2 \chi^2 / n \qquad \text{(F.7)}$$

where $\sigma^2 = \ell n(1+\alpha^2 + \beta^2 P^* / \hat{P})$, and

χ^2 is a random number from a Chi-square distribution with *n* degrees of freedom (where *n*=10 as used for the North Pacific minke whale *Implementation trials*; IWC, 2004).

Table 4a

Sighting survey plan. The pattern of surveys from 2020-25 will be repeated every 6 years in the E areas, every 7 years in the C areas and every 10 years in sub-area WG. The years when Assessments are run are also shown.

	Country			
Season	Norway	Iceland	Greenland	Assessment year
2014	ESW, ESE	-	-	-
2015	EW, CM*	CIC, CIP, CG	WG	Yes
2016	EB	-	-	-
2017	EN	-	-	-
2018	-	-	-	-
2019	-	-	-	-
2020	EW	-	-	-
2021	ESW, ESE	-	-	Yes
2022	EB	CIC, CIP, CG, CM	-	-
2023	EN	-	-	-
2024	-	-	-	-
2025	-	-	WG	-

**CM to be covered as a NAMMCO joint effort in TNASS-2015.*

Table 4b

List of past and planned sightings surveys and the constituents used in setting estimates for areas that are combinations of sub-areas. -=No survey, 1=survey.

	CIP	CG	CIC	CM	CIP, CIC, CM	All C subareas	EN	EW	ESW	ESE	EB	EB, ESW, ESE, EW	EB, EW	ESW, ESE	All E subareas
1987	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
1988	1	0	0	1	1=1987-8	1=1987-8	0	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	1	1	0	1	1	1=1989	1=1989	1=1989	1=1989
1990	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1993	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1995	1*	1*	0	1	0	0	1	1	1	1	1	1=1995	1=1995	1=1995	1=1995
1996	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
1997	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
1998	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
1999	0	0	0	0	0	0	0	0	1	1	0	0	0	1=1999	0
2000	0	0	0	0	0	0	0	0	0	0	1	1=1996-2000	1=1996-2000	0	1=1996-2000
2001	1	1	1	0	1=1995-2001	1=1995-2001	0	0	0	0	0	0	0	0	0
2002	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2003	0	0	0	0	0	0	0	0	0	1	0	0	0	1=2003	0
2004	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
2005	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
2006	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
2007	1	1	1	0	0	0	0	0	0	0	1	1=2003-7	1=2006-7	0	1=2003-7
2008	0	0	0	0	0	0	0	0	1	1	0	0	0	1=2008	0
2009	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0
2010	0	0	0	1	1=2005-10	1=2005-10	0	0	0	0	0	0	0	0	0
2011	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
2012	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	0	0	0	0	0	0	0	0	0	0	1	1=2008-13	1=2011-13	0	1=2008-13
2014	0	0	0	0	0	0	0	0	1	1	0	0	0	1=2014	0
2015	1	1	1	1	1=2015	1=2015	0	1	0	0	0	0	0	0	0
2016	0	0	0	0	0	0	0	0	0	0	1	1=2014-6	1=2015-6	0	0
2017	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1=2014-7
2018	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2019	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2020	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
2021	0	0	0	0	0	0	0	0	1	1	0	0	0	1=2021	0
2022	1	1	1	1	1=2022	1=2022	0	0	0	0	1	1=2020-22	1=2020-22	0	0
2023	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1=2020-23
2024	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2025	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2026	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
2027	0	0	0	0	0	0	0	0	1	1	0	0	0	1=2027	0
2028	0	0	0	0	0	0	0	0	0	0	1	1=2026-28	1=2026-28	0	0
2029	1	1	1	1	1=2029	1=2029	1	0	0	0	0	0	0	0	1=2026-29

*Only used when applying the *CLA* to *Small* or Combination Areas consisting of both CIP and CG, and not used for CIP or CG sub-areas separately.

G. Parameters and conditioning
The values for the biological and technological parameters are listed in Tables 5a and 5b.

Table 5a
The values for the biological parameters that are fixed.

Parameter	Value
Plus group age, *x*	20 years
Natural mortality, *M*	$M_a \begin{cases} 0.085 & \text{if } a \le 4 \\ 0.0775 + 0.001875a & \text{if } 4 < a < 20 \\ 0.115 & \text{if } a \ge 20 \end{cases}$
Maturity (first parturition), β_a	$a_{50} = 8$; δ=1.2
Maximum Sustainable Yield Level, *MSYL*	0.6 in terms of the 1+ population

Table 5b
The values for the selectivity parameters by area.

Parameter	Value
West *Medium Area* (commercial)	$a_{50}^{g,k} = 5;\ \delta^{g,k} = 1.2$
West Greenland (aboriginal)	$a_{50}^{g,k} = 1;\ \delta^{g,k} = 1.2$
Central *Medium Area*	$a_{50}^{g,k} = 4;\ \delta^{g,k} = 1.2$
Eastern *Medium Area*	$a_{50}^{g,k} = 5;\ \delta^{g,k} = 1.2$

The 'free' parameters of the operating model are the initial (pre-exploitation) sizes of each of the sub-stocks/stocks, the values that determine the mixing matrices (i.e. the γ and Ω parameters) and the hunt factors that allow for differences between survey and fishery selectivity (the ω^h parameters). The process used to select the values for these 'free' parameters is known as conditioning. The conditioning process involves first generating 100 sets of 'target' data as detailed in steps (a) and (b) below, and then fitting the population model to each (in the spirit of a bootstrap). The number of animals in sub-area *k* at the start of year *t* is calculated starting with guessed values of the initial population sizes and projecting the operating model forward to 2014 to obtain values of abundance and sex ratios by sub-area for comparison with the generated data.

The likelihood function used when fitting the model consists of three components. Equations G.2, G.3 and G.6 list the negative of the logarithm of the likelihood for each of these components so the objective function minimised is $L_1+L_2+L_3$. An additional penalty is added to the likelihood if the full historical catch is not removed.

(a) Abundance estimates
The 'target' values for the historical abundance by sub-area are generated using the formula:

$$P_t^k = O_t^k \exp[\mu_t^k - (\sigma_t^k)^2 / 2];\ \mu_t^k \sim N[0;(\sigma_t^k)^2] \qquad \text{(G.1)}$$

where

P_t^k is the abundance for sub-area *k* in year *t*;

O_t^k is the actual survey estimate for sub-area *k* in year *t* (Table 3); and

σ_t^k is the CV of O_t^k.

The contribution to the likelihood from the abundance data is given by:

$$L_1 = 0.5\sum_n \frac{1}{(\sigma_n)^2} \ell n\left(P_n / \hat{P}_n\right)^2 \qquad \text{(G.2)}$$

where $\hat{P}_n$ is the model estimate of the 1+ abundance in the same year and sub-area as the n^{th} estimate of abundance P_n (the target abundances).

(b) Sex ratios
The parameters used to define the catch and the sightings mixing matrices are set up during the conditioning process. The data on catch sex-ratios by month (see adjunct 2 in IWC, 2016, pp.168-70) for North Atlantic minke whales suggest that the relative proportion of males differs between the primary catching season (i.e. before July) and the time when surveys are conducted and thereafter (July onwards) for at least sub-areas ES and EB.

In principle, the entries of the catch and sightings mixing matrices can be estimated given information on the numbers of animals by sub-area and their age-/sex-structure when catching/sighting surveys take place. However, there is insufficient information to allow estimation in this case so the parameters are set as detailed below.

(I) SEX RATIO DURING SIGHTING SURVEYS

The sighting mixing matrix is used to calculate the number of animals in each sub-area by stock, sex and age in order to generate the sightings abundance estimates on which *SLA*s and the RMP are based (see equation F.2).

The 'observed' values for the pristine sex-ratios by sub-area are obtained by assigning sex ratios (the 'survey' sex ratios) to each sub-area. These 'survey' sex-ratios are not measured directly, so they have to be inferred (and hence are not strictly data in the customary meaning of the word). The operating models are conditioned to values intended to reflect such ratios at the time when whaling commenced. These values and their associated standard errors are estimated from catch-by-sex information for the earliest period of relatively substantial whaling in each sub-area for the month in which surveys take place (in September for WG and in July for all other areas). The details of the estimation process are given in Punt (2016) and the data on which they are based are given in adjunct 2 in IWC (2016, pp.168-70). The conditioning uses the values as estimated for each area, but rounded values for their standard errors, which were agreed to be 0.05 for all sub-areas except that CIP and ESW (for which there is less past information because of fewer catches) which were agreed to be 0.1 (these values are somewhat larger than the averages of corresponding values in Punt (2016) because the estimation process used there is negatively biased, for example because of overdispersion of the samples compared to the binomial variance assumption made). The proportions and the standard deviations used are listed in Table 6. The 'target' values ($\lambda^{1,k}$) are generated as normal variates of these values, bounded by 0.02 and 0.98.

Table 6

The proportion of females in the surveys (the 'observed' survey sex-ratios).

Sub-area (*k*)	WC	WG	CIP	CG	CIC	CM	EN	EW	ESW	ESE	EB
'Survey' sex ratio	0.527	0.556	0.276	0.429	0.399	0.584	0.403	0.446	0.562	0.481	0.437
SE	0.05	0.05	0.1	0.05	0.05	0.05	0.05	0.05	0.1	0.05	0.05

The contribution to the likelihood from the survey sex ratios is given by:

$$L_2 = 0.5\sum_k \left(\hat{\lambda}^{1,k} - \lambda^{1,k}\right)^2 / \left(\sigma^{1,k}\right)^2 \tag{G.3}$$

where

$\lambda^{1,k}$ is the target sex-ratio (proportion of females) for sub-area *k* in the pristine population during the month in which surveys take place;

$\hat{\lambda}^{1,k}$ is the model-estimate of the sex-ratio for sub-area *k* in the pristine population:

$$\hat{\lambda}^{1,k} = \frac{\sum_a \sum_j V^{f,j,k}_{-\infty,a} S^{f,k}_a N^{f,j}_{-\infty,a}}{\sum_g \sum_{a'} \sum_{j'} V^{g,j',k}_{-\infty,a'} S^{g,k}_a N^{g,j'}_{-\infty,a'}} \tag{G.4}$$

$\sigma^{1,k}$ is the between-period variation in the sex-ratios for sub-area *k* during the month in which surveys take place (see table 6).

$S^{g,k}_a$ is the survey selectivity for gender *g* in subarea *k* and is equal to the 'Reference' selectivity $R^{g,h\in k}_a$ where

$$R^{g,h}_a = (1 + e^{-(a - a^{g,h}_{50})/\delta^{g,h}})^{-1} \tag{G.5}$$

$a^{g,h}_{50}$, $\delta^{g,h}$ are the parameters of the (logistic) selectivity ogive for gender *g* and hunt *h* (see Table 5b); and

in sub-area WG (where there are two hunts), the survey selectivity is based on the reference selectivity of the commercial hunt ($R^{g,h=\text{WG-com}}_a$) rather than the aboriginal hunt (see Table 7 for the relationship between the 'Reference' selectivity and the survey selectivity values).

Table 7

Relationship between hunts, sub-areas and the selectivity arrays.

Hunt (h)	WC	WG-com	WG-ab	CIP	CG	CIC	CM	EN	EW	ESW	ESE	EB
Sub-area (k)	WC	WG	-	CIP	CG	CIC	CM	EN	EW	ESW	ESE	EB
Parameters used in setting the Reference selectivity $R_a^{g,h}$ (see equation G.5):												
$a_{50}^{g,h}$	5	5	1	4	4	4	4	5	5	5	5	5
$\delta^{g,h}$	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
The survey selectivity $S_a^{g,k}$ =	$R_a^{g,h}$	$R_a^{g,h=\text{WG-com}}$	-	$R_a^{g,h}$	$R_a^{g,h}$	$R_a^{g,h}$	$R_a^{g,h}$	$R_a^{g,h}$	$R_a^{g,h}$	$R_a^{g,h}$	$R_a^{g,h}$	$R_a^{g,h}$
Fishing selectivity parameters (see equation G.8)												
ω^h	1	1	Est.	1	Est.	Est.	1	Est.	Est.	1	Est.	Est.

(II) FISHERY SEX RATIOS

The catch mixing matrix for these trials is based on the sightings mixing matrix, with the selectivity pattern by sex adjusted so that the split of the catch to sex in a sub-area matches that actually observed over a recent period if the whalers selected whales at random from those available. In the base-case, the most recent period (2008-13) is used to estimate the parameters by sub-area to adjust the selectivity pattern given that this period is likely to be best reflective of how future whaling operations will occur, and is trial-dependent. Trials NM07-1 and NM07-4 test the effect of using sex-ratios based on catches from the 2002-07 period.

These 'fishery' sex-ratios apply to the season as a whole. Since catch-by-sex data are available for all sub-areas/hunts and seasons for which future catches will be simulated (see Table 8), the fishery sex-selectivity parameter estimated for these sub-areas/hunts provides the flexibility for an exact fit by the model to this information.

Two fishing selectivity patterns are modelled in the WG sub-area to reflect the different sex ratio shown in different hunts: the recent aboriginal hunt in this area compared to that in the earlier commercial catches. All other sub-areas have just one hunt type and thus a single fishing selectivity per sub-area.

The 'target' values ($\lambda^{2,h}$) for the fishery sex ratios are generated as normal variates from the estimated proportion of females over a recent period bounded by 0.02 and 0.98. The estimated female proportions are given in Table 8; details of the estimation process is given in Punt (2016) and the data on which they are based are given in adjunct 2 in IWC (2016, pp.168-70).

Table 8

The proportion of females in recent catches (the 'observed' fishery sex-ratios and their standard errors).

Hunt	WG-ab	CG	CIC	EN	EW	ESE	EB
Baseline Fishery sex ratio (using years 2008-13)	0.722	0.436	0.267	0.738	0.434	0.926	0.662
SE $\sigma^{2,h}$	0.023	0.12	0.058	0.096	0.023	0.014	0.071
Fishery sex ratio in Trial 07 (using years 2002-07)	0.747	0.665	0.502	0.506	0.496	0.944	0.691
SE	0.015	0.156	0.051	0.042	0.018	0.016	0.094

The contribution to the likelihood from the fishery sex ratios is given by:

$$L_3 = 0.5\sum_h \left(\hat{\lambda}^{2,h} - \lambda^{2,h}\right)^2 / \left(\sigma^{2,h}\right)^2 \tag{G.6}$$

where

$\lambda^{2,h}$ is the target fishery sex-ratio (proportion of females) for hunt h (see above);

$\hat{\lambda}^{2,h}$ is the model-estimate of the sex-ratio for hunt h:

$$\hat{\lambda}^{2,h} = \sum_t \left\{ \left(C_t^{\text{m},h} + C_t^{\text{f},h}\right) \frac{\sum_a \sum_j \sum_{k\in h} V_{t,a}^{\text{f},j,k} \tilde{S}_a^{\text{f},h} N_{t,a}^{f,j}}{\sum_g \sum_{a'} \sum_{j'} \sum_{k\in h} V_{t,a'}^{g,j',k} \tilde{S}_{a'}^{g,h} N_{t,a'}^{f,j'}} \right\} / \sum_{t'} \left(C_{t'}^{\text{m},h} + C_{t'}^{\text{f},h}\right) \tag{G.7}$$

$\tilde{S}_a^{g,h}$ is the fishing selectivity on animals of gender g and age a by the hunt h (within sub-area k) which is based on the reference selectivity $R_a^{g,h}$ (see Equation G.5 and Table 7):

$$\tilde{S}_a^{\text{m},h} = \omega^h R_a^{\text{m},h} \quad \text{and} \quad \tilde{S}_a^{\text{f},h} = R_a^{\text{f},h} \tag{G.8}$$

ω^h is the difference in male selectivity in the catches over the year compared to the value at the time of the survey in hunts h for which a future catch is set (and is set to 1 in other hunts); and

$\sigma^{2,h}$ is the between-period variation in the catch sex-ratios for hunt h; (see Table 8).

H. Trials

The *Implementation Simulation Trials* for the North Atlantic minke whales are listed in Table 9. All trials are based on the assumption that $g(0)=1$. The majority of the sensitivity tests are based on stock structure hypothesis I because this hypothesis is likely to be the most challenging from a conservation standpoint.

Table 9

The *Implementation Simulation Trials* for North Atlantic minke whales.

Trial no.	Stock hypothesis	*MSYR*	No. of stocks	Boundaries	Catch sex-ratio for selectivity	Trial weight	Notes
NM01-1	I	1%[1]	3	Baseline	2008-13	M	3 stocks, E and W with sub-stocks
NM01-4	I	4%[2]	3	Baseline	2008-13	H	3 stocks, E and W with sub-stocks
NM02-1	II	1%[1]	2	Baseline	2008-13	M	2 stocks, E with sub-stocks
NM02-4	II	4%[2]	2	Baseline	2008-13	H	2 stocks, E with sub-stocks
NM03-1	III	1%[1]	1	Baseline	2008-13	M	1 stock
NM03-4	III	4%[2]	1	Baseline	2008-13	M	1 stock
NM04-1	IV	1%[1]	2	Baseline	2008-13	M	2 cryptic stocks
NM04-4	IV	4%[2]	2	Baseline	2008-13	M	2 cryptic stocks
NM05-1	I	1%[1]	3	Stock C not in ESW	2008-13	M	3 stocks, E and W with sub-stocks
NM05-4	I	4%[2]	3	Stock C not in ESW	2008-13	M	3 stocks, E and W with sub-stocks
NM06-1	II	1%[1]	2	Stock C not in ESW	2008-13	M	2 stocks, E with sub-stocks
NM06-4	II	4%[2]	2	Stock C not in ESW	2008-13	M	2 stocks, E with sub-stocks
NM07-1	I	1%[1]	3	Baseline	**2002-07**	M	Alternative years to adjust selectivity-at-age
NM07-4	I	4%[2]	3	Baseline	**2002-07**	M	Alternative years to adjust selectivity-at-age
NM09-1	I	1%	3	Baseline	2008-13	M	E-2 stock in EN 10%
NM09-4	I	4%	3	Baseline	2008-13	M	E-2 stock in EN 10%
NM10-1	I	1%	3	Baseline	2008-13	M	E-2 stock in EN 90%
NM10-4	I	4%	3	Baseline	2008-13	M	E-2 stock in EN 90%
NM12-1	I	1%[1]	3	Stock E1 not in ESW	2008-13	M	3 stocks, E and W with sub-stocks
NM12-4	I	4%[2]	3	Stock E1 not in ESW	2008-13	M	3 stocks, E and W with sub-stocks
NM13-1	II	1%[1]	2	Stock E1 not in ESW	2008-13	M	2 stocks, E with sub-stocks
NM13-4	II	4%[2]	2	Stock E1 not in ESW	2008-13	M	2 stocks, E with sub-stocks
NM01-1v	I	1%[1]	3	Baseline	2008-13	M	CV of future abundance = ½ basecase value
NM01-4v	I	4%[2]	3	Baseline	2008-13	H	CV of future abundance = ½ basecase value
NM02-1v	II	1%[1]	2	Baseline	2008-13	M	CV of future abundance = ½ basecase value
NM02-4v	II	4%[2]	2	Baseline	2008-13	H	CV of future abundance = ½ basecase value
NM03-1v	III	1%[1]	1	Baseline	2008-13	M	CV of future abundance = ½ basecase value
NM03-4v	III	4%[2]	1	Baseline	2008-13	M	CV of future abundance = ½ basecase value
NM04-1v	IV	1%[1]	2	Baseline	2008-13	M	CV of future abundance = ½ basecase value
NM04-4v	IV	4%[2]	2	Baseline	2008-13	M	CV of future abundance = ½ basecase value

[1]1+; [2]mature

I. Management options

All the Management variants are based on applying catch cascading from the C and E *Combination areas* (which are identical to the C and E *Medium areas*). In all cases catch limits for sub-areas WG and CG are based on an *SLA*[3] and WC is a residual area. The following management variants will be considered:

V1 Sub-areas CIC, CM, CG, CIP, EN, EB, ESW+ESE and EW are *Small Areas*, with the catch limits for these *Small Areas* based on catch cascading from the C and E *Combination Areas*. The catch from the ESW+ESE *Small Area* is all taken in the ESE sub-area. The catch limits set for the CM, CG and CIP *Small Areas* are not taken (except that the Aboriginal catch is taken from CG);

V2 Sub-areas CIC, CM, CG, CIP, EN and EB+ESW+ESE+EW are *Small Areas*, with the catch limits for these *Small Areas* based on catch cascading from the C and E *Combination Areas*. The catch from the EB+ ESW+ESE +EW *Small Area* is all taken in the EW sub-area. The catch limits set for the CM, CG and CIP *Small Areas* are not taken (except that the Aboriginal catch is taken from CG);

V3 Sub-areas CIC, CM, CG, CIP, EN, ESW+ESE, and EB+EW are *Small Areas*, with the catch limits for these *Small Areas* based on catch cascading from the C and E *Combination Areas*. The catch from the EB+ EW *Small Area* is all taken in the EW sub-area and the catch from the ESW+ESE *Small Area* is taken in the ESE sub-area. The catch limits set for the CM, CG and CIP *Small Areas* are not taken (except that the Aboriginal catch is taken from CG);

V4 As for V1, except that sub-areas CIC+CIP+CM are a single *Small Area* and all of the catches from this *Small Area* are taken in the CIC sub-area. The catch limits set for the CG *Small Area* are not taken (except that the Aboriginal catch is taken); and

V5 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 the CIC sub-area (after taking the Aboriginal catch from CG) and those for the ESW+ESE *Small Area* are taken in the ESE sub-area.

[3]In the absence of an *SLA* the quota for the years 2015, 2016, 2017, and 2018 is used: 164 in the WG sub-area and 12 in CG.

If the RMP catch limit for the *Combination Area* or *Small Area* containing the CG sub-area is:

(i) ≤ the aboriginal strike limit, 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

(ii) > the aboriginal strike limit, the RMP catch limits are set as usual.

J. Output statistics

The population-size statistics are produced for each feeding ground and stock, while the catch-related statistics are for each sub-area.

(1) Total catch (TC) distribution: (a) median; (b) 5th value; (c) 95th value.

(2) Initial mature female population size (P_{initial}) distribution: (a) median; (b) 5th value; (c) 95th value.

(3) Final mature female population size (P_{final} distribution: (a) median; (b) 5th value; (c) 95th value.

(4) Lowest mature female population size (P_{lowest}) distribution: (a) median; (b) 5th value; (c) 95th value.

(5) Average catch by sub-area over the first ten years of the 100-year management period: (a) median; (b) 5th value; (c) 95th value.

Average catch by sub-area over the last ten years of the 100-year management period: (a) median; (b) 5th value; (c) 95th values.

Plots are produced showing following types of outputs for all variants and the no-catch scenarios:

(a) the median population size trajectories by stock;

(b) the 5%-ile, median and 95%-ile of the population depletion trajectories by stock (from 2000 to the end of the projection period);

(c) the median catch trajectories from 2000 onwards; and

(d) ten individual population trajectories for each stock.

In addition, plots and tables are produced summarising the application of the procedure for defining 'acceptable' - A, 'borderline' - B and 'unacceptable' - U performance, by comparison with the equivalent single stock trials; see IWC (2005).

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