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COMING SOON - RMP Intersessional Workshop on the North Atlantic Minke Whale Implementation Review, February 2015, Copenhagen, Denmark

International Whaling Commission

INTERNATIONAL
WHALING COMMISSION

Report of the Workshop on the *Implementation Review* for North Atlantic Common Minke Whales

Contents

The Workshop was held at the Greenland Representation, Copenhagen, 16-20 February 2015[1]. The list of participants is given as Annex A.

1 INTRODUCTORY ITEMS

1.1 Convenor's opening remarks

Donovan welcomed the Participants to the Greenland Representation and thanked the hosts for once again providing excellent facilities. This Workshop was approved by the Scientific Committee in 2014 (IWC, 2015) to further the work on the *Implementation Review* for North Atlantic common minke whales which it is hoped to be completed in 2016. The Committee has developed an initial trials structure and work has commenced to code the trials and condition them. The objectives of this workshop are to: (a) review progress with the conditioning of the trials; (b) finalise trial specifications; and (c) specify the management variants to consider intersessionally.

1.2 Election of Chair

Donovan was elected Chair.

1.3 Appointment of rapporteurs

Allison, Butterworth, Punt and Donovan acted as rapporteurs.

1.4 Adoption of Agenda

The adopted Agenda is given as Annex B.

1.5 Documents available

The list of documents is given as Annex C.

2 PROGRESS ON INTERSESSIONAL TASKS

2.1 Finalise survey estimates for conditioning

Allison circulated the most recent information on abundance estimates and these were reviewed by the Workshop. The agreed estimates are listed in Annex E, which contains the most recent version of the trial specifications. In particular, the Workshop **agreed** that the estimates from the most recent set of Norwegian surveys, which will be submitted to the 2015 annual Scientific Committee meeting, were suitable to be used in conditioning, recognising that a full discussion of the estimates will take place at that meeting.

2.2 Finalise commercial and aboriginal catch series

Allison reported that she had updated the commercial and aboriginal catch series but that bycatches had not yet been added.

2.3 Finalise code

Allison reported that considerable progress in finalising the code developed by Punt after the 2014 Scientific Committee meeting had been achieved in conjunction with DeMoor.

2.4 Conditioning

Allison reported on the results of some initial conditioning runs based on the work of Punt. This is discussed further under Item 3.

2.5 Review relevant information from AWMP workshop

Donovan reported that there was no relevant new information from the recent AWMP workshop to develop *Strike Limit Algorithms* for the Greenland hunts. However, it was noted that the projections would account for aboriginal subsistence catches off West Greenland (see Item 6).

3 REVIEW RESULTS OF CONDITIONING OF INITIAL TRIALS

IWC (2015) developed an initial set of *Implementation Simulation Trials* for North Atlantic common minke whales. These trials were based on four stock-structure hypotheses, and two values for the MSY rate (Table 1 and Figs 1 and 2). The stock-structure hypotheses explore scenarios with between one and three stocks, with some of the stocks consisting of sub-stocks. The trials are conditioned by fitting the operating model to three sources of 'data':

(a) abundance estimates (from surveys that take place in July for all sub-areas except West Greenland where surveys are in September);
(b) sex-ratios by sub-area for the month when surveys take place (the 'survey' sex-ratios); and
(c) sex-ratios by sub-area when catches take place (the 'fishery' sex-ratios).

[1] Note: this time period was shared with the RMP Workshop on fin whales in the North Atlantic.

Table 1

Initial list of North Atlantic minke whale *Implementation Simulation Trials* developed at SC65b

Trial No.	Stock Hypothesis	*MSYR*	No. of Stocks	Boundaries	Catch sex-ratio for selectivity	Sex ratio in sub-areas ES, EB and WG, CM	Notes
NM01-1 & 4	I	1%1 & 4%[2]	3	Baseline	2008-13	Baseline	3 stocks, E and W with sub-stocks
NM02-1& 4	II	1%[1]	2	Baseline	2008-13	Baseline	2 stocks, E with sub-stocks
NM03-1& 4	III	1%[1]	1	Baseline	2008-13	Baseline	1 stock
NM04-1& 4	IV	1%[1]	2	Baseline	2008-13	Baseline	2 cryptic stocks
NM05-1& 4	I	1%[1]	3	Stock C not in ESW	2008-13	Baseline	3 stocks, E and W with sub-stocks
NM06-1& 4	II	1%[1]	2	Stock C not in ESW	2008-13	Baseline	2 stocks, E with sub-stocks
NM07-1& 4	I	1%[1]	3	Baseline	**2002-07**	Baseline	Alternative years to adjust selectivity-at-age
NM08-1& 4	I	1%[1]	3	Baseline	2008-13	Half baseline	Lower proportion of males in the northern areas

1 – 1+; 2 –mature

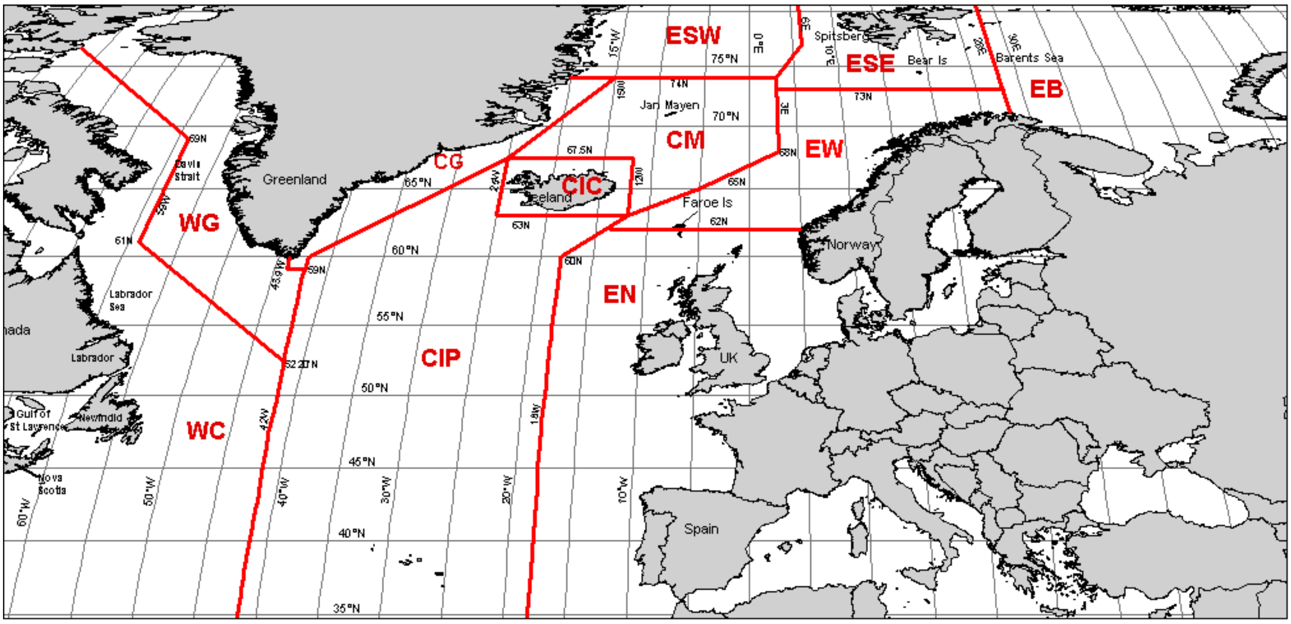

Fig. 1. Map of the North Atlantic showing the sub-areas defined for the North Atlantic Minke whales.

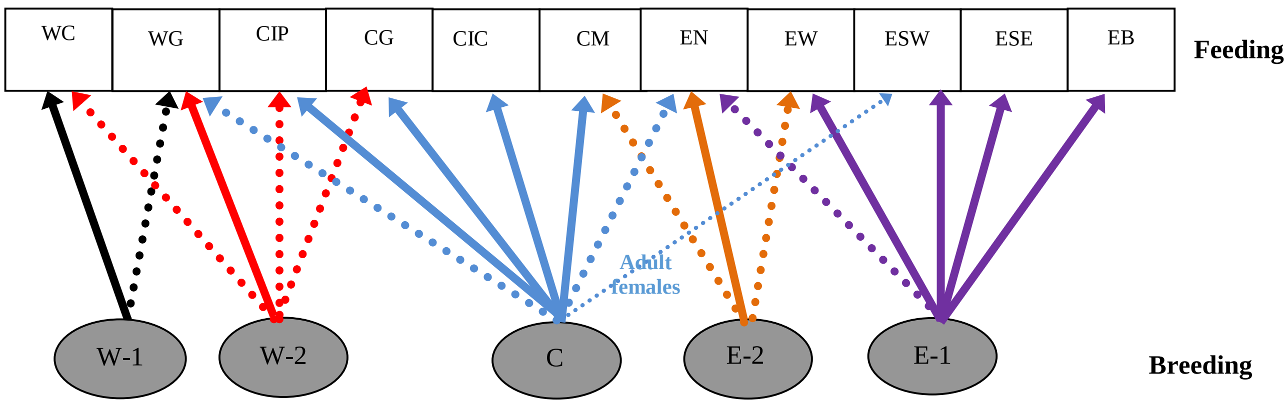

Fig. 2a. Hypothesis (I). Base case: 3 breeding stocks, two with two sub-stocks. The solid lines indicate low mixing. The dotted lines in addition to the solid lines indicate high mixing, with the feint lines indicating mixing of adult females only.

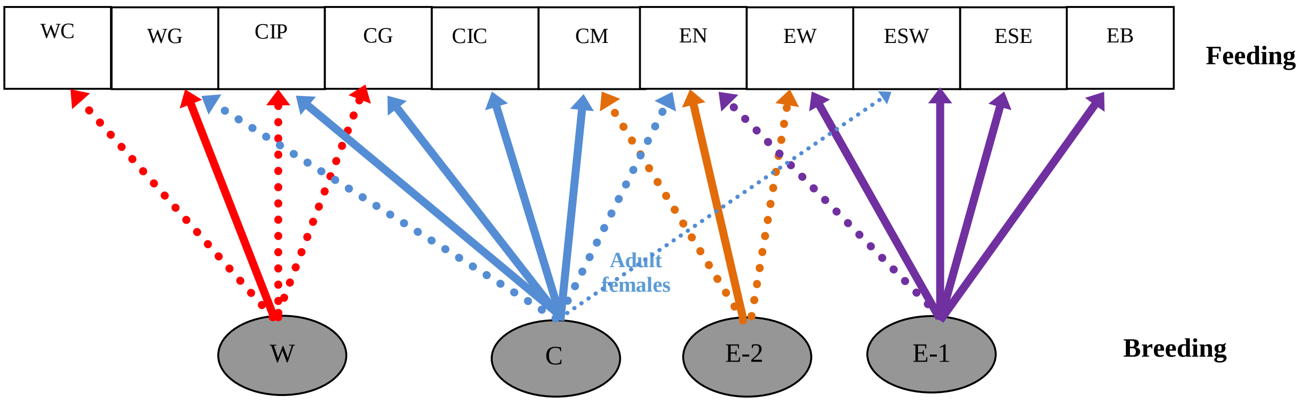

Fig. 2b. Hypothesis (II). 3 breeding stocks, one with two sub-stocks.

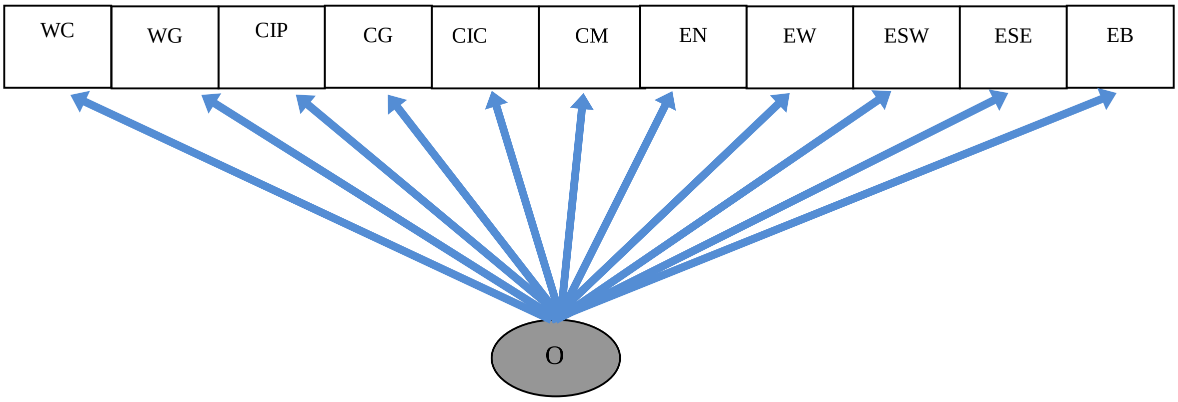

Fig. 2c. Hypothesis (III). 1 breeding stock.

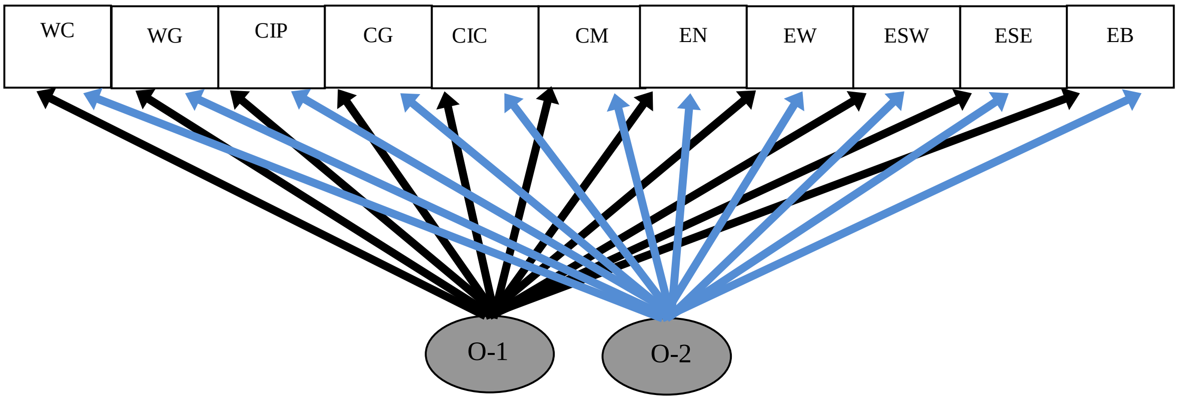

Fig. 2d. Hypothesis (IV). 1 breeding stock, with two sub-stocks.

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

The ‘fishery’ sex-ratios differ from the survey sex-ratios because they apply to the season as a whole, not to the month in which the survey takes place only. Unlike the ’survey’ sex-ratio ratios, the ‘fishery’ sex-ratios are computed using catches for 2008-2013 (except for trials NM07 for which these sex-ratios are based on catches for 2002-2007) as the ‘fishery’ sex-ratios are used in the projections to determine the sex-ratio of future catches. Since catch-by-sex data are available for all sub-areas and seasons for which future catches will be simulated, the fishery sex-selectivity parameter estimated for each sub-area provides the flexibility for an exact fit by the model to this information. Although there are indications in the results in Annex E of possible temporal trends in some sub-areas, it was **agreed** that the baseline trials would use the catch sex-selectivity parameter for each sub-area, as provided by the point estimates replicate-by-replicate, in projections. However, sensitivity to this assumption would be checked in robustness trials, as discussed below.

The initial conditioning results for trial NM01-1 and NM01-4 indicated that the data used for conditioning are uninformative regarding the size of the E-2 sub-stock. The information used to condition the trials was therefore extended to include the size of the E-2 sub-stock in sub-area EN relative to the total number of animals in sub-area EN in a pristine state. The base-case value for this ratio is 0.5, with sensitivity explored to values of 0.1 and 0.9 (see Item 4).

These initial results also indicated a conflict between the abundance data and the 'survey' sex ratios for the operating models as specified by IWC (2015). This was addressed by adjusting which entries in the catch-mixing matrix are estimable (see Annex E). With this modification, the fits to both the abundance estimates and the 'survey' sex ratios were found to be very good, with little qualitative difference in the fits for stock structure hypotheses I and II, and similar levels of fit acceptability for the two MSY rates, as evident in the initial conditioning results in Fig. 3.

The one exception to these good fits was for the 'survey' sex ratio for the EN sub-area, for which the operating model estimates reflected notably higher proportions of males than inferred from the catch sex-ratio data (see Fig. 3). However this is a sub-area in which catches have occurred primarily in the southern part, whereas the surveys have covered the northern part. The only other sub-area for which a similar situation exists is CIP, and there the 'survey' sex ratio uncertainty is recognised to be greater (see above). Accordingly, this exception was not seen to raise any real concern as regards accepting the adequacy of the operating model fits obtained.

4 FINALISE TRIAL SPECIFICATIONS

The final set of trials agreed are listed in Table 2, and reflects only a few modifications to the earlier list reported in Table 1.

First the trials with lower proportions of males in northern waters (NM08) were removed. These scenarios, allowing for the possibility of 'cryptic' males, had been included earlier when it had seemed that there might be difficulty in fitting to both the abundance and sex-ratio information under the assumption that all males and females are in the modelled area, but they were **agreed** to be no longer necessary given the good fits obtained for baseline operating models as reported above. The need to allow for males which were always south of the modelled area therefore no longer exists.

Further trials added related first to the uncertainty about the size of the E-2 sub-stock in sub-area EN relative to the total number of animals in sub-area EN in a pristine state, which the information available is unable to resolve. Accordingly, the addition of two trials (NM09 and NM10) with different values to the baseline choice of 0.5 for this proportion was **agreed**. Secondly, given the lack of fit of the baseline operating models to the 'survey' sex-ratio in the EN sub-area, it was **agreed** to add one trial (NM11) for which the model would be forced to fit this input value by artificially reducing the standard error for this proportion when fitting the operating model – the standard error used when generating pseudo data sets would remain at the values in Annex D.

Finally the Workshop agreed specifications for the '2 cryptic stocks' trials NM04-1 and NM04-4. Both stocks cover the whole North Atlantic, as for the single stock trials, and for each past year constituted 80% and 20% of the abundances estimated for the corresponding single stock trial (in each replicate). However, when projecting into the future, the mixing matrix for each stock will have independent stochastic components added, so that their future abundances will start to differ as catches by stock in each sub-area will then differ from the earlier 80:20 split. The specification of the variance for the stochastic components would be finalised at the 2015 Scientific Committee meeting, based on the extent of over-dispersion of survey abundance estimate variances in relation to estimated survey sampling variability.

5 WORKPLAN

The Workshop **agreed** that considerable intersessional work was required for the Scientific Committee to be able to complete the *Implementation Review* by the 2015 Annual Meeting. This work relates to:

(1) finalising any outstanding coding required (and updating associated datasets);

(2) completing the conditioning; and

(3) running the revised trials and presenting the results in the standard format.

The Workshop recognised that this would represent a considerable investment in time by Allison and De Moor and that it would need to be an iterative process. It was **agreed** that a Steering Group comprising Allison, Butterworth, De Moor, Donovan, Øien, Punt and Walløe would work intersessionally to facilitate progress.

6 SPECIFY MANAGEMENT VARIANTS

The agreed management variants are specified in Annex D.

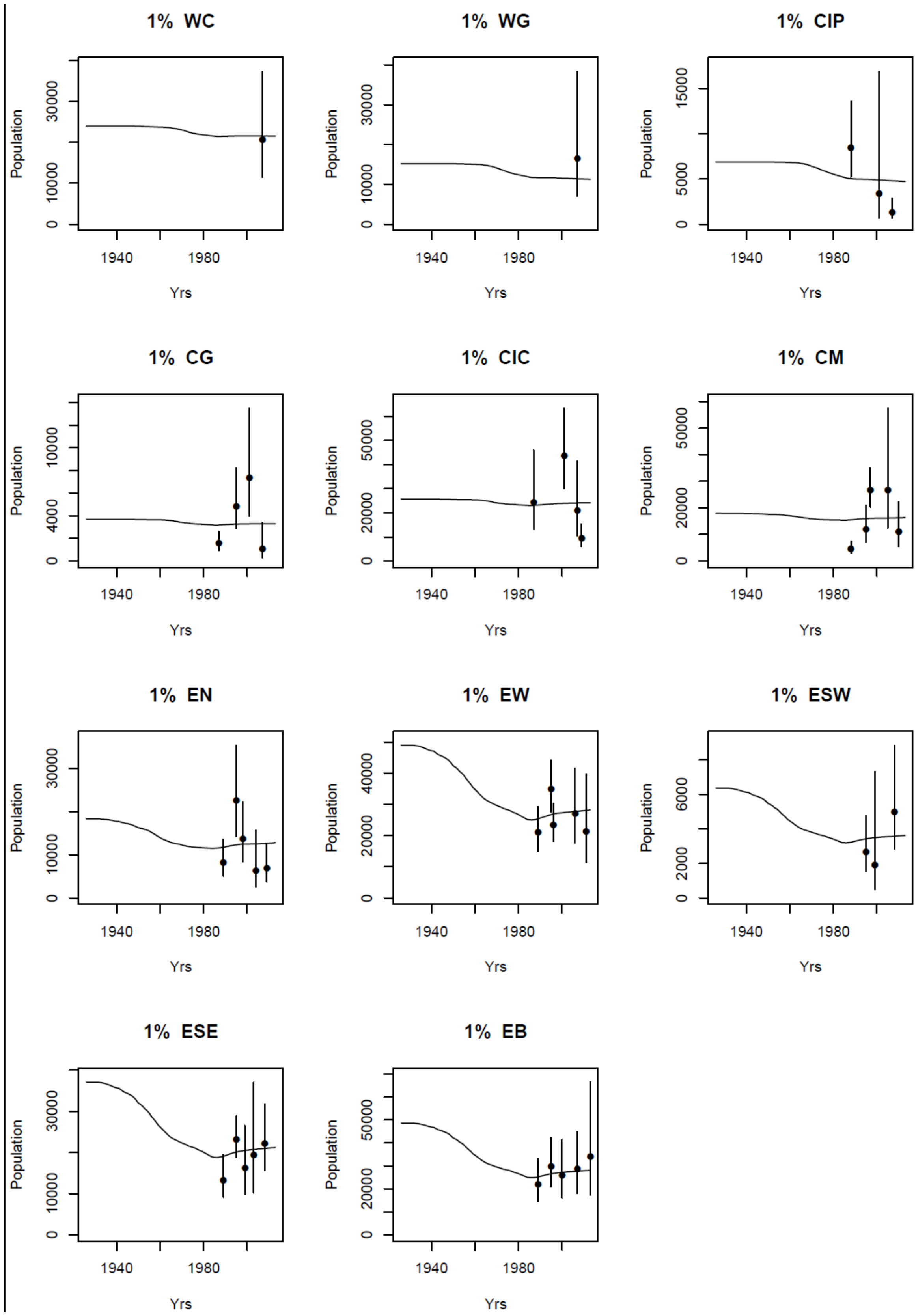

Fig. 3 Initial conditioning results (see text)

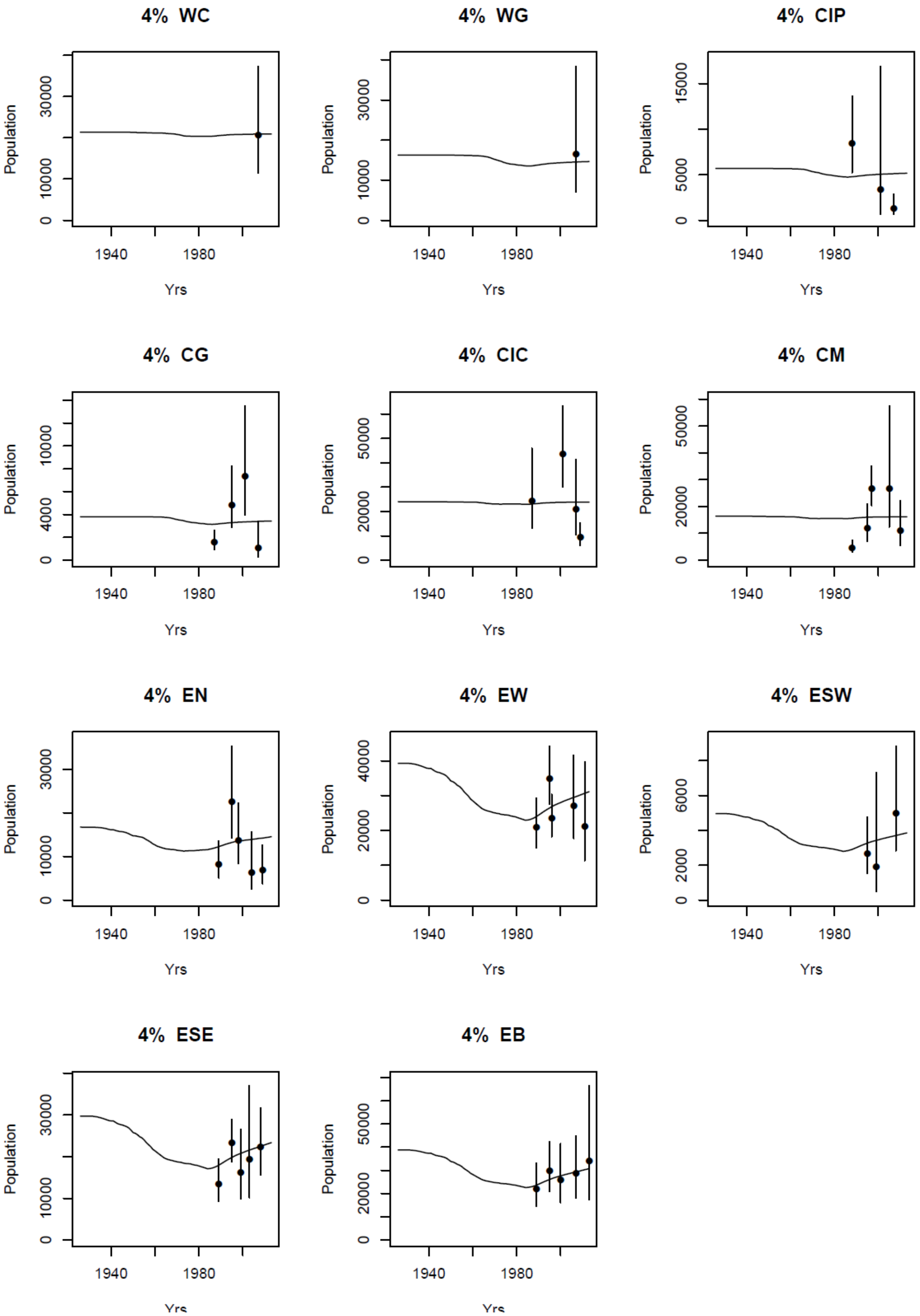

Fig. 3 cont. Initial conditioning results (see text.

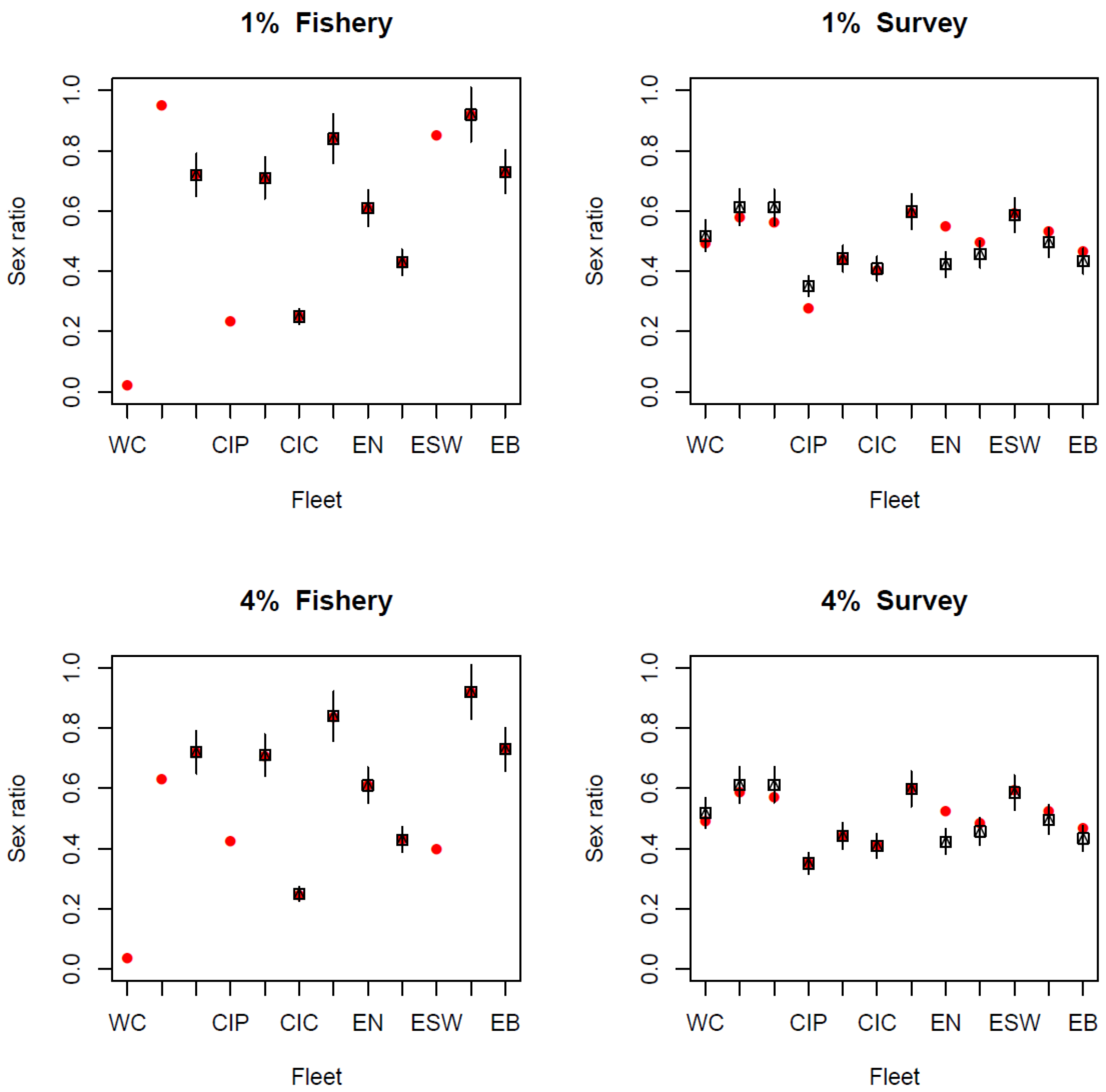

Fig. 3 cont. Initial conditioning results (see text).

7 ADOPTION OF REPORT

The majority of the report was adopted at 1700hrs on 20 February, subject to some additional work required to finalise figures, tables and Annexes. It was agreed that it was important to try to get the 'trials' Annex as complete as possible before publishing the report recognising that this would require considerable intersessional work. The Chair thanked the participants and especially Allison and De Moor for their hard work. The Workshop thanked the Chair for his usual efficient handling of the meeting.

Table 2
The *Implementation Simulation Trials* for North Atlantic minke whales

Trial No.	Stock Hypothesis	*MSYR*	No. of Stocks	Boundaries	Catch sex-ratio for selectivity	Sex ratio in sub-areas ES, EB and WG, CM	Notes
NM01-1	I	1%[1]	3	Baseline	2008-13	Baseline	3 stocks, E and W with sub-stocks
NM01-4	I	4%[2]	3	Baseline	2008-13	Baseline	3 stocks, E and W with sub-stocks
NM02-1	II	1%[1]	2	Baseline	2008-13	Baseline	2 stocks, E with sub-stocks
NM02-4	II	4%[2]	2	Baseline	2008-13	Baseline	2 stocks, E with sub-stocks
NM03-1	III	1%[1]	1	Baseline	2008-13	Baseline	1 stock
NM03-4	III	4%[2]	1	Baseline	2008-13	Baseline	1 stock
NM04-1	IV	1%[1]	2	Baseline	2008-13	Baseline	2 cryptic stocks
NM04-4	IV	4%[2]	2	Baseline	2008-13	Baseline	2 cryptic stocks
NM05-1	I	1%[1]	3	Stock C not in ESW	2008-13	Baseline	3 stocks, E and W with sub-stocks
NM05-4	I	4%[2]	3	Stock C not in ESW	2008-13	Baseline	3 stocks, E and W with sub-stocks
NM06-1	II	1%[1]	2	Stock C not in ESW	2008-13	Baseline	2 stocks, E with sub-stocks
NM06-4	II	4%[2]	2	Stock C not in ESW	2008-13	Baseline	2 stocks, E with sub-stocks
NM07-1	I	1%[1]	3	Baseline	**2002-07**	Baseline	Alternative years to adjust selectivity-at-age
NM07-4	I	4%[2]	3	Baseline	**2002-07**	Baseline	Alternative years to adjust selectivity-at-age
~~NM08-1~~	~~I~~	~~1%[1]~~	~~3~~	~~Baseline~~	~~2008-13~~	~~Half baseline~~	~~Lower proportion of males in the northern areas~~
~~NM08-2~~	~~I~~	~~4%[2]~~	~~3~~	~~Baseline~~	~~2008-13~~	~~Half baseline~~	~~Lower proportion of males in the northern areas~~
NM09-1	I	1%[1]	3	Baseline	2008-13	Baseline	E-2 stock in EN 10%
NM09-1	I	4%[2]	3	Baseline	2008-13	Baseline	E-2 stock in EN 10%
NM10-1	I	1%[1]	3	Baseline	2008-13	Baseline	E-2 stock in EN 90%
NM10-1	I	4%[2]	3	Baseline	2008-13	Baseline	E-2 stock in EN 90%
NM11-1	I	1%[1]	3	Baseline	2008-13	Baseline	Force fit to EN survey sex ratio

1 – 1+; 2 –mature

REFERENCES

International Whaling Commission. 2015. Report of the Scientific Committee. Annex D. Report of the Sub-Committee on the Revised Management Procedure. Appendix 5. *Implementation Review* for North Atlantic common minke whales. *J. Cetacean Res. Manage. (Suppl.)* 16:112-136.

Annex A
List of Participants

Denmark

Lars Witting

Iceland

Gislí Víkingsson

Thorvalður Gunnlaugsson

Bjarki Elvarsson

Norway

Lars Walløe

Nils Øien

Invited Participants

Doug Butterworth

Carryn de Moor

André Punt

Annex B

Agenda

1 Introductory items

- 1.1 Convenor's opening remarks
- 1.2 Election of Chair
- 1.3 Appointment of rapporteurs
- 1.4 Adoption of Agenda
- 1.5 Documents available

2 Progress on intersessional Tasks

- 2.1 Finalise survey estimates for conditioning
- 2.2 Finalise commercial and aboriginal catch series
- 2.3 Finalise code
- 2.4 Conditioning
- 2.5 Review relevant information from AWMP workshop

3 Review results of conditioning of initial trials

4 Finalise trial specifications

5 Specify management variants

6 Workplan

7 Adoption of report

Annex D

An initial attempt to estimate mean sex ratios and associated standard errors

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The sex-ratios for the ‘survey’ and ‘fishery’ by sub-area are required to implement the trials structure. The data on sex-ratios are numbers of males and females caught by year and sub-area. In principle, the numbers of males and females can be simply summed to estimate an overall sex-ratio. However, the standard error of the mean would be under-estimated as there appears to over-dispersion associated with the sex-ratio data, owing for example to clustering of catches within years. A simple way to estimate a sex-ratio by sub-area and its associated standard error is to assume that the observed sex-ratios by year are normally distributed with a variance that is the sum of that due to sampling and process error (with the latter assumed to be independent of year). The associated negative log-likelihood is given by:

$$-\ell nL = \sum_y \left(\ell\mathrm{n}\sigma_y + \tfrac{1}{2(\sigma_y)^2}\left[p_y - \bar{p} \right]^2 \right) \tag{1}$$

where p_y is the observed sex-ratio for year *y*, $\bar{p}$ and the mean sex-ratio, and σ_y is standard error of the sex-ratio for year *y*, accounting for over-dispersion, i.e.:

$$\sigma_y = \sqrt{\tau^2 + p_y(1-p_y)/n_y} \tag{2}$$

where n_y is the number of animals sexed during year *y*.

Figures 1 and 2 show the results of applying this method to compute ‘survey’ and ‘fishery’ sex-ratios. The ‘survey’ sex-ratios are based on the data for the months corresponding to when surveys take place (July for all except sub-area WG for which the data pertain to September) while the ‘fishery’ sex-ratios are based on data for all months combined but restricted to the years 2008-2013. Data for years for which no females or no males were recorded were ignored. The estimates of $\bar{p}$ and their associated standard errors are shown in Tables 1 and 2, along with the estimates of τ. The estimates of $\bar{p}$ are not identical to summing the total numbers of males and dividing by the total number of animals sexed. This is because allowing for additional variance changes the weight assigned to each year’s data, with higher sample size downweighted more than small sample size (Fig. 3).

The approach outlined is somewhat approximate. A better approach would be to treat p_y as beta-binomial distributed to account for overdispersion within-years, and treating the p_y s and the parameters determining the extent of overdispersion by year as random effects. The author was unable to conduct this analysis in the time available.

Table 1

Results of applying the sex-ratio estimator to the ‘survey’ sex-ratio data. The sex-ratio data are for July, except for sub-area WG for which the data are for September.

Sub-area	$\bar{p}$	SE($\bar{p}$)	τ	Years
WC	0.527	0.040	0.104	All
WG	0.556	0.043	0.000	Pre-1986
WG alternative	0.686	0.021	0.065	All
CG	0.429	0.045	0.137	All
CM	0.584	0.055	0.220	All
CIC	0.399	0.021	0.090	All
CIP	0.276	0.068	0.001	All
EB	0.437	0.040	0.132	Pre-1960
EW	0.446	0.006	0.000	Pre-1960
EN	0.403	0.017	0.036	Pre-1960
ESE	0.481	0.025	0.000	Pre-1960
ESW	0.562	0.084	0.002	All

Table 2a
Results of applying the sex-ratio estimator to the ‘fishery’ sex-ratio data. The analyses use all of the data by year (no restriction to particular months) for the years 2008 onwards.

Sub-area	$\bar{p}$	SE($\bar{p}$)	τ
WG	0.722	0.023	0.043
CG	0.436	0.120	0.012
CIC	0.267	0.058	0.128
EN	0.738	0.096	0.205
EW	0.434	0.023	0.042
ESE	0.926	0.014	0.030
EB	0.662	0.071	0.126

Table 2b
Results of applying the sex-ratio estimator to the ‘fishery’ sex-ratio data. The analyses use all of the data by year (no restriction to particular months) for the years 2002-7 onwards.

Sub-area	$\bar{p}$	SE($\bar{p}$)	τ
WG	0.747	0.015	0.016
CG	0.665	0.156	0.209
CIC	0.502	0.051	0.083
EN	0.506	0.042	0.073
EW	0.496	0.018	0.027
ESE	0.944	0.016	0.031
EB	0.691	0.094	0.204

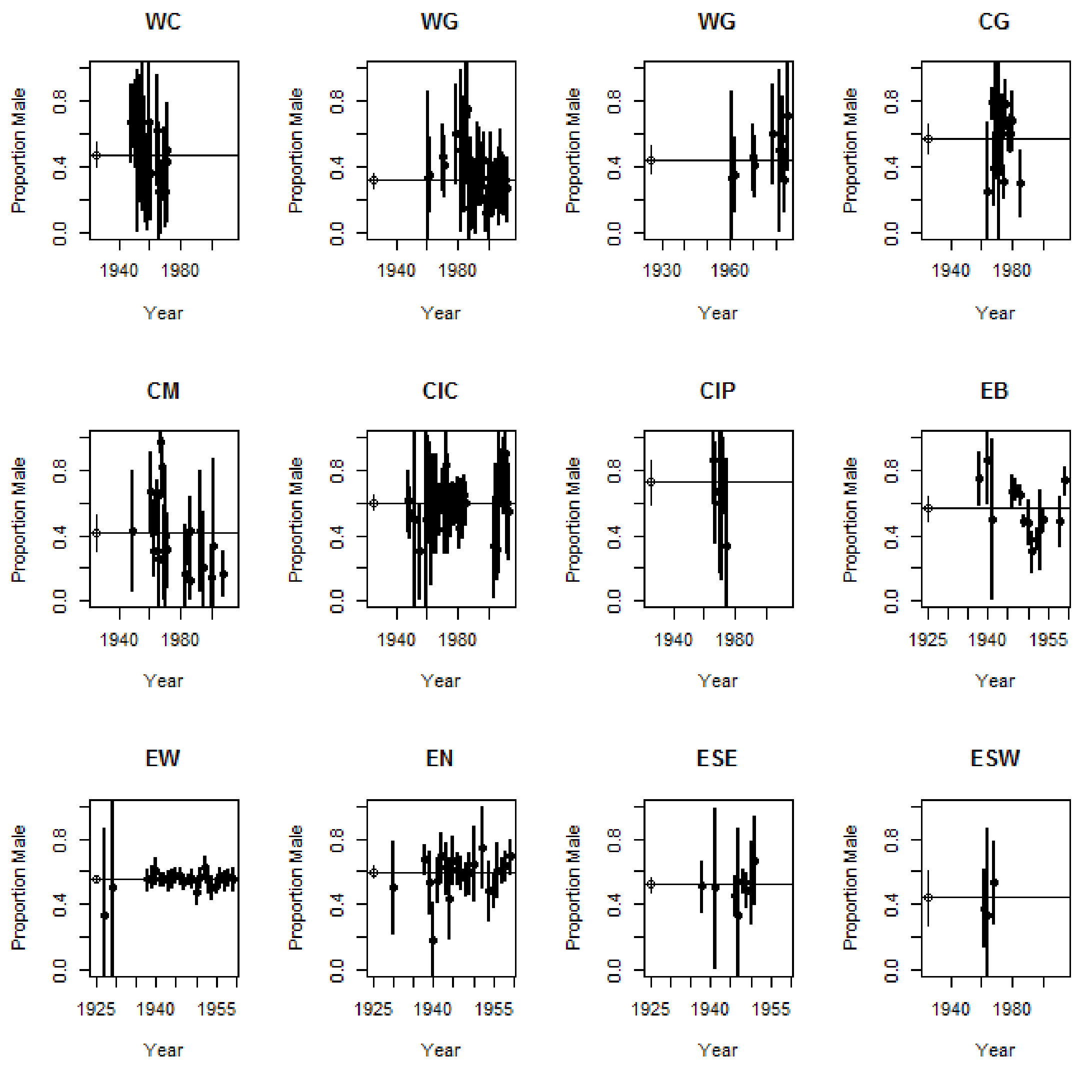


Fig.1 ‘Survey’ sex-ratio data with asymptotic 95% confidence intervals and the estimate of the mean sex-ratio and its 95% confidence interval (open circle plotted at 1925). The two plots for WG show results for all years and up to 1985.

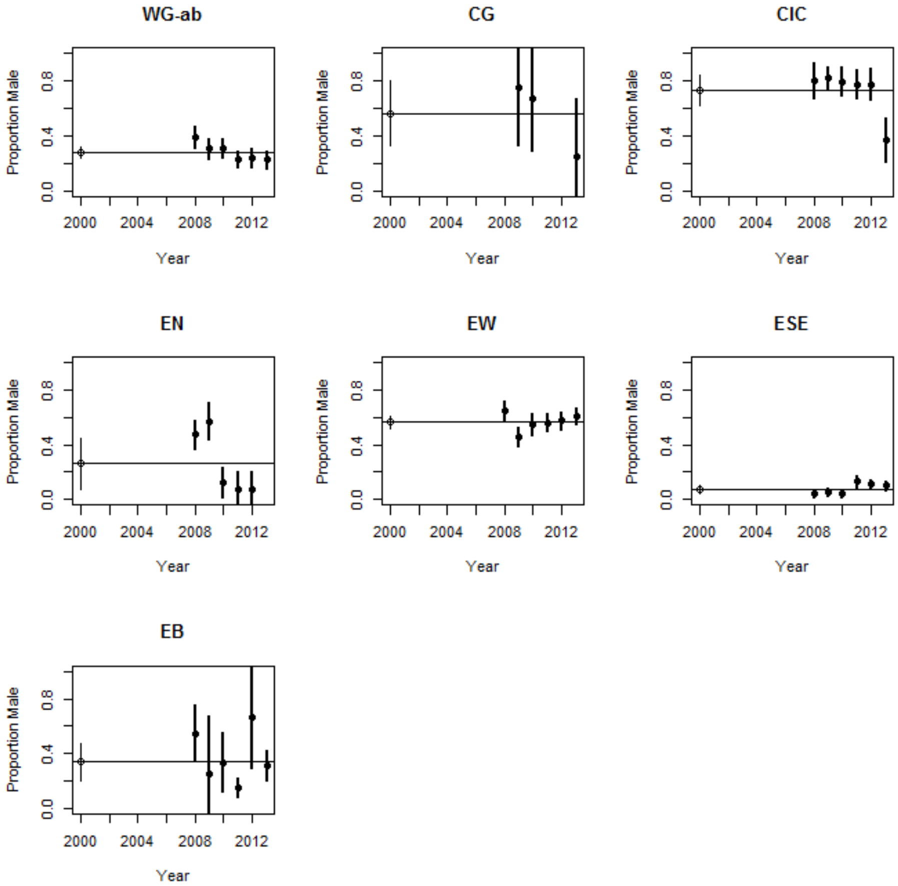


Fig. 2a. ‘Fishery’ sex-ratio data with asymptotic 95% confidence intervals and the estimate of the mean sex-ratio and its 95% confidence interval (open circle plotted at 2000) using data from 2008-13.

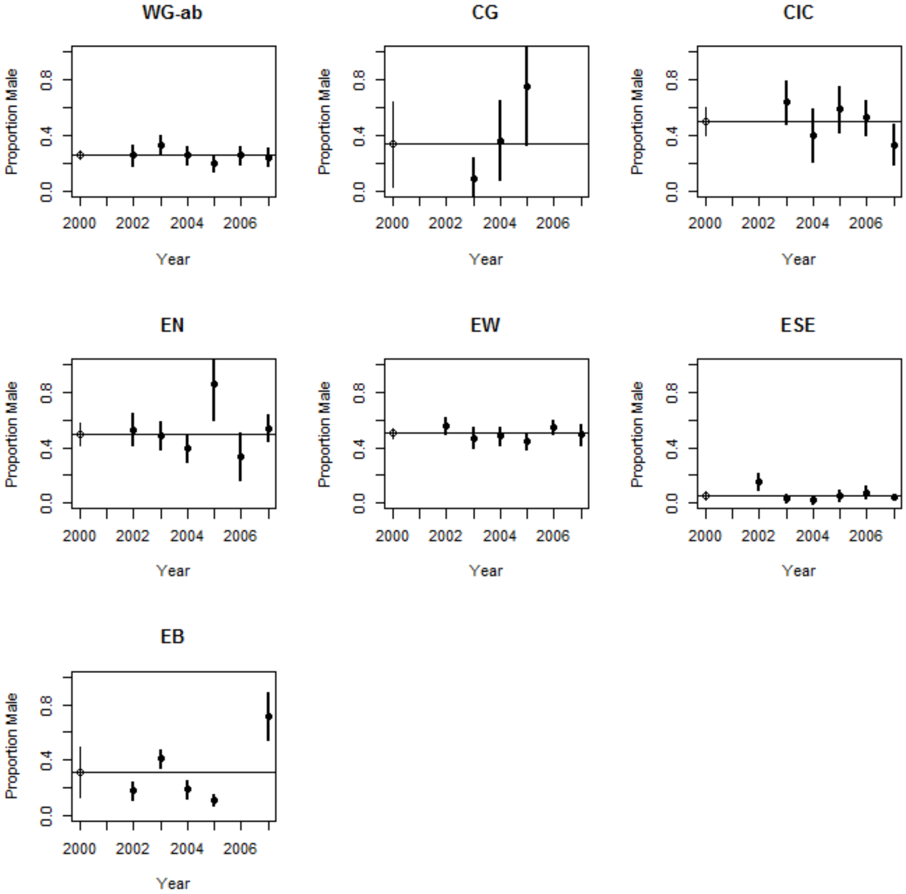


Fig. 2b. ‘Fishery’ sex-ratio data with asymptotic 95% confidence intervals and the estimate of the mean sex-ratio and its 95% confidence interval (open circle plotted at 2000) using data from 2002-7.

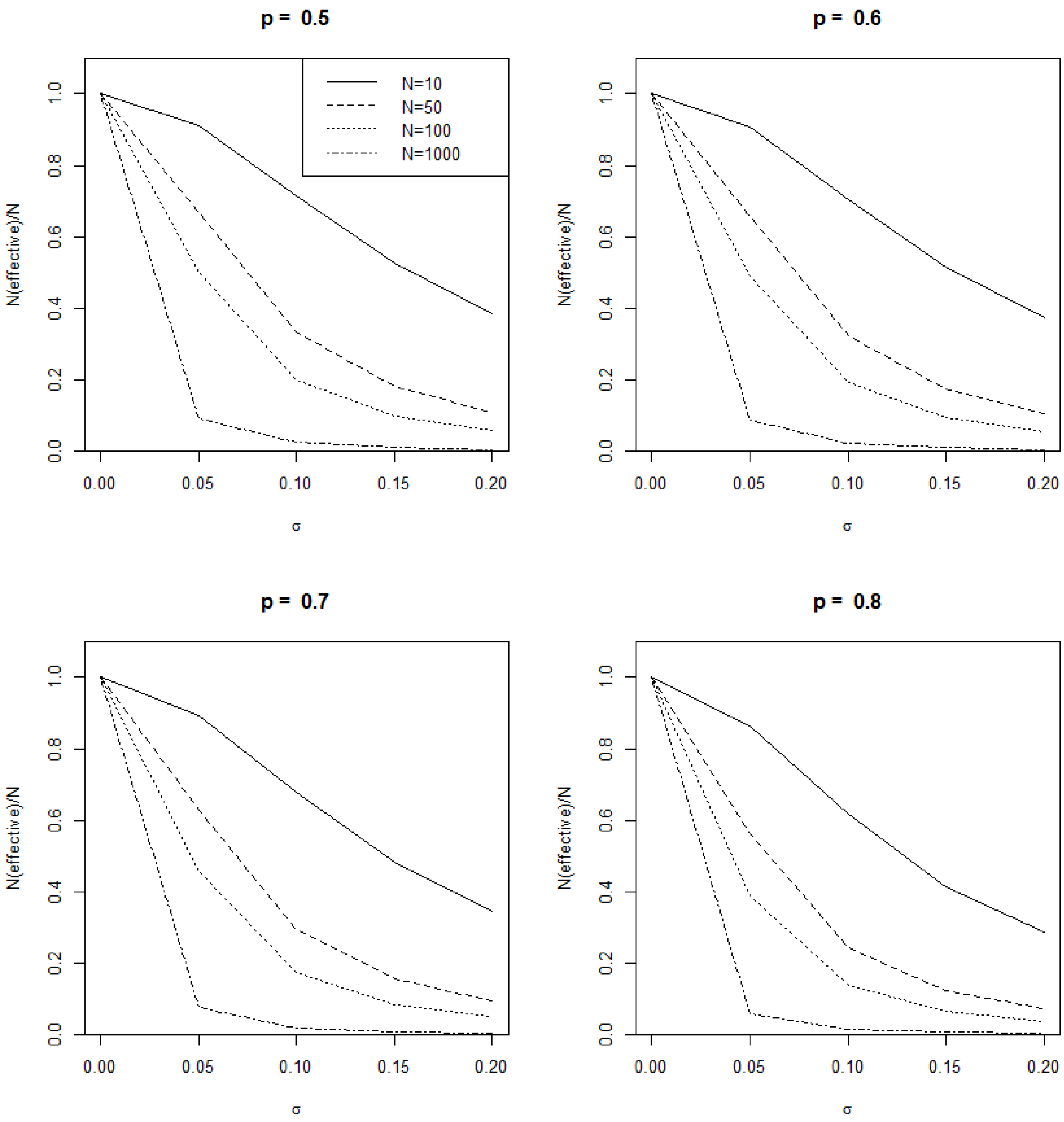


Fig.3. Ratio between the effective sample size (the multinomial sample size equivalent to the variance about the proportion given the actual numbers sampled) and the number of samples as a function of the extent of overdispersion.

Annex D Last updated 15 May 2015

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 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 a 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, at least in the base-case trials. The rationale for the position of the sub-area boundaries is given in IWC 1993 p194;; IWC2004p12-13 IWC 2009 p138.

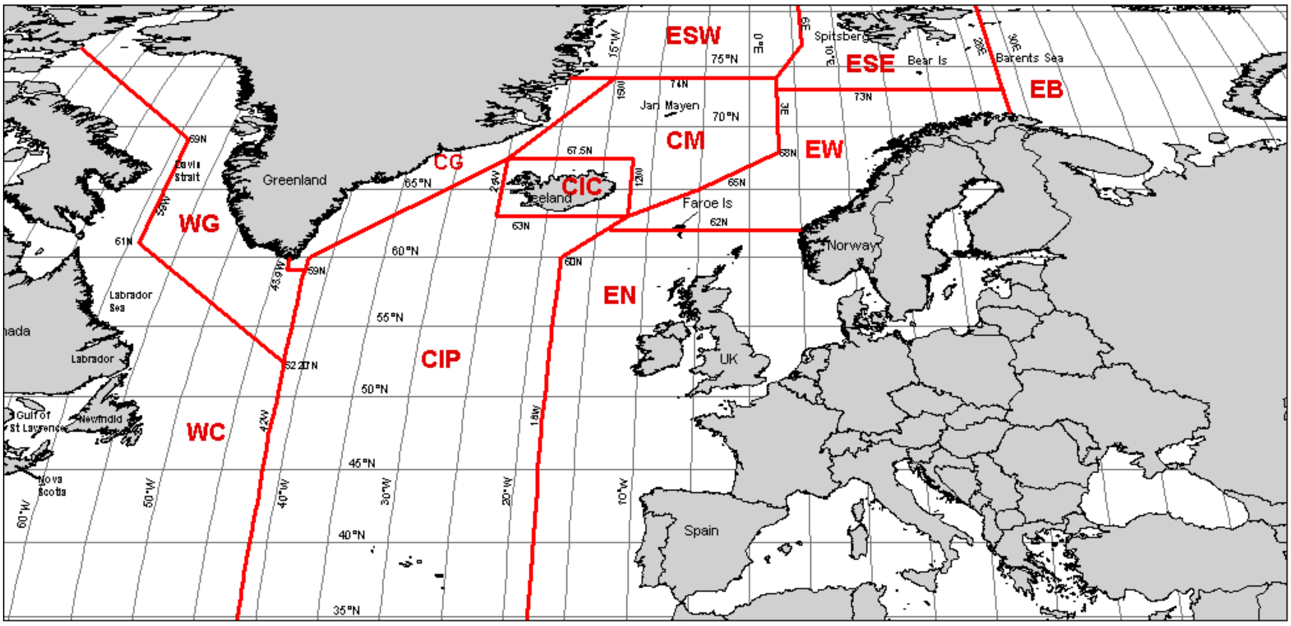


Fig. 1. Map of the North Atlantic showing the sub-areas defined for the North Atlantic Minke whales.

There are three general hypotheses regarding stock structure (see IWC [2014] 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.

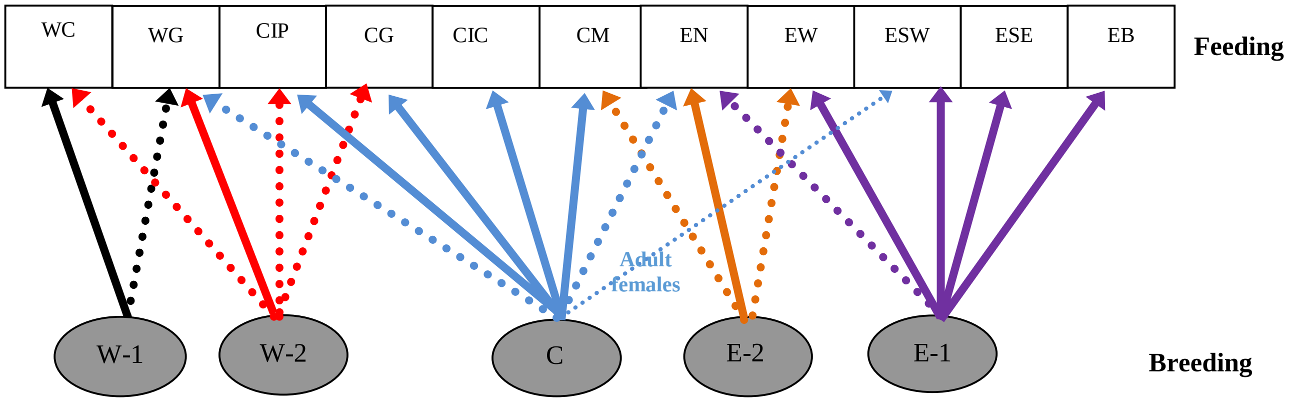
(III) *One stock*. There is only a single (‘O’) stock of minke whales in the North Atlantic.

(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[2].

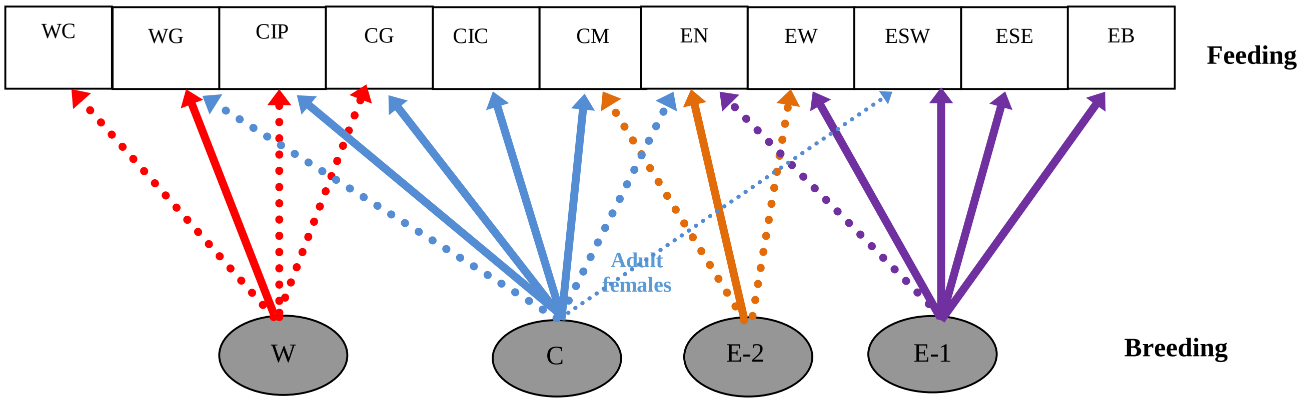
The trials (see Section H) include variants of these general hypotheses to capture further aspects of uncertainty regarding stock structure.

[2] 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, 2014).

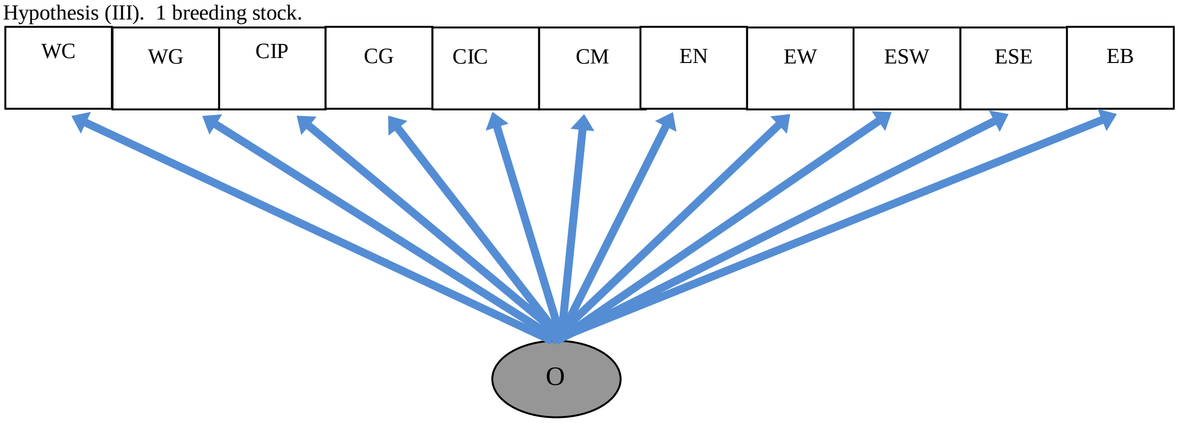
Hypothesis (I). Base case: 3 breeding stocks, two with two sub-stocks. The solid lines indicate low mixing. The dotted lines in addition to the solid lines indicate high mixing, with the feint lines indicating mixing of adult females only.



Hypothesis (II). 3 breeding stocks, one with two sub-stocks.



Hypothesis (III). 1 breeding stock.



Hypothesis (IV). 1 breeding stock, with two sub-stocks.

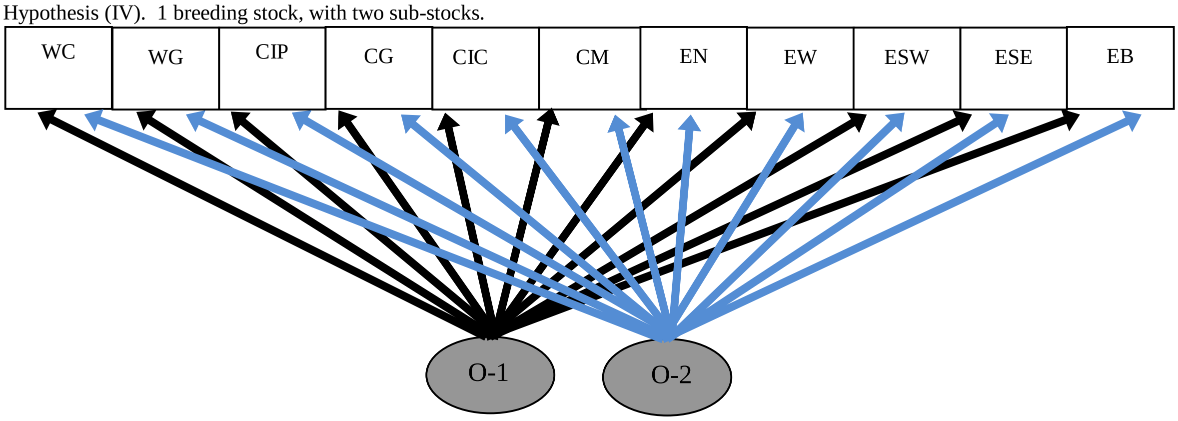


Fig. 1. Stock structure hypotheses for North Atlantic Minke whales

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 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 2014.

C. 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.

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

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*;

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

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

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

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

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

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

To come: explanation of 'expedition type': 2 expedition types in WG (aboriginal and commercial); one only in the other sub-areas.

Explanation of sex ratios and selectivity patterns by area (or pointer to where sex ratios are described).

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 mixing matrix *V*, i.e.:

$$C_{t,a}^{g,j} = \sum_{l}\sum_{k\in l} F_t^{g,l} V_{t,a}^{g,j,k} S_a^{g,l} N_{t,a}^{g,j} \tag{D.1}$$

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

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

$S_a^{g,e}$ is the selectivity on animals of gender *g* and age *a* by expedition type *e* :

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

$a_{50}^{g,e}$, $\delta^{g,e}$ are the parameters of the (logistic) selectivity ogive for gender *g* by expedition type *e*;

$C_t^{g,e}$ is the observed catch of animals of gender *g* by expedition type *e* during year *t* (see appendix 1); and

$V_{t,a}^{g,j,k}$ 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*.

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, the mixing matrix for each year is selected at random from a matrix in which mixing is 'high' and in which it is 'low' (matrices A and B in Table 1). For the one stock and two cryptic stocks Hypotheses III and IV, the values for the mixing matrix in Table 1 are each multiplied by a log-normal normal random variable, with mean 1 and CV xxx and renormalized.

In Hypothesis IV the ratio of the two pristine stocks is set equal to 4. The stochastic mixing is only for projections. The idea is to add log-normal error (each year) to the entries of the catch mixing matrix based on the between-year variation in abundance estimates - to capture additional variation if there is any!"

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.

Table 1

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 for each stock structure hypothesis.

Stock structure hypothesis I (matrix Ai) [high mixing]

	WC	WG	CIP	CG	CIC	CM	EN	EW	ESW	ESE	EB
Adult females (ages 10+)											
W-1	0.5	0.5									
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	0.1γ_6	γ_8	γ_9
E-2						0.1	0.8	0.1			
Adult males (ages 10+) and juveniles											
W-1	0.5 Ω_{11}	0.5 Ω_{12}									
W-2	0.2 Ω_{11}	0.45 Ω_{12}	0.15 Ω_{13}	0.2Ω_{14}							
C		0.1 Ω_{12}	γ_2 Ω_{13}	$\gamma_3\Omega_{14}$	$\gamma_4\Omega_{15}$	γ_5 Ω_{16}	0.05Ω_{17}				
E-1							0.1 Ω_{17}	γ_7 Ω_{18}	0.1γ_6 Ω_{19}	$\gamma_8\Omega_{20}$	$\gamma_9\Omega_{21}$
E-2						0.1Ω_{16}	0.8 Ω_{17}	0.1 Ω_{18}			

Stock structure hypothesis I (matrix Bi) [low mixing]

	WC	WG	CIP	CG	CIC	CM	EN	EW	ESW	ESE	EB
Adult females (ages 10+)											
W-1	1										
W-2		1									
C			γ_2	γ_3	γ_4	γ_5					
E-1								γ_7	5γ_6	5 γ_8	γ_9
E-2							1				
Adult males (ages 10+) and juveniles											
W-1	Ω_{11}										
W-2		Ω_{12}									
C			$\gamma_2\Omega_{13}$	γ_3 Ω_{14}	2 γ_4 Ω_{15}	$\gamma_5\Omega_{16}$					
E-1								γ_7 Ω_{18}	5γ_6 Ω_{19}	5 γ_8 Ω_{20}	γ_9 Ω_{21}
E-2							Ω_{17}				

Stock structure hypothesis II (matrix Aii) [high mixing]

	WC	WG	CIP	CG	CIC	CM	EN	EW	ESW	ESE	EB
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	0.1γ_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 $\gamma_1\Omega_{12}$	γ_2 Ω_{13}	$\gamma_3\Omega_{14}$	$\gamma_4\Omega_{15}$	γ_5 Ω_{16}	0.05Ω_{17}				
E-1							0.1 Ω_{17}	γ_7 Ω_{18}	0.1$\gamma_6\Omega_{19}$	$\gamma_8\Omega_{20}$	$\gamma_9\Omega_{21}$
E-2						0.1Ω_{16}	0.8 Ω_{17}	0.1 Ω_{18}			

Stock structure hypothesis II (matrix Bii) [low mixing]

	WC	WG	CIP	CG	CIC	CM	EN	EW	ESW	ESE	EB
Adult females (ages 10+)											
W	1										
C		γ_1	γ_2	γ_3	γ_4	γ_5					
E-1								γ_7	5γ_6	5 γ_8	γ_9
E-2							1				
Adult males (ages 10+) and juveniles											
W	Ω_{11}										
C		γ_1 Ω_{12}	$\gamma_2\Omega_{13}$	γ_3 Ω_{14}	2 $\gamma_4\Omega_{15}$	$\gamma_5\Omega_{16}$					
E-1								γ_7 Ω_{18}	5γ_6 Ω_{19}	5 γ_8 Ω_{20}	γ_9 Ω_{21}
E-2							Ω_{17}				

Stock structure hypotheses III [high mixing]

	WC	WG	CIP	CG	CIC	CM	EN	EW	ESW	ESE	EB
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]

	WC	WG	CIP	CG	CIC	CM	EN	EW	ESW	ESE	EB
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}

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 RMP and *SLA*, i.e. a survey conducted in 2009 could first be used for setting the catch limit in 2011.

Table 2
The estimates of abundance and their sampling standard errors

Year	Sub-Area	Abundance	CV	Year	Sub-Area	Abundance	CV
2007	WC	20741	0.3	1989	EN	8318	0.25
1987	WG	3266	0.31	1995	EN	22536	0.23
1993	WG	8371	0.43	1998	EN	13673	0.25
2005	WG	10792	0.59	2004	EN	6246	0.47
2007	WG	16609	0.428	2009	EN	6891	0.31
1988	CIP	8431	0.245	1989	EW	20991	0.17
2001	CIP	3391	0.82	1995	EW	34986	0.12
2007	CIP	1350	0.38	1996	EW	23522	0.13
1995	CIP+CG	4854	0.27	2006	EW	27152	0.218
1987	CG	1555	0.26	2011	EW	21218	0.32
2001	CG	7349	0.31	1995	ESW	2691	0.29
2007	CG	1048	0.6	1999	ESW	1932	0.68
1987	CIC	24532	0.32	2008	ESW	5009	0.29
2001	CIC	43633	0.19	1989	ESE	13370	0.19
2007	CIC	20834	0.35	1995	ESE	23278	0.11
2009	CIC	9588	0.24	1999	ESE	16241	0.25
1988	CM	4732	0.23	2003	ESE	19377	0.33
1995	CM	12043	0.28	2008	ESE	22281	0.18
1997	CM	26718	0.14	1989	EB	21868	0.21
2005	CM	26739	0.39	1995	EB	29712	0.18
2010	CM	10991	0.36	2000	EB	25885	0.24
				2007	EB	28625	0.23
				2013	EB	34125	0.34

Table 3
Sighting survey plan. The years when Assessments are run are also shown

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

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

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

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

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 $E(w) = \mathrm{var}(w) = \mu = (P/P^*)/\beta^2$, Y and w are independent;

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

$$P = P_t^E = \sum_{k\in E}\sum_j V_t^{j,k}\sum_g\sum_{a\geq 1} N_{t,a}^{g,j} \tag{F.2}$$

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

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

The value of τ is calculated from the survey sampling CV's of earlier surveys in 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:

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

Note therefore that:

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

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:

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

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

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

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).

G. Parameters and conditioning

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

Table 4a

The values for the biological parameters that are fixed

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

Table 4b

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 model above 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 12 "factors" by expedition type allowing difference between male survey and fishery selectivity. 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), (b) and (c) 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.

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 2); and

σ_t^k is the CV of O_t^k.

(b) The 'target' values for the pristine sex-ratios by sub-area are obtained by assigning sex ratios to each sub-area and year for which the actual sex-ratio is non-zero by sampling sex-ratios for July with replacement for that sub-area.

The '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 Annex E. 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 Annex E because the estimation process used there will be negatively biased, for example because of overdispersion of the samples compared to the binomial variance assumption made).

(c) The 'target' values for the sex-ratios by sub-area when catches take place are obtained by assigning sex ratios to each sub-area and year by sampling with replacement from those for 2008-2013, and computing an overall sex ratio by weighting each resampled sex-ratio by the annual catch.

The 'fishery' sex-ratios apply to the season as a whole and are computed using the historical catches for 2008-2013 (except for trials NM07 for which these sex-ratios are based on catches for 2002-2007). They are used in the projections to determine the sex-ratio of future catches. Since catch-by-sex data are available for all sub-areas and seasons for which future catches will be simulated, the fishery sex-selectivity parameter estimated for each sub-area provides the flexibility for an exact fit by the model to this information. These data only apply to sub-areas in which catches are modelled in future.

Add Table of sex ratios used here

The likelihood function consists of three components.

a) Abundance estimates

$$L_1 = 0.5\sum_k \sum_t \tfrac{1}{(\sigma_t^k)^2}\left(P_t^k / \hat{P}_t^k\right)^2 \qquad \text{(G.2)}$$

where $\hat{P}_t^k$ is the model estimate of the number of animals aged 1 and older at the start of year *t*.

b) Sex ratio during sighting surveys

$$L_3 = \tfrac{1}{2(\sigma^{2,k})^2}\sum_k (\hat{\lambda}^k - \lambda^k)^2 \qquad \text{(G.5)}$$

where λ^k is the observed catch sex-ratio (proportion of females) for expedition type *e* during July:

$\hat{\lambda}^k$ is the model-estimate of the sex-ratio for expedition type *e*:

$$\hat{\lambda}^l = \frac{\sum_a \sum_j \sum_{k\in e} V_{-\infty,a}^{f,j,k} S_a^{survey,f,e} N_{-\infty,a}^{f,j}}{\sum_g \sum_{a'} \sum_{j'} \sum_{k\in e} V_{-\infty,a'}^{g,j',k} S_{a'}^{survey,g,e} N_{-\infty,a'}^{f,j'}} \quad \hat{\lambda}^k = \frac{\sum_a \sum_j V_{-\infty,a}^{f,j,k} N_{-\infty,a}^{f,j}}{\sum_g \sum_a \sum_j V_{-\infty,a}^{g,j',k} N_{-\infty,a'}^{g,j'}}$$

(G.6)

$S_a^{survey,g,l}$ is the survey selectivity on animals of gender *g* and age *a* by expedition type *e* :

$$S_a^{survey,f,e} = S_a^{f.e} \quad \text{and} \quad S_a^{survey,m,e} = \omega^e S_a^{m.e}$$

ω^e is the difference in male selectivity in the catches over the year compared to at the time of the survey;

$\sigma^{2,k}$ is the between-period variation in the July catch sex-ratios for expedition type *e*. In these trials it is assumed that $\sigma^{2,k} = 0.2$.

c) Catch sex ratio

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

where λ^k is the observed catch sex-ratio (proportion of females) for expedition type *e (if there is a catch*;

$\hat{\lambda}^k$ is the model-estimate of the sex-ratio for expedition type *e*:

$$\hat{\lambda}^e = \sum_t \left\{ \left(C_t^{m,e} + C_t^{f,e}\right) \frac{\sum_a \sum_j \sum_{k\in e} V_{t,a}^{f,j,k} S_a^{f,e} N_{t,a}^{f,j}}{\sum_g \sum_{a'} \sum_{j'} \sum_{k\in e} V_{t,a'}^{g,j',k} S_{a'}^{g,e} N_{t,a'}^{f,j'}} \right\} / \sum_{t'} \left(C_{t'}^{m,e} + C_{t'}^{f,e} \right) \tag{G.4}$$

$\sigma^{1,k}$ is the between-year variation in catch sex-ratios for expedition type *e*. In these trials it is assumed that $\sigma^{1,k} = 0.2$.

H. Trials

The *Implementation Simulation Trials* for the North Atlantic minke whales are listed in Table 5. All trials are based on the assumption that g(0)=1.

Table 5

The *Implementation Simulation Trials* for North Atlantic minke whales (Trial NM08 was deleted and so is not shown here).

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		3 stocks, E and W with sub-stocks
NM01-4	I	4%[2]	3	Baseline	2008-13		3 stocks, E and W with sub-stocks
NM02-1	II	1%[1]	2	Baseline	2008-13		2 stocks, E with sub-stocks
NM02-4	II	4%[2]	2	Baseline	2008-13		2 stocks, E with sub-stocks
NM03-1	III	1%[1]	1	Baseline	2008-13		1 stock
NM03-4	III	4%[2]	1	Baseline	2008-13		1 stock
NM04-1	IV	1%[1]	2	Baseline	2008-13		2 cryptic stocks
NM04-4	IV	4%[2]	2	Baseline	2008-13		2 cryptic stocks
NM05-1	I	1%[1]	3	Stock C not in ESW	2008-13		3 stocks, E and W with sub-stocks
NM05-4	I	4%[2]	3	Stock C not in ESW	2008-13		3 stocks, E and W with sub-stocks
NM06-1	II	1%[1]	2	Stock C not in ESW	2008-13		2 stocks, E with sub-stocks
NM06-4	II	4%[2]	2	Stock C not in ESW	2008-13		2 stocks, E with sub-stocks
NM07-1	I	1%[1]	3	Baseline	**2002-07**		Alternative years to adjust selectivity-at-age
NM07-4	I	4%[2]	3	Baseline	**2002-07**		Alternative years to adjust selectivity-at-age
NM09-1	I	1%	3	Baseline	2008-13		E-2 stock in EN 10%
NM09-4	I	4%	3	Baseline	2008-13		E-2 stock in EN 10%
NM10-1	I	1%	3	Baseline	2008-13		E-2 stock in EN 90%
NM10-4	I	4%	3	Baseline	2008-13		E-2 stock in EN 90%
NM11-1	I	1%	3	Baseline	2008-13		Force fit to EN survey sex ratio

1 – 1+; 2 –mature

Note: the above trials do not include a sensitivity to the ES/CM boundary - see 2014 SC report (Annex D Appendix 5 Item 2.2): three stocks with a changed CM/ES boundary (the ES sub-area is to the north of the CM sub-area with a boundary based on primarily catch data - uncertainty in this boundary will be tested) such that ES is split into ESW and ESE with the large catches in ESE and the ESW sub-area included as part of the C stock.

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-area 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

[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.

all taken in the ESE sub-area. The catch limits set for the 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 *Medium 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 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 *Medium 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 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);.

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.

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

K. References

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To come: Appendix 1: Catches