Annex D

The AWMP/RMP *Implementation Simulation Trials* for the North Atlantic Minke Whales

The operating model for the trials used in the development of *SLA*s for East and West Greenland is based on the model used in the RMP *Implementation Review* for this species in the North Atlantic (see IWC, 2018a), but with greater focus placed on the western and central North Atlantic.

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), IWC (2004a, p.12-13) and IWC (2009, p.138).

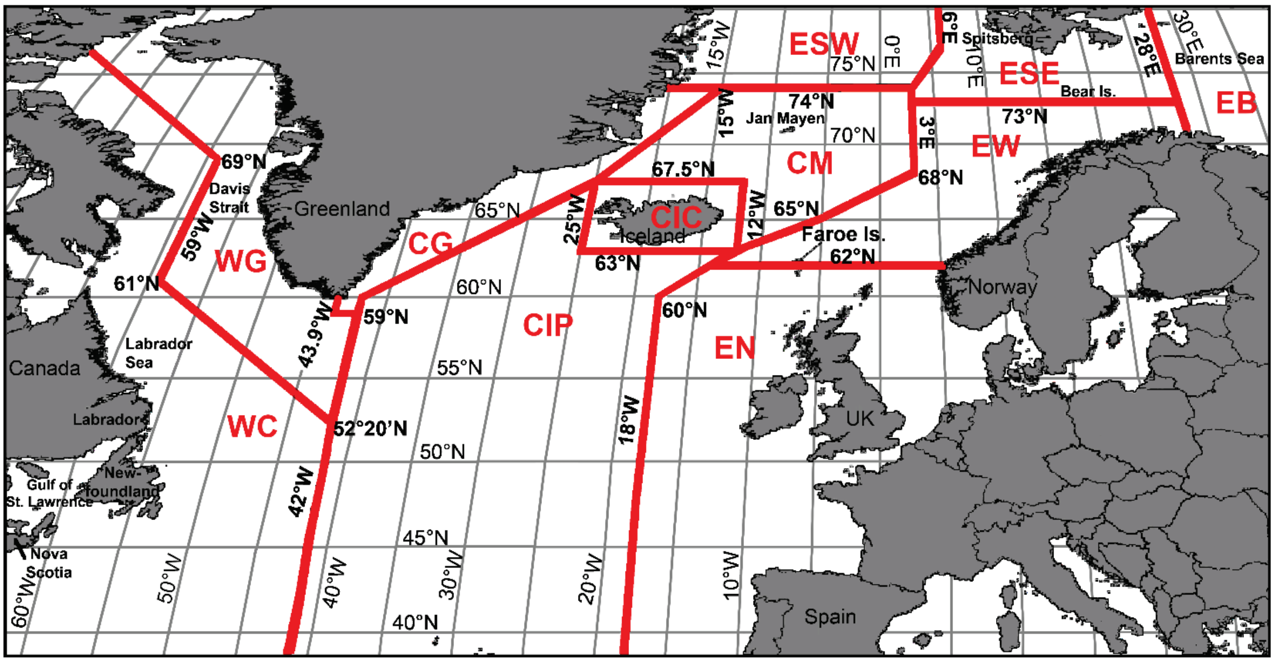

Fig. 1. Map of the North Atlantic showing the sub-areas defined for the North Atlantic minke whales.

There are two general hypotheses regarding stock structure (see IWC, 2015)[1] 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.

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 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).

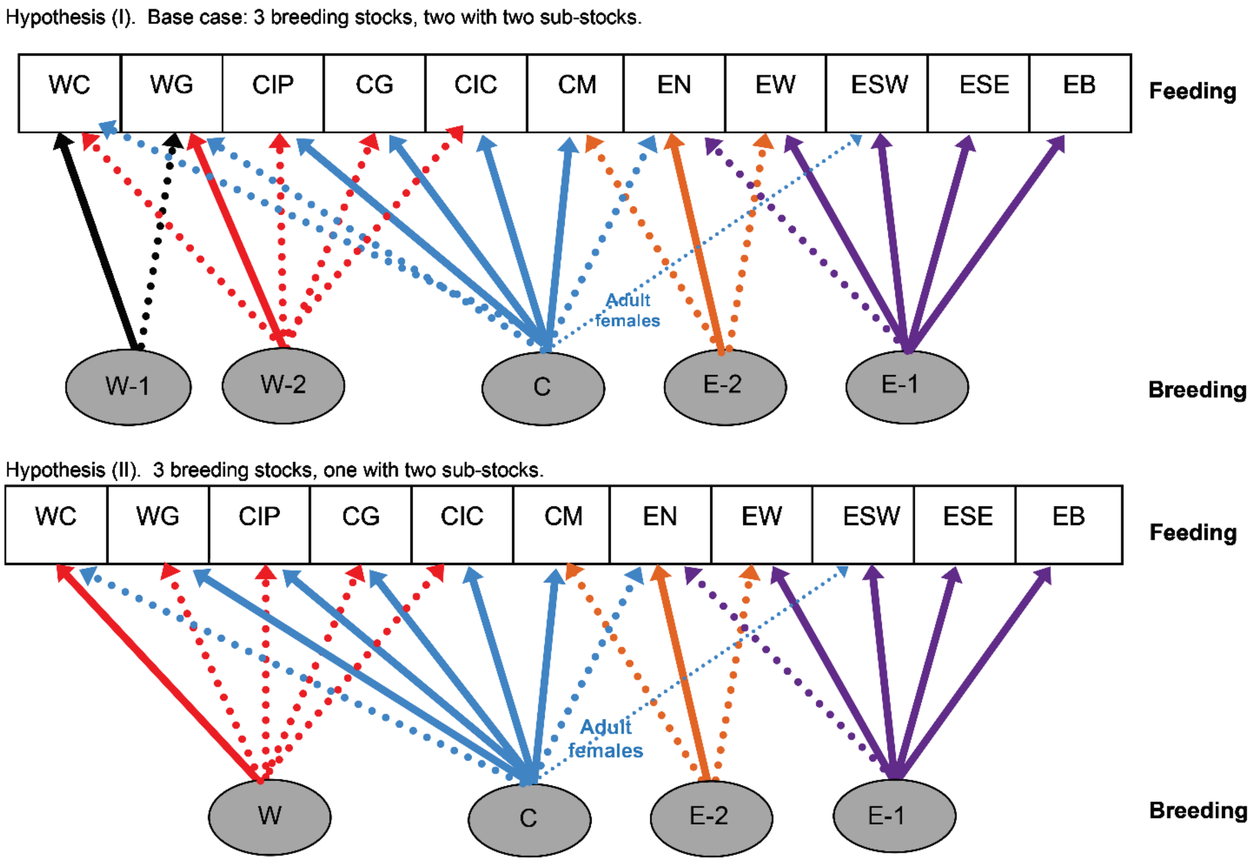

Fig. 2. Stock structure hypotheses for North Atlantic Minke whales. [The ranges of the W and C stocks are updated from the model used in the RMP *Implementation Review* based on results of genetic analyses (IWC, 2019, item 3.2)].

[1]Hypotheses III and IV tested in the RMP *Implementation Review* were dropped from further consideration because the results of the genetic analyses (IWC, 2019, item 3.2) indicate that these stock structure hypotheses are not consistent with the available information.

B. Basic dynamics

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

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

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 2016.

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.

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

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:

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

β_a is the proportion of females of age a that 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:

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

$N_t^{1+,j}$ is the number of 1+ animals in stock/sub-stock j at the start of year t:

$$N_t^{1+,j} = \sum_{g}\sum_{a=1}^{x} N_{t,}^{g,j} \qquad \text{(C.4)}$$

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-2016) catch series used is listed in Adjunct 1 and includes commercial, aboriginal, 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 ratios 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 the catch mixing matrices and how the parameters are set are given in sections E and 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 hunt h (within sub-area k), which is based on the reference selectivity $R_a^{g,h\in k}$ (see Equation G.7):

$C_t^{g,h}$ is the observed catch of animals of gender g in hunt h (within sub-area k) during year t. See adjunct 1 for the historical catches. Future catches are allocated to sex using the modelled fishery sex ratio $\hat{\lambda}^{2,h}$ (see equation G.9).

The maximum exploitation rate for future removals from the WG sub-area (catch as a proportion of the number of 1+ whales) is set equal to twice the maximum historical aboriginal exploitation rate achieved by aboriginal hunters (IWC, 2018b, pp.539-42). This limit is selected to be realistic given past exploitation rates achieved by aboriginal whalers, but not so low that the conservation performance of a candidate *SLA* would be impacted substantially, such that it would be difficult for any candidate to fail on conservation performance.

E. Mixing

The entries in the mixing matrix V (see Table 1) are selected to model the distribution of each stock/sub-stock at the time when the catch is removed/when the surveys are conducted.

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 sub-areas 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^{2}s (see Table 2).

This variation in future abundance is implemented by applying a power parameter to the mixing matrix entries for each sub-area and year. The power parameters are generated every year from $U\left[\max\left(0,1-\chi_k\right),1+\chi_k\right]$, where the χ_k parameters defining the power parameter distributions are selected such that the realised variability of future populations over years 50-100 for the NM01-4 trial (IWC, 2018a), are close to the adjusted (target) CVs listed in Table 2.

[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 1

The mixing matrices. The γs and Ωs indicate that the entry concerned is estimated during the conditioning process.

	WC	WG	CIP	CG	CIC	CM	EN	EW	ESW	ESE	EB
Stock structure hypothesis I											
Adult females (ages 10+)											
W-1	1	γ_{10}	-	-	-	-	-	-	-	-	-
W-2	γ_{11}	1	γ_{12}	γ_{13}	γ_{14}	-	-	-	-	-	-
C	γ_{15}	γ_{16}	γ_2	γ_3	γ_4	γ_5	0.05	-	0.2 γ_6	-	-
E-1	-	-	-	-	-	-	0.1	γ_7	γ_6	γ_8	γ_9
E-2	-	-	-	-	-	0.05	0.9	0.05	-	-	-
Adult males (ages 10+) and juveniles											
W-1	Ω_{11}	$\gamma_{10}\Omega_{12}$	-	-	-	-	-	-	-	-	-
W-2	$\gamma_{11}\Omega_{11}$	Ω_{12}	$\gamma_{12}\Omega_{13}$	$\gamma_{13}\Omega_{14}$	$\gamma_{14}\Omega_{15}$	-	-	-	-	-	-
C	$\gamma_{15}\Omega_{11}$	$\gamma_{16}\Omega_{12}$	$\gamma_2\Omega_{13}$	$\gamma_3\Omega_{14}$	$\gamma_4\Omega_{15}$	$\gamma_5\Omega_{16}$	0.05 Ω_{17}	-	-	-	-
E-1	-	-	-	-	-	-	0.1 Ω_{17}	$\gamma_7\Omega_{18}$	$\gamma_6\Omega_{19}$	$\gamma_8\Omega_{20}$	$\gamma_9\Omega_{21}$
E-2	-	-	-	-	-	0.05Ω_{16}	0.9 Ω_{17}	0.05 Ω_{18}	-	-	-
Stock structure hypothesis II											
Adult females (ages 10+)											
W	1	γ_{11}	γ_{12}	γ_{13}	γ_{14}	-	-	-	-	-	-
C	γ_{15}	γ_{16}	γ_2	γ_3	γ_4	γ_5	0.05	-	0.2 γ_6	-	-
E-1	-	-	-	-	-	-	0.1	γ_7	γ_6	γ_8	γ_9
E-2	-	-	-	-	-	0.05	0.9	0.05	-	-	-
Adult males (ages 10+) and juveniles											
W	Ω_{11}	$\gamma_{11}\Omega_{12}$	$\gamma_{12}\Omega_{13}$	$\gamma_{12}\Omega_{14}$	$\gamma_{14}\Omega_{15}$	-	-	-	-	-	-
C	$\gamma_{15}\Omega_{11}$	$\gamma_{16}\Omega_{12}$	$\gamma_2\Omega_{13}$	$\gamma_3\Omega_{14}$	$\gamma_4\Omega_{15}$	$\gamma_5\Omega_{16}$	0.05 Ω_{17}	-	-	-	-
E-1	-	-	-	-	-	-	0.1 Ω_{17}	$\gamma_7\Omega_{18}$	$\gamma_6\Omega_{19}$	$\gamma_8\Omega_{20}$	$\gamma_9\Omega_{21}$
E-2	-	-	-	-	-	0.05Ω_{16}	0.9 Ω_{17}	0.05 Ω_{18}	-	-	-

Density dependent mixing

The hunt of minke whales in West Greenland is relatively large compared with the estimates of absolute abundance for the area, but a constant female biased sex ratio in catches over the last 20 years indicates that the hunt is sustainable and that the hunt is likely to be supported by whales from other areas. Operating model variants that allow for density-dependent mixing were also developed that involved:

$$V_{t,a}^{g,j,k} = V_{t,a}^{g,j,k} Q_t^{g,k} \Big/ \sum_{k'} V_{t,a}^{g,j,k'} Q_t^{g,k'} \tag{E.1}$$

where $Q_t^{g,k}$ is a quantity that accounts for the attractiveness of sub-area *k* for animals of gender *g* relative to the other sub-areas during year *t*, defined as:

$$Q_t^{g,k} = (\tilde{Q}^g)^{(1-\tilde{N}_t^{g,k}/\tilde{N}_{-\infty}^{g,k})} \tag{E.2}$$

for the WG sub-area and 1 otherwise;

$\tilde{Q}^g$ are the two parameters (for male and female) that define how mixing rates change with density; and

$$\tilde{N}_t^{g,k} = \sum_j \sum_{a\geq 1} V_{t,a}^{g,j,k} N_{t,a}^{g,j} \qquad \tilde{N}_{-\infty}^{g,k} = \sum_j \sum_{a\geq 1} V_{-\infty,a}^{g,j,k} N_{-\infty,a}^{g,j} \tag{E.3}$$

Table 2

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 sub-area. 'Adjusted' CVs equal 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 (the values in this table were set before the 2015 abundance estimates became available).

	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

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

Table 3

The estimates of abundance and their sampling standard errors.

Year	Sub-area	Abundance	CV	Year	Sub-area	Abundance	CV	Year	Sub-area	Abundance	CV
2007	WC	20,741	0.3	1987	CIC	24,532	0.32	1989	EW	20,991	0.17
1987	WG*	3,266	0.31	2001	CIC	43,633	0.19	1995	EW	34,986	0.12
1993	WG*	8,371	0.43	2007	CIC	20,834	0.35	1996	EW	23,522	0.13
2005	WG	10,792	0.59	2009	CIC	9,588	0.24	2006	EW	27,152	0.218
2007	WG	9,066	0.39	2015	CIC	12,710	0.53	2011	EW	21,218	0.32
2015	WG	5,095	0.46	1988	CM	4,732	0.23	1995	ESW	2,691	0.29
1988	CIP	8,431	0.245	1995	CM	12,043	0.28	1999	ESW	1,932	0.68
2001	CIP	3,391	0.82	1997	CM	26,718	0.14	2008	ESW	5,009	0.29
2007	CIP	1,350	0.38	2005	CM	26,739	0.39	1989	ESE	13,370	0.19
2015	CIP	6,306	0.345	2010	CM	10,991	0.36	1995	ESE	23,278	0.11
1995	CIP+CG*	4,854	0.27	1989	EN	8,318	0.25	1999	ESE	16,241	0.25
1987	CG	1,555	0.26	1995	EN	22,536	0.23	2003	ESE	19,377	0.33
2001	CG	7,349	0.31	1998	EN	13,673	0.25	2008	ESE	22,281	0.18
2007	CG	1,048	0.6	2004	EN	6,246	0.47	1989	EB	21,868	0.21
2015	CG	5,489	0.35	2009	EN	6,891	0.31	1995	EB	29,712	0.18
								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*).

Table 4a

Sighting survey plan. The pattern of surveys from 2020-25 will be repeated every 6 years in the E sub-areas, every 7 years in the C sub-areas and every 10 years in sub-area WG. The years when Assessments are run are also shown (assessments are run every 6 years from 2021 on).

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

*CM was covered as a NAMMCO joint effort in TNASS-2015 but the combined survey estimate is not yet available. $^{\Delta}$The results of the surveys conducted in sub-areas CM, EW, ESW and ESE during 2014 and 2015 are not yet available and are therefore assumed to apply to 2016.

Table 4b

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

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

F. Generation of Data

The actual historical estimates of absolute abundance provided to the RMP (and their associated CVs) are listed in Table 3. 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 in setting the catch limit for 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):

$$\hat{P} = PYw / \mu = P^* \beta^2 Yw \tag{F.1}$$

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 K:

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

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; 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 $CV^2(\hat{P}) = \alpha^2 + \beta^2 P^*/P$.

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:

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

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 $\bar{P}$ is the average value of the total (1+) population sizes in area K in the years of these surveys, then:

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

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 the North Pacific minke whale *Implementation Trials*; IWC (2004b)).

The CVs used by Norway when applying the RMP to the E *Medium Area* during the *catch cascading* process account for process error. However, the trials considered at the 2016 Scientific Committee ignored process error, which led to larger catch limits than would be expected in reality. The trials were therefore modified to multiply the CVs of abundance estimates for the E *Medium Area* by the slope of a regression of the CVs for the E *Medium Area* which took process error into account against the CVs for this Area when process error is ignored (1.43) (IWC, 2018b).

G. Parameters and conditioning

The values for the biological and technological parameters are listed in Table 5a.

Table 5a

The values for the biological parameters that are fixed and the selectivity parameters by area

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	$a_{50} = 8$; $\delta = 1.2$
Maximum Sustainable Yield Level, *MSYL*	0.6 in terms of the 1+ population
Selectivity 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 trials with density-dependent mixing estimate two additional parameters ($\tilde{Q}$ for males and females). 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 2016 to obtain values of abundance, mixing proportions and sex ratios by sub-area for comparison with the generated data.

The likelihood function used when fitting the model consists of four components (or five in trials that allow for density-dependent mixing). Equations G.2, G.3, G.5, G.8 and G.11 list the negative of the logarithm of the likelihood for each of these components so the objective function minimised is $L_1+L_2+L_3+L_4$. 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:

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

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 negative log-likelihood from the abundance data is given by:

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

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

(b) Mixing Proportions

Table 5b lists the mixing proportions of the W and C stocks used to estimate the mixing matrices entries. The rationale for these values is given in IWC (2019, item 3.4). In order to ensure that the conditioning leads to the specified model predictions, the mixing proportions are fixed (not generated) in the conditioning process and assigned low CVs (0.01).

Table 5b

The mixing proportions for use in the trials.

(a) Stock structure hypothesis I

Scenario	(and basis)	MSYR	Proportion of W-1 stock in sub-area		Proportion of W-2 stock in sub-area				
			WC	WG	WC	WG	CIP	CG	CIC
A1: Base line	(80% of B1 W stk)	$MSYR_{1+}$ = 1% & $MSYR_{mat}$=4%	0.52	0.13	0.13	0.52	0.30	0.60	0.30
A2:	(94% of B1 W stk)	$MSYR_{1+}$ = 1% & $MSYR_{mat}$=4%	0.60	0.05	0.05	0.60	0.30	0.60	0.30
A3: Concentrated	(80% of B2 W stk)	$MSYR_{1+}$ = 1% & $MSYR_{mat}$=4%	0.65	0.15	0.15	0.65	0.20	0.70	0.20
A4:	(94% of B2 W stk)	$MSYR_{1+}$ = 1% & $MSYR_{mat}$=4%	0.75	0.05	0.05	0.75	0.20	0.70	0.20
A5: Concentrated	(80% of B2 W stk)	$MSYR_{1+}$ = 1% & $MSYR_{mat}$=4%	0.45	0.10	0.10	0.45	0.40	0.50	0.40
A6:	(94% of B2 W stk)	$MSYR_{1+}$ = 1% & $MSYR_{mat}$=4%	0.52	0.03	0.03	0.52	0.40	0.50	0.40

(b) Stock structure hypothesis II

Scenario	MSYR	Proportion of W stock in sub-area				
		WC	WG	CIP	CG	CIC
B1: Best	$MSYR_{1+}$ = 1% & $MSYR_{mat}$=4%	0.65	0.65	0.30	0.60	0.30
B2: Concentrated	$MSYR_{1+}$ = 1% & $MSYR_{mat}$=4%	0.80	0.80	0.20	0.70	0.20
B3: Spread out	$MSYR_{1+}$ = 1% & $MSYR_{mat}$=4%	0.55	0.55	0.40	0.50	0.40

The contribution of the mixing proportions to the negative log-likelihood is given by:

$$L_2 = 0.5\sum_n \tfrac{1}{\sigma_n^2}(\rho_n - \hat{\rho}_n)^2 \quad \text{(G.3)}$$

where:

ρ_n is the *n*th stock mixing proportion; and

$\hat{\rho}_n$ is the model-estimate corresponding to the *n*th stock mixing proportion, i.e.:

$$\hat{\rho}_n = \sum_{t \in t^*}\sum_g \sum_a V_{t,a}^{g,j^*,k^*} N_{t^*,a}^{g,j^*} \,/\, \sum_{t \in t^*}\sum_j \sum_g \sum_a V_{t,a}^{g,j,k^*} N_{t,a}^{g,j} \quad \text{(G.4)}$$

t^*, k^*, j^* are the year range (2000-2015), sub-area and stock corresponding to the *n*th stock mixing proportion.

(c) Average sex ratios

The parameters used to define the catch and the sightings mixing matrices are estimated during the conditioning process. The data on catch sex-ratios by month for North Atlantic minke whales (see Adjunct 2) 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 the WG sub-area and in July for all other sub-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. 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 for those for sub-areas 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 negative log- likelihood from the survey sex ratios is given by:

$$L_3 = 0.5\sum_k \left(\hat{\lambda}^{1,k} - \lambda^{1,k}\right)^2 / \left(\sigma^{1,k}\right)^2 \qquad \text{(G.5)}$$

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:

$$\hat{\lambda}^{1,k} = \frac{\sum_a \sum_j V^{f,j,k}_{-\infty,a} S^{f,k}_a N^{f,j}_{-\infty,a}}{\sum_g \sum_{a'} \sum_{j'} V^{g,j',k}_{-\infty,a'} S^{g,k}_a N^{g,j'}_{-\infty,a'}} \qquad \text{(G.6)}$$

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

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

$$R^{g,h}_a = (1+e^{-(a-a^{g,h}_{50}/\delta g,h)})^{-1} \qquad \text{(G.7)}$$

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

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 $\sigma^{2,\text{h}}$	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

$$L_4 = 0.5\sum_h \left(\hat{\lambda}^{2,h} - \lambda^{2,h}\right)^2 / \left(\sigma^{2,h}\right)^2 \qquad \text{(G.8)}$$

where:

$\lambda^{2,h}$ is the target fishery sex-ratio (proportion of females) for hunt h (see Table 8);

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

$$\hat{\lambda}^{2,h} = \sum_t \left\{ \left(C_t^{\mathrm{m},h} + C_t^{\mathrm{f},h}\right) \frac{\sum_a \sum_j \sum_{k\in h} V_{t,a}^{\mathrm{f},j,k}\tilde{S}_a^{\mathrm{f},h} N_{t,a}^{f,j}}{\sum_g \sum_{a'} \sum_{j'} \sum_{k\in h} V_{t,a'}^{g,j',k}\tilde{S}_{a'}^{g,h} N_{t,a'}^{f,j'}} \right\} / \sum_{t'}\left(C_{t'}^{\mathrm{m},h} + C_{t'}^{\mathrm{f},h}\right) \qquad \text{(G.9)}$$

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

$$\tilde{S}_a^{\mathrm{m},h} = \omega^h R_a^{\mathrm{m},h} \quad \text{and} \quad \tilde{S}_a^{\mathrm{f},h} = R_a^{\mathrm{f},h} \qquad \text{(G.10)}$$

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).

(d) Time-series of sex ratios for West Greenland

The trials that allow for density-dependent mixing include an additional component to the negative log-likelihood that reflects the time series of sex ratios for West Greenland.

$$L_5 = \sum_t \left(\ell n\sigma_C + \frac{1}{2\sigma_C^2}[\mathrm{logit}(\phi_t^{\mathrm{WG}}) - \mathrm{logit}(\hat{\phi}_t^{\mathrm{WG}})]^2 \right) \qquad \text{(G.11)}$$

where:

ϕ_t^{WG} is the observed catch sex ratio in the West Greenland sub-area during year t for years 1994-2015,

$\hat{\phi}_t^{WG}$ is the model-estimate corresponding to ϕ_t^{WG}:

$$\hat{\phi}_t^{WG} = \frac{\sum_a \sum_j V_{t,a}^{\mathrm{f},j,WG}\tilde{S}_a^{\mathrm{f},h} N_{t,a}^{f,j}}{\sum_g \sum_{a'} \sum_{j'} V_{t,a'}^{g,j',WG}\tilde{S}_{a'}^{g,h} N_{t,a'}^{f,j'}} \qquad \text{(G.12)}$$

σ_C quantifies the extent of variability in catch sex-ratio.

The additional estimable parameters for the model are the density-dependence parameter $\tilde{Q}^g$ for the two sexes.

H. Trials

Table 9 summarises the factors considered in the trials. Table 10 lists the set of trials. Need envelopes for West Greenland are a constant 164 (A), increasing from 164 to 250 over the 100-year period (B) and increasing from 164 to 350 over the 100-year period (C). The need envelope for East Greenland is constant and equal to 20 per year.

For trials used in the development of an *SLA,* instead of applying the RMP to set the annual catch limits by sub-area and year for each simulation, the RMP catch limits are pre-specified as detailed in Section I.

Table 9

Factors considered in the *Evaluation and Robustness Trials*.

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

1: Default.

Table 10

The final set of trials. Trials M03, M05 and M07 were initially included in the *Evaluation Trials*, but at the SC meeting in 2018 it was agreed trials using 94% proportions (mixing proportions A2,A4 and A6) would be relegated to *Robustness Trials*. Trials are performed for each of the Need envelopes (A, B or C)

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

I. Management Options

Rather than applying the RMP to set the annual catch limits by sub-area and year for each simulation, the RMP catch limits are pre-specified, with trial-specific catch limits by year based on the two Baseline Hypothesis I trials (M01-1 and M01-4). Pre-specifying the RMP catches allows the trials to run more quickly. The trials used to calculate the RMP catches involve (a) using the interim *SLA* to set the strike limit for the WG and CG sub-areas and (c) applying RMP Variant 5 (IWC, 2018a) to determine RMP catch limits, but capping the CIC catch at 100 whales. The cap is introduced because catches in the CIC sub-area have the most impact on stocks in the WG sub-area, and the catch being set is much higher than is currently taken (the highest annual catch in the CIC sub-area since 1986 is 81 whales).

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

(i) ≤ the aboriginal strike limit (as set by the *SLA*), the catch limit for that *Combination Area* or *Small Area* is set to zero and the aboriginal catch is equal to the strike limit; or

(ii) > the aboriginal strike limit, the catch limit for that *Combination Area* or *Small Area* is set to the RMP catch limit less the aboriginal strike limit.

J. Output Statistics

The risk- and recovery-related performance statistics are computed both for the mature female and for the total (1+) population sizes (i.e. P_t is either the size of the mature female component of the population, N_t^f, or the size of the total (1+) population, N_t^{1+}). P_t^* is the population size in year t under a scenario of zero strikes over the years $t \geq 2016$ (defined as t=0 below). $P_t^*(0)$ is used to denote the population size in year t under a scenario of zero strikes or removals of any kind, and $P_t^*(inc) = P_t^*$ reflects the case when there are zero strikes but some incidental removals may occur. K^* is the population size in year t if there had never been any anthropogenic removals.

The trials are based on a 100-year time horizon, but a final decision regarding the time horizon will depend *inter alia* on interactions between the Committee and the Commission regarding need envelopes and on the period over which recovery might occur. To allow for this, results are calculated for T=20 and 100 (T^* denotes the number of blocks for a given T; T^* is 3 and 19 respectively for T=20 and T=100).

Statistics marked in bold face are considered the more important. Note that the statistic identification numbers have not been altered for reasons of consistency over time. Hence, there are gaps in the numbers where some statistics have been deleted.

E.1 Risk

D1. Final depletion: P_T/K. In trials with varying K this statistic is defined as P_T/K_t^*.

D2. Lowest depletion: $\min(P_t/K)$: t=0,1,..., T. In trials with varying K this statistic is defined as $\min(P_t/K_t^*)$: t=0,1,..., T.

D6. Plots for simulations 1-100 of $\{P_t$: $t = 0,1,.., T\}$ and $\{P_t^*$: $t = 0,1,.., T\}$.

D7. Plots of $\{P_{t[x]}$: $t = 0,1,.., T\}$ and $\{P^*_{t[x]}$: $t = 0,1,.., T\}$ where $P_{t[x]}$: is the xth percentile of the distribution of P_t. Results are presented for x=5 and x=50.

D8. Rescaled (1+) final population: P_T / P_T^*. There are two versions of this statistic: D8(0)= $P_T / P_T^*(0)$ and D8(inc)= P_T / P_T^* (inc).

D9. Minimum (mature female) population level: $\min(P_t)$: t=0,1,..., T.

D10. Relative increase of 1+ population size, P_T/P_0.

E.2 Need

N1. Total need satisfaction: $\sum_{t=0}^{T-1} C_t / \sum_{t=0}^{T-1} Q_t$.

N2. Length of shortfall = (negative of the greatest number of consecutive years in which $C_b < Q_b$) / T^*, where C_b is the catch for block b and Q_b is the total need for block b.

N4. Fraction of years in which $C_t = Q_t$.

N7. Plot of $\{V_{t[x]} : t = 0,1,T-1\}$ where $V_{t[x]}$ is the xth percentile of the distribution of $V_t = C_t/Q_t$.

N8. Plots of V_t for simulations 1-100.

N9. Average need satisfaction: $\frac{1}{T}\sum_{t=0}^{T-1}\frac{C_t}{Q_t}$.

N10. AAV (Average Annual Variation): $\sum_{b=0}^{T^*-1}|C_{b+1}-C_b| / \sum_{b=0}^{T^*-1}C_b$.

N11. Anti-curvature: $\frac{1}{T^*-1}\sum_{b=0}^{T^*-2}\left|\frac{C_b - M_b}{\max(10,M_b)}\right|$ where $M_b = (C_{b+1}+C_{b-1})/2$.

N12. Mean downstep (or modified AAV): $\sum_{b=0}^{T^*-1}|\min(C_{b+1}-C_{b^2},0)| / \sum_{b=0}^{T^*-1}C_b$

E.3 Recovery

R1. Relative recovery: $P_{t_r^*} / P^*_{t_r^*}$ where t_r^* is the first year in which P_t^* passes through $MSYL$. If P_t^* never reaches $MSYL$, the statistic is P_T / P_t^*. If $P_0 > MSYL$ the statistic is $\min(1, P_T/MSYL)$.

The following plots are to be produced to evaluate conditioning.

Time-trajectories of 1+ population size in absolute terms and relative to carrying capacity, along with the fits to abundance estimates. This plot allows an evaluation of whether conditioning has been achieved satisfactorily.

Histograms of the 100 parameter vectors for each trial. This plot allows an evaluation of whether and how conditioning has impacted the priors for these parameters.

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Adjunct 1: The Catch Series

C. Allison

The catch series used in the trials is given in Table 1 and includes all known direct and indirect catches of minke whales in the North Atlantic. Details of the sources of the direct catch data are given in Allison (2015) and of the indirect catches in IWC (2015, pp.123-4). Two catches known to have been taken prior to 1900 are ignored. Catches from the Faroes (125 whales) are allocated to the EW sub-area, as they were all taken from land stations in the north of the Faroes. Data for catches by Norway from 1938 onwards includes detailed positions for all except 16 records; these have been allocated to sub-area in accordance with the ratio of other catches in the same year.

Catches known by sex are listed by sex and sub-area/hunt in Table 2. The average sex ratio for the hunt is assumed for any other catches.

Table 1

The 'Best' Catch Series.

Year	WC	WG-comm.	WG-aborig.	CIP	CG	CIC	CM	EN	EW	ESW	ESE	EB	Total
1914	0	0	0	0	0	1	0	0	0	0	0	0	1
1915	0	0	0	0	0	10	0	0	0	0	0	0	10
1916	0	0	0	0	0	6	0	0	0	0	0	0	6
1917	0	0	0	0	0	6	0	0	0	0	0	0	6
1918	0	0	0	0	0	6	0	1	0	0	0	0	7
1919	0	0	0	0	0	6	0	5	3	0	0	0	14
1920	0	0	0	0	0	6	0	0	0	0	0	0	6
1921	0	0	0	0	0	20	0	0	0	0	0	0	20
1922	0	0	0	0	0	20	0	0	0	0	0	0	20
1923	0	0	0	0	0	20	0	0	0	0	0	0	20
1924	0	0	0	0	0	20	0	0	0	0	0	0	20
1925	0	0	0	0	0	20	0	0	0	0	0	0	20
1926	0	0	0	0	0	9	0	0	4	0	0	0	13
1927	0	0	0	0	0	9	0	0	4	0	0	0	13
1928	0	0	0	0	0	9	0	0	0	0	0	0	9
1929	0	0	0	0	0	9	0	2	4	0	0	0	15
1930	0	0	0	0	0	9	0	28	10	0	0	0	47
1931	0	0	0	0	0	7	0	0	175	0	0	0	182
1932	0	0	0	0	0	5	0	0	350	0	0	0	355
1933	0	0	0	0	0	10	0	0	525	0	0	0	535
1934	0	0	0	0	0	4	0	30	670	0	0	0	704
1935	0	0	0	0	0	2	0	50	828	0	0	0	880
1936	0	0	0	0	0	1	0	84	909	0	30	30	1,054
1937	0	0	0	0	0	1	0	125	996	0	60	50	1,232
1938	0	0	0	0	0	1	0	266	907	0	112	68	1,354
1939	0	0	0	0	0	1	0	137	762	1	12	6	919
1940	0	0	0	0	0	1	0	35	503	0	1	13	553
1941	0	0	0	0	0	5	0	186	1,914	0	4	6	2,115
1942	1	0	0	0	0	18	0	158	1,976	0	0	0	2,153
1943	0	0	0	0	0	16	0	158	1,455	0	0	0	1,629
1944	0	0	0	0	0	15	0	97	1,252	0	0	0	1,364
1945	0	0	0	0	0	16	0	165	1,611	0	0	10	1,802
1946	0	0	0	0	0	34	0	305	1,337	0	140	101	1,917
1947	16	0	0	0	0	34	0	373	1,810	0	136	237	2,606
1948	38	0	4	0	0	102	0	358	2,035	0	559	535	3,631
1949	38	0	5	0	0	106	7	241	1,206	0	701	1,693	3,997
1950	3	0	9	0	0	80	0	106	1,173	0	274	437	2,082
1951	55	0	16	0	0	63	0	89	1,836	0	155	672	2,886
1952	17	0	32	0	0	64	0	122	1,273	0	101	1,829	3,438
1953	0	0	32	0	0	79	0	63	1,231	0	62	1,079	2,546
1954	0	0	22	0	0	54	0	359	1,508	0	88	1,544	3,575
1955	13	0	22	0	6	57	1	435	2,138	1	56	1,679	4,408
1956	57	0	22	0	0	21	3	441	1,611	10	483	1,111	3,759
1957	37	0	24	1	0	37	0	593	1,417	12	612	1,000	3,733
1958	42	0	30	0	0	36	0	639	1,658	3	498	1,543	4,449
1959	18	0	55	0	14	35	2	575	900	15	495	1,091	3,200
1960	11	0	56	4	12	82	0	628	1,039	14	369	1,223	3,438
1961	22	0	35	1	3	108	72	377	1,322	13	208	1,187	3,348

Year	WC	WG-comm.	WG-aborig.	CIP	CG	CIC	CM	EN	EW	ESW	ESE	EB	Total
1962	50	0	72	0	3	134	158	400	1,302	22	113	1,225	3,479
1963	18	0	166	5	10	115	80	340	1,043	5	324	1,355	3,461
1964	54	0	162	1	8	153	151	400	1,057	10	233	769	2,998
1965	41	0	196	3	0	147	255	268	1,062	5	534	253	2,764
1966	11	0	225	15	87	123	88	330	633	1	288	671	2,472
1967	40	0	244	44	143	193	66	181	901	91	536	118	2,557
1968	0	20	315	62	211	409	45	355	893	90	656	114	3,170
1969	60	165	269	22	94	214	21	479	667	22	397	467	2,877
1970	88	126	207	8	159	222	13	350	632	20	628	282	2,735
1971	84	263	196	38	29	228	17	410	385	0	524	483	2,657
1972	214	123	156	32	139	199	0	319	231	0	158	1467	3,038
1973	3	221	276	24	222	147	0	200	267	3	253	839	2,455
1974	3	252	217	12	102	127	15	172	291	0	26	931	2,148
1975	4	102	222	15	217	193	0	186	269	0	324	651	2,183
1976	3	187	191	3	81	216	0	186	148	0	365	1190	2,570
1977	1	75	285	0	1	194	0	118	281	0	749	551	2,255
1978	2	75	180	0	130	199	3	83	312	0	162	826	1,972
1979	9	75	250	0	119	198	1	76	446	0	62	1202	2,438
1980	10	78	258	0	119	202	0	67	259	0	477	1004	2,474
1981	8	61	204	0	45	201	0	62	385	0	714	610	2,290
1982	4	66	250	0	109	212	0	60	344	0	655	723	2,423
1983	4	68	268	0	98	204	15	36	158	0	623	871	2,345
1984	6	70	235	0	25	178	90	19	219	0	183	209	1,234
1985	7	52	222	0	44	145	55	23	171	0	209	231	1,159
1986	4	0	145	0	2	0	50	33	129	0	128	39	530
1987	8	0	86	0	4	0	50	34	92	0	157	40	471
1988	9	0	109	0	10	0	0	0	29	0	0	0	157
1989	10	0	63	0	10	0	0	0	1	0	16	0	100
1990	11	0	89	0	6	0	0	0	5	0	0	0	111
1991	5	0	109	0	10	0	0	0	1	0	0	0	125
1992	8	0	110	0	11	0	0	0	37	0	36	22	224
1993	5	0	113	0	9	0	13	8	120	0	51	34	353
1994	5	0	104	0	5	0	41	9	94	0	31	105	394
1995	7	0	155	0	9	0	42	3	38	0	46	89	389
1996	0	0	170	0	13	0	40	24	75	0	112	137	571
1997	2	0	148	0	14	0	20	40	74	0	129	240	667
1998	5	0	169	0	10	0	57	137	85	0	129	217	809
1999	9	0	172	0	14	0	58	122	158	0	112	141	786
2000	1	0	147	0	10	0	57	65	192	0	103	70	645
2001	10	0	139	0	17	0	31	104	247	0	120	50	718
2002	9	0	140	0	10	2	35	74	253	0	146	126	795
2003	6	0	185	0	14	37	21	98	157	0	150	221	889
2004	8	0	179	0	11	25	17	93	199	0	113	125	770
2005	6	0	176	0	4	41	5	9	244	0	99	284	868
2006	2	0	181	0	3	62	0	34	373	0	118	23	796
2007	7	0	167	0	2	45	0	99	176	0	295	28	819
2008	6	0	154	0	1	38	31	98	160	0	230	22	740
2009	0	0	165	0	4	81	0	50	182	0	250	4	736
2010	5	0	187	0	9	60	1	35	145	0	270	18	730
2011	4	0	179	0	10	58	0	14	218	0	201	100	784
2012	0	0	148	0	4	52	0	14	200	0	244	6	668
2013	0	0	175	0	6	35	0	2	242	0	282	68	810
2014	0	0	146	0	11	24	0	20	231	0	377	108	917
2015	0	0	133	0	6	29	0	4	137	0	426	93	828
Total	1,244	2,079	9,973	290	2,479	6,423	1,727	13,574	55,002	338	18,720	36,596	148,445

Table 2
Catches known by sex.

	WC		WG-com		WG-ab		CIP		CG		CIC		CM		EN		EW		ESW		ESE		EB	
Year	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
1914	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1915	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1916	0	0	0	0	0	0	0	0	0	0	0	0	0	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	0	0	0	0	0	0	0
1918	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1919	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1920	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1921	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1922	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1923	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1924	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1925	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1926	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0
1927	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0
1928	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1929	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	3	1	0	0	0	0	0	0
1930	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	13	0	0	0	0	0	0	0	0
1931	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1932	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1933	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1934	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1935	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0
1936	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0
1937	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	1	0	0	0	0	0	0
1938	0	0	0	0	0	0	0	0	0	0	0	0	0	0	143	98	463	386	0	0	50	50	47	19
1939	0	0	0	0	0	0	0	0	0	0	0	0	0	0	63	70	383	323	1	0	5	7	4	2
1940	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	25	257	207	0	0	0	0	9	4
1941	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	78	1,003	863	0	0	2	2	3	3
1942	0	0	0	0	0	0	0	0	0	0	0	0	0	0	94	64	1,112	853	0	0	0	0	0	0
1943	0	0	0	0	0	0	0	0	0	0	0	0	0	0	88	69	844	592	0	0	0	0	0	0
1944	0	0	0	0	0	0	0	0	0	0	0	0	0	0	45	52	658	585	0	0	0	0	0	0
1945	0	0	0	0	0	0	0	0	0	0	0	0	0	0	104	55	891	705	0	0	0	0	7	3
1946	0	0	0	0	0	0	0	0	0	0	0	0	0	0	190	114	737	588	0	0	58	78	65	35
1947	0	0	0	0	0	0	0	0	0	0	9	3	0	0	202	166	1,013	779	0	0	47	89	162	72
1948	24	14	0	0	0	0	0	0	0	0	38	28	0	0	207	148	1,100	905	0	0	234	317	321	200
1949	24	14	0	0	0	0	0	0	0	0	38	33	3	4	141	99	652	542	0	0	250	446	841	826
1950	2	1	0	0	0	0	0	0	0	0	0	0	0	0	61	44	649	510	0	0	62	212	179	254
1951	26	29	0	0	0	0	0	0	0	0	0	0	0	0	68	20	1030	791	0	0	68	87	243	428
1952	10	7	0	0	0	0	0	0	0	0	1	1	0	0	75	46	704	561	0	0	59	42	632	1,185
1953	0	0	0	0	0	0	0	0	0	0	0	0	0	0	37	26	721	504	0	0	37	24	436	642
1954	0	0	0	0	0	0	0	0	0	0	0	0	0	0	204	149	795	702	0	0	54	34	688	852
1955	5	8	0	0	7	8	0	0	1	5	4	9	0	1	244	181	1,156	972	1	0	18	37	620	1,053
1956	27	27	0	0	5	15	0	0	0	0	0	0	3	0	288	149	906	694	4	6	159	323	451	659
1957	6	12	0	0	6	18	1	0	0	0	1	0	0	0	380	210	772	634	1	11	151	457	347	651
1958	0	0	0	0	5	6	0	0	0	0	0	0	0	0	412	225	950	704	2	1	152	346	470	1,052
1959	6	12	0	0	2	17	0	0	9	5	1	0	0	2	423	149	483	414	1	14	121	373	594	480
1960	5	6	0	0	3	15	3	1	4	8	7	2	0	0	436	187	531	482	2	12	114	253	443	779
1961	8	14	0	0	7	9	1	0	3	0	42	8	45	27	236	140	779	530	9	4	65	143	349	821
1962	0	0	0	0	18	43	0	0	3	0	48	24	82	75	261	137	704	583	8	14	34	79	364	839
1963	2	16	0	0	32	47	3	2	9	1	40	28	33	47	214	126	592	450	2	3	115	209	517	836
1964	12	42	0	0	26	37	1	0	5	3	85	22	88	63	278	121	549	500	4	6	65	168	289	478
1965	7	4	0	0	19	30	2	1	0	0	51	36	112	143	175	93	583	477	3	2	151	381	112	137
1966	0	0	0	0	24	49	13	2	69	18	31	28	12	76	218	111	362	249	1	0	96	192	171	498
1967	15	25	0	0	7	42	31	13	108	35	78	38	42	24	125	53	553	338	31	60	154	381	59	59
1968	0	0	7	13	10	47	33	29	106	104	163	157	32	13	233	117	528	329	51	39	346	304	59	54
1969	33	27	119	46	14	42	11	11	64	30	37	17	6	15	300	173	444	221	12	10	80	317	177	289
1970	22	66	74	52	12	20	4	4	91	68	56	32	6	7	197	148	383	245	7	13	239	389	62	218
1971	20	63	86	177	6	25	2	4	23	6	47	34	6	11	281	115	212	166	0	0	177	345	183	299
1972	84	130	32	91	6	40	16	16	74	65	42	23	0	0	189	126	116	111	0	0	39	119	446	1,014
1973	0	0	67	154	8	39	17	6	159	62	13	7	0	0	109	90	149	117	0	3	54	199	334	503
1974	1	0	43	209	6	34	7	4	73	28	60	62	1	14	89	81	144	136	0	0	3	23	290	636
1975	0	0	11	91	1	17	7	8	84	132	89	80	0	0	131	55	156	109	0	0	66	257	246	405
1976	0	1	38	149	2	20	3	0	57	23	114	87	0	0	115	71	64	74	0	0	85	279	351	839

	WC		WG-com		WG-ab		CIP		CG		CIC		CM		EN		EW		ESW		ESE		EB	
Year	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
1977	0	0	21	54	15	39	0	0	0	0	103	86	0	0	70	48	186	90	0	0	231	517	223	328
1978	0	0	10	65	2	13	0	0	72	58	85	113	3	0	54	29	152	159	0	0	13	148	251	574
1979	0	1	31	44	0	1	0	0	75	43	111	87	1	0	41	32	296	148	0	0	14	48	409	783
1980	2	2	14	64	0	0	0	0	77	39	120	81	0	0	54	12	182	73	0	0	155	320	388	604
1981	0	0	15	46	1	1	0	0	10	35	113	77	0	0	36	25	209	168	0	0	257	454	256	354
1982	0	0	24	42	0	0	0	0	84	24	127	85	0	0	44	16	168	174	0	0	184	471	233	476
1983	0	0	25	42	0	0	0	0	51	38	117	87	1	14	23	13	88	67	0	0	182	440	315	543
1984	0	0	20	49	0	0	0	0	6	9	91	71	28	62	17	2	164	54	0	0	65	118	89	119
1985	0	0	28	24	0	0	0	0	15	15	92	50	3	52	19	2	142	28	0	0	56	153	103	126
1986	0	0	0	0	0	0	0	0	0	0	0	0	6	44	24	9	109	19	0	0	66	62	27	12
1987	0	0	0	0	14	29	0	0	0	4	0	0	12	38	20	14	46	46	0	0	61	96	27	13
1988	0	0	0	0	5	35	0	0	1	4	0	0	0	0	0	0	21	8	0	0	0	0	0	0
1989	0	0	0	0	16	34	0	0	0	1	0	0	0	0	0	0	1	0	0	0	1	15	0	0
1990	0	0	0	0	14	62	0	0	0	5	0	0	0	0	0	0	4	1	0	0	0	0	0	0
1991	0	0	0	0	19	63	0	0	2	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1992	0	1	0	0	18	75	0	0	0	8	0	0	0	0	0	0	22	13	0	0	15	20	14	8
1993	1	0	0	0	25	71	0	0	0	2	0	0	5	8	1	7	79	36	0	0	4	45	6	26
1994	0	0	0	0	20	77	0	0	0	5	0	0	3	38	5	3	61	29	0	0	5	25	57	47
1995	0	1	0	0	46	105	0	0	0	2	0	0	4	38	1	2	14	23	0	0	2	43	13	76
1996	0	0	0	0	37	126	0	0	1	12	0	0	1	39	5	18	18	56	0	0	2	110	27	107
1997	0	0	0	0	42	102	0	0	1	10	0	0	0	19	9	29	33	41	0	0	1	126	70	168
1998	1	0	0	0	41	124	0	0	1	9	0	0	8	49	50	82	31	53	0	0	2	125	37	177
1999	0	3	0	0	35	133	0	0	1	13	0	0	9	46	47	69	67	81	0	0	2	104	37	95
2000	0	0	0	0	37	103	0	0	2	8	0	0	23	33	25	39	101	85	0	0	1	96	24	43
2001	0	0	0	0	32	91	0	0	0	14	0	0	4	27	31	71	150	92	0	0	0	116	11	39
2002	0	2	0	0	33	97	0	0	0	10	1	1	6	29	37	33	140	111	0	0	21	114	22	102
2003	2	2	0	0	57	118	0	0	1	11	23	13	1	19	45	48	73	82	0	0	5	135	89	127
2004	0	3	0	0	44	129	0	0	4	7	10	15	0	17	35	55	95	102	0	0	2	109	23	100
2005	1	0	0	0	34	135	0	0	3	1	20	15	4	1	6	3	108	133	0	0	5	92	31	249
2006	0	0	0	0	44	127	0	0	2	0	31	28	0	0	11	21	200	166	0	0	9	108	0	22
2007	0	1	0	0	38	121	0	0	0	1	14	28	0	0	52	44	86	88	0	0	12	271	20	8
2008	0	1	0	0	55	87	0	0	0	1	28	7	5	26	44	50	99	55	0	0	9	220	12	10
2009	0	0	0	0	47	107	0	0	3	1	64	14	0	0	29	21	83	98	0	0	13	237	1	3
2010	1	0	0	0	54	122	0	0	4	2	47	12	0	1	5	29	80	65	0	0	11	256	6	12
2011	0	0	0	0	39	133	0	0	0	9	45	13	0	0	1	13	121	95	0	0	26	173	15	83
2012	0	0	0	0	34	108	0	0	0	4	38	11	0	0	1	13	113	84	0	0	26	214	4	2
2013	0	0	0	0	37	127	0	0	1	3	13	22	0	0	1	0	144	94	0	0	28	253	21	47
2014	0	0	0	0	27	115	0	0	1	9	16	7	0	0	7	11	122	108	0	0	79	297	28	79
2015	0	0	0	0	26	101	0	0	0	6	21	8	0	0	3	1	60	77	0	0	75	351	21	72
Total	347	535	665	1,412	1,214	3,531	155	101	1,360	1,021	2,425	1,690	598	1,122	8,036	5,058	28,011	21,840	140	198	5,050	13,444	13,481	22,758

References

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Adjunct 2: Data used to estimate the Survey and Fishery Sex Ratios (see Annex D, Tables 6 and 8)

C. Allison

The sex ratios in the catches of North Atlantic minke whales have been shown to be both spatially and seasonally variable (see IWC, 2015, Item 5, pp.120-122). The trials 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 Annex D, Section G).

'Survey' sex-ratio data

The 'Survey' sex-ratios are intended to reflect such ratios at the time when whaling commenced, and 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 data used are listed in Table 1. The 'survey' sex ratios for the sub-areas where the catches in the survey month are relatively small (WC, CIP, CG, CIC and CM) are estimated using data from all years (see Table 1). Catches in the CIC sub-area from the 1986-92 period are excluded as they were primarily taken during a scientific whaling program and hence may be more widely distributed across the area than commercial catches and with a different sex ratio. The 'Survey' sex-ratio for the WG sub-area is estimated using the data for 1986 on as the sex ratio from the recent aboriginal hunt differs from that in the earlier commercial catches (see IWC, 2015, pp.120-122). Bycatch data are omitted.

Table 1

Catches used to estimate 'survey' sex ratios by sub-area.

Month:	July		September		July		July		July		July		July	
Years:	All		<1986		All		All		All		All		All	
Sub-area:	WC		WG		CIP		CG		CIC		CM		ESW	
Year	M	F	M	F	M	F	M	F	M	F	M	F	M	F
1948	10	5	-	-	-	-	-	-	16	10	-	-	-	-
1949	15	6	-	-	-	-	-	-	21	18	3	4	-	-
1950	0	1	-	-	-	-	-	-	-	-	-	-	-	-
1951	8	4	-	-	-	-	-	-	-	-	-	-	-	-
1952	2	2	-	-	-	-	-	-	1	1	-	-	-	-
1953	5	3	-	-	-	-	-	-	-	-	-	-	-	-
1954	9	14	-	-	-	-	-	-	-	-	-	-	-	-
1955	2	1	-	-	-	-	-	-	3	7	0	1	-	-
1956	8	6	-	-	-	-	-	-	-	-	3	0	-	-
1957	4	8	-	-	-	-	-	-	-	-	-	-	-	-
1959	3	7	-	-	-	-	-	-	-	-	-	-	-	-
1960	4	2	0	1	-	-	-	-	1	1	-	-	-	-
1961	4	7	1	2	-	-	3	0	20	3	10	5	-	-
1962	0	0	6	11	-	-	0	0	6	3	42	41	6	10
1963	0	0	-	-	-	-	1	0	3	3	11	25	0	0
1964	0	2	-	-	-	-	1	3	6	4	29	25	1	2
1965	5	3	-	-	-	-	0	0	22	18	50	29	0	0
1966	1	3	-	-	6	1	0	0	6	4	1	3	0	0
1967	3	11	-	-	6	3	52	14	39	27	32	1	0	0
1968	0	0	0	0	0	0	7	11	22	17	14	3	8	7
1969	9	12	0	0	0	1	3	1	0	0	3	7	1	0
1970	4	12	11	13	3	2	30	24	31	15	2	3	0	3
1971	3	4	11	16	0	0	1	1	20	26	5	11	-	-
1972	22	22	1	0	2	1	7	4	29	16	-	-	-	-
1973	-	-	0	0	10	3	26	16	5	1	-	-	-	-
1974	-	-	0	1	1	0	9	6	6	4	-	-	-	-
1975	-	-	0	0	1	2	25	55	24	18	-	-	-	-
1976	-	-	0	0	-	-	22	6	25	21	-	-	-	-
1977	-	-	0	0	-	-	0	0	44	28	-	-	-	-
1978	-	-	0	0	-	-	55	36	51	39	-	-	-	-
1979	-	-	6	4	-	-	43	28	37	25	1	0	-	-
1980	-	-	0	0	-	-	17	8	63	32	-	-	-	-
1981	-	-	1	0	-	-	-	-	26	32	-	-	-	-
1982	-	-	2	2	-	-	-	-	30	19	-	-	-	-
1983	-	-	8	6	-	-	-	-	30	28	1	5	-	-
1984	-	-	7	15	-	-	-	-	40	22	25	52	-	-
1985	-	-	5	2	-	-	6	14	31	21	0	10	-	-
1986	-	-	-	-	-	-	-	-	-	-	4	29	-	-

Month:	July		September		July		July		July		July		July	
Years:	All		<1986		All		All		All		All		All	
Sub-area:	WC		WG		CIP		CG		CIC		CM		ESW	
Year	M	F	M	F	M	F	M	F	M	F	M	F	M	F
1987	-	-	3	1	-	-	-	-	-	-	9	12	-	-
1988	-	-	1	6	-	-	-	-	-	-	-	-	-	-
1989	-	-	3	7	-	-	-	-	-	-	-	-	-	-
1990	-	-	4	12	-	-	-	-	-	-	-	-	-	-
1991	-	-	4	14	-	-	-	-	-	-	-	-	-	-
1992	-	-	3	13	-	-	-	-	-	-	-	-	-	-
1993	-	-	8	10	-	-	-	-	-	-	3	4	-	-
1994	-	-	7	10	-	-	-	-	-	-	0	7	-	-
1995	-	-	9	16	-	-	-	-	-	-	1	4	-	-
1996	-	-	11	22	-	-	-	-	-	-	0	16	-	-
1997	-	-	14	18	-	-	-	-	-	-	0	1	-	-
1998	-	-	4	30	-	-	-	-	-	-	1	0	-	-
1999	-	-	7	33	-	-	-	-	-	-	0	1	-	-
2000	-	-	2	11	-	-	-	-	-	-	2	12	-	-
2001	-	-	5	15	-	-	-	-	-	-	0	0	-	-
2002	-	-	9	13	-	-	-	-	-	-	1	2	-	-
2003	-	-	7	20	-	-	-	-	-	-	0	5	-	-
2004	-	-	8	23	-	-	-	-	3	6	-	-	-	-
2005	-	-	11	26	-	-	-	-	11	7	-	-	-	-
2006	-	-	15	32	-	-	-	-	8	17	-	-	-	-
2007	-	-	4	10	-	-	-	-	3	2	-	-	-	-
2008	-	-	11	14	-	-	-	-	12	0	5	25	-	-
2009	-	-	7	16	-	-	-	-	20	6	-	-	-	-
2010	-	-	7	17	-	-	-	-	10	3	-	-	-	-
2011	-	-	13	28	-	-	-	-	18	2	-	-	-	-
2012	-	-	5	14	-	-	-	-	6	4	-	-	-	-
2013	-	-	-	-	-	-	-	-	6	5	-	-	-	-

Month:	July		July		July		July	
Years:	< 1960		< 1960		< 1960		< 1960	
Sub-area:	EN		EW		ESE		EB	
Year	M	F	M	F	M	F	M	F
1927	0	0	1	2	0	0	0	0
1929	2	0	1	1	0	0	0	0
1930	6	6	0	0	0	0	0	0
1938	70	34	128	104	20	19	21	7
1939	14	12	138	105	0	0	0	0
1940	2	9	91	59	0	0	6	1
1941	29	24	334	268	2	2	2	2
1942	27	12	292	233	0	0	0	0
1943	23	14	146	124	0	0	0	0
1944	7	9	186	147	0	0	0	0
1945	26	13	280	205	0	0	5	0
1946	58	36	232	172	29	35	56	28
1947	54	37	228	196	1	2	134	61
1948	56	45	464	375	104	86	162	89
1949	33	23	172	136	39	41	354	369
1950	11	6	87	95	8	7	24	26
1951	7	0	133	102	8	4	16	37
1952	9	3	104	63	0	0	87	142
1953	0	1	90	75	0	0	7	9
1954	14	15	96	96	0	0	116	118
1955	45	47	225	211	0	0	0	0
1956	20	13	185	137	0	0	0	0
1957	97	62	152	127	0	0	0	0
1958	66	38	195	152	0	0	21	22
1959	50	22	98	79	0	0	76	27

'Fishery' sex-ratio data

The 'Fishery' sex ratios are estimated for all future hunts and are based on recent catches as this is likely to be best reflective of how future whaling operations will occur. In the base case all catches from the 2008-13 period are used (except any by-catches) and for trials NM07-1 and NM07-4 the 2002-07 period is used. The data are listed in Table 2.

Table 2

Catches used to estimate 'fishery' sex ratios (for all future hunts).

	WG-ab	WG-ab	CG	CG	CIC	CIC	CM	CM	EN	EN	EW	EW	ESE	ESE	EB	EB
Year	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
2002	33	97	0	10	0	0	6	29	37	33	140	111	21	114	22	102
2003	57	118	1	11	23	13	1	19	45	48	73	82	5	135	89	127
2004	44	129	4	7	10	15	0	17	35	53	95	102	2	109	23	100
2005	34	135	3	1	20	14	4	1	6	1	108	133	5	92	31	249
2006	44	127	2	0	31	28	0	0	10	20	200	166	9	108	0	22
2007	38	121	0	1	14	28	0	0	52	44	86	88	12	271	20	8
2008	55	87	0	1	28	7	5	25	43	48	99	55	9	220	12	10
2009	47	107	3	1	64	14	0	0	28	21	83	98	13	237	1	3
2010	54	122	4	2	47	12	0	1	4	29	80	65	11	256	6	12
2011	39	133	0	9	45	13	0	0	1	13	121	95	26	173	15	83
2012	34	108	0	4	38	11	0	0	1	13	113	84	26	214	4	2
2013	37	127	1	3	13	22	0	0	1	0	144	94	28	253	21	47

Reference

International Whaling Commission. 2015. Report of the Scientific Committee. Annex D. Report of the Sub-Committee on the Revised Management Procedure, Appendix 5. *J. Cetacean Res. Manage. (Suppl.)* 17:120-24.