Annex E

Report of the Standing Working Group on Aboriginal Subsistence Whaling Management Procedures

Members: Donovan (Convenor), Allison, Aoki, Baba, Baird, Bell, Bickham, Brandão, Brandon, Brierley, Brownell, Burkhardt, Butterworth, Cubaynes, De Moor, DeMaster, Doniol-Valcroze, Double, Ferguson, Ferriss, Fortuna, Frey, Gallego, George, Givens, Haug, Hielscher, Holm, Hubbell, Iñíguez, Jaramillo-Legorreta, Johnson, Kitakado, Lang, Litovka, Lundquist, Mallette, Mckinlay, Morishita, Morita, Moronuki, Nelson, Palka, Pastene, Phillips, Punt, Reeves, R., Reeves, S., Ritter, Rodriguez-Fonseca, Rojas Bracho, Safonova, Scordino, Scott, Simmonds, Skaug, Slugina, Smith, Stachowitsch, Stimmelmayr, Suydam, Svoboda, Taylor, Terai, Thomas, Tiedemann, Víkingsson, Wade, Walløe, Walters, Weinrich, Weller, Wilberg, Witting, Zagrebelnyy, Zerbini, Zharikov.

1. INTRODUCTORY ITEMS

1.1 Convenor's opening remarks

Donovan welcomed the participants. The workload this year was immense. Two priority topics are: (1) work towards completion of the remaining *SLA*s for the Greenland hunts; and (2) developing a recommended Aboriginal Whaling Scheme. Both topics have been the subject of intense intersessional work including two workshops in Copenhagen in October 2017 and March 2018, as well as a small technical meeting in December at OSPAR headquarters in London. He stressed that this year, the Commission would be setting new catch/strike limits for all aboriginal subsistence hunts and therefore the third major topic is to provide advice on these. Finally, the SWG will try to complete the *Implementation Review* for Bering-Chukchi-Bering Sea (B-C-B) bowhead whales. He also reminded participants that we will need to provide a two-year workplan and budget.

Donovan noted that Cherry Allison was unable to attend the meeting in person this year and thanked her greatly for all the intersessional work undertaken as well as providing tremendous support from Cambridge. He also thanked Punt, de Moor, Brandão, Witting who have stepped up even more than usual with computing assistance.

He explained that the work of the intersessional Steering Group on developing *SLA*s for the Greenland hunts is ongoing and will continue during this meeting as the report of this group will assist greatly in discussing Item 2. Similarly, the intersessional group on the AWS is continuing and the group's final report will greatly facilitate discussions under Item 3.

1.2 Election of Chair and appointment of Rapporteurs

Donovan and Brandon were named co-Chairs. Brandão, Brandon and Givens acted as rapporteurs with the assistance of the Chair.

1.3 Adoption of Agenda

The agenda was adopted. See Appendix 1.

1.4 Documents available

The documents available included SC/67b/AWMP01rev1, SC/67b/AWMP02-08, SC/67b/AWMP10, SC/67b/AWMP12, SC/67b/AWMP13rev1, SC/67b/AWMP14-19, SC/67b/AWMP20rev1, SC/67b/Rep06, and SC/67b/Rep07.

Donovan drew attention to the fact that Canadian scientists had submitted two papers (Frasier *et al.*, 2015 and Doniol-Valcroze *et al.,* 2015) providing abundance estimates for Eastern Canadian-West Greenland bowhead whales. The SWG **greatly appreciated** these contributions.

2. *SLA* DEVELOPMENT

2.1 Fin whales (Greenland)

2.1.1 Review results of intersessional workshops

Donovan presented SC/67b/Rep06 and provided an overview of progress made during two intersessional Workshops and the small working group meeting.

He reported that considerable progress was made in relation to the following|:

(a) updated abundance estimates (and see Item 5.6.2);
(b) finalisation of the trial structure;
(c) review and approval of conditioning;
(d) initial consideration of new *SLA*s and results.

2.1.2 Review post-Workshop progress

Most of the work undertaken after the final workshop involved *SLA* development. The final trial specifications are provided as Appendix 2. Table 4 of Appendix 2 summarises the main factors considered in the *Evaluation Trials.*

SC/67b/AWMP13 developed a candidate *SLA* for West Greenland fin whales. The new fin whale trials have a large amount of variation in the point estimates of abundance, and the *SLA* takes an inverse variance weighted average of the last three estimates as an estimate of abundance. The strike limit is then calculated as a growth rate fraction of a lower percentile of the abundance measure, conditional on a trend modifier, a snap to need feature, and a protection level. This *SLA* is somewhat simpler than the earlier fin whale *SLA*s developed by Witting. Those fitted a straight line to the abundance estimates in order to obtain a measure of abundance and trend. However, these estimates were unreliable due to the highly variable abundance estimates of the trials. The *SLA* is proposed in three versions, where the D10 statistics for the 5th percentile of the 'Influx' trial F34-1 is tuned to 1.0, 0.9 and 0.8 for the medium (B) need envelope.

SC/67b/AWMP15 presented three potential *SLA*s for West Greenlandic fin whales that are based on a weighted-average interim *SLA* which uses all abundance estimates, but earlier abundance estimates are down-weighted compared to more recent ones. An adjustment to the multiplier of the abundance estimate in the interim *SLA* is applied which depends on the trend of the abundance indices. This approach allows for additional reduction of the *Strike Limit* if the time series of abundances shows a reasonably precise downward trend in abundance. Three candidate *SLA*s are tuned to achieve 1.0, 0.9 and 0.8 for the conservation statistic (D10, relative increase) at the lower 5th percentile for the Influx hypothesis trial GF34-1B with an $MSYR_{1+}$ of 1% and the middle need envelope (B) as suggested at the 2018 Workshop (SC/67b/

Rep06). Dropping the D10 statistic to 0.8 for this trial improves need satisfaction by all other trials without sacrificing conservation performance (except for the Influx hypothesis trials at MSYR1+= 1%). It was noted that these *SLA*s do not have a snap to need feature.

2.1.3 Review final results and performance

In total, seven potential *SLA*s (which include the 'Interim' *SLA* – a modified version of the *Interim SLA* that has been used to provide advice for the last two blocks) were reviewed. As in previous years, an initial examination of the full set of results was undertaken by a 'winnowing' group with the aim to focus the SWG to those aspects of the performance of the *SLA*s that needed to be discussed further. Initially, the focus was on projections of the lower 5th percentiles and medians for 1+ population abundance and 'Zeh' plots for various performance statistics. Focus was given to the exploration of the univariate performance statistics D1 (final depletion) and D10 at the lower 5th percentile. The desired performance for these statistics is to obtain a value of D10 greater or equal to one and for D1 to be above 0.6 (MSYL). In other words, satisfactory performance on the conservation criteria by an *SLA* is deemed if either the population is not at MSYL but it is increasing or the population is increasing/decreasing but is above MSYL.

Tables which highlighted which *SLA* was performing well or not relative to the 'best' performance amongst all the *SLA*s (including the 'Interim' *SLA*) were also examined to evaluate the performance of the proposed *SLA*s. Plots of depletion where examined as the conservation statistics are based on this rather than on population abundance numbers. Trials for which at least one of the proposed *SLA*s failed either the D1 or the D10 conservation statistics were highlighted for further investigation (5 trials). Looking at results on a single dimension was not helpful because the D10 statistic does not need to be at or above one if the population is above MSYL. Thus, further focus on the performance of the *SLA*s was placed rather on the joint statistic of D1 and D10 for these five trials.

The bivariate plots of the D1 and D10 statistics (see fig. 4 of Appendix 3) were examined for all the proposed *SLA*s, with a focus on the simulation results in the quadrant in which D1 <0.6 and D10 <1. The counts of the simulations for all *SLA*s that fall in this quadrant were examined to see if this could help to distinguish the performance amongst the different *SLA*s. Examination of these plots concluded that for all the trials that had failed on at least one of the univariate conservation statistics, only trial F34-1C (a low MSYR, high need case for the Influx model) showed unacceptable conservation performance.

The SWG **agreed** that the proposed *SLA*s performed satisfactorily on the joint conservation statistics for the A and B (but not for C) need envelopes for all trials, and the selection between *SLA*s was narrowed down to those that had been tuned to obtain D10 of 0.8 for the more difficult Influx hypothesis trial F34-1B (B0.8 and L0.8). The focus on selecting amongst the *SLA*s should be on the *SLA* that meets need satisfaction best and that also achieves stability in the catches. 'Zeh' plots were examined for all trials, concentrating on the need satisfaction statistics, N9(20) the average need satisfaction over the first 20 years, N9(100) the average need satisfaction over the 100 years and N12 the mean downstep statistic, which is a modified average annual variability statistic.

It was noted that because of the present incorporation into the trial structure of the widely different 'Influx' and 'partial' hypotheses to explain the variability of the abundance estimates, the need satisfaction over 20 years is more appropriate to consider than over 100 years as it is likely that future *Implementation Reviews* may be able to remove one or other scenario.

After an examination of the full range of results, there was no obvious 'winner' between the two *SLA*s. Depending on the trials considered, and which statistic was examined, the different *SLA*s performed slightly differently but their performance overall was equivalent.

Following an approach originally adopted during the development of the *Bowhead SLA*, the SWG **agreed** that an *SLA* which sets the strike limit to the average of the values obtained by the two *SLA*s tuned to a D10 of 0.8 for the influx trial F34-1B (B0.8 and L0.8) would be preferable, providing performance was as good or better than either individual *SLA*; no snap to need for the averaged *SLA* has been applied. The results of the 'combined *SLA'* are summarised in Appendix 3.

2.1.4 Conclusions and recommendations

The SWG **agreed** that the *SLA* which sets the strike limit to the average of the values obtained by the two *SLA*s tuned to a D10 of 0.8 for the influx trial F34-1B (B0.8 and L0.8) performed satisfactorily in terms of conservation performance and that it was to be preferred over the individual proposed *SLA*s in terms of need satisfaction. The SWG **agreed** that this '*WG-fin SLA*' be used to provide management advice to the Commission on the subsistence hunt for West Greenland fin whales under need scenarios A and B. For the management advice see Item 5.6.

In conclusion, the SWG expressed its **great thanks** to the developers, Brandão and Witting for the vast amount of work put into the development process. It also expressed similar thanks to Allison and Punt for their extensive work developing the operating models and running the trials. It noted that final validation and archiving would be undertaken by Allison.

The SWG also concurred with the intersessional Workshop (SC/67b/Rep06, item 2.7) that one focus of the next *Implementation Review* would be to examine further stock structure in relation to the two hypotheses being considered at present, and especially the influx model which was developed in the context of low abundance estimates in some years rather than genetic information.

Attention: C-A, SC

*The Committee **draws attention** to the extensive work undertaken over recent years to develop an* SLA *for the West Greenland hunt for fin whales. In concluding this work, the Committee:*

*(1) **agrees** that the combined* SLA *(which sets the strike limit to the average of the values obtained by the two best* SLA*s considered) performed satisfactorily in terms of conservation performance and was to be preferred over the individual* SLA*s in terms of need satisfaction;*

*(2) **recommends** that this* 'WG-Fin SLA' *be used to provide management advice to the Commission on the subsistence hunt for West Greenland fin whales (provided the need request falls within need scenarios A and B);*

*(3) **expresses** its great thanks to the developers, Brandão and Witting for the vast amount of work put into the development process and to Allison and Punt for their extensive work developing the operating models and running the trials; and*

*(4) **agrees** that one focus of the next Implementation Review will be to examine further stock structure in relation to the two hypotheses being considered at present, and especially the 'influx' model which w\as developed in the context of low abundance estimates in some years, rather than being based upon genetic information.*

2.2 Common minke whales (Greenland)

2.2.1 Review results of intersessional workshops

Donovan summarised report SC/67b/Rep06 and the intersessional progress made on common minke whales. He noted that enormous effort had been devoted to reviewing the new genetic information that had been provided in response to a recommendation at SC/67a. This had greatly assisted in developing the final stock structure hypotheses and mixing matrices to be considered in the trials. These extensive discussions can be found under items 3.3.1 and 3.3.2 of SC/67b/Rep04.

Finally, the Workshop **agreed** that instead of formally using the RMP to set catch limits by sub-area and year for each simulation, the RMP catch limits would be pre-specified based upon baseline hypothesis 1 trials (M01-1 and M01-4). This allows the trials to run more quickly and focus to be given on *SLA* development – the objective of this work. Details can be found in the full trials specification (Appendix 4).

2.2.2 Review post-Workshop progress

Considerable work was undertaken to finalise the list of trials, to ensure that the mixing matrices were correctly specified and to complete and agree conditioning. The final trial specifications are provided as Appendix 4.

Table 9 of Appendix 4 summarises the factors considered in the *Evaluation Trials.*

2.2.3 Candidate SLAs

SC/67b/AWMP14 developed a candidate *SLA* for common minke whales off West Greenland. It operates, like the fin whale *SLA* in SC/67b/AWMP13, on an inverse variance weighted average of the last three abundance estimates. The strike limit is calculated as a growth rate fraction of a lower percentile of the abundance measure, conditional on a snap to need feature, and a protection level. The *SLA* for common minke whales, however, does not include a trend modifier, as it is almost impossible to detect an underlying trend from the abundance data in West Greenland.

The *SLA* was tuned to have a 5th percentile of D10 of 0.80 for a flat need envelope of 164 on the most difficult *Evaluation Trial* (trial M04-1A, where there are two sub-stocks in the western North Atlantic, where the mixing between the Central and the Western stock, and the mixing between the putative western sub-stocks, are minimal, and where the MSYR is 1%). Conservation performance on all other measures was adequate for all trials with a flat need of 164, and the *SLA* produces an expected average need satisfaction of 99% (with a lower 5th percentile of 89%) for the first 20 years, and 89% (5th percentile of 61%) for the 100-year simulation period.

2.2.4 Consideration of results

The SWG **agreed** that conditioning of the *Evaluation Trials* had been completed satisfactorily. A summary of the results of the *Evaluation Trials* is provided in Appendix 5.

In determining satisfactory conservation and need performance when evaluating *SLA*s, the SWG considers the full range of results across all of the *Evaluation Trials* not simply the worst-case scenarios. The SWG **agreed** that conservation performance was satisfactory in all but one of the trials. This trial was a trial with low MSYR and two W-stocks and had been originally considered in the context of potential problems for the hunt to simulate possible local depletion in the hunting area rather than for conservation reasons. It was noted that genetic stock structure in the entire North Atlantic is subtle such that even a hypothesis of almost complete panmixia is not rejected by most of the analyses. Hence, differentiation among C and W is very low. This is even more true for substructure within the W stock (if there is any. Given that trials are conservative in so far to overrate isolation among stocks and the very subtle differentiation among stocks and sub-stocks in the North Atlantic, a single trial (which implements fully separate W1 and W2 sub-stocks for which evidence is weak) not meeting the D1/D10 criteria is not of conservation concern.

In developing this advice, the SWG noted that given the unforeseen situation with Secretariat computing, there had been insufficient time to consider the results of the *Robustness Trials* in the SWG. Such trials are not needed to determine an *SLA* but are examined to ensure that the selected *SLA* has no unforeseen properties in extreme trials. Given the importance of being able to provide the best management advice to the Commission, the SWG agreed that the Steering Group set up for *SLA* development should take responsibility to review the results of the *Robustness Trials* as soon as they become available and report to the Plenary session[1].

2.2.5 Conclusions and recommendations

Given the overall satisfactory performance in the *Evaluation Trials* with respect to meeting the Commission's conservation and management objectives for need envelope A (i.e. constant need over the simulation period), the SWG **agreed** to recommend this, the '*WG-common minke SLA'* to the Committee as the best way to provide management advice for the West Greenland hunt of common minke whales. The management advice developed using the *WG-common minke SLA* is provided under Item 5.5.

In accordance with the AWS (see Item 3), the first *Implementation Review* is scheduled for 2023. The SWG **agreed** that one focus of that review should be consideration of the results of analyses of genetic data using additional samples from Canada (as well as the additional samples that will become available from West Greenland and Iceland). To this end it **agrees** that planning for the *Implementation Review* should begin two years before the scheduled review. A small group comprising Tiedemann, Doniol-Valcroze, Witting and Víkingsson was established to facilitate issues related to obtaining samples.

In conclusion, the SWG expressed its **great thanks** to the developers, Brandão and Witting for the vast amount of work put into the development process. It also expressed similar **thanks** to Allison and Punt for their extensive work developing the operating models and running the trials. It noted that final validation/archiving would be undertaken by Allison.

Attention: C-A, SC

*The Committee **draws attention** to the extensive work undertaken over recent years to develop an* SLA *for the West Greenland hunt for common minke whales. In concluding this work, the Committee:*

[1]Editor's note: this was completed and no problems were detected.

(1) ***agrees*** *that the tested* SLA *which performed satisfactorily in terms of conservation performance;*
(2) ***agrees*** *that this* 'WG-Common minke SLA' *be used to provide management advice to the Commission on the subsistence hunt for West Greenland common minke whales provided the need request falls within need scenario A (i.e. does not exceed 164 annually);*
(3) ***expresses*** *its great thanks to the developers, Brandão and Witting for the vast amount of work put into the development process and to Allison and Punt for their extensive work developing the operating models and running the trials; and*
(4) ***agrees*** *that one focus of the next* Implementation Review *will be to examine further stock structure in relation to the two hypotheses being considered at present, should be also consideration of the results of analyses of genetic data using additional samples from Canada (as well as the additional samples that will become available from West Greenland and Iceland); and*
(5) ***agrees*** *to establish an intersessional group to facilitate issues relating to samples.*

2.3 North Pacific gray whales (Makah whaling)

2.3.1 Management plan proposed by the US for Makah whaling

The Makah Indian Tribe has requested that the US National Marine Fisheries Service (NMFS) authorises a tribal hunt for Eastern North Pacific gray whales in the coastal portion of its 'usual and accustomed fishing area'. The Tribe intends to hunt gray whales from the ENP population, which currently numbers approximately 27,000 animals (Durban *et al.*, 2017). In the management plan, NMFS has taken measures to restrict the number of PCFG whales that are struck or landed in a given 10-year period and to avoid, to the extent possible, striking or killing a Western North Pacific gray whale. The US government has requested that the Committee test this plan to ensure that it meets IWC conservation objectives. An overview of the hunt management plan and how it was operationalised in the coding of the *SLA* trials is provided in Annex E, Appendix 1 of SC/67b/Rep/07.

2.3.2 Review intersessional progress including at the Rangewide Workshop

Donovan summarised the report of the Fifth Rangewide Workshop on the Status of North Pacific Gray Whales (SC/67b/Rep07rev1). The Workshop was held at the Granite Canyon Laboratory, California of the Southwest Fisheries Science Center from 28-31 March 2018. The primary tasks of the Workshop were to: (a) review the results of the modelling work identified at the Fourth Workshop (IWC, 2018a) and SC/67a (IWC, 2018b); (b) examine the new proposed Makah Management Plan (submitted by the USA – described above and illustrated in SC/67b/Rep/07 under Annex E, Appendix 1 of that report) for gray whaling off Washington state; and (c) to update as possible (and develop a workplan for) the scientific components of the Conservation Management Plan (CMP) for western gray whales.

The major focus of the Workshop related to finalising the specifications for modelling to enable results to be available for SC/67b. A new component included the need to incorporate the recently developed Makah Management Plan (SC/67b/Rep07, Annex E, Appendix 1) into the modelling framework; the Plan is somewhat complex and the Workshop focus was on understanding the intended process and ensuring that it was parameterised in an appropriate way. A further key area was finalising the stock structure hypotheses to be given priority. After a review, the Workshop concluded that Hypotheses 3a and 5a would form the reference cases but that sensitivity trials would be conducted for Hypotheses 3b, 3c, 3e and 6b. The full specifications for these hypotheses are provided in SC/67b/Rep07 (Annex E, Appendix 1 of that report).

In summary, Hypothesis 3a assumes that whilst two breeding stocks (Western and Eastern) may once have existed, the Western breeding stock (WBS) is extirpated. Whales show matrilineal fidelity to feeding grounds, and the Eastern breeding stock includes three feeding aggregations: PCFG (Pacific Coast Feeding Group), NFG (Northern Feeding Group) and WFG (Western Feeding Group). Hypothesis 5a assumes that both breeding stocks are extant and that the WBS feeds off both coasts of Japan and Korea and in the northern Okhotsk Sea west of the Kamchatka Peninsula. Whales feeding off Sakhalin include both whales that are part of the extant WBS and remain in the western North Pacific year-round, and whales that are part of the Eastern breeding stock and migrate between Sakhalin and the eastern North Pacific (the WFG).

Another important component of the trials relates to bycatch. Considerable effort was put into capturing the uncertainty in past and future estimates of bycatch mortality based upon the available data. The base case for trials was that observed deaths due to bycatch account for only 25% of the true incidental human caused mortality. This fraction was based on a study of bottlenose dolphin stranding data off the coast of California (Carretta *et al*. 2016). Trials were also considered with higher rates of cryptic mortality, including scenarios where observations represent only 5% of true incidental human caused mortality.

Abundance estimates for the eastern North Pacific and the PCFG had been approved by the Committee last year (IWC, 2017). New estimates of abundance for western gray whales were provided by Cooke (SC/67B/ASI/02), and correspond with the various stock structure hypotheses for the western feeding group (WFG), WBS and WST (WFG + WBS). These estimates were reviewed and adopted by the SWG on ASI (Annex Q). Modifications were also made to the mixing matrices in the rangewide model based on the new estimates.

Each stock structure hypothesis was combined with multiple assumptions about other factors (e.g. bycatch rates) and this led to the development of 53 'trials' (see Table 6 of SC/67b/Rep07). Each trial was based on 100 simulations that reflect uncertainty in the estimated parameters of the model. Projections thus lead to a very large amount of model output that needed to be distilled to address questions such as the conservation performance of the new management plan for Makah whaling with respect to the stocks in question (in particular, the PCFG and the WFG). The Rangewide Workshop identified several plots and 'performance statistics' to summarise results from each trial (see Section 4.4.5 of SC/67b/Rep07 and Appendix 6).

Brandon presented an update on the code validation for the model. The first phase of code validation was completed prior to Fifth Rangewide Workshop. That effort focused on the code implementing the operating model and the conditioning process. A summary, including a brief overview of the code and input files was provided to the Workshop (SC/M18/CMP03). Like the first phase, the second phase of code validation involved checking the code against the mathematical and statistical model specifications. The focus of this validation phase was on three aspects of the code: (1) future projections and the updated US management plan concerning strike and landing limits for Makah whaling; (2) input files for the factors considered across conditioning trials and; (3) processing results across simulations into relevant performance statistics. Code validation was completed prior to the presentation of model results to the SWG.

The sub-committee on CMP reviewed and approved the conditioning results in the context of the full rangewide review. The SWG reviewed the model results with a focus on conservation performance of the management plan for Makah whaling. To aid in this evaluation, bivariate plots were generated for the lower 5th percentiles of the D1 and D10 performance statistics. Trials for which the D1 statistic is less the 0.6 after 100 years (i.e. the stock is not above its MSYL) and the D10 statistic after 100 years is not larger than 1 (i.e. the stock is not increasing towards MSYL) represent a scenario under which the management plan would not be expected to meet the conservation objectives for ASW (this is denoted by the gray quadrant in fig 1 of Appendix 6). Several trials were identified in this category, but they corresponded with scenarios that were considered to have the low plausibility (e.g. bycatch mortality of ~ 20 PCFG whales per year). The SWG **agreed** that the performance of the management plan for Makah whaling was adequate to meet the Commission's conservation objectives for the PCFG, WFG and northern feeding group gray whales in the context of the proposed Makah hunt.

2.3.3 Conclusions and recommendations

The SWG **agreed** that the newly proposed hunt management plan for the Makah Tribe's gray whale hunt meets the IWC conservation objectives for PCFG, WFG, and ENP gray whales (see Appendix 6). Similar to its recommendations regarding the hunt plan evaluated during the last *Implementation Review* (IWC, 2012; 2013), the new hunt management plan is dependent on photo-identification studies to estimate PCFG abundance and the mixing proportions of PCFG whales available to the hunt (and bycatch in its range). The SWG's conclusions are dependent on the assumption that these studies will continue in the future.

Attention: C-A, SC

The Committee was asked by the USA to review a US Management Plan for a Makah hunt of gray whales off Washington State (the Committee had evaluated a previous plan in 2011 – IWC, 2011; 2012). The Committee conducted this work using the modelling framework developed for its rangewide review of gray whales (SC/67b/Rep07). In conclusion, the Committee:

*(1) **agrees** that the performance of the Management Plan was adequate to meet the Commission's conservation objectives for the Pacific Coast Feeding Group, Western Feeding Group and Northern Feeding Group gray whales;*
*(2) **notes** that the proposed management plan is dependent on photo-identification studies to estimate PCFG abundance and the mixing proportions of PCFG whales available to the hunt (and to bycatch in its range);*
*(3) **stresses** that its conclusions are dependent on the assumption that these studies will continue in the future; and*
*(4) **expresses** its great thanks to Punt, Brandon and Allison for their excellent work in developing and validating the testing framework and running the trials.*

2.4 West Greenland bowhead whales

2.4.1 Review results using 400 replicates

Following a previous examination of the precision with which estimates of the 5th percentiles of the performance statistics could be obtained as the number of replicates was increased; an agreement was made that 400 simulations should be used to determine the performance of the selected *SLA* for West Greenland bowhead whales. SC/O17/AWMP03 had showed projection plots for the 5th percentile and the median of the 1+ population for the baseline evaluation trials for this *SLA* based on 400 simulations. For comparison purposes, the projections for the *SLA* under 100 simulations were also shown. These show substantial variability between estimates of the 5th percentile of the distribution of population size.

Wilberg presented an analysis (Appendix 7) based on bootstrapping that was used to determine the effect of the number of simulations on the precision of the estimates of the 5th percentile of several performance measures. Projections for the selected *SLA* for West Greenland bowhead whales showed substantial differences in estimates of the 5th percentile of abundance based on 100 and 400 simulations. With only 100 simulations, the confidence intervals of the 5th percentile were quite wide, but 400 simulations led to a substantial improvement in precision. The investigation concluded that continuing to use 400 trials for the simulations appears to be sufficient to estimate the lower 5th percentile with a reasonable amount of precision.

2.4.2 Testing the Interim Allowance strategy

The SWG noted that the interim relief strategy (see Item 3) has not been examined for this *SLA* yet and **agreed** that this should be added to the workplan.

2.4.3 Conclusions and recommendations

It was agreed that continuing to use 400 replicates for the simulations is sufficient to estimate the lower 5th percentile with adequate precision.

3. ABORIGINAL WHALING MANAGEMENT SCHEME (AWS)

The Scientific Committee's Aboriginal Whaling Management Procedure (AWMP) applies stock-specific *Strike Limit Algorithms* (*SLA*s) to provide advice on aboriginal subsistence whaling (ASW) strike/catch limits.

ASW management (as part of an AWS, the aboriginal whaling scheme) incorporates several components, several of which have a scientific component:

(a) *Strike Limit Algorithms* (case-specific) used to provide advice on safe catch/strike limits;
(b) operational rules (generic to the extent possible) including carryover provisions, block quotas and interim relief allocations;
(c) Guidelines for *Implementation Reviews*; and
(d) Guidelines for data and analysis (e.g. guidelines for surveys, other data needs).

3.1 Review intersessional work

In 2017, the Scientific Committee appointed an intersessional correspondence group (Givens (Chair), Allison, Donovan, George, Scordino, Stachowitsch, Suydam, Tiedemann, Witting) to develop draft text regarding the scientific aspects of an Aboriginal Whaling Scheme. The starting place was a previous version agreed by the Scientific Committee (IWC, 2003). Two key components of a new draft AWS were the interim relief allowance and carryover provisions. The report of this group is SC/67b/AWMP21.

Donovan summarised the results from the intersessional workshops on the AWS. In addition to continuation of discussions on the extensive work of the intersessional group under Givens (see above), the Governments of Denmark and the USA had requested advice on the conservation implications of provisions that:

> '…allow for the carry forward of unused strikes from the previous three blocks, subject to the limitation that the number of such carryover strikes used in any year does not exceed 50% of the annual strike limit'.

This request was tested using the *Bowhead SLA* (applicable to the Bering-Chukchi-Beaufort Seas stock) and the *WG-Humpback SLA* (applicable to West Greenland) and three types of options were examined:

(1) baseline case – all strikes taken annually (i.e. no need for carryover);
(2) 'frontload' case – strikes taken as quickly as possible within block (+50% limit annually until the block limit is reached); and
(3) two alternative scenarios where carryover strikes are accrued for one or three blocks, followed by a period of carryover usage subject to the +50% limit.

The three-block scenario considered in (3) served as a direct test of the provision described in the request of USA and Denmark/Greenland. The Committee agreed that the Commission's conservation objectives were met for both *SLA*s for all of the options above and would also be met for a proposal carrying forward strikes from the previous two blocks.

Attention: CG-A

The Committee received a request from the USA and Denmark/Greenland (SC/67b/Rep06, Annex F, appendix) on the conservation implications of carryover provisions that:

> *'…allow for the carry forward of unused strikes from the previous three blocks, subject to the limitation that the number of such carryover strikes used in any year does not exceed 50% of the annual strike limit'.*

The Committee reviewed the request using its simulation frameworks and the two SLA*s available for stocks hunted by the USA and Greenland available at the time of the Workshop i.e. the* Bowhead SLA *(applicable to the Bering-Chukchi-Beaufort Seas stock) and the* WG-Humpback SLA *(applicable to West Greenland) and*

(1) ***agrees*** *that a carryover provision for up to 3-blocks meets Commission's conservation objectives; and*
(2) ***reiterates*** *its previous advice, applicable for all* SLA*s, that interannual variation of 50% within a block with the same allowance from the last year of one block to the first year of the next is acceptable; and*
(3) ***agrees*** *to evaluate the above request for the other Greenland SLAs at the 2019 Committee meeting.*

3.2 Review proposed updates to the AWS

The SWG considered a proposed update to the previous AWS based upon the work of the intersessional correspondence group. It considers carryover, block quotas, interim relief allocation, *Implementation Reviews* and Guidelines for surveys and data. The agreed text can be found as Appendix 9.

3.3 Conclusions and recommendations

The SWG **recommends** the AWS provided in Appendix 9 to the Committee. It notes that the Commission's AWS may include additional, non-scientific provisions.

Attention: C-R

The Committee has been working for some years to update the scientific components of an Aboriginal Whaling Scheme. It has completed this work and recommends the AWS provided in Appendix 9 to the Commission. It has sections on carryover, block quotas, interim relief allocation (and see Appendix 8), Implementation Reviews and guidelines for surveys and data. It notes that the Commission's AWS may include additional, non-scientific provisions.

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4. *IMPLEMENTATION REVIEW* OF B-C-B BOWHEAD WHALES

From the Committee's Guidelines (IWC, 2013, pp.170-1), the primary objectives of an *Implementation Review* are to:

(1) review the available information (including biological data, abundance estimates and data relevant to stock structure issues) to ascertain whether the present situation is as expected (i.e. within the space tested during the development of a *Strike Limit Algorithm* (*SLA*)) and determine whether new simulation trials are required to ensure that the *SLA* still meets the Commission's objectives; and
(2) to review information required for the *SLA*, i.e. catch data and, when available at the time of the *Review*, new abundance estimates (note that this can also occur outside an *Implementation Review* at an Annual Meeting).

The *Bowhead SLA* was adopted in 2002 (IWC, 2003, p.158) and there was an extensive *Implementation Review* completed in 2007 (IWC, 2008, p.124) with a major focus on stock structure including three intersessional workshops. That included consideration of additional trials investigating management implications of assuming additional population structure even though these were considered of low plausibility. The Committee concluded that the *Bowhead SLA* remained the best tool to provide management advice. The next *Implementation Review* was completed in 2012 (IWC, 2013, p.147); that concluded that there was no need to develop additional trials to those evaluated during the previous *Implementation Review* (IWC, 2008).

In Committee discussions last year (IWC, 2018), it was agreed that at that time, there was no information that suggested that the situation for this stock was outside the tested parameter space. Given that, the Committee had agreed that it should be possible to complete the *Implementation Review* at the 2018 Annual Meeting. It established a Steering Group (Suydam [Convenor], Donovan, George) to prepare for the *Review* and Donovan confirmed that the Data Availability deadlines were met and that papers on the necessary topics were submitted. Donovan thanked the US colleagues for the extremely hard work that they have put in to providing the SWG with papers to facilitate this review.

Discussions within the SWG benefitted from the discussions within two other sub-committees, SD-DNA (Annex I) and ASI (Annex Q) and, as relevant, conclusions from those groups are briefly summarised under the agenda items below.

4.1 Stock structure: review new information
The Working Group on SD-DNA provided a summary of their discussions relevant to the *Implementation Review*. Genetic analyses (SC/67b/SDDNA01) confirmed that B-C-B bowheads and bowheads in the Sea of Okhotsk constitute two distinct stocks. There may be some weak distinction between B-C-B and EC-WG bowheads, but the majority of the evidence found no significant difference between these two populations. There is one known instance of interchange (from east to west), and one set of overlapping telemetry tracks, although those two whales returned to the populations from which they came. SC/67b/AWMP04 presented data from 64 satellite tagged whales, all but one of which followed the well-known counter-clockwise Bering-Beaufort-Chukchi circuit. The unusual track corresponded to a whale tagged in Utqiaġvik(Barrow) in autumn that migrated to the north coast of Chukotka the following spring, rather than swimming east into the Beaufort Sea. Considering the multiple lines of evidence as a whole, the Working Group on SDDNA had concluded that B-C-B bowheads constituted a single population, with no signs of substructure.

The SWG welcomed this information and thanked the hunters for their skill in making the tagging efforts efficient and successful. It **encouraged** continuation of these tagging studies. The SWG **agreed** that there was no need to consider any new *SLA* trials regarding stock structure, since the trials conducted in 2002 and 2007 already covered all plausible stock structure hypotheses.

Attention: SC

With respect to stock structure, considering the multiple lines of evidence, the Committee:

(1) agrees that BCB bowheads comprise a single population, with no signs of substructure;
(2) agrees that there was no need to consider any new SLA trials regarding stock structure, since the trials conducted in 2002 and 2007 already covered all plausible stock structure hypotheses;
(3) welcomes the telemetry information provided, thanks the hunters involved for their skill and assistance;
(4) encourages additional telemetry efforts; and
(5) agrees with the suggestions for future genetic studies in the Arctic provided under Item 11.

4.2 Abundance estimates: review new information
The Working Group on ASI (Annex Q) received new information about the 2011 B-C-B bowhead abundance from a long-term photo-identification capture-recapture study (SC/67b/AWMP01rev1). The estimated 1+ abundance was 27,133 (CV=0.217; 95% CI from 17,809 to 41,337). They concluded that this estimate could be classified as having been examined in detail and found to be suitable for providing management advice and for use in the *SLA*.

The SWG **welcomed** this information and noted that there was a completely independent 2011 abundance estimate from an ice-based survey (Givens *et al.,* 2016). This estimate is 16,820 (CV=0.052; 95% CI 15,176 to 18,643). It is not surprising that these two estimates differ because – in addition to random variability – the ice-based estimate does not count whales that are spatially or temporally excluded from the survey, whereas the photo-id dataset is more likely to contain false negative matches than false positive matches and this imbalance will tend to inflate the resulting abundance estimate.

There are thus two independent estimates for the same year considered suitable for use in the *SLA* (the ice-based estimate is already used). Discussion on how to consider such circumstances is provided under Items 3 and 5.

The Working Group on ASI (Annex Q) also received two reports on future B-C-B bowhead survey plans (SC/67b/AWMP12 and SC/67b/AWMP16). The first is for an ice-based survey in spring 2019, following methods used in earlier such surveys but not including an acoustic component. The availability of bowhead whales will be estimated from past acoustic data, as has been done with previously accepted estimates. The second survey is an August 2019 aerial line transect survey of unprecedented scope for B-C-B bowheads, covering the eastern edge of the Chukchi Sea and the entire Beaufort Sea (including Canadian waters) with most transects extending to the 200 m isobaths and some to the 2,000m isobaths. Detailed plans for the latter survey were presented in SC/67b/AWMP16, and were thoroughly discussed by the Working Group on ASI (see Annex Q).

The SWG thanked the authors for these papers, noting that their presentation is an accord with the AWS Guidelines (see Item 3) that 'plans for undertaking a survey/census should be submitted to the Scientific Committee in advance of their being carried out, although prior approval by the Committee is not required. This should normally be at the Annual Meeting before the survey/census is carried out'.

The SWG noted that the degree of precision to be achieved by the 2019 aerial survey is unknown and may be lower than for some other recent abundance estimates. The *Bowhead Evaluation and Robustness Trials* mainly specified CVs of 0.25 or less. If the new CV turns out to be higher than this, additional trials may be required at the next *Implementation Review*.

4.3 Biological parameters: review new information
The SWG received new information about length at sexual maturity and pregnancy rate (SC/67b/AWMP07). Studies of bowhead reproduction have been conducted by the North Slope Borough Department of Wildlife Management (Alaska) over the past 35 years, with the co-operation of Alaska Native hunters. Although low calf counts and few pregnant harvested females were a concern at the inception of the programme, the situation has improved markedly since then. For SC/67b/AWMP07, pregnancy rates were estimated from examinations of reproductively mature bowhead whales (n=208) landed during the Alaska Native subsistence harvest from 1976-2016. The estimated pregnancy rate was 0.317 (95% CI 0.251 to 0.385). This suggests an inter-birth interval of just over 3 years. Whales harvested in the autumn at Utqiaġvik (Barrow) and Kaktovik comprise the most reliable pregnancy dataset because pregnancies are easier to detect and whales are more carefully examined. From this restricted dataset (n=33), the pregnancy rate is estimated to be 0.394 (95% CI 0.211 to 0.553); which the authors considered is at the high end of what is plausible for this species.

Logistic regression was used to estimate length at maturity from a separate dataset (n=150) that included whale lengths. Length at maturity was defined, relative to an equally balanced set of mature and immature whales, as the length at which the estimated probability of maturity equals 0.5. Since the actual dataset is neither balanced nor representative, the authors introduced a correction calculation. The resulting length at maturity is estimated to be 13.65m (95% CI 13.29 to 13.94). The authors recognised that their data could be biased by sampling from harvested animals where hunter selectivity occurs and by the approximately 14-month gestation period of bowheads. The estimates are consistent with past investigations and suggest a reproductively robust population. The finding that pregnancy rates are stable or possibly increasing over the past 40 years is also consistent with the increase in population abundance seen over the same time span. Finally, the authors believe that there is no evidence in the reproductive data of density-regulated reproduction or the population approaching carrying capacity.

In discussion, the SWG noted that selectivity patterns in the bowhead harvest make some types of inference from such data difficult. In particular, there are several factors that may affect the determination of pregnancy rate and trends in pregnancy rate. The SWG concluded that it was not possible therefore, to conclude that there had been a long-term increase in pregnancy rate despite the statistically significant positive trend reported in the paper; the authors concurred. However, the SWG noted that the length-at-maturity analysis was specifically corrected for age selectivity in hunting so such concerns do not arise in that analysis.

The SWG welcomed information about the potential use of samples from baleen plates to examine hormone cycles and pregnancy. Since baleen provides up to 20 years of record, it may be possible to correlate reproductive information with other variables such as environmental factors. The SWG **encouraged** future work on this subject.

SC/67b/AWMP03 summarised sightings of bowhead whale calves in the western Beaufort Sea during July-October, 2012-17, from the Aerial Surveys of Arctic Marine Mammals (ASAMM) project. Overall, 76% of the calves recorded were first sighted only after the aircraft broke from the transect line to circle an adult whale sighting. Calves were detected during all months, although more calves were detected in autumn (September-October, 245 calves) than summer (July-August, 160 calves). Total number of calves sighted per year ranged from 22 in 2012 to 155 in 2017. The highest calf ratio (number of calves/number of whales) and sighting rate (number of calves/km of effort) occurred in 2017, although 2013 and 2016 were also high. Preliminary analysis of photo- identification data suggests that it is rare to see an individual calf more than once in a given year.

The SWG welcomed this information, recognising that that it relates to successful pregnancies and, if it can be collected and analysed to provide a calving rate/index representative of the population, can provide valuable information for future *Implementation Reviews*. In discussion, it was also noted that the ASAMM aerial survey data could potentially be useful as an independent index of calf production for comparative purposes with the pregnancy rates presented in SC/67b/AWMP07. The SWG **encouraged** the continuation of the ASAMM surveys and any future collaboration involving life history data from the harvest.

Attention: SC

With respect to biological parameter information, the Committee:

(1) welcomes the extensive information presented;
(2) encourages the continued collection of such data from the hunt;
(3) encourages the work on the baleen plate analyses to examine hormone levels and pregnancy;
(4) encourages continued aerial surveys under the ASAMM surveys and any future collaboration involving life history data from the harvest; and
(5) agrees that the information presented does not suggest the need to consider any new SLA trials regarding stock structure.

4.4 Removals: review new information

The SWG received updated information about the 2017 harvest (SC/67b/AWMP05) and long-term removals (SC/67b/AWMP06). The authors of SC/67b/AWMP05 reported that in 2017, 57 bowhead whales were struck resulting in 50 animals landed. The total landed for the hunt in 2017 was higher than the average over the past 10 years (2007-16 mean of landed=41.7; SD=6.7). Efficiency (no. landed/no. struck) in 2017 was 88%, which was also higher than the average for the past 10 years (mean of efficiency= 75.2%; SD=6.5%). Of the landed whales, 28 were females and 22 were males. Based on total length (>13.4m in length) or pregnancy, 13 females were presumed mature. Six of those animals were examined and two were pregnant, one with a term foetus and another with a mid-term foetus, and one female was lactating. The fact that one third of the mature females were pregnant is consistent with past years.

SC/67b/AWMP06 provided a summary of bowhead whale catches in Alaska between 1974 and 2016. The authors pointed to the excellent cooperation and contribution of the whale hunters from the 11 villages that are members of the Alaska Eskimo Whaling Commission (AEWC). In total, 1,373 whales were landed. Over half (700) were landed in Barrow, while Shaktoolik and Little Diomede landed only one and two whales, respectively. Five of the 11 villages hunt only in the spring, two hunt only in the autumn whilst the remaining four have landed bowhead whales in both the spring and autumn/winter. Three of those villages (Gambell, Savoonga, and Wainwright) used to primarily hunt in the spring, but they now also hunt in the autumn or winter because changing ice conditions have made hunting more difficult in the spring. The efficiency of the hunt has improved over time. In the late 1970s, the efficiency averaged about 50% – because of improved hunting gear, communication, training and other factors, the efficiency now averages about 80%. Kaktovik and Nuiqsut hunt in the autumn in open water conditions and rarely have struck and lost whales. Some villages (Gambell, Savoonga, and Wainwright) on average land longer whales than others (Barrow and Point Hope). The length of landed whales within a season is correlated with the timing of the hunt. During spring, shorter whales tend to be landed earlier in the season while larger whales tend to be landed later. The opposite occurs in the autumn when larger whales tend to be landed earlier. The sex ratio of landed whales is even.

From 2013 to 2017, four bowhead whales (2 females and 2 males) were harvested near Chukotka, mainly in Anadyr Bay (SC/67b/AWMP20). The average length was 14.5m (minimum 13.0m, maximum 17.0m). Although the portion of the annual strike limit allocated to Russia under their bilateral agreement with the USA is five animals, the actual annual take is usually only 1-2 whales per year, and this has been the case since at least 2004.

The SWG thanked the authors of the provision of this information; catch and strike data are used in the *SLA* calculations (see Item 5.)

4.5 Other anthropogenic threats and health: review new information

New information about detection of carcasses in the eastern Chukchi and western Beaufort seas from the ASAMM project (2009-17, see summary under Item 3 above) was reported in SC/67b/AWMP02. A total of 27 bowhead whale carcasses (21 in the eastern Chukchi Sea) was detected, most in September but with the highest sighting rate in October. Survey effort does not account for the difference between the eastern Chukchi and western Beaufort study areas. A total of six carcasses, including all three of the calf/yearling carcasses sighted, showed signs of killer whale injuries; knowledge of killer whale behaviour and the location of the injuries on the whales, suggested to the authors that killer whale predation not scavenging was the cause of death. One carcass, with subsistence hunting gear (i.e., a line and float) attached, was observed in late October 2015. There were two struck and lost whales reported from about that same time; one at Barrow in late September and one in Wainwright in mid-October. Both of those whales were reported by the whaling captains to have likely died.

SC/67b/AWMP08 reported that during 2017, around 14% of landed whales carried injuries from line entanglement but none had ship strike injuries (consistent with 1990-2012 baselines). Two whales landed at Utqiaġvik (Barrow) in spring 2017 were carrying line associated with pot gear and had severe entanglement injuries such that veterinarians and the attending hunters thought that they were dying when captured.

The SWG **agreed** that whilst the present level of unintentional human induced mortality is too low to require new *Implementation* trials or incorporation into the *SLA* calculations, the situation should continue to be monitored and evaluated at the next *Implementation Review*. The SWG **welcomed** information that discussions between the AEWC and the Bering Sea Crabbers Association were ongoing, with the goal of limiting or reducing bowhead mortality attributable to their fishing gear.

The SWG **agreed** with the authors that the carcasses with killer whale injuries were probably a result of predation not scavenging. George expressed his opinion that killer whale/bowhead interactions have increased in the NE Chukchi Sea over the past 40 years. While beachcast gray whale calves killed by killer whales are commonly observed in Alaska along the NE Chukchi coast, dead bowhead calves (or subadults) were first seen only three years ago. There has also been an increase in observations of killer whale predation from ASAMM surveys and from hunters. In fact, a bowhead calf, probably killed by killer whales, was recovered by hunters northeast of Barrow; such a recovery has not happened before in the memory of native Alaskan hunters.

SC/67b/AWMP08 provided a comprehensive review of B-C-B bowhead health. The authors first noted that the strong, steady rate of population increase and the recent estimate of survival rate are possibly the best indicators that this population is healthy. A body condition index has shown a significant increase (fatter whales) over the period 1990-2012 but there is some evidence it has slowed or reduced in the last five years. This may reflect a density dependent effect of a population nearing carrying capacity, but further analysis is required. Post-mortem analyses indicate that whales caught in the spring migration are generally not feeding, while most (75-100%) in the autumn are. This is consistent with past findings and suggests that bowhead whale feeding habitat remains viable and productive.

General health information on landed bowhead whales was obtained from several major retrospective screening survey studies and from pathological analysis of 2017 post-mortem examinations. Key findings included: (i) declining body burden trend (blubber and muscle) in organic pollutants; (ii) limited detection of anthropogenic radionuclides (low levels in muscle); (iii) continued absence of major pathogens that could impact health; (iv) interannual variation of *Giardia* spp. with some suggestion of environmental marine contamination with human faeces; and (v) variable presence of marine biotoxins in faeces suggesting complex environmental drivers of harmful algae blooms in the Arctic. Pathological findings in 2017 were consistent with previous years e.g.: (i) low prevalence of fatty benign tumors in livers and gastric nodules associated with anisakis infection; and (ii) presence of kidney worm infection. Further work is underway on species characterisation of kidney worm specimens. The authors suggest that Arctic climate change (e.g., diminishing sea ice, increased sea surface temperature, opening of the Northwest Passage, range overlap with seasonal southern baleen whale migrants known to carry kidney worms, and prey shifts) may be setting the stage for an evolving host-parasite relationship in B-C-B bowhead whale stock.

The SWG **thanked** the authors for this valuable summary and **agreed** that nothing in the health analyses was cause for concern with respect to the continued application of the *Bowhead SLA*.

Attention: SC

With respect to threats and health to the B-C-B bowhead whales, the Committee:

(1) ***welcomes** the extensive information presented;*
(2) ***agrees** that whilst the present level of unintentional human induced mortality is too low to require new* Implementation *trials or incorporation into the* SLA *calculations, the situation should continue to be monitored and evaluated at the next* Implementation Review*;*
(3) ***agrees** that the health analyses give no cause for concern with respect to the continued application of the* Bowhead SLA*; and*
(4) ***encourages** that the excellent work on health-related issues continues.*

4.6 Conclusions and recommendations (and, if needed, workplan to complete *Review*)

The SWG **concluded** that no additional work was required to complete the *Implementation Review*. It further **concluded** that the range of hypotheses and parameter space already tested in *Bowhead SLA* trials was sufficient and therefore the *Bowhead SLA* could continue to be **recommended** to the Commission as the best way to provide management advice. This advice is presented under Item 5.3.

Attention: SC

With respect to the Implementation Review *of B-C-B bowhead whales, the Committee **concludes** that:*

(1) *the* Implementation Review *has been satisfactorily completed; and*
(2) *the range of hypotheses and parameter space already tested in* Bowhead SLA *trials was sufficient and therefore the* Bowhead SLA *remains the best way to provide management advice for this stock;*

In addition, it thanks the US scientists for the extremely hard work that they have put into providing comprehensive papers to facilitate this review

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5. STOCKS SUBJECT TO ASW (NEW INFORMATION AND MANAGEMENT ADVICE)

The SWG noted that the Commission will be setting new catch/strike limits for at its 2018 biennial meeting in Brazil. It had received written or verbal requests for limits to be considered for each hunt as discussed below.

In addition, there had been a general request to the intersessional workshop from the USA and Denmark (SC/67b/Rep06, annex F) for advice on whether there would be a conservation issue if there was a one-time seven-year block followed by a return to six-year blocks to address logistical issues from a Commission perspective. The SWG **agreed** with the intersessional workshop that there are no conservation issues associated with this suggestion.

5.1 Eastern Canada/West Greenland bowhead whales

5.1.1 New abundance information

Last year, the SWG had recommended that Canadian scientists attend the Committee to present the results of their work on abundance. It was very pleased that Doniol-Valcroze from Department of Fisheries and Oceans Canada and the primary author of the paper on aerial survey abundance estimate was present at the meeting.

The two relevant papers were first discussed by the Standing Working Group on ASI (see Annex Q for details). Doniol-Valcroze *et al.* (2015) provided a fully corrected estimate from the 2013 aerial survey of 6,446 bowheads (CV=0.26, 95% CI 3,722-11,200). The survey covered the major summering area for the Eastern Canada/West Greenland stock. The Working Group on ASI agreed that this was acceptable for management advice and for use within the AWMP. The other paper (ref) contained a genetic mark-recapture estimate that was considered preliminary at this stage.

The SWG **welcomed** this information and recalled that the *WG-Bowhead SLA* had been developed on the conservative assumption that the abundance estimates for the West Greenland area alone (1,274 whales in 2012 (CV=0.12)) represented the abundance of the whole stock, as it believed that it was not possible to assume that a non-member country would continue with regular surveys. Doniol-Valcroze advised the SWG that the present management strategy of Canada does involve obtaining regular abundance estimates. The SWG noted it would be pleased to receive such estimates from Canada being presented to the Committee in the future.

The SWG **welcomed** this information. It **agreed** that consideration of how to incorporate abundance estimates from Canada should be one focus of the next *Implementation Review.* It noted the regular collaboration of Canadian and Greenlandic scientists on other matters such as genetic sampling (*inter alia* for mark-recapture abundance estimation). It **encouraged** further collaboration between Canada, Greenland and the USA for the study of bowhead whales across their range and the presentation of these results at future Committee meetings.

In this regard, Witting reported that Greenland continues its biopsy sampling programme, with 60 biopsy samples collected in 2017. Bickham noted that many SNPs had been developed for B-C-B bowheads (SC/67b/SDDNA01) and that it would be productive for the same markers to be analysed for the Canadian samples since between-lab calibration is straightforward for SNPs and the increased statistical power would improve stock structure analyses, e.g. the ability to identify individual whales could provide information relevant to mixing proportions between areas.

5.1.2 New catch information

SC/67b/AWMP10 provided an update of recent Canadian takes made in the Inuit subsistence harvest of EC-WG bowhead whales. In the eastern Canadian Arctic, the maximum take is 7 bowhead whales per year according to domestic policy, with no carry-over of unused takes between years. Since 2015, five strikes were taken and four bowhead whales were successfully landed (one in 2015, two in 2016 and one in 2017).

The SWG **thanked** Canada for regularly providing catch information. It noted that the reported number of strikes was within the parameter space that was tested for the *WG-Bowhead SLA* and **encouraged** the continued collection of genetic samples from harvested whales.

Witting reported that West Greenland hunters struck no bowheads in 2017. There was one whale of 14.7m in length that died from entanglement in crab gear.

5.1.3 Management advice

SC/67b/AWMP19 reported Greenland's plans for requesting aboriginal whaling provisions at IWC/67 and no changes were requested for bowhead whales.

The SWG **agreed** that the *WG Bowhead SLA* remains the best available ways for management advice, and noted that this *SLA* had been developed under the conservative assumption that the number of bowhead whales estimated off West Greenland represented the total abundance between West Greenland and Eastern Canada. Based on the agreed 2012 estimate of abundance for West Greenland (1,274, CV=0.12), the catch of one whale in Canada in 2017, and using the agreed *WG-Bowhead SLA*, the SWG **repeated its advice** that an annual strike limit of two whales will not harm the stock and meets the Commissions conservation objectives.

Although the SWG had not yet had time to examine the request from the US/Denmark (SC/67b/Rep06, Annex F, appendix) for this *SLA,* it **agreed,** based on *WG-bowhead SLA* testing thus far, that its previous advice that the interannual variation of 50% within a block with the same allowance from the last year of one block to the first year of the next was acceptable.

Attention: C-A

A general request had been received from the USA and Denmark for advice on whether there would be a conservation issue if there was a one-time 7-year block followed by a return to 6-year blocks to address logistical issues related to the Commission.

The Committee ***agrees*** *there are no conservation issues associated with this suggestion.*

Attention: SC

The Committee greatly appreciated the presence of a Canadian scientist at its meeting. The Committee:

(1) ***welcomes*** *the provision of the abundance estimate for the Eastern Canada/West Greenland stock and (see Item 8.1.2) the regular provision of information on catch data by Canada;*
(2) ***welcomes*** *the attendance of Canadian scientists at its meetings;*
(3) ***agrees*** *that consideration of how to incorporate abundance estimates from Canada should be one focus of the next* Implementation Review *for this stock;*

(4) ***notes*** *the regular collaboration of Canadian and Greenlandic scientists on other matters such as genetic sampling (inter alia for mark-recapture abundance estimation); and*

(5) ***encourages*** *further collaboration between Canada, Greenland and the USA for the study of bowhead whales across their range and the presentation of these results at future Committee meetings.*

Attention: C-A

SC/67b/AWMP19 reported Greenland's plans for requesting aboriginal whaling provisions at IWC67 and no changes were requested for bowhead whales. The Committee therefore:

(1) ***agrees*** *that the* WG-Bowhead SLA *remains the best available way to provide management advice for the Greenland hunt;*

(2) ***notes*** *that this SLA had been developed under the conservative assumption that the number of bowhead whales estimated off West Greenland represented the total abundance between West Greenland and Eastern Canada;*

(3) based on the agreed 2012 estimate of abundance for West Greenland (1,274, CV=0.12), the catch of one whale in Canada in 2017, and using the agreed WG-Bowhead SLA*,* ***agrees*** *that an annual strike limit of two whales will not harm the stock and meets the Commissions conservation objectives; and*

(4) although the Committee has not yet had time to examine the request from the US/Denmark for the WG-Bowhead SLA, reiterates its advice, applicable for all SLAs, that interannual variation of 50% within a block with the same allowance from the last year of one block to the first year of the next, is acceptable.

5.2 North Pacific gray whales

The Russian Federation (SC/67b/AWMP17) had requested advice on the following provision:

'For the **seven** years 2019, 2020, 2021, 2022, 2023, 2024 and 2025, the number of gray whales taken in accordance with this sub-paragraph shall not exceed 980 (i.e. 140 per annum on average) provided that the number of gray whales taken in any one of the years 2019, 2020, 2021, 2022, 2023, 2024 and 2025 shall not exceed 140.'

5.2.1 New information (including catch data)

SC/67b/AWMP20 presented a comparison of gray whale catch data off Chukotka during: (i) the Soviet era (i.e. data from the catcher boat *Zvezdny*, from 1969-91); with (ii) recent data from 2013-17. The average length and weight of harvested whales in recent years is smaller than it was during the Soviet era. This discrepancy could be due to a difference in the selectivity patterns between the Soviet era industrial-sized catcher boat and the small boats used by native Chukotkans. The average annual number of whales was also higher during the Soviet era (150 *vs* 123). The annual biomass of removals in recent years is estimated to be one-third of that during the Soviet era. In recent years, most whales have been taken by the eastern and northeastern settlements of the Chukchi Peninsula – in the Bering Strait and east Chukchi Sea. Authors speculated that more mature whales migrate to the Arctic via the Bering Strait compared to those remaining in Anadyr Bay. Whales caught on Chukotka's Arctic coast were found to be statistically larger with a higher fat index than whales harvested on the eastern coast. Considering the 11% rise of native population in Chukotka since 2010 and also considering the drop in acquired whaling products comparing to 1980s-1990s, the authors concluded that the subsistence need of indigenous people is not satisfied.

Zharikov presented results of the 2017 whaling season in Chukotka. A total of 119 gray whales were struck in 2017 (37 males and 82 females). No whales were struck and lost, and no stinky (inedible) gray whales were taken. Similar whaling methods were employed as in recent years and the overall efficiency of the hunt was almost same as in 2016. It was noted that whale products are a large part of the local diet; there is also exchange with inland aborigines and use for non-nutritional purposes. A total of 615 gray whales have been taken in 2013-17 (SC/67b/AWMP17). Therefore only 105 strikes remain for 2018 under the current block quota, while the average annual take in recent years is 123 whales. The *SLA* trials performed in 2017 at the request of the Government of the Russian Federation (IWC, 2018) showed that a take of up to 136 whales per year by indigenous people of Chukotka will not harm the population. He noted that a possible overrun of 2013-18 quota by Chukotka native whalers was within this catch level and believed that such needs should be taken into account in the near future.

SC/67b/AWMP17 presented proposed text by the Russian Federation for amendments to Paragraph 13(b)(2) of the Schedule for gray whales. It was noted that a specific native diet has been documented. The consumption of relatively high amounts of proteins and fats is a necessary component of health and longevity in the native population of Chukotka. The importance of aboriginal whaling to the social, cultural and economic structure of Chukotka's coastal villages was also noted. Under the current block quota, the annual strike limit is 140 per year (including any strikes allocated to the Makah tribe). The proposed amendments would extend the duration of this block quota from six to seven years. Under the proposed seven-year block quota, the total number of strikes would be increased to 980 (140x7yrs). This provision would continue to be reviewed biannually by the Commission in light of the annual advice of the Scientific Committee.

5.2.2 Management advice

The SWG **agreed** that the *Gray Whale SLA* remains the best available way for management advice for this stock. It **advised** that an average annual strike limit of 140 whales will not harm the stock and meets the Commission's conservation objectives. It also noted that its previous advice that the interannual variation of 50% within a block with the same allowance from the last year of one block to the first year of the next was acceptable. It also **advised** that the Makah Management Plan (Item 2.3) is in accord with the Commission's management objectives.

Attention: SC

In reviewing the results of new genetic analyses of gray whales in the North Pacific, the Committee ***agrees*** *that the genetic and photographic data for this species be combined to better assess stock structure-related questions. Given the potential for genomic data to aid in better evaluating the stock structure hypotheses currently under consideration for North Pacific gray whales, the Committee* ***encourages*** *the continuation of work to produce additional genomic data from sampled gray whales.*

Attention: C-A

The Russian Federation (SC/67b/AWMP/17) had requested advice on the following provision:

> *'For the seven years 2019, 2020, 2021, 2022, 2023, 2024 and 2025, the number of gray whales taken in accordance with this sub-paragraph shall not exceed 980 (i.e. 140 per annum on average) provided that the number of gray whales taken in any one of the years 2019, 2020, 2021, 2022, 2023, 2024 and 2025 shall not exceed 140.'*

The Committee therefore:

(1) ***agrees*** *that the* Gray Whale SLA *remains the best available way to provide management advice for the gray whale hunts;*
(2) ***advises*** *that an average annual strike limit of 140 whales will not harm the stock and meets the Commission's conservation objectives;*
(3) ***notes*** *that its previous advice that the interannual variation of 50% within a block with the same allowance from the last year of one block to the first year of the next remains acceptable;*
(4) ***advises*** *that the Makah Management Plan (see Item 2.3) also is in accord with the Commission's management objectives.*

5.3 Bering-Chukchi-Beaufort Seas bowhead whale

5.3.1 New information

New information was considered as part of the *Implementation Review* discussed under Item 4.

The USA had indicated that it was proposing no changes to the present catch/strike limits although it may suggest changes to its carryover request in light of the advice received by the Committee as discussed at the intersessional Workshop (SC/67b/Rep06).

The SWG noted that there are now two independent estimates of abundance for this stock in 2011 (see Item 4). Recognising the need to formally consider the general question of how best to combine estimates in such cases as part of the workplan in the next biennium, the SWG noted that if they are combined as a weighted average by the inverse of their variances, there is little difference (it is slightly higher) between the combined estimate and that from the ice-based census estimate that is the approach used to obtain the other estimates used in the *SLA*. It therefore **agreed** to use the ice-based census estimate for 2011 survey (Givens *et al.,* 2016; 16,820, CV=0.052, 95% CI 15,176 to 18,643) as the most recent estimate of abundance for use in the *Bowhead SLA* this year.

5.3.2 Management advice

The SWG **agreed** that the *Bowhead SLA* remains the best available way for management advice for this stock. It **advised** that a continuation of the present average annual strike limit of 67 whales will not harm the stock and meets the Commission's conservation objectives.

The SWG also **advised** that provisions allowing for the carry forward of unused strikes from the previous three blocks, subject to the limitation that the number of such carryover strikes used in any year does not exceed 50% of the annual strike limit' has no conservation implications (see SC/67b/Rep04).

Attention: C-A

The USA indicated that it requested advice on the existing catch/strike limits. The Committee therefore:

(1) ***agrees*** *that the* Bowhead Whale SLA *remains the best available way to provide management advice for this stock;*
(2) ***advises*** *that a continuation of the present average annual strike limit of 67 whales will not harm the stock and meets the Commission's conservation objectives; and*
(3) ***advises*** *that provisions allowing for the carry forward of unused strikes from the previous three blocks, subject to the limitation that the number of such carryover strikes used in any year does not exceed 50% of the annual strike limit, has no conservation implications (see SC/67b/Rep04).*

5.4 Common minke whales off East Greenland

SC/67b/AWMP19 reported Greenland's plans for requesting aboriginal whaling provisions at IWC/67. It requested advice on an annual take of 20 animals (it had previously been 12).

5.4.1 New information on catches

In the 2017 season, 9 common minke whales were landed in East Greenland, and one was struck and lost. Three of the landed whales were males, 6 were females, and genetic samples were obtained from 8 of the landed whales. One common minke whale died from entanglement in fishing gear. The SWG **encouraged** the continued collection of genetic samples and collaborative studies (see Item 5.1.1).

5.4.2 New information on abundance

The Working Group on ASI endorsed the 2015 aerial survey abundance estimate of 2,762 (CV=0.47; 95%CI 1,160-6,574). This is only a small part of the wider Western and Central stocks.

5.4.2 Management advice

The SWG noted that in the past its advice for the East Greenland hunt had been based upon the fact that the catch was a small proportion of the number of animals in the Central Stock. During the process to develop an *SLA* for common minke whales off West Greenland produced a simulation framework that produces a considerably more rigorous way to provide advice for this hunt, taking into account stock structure issues. In addition, there is for the first time a separate estimate of abundance for common minke whales off East Greenland alone (this is only a small part of the wider western and Central stocks from which the catches can be drawn). The results of the simulation trials that incorporated a continuing catch of 20 whales from East Greenland led to no conservation concerns (see Appendix 4). The SWG noted that a formal *SLA* for this hunt should be developed in the future.

Given the above information, the SWG **advised** that an annual strike limit of 20 whales for the next block will not harm the stock and meets the Commission's conservation objectives.

In response to a request for advice on the length of the season for the common minke whale hunts in SC/67b/AWMP19, the SWG **agreed** that changing the length of the season to 12 months had no conservation implications.

Attention: C-A

SC/67b/AWMP19 reported Greenland's plans for requesting aboriginal whaling provisions at IWC67. It requested advice on an annual take of 20 animals (it had previously been 12). It had also requested advice on any conservation implications of a 12-month hunting season for common minke whales.

The Committee therefore:

(1) ***notes*** *that in the past its advice for the East Greenland hunt had been based upon the fact that the catch was a small proportion of the number of animals in the Central Stock;*
(2) ***notes*** *the process to develop an* SLA *for common minke whales off West Greenland resulted in a simulation framework that produces a considerably more rigorous way to provide advice for this hunt than before, by taking into account stock structure issues;*
(3) ***notes*** *that the results of the simulation trials that incorporated a continuing catch of 20 whales from East Greenland gave rise to no conservation concerns;*
(4) ***notes*** *that the 2015 aerial survey abundance estimate of 2,762 (CV=0.47; 95%CI 1,160-6,574) is only a small part of the wider western and central stocks;*
(5) ***advises*** *that a continuation of the present average annual strike limit of 20 whales will not harm the stock and meets the Commission's conservation objectives;*
(6) ***advises*** *that changing the length of the season to 12 months had no conservation implications; and*
(7) ***agrees*** *that an* SLA *should be developed for this hunt in the future; and*
(8) ***encourages*** *the continued collection of samples for collaborative genetic analyses (and see Item 7.1.2.3).*

5.5 Common minke whales off West Greenland

SC/67b/AWMP19 reported Greenland's plans for requesting aboriginal whaling provisions at IWC/67. It requested advice on annual strikes of 164 animals (i.e. no change).

5.5.1 New information on catches

In the 2017 season, 129 common minke whales were landed in West Greenland and four were struck and lost. Of the landed whales, there were 95 females, 33 males and one of unknown sex. Genetic samples were obtained from 104 of these common minke whales in 2017, and the SWG was pleased to note that samples were already part of the data used in the genetic analyses of common minke whales in the North Atlantic. The SWG **encouraged** the continued collection of samples and the collaborative approach of the genetic analysis.

5.5.2 New information on abundance

The Working Group on ASI endorsed the 2015 aerial survey abundance estimate of 5,095 (CV=0.46; 95%CI 2,171-11,961) as discussed in Annex Q.

5.5.3 Management advice

The SWG **agreed** that the new *WG-common minke SLA* (Item 2.2) is the best available way to provide management advice for this stock. It **advised** that an annual strike limit of 164 whales will not harm the stock and meets the Commission's conservation objectives. Although the SWG had not yet had time to examine the request from the US/Denmark (SC/67b/Rep06, Annex F, appendix) for this new *SLA,* it **agreed,** based on *WG-common minke SLA* testing thus far, that its previous advice that the interannual variation of 50% within a block with the same allowance from the last year of one block to the first year of the next was acceptable.

In response to a request for advice on the length of the season for the common minke whale hunts in SC/67b/AWMP19, the SWG **agreed** that changing the length of the season to 12 months had no conservation implications.

Attention: C-A

SC/67b/AWMP19 reported Greenland's plans for requesting aboriginal whaling provisions at IWC67. It requested advice on annual strikes of 164 animals (i.e. no change). It had also requested advice on any conservation implications of a 12-month hunting season for common minke whales.

The Committee therefore:

(1) ***agrees*** *that the WG-Common minke SLA is the best available way to provide management advice for this stock under need scenario A;*
(2) ***advises*** *that a continuation of the present average annual strike limit of 164 whales will not harm the stock and meets the Commission's conservation objectives;*
(3) although the Committee has not yet had time to examine the request from the US/Denmark (SC/67b/Rep06, annex F, appendix) for this SLA, reiterates its previous advice, applicable for all SLAs, that interannual variation of 50% within a block with the same allowance from the last year of one block to the first year of the next is acceptable;
(4) ***advises*** *that changing the length of the season to 12 months had no conservation implications; and*
(5) ***encourages*** *the continued collection of samples for collaborative genetic analyses (and see Item 7.1.2.3).*

5.6 Fin whales off West Greenland

SC/67b/AWMP19 reported Greenland's plans for requesting aboriginal whaling provisions at IWC/67. It requested advice on annual strikes of 19 animals (i.e. no change).

5.6.1 New information on the catch

A total of seven fin whales (five females and two males) was landed, and one was struck and lost, off West Greenland during 2017. The SWG was pleased to note that genetic samples were obtained from five of these, and that the genetic samples are analysed together with the genetic samples from the hunt in Iceland. It **encouraged** the continued collection of samples and collaborative work on analyses.

5.6.2 New information on abundance

The Working Group on ASI endorsed the 2015 aerial survey abundance estimate of 2,215 (CV=0.41; 95%CI 1,017-4,823) as discussed in Annex Q.

5.6.3 Management advice

The SWG **agreed** that the new *WG-fin SLA* (Item 2.2) is the best available way to provide management advice for this stock. It **advised** that an annual strike limit of 19 whales will not harm the stock and meets the Commission's conservation objectives.

Although the SWG had not yet had time to examine the request from the US/Denmark (SC/67b/Rep06, Annex F, appendix) for this new *SLA,* it **agreed,** based on *WG-fin SLA* testing thus far, that its previous advice that the interannual variation of 50% within a block with the same allowance from the last year of one block to the first year of the next was acceptable.

In response to a request for advice on length limits for fin whales in SC/67b/AWMP19, the SWG **agreed** that removing the length limits had no conservation implications.

Attention: C-A

SC/67b/AWMP19 reported Greenland's plans for requesting aboriginal whaling provisions at IWC/67. It requested advice on annual strikes of 19 animals (i.e. no change). It also requested advice on whether there were any conservation implications of removing length limits (while retaining the prohibitions relating to calves.

The Committee therefore:

(1) *agrees that the* WG-Fin SLA *is the best available way to provide management advice for this stock;*
(2) *advises that a continuation of the present average annual strike limit of 19 whales will not harm the stock and meets the Commission's conservation objectives;*
(3) *although the Committee has not yet had time to examine the request from the US/Denmark (SC/67b/Rep06, annex F, appendix) for this SLA, reiterates its advice, applicable for all SLAs, that interannual variation of 50% within a block with the same allowance from the last year of one block to the first year of the next is acceptable;*
(4) *advises that removing the length limits had no conservation implications; and*
(5) *encourages the continued collection of samples for collaborative genetic analyses (and see Item 7.1.1.3).*

5.7 Humpback whales off West Greenland

SC/67b/AWMP19 reported Greenland's plans for requesting aboriginal whaling provisions at IWC/67. It requested advice on annual strikes of 10 animals (i.e. no change).

5.7.1 New information on catches

A total of two (two females) humpback whales were landed and none were struck and lost in West Greenland during 2017. The SWG was pleased to learn that genetic samples were obtained from all the landed whales. The SWG again **emphasised** the importance of collecting genetic samples and photographs of the flukes from these whales.

The SWG noted that five humpback whales were observed entangled in fishing gear in West Greenland in 2017. Of these, one died, two became free and one was successfully disentangled by a disentanglement team. The remaining animal was alive and still entangled when it was last sighted.

The SWG noted that some bycaught whales had been included in the scenarios for the development of the *Humpback SLA*. If high levels continued, then this would need to be taken into account in any *Implementation Review.* It noted the IWC efforts with respect to disentanglement and prevention and **welcomed** the news that the Greenland authorities requested IWC disentanglement training that took place in 2016 and that they successfully disentangled one humpback whale.

5.7.2 New information on abundance

The Working Group on ASI endorsed the 2015 aerial survey abundance estimate of 993 (CV=0.46; 95%CI 434-2,272) as discussed in Annex Q.

5.7.3 Management advice

The SWG **agreed** that the *WG humpback SLA* remains the best available tool for management advice for this stock. It **advised** that a continuation of the present average annual strike limit of 10 whales will not harm the stock and meets the Commission's conservation objectives.

The SWG also **advised** that provisions allowing for the carry forward of unused strikes from the previous three blocks, subject to the limitation that the number of such carryover strikes used in any year does not exceed 50% of the annual strike limit' has no conservation implications (see SC/67b/Rep04).

Attention: C-A

SC/67b/AWMP19 reported Greenland's plans for requesting aboriginal whaling provisions at IWC/67. It requested advice on annual strikes of 10 animals (i.e. no change).

The Committee therefore:

(1) ***agrees** that the* WG-Humpback SLA *is the best available way to provide management advice for this stock;*
(2) ***advises** that a continuation of the present average annual strike limit of 10 whales will not harm the stock and meets the Commission's conservation objectives;*
(3) ***advises** that that provisions allowing for the carry forward of unused strikes from the previous three blocks, subject to the limitation that the number of such carryover strikes used in any year does not exceed 50% of the annual strike limit' has no conservation implications (see SC/67b/Rep04); and*
(4) ***encourages** the continued collection of samples and photographs for collaborative analyses.*

5.8 Humpback whales off St Vincent and The Grenadines

The alternate Commissioner for St Vincent and The Grenadines advised that no change to the present limits were envisaged.

5.8.1 New information on catch

It was reported that one humpback whale was struck and landed in 2017 by St Vincent and The Grenadines.

5.8.2 New information on abundance

Last year, the Committee had requested that the USA provide a new abundance estimate for the western North Atlantic based upon the available NOAA data (IWC, 2018). Clapham and Wade provided a progress report on this work with a focus on information on abundance estimates generated by the MONAH study, conducted in 2004 and 2005 on Silver Bank (a breeding ground in the West Indies) and in the Gulf of Maine feeding ground. The best estimate was judged to be a genotype-based two-year pooled feeding-to-breeding male-only Chapman estimate. This estimate was 6,156 (95% CI 4,344, 7,977), which when doubled (to account for females) equals 12,312. This was slightly higher than, although not significantly different from, the best estimate from the YONAH project from 1992/93, which was 10,400 (8,000, 13,600). The lack of strong population growth was unexpected given information on rates of increase from some other areas of the North Atlantic, and may reflect either a true rate of increase, unidentified sampling bias, and/or the idea that Silver Bank as a habitat has reached a maximum capacity. Given this, it was not clear whether the MONAH estimate is representative of the entire population, nor whether it can be applied to the southeastern Caribbean in the context of the St Vincent hunt. Four animals from the southeastern Caribbean have been linked to animals seen in the Gulf of Maine (one was caught in the hunt).

The SWG also noted the recent new abundance estimates of humpback whales in the North Atlantic including 993 (95% CI: 434-2,272) in West Greenland in 2015, 4,223 (95% CI: 1,845-9,666) in East Greenland in 2015 and Iceland-Faroes with 12,879 (95% CI 5,074; 26455) estimated from the 2007 ship survey

It has now been nearly two decades since the IWC has undertaken an In-Depth Assessment on North Atlantic humpback whales. The SWG **agreed** that it would be a valuable exercise to perform a North Atlantic Rangewide review of humpback whales, similar in scope to the Rangewide Review for North Pacific gray whales and taking into account recent work on stock structure including that of Stevick *et al.* (2018).

5.8.3 Management advice

The SWG noted that it did not have an approved abundance estimate for western North Atlantic since that in 1992. In accord with the advice provided in the AWS (see Appendix 9), it therefore considered the available evidence to see if was sufficient to provide safe management advice. Given the information above on recent abundance in the North Atlantic and the size of the requested catch/strikes (an average of four annually), the SWG **advised** that continuation of the present limits will not harm the stock.

The SWG also **repeats** its earlier advice that:

(1) the status and disposition of genetic samples collected from past harvested whales be determined and reported next year;
(2) photographs for photo-ID (where possible) and genetic samples are collected from all whales landed in future hunts; and that
(3) the USA (NOAA, NMFS) provides an abundance estimate from the MONAH data as soon as possible for the Committee.

Attention: C-A

The alternate Commissioner for St Vincent and The Grenadines advised that no change to the present limits were envisaged. The Committee therefore:

(1) ***notes*** *that it does not have an approved abundance estimate for western North Atlantic since that in 1992;*
(2) ***notes*** *that in accord with the advice provided in the AWS (see Appendix 9), it therefore considered the available evidence to see if was sufficient to provide safe management advice; and*
(3) ***advises*** *that, given the information above on recent abundance in the North Atlantic combined with the size of the requested catch/strikes (an average of four annually), continuation of the present limits will not harm the stock;*

The Committee also ***reiterates*** *its previous advice that:*

(1) the status and disposition of genetic samples collected from past harvested whales be determined and reported next year;
(2) photographs for photo-ID (where possible) and genetic samples are collected from all whales landed in future hunts; and that
(3) the USA (NOAA, NMFS) provides an abundance estimate from the MONAH data as soon as possible for the Committee.

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6. WORKPLAN 2019-20 (INCLUDING WORKSHOPS AND INTERSESSIONAL GROUPS)

Table 1 summarises the work plan for work related to aboriginal subsistence whaling.

Simulation testing of interim relief allowances has been conducted for B-C-B bowheads and WG humpbacks (item 3 of Appendix 9). Interim relief will be tested for eastern NP gray whales at the next *Implementation Review* for that stock. Testing for the remaining ASW stocks will be added to the future workplan of the Committee.

7. BUDGETARY ITEMS 2019-20

The SWG has no budget requests for the next biennium.

8. ADOPTION OF REPORT

The Chair noted that this meeting represented the end of a long journey – with the adoption of the two new *SLA*s, the SWG had completed the development tasks it had been assigned by the Commission. He thanked all of the people who have made such a wonderful contribution over the years – the SWG has, in his view, achieved ground-breaking work over the last two decades in a spirit of great collaboration and co-operation, even when there were disagreements as inevitably there were. At this meeting, he thanked the rapporteurs, and especially John Brandon for their hard work. Primarily, though thanks were due to André Punt, Lars Witting and Anabela Brandão for their herculean efforts in developing and running trials and developing *SLA*s. However, greatest praise should go to Cherry Allison who under extremely difficult circumstances provided superb support from Cambridge. The whole SWG sends their thanks, support and best wishes.

Table 1

Work plan for matters related to aboriginal subsistence whaling.

Topic	Intersessional 2018/19	2019 Annual Meeting (SC/68a)	Intersessional 2019/20	2020 Annual meeting
(1) Annual review of catch/strike limits		Carry out		Carry out
(2) *Implementation Review*		Gray whales based upon rangewide review		West Greenland humpback whales
(3) *SLA*s		Consider development of an *SLA* for the hunt of common minke whales off East Greenland based on operational models developed for the West Greenland hunt		Adopt *SLA* if it is decided one is necessary
(5) Interim relief allowance testing	Run trials for gray whale hunts	Review results	Run trials for West Greenland common minke whales and fin whales	Review results
(6) Carryover (US/Denmark request)	Run trials for remaining Greenland hunts (West Greenland common minke whales, bowhead whales and fin whales	Review results		

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Appendix 1

AGENDA

1. Introductory items
   1.1 Convenor's opening remarks
   1.2 Election of Chair and appointment of Rapporteurs
   1.3 Adoption of Agenda
   1.4 Documents available
2. *SLA* development
   2.1 Fin whales (Greenland)
      2.1.1 Review results of intersessional Workshops
      2.1.2 Review post-Workshop progress
      2.1.3 Review final results and performance
      2.1.4 Conclusions and recommendations
   2.2 Common minke whales (Greenland)
      2.2.1 Review results of intersessional Workshops
      2.2.2 Review post-Workshop progress
      2.2.3 Review description of and results for candidate *SLA*s
      2.2.4 Conclusions and recommendations
   2.3 North Pacific gray whales (Makah Management Plan)
      2.3.1 Summarise the plan
      2.3.2 Review intersessional progress including at the Rangewide Workshop
      2.3.3 Conclusions and recommendations
   2.4 WG-bowhead whales
      2.4.1 Review results using 400 replicates
      2.3.2 Testing the Interim Allowance strategy
      2.3.3 Conclusions and recommendations
3. Aboriginal Whaling Management Scheme (AWS)
   3.1 Review results of intersessional Workshops
   3.2 Review proposed updates to the AWS
   3.2 Conclusions and recommendations
4. *Implementation Review* of B-C-B bowhead whales
   4.1 Stock structure: review new information (including advice from SD)
   4.2 Abundance estimates: review new information (including advice from ASI)
   4.3 Biological parameters: review new information
   4.4 Removals: review new information
   4.5 Other anthropogenic threats and health: review new information
   4.6 Conclusions and recommendations (and, if needed, work plan to complete *Review*)
5. Stocks subject to ASW (new information and management advice)
   5.1 Eastern Canada/West Greenland bowhead whales
   5.2 North Pacific gray whales
   5.3 Bering-Chukchi-Beaufort Seas bowhead whale
   5.4 Common minke whales off East Greenland
   5.5 Common minke whales off West Greenland
   5.6 Fin whales off West Greenland
   5.7 Humpback whales off West Greenland
   5.8 Humpback whales off St Vincent and The Grenadines
6. Work plan 2019-20 (including workshops and intersessional groups)
7. Budgetary items 2019-20
8. Adoption of report

Appendix 2

WEST GREENLAND FIN WHALE *SLA* TRIAL SPECIFICATIONS

In initial trials, fin whales off West Greenland were modelled as a single isolated population (see discussion in IWC [2016, p.476], with this approach justified as being more conservative in terms of population risk compared to modelling the whole North Atlantic). Following a new point estimate of abundance from a 2015 survey that was significantly smaller than the previous one, the abundance is modelled by means of a two-component process whereby each year either all whales in the population entered the West Greenland region, or only a proportion of those whales, where the proportion is drawn from a distribution (see section B). An alternative 'Influx' model is also trialled.

A. The population dynamics model

The underlying dynamics model is deterministic, age- and sex-structured, and based on the Baleen II model (Punt, 1999).

A.1 Basic dynamics

Equations A1.1 provide the underlying 1+ dynamics.

$$\begin{aligned} R^{m/f}_{t+1,a+1} &= (R^{m/f}_{t,a} - C^{m/f}_{t,a}) S_a + U^{m/f}_{t,a} S_a \delta_{a+1} && 0 \le a \le x-2 \\ R^{m/f}_{t+1,x} &= (R^{m/f}_{t,x} - C^{m/f}_{t,x}) S_x + (R^{m/f}_{t,x-1} - C^{m/f}_{t,x-1}) S_{x-1} && \\ U^{m/f}_{t+1,a+1} &= U^{m/f}_{t,a} S_a (1-\delta_{a+1}) && 0 \le a \le x-2 \end{aligned} \qquad \text{(A1.1)}$$

$R^{m/f}_{t,a}$ is the number of recruited males/females of age a at the start of year t;

$U^{m/f}_{t,a}$ is the number of unrecruited males/females of age a at the start of year t;

$C^{m/f}_{t,a}$ is the catch of males/females of age a during year t (whaling is assumed to take place in a pulse at the start of each year);

δ_a is the fraction of unrecruited animals of age a-1 which recruit at age a (assumed to be independent of sex and time);

S_a is the annual survival rate of animals of age a:

$$S_a = \begin{cases} S_J S_{1+} & \text{if } a = 0 \\ S_J & \text{if } 1 \le a \le a_T \\ S_{1+} & \text{if } a > a_T \end{cases} \qquad \text{(A1.2)}$$

S_J is the juvenile survival rate (note that for calves, a=0, the assumption made above is that if the mother dies, the calf dies too);

S_{1+} is the survival rate for animals older than age a_T;

a_T is the age at which survival rate changes from juvenile to adult; and

x is the maximum (lumped) age-class (all animals in this and the x-1 class are assumed to be recruited and to have reached the age of first parturition). x is taken to be 15 for fin whales for these trials.

A.2 Births

The number of births at the start of year t+1, B_{t+1}, is given by Equation A2.1:

$$B_{t+1} = b_{t+1} N^f_{t+1} \qquad \text{(A2.1)}$$

N^f_t is the number of mature females at the start of year t:

$$N^f_t = \sum_{a=a_m}^{x} (R^f_{t,a} + U^f_{t,a}) \qquad \text{(A2.2)}$$

a_m is the age-at-maturity (the standard IWC 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+1} is the probability of birth/calf survival for mature females:

$$b_{t+1} = \max(0, b_K \{1 + A(1 - [N^{1+}_{t+1} / K^{1+}]^z)\}) \qquad \text{(A2.3)}$$

$$N_t^{1+} = \sum_{a=1}^{x} (R^f_{t,a} + U^f_{t,a} + R^m_{t,a} + U^m_{t,a}) \qquad \text{(A2.4)}$$

$$K^{1+} = \sum_{a=1}^{x} (R^f_{-\infty,a} + U^f_{-\infty,a} + R^m_{-\infty,a} + U^m_{-\infty,a})$$

b_k is the average number of live births per year per mature female at carrying capacity;

A is the resilience parameter; and

z is the degree of compensation.

The number of female births, B_t^f , is computed from the total number of the births during year *t* using Equation A2.5:

$$B_t^f = 0.5 \ \ B_t \qquad \text{(A2.5)}$$

The numbers of recruited/unrecruited calves is given by:

$$\begin{array}{ll} R^f_{t,0} = \alpha_0 \, B_t^f & R^m_{t,0} = \alpha_0 \, (B_t - B_t^f) \\ U^f_{t,0} = (1-\alpha_0) \, B_t^f & U^m_{t,0} = (1-\alpha_0)(B_t - B_t^f) \end{array} \qquad \text{(A2.6)}$$

α_0 is the proportion of animals of age 0 which are recruited (0 for these trials).

A.3 Removals

The historical ($t \leq 2015$) removals are taken to be equal to the total reported removals (including struck and lost, bycatch, ship strikes etc.) (Table 1). National progress reports indicate that mortality rates due to by-catches and ship strikes off West Greenland are low and so are ignored in future in these trials. The sex-ratio of future aboriginal catches is assumed to be 50:50 F:M. Catches are taken uniformly from the recruited component of the population:

$$C^m_{t,a} = C^m_t \, R^m_{t,a} / \sum_{a'} R^m_{t,a'} \ ; \ \ C^f_{t,a} = C^f_t \, R^f_{t,a} / \sum_{a'} R^f_{t,a'} \qquad \text{(A3.1)}$$

$C_t^{m/f}$ is the number of males/females removed from the population during year *t*.

The total removal in a given future year is the sum of:

(a) the minimum of the need for that year, Q_t, and the corresponding strike limit; and

(b) bycatches in fisheries and ship strikes (taken to be 0 in these trials).

Table 1

Total removals of fin whales (direct catches and bycatches) from West Greenland.
Catches of unknown sex are allocated to sex assuming a 50:50 ratio.

Year	Male	Female	Year	Male	Female	Year	Male	Female	Year	Male	Female
1940			1960	0	0	1980	6.5	6.5	2000	3.5	3.5
1941			1961	0	0	1981	3.5	3.5	2001	3.5	4.5
1942			1962	0	0	1982	4.5	4.5	2002	5	8
1943			1963	0	0	1983	4	4	2003	3.5	5.5
1944			1964	0.5	0.5	1984	5	5	2004	6	7
1945			1965	0.5	0.5	1985	4	5	2005	1.5	11.5
1946	26	21	1966	0	0	1986	5	4	2006	3	7
1947	29	22	1967	0	0	1987	4	5	2007	7	5
1948	10	11	1968	1.5	1.5	1988	4	5	2008	9.5	4.5
1949	5	16	1969	0	0	1989	7	7	2009	2	8
1950	18	18	1970	0	0	1990	11	8	2010	0.5	5.5
1951	8	7	1971	0	0	1991	8.5	9.5	2011	0	5
1952	4	12	1972	0.5	0.5	1992	8.5	13.5	2012	0.5	4.5
1953	6	9	1973	1	1	1993	2.5	11.5	2013	3.5	5.5
1954	17	5	1974	2.5	2.5	1994	11	11	2014	6.5	5.5
1955	14	8	1975	0.5	0.5	1995	9	3	2015	3	9
1956	17	11	1976	4.5	4.5	1996	8.5	10.5			
1957	11	10	1977	6.5	6.5	1997	6.5	6.5			
1958	2	6	1978	4.5	3.5	1998	2	9			
1959	0	0	1979	3.5	3.5	1999	4	5			

A.4 Recruitment

The proportion of animals of age *a* that would be recruited if the population was pristine is a knife-edged function of age at age a_r, i.e.:

$$\alpha_a = \begin{cases} 0 & \text{if } 0 \le a < a_r \\ 1 & \text{otherwise} \end{cases} \tag{A4.1}$$

a_r is the age-at-recruitment (assumed to be 1 for fin whales).

The (expected) number of unrecruited animals of age a that survive to age a+1 is $U_{t,a}^{m/f} S_a$. The fraction of these that then recruit is:

$$\delta_{a+1} = \begin{cases} [\alpha_{a+1} - \alpha_a]/[1-\alpha_a] & \text{if } 0 \le \alpha_a < 1 \\ 1 & \text{otherwise} \end{cases} \tag{A4.2}$$

A.5 Maturity

Maturity is assumed to be a knife-edged function of age at age a_m.

A.6 Initialising the population vector

The numbers at age in the pristine population are given by:

$$\begin{aligned} R_{-\infty,a}^{m/f} &= 0.5\ N_{-\infty,0}\ \alpha_a \prod_{a'=0}^{a-1} S_{a'} && \text{if } 0 \le a < x \\ U_{-\infty,a}^{m/f} &= 0.5\ N_{-\infty,0}\ (1-\alpha_a) \prod_{a'=0}^{a-1} S_{a'} && \text{if } 0 \le a < x \\ R_{-\infty,x}^{m/f} &= 0.5\ N_{-\infty,0} \prod_{a'=0}^{x-1} \frac{S_{a'}}{(1-S_x)} && \text{if } a = x \end{aligned} \tag{A6.1}$$

$R_{-\infty,a}^{m/f}$ is the number of animals of age *a* that would be recruited in the pristine population;

$U_{-\infty,a}^{m/f}$ is the number of animals of age *a* that would be unrecruited in the pristine population; and

$N_{-\infty,0}$ is the total number of animals of age 0 in the pristine population.

The value for $N_{-\infty,0}$ is determined from the value for the pre-exploitation size of the 1+ component of the population using the equation:

$$N_{-\infty,0} = K^{1+} / \left(\sum_{a=1}^{x-1} \left(\prod_{a'=0}^{a-1} S_{a'} \right) + \frac{1}{1-S_x} \prod_{a'=0}^{x-1} S_{a'} \right) \tag{A6.2}$$

In common with the trials for the Eastern North Pacific gray whales (IWC, 2012), these trials are based on the assumption that the age-structure at the start of year τ is stable rather than modelling the population from its pre-exploitation equilibrium size. The determination of the age-structure at the start of year τ involves specifying the effective 'rate of increase', γ, that applies to each age-class. There are two components contributing to γ, one relating to the overall population rate of increase (γ+) and the other to the exploitation rate. Under the assumption of knife-edge recruitment to the fishery at age a_r, only the γ+ component (assumed to be zero following Punt and Butterworth (2002) applies to ages of a_r or less. The number of animals of age *a* at the start of year τ relative to the number of calves at that time, $N_{\tau,0}^*$, is therefore given by the equation:

$$N_{\tau,a}^* = \begin{cases} 1 & \text{if } a = 0 \\ N_{\tau,a-1}^* S_{a-1} & \text{if } 1 \le a \le a_r \\ N_{\tau,a-1}^* S_{a-1} (1-\gamma^+) & \text{if } a_r < a < x \\ N_{\tau,x-1}^* S_{x-1} (1-\gamma^+)/(1-S_x(1-\gamma^+)) & \text{if } a = x \end{cases} \tag{A6.3}$$

B_τ is the number of calves in year τ and is derived directly from equations A2.1 and A2.3 - for further details see Punt (1999):

$$B_\tau = \left(1 - \left[1/(N_\tau^f b_K) - 1\right]/A\right)^{1/z} \frac{K^{1+}}{N_\tau^{1+,*}} \tag{A6.4}$$

The effective rate of increase, γ, is selected so that if the population dynamics model is projected from year τ to a year Ψ, the size of the 1+ component of the population in a reference year Ψ equals a value, P_Ψ which is drawn from a prior (see Table 2).

Table 2

The prior distributions.

Parameter	Prior distribution
Non-calf survival rate, S_{1+}	U[0.90, 0.995]
Age-at-maturity, a_m	U[4, 14]
Transition age from juvenile to adult survival, a_T	0
Carrying capacity, K^{1+}	U[0, 20,000]
$MSYL_{1+}$	Pre-specified
$MSYR_{1+}$	Pre-specified
Maximum pregnancy rate, $1/f_{max}$	U[1.7, 3.3]
Additional variation (population estimates), CV_{add}, in year Ψ (where Ψ = 1987)	U[0, 0.35]
Abundance in year Ψ (=2005), P_Ψ	$\ell nP_{2005} = N(\ell n3,230;(0.44^2 + CV_{add}^2))$

A.7 z and A

A, z and S_0, are obtained by solving the system of equations that relate *MSYL*, *MSYR*, S_0, S_{1+}, f_{max} a_m, a_T, *A* and *z,* where f_{max} is the maximum possible pregnancy rate (Punt, 1999).

A.8 Conditioning

The method for conditioning the trials (i.e. selecting the 100 sets of values for the parameters a_m, a_T, S_0, S_{1+}, K^{1+}, A and z) is based on a Bayesian assessment. The algorithm for conducting the Bayesian assessment is as follows.

(a) Draw values for the parameters S_{1+}, f_{max}, a_m, a_T, $MSYR_{1+}$, $MSYL_{1+}$, K^{1+}, P_Ψ, and CV_{add} (the additional variance for the estimates of 1+ abundance in year Ψ), from the priors in Table 2. It is not necessary to draw values for $MSYR_{1+}$ and $MSYL_{1+}$ because the values for these quantities are pre-specified rather than being determined during the conditioning process.

(b) Solve the system of equations that relate *MSYL*, *MSYR*, S_0, S_{1+}, f_{max}, a_m, a_T, A and z to find values for S_0, A and z.

(c) Calculate the likelihood of the projection which is given by[1]:$L=L_1$ where:

$$L_1 = \prod_t \frac{1}{\sqrt{\Omega_t^2 + CV_{add2,t}^2}} \exp\left(-\frac{(\ell nP_t^{obs} - \ell n\left(B_c\hat{P}_t\right))^2}{2(\Omega_t^2 + CV_{add2,t}^2)}\right) \qquad \text{(A8.1a)}$$

P_t^{obs} is the estimate of the (1+) abundance at the start of year t (Table 3);

$\hat{P}_t$ is the model-estimate of the (1+) abundance which pertains to the survey estimate of abundance at the start of year t:

$$\hat{P}_t = \tilde{S}^f \sum_{a=1}^{x} (R_{t,a}^f + U_{t,a}^f) + \tilde{S}^m \sum_{a=1}^{x} (R_{t,a}^m + U_{t,a}^m) \qquad \text{(A8.2)}$$

Ω_t is the (sampling) standard deviation of the logarithm of P_t^{obs} (approximated by its coefficient of variation, $CV_{est,t}^{obs}$ - see Table 3);

$\tilde{S}^f, \tilde{S}^m$ are the relative selectivities for females and males (1:1 for fin whales); and

$E(CV_{add2,t}^2)$ is the square of the actual CV of the additional variation for year t (using the formula developed under the RMP first stage screening trials for a single stock [IWC (1991), IWC (1994)]):

$$E(CV_{add2,t}^2) = \eta(0.1 + 0.013P^* / \hat{P}_t) = CV_{add2}^2 \frac{0.1 + 0.013P^* / \hat{P}_t}{0.1 + 0.013P^* / \hat{P}_\Psi} \qquad \text{(A8.3)}$$

Steps (a)-(c) are repeated a large number (typically 1,000,000) of times.

100 sets of parameters vectors are selected randomly from those generated using steps (a)-(c), assigning a probability of selecting a particular vector proportional to its likelihood. The number of times steps (a)-(c) are repeated is chosen to ensure that each of the 100 parameter vectors is unique.

The trials for fin whales are conditioned on the estimates of absolute abundance (Table 3) (there is no series of relative abundance estimates).

Table 3

Estimates of absolute abundance

Year	Estimate	CV	Reference
1987	1,100	0.35	IWC (1992); IWC (1993)
2005	9,800	0.62	Heide-Jørgensen *et al.* (2008); IWC (2008)
2007	15,957	0.72	Heide-Jørgensen *et al.* (2010); IWC (2010)
2015	2,215	0.41	Hansen *et al* (2016); Annex Q of this report

[1]The priors for the survey bias and additional variation are integrated out as these are nuisance parameters.

B. Data generation

B.1 Absolute abundance estimates

The historical ($t \leq 2015$) abundance estimates (and their CVs) are provided to the *SLA* and are taken to be those in Table 3. An estimate of abundance together with an estimate of its CV is generated, and is provided to the *SLA,* once every *U* years during the management period (starting in year 2025 for the base case trials i.e. U=10 years beyond the year with the last estimate of abundance [2]). The CV of future abundance estimates (CV_{true}) is different from the CV provided to the *SLA*.

The survey estimate, $\hat{S}$, may be written as:

$$\hat{S} = B_A P Y w / \mu \;=\; B_A P^* \beta^2 Y w \qquad \text{(B1.1)}$$

B_A is the bias;

P is the current 1+ population size ($= \hat{P}_t$); (B1.2)

Y is a lognormal random variable: $Y = e^{\phi}$ where: $\phi \sim N[0; \sigma_\phi^2]$ and $\sigma_\phi^2 = \ell n(1+\alpha^2)$; (B1.3)

w is a Poisson random variable, independent of Y, with $E(w) = \text{var}(w) = \mu = (P / P^*) / \beta^2$; and (B1.4)

P^* is the reference population level (the pristine value of $\hat{P}_t$).

[3]The steps used in the program to generate the abundance estimates and their CVs are listed below.

The *SLA* is provided with estimates of CV_{est} for each future sightings estimate. The estimate of $CV_{est,t}$ is given by:

$$\hat{C}V_{est,t} = \sqrt{\sigma_t^2 (\chi_n^2 / n)} \qquad \sigma_t^2 = \ell n(1 + E(CV_{est,t}^2)) \qquad \text{(B1.5)}$$

$E(CV_{est,t}^2)$ is the sum of the squares of the actual CVs due to estimation error:

$$E(CV_{est,t}^2) = \theta^2 (a^2 + b^2 / w\beta^2) \qquad \text{(B1.6)}$$

χ_n^2 is a random number from a χ^2 distribution with n (=19; the value assumed for the single stock trials for the RMP) degrees of freedom; and

a^2, b^2 are constants and equal to 0.02 and 0.012 respectively.

The relationship between CV_{est} and CV_{true} is given by:

$$\eta = [E(CV_{true}^2) - E(CV_{est}^2)] / (0.1 + 0.013 P^* / P) \qquad \text{(B1.7)}$$

where η is a constant known as the additional variance factor whose value is based on the population size and CVs for year Ψ:

$$\eta = CV_{add}^2 / (0.1 + 0.013 P^* / P_\Psi) \qquad \text{(B1.8)}$$

The values of α and β are then computed as:

$$\alpha^2 = \theta^2 a^2 + \eta \;\; 0.1 , \qquad \beta^2 = \theta^2 b^2 + \eta \;\; 0.013 \qquad \text{(B1.9)}$$

In initial trials, fin whales off West Greenland were modelled as a single isolated population. Following a new point estimate of abundance from a 2015 survey that was significantly smaller than the previous one (2,215 in 2015 compared to 15,957 in 2007) the trials were modified to model the abundance as a two-component process whereby each year either all whales in the population enter the West Greenland region, or only a proportion of those whales. See IWC (2018, p552-3) for further discussion of this '**partial presence**' hypothesis.

The two years 2005 and 2007 (with the highest estimates of abundance) are considered to be instances where all whales entered the West Greenland region and were available to be surveyed. The probability in a future year that this would occur is modelled by a Beta(3;3) distribution, which reflects the posterior resulting from the assumption of a uniform

[2] The next survey is assumed to take place in 2020 for trials with a 5 year survey interval and in 2030 for those with a 15 year survey interval.

[3]The steps used to generate estimates of abundance and their CVs are as follows (steps (i)-(iii) are part of the conditioning process).

(i) Read in CV_{est} (Table 4). Generate values of CV^2_{add} for year Ψ.

(ii) Set η using equation B1.8 and the value of CV_{add} from step (i).

(iii) Set θ^2 using equation B1.6 with the values for CV_{est} from step (i) and $w\beta^2 = P/P^* = P_{1968}/P^*$. Set α^2 and β^2 using equation B1.9.

(iv) Generate w (Poisson random variable – equation B1.4) and ϕ (lognormal random variable – equation B1.3).

(v) Set abundance estimate $\hat{S}$ using equation B1.1.

(vi) Generate $\hat{C}V_{est,t}$ from a χ_n^2 distribution using equation B1.5.

prior over [0; 1], updated by data indicating that this had occurred in two out of four instances. In years for which only a proportion of the whales enter the region, that proportion is to be modelled by a Beta(2;8) distribution, which implies a proportion of 20% on average, and allows the operating model to mimic the available abundance estimates. Further details are given in Adjunct 2.

High CVs are associated with the high abundance estimates and vice versa – perhaps because of the higher school sizes observed when there are more whales. Hence two different values of the CVest (the expectation value of CVX) are used: 0.38 in years when the abundance is low and 0.67 in high abundance years.

An alternative '**influx**' hypothesis is also modelled where only a total WG-associated stock is present for the years with low abundance estimates, and the years with high estimates reflect mixing from adjacent stocks (the 'extra' stock). Details of the changes to the operating model required for this hypothesis are given in Adjunct 3.

C. Need

The level of need supplied to the *SLA* is the total need for the six-year period for which strike limits are to be set. The scenarios regarding need are listed in Table 4.

D. Trials

Table 4 lists all of the factors considered in the trials. The set of *Evaluation Trials* is given in Table 5 and the set of *Robustness Trials* in Table 6. See Adjunct 1 for the equations used in the Asymmetric environmental stochasticity trials. The *SLA* is applied every six years, starting in 2016.

Table 4

Factors to be tested in the trials for fin whales off West Greenland

Factors	Levels (Reference levels shown bold and underlined)
$MSYR_{1+}$	1%, **<u>2.5%</u>**, **<u>4%,</u>** 7%
$MSYL_{1+}$	**<u>0.6</u>**
Time dependence in K *	**<u>Constant</u>**, halve linearly over 100yr
Time dependence in natural mortality, M *	**<u>Constant,</u>** double linearly over 100yr
Episodic events *	**<u>None</u>**,
	3 events occur between yrs 1-75 (with at least 2 in yrs 1-50) in which 20% of the animals die,
	Events occur every 5 years in which 5% of the animals die
Population Drop	**<u>None</u>**,
	50% in 2016, 80% in 2016;
	50% in 2051; 80% in 2051
Need envelope	A: constant 19;
	B: 19 to 38 over 100 years;
	C: 19 to 57 over 100 years
Survey frequency	5 yr, **<u>10 yr</u>**, 15 yr
Historical survey bias	0.8, **<u>1.0</u>**, 1.2
First year of projection, τ	**<u>1950</u>**
Strategic surveys	Extra survey if a survey estimate is half of the previous survey estimate
Asymmetric environmental stochasticity parameters[$]	$\rho = 0.320$
Depletion (as used for env. stochasticity trials)[$]	Depletion = 0.3
Abundance hypothesis	**<u>Partial Presence *p* = 0.5; proportion generated from beta (2,8)</u>**
	Partial Presence alternative parameters: $p = 0.189$; $p = 0.811$
	proportion generated from beta (1,9)
	Influx hypothesis with upper bound on the uniform prior for K = 6,000 or 9,000
Future Survey CV (CV_{est}). Values are given for Low abundance / High abundance years	0.20 / 0.50, 0.33 / 0.62, **<u>0.38 / 0.67,</u>** 0.43 / 0.72

* Effects of these factors begin in year 2016 (i.e. at start of management). The adult survival rate is adjusted so that if catches were zero, then the average population size during years 250-500 equals the carrying capacity. (Note: for some biological parameters and levers of episodic events, it may not be possible to find an adult survival rate which satisfies this requirement).

[$] Details of the asymmetric environmental stochasticity model and the parameters used are given in Adjunct 1.

Table 5

The *Evaluation Trials* for fin whales. Values given in bold type show differences from the base case values. For all 'Partial Presence' (PP) trials, the probability *p* that all animals are off West Greenland when a survey takes place = 0.5; if some whales are not off W. Greenland, the proportion off W. Greenland is generated from a beta distribution with parameters (2,8).

Trial	Description	$MSYR_{1+}$	Need Scenarios	Survey freq.	Historical Survey Bias	No of Replicates	Future Survey CV (CV_{est})	Abundance Model	Conditioning Option
1-4	$MSYR_{1+}$ = 4%	4%	A, B, C	10	1	400	0.38 / 0.67	PP	Y
1-2	$MSYR_{1+}$ = 2.5%	2.5%	A, B, C	10	1	400	0.38 / 0.67	PP	Y
1-1	$MSYR_{1+}$ = 1%	**1%**	A, B, C	10	1	400	0.38 / 0.67	PP	Y
1-7	$MSYR_{1+}$ = 7%	**7%**	A, B, C	10	1	400	0.38 / 0.67	PP	Y
2-4	5 year surveys	4%	A, B	**5**	1	400	0.38 / 0.67	PP	1-4
2-2	5 year surveys; $MSYR_{1+}$ =2.5%	2.5%	A, B, C	**5**	1	400	0.38 / 0.67	PP	1-2
3-4	15 year surveys	4%	A, B	**15**	1	400	0.38 / 0.67	PP	1-4
3-2	15 year surveys; $MSYR_{1+}$ =2.5%	2.5%	A, B, C	**15**	1	400	0.38 / 0.67	PP	1-2
3-1	15 year surveys; $MSYR_{1+}$ =1%	**1%**	A, B, C	**15**	1	400	0.38 / 0.67	PP	1-1
4-4	Survey bias = 0.8	4%	A, B	10	**0.8**	400	0.38 / 0.67	PP	Y
4-2	Survey bias = 0.8; $MSYR_{1+}$ =2.5%	2.5%	A, B	10	**0.8**	400	0.38 / 0.67	PP	Y
5-4	Survey bias = 1.2	4%	A, B	10	**1.2**	400	0.38 / 0.67	PP	Y
5-2	Survey bias = 1.2; $MSYR_{1+}$ =2.5%	2.5%	A, B	10	**1.2**	400	0.38 / 0.67	PP	Y
6-4	3 episodic events (20% reduction)	4%	A, B	10	1	400	0.38 / 0.67	PP	1-4
6-2	3 episodic events (20%); $MSYR_{1+}$ =2.5%	2.5%	A, B, C	10	1	400	0.38 / 0.67	PP	1-2
6-1	3 episodic events (20%); $MSYR_{1+}$ =1%	**1%**	A, B, C	10	1	400	0.38 / 0.67	PP	1-1
7-4	Stochastic events (5%) every 5 years	4%	A, B	10	1	**100**	0.38 / 0.67	PP	1-4
7-2	Stochastic events (5%) every 5 years	2.5%	A,B	10	1	**100**	0.38 / 0.67	PP	1-2
8-4	Asymmetric environmental stochasticity	4%	A, B	10	1	**100**	0.38 / 0.67	PP	Y
8-2	Asymmetric environmental stochasticity	2.5%	A, B, C	10	1	**100**	0.38 / 0.67	PP	Y
8-1	Asymmetric environmental stochasticity	**1%**	A, B, C	10	1	**100**	0.38 / 0.67	PP	Y
9-2	$MSYR_{1+}$ =2.5%; future survey CV 0.33/0.62	2.5%	A, B, C	10	1	400	**0.33 / 0.62**	PP	1-2
10-2	$MSYR_{1+}$ =2.5%; future survey CV 0.43/0.72	2.5%	A, B, C	10	1	400	**0.43 / 0.72**	PP	1-2
34-1	Influx-hypothesis; K prior of U[0,6000]	1%	A,B,C	100	1	400	0.38 / 0.67	Influx	Y
35-2	Influx-hypothesis; K prior of U[0,6000]	2.5%	A,B,C	100	1	400	0.38 / 0.67	Influx	Y
36-2	Influx-hypothesis; K prior of U[0,9000]	2.5%	A,B,C	100	1	400	0.38 / 0.67	Influx	Y

Table 6

The *Robustness Trials* for fin whales (On review, trials 24-2 and 24-4 were deleted as low plausibility). All *Robustness Trials* use the 'Partial Presence' hypothesis for survey abundance.

Trial No.	Factor	$MSYR_{1+}$	Need Scenario	No of Rep	Future Survey CV	Conditioning opt.
21-4	Linear decrease in *K* in future	4%	A, B	100	0.38 / 0.67	1-4
21-2	Linear decrease in *K* in future	2.5%	A, B	100	0.38 / 0.67	1-2
22-4	Linear increase in *M* in future	4%	A, B	100	0.38 / 0.67	1-4
22-2	Linear increase in *M* in future	2.5%	A, B	100	0.38 / 0.67	1-2
23-4	Strategic Surveys	4%	A, B	100	0.38 / 0.67	1-4
23-2	Strategic Surveys	2.5%	A, B	100	0.38 / 0.67	1-2
~~24-4~~	~~*p*=0.5; Propn generated from beta (7,3)~~	~~4%~~	~~A, B~~	~~100~~	~~0.40~~	~~Y~~
~~24-2~~	~~*p*=0.5; Propn generated from beta (7,3)~~	~~2.5%~~	~~A, B~~	~~100~~	~~0.40~~	~~Y~~
25-4	*p*=0.5; Propn generated from beta (1,9)	4%	A, B	100	0.38 / 0.67	Y
25-2	*p*=0.5; Propn generated from beta (1,9)	2.5%	A, B	100	0.38 / 0.67	Y
26-4	*p*=0.189 Propn generated from beta (2,8)	4%	A, B	100	0.38 / 0.67	Y
26-2	*p* =0.189 Propn generated from beta (2,8)	2.5%	A, B	100	0.38 / 0.67	Y
27-4	*p* =0.811 Propn generated from beta (2,8)	4%	A, B	100	0.38 / 0.67	Y
27-2	*p* =0.811 Propn generated from beta (2,8)	2.5%	A, B	100	0.38 / 0.67	Y
28-2	Baseline with future survey CV 0.2/0.50	2.5%	A, B	100	**0.20 / 0.50**	1-2
29-2	*p*=0.5; beta (1,9); future survey CV 0.2/0.50	2.5%	A, B	100	**0.20 / 0.50**	25-2
30-2	Population drop of 50% in 2016	2.5%	A, B	100	0.38 / 0.67	1-2
31-2	Population drop of 80% in 2016	2.5%	A, B	100	0.38 / 0.67	1-2
32-2	Population drop of 50% in 2051 (year 35)	2.5%	A, B	100	0.38 / 0.67	1-2
33-2	Population drop of 80% in 2051 (year 35)	2.5%	A, B	100	0.38 / 0.67	1-2

E. Statistics

The risk- and recovery-related performance statistics are computed 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*≥2016 (defined as *t*=0 below). Note that incidental removals may still occur in the absence of strikes. To emphasise this distinction, $P_t^*(0)$ is used to denote the population size in year *t* under a scenario of zero strikes or removals of any kind, and $P_t^*(\text{inc}) = P_t^*$ 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): $\sum_{b=0}^{T^*-1}\left|C_{b+1}-C_b\right| / \sum_{b=0}^{T^*-1} C_b$.

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): $\sum_{b=0}^{T^*-1}\left|\min(C_{b+1} - C_b, 0)\right| \ / \ \sum_{b=0}^{T^*-1} C_b$

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 Environmentally-Driven Stochasticity Model

A. Basic principles

The number of calves born annually is modelled as:

$$C_y = f_y N_y^{mat} \qquad \text{(Adj.1.1)}$$

where f_y is the fecundity during year y, and N_y^{mat} is the number of mature females at the start of year y; f_y is assumed to be density-dependent:

$$f_y = f_0(1 + A(1-(N_y^{1+}/K^+)^z)) \qquad \text{or}$$
$$f_y = f_0 + (f_{\max} - f_0)(1-(N_y^{1+}/K^+)^z) \qquad \text{(Adj.1.2)}$$

To incorporate stochasticity, f_y is modelled as follows:

$$f_y^{act} = \frac{f_{\max} f_0 e^{x_y}}{f_0 e^{x_y} + (f_{\max} - f_0)} \quad \text{with} \quad x_y = \log\left[\frac{\hat{f}_y (f_{\max} - f_0)}{(f_{\max} - \hat{f}_y) f_0}\right] + \alpha_y \qquad \text{(Adj.1.3)}$$

where $\hat{f}_y$ is the 'expected' value of f_y from equation App.1.1, and α_y accounts for auto-correlated noise. At the maximum value of f ($f_{\max}$), $\mathrm{var}(f_y) = 0$, and $\mathrm{var}(f_y)$ increases with decreasing f_y. The noise term α_y is modelled as:

$$\alpha_y = \rho_\alpha \alpha_{y-1} + \sqrt{1+\rho_\alpha^2}\,\eta_y \qquad \eta_y \sim N(0;\sigma_\alpha^2) \qquad \text{(Adj.1.4)}$$

where σ_α and ρ_α determine the extent of the variation and its auto-correlation respectively.

B. Parameterisation

The values for σ_α and ρ_α for West Greenland fin whales, humpbacks and bowheads are based on the realised variation and temporal autocorrelation of calving rates for the Eastern North Pacific humpback whales and the Bering-Chuckhi-Beaufort Seas stock of bowhead whales (Fig. App.1.1, left panel). The value for σ_α is computed for each stock by projecting equations App.1.1-App.1.4 forwards with values with $f_{\max}$ and f_0 set to the posterior medians from the conditioning process, and solving for ρ_α so that the resulting value for $\tilde{\sigma}_f$ allows the population model to match the CV of the calving rates (see Fig. App.1.1, right panel).

Application of this approach involves setting N_y^{1+}/K^{1+} in equation App.1.2 (see Fig. App.1.2 for the sensitivity of variation in calving rates to the value of N_y^{1+}/K^{1+}). The base value for N_y^{1+}/K^{1+} is set to 0.3. Sensitivity is examined to values of 0.15 and 0.6 (half and double the base value) in *Robustness Trials* for humpbacks and bowheads.

The base value reflects the fact that the stocks selected by IWC (2014), which included the Eastern North Pacific humpback whales and the Bering-Chuckhi-Beaufort Seas stock of bowhead whales, were assessed to have been mainly at a low level of abundance (no more than approximately 30% of carrying capacity) over the period that the data analysed had been collected. The data for the B-C-B bowheads are too sparse to allow the extent of correlation in calving rates to be estimated reliability. The values of ρ_α for the two stocks are consequently set to the extent of autocorrelation in fecundity estimated by IWC (2014) for humpback whales.

C. Adjusting MSYR

It is well-known (Clark, 1993) that for the same parameter values MSY under stochastic conditions is less than under deterministic conditions. The aim of the trials with environmentally-driven stochasticity is to evaluate the consequences of environmental variation on fecundity without the confounding effect of a lower effective MSYR. Therefore, the input value of $MSYR_{1+}$ is adjusted for the trials with environmentally-driven stochasticity by projecting the operating model forward 100 times for 1000 years when the exploitation rate is $MSYR_{1+}$, and comparing the realised $MSYR_{1+}$ with the intended MSYR. The $MSYR_{1+}$ value input is then rescaled so that the realised $MSYR_{1+}$ equals the intended $MSYR_{1+}$. This means that each trial needs to be conducted twice, once to obtain the scaling factor for $MSYR_{1+}$ and the parameters needed to compute σ_α (see Section B above), and again once $MSYR_{1+}$ has been adjusted. The results of the second conditioning are then used to evaluate *SLA* variants.

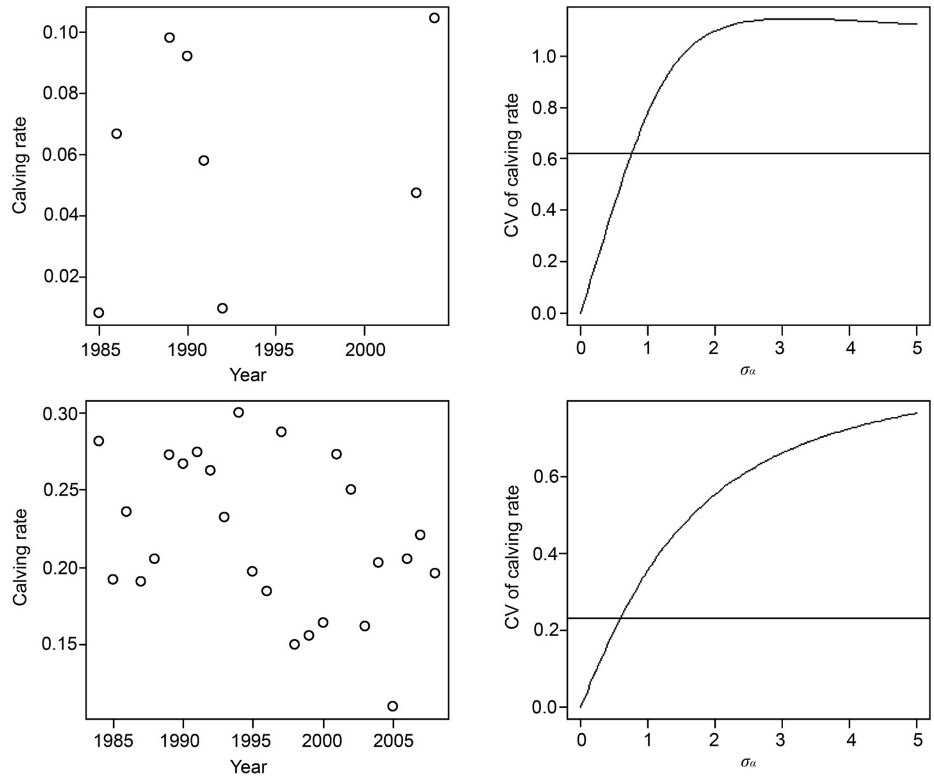

Fig. App.1.1. Calving rates (left panels) and the inferred relationships between the CV of the calving rate and σ_α based on equations App.1.1-App.1.4 (right panels). The horizontal line in the right panels indicates the observed CVs of the calving rates. Results are shown for the Eastern North Pacific humpback whales and the Bering-Chuckhi-Beaufort Seas stock of bowhead whales in the upper and lower sets of panels. The calving rates for the Eastern North Pacific humpback whales are restricted to the years in which the population size was at least 30 animals to avoid the impact of observation error being interpreted as true variation in calving rates.

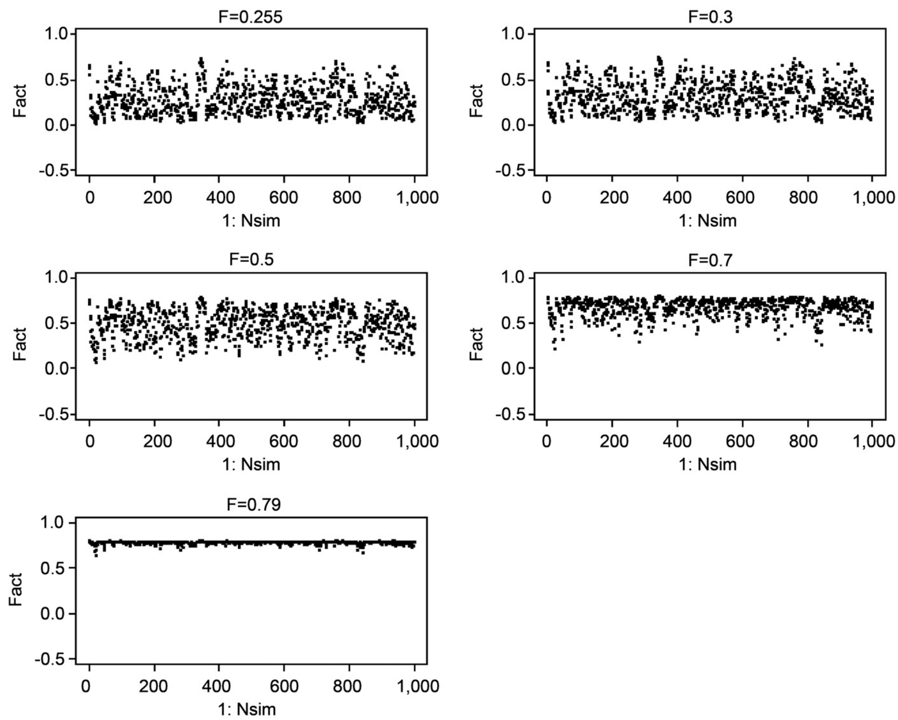

Fig. App.1.2. Time-trajectories of fecundity for σ_α=1 and ρ_α=0.707 for different levels of exploitation rate F (which correspond to different levels of depletion of the 1+ component of the population)

References

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Adjunct 2. Accounting for a Time-Varying Proportion of Fin Whales off West Greenland – A.E. Punt

The proposed working model for West Greenland fin whales is that there is a probability *p* that all of the animals in the "stock" exploited off West Greenland are off West Greenland when a survey takes place (and hence there is a probability of 1-*p* that at least some of the animals are not off West Greenland). When some of the whales are not off West Greenland, the proportion off West Greenland, β, is generated from a beta distribution with parameters (3,7).

Conditioning of the operating model involves constructing a posterior distribution for the parameters given the available data. The likelihood function for the analysis consists of two components: (a) the estimates of abundance for 2005 and 2007, which are assumed to be estimates of absolute abundance, and (b) the estimates of abundance for 1987 and 2015, which are assumed to be subject to bias owing to the proportion β. The likelihood for the estimates of abundance for 1987 and 2015 marginalize over the distribution for β under the assumption that β for each year is treated as a random effect, i.e.:

$$L_y \propto \int_{\alpha}^{1} \frac{1}{\sqrt{2\pi}\sigma_y I_y} e^{-(\ell n I_y - \ell n(\beta N_y))^2/(2\sigma_y^2)} \beta^2 (1-\beta)^6 \, d\beta \qquad \text{(D.1)}$$

where L_y is the likelihood for the i[th] abundance estimate, I_y is the estimate of abundance for year *y*, N_y is the total (1+) number of animals in year *y*, and σ_y is the standard error of the log of I_y.

Data generation for each future year *y* will be based on first generating a value from U[0,1]. If this value is less than *p*, the bias, β, is assumed to be equal 1 otherwise β is generated from Beta(2,8).

Adjunct 3. Summary of Changes to the Control Program to Implement the 'Influx' Hypothesis – A.E. Punt

- Conditioning is based on the 1987 and 2015 estimates only. The 2005 and 2007 estimates are ignored – there are consequently no 'biased' estimates.
- The abundance of the 'extra stock' is 3,000 animals, with a probability of being off West Greenland of 0.5. The abundance of the 'extra stock' is 1,500 for the purposes of conditioning (but the abundance estimates pertain only to WG stock).
- The catches are allocated to WG stock in the proportion to the number of 1+ WG animals to the total number of animals (WG and Extra) off West Greenland.
- The factor used to determine the Poisson component of the process for generating future abundance estimates is carrying capacity for the WG stock plus half of the size of the 'extra stock'.
- The Prior for carrying capacity for the WG stock is U[0, 5,000]

Appendix 3

WEST GREENLAND FIN WHALE *SLA* PERFORMANCE STATISTICS

Table 1 is a summary of results over all trials for the combined *SLA* for fin whales ('GUP') compared to the Interim *SLA* and two *SLA*s tuned to a D10 of 0.8 for the Influx trial F34-1B (B-0.8 and L-0.8). Figures 1-5 give examples of the plots examined when selecting the *SLA*. The full set of trial results and plots are available from the Secretariat.

Table 1

Proportion of times that each *SLA* meets the conservation performance and need satisfaction (over 20 and 100 years) criteria for various subsets of the 68 evaluation trials for West Greenland fin whales, the minimum lower 5 percentile of the conservation performance and the mean of the lowert5thtpercentile need satisfaction (over 20 and 100 years) and of the conservation performance.

(a) Results by MSY rate

	Interim	B-0.8	L-0.8	GUP
MSYR1+ = 1% (15 trials)				
Conservation performance (D10)	0.8	0.8	0.8	0.8
Mean conservation performance (D10)	1.17	1.16	1.17	1.17
Minimum D10 value	0.62	0.57	0.62	0.59
Mean Need satisfaction 20 yrs	0.8	0.88	0.86	0.86
Mean Need satisfaction 100 yrs	0.74	0.78	0.63	0.68
Proportion Need satisfaction 20 yrs	0.8	1	0.8	1
Proportion Need satisfaction 100 yrs	0.47	0.67	0.13	0.27
MSYR1+=2.5% (33 trials)				
Conservation performance (D10)	0.97	0.97	0.97	0.97
Mean conservation performance (D10)	1.17	1.16	1.17	1.17
Minimum D10 value	0.97	0.96	0.96	0.95
Mean Need satisfaction 20 yrs	0.85	0.92	0.87	0.88
Mean Need satisfaction 100 yrs	0.84	0.89	0.81	0.83
Proportion Need satisfaction 20 yrs	1	1	0.97	1
Proportion Need satisfaction 100 yrs	0.97	0.97	0.76	0.82
MSYR1+=4% (17 trials)				
Conservation performance (D10)	1	1	1	1
Mean conservation performance (D10)	1.08	1.07	1.08	1.08
Minimum D10 value	1.02	1.02	1.02	1.02
Mean Need satisfaction 20 yrs	0.92	0.98	0.93	0.94
Mean Need satisfaction 100 yrs	0.88	0.94	0.87	0.89
Proportion Need satisfaction 20 yrs	1	1	1	1
Proportion Need satisfaction 100 yrs	1	1	1	1
MSYR1+ = 7% (3 trials)				
Conservation performance (D10)	1	0.67	1	1
Mean conservation performance (D10)	1	1	1	1
Minimum D10 value	1	0.99	1	1
Mean Need satisfaction 20 yrs	0.94	0.99	0.94	0.94
Mean Need satisfaction 100 yrs	0.81	0.86	0.72	0.76
Proportion Need satisfaction 20 yrs	1	1	1	1
Proportion Need satisfaction 100 yrs	0.67	1	0.33	0.67

(b) Results by need envelope

	Interim	B-0.8	L-0.8	GUP
Need Scenario A (26 trials)				
Conservation performance (D10)	0.96	0.96	0.96	0.96
Mean conservation performance (D10)	1.15	1.15	1.15	1.15
Minimum D10 value	0.93	0.93	0.92	0.93
Mean Need satisfaction 20 yrs	0.88	0.95	0.91	0.92
Mean Need satisfaction 100 yrs	0.88	0.93	0.87	0.89
Proportion Need satisfaction 20 yrs	1	1	0.96	1
Proportion Need satisfaction 100 yrs	1	1	0.89	0.96
Need Scenario B (26 trials)				
Conservation performance (D10)	0.96	0.96	0.96	0.96
Mean conservation performance (D10)	1.13	1.13	1.13	1.13
Minimum D10 value	0.8	0.8	0.8	0.8
Mean Need satisfaction 20 yrs	0.86	0.93	0.88	0.89
Mean Need satisfaction 100 yrs	0.82	0.88	0.77	0.8
Proportion Need satisfaction 20 yrs	0.96	1	0.96	1
Proportion Need satisfaction 100 yrs	0.89	0.96	0.77	0.81
Need Scenario C (16 trials)				
Conservation performance (D10)	0.88	0.81	0.88	0.88
Mean conservation performance (D10)	1.12	1.12	1.13	1.12
Minimum D10 value	0.62	0.57	0.62	0.59
Mean Need satisfaction 20 yrs	0.83	0.89	0.85	0.86
Mean Need satisfaction 100 yrs	0.75	0.79	0.65	0.7
Proportion Need satisfaction 20 yrs	0.88	1	0.88	1
Proportion Need satisfaction 100 yrs	0.56	0.69	0.13	0.25

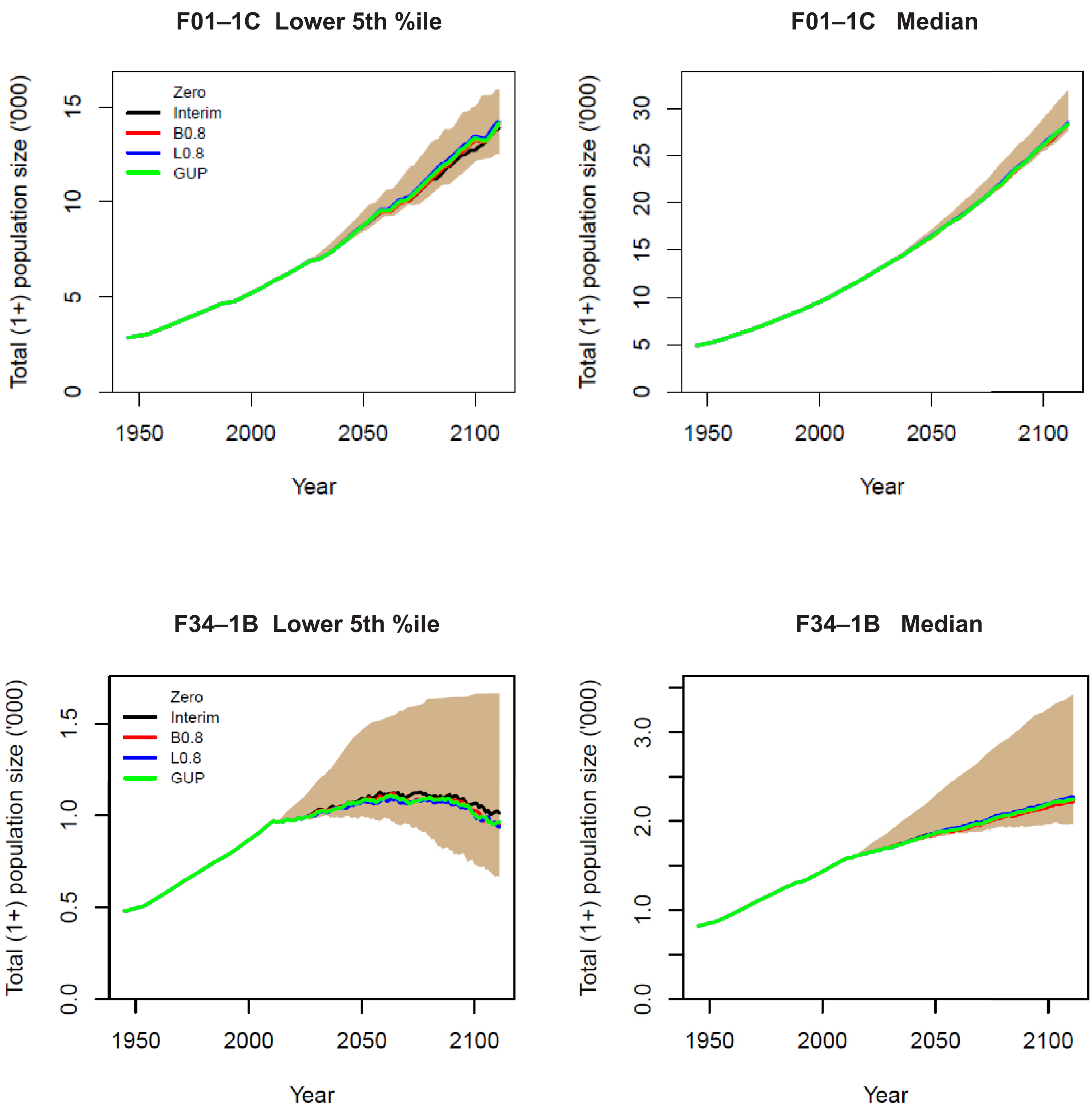


Fig. 1. Examples of the 5th percentile and the median total (1+) population size plots for the combined *SLA* ('GUP') compared to the Interim SLA and the B-0.8 and L-0.8 *SLA*s.

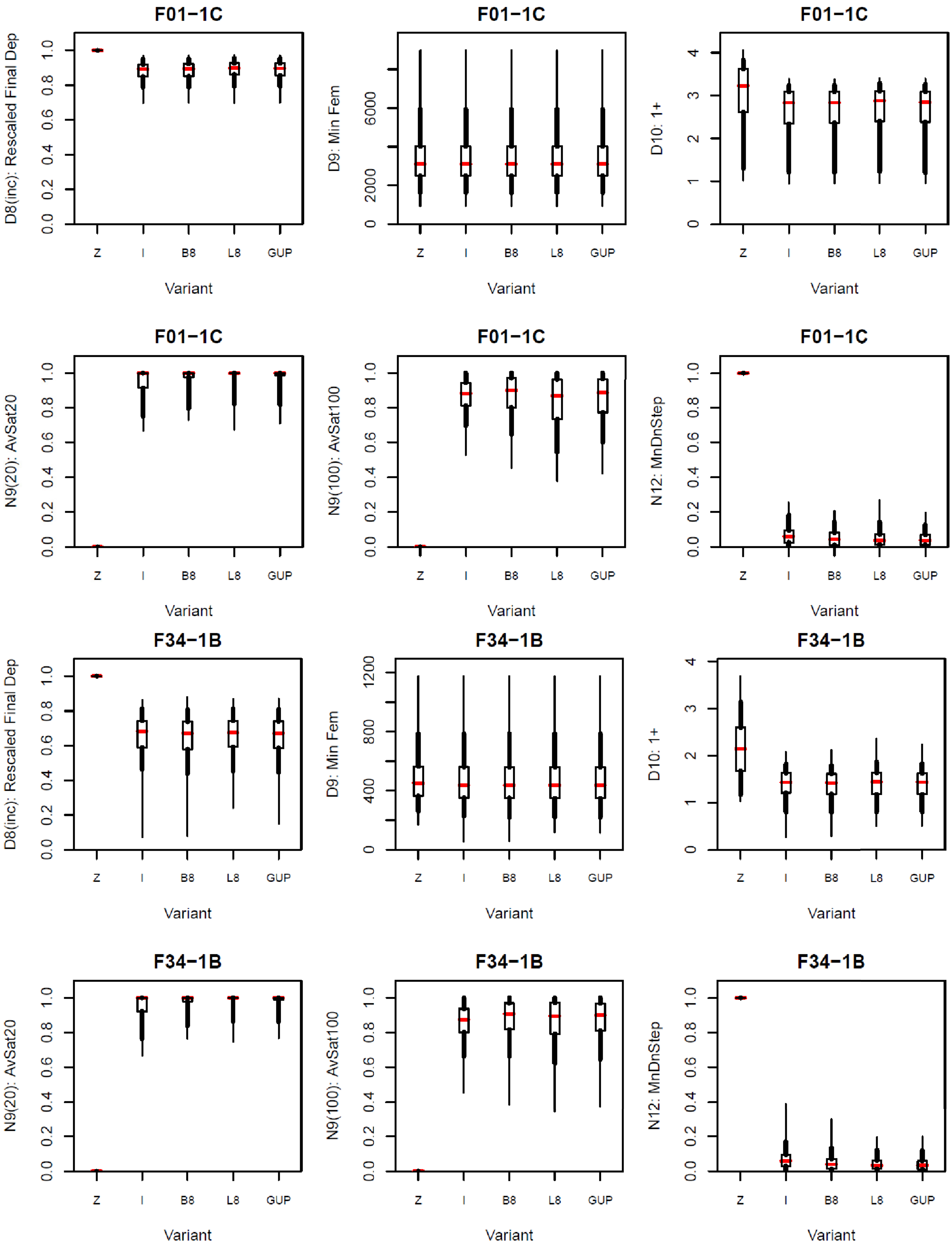


Fig. 2. Examples of the Zeh plots for several performance statistics for the combined *SLA* ('GUP') compared to the Interim *SLA* and the B-0.8 and L-0.8 *SLA*s.

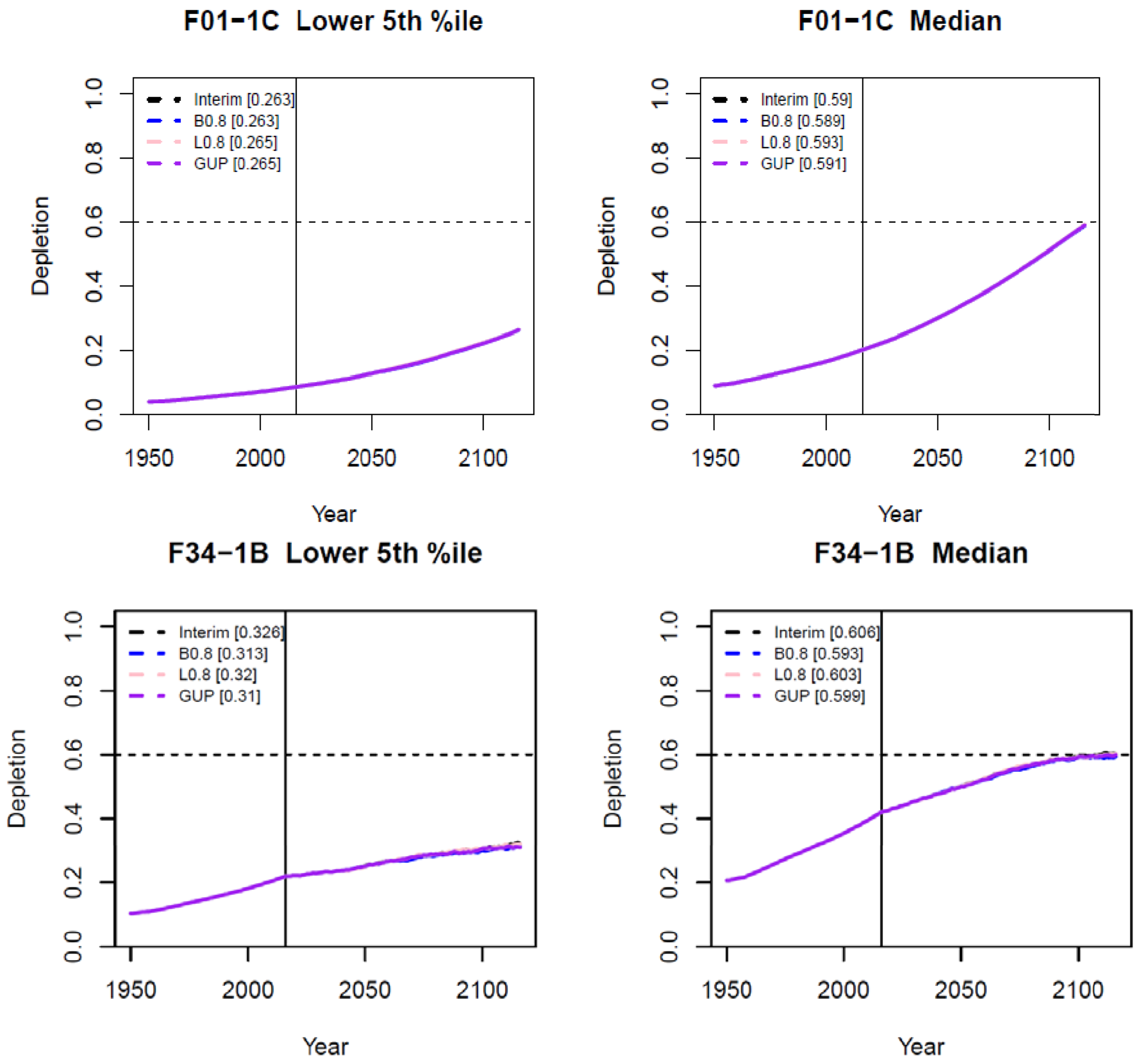


Fig. 3. Examples of plots of the 5th percentile and the median depletion for the combined *SLA* ('GUP') compared to the Interim *SLA* and the B-0.8 and L-0.8 *SLA*s. The numbers in square brackets in the legend are the 5th percentile (LHS) and the median (RHS) final depletion values.

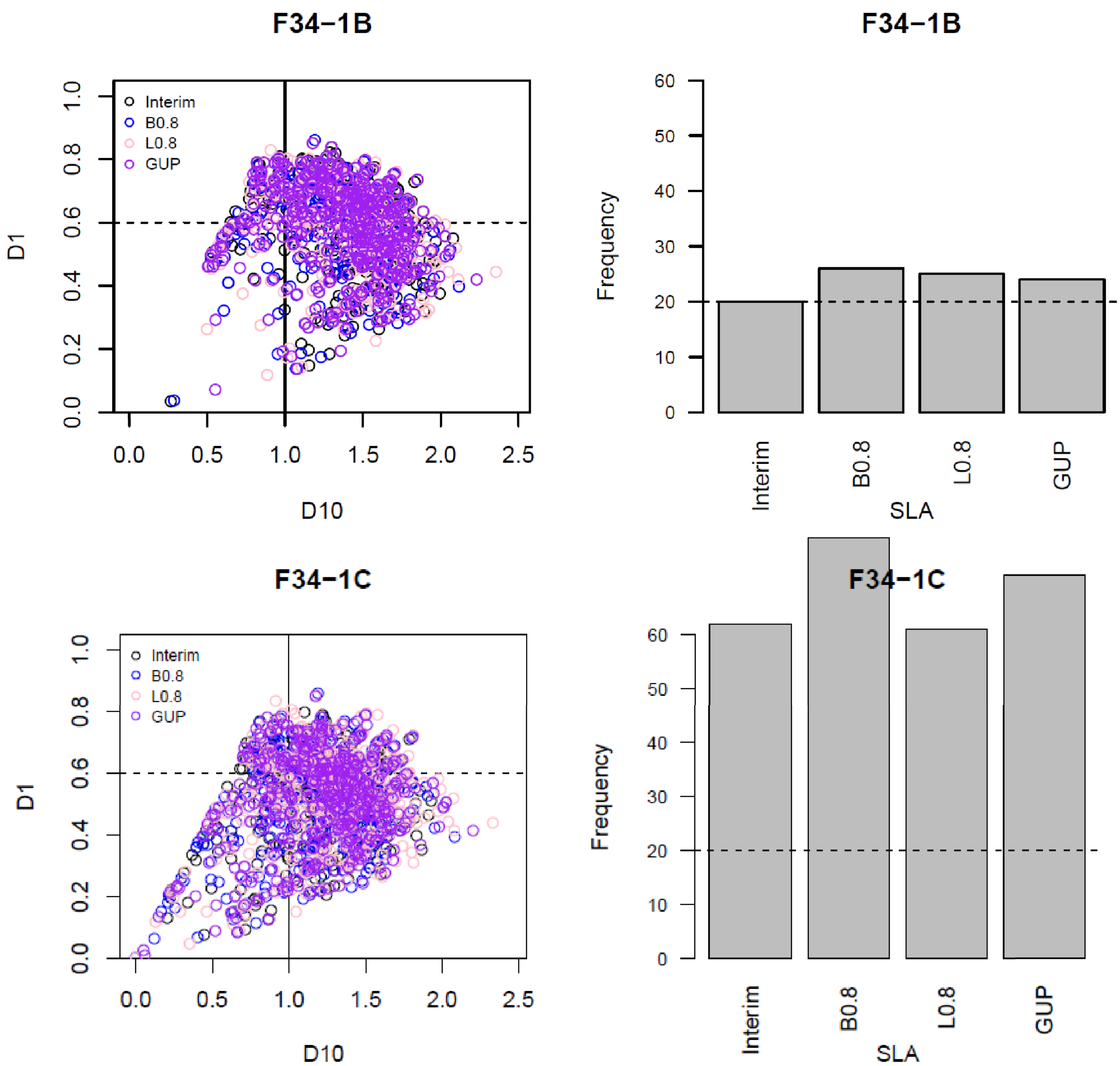


Fig. 4. Example plots of the D1 (final depletion) versus the D10 (relative increase of the 1+ population size) statistics, for each simulation for one of the influx hypothesis trials including the Interim *SLA* together with the frequency of each *SLA* falling within the quadrant of D1 less than 0.6 and D10 less than one. Note that there are 400 replicates for each trial so a "5% criteria" would correspond to more than 5% of replicates having D1 < 0.6 and D10 < 1 simultaneously.

Appendix 4

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

The operating model for trials used in the development of an *SLA* 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; IWC2004a p.12-13, IWC 2009 p.138.

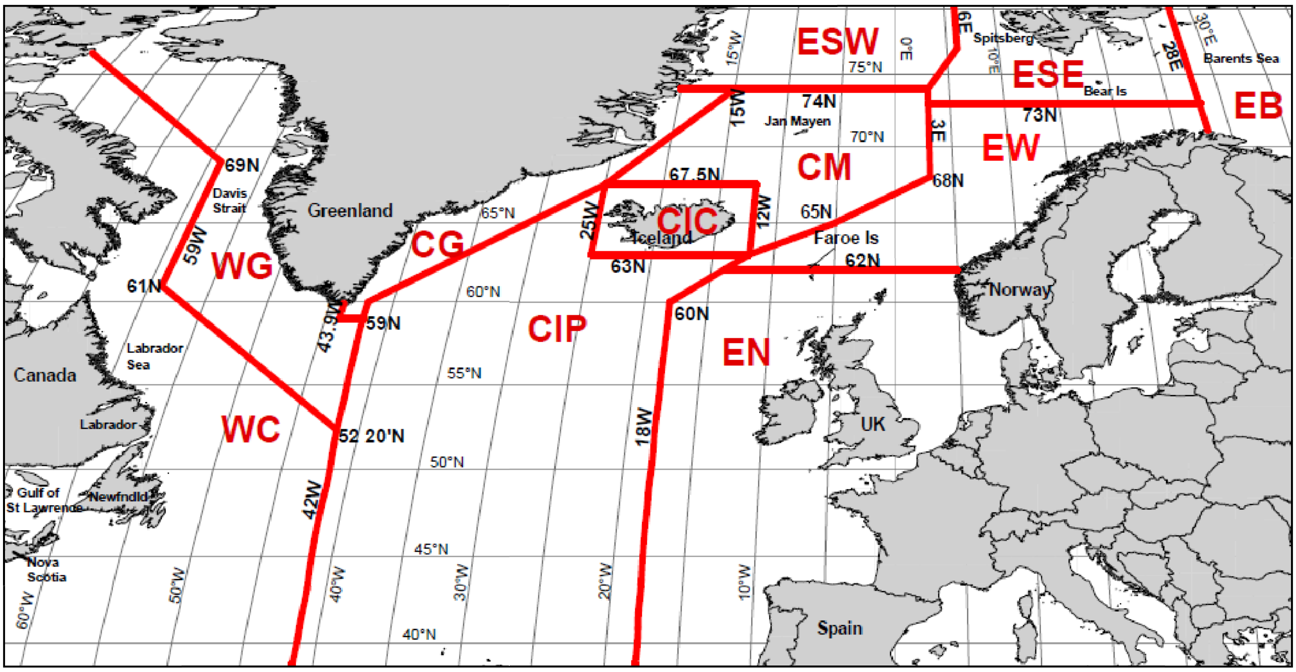


Fig. 1. Map of the North Atlantic showing the sub-areas defined for the North Atlantic Minke whales.

There are two general hypotheses regarding stock structure (see IWC [2015][1] for the rationale for these hypotheses):

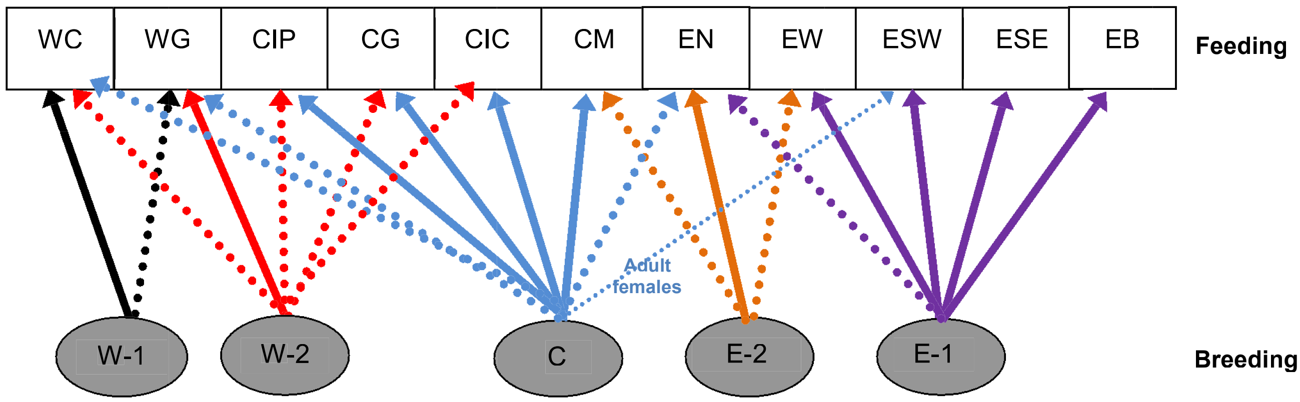
(I) *Three stocks*. There are three stocks 'W', 'C', and 'E'. The 'W' stock consists of two sub-stocks ('W-1' and 'W-2') and the 'E' stock consists of two sub-stocks ('E-1' and 'E-2').

(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 the catch sex-ratios between the primary catching season (i.e. before July) and the time when surveys are conducted (July onwards) (see details in Section G).

[1] Hypotheses III and IV tested in the RMP *Implementation Review* were dropped from further consideration because the results of the genetic analyses (SC/67b/Rep06 item 3.2.) indicate that these stock structure hypotheses are not consistent with the available information.

Hypothesis (I). Base case: 3 breeding stocks, two with two sub-stocks.



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

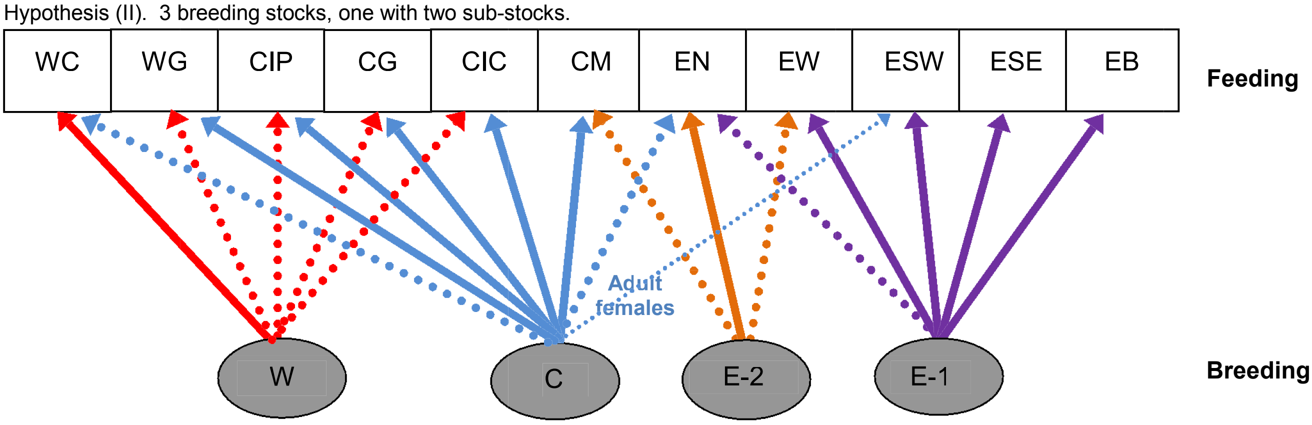


Fig. 1. Stock structure hypotheses for North Atlantic Minke whales [The ranges of the W and C stocks are updated from the model used in the RMP *Implementation Review* based on results of genetic analyses (SC/67b/Rep06, item 3.2)]

B. Basic dynamics

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

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

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

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

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

$\tilde{S}_a$ 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.

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

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;

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

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

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

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

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

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

D. Catches

The historical (pre-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 ratio shown in different hunts: the recent aboriginal hunt in this area compared to that in the earlier commercial catches. All other sub-areas have just one hunt type and thus a single fishing selectivity per sub-area. Details of the catch mixing matrices and how the parameters are set up 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 the hunt h (within sub-area k) which is based on the reference selectivity $R_a^{g,h}$ (see Equation G.5):

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

The maximum exploitation rate for future removals from the WG sub-area (catch as a proportion of the no. of 1+) is set equal to two times the maximum historical aboriginal exploitation rate achieved by aboriginal hunters (see IWC, 2018c p.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.

Table 1

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

Stock structure hypothesis I

	WC	WG	CIP	CG	CIC	CM	EN	EW	ESW	ESE	EB
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

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

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

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

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 subarea. 'Adjusted' CVs equal the square root of the difference between the CV^2 of the abundance estimates for that subarea and the corresponding median of the sampling error CV^2s. (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.

Density Dependent mixing

Operating model variants that allow for density-dependent mixing were also developed and are specified in IWC, 2018b. These specifications assume that the extent of density-dependence in dispersal between two stocks depends on the ratio of the depletions of the two stocks. This is equivalent to whales 'seeking' to make depletion constant among the W-1 sub-stock, the W-2 sub-stock and the C stock (for stock structure hypothesis II).

F. Generation of Data

The actual historical estimates of absolute abundance (and their associated CVs) provided to the RMP 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 for setting the catch limit in 2017. The future estimates of abundance for a survey area (a sub-area for these trials) (say survey area K) are generated using the formula (IWC, 1991)

$$\hat{P} = P\,Y\,w/\mu = P^*\,\beta^2\,Y\,w \tag{F.1}$$

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

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:

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

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 being surveyed; and

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

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

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

[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.

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

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

Note therefore that:

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

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

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

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

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

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

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

Table 3.

The estimates of abundance and their sampling standard errors

Year	Sub-Area	Abundance	CV	Year	Sub-Area	Abundance	CV
2007	WC	20,741	0.3	1989	EN	8318	0.25
1987	WG*	3,266	0.31	1995	EN	22536	0.23
1993	WG*	8,371	0.43	1998	EN	13673	0.25
2005	WG	10,792	0.59	2004	EN	6246	0.47
2007	WG	9,066	0.39	2009	EN	6891	0.31
2015	WG	5,095	0.46	1989	EW	20991	0.17
1988	CIP	8,431	0.245	1995	EW	34986	0.12
2001	CIP	3,391	0.82	1996	EW	23522	0.13
2007	CIP	1,350	0.38	2006	EW	27152	0.218
2015	CIP	6,306	0.345	2011	EW	21218	0.32
1995	CIP+CG*	4,854	0.27	1995	ESW	2691	0.29
1987	CG	1,555	0.26	1999	ESW	1932	0.68
2001	CG	7,349	0.31	2008	ESW	5009	0.29
2007	CG	1,048	0.6	1989	ESE	13370	0.19
2015	CG	5,489	0.35	1995	ESE	23278	0.11
1987	CIC	24532	0.32	1999	ESE	16241	0.25
2001	CIC	43633	0.19	2003	ESE	19377	0.33
2007	CIC	20834	0.35	2008	ESE	22281	0.18
2009	CIC	9588	0.24	1989	EB	21868	0.21
2015	CIC	12710	0.53	1995	EB	29712	0.18
1988	CM	4732	0.23	2000	EB	25885	0.24
1995	CM	12043	0.28	2007	EB	28625	0.23
1997	CM	26718	0.14	2013	EB	34125	0.34
2005	CM	26739	0.39				
2010	CM	10991	0.36				

*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*).

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 SC 2016 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, 2018c).

Table 4a

Sighting survey plan. The pattern of surveys from 2020-2025 will be repeated every 6 years in the E areas, every 7 years in the C areas and every 10 years in sub-area WG. The years when Assessments are run are also shown (assessments are run every 6 years from 2021 on).

Season	**Country**			**Assessment Year**
	Norway	**Iceland**	**Greenland**	
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 used in setting estimates for areas that are combinations of sub-areas.

	CIP	CG	CIC	CM	CIP, CIC,CM	All C subareas	EN	EW	ESW	ESE	EB	EB,ESW, ESE, EW	EB, EW	ESW, ESE	All E subareas
1987	-	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

-=No survey, 1=survey. *Only used when applying the *CLA* to *Small* or Combination Areas consisting of both CIP and CG, and not used for CIP or CG sub-areas separately.

G. Parameters and conditioning

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

Table 5a

The values for the biological parameters that are fixed

Parameter	Value
Plus group age, *x*	20 yrs
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

Table 5b

The values for the selectivity parameters by area.

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

The 'free' parameters of the operating model are the initial (pre-exploitation) sizes of each of the sub-stocks/stocks, the values that determine the mixing matrices (i.e. the γ and Ω parameters) and the hunt factors that allow for differences between survey and fishery selectivity (the ω^h parameters). The process used to select the values for these 'free' parameters is known as conditioning. The conditioning process involves first generating 100 sets of 'target' data as detailed in steps (a) and (b) below, and then fitting the population model to each (in the spirit of a bootstrap). The number of animals in sub-area *k* at the start of year *t* is calculated starting with guessed values of the initial population sizes and projecting the operating model forward to 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 three components. Equations G.2, G.3 and G.6 list the negative of the logarithm of the likelihood for each of these components so the objective function minimised is $L_1+L_2+L_3$. An additional penalty is added to the likelihood if the full historical catch is not removed.

(a) Abundance estimates

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

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

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 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 n^{th} estimate of abundance P_n (the target abundances).

(b) Mixing Proportions

Table 5c 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 SC/67b/Rep06 (item 3.4). In order to ensure that the conditioning leads to the specified model predictions, the mixing proportions are be fixed (not generated) in the conditioning process and assigned low CVs.

Table 5c

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-areas				
		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

(c) Sex ratios

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

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

I) SEX RATIO DURING SIGHTING SURVEYS

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

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

Table 6.

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

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

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

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

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

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

$$\hat{\lambda}^{1,k} = \frac{\sum_a \sum_j V_{-\infty,a}^{f,j,k} S_a^{f,k} N_{-\infty,a}^{f,j}}{\sum_g \sum_{a'} \sum_{j'} V_{-\infty,a'}^{g,j',k} S_a^{g,k} N_{-\infty,a'}^{g,j'}} \quad \text{(G.4)}$$

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

$S_a^{g,k}$ is the survey selectivity for gender g in subarea k and is equal to the 'Reference' selectivity $R_a^{g,h \in k}$ where

$$R_a^{g,h} = (1 + e^{-(a - a_{50}^{g,h})/\delta^{g,h}})^{-1} \quad \text{(G.5)}$$

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

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

Table 7.

Relationship between hunts, sub-areas and the selectivity arrays

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

II) FISHERY SEX RATIOS

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

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

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

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

Table 8.

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

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

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

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

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:

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

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

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

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

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

H. Trials

Table 9 summarises the factors considered in the trials. Table 10 lists the set of trials. Need envelopes 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).

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 Trials*.

Factor	Values
MSYR	1% (1+), 4% (mature), 4% (1+)
Need envelope	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 until additional trials are coded and evaluated.

Table 10

The final set of trials.

Trial	MSYR	Hypothesis	Mixing Proportions	Mixing	Survey Bias	Survey period	Survey CV	Condition
M01	1% (1+) & 4 % (mat)	1	A1	Independent	1	10	Base	Yes
M02	1% (1+) & 4 % (mat)	2	B1	Independent	1	10	Base	Yes
M03	1% (1+) & 4 % (mat)	1	A2	Independent	1	10	Base	Yes
M04	1% (1+) & 4 % (mat)	1	A3	Independent	1	10	Base	Yes
M05	1% (1+) & 4 % (mat)	1	A4	Independent	1	10	Base	Yes
M06	1% (1+) & 4 % (mat)	1	A5	Independent	1	10	Base	Yes
M07	1% (1+) & 4 % (mat)	1	A6	Independent	1	10	Base	Yes
M08	1% (1+) & 4 % (mat)	2	B2	Independent	1	10	Base	Yes
M09	1% (1+) & 4 % (mat)	2	B3	Independent	1	10	Base	Yes
~~M10~~	~~1% (1+) & 4 % (mat)~~	~~2~~	~~B4~~	~~Independent~~	~~1~~	~~10~~	~~Base~~	~~Yes~~
M11	1% (1+) & 4 % (mat)	1	A1	Density-dependent	1	10	Base	Yes &
M12	1% (1+) & 4 % (mat)	2	B1	Density-dependent	1	10	Base	Yes &

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 1 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 will involve (a) using the interim *SLA* to set the strike limit for the WG sub-area, (b) setting the strike limit to 12 [20] for the CG sub-area 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, the catch limit for that *Combination Area* or *Small Area* is set to zero and the aboriginal catch is equal to the strike limit; or

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

J. Output Statistics

The risk- and recovery-related performance statistics are computed 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). Note that incidental removals may still occur in the absence of strikes. To emphasise this distinction, $P_t^*(0)$ is used to denote the population size in year t under a scenario of zero strikes or removals of any kind, and $P_t^*(\text{inc}) = P_t^*$ 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): $\sum_{b=0}^{T^*-1}\left|C_{b+1}-C_b\right| / \sum_{b=0}^{T^*-1} C_b$.

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): $\sum_{b=0}^{T^*-1}\left|\min(C_{b+1}-C_b, 0)\right| \,/\, \sum_{b=0}^{T^*-1} C_b$

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.

K. References

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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. Details of the sources of the direct catch data are given in Allison (2015) and of the indirect catches in IWC (2015) p123-4. The 2 known catches prior to 1900 are ignored. The Faroes catches (125 whales) are allocated to the EW sub-area as they were all taken from land stations in the north of the Faroes. The Norwegian catch data from 1938 on includes detailed positions except for 16 records; these have been allocated to sub-area in accordance with the ratio of other catches in the same year. Table 2 lists the catches known by sex and sub-area/hunt. The average sex ratio for the hunt is assumed for all 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	1054
1937	0	0	0	0	0	1	0	125	996	0	60	50	1232
1938	0	0	0	0	0	1	0	266	907	0	112	68	1354
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	1914	0	4	6	2115
1942	1	0	0	0	0	18	0	158	1976	0	0	0	2153
1943	0	0	0	0	0	16	0	158	1455	0	0	0	1629
1944	0	0	0	0	0	15	0	97	1252	0	0	0	1364
1945	0	0	0	0	0	16	0	165	1611	0	0	10	1802
1946	0	0	0	0	0	34	0	305	1337	0	140	101	1917
1947	16	0	0	0	0	34	0	373	1810	0	136	237	2606
1948	38	0	4	0	0	102	0	358	2035	0	559	535	3631
1949	38	0	5	0	0	106	7	241	1206	0	701	1693	3997
1950	3	0	9	0	0	80	0	106	1173	0	274	437	2082
1951	55	0	16	0	0	63	0	89	1836	0	155	672	2886
1952	17	0	32	0	0	64	0	122	1273	0	101	1829	3438
1953	0	0	32	0	0	79	0	63	1231	0	62	1079	2546
1954	0	0	22	0	0	54	0	359	1508	0	88	1544	3575
1955	13	0	22	0	6	57	1	435	2138	1	56	1679	4408
1956	57	0	22	0	0	21	3	441	1611	10	483	1111	3759
1957	37	0	24	1	0	37	0	593	1417	12	612	1000	3733
1958	42	0	30	0	0	36	0	639	1658	3	498	1543	4449
1959	18	0	55	0	14	35	2	575	900	15	495	1091	3200
1960	11	0	56	4	12	82	0	628	1039	14	369	1223	3438
1961	22	0	35	1	3	108	72	377	1322	13	208	1187	3348
1962	50	0	72	0	3	134	158	400	1302	22	113	1225	3479
1963	18	0	166	5	10	115	80	340	1043	5	324	1355	3461
1964	54	0	162	1	8	153	151	400	1057	10	233	769	2998
1965	41	0	196	3	0	147	255	268	1062	5	534	253	2764
1966	11	0	225	15	87	123	88	330	633	1	288	671	2472
1967	40	0	244	44	143	193	66	181	901	91	536	118	2557
1968	0	20	315	62	211	409	45	355	893	90	656	114	3170
1969	60	165	269	22	94	214	21	479	667	22	397	467	2877
1970	88	126	207	8	159	222	13	350	632	20	628	282	2735
1971	84	263	196	38	29	228	17	410	385	0	524	483	2657
1972	214	123	156	32	139	199	0	319	231	0	158	1467	3038
1973	3	221	276	24	222	147	0	200	267	3	253	839	2455
1974	3	252	217	12	102	127	15	172	291	0	26	931	2148
1975	4	102	222	15	217	193	0	186	269	0	324	651	2183
1976	3	187	191	3	81	216	0	186	148	0	365	1190	2570

Year	WC	WG-comm.	WG-aborig.	CIP	CG	CIC	CM	EN	EW	ESW	ESE	EB	Total
1977	1	75	285	0	1	194	0	118	281	0	749	551	2255
1978	2	75	180	0	130	199	3	83	312	0	162	826	1972
1979	9	75	250	0	119	198	1	76	446	0	62	1202	2438
1980	10	78	258	0	119	202	0	67	259	0	477	1004	2474
1981	8	61	204	0	45	201	0	62	385	0	714	610	2290
1982	4	66	250	0	109	212	0	60	344	0	655	723	2423
1983	4	68	268	0	98	204	15	36	158	0	623	871	2345
1984	6	70	235	0	25	178	90	19	219	0	183	209	1234
1985	7	52	222	0	44	145	55	23	171	0	209	231	1159
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.

Year	WC		WG-com		WG-ab		CIP		CG		CIC		CM		EN		EW		ESW		ESE		EB	
	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	1003	863	0	0	2	2	3	3
1942	0	0	0	0	0	0	0	0	0	0	0	0	0	0	94	64	1112	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

Year	WC		WG-com		WG-ab		CIP		CG		CIC		CM		EN		EW		ESW		ESE		EB	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
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	1013	779	0	0	47	89	162	72
1948	24	14	0	0	0	0	0	0	0	0	38	28	0	0	207	148	1100	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	1185
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	1156	972	1	0	18	37	620	1053
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	1052
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	1014
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
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	1412	1214	3531	155	101	1360	1021	2425	1690	598	1122	8036	5058	28011	21840	140	198	5050	13444	13481	22758

References

Allison 2015. IWC Summary catch database version 6.1.

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.

Adjunct 2 Data used to estimate the Survey and Fishery Sex Ratios (see Appendix 4, 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 Section G of Appendix 4).

'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. In areas where the catches in the survey month are relatively small (WC, CIP, CG, CIC and CM), the 'survey' sex ratios are estimated using data from all years (see Table 1). Catches in the CIC 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 have 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		
1948	10	5							16	10			M	F
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		
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		

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	
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)

Year	WG-ab	WG-ab	CG	CG	CIC	CIC	CM	CM	EN	EN	EW	EW	ESE	ESE	EB	EB
	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

References

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.

Appendix 5

WEST GREENLAND MINKE WHALE *SLA* PERFORMANCE STATISTICS

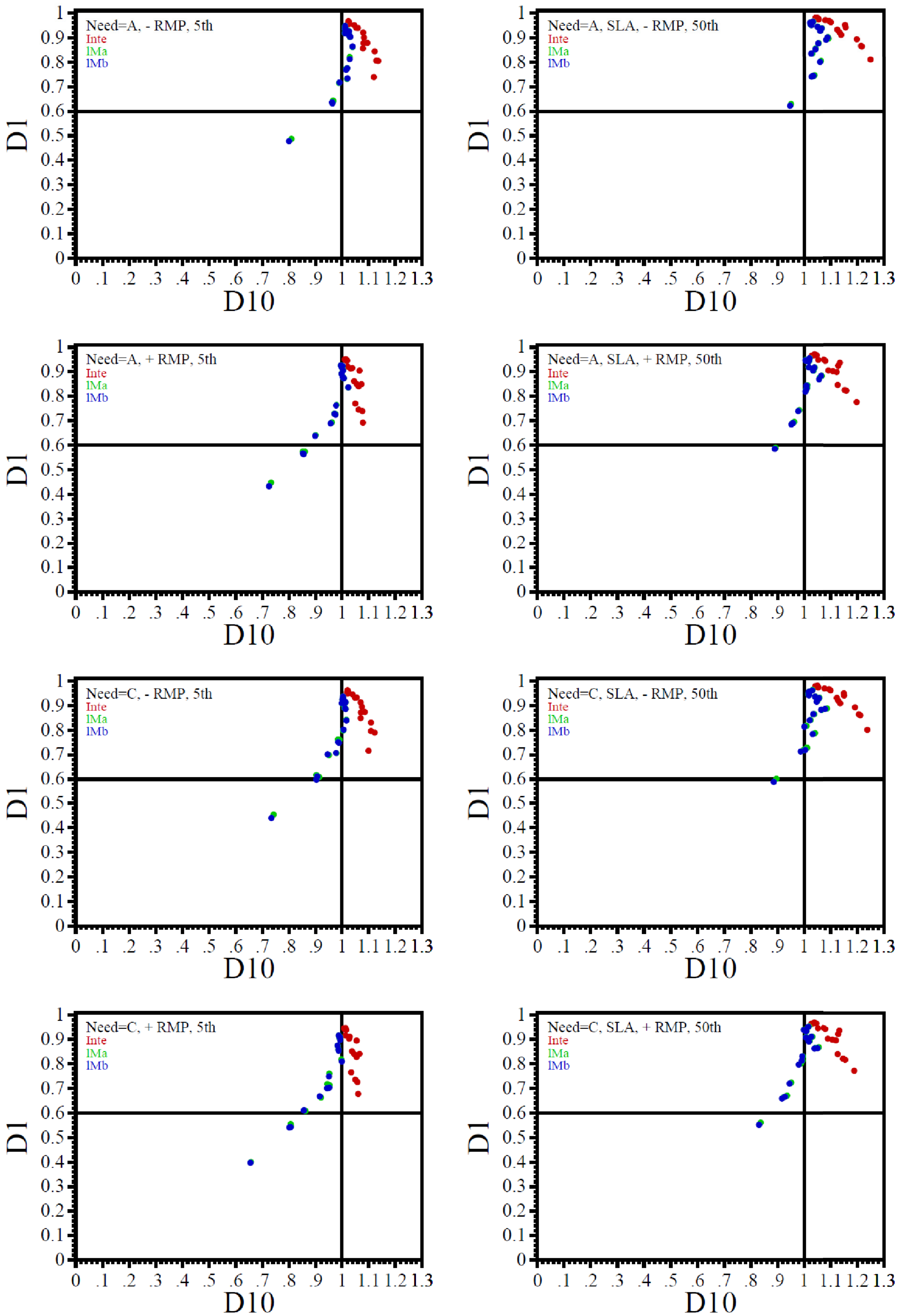

Figure 1. D10 - D1 trade-off plots for need envelopes A and C, with and without the (pre-specified) RMP catches. Points in the lower left quadrant are of interest

Table 1.

Performance statistics for *Evaluation Trials* with need envelopes A and C, with no RMP catches for the Interim *SLA* and two tuning versions (lMa and lMb - with lMa being the final selected *SLA*). Figures in bold indicate possible conservation issues.

		Need: A										Need: C									
Trial	SLA	D1l	D1m	D10l	D10m	N20l	N20m	N100l	N100m	N12U	N12m	D1l	D1m	D10l	D10m	N20l	N20m	N100l	N100m	N12U	N12m
M01-1A	Inte	.806	.865	1.129	1.217	.238	.299	.285	.470	.310	.211	.796	.860	1.109	1.212	.234	.293	.258	.430	.316	.217
	lMa	.643	.743	.965	1.034	.916	1.000	.662	.924	.074	.027	.617	.720	.903	.999	.910	1.000	.622	.885	.077	.033
	lMb	.632	.741	.963	1.028	.934	.999	.700	.938	.069	.022	.611	.713	.906	.987	.927	.995	.651	.901	.071	.030
M01-4A	Inte	.940	.963	1.060	1.101	.239	.299	.281	.456	.312	.214	.933	.962	1.055	1.100	.235	.293	.255	.417	.318	.220
	lMa	.903	.928	1.030	1.061	.916	1.000	.689	.933	.075	.023	.887	.920	1.014	1.050	.910	1.000	.638	.888	.082	.031
	lMb	.904	.928	1.031	1.061	.934	1.000	.708	.942	.067	.020	.886	.916	1.014	1.047	.927	.998	.668	.903	.073	.026
M02-1A	Inte	.878	.922	1.081	1.133	.237	.292	.275	.458	.320	.216	.872	.920	1.071	1.129	.233	.286	.249	.421	.329	.218
	lMa	.772	.857	1.016	1.044	.914	1.000	.640	.910	.075	.030	.762	.841	.984	1.024	.908	1.000	.595	.872	.083	.038
	lMb	.769	.853	1.016	1.043	.932	.996	.666	.919	.066	.024	.751	.840	.985	1.021	.925	.992	.621	.889	.074	.032
M02-4A	Inte	.959	.977	1.024	1.046	.239	.294	.269	.447	.322	.218	.954	.976	1.019	1.046	.235	.288	.244	.409	.332	.221
	lMa	.936	.956	1.011	1.024	.914	1.000	.622	.915	.073	.029	.925	.950	1.002	1.018	.907	1.000	.586	.878	.082	.035
	lMb	.936	.955	1.011	1.025	.931	.999	.654	.917	.068	.024	.925	.949	1.002	1.018	.924	.993	.609	.892	.075	.029
M04-1A	Inte	.739	.811	1.120	1.250	.239	.301	.297	.469	.292	.209	.716	.801	1.100	1.238	.235	.295	.267	.435	.305	.215
	lMa	**.487**	**.629**	**.809**	**.951**	**.920**	**1.000**	**.678**	**.918**	**.075**	**.029**	.454	.602	.742	.896	.914	1.000	.625	.870	.082	.036
	lMb	**.478**	**.622**	**.800**	**.947**	**.939**	**1.000**	**.706**	**.931**	**.065**	**.024**	.440	.588	.734	.886	.932	.998	.651	.887	.076	.030
M04-4A	Inte	.921	.952	1.080	1.154	.243	.309	.309	.479	.290	.209	.913	.950	1.070	1.150	.239	.302	.277	.439	.302	.215
	lMa	.863	.902	1.040	1.090	.921	1.000	.705	.943	.068	.021	.842	.883	1.017	1.067	.915	1.000	.654	.906	.080	.030
	lMb	.865	.901	1.040	1.088	.939	1.000	.730	.949	.060	.017	.839	.883	1.017	1.064	.932	1.000	.685	.918	.068	.023
M06-1A	Inte	.845	.894	1.123	1.198	.238	.293	.286	.473	.315	.214	.831	.893	1.109	1.192	.234	.287	.257	.430	.317	.218
	lMa	.732	.805	1.019	1.064	.916	1.000	.643	.921	.071	.028	.706	.788	.979	1.041	.910	1.000	.605	.885	.077	.034
	lMb	.734	.801	1.021	1.060	.934	.997	.684	.934	.064	.022	.707	.784	.977	1.032	.927	.994	.634	.899	.070	.029
M06-4A	Inte	.951	.971	1.046	1.080	.239	.296	.266	.460	.315	.218	.946	.970	1.040	1.077	.235	.290	.241	.419	.325	.222
	lMa	.927	.945	1.026	1.051	.916	1.000	.649	.925	.070	.027	.913	.937	1.014	1.042	.909	1.000	.610	.892	.077	.033
	lMb	.926	.944	1.026	1.050	.934	1.000	.692	.941	.066	.022	.914	.936	1.014	1.041	.926	.996	.639	.906	.069	.027
M08-1A	Inte	.857	.912	1.079	1.139	.239	.297	.288	.458	.312	.212	.849	.909	1.070	1.136	.235	.291	.261	.424	.322	.219
	lMa	.715	.837	.988	1.031	.916	1.000	.660	.917	.076	.028	.698	.817	.950	1.009	.910	1.000	.610	.877	.080	.037
	lMb	.717	.836	.990	1.027	.934	1.000	.697	.926	.062	.023	.701	.814	.945	1.001	.927	.996	.643	.897	.073	.030
M08-4A	Inte	.956	.975	1.026	1.055	.242	.300	.274	.447	.317	.217	.949	.974	1.021	1.053	.237	.294	.249	.412	.321	.223
	lMa	.919	.951	1.011	1.027	.919	1.000	.640	.921	.079	.026	.909	.943	1.001	1.018	.913	1.000	.602	.885	.082	.035
	lMb	.919	.951	1.011	1.028	.936	1.000	.688	.931	.072	.022	.910	.942	1.000	1.018	.930	.997	.629	.898	.077	.029
M09-1A	Inte	.901	.933	1.083	1.125	.237	.293	.272	.457	.331	.217	.895	.931	1.075	1.124	.233	.287	.245	.422	.338	.222
	lMa	.822	.878	1.029	1.055	.910	.999	.630	.907	.077	.031	.799	.865	1.005	1.038	.903	.998	.584	.873	.084	.038
	lMb	.813	.877	1.029	1.053	.928	.993	.662	.916	.071	.026	.802	.865	1.006	1.034	.920	.990	.618	.887	.078	.031
M09-4A	Inte	.967	.981	1.024	1.043	.236	.293	.263	.446	.339	.223	.963	.979	1.021	1.042	.232	.287	.237	.410	.347	.228
	lMa	.947	.962	1.012	1.024	.913	1.000	.616	.903	.078	.031	.936	.957	1.004	1.019	.907	1.000	.578	.868	.085	.040
	lMb	.947	.961	1.012	1.023	.930	.996	.647	.912	.070	.026	.936	.956	1.004	1.018	.923	.991	.604	.882	.078	.032
M11-1A	Inte	.805	.867	1.136	1.214	.234	.285	.274	.456	.341	.228	.790	.864	1.123	1.206	.230	.279	.246	.432	.349	.233
	lMa	.642	.747	.967	1.039	.889	.991	.608	.892	.095	.035	.609	.728	.913	1.011	.882	.989	.559	.863	.101	.044
	lMb	.636	.744	.962	1.034	.904	.984	.642	.912	.083	.031	.598	.719	.903	1.004	.897	.979	.596	.878	.086	.038
M11-4A	Inte	.941	.968	1.053	1.094	.226	.279	.211	.407	.380	.253	.932	.967	1.049	1.094	.222	.274	.196	.375	.385	.260
	lMa	.911	.939	1.027	1.067	.834	.973	.511	.841	.114	.050	.890	.932	1.010	1.058	.826	.970	.467	.800	.119	.054
	lMb	.909	.938	1.027	1.066	.841	.971	.537	.862	.105	.044	.889	.930	1.011	1.056	.834	.966	.494	.823	.113	.048
M12-1A	Inte	.879	.942	1.095	1.156	.214	.259	.134	.362	.470	.274	.874	.941	1.086	1.151	.211	.254	.122	.334	.470	.279
	lMa	.776	.897	1.020	1.092	.683	.926	.317	.751	.187	.069	.761	.888	.990	1.087	.675	.920	.295	.707	.193	.077
	lMb	.775	.892	1.020	1.083	.693	.939	.334	.773	.183	.060	.748	.886	.988	1.079	.685	.932	.311	.721	.184	.066
M12-4A	Inte	.965	.981	1.026	1.050	.224	.268	.182	.355	.412	.284	.959	.981	1.023	1.050	.220	.263	.165	.327	.416	.288
	lMa	.940	.965	1.013	1.034	.761	.930	.438	.759	.148	.072	.927	.964	1.005	1.031	.754	.915	.408	.716	.152	.076
	lMb	.940	.965	1.013	1.033	.773	.932	.468	.791	.140	.066	.927	.962	1.005	1.030	.766	.926	.435	.745	.142	.071

Table 2.

Performance statistics for *Evaluation Trials* with need envelopes A and C, with RMP catches for the Interim *SLA* and two tuning versions (lMa and lMb - with lMa being the final selected *SLA*). Figures in bold indicate possible conservation issues.

		Need: A										Need: C									
Trial	SLA	D1l	D1m	D10l	D10m	N20l	N20m	N100l	N100m	N12U	N12m	D1l	D1m	D10l	D10m	N20l	N20m	N100l	N100m	N12U	N12m
M01-1A	Inte	.745	.823	1.063	1.159	.238	.299	.279	.464	.312	.216	.736	.817	1.050	1.155	.234	.293	.253	.424	.319	.220
	lMa	**.574**	**.690**	**.860**	**.956**	**.916**	**1.000**	**.646**	**.921**	**.077**	**.028**	**.555**	**.665**	**.806**	**.924**	**.910**	**1.000**	**.606**	**.872**	**.085**	**.039**
	lMb	**.564**	**.685**	**.855**	**.952**	**.934**	**.999**	**.682**	**.932**	**.072**	**.024**	**.542**	**.659**	**.806**	**.917**	**.927**	**.994**	**.637**	**.887**	**.074**	**.032**
M01-4A	Inte	.915	.944	1.039	1.080	.239	.299	.277	.454	.311	.216	.911	.943	1.029	1.080	.235	.293	.251	.414	.322	.222
	lMa	.873	.904	1.007	1.035	.916	1.000	.684	.924	.077	.025	.855	.894	.987	1.021	.910	1.000	.630	.880	.084	.033
	lMb	.873	.905	1.007	1.033	.934	1.000	.699	.940	.068	.022	.854	.891	.987	1.018	.927	.998	.659	.899	.075	.028
M02-1A	Inte	.849	.902	1.056	1.109	.237	.292	.266	.453	.332	.218	.840	.899	1.046	1.107	.233	.286	.239	.413	.335	.221
	lMa	.729	.834	.970	1.011	.914	1.000	.637	.907	.075	.032	.718	.814	.944	.994	.907	1.000	.585	.868	.083	.041
	lMb	.728	.830	.971	1.009	.932	.996	.664	.916	.067	.025	.701	.814	.943	.991	.924	.992	.619	.884	.074	.033
M02-4A	Inte	.946	.966	1.014	1.036	.239	.292	.263	.443	.324	.218	.942	.966	1.011	1.035	.235	.286	.238	.406	.334	.222
	lMa	.918	.944	1.000	1.011	.913	1.000	.621	.908	.075	.030	.908	.938	.989	1.004	.907	1.000	.582	.872	.083	.037
	lMb	.917	.943	1.000	1.011	.931	.999	.652	.914	.070	.025	.908	.937	.990	1.003	.924	.993	.608	.885	.075	.030
M04-1A	Inte	.692	.776	1.079	1.198	.239	.300	.287	.464	.295	.211	.678	.772	1.061	1.189	.235	.294	.257	.428	.309	.217
	lMa	**.448**	**.589**	**.733**	**.893**	**.920**	**1.000**	**.644**	**.913**	**.076**	**.030**	**.400**	**.561**	**.657**	**.837**	**.914**	**1.000**	**.606**	**.866**	**.088**	**.038**
	lMb	**.433**	**.585**	**.725**	**.890**	**.939**	**1.000**	**.683**	**.921**	**.066**	**.026**	**.397**	**.552**	**.655**	**.831**	**.931**	**.998**	**.633**	**.879**	**.077**	**.033**
M04-4A	Inte	.904	.937	1.066	1.135	.243	.306	.306	.474	.292	.211	.895	.936	1.055	1.133	.239	.299	.274	.434	.303	.217
	lMa	.835	.883	1.024	1.067	.921	1.000	.704	.941	.070	.021	.818	.865	.998	1.042	.915	1.000	.651	.904	.080	.033
	lMb	.836	.883	1.024	1.064	.939	1.000	.723	.946	.061	.018	.810	.863	1.000	1.039	.932	1.000	.682	.911	.071	.024
M06-1A	Inte	.770	.846	1.050	1.127	.238	.293	.275	.462	.319	.217	.766	.840	1.035	1.127	.234	.287	.247	.422	.324	.222
	lMa	.641	.743	.900	.982	.916	1.000	.636	.918	.073	.029	.609	.724	.862	.952	.910	1.000	.598	.873	.081	.037
	lMb	.638	.739	.898	.978	.934	.997	.671	.924	.067	.024	.611	.720	.856	.945	.927	.993	.627	.887	.070	.031
M06-4A	Inte	.921	.948	1.021	1.053	.239	.294	.263	.453	.318	.219	.916	.946	1.014	1.052	.235	.288	.239	.413	.328	.223
	lMa	.892	.918	.999	1.018	.916	1.000	.647	.924	.071	.028	.875	.910	.983	1.008	.909	1.000	.608	.882	.081	.033
	lMb	.891	.918	.999	1.018	.933	1.000	.686	.934	.066	.023	.875	.908	.983	1.007	.926	.996	.637	.900	.069	.029
M08-1A	Inte	.840	.899	1.063	1.123	.239	.297	.280	.455	.312	.213	.829	.896	1.055	1.120	.235	.291	.254	.419	.320	.222
	lMa	.693	.823	.961	1.006	.916	1.000	.654	.913	.076	.028	.663	.801	.920	.987	.910	1.000	.606	.875	.082	.036
	lMb	.689	.819	.956	1.005	.934	1.000	.689	.921	.067	.024	.668	.797	.915	.980	.927	.995	.640	.895	.073	.031
M08-4A	Inte	.945	.967	1.020	1.047	.242	.300	.274	.444	.317	.217	.939	.966	1.016	1.046	.237	.294	.249	.410	.321	.223
	lMa	.907	.943	1.004	1.019	.916	1.000	.640	.919	.080	.026	.900	.934	.992	1.009	.910	1.000	.602	.884	.083	.034
	lMb	.904	.943	1.004	1.018	.934	1.000	.682	.928	.072	.023	.898	.934	.992	1.008	.927	.997	.629	.894	.077	.029
M09-1A	Inte	.861	.905	1.046	1.092	.237	.291	.261	.451	.333	.221	.852	.903	1.038	1.090	.233	.285	.235	.415	.340	.225
	lMa	.764	.845	.979	1.012	.909	.999	.620	.896	.077	.033	.761	.831	.951	.995	.903	.998	.574	.864	.084	.041
	lMb	.762	.843	.977	1.009	.927	.993	.662	.913	.071	.026	.749	.831	.950	.993	.920	.989	.610	.881	.078	.034
M09-4A	Inte	.950	.965	1.011	1.028	.236	.291	.260	.443	.342	.225	.946	.965	1.008	1.027	.232	.285	.235	.405	.346	.228
	lMa	.925	.947	.996	1.006	.913	1.000	.615	.897	.078	.032	.916	.940	.987	1.000	.907	1.000	.576	.863	.086	.041
	lMb	.925	.946	.996	1.005	.930	.996	.645	.908	.071	.027	.916	.939	.987	.999	.923	.990	.603	.880	.078	.032
M11-1A	Inte	.739	.825	1.077	1.153	.233	.285	.264	.447	.342	.231	.726	.821	1.058	1.147	.229	.279	.239	.423	.350	.233
	lMa	**.574**	**.695**	**.851**	**.963**	**.881**	**.991**	**.600**	**.884**	**.102**	**.037**	**.547**	**.671**	**.807**	**.936**	**.871**	**.988**	**.554**	**.856**	**.095**	**.047**
	lMb	**.566**	**.690**	**.852**	**.958**	**.896**	**.984**	**.636**	**.903**	**.086**	**.033**	**.541**	**.666**	**.801**	**.928**	**.885**	**.978**	**.589**	**.868**	**.091**	**.041**
M11-4A	Inte	.913	.949	1.033	1.075	.226	.278	.208	.403	.380	.254	.903	.948	1.027	1.074	.222	.272	.193	.373	.384	.261
	lMa	.880	.917	1.003	1.040	.831	.972	.509	.838	.116	.051	.860	.911	.986	1.031	.825	.968	.463	.791	.122	.055
	lMb	.878	.917	1.003	1.038	.839	.970	.534	.854	.108	.046	.859	.911	.986	1.027	.833	.965	.492	.817	.114	.051
M12-1A	Inte	.849	.924	1.073	1.129	.214	.258	.132	.355	.472	.278	.841	.922	1.066	1.129	.211	.254	.119	.330	.472	.280
	lMa	.727	.875	.976	1.058	.681	.925	.311	.745	.187	.069	.713	.868	.952	1.055	.673	.919	.290	.689	.195	.077
	lMb	.724	.869	.975	1.056	.691	.938	.328	.759	.183	.061	.703	.864	.951	1.050	.683	.931	.306	.711	.184	.068
M12-4A	Inte	.950	.971	1.016	1.039	.224	.268	.181	.351	.414	.285	.947	.970	1.014	1.038	.220	.263	.165	.325	.417	.289
	lMa	.923	.954	1.002	1.021	.760	.927	.433	.755	.148	.072	.908	.953	.994	1.018	.753	.913	.404	.713	.152	.077
	lMb	.923	.954	1.002	1.020	.772	.931	.463	.785	.141	.067	.908	.952	.993	1.016	.764	.925	.430	.740	.142	.071

Appendix 6

SOME PLOTS PERTINENT TO THE EVALUATION OF CONSERVATION PERFORMANCE FOR THE MAKAH MANAGEMENT PLAN

André E. Punt

The evaluation of conservation performance relates to two factors: (a) whether the final depletion (quantified using the D1 statistic) exceeds the MSYL (nominally 0.6K) with high probability (conventionally 95% in the AWMP evaluation process), and (b) whether the stock is projected to increase (quantified by the D10 statistic) if it is below MSYL with high probability. A failure to achieve conservation objectives could be considered a case where there is more than a 5% chance (i.e. 5 simulations out of 100) where the stock is not above MSYL and not increasing and the trial is considered sufficiently plausible to be considered in the 'evaluation set'.

To examine the conservation performance for the Makah Management Plan, 'Brandon Plots' have been produced by stock (left panels of Fig. 1). These plots identify trials (see Table 1 for the list of trials) where the lower 5th percentiles of the D1 and D10 statistics (individually) are less than 0.6 and 1 respectively. These trials are 5a11 (for the WFG) and 3a16, 5a16 and 5a20 (for the PCFG). Figure 2 examines this issue using 'Wilberg-Brandao' plots, which show the D1 vs D10 statistics by simulation for trials 3a16, 5a11, 5a16 and 5a20. Figure 2 indicates that more than 5% of simulations are 'in the gray' and need to be examined further.

The four trials 'in the gray' in Figure 1 are all trials that involve higher levels of bycatch than for the baseline trials (see the column 'Bycatch' in Table 1). The question then arises whether the 'poor' performance is due to the Makah Management Plan, the harvest at Chukotka, or future bycatch.

The right panels of Figure 1 consequently examine (using 'Brandon Plots') the values for the D8 and D10 statistics. The D8 statistic is the ratio of the final depletion when the Makah Management Plan is implemented, harvest occurs at Chukotka, and there is future bycatch to the final depletion when harvest occurs at Chukotka, and there is future bycatch, but no catches occur off Washington. Values close to 1 on the y-axis indicate that the harvest off Washington has a negligible effect compared to the other two sources of modelled removals. This is most evident for the Northern Feeding Aggregation and the Western Feeding Group and (as expected) to a lesser extent for the PCFG. These results suggest that the poor performance in Figures 1 (left) and 2 are due primarily to bycatch (most likely) and catches of Chukotka (less likely given they do not involve the WFG and PCFG for almost all trials).

Table 1

List of Trials

			MSYR$_{1+}$			PCFG			
Trial	Description/stock hypothesis	PCFG or WFG in BSCS	North	PCFG	WFG	Imm.	Pulse	Bycatch	Conditioning
Base-case Trials									
0A	Reference 3a	No	4.50%	4.50%	4.50%	2	20	D x 4	Yes
0B	Reference 5a	No	4.50%	4.50%	4.50%	2	20	D x 4	Yes
Sensitivity tests									
1A	Lower MSYR PCFG 3a	No	**4.50%**	**2%**	**4.50%**	2	20	D x 4	Yes
1B	Lower MSYR PCFG 5a	No	**4.50%**	**2%**	**4.50%**	2	20	D x 4	Yes
2A	Higher MSYR PCFG & North 3a	No	**5.50%**	**5.50%**	**4.50%**	2	20	D x 4	Yes
2B	Higher MSYR PCFG & North 5a	No	**5.50%**	**5.50%**	**4.50%**	2	20	D x 4	Yes
3A	Lower WBS in Sakhalin 5a (Hyp 3e)	No	4.50%	4.50%	4.50%	2	20	D x 4	Yes
3B	Higher WBS in Sakhalin 5a	No	4.50%	4.50%	4.50%	2	20	D x 4	Yes
4A	PCFG mixing based on Northern WA only 3a	No	4.50%	4.50%	4.50%	2	20	D x 4	Yes
4B	PCFG mixing based on Northern WA only 5a	No	4.50%	4.50%	4.50%	2	20	D x 4	Yes
5A	No PCFG Immigration 3a	No	4.50%	4.50%	4.50%	**0**	20	D x 4	Yes
5B	No PCFG Immigration 5a	No	4.50%	4.50%	4.50%	**0**	20	D x 4	Yes
6A	Higher PCFG Immigration 3a	No	4.50%	4.50%	4.50%	**4**	20	D x 4	Yes
6B	Higher PCFG Immigration 5a	No	4.50%	4.50%	4.50%	**4**	20	D x 4	Yes
7A	Lower Pulse into PCFG 3a (& no 1998-2002 PCFG data)	No	4.50%	4.50%	4.50%	2	**10**	D x 4	Yes
7B	Lower Pulse into PCFG 5a (& no 1998-2002 PCFG data)	No	4.50%	4.50%	4.50%	2	**10**	D x 4	Yes
8A	Higher pulse into PCFG 3a	No	4.50%	4.50%	4.50%	2	**30**	D x 4	Yes
8B	Higher pulse into PCFG 5a	No	4.50%	4.50%	4.50%	2	**30**	D x 4	Yes
9A	Bycatch=Dead + MSI 3a	No	4.50%	4.50%	4.50%	2	20	**D + MSI**	Yes
9B	Bycatch=Dead + MSI 5a	No	4.50%	4.50%	4.50%	2	20	**D + MSI**	Yes
10A	Bycatch x 10 3a	No	4.50%	4.50%	4.50%	2	20	**D x 10**	Yes
10B	Bycatch x 10 5a	No	4.50%	4.50%	4.50%	2	20	**D x 10**	Yes
11A	Bycatch x 20 3a	No	4.50%	4.50%	4.50%	2	20	**D x 20**	Yes
11B	Bycatch x 20 5a	No	4.50%	4.50%	4.50%	2	20	**D x 20**	Yes
12A	PCFG in BSCS 3a	**PCFG**	4.50%	4.50%	4.50%	2	20	D x 4	Yes
12B	PCFG in BSCS 5a	**PCFG**	4.50%	4.50%	4.50%	2	20	D x 4	Yes
13A	WFG in BSCS 3a	**WFG**	4.50%	4.50%	4.50%	2	20	D x 4	Yes
13B	WFG in BSCS 5a	**WFG**	4.50%	4.50%	4.50%	2	20	D x 4	Yes
14A	MSYR1+ estimated (common) 3a	No		**Est**		2	20	D x 4	Yes
14A	MSYR1+ estimated (common) 5a	No		**Est**		2	20	D x 4	Yes
15A	MSYR1+ estimated (by FA) 3a	No	**Est**	**Est**	**Est**	2	20	D x 4	Yes
15B	MSYR1+ estimated (by FA) 5a	No	**Est**	**Est**	**Est**	2	20	D x 4	Yes
16A	Lower PCFG immigration & higher bycatch 3a (& no 1998-2002 PCFG data)	No	4.50%	4.50%	4.50%	**0**	20	**D x 10**	Yes
16B	Lower PCFG immigration & higher bycatch 5a (& no 1998-2002 PCFG data)	No	4.50%	4.50%	4.50%	**0**	20	**D x 10**	Yes
17A	MSYR estimated & lower pulse 3a	No	**Est**	**Est**	**Est**	2	**10**	D x 4	Yes
17B	MSYR estimated & lower pulse 5a	No	**Est**	**Est**	**Est**	2	**10**	D x 4	Yes
18A	Stock hypothesis 3b	No	4.50%	4.50%	4.50%	2	20	D x 4	Yes
18B	Stock hypothesis 6b	No	4.50%	4.50%	4.50%	2	20	D x 4	Yes
18C	Stock hypothesis 3c	No	4.50%	4.50%	4.50%	2	20	D x 4	Yes
19A	Lower PCFG Immigration 3a	No	4.50%	4.50%	4.50%	**1**	20	D x 4	Yes
19B	Lower PCFG Immigration 5a	No	4.50%	4.50%	4.50%	**1**	20	D x 4	Yes
20A	Lower PCFG immigration & higher bycatch 3a	No	4.50%	4.50%	4.50%	**1**	20	**D x 10**	Yes
20B	Lower PCFG immigration & higher bycatch 5a	No	4.50%	4.50%	4.50%	**1**	20	**D x 10**	Yes
21A	Survival = 0.95; 3a	No	4.50%	4.50%	4.50%	2	20	D x 4	Yes
21B	Survival = 0.95; 3a	No	4.50%	4.50%	4.50%	2	20	D x 4	Yes
22A	Future catastrophic events (once in each of yrs 1-50 & 51-99) - 3a	No	4.50%	4.50%	4.50%	2	20	D x 4	No, 3a
22B	Future catastrophic events (once in each of yrs 1-50 & 51-99) - 5a	No	4.50%	4.50%	4.50%	2	20	D x 4	No, 5a
23A	Summer S&L rate = 0.5 - 3a	No	4.50%	4.50%	4.50%	2	20	D x 4	No, 3a
23B	Summer S&L rate = 0.5 - 5a	No	4.50%	4.50%	4.50%	2	20	D x 4	No, 5a
24A	PCFG false negative rate = 0.1 - 3a	No	4.50%	4.50%	4.50%	2	20	D x 4	No, 3a
24B	PCFG false negative rate = 0.1 - 5a	No	4.50%	4.50%	4.50%	2	20	D x 4	No, 5a
25A	PCFG mixing based on Northern WA is 100%	No	4.50%	4.50%	4.50%	2	20	D x 4	Yes
25B	PCFG mixing based on Northern WA is 100%	No	4.50%	4.50%	4.50%	2	20	D x 4	Yes

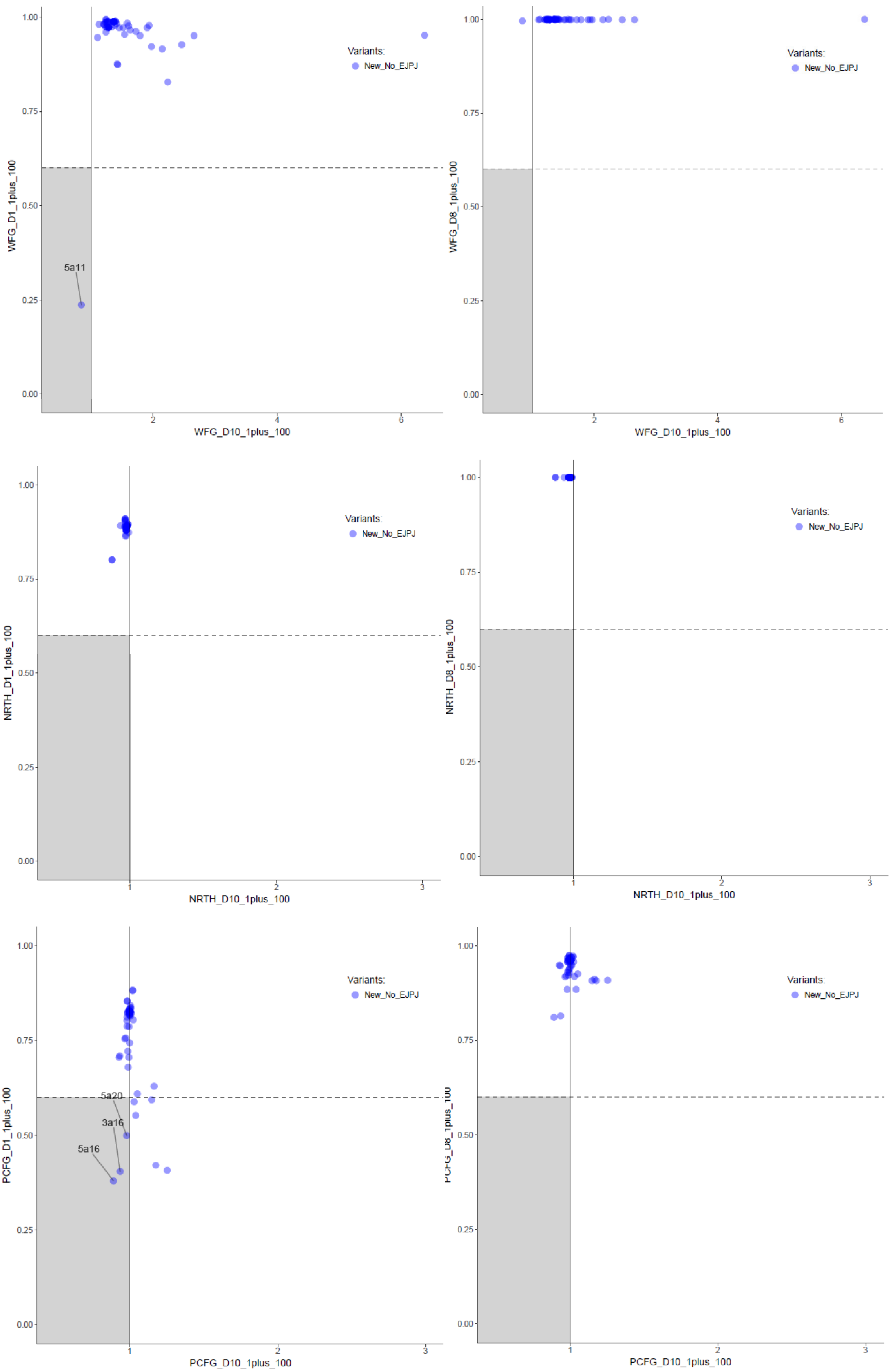

Figure 1. Lower 5th percentile of the D1 statistic versus the lower 5th percentile of the D10 statistic by stock (left panels) and the lower 5th percentile of the D8 statistic versus the lower 5th percentile of the D10 statistic by stock

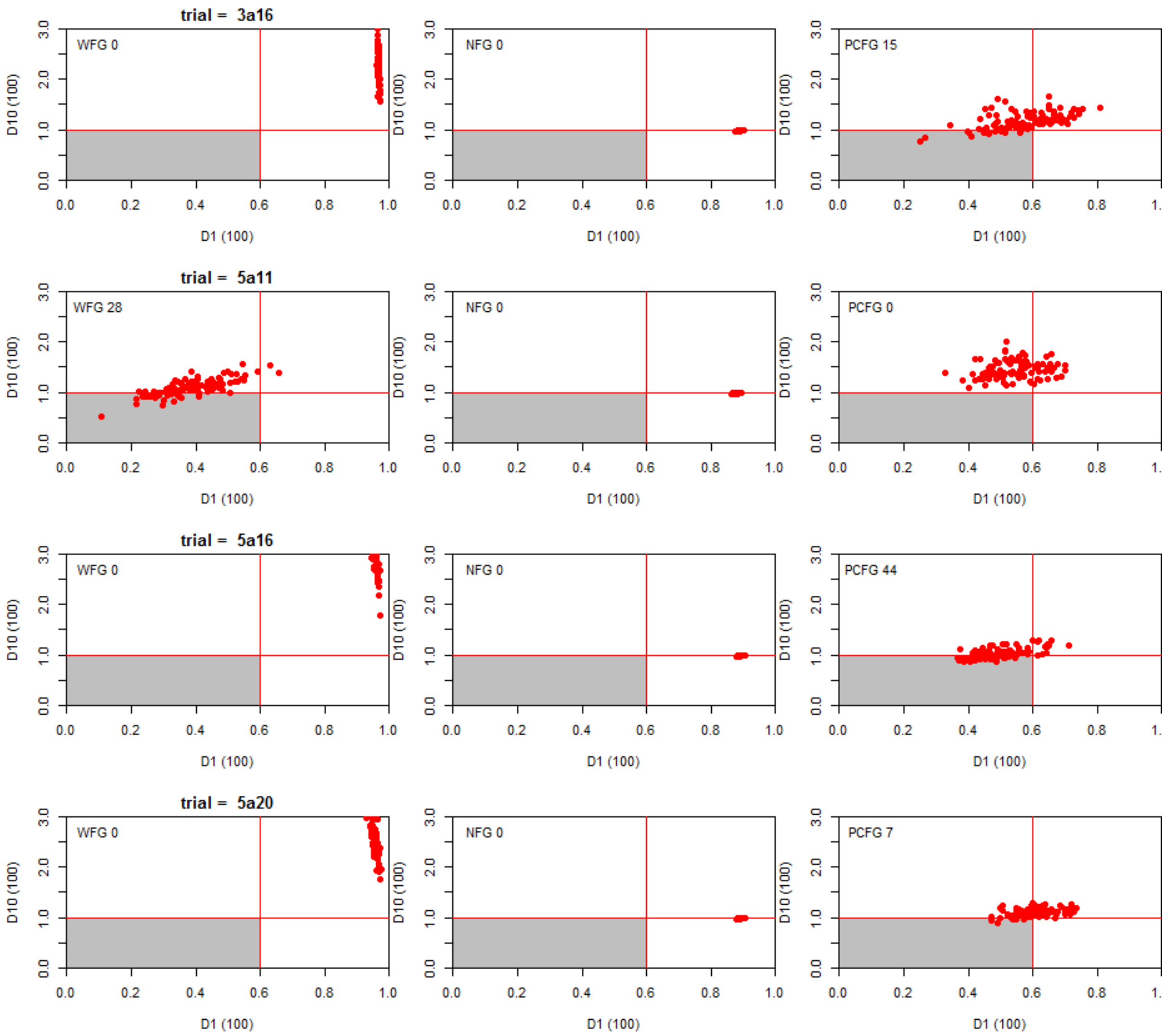

Figure 2. 'Wilberg-Brandao' plots (individual values for D1 and D10 by simulation) for the four simulations highlighted in Figure 1. The number in the top left corner of each panel is the number of simulations 'in the gray'.

Appendix 7

INVESTIGATING THE VARIABILITY OF THE 1+ POPULATION PROJECTIONS BASED ON 400 AND 100 SIMULATIONS FOR WEST GREENLAND BOWHEAD WHALES

Michael Wilberg and Anabela Brandão

Problem:

SC/O17/AWMP03 showed projection plots for the r t5 percentile and the median of the 1+ population for the baseline evaluation trials for the selected *SLA* for West Greenland bowheadt whales based on 400 simulations. For comparison purposes, the projections for the *SLA* undelt100 simulations were also shown. These show substantial variability between estimates of the r 5 percentile of the distribution of population size (see Figure 1 for an example). It was uncertain what was causing this behaviour and this paper investigates this.

Methods:

Firstly the 400 simulations were split into blocks of 100, and the *SLA* was run for each 100-tsimulation block.

Secondly, we evaluated the percentiles of the results from four 100-trial simulations to determine the potential cause of the issue. We examined the distributions of several variables including carrying capacity and abundance and depletion at different time points. For demonstration in this working paper, we focused on depletion in year 100 as the primary variable of interest. We combined the results of the four 100-trial sets of results and used bootstrapping with 10,000 bootstrap replicates to determine the effect of the number of trials on the precision of the estimate.

Results:

Figure 2 shows the projections for the r 5 percentile and the median for the1+ population for the selected *SLA* based under 400 simulations and for blocks of 100 simulations. This shows the large amount of variability, especially in the r t5 percentile of the 1+ population. The approximate 95% CI for 100 trials was 0.56-0.72. The precision of the estimate was substantially improved with an increase in the number of trials to 400 or 1000, 95% CI 0.61-0.66 and 0.62-0.65, respectively. The r t5 percentile of the distribution is imprecisely estimated with a sample of 100 trials because of the long left hand tail of the distribution (Figure 3).

Conclusion:

Continuing to use 400 trials for the simulations appears to be sufficient to estimate the lower r 5 percentile with a reasonable amount of precision.

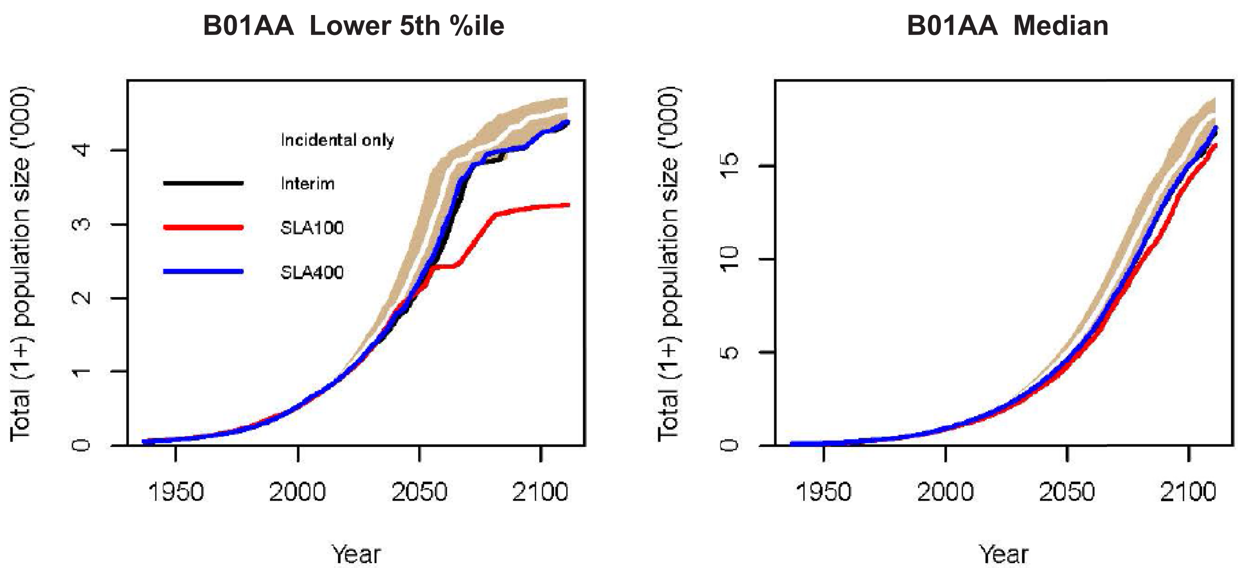

Fig. 1. Projections of the 1+ population for the West Greenland bowhead whales under the selected *SLA* based on trials with 100 and 400 replicates.

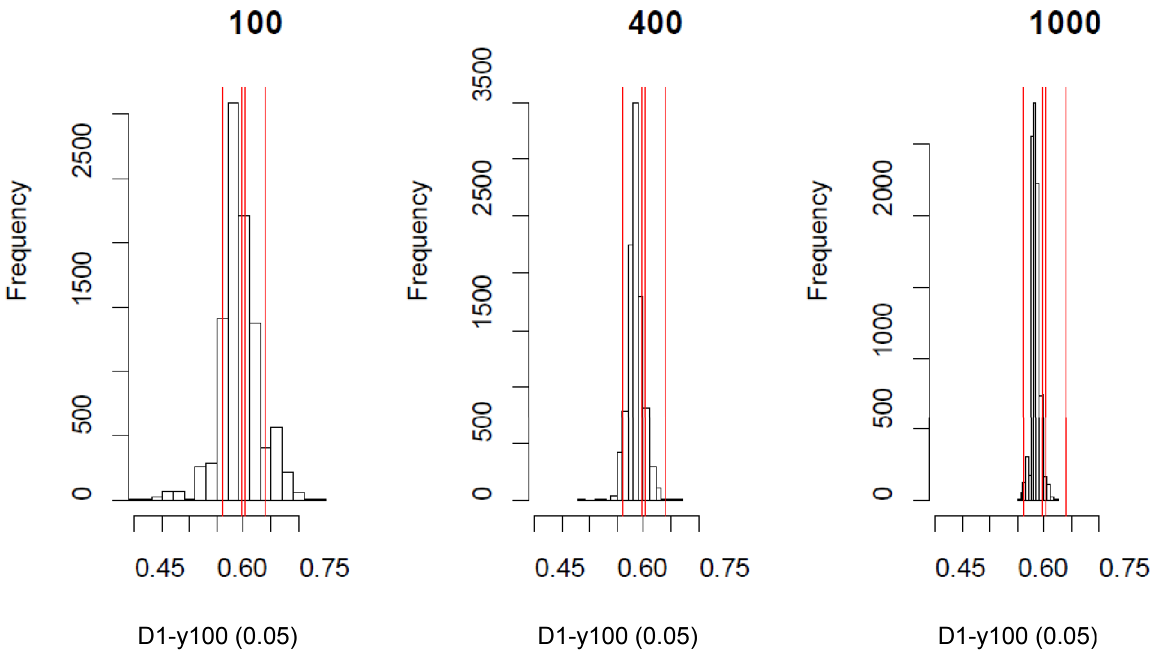

Fig. 2. Distribution of the 5th percentile of depletion in year 100 under three levels of the number of trials (100, 400, and 1,000) for West Greenland bowhead whales. The red lines indicate the estimated 5th percentile from four simulations of 100 trials. Note the wide range of the distribution for 100 trials.

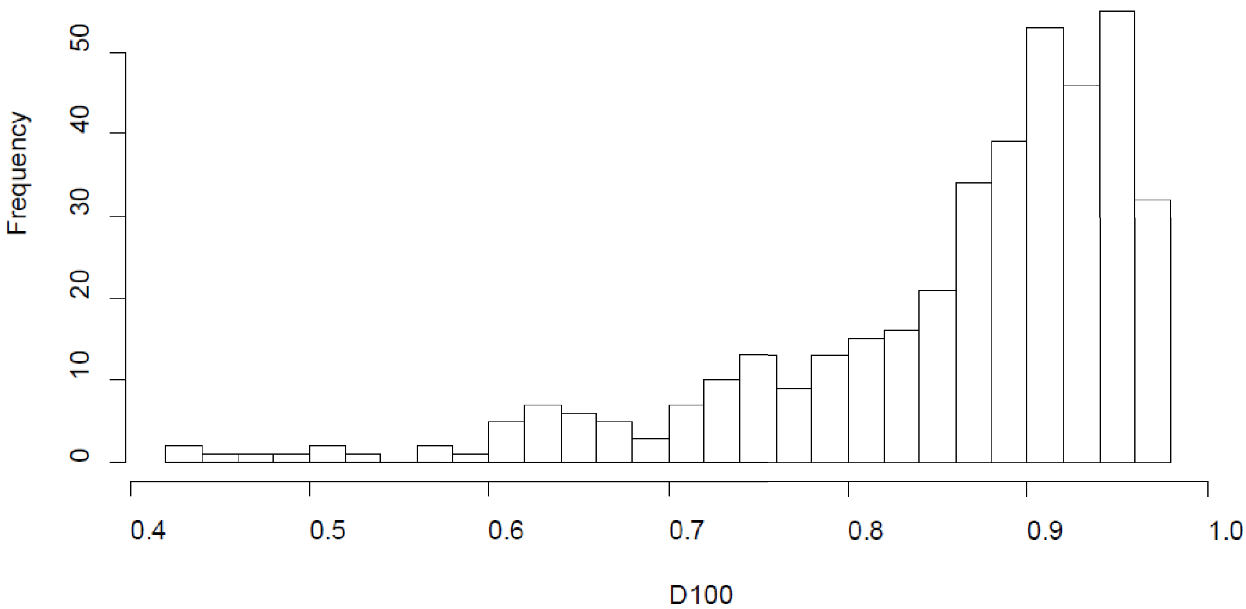

Fig. 3. Distribution of depletion in year 100 from 400 simulations for West Greenland bowhead whales.

Appendix 8

INTERIM RELIEF SCENARIOS

Appendix 9 specifies an interim relief provision for the Aboriginal Whaling Scheme. Under this provision, a survey is required at least every 10 years. If no survey is available after that time and third quota block has begun, the Committee has **endorsed** the use of an ‘interim relief’, namely a ‘grace period’ strike limit equal to the limit produced by the applicable Strike Limit Algorithm, without reduction, for a single block.

The 10-year survey interval requirement is complicated by the fact that there will usually be a delay between when the survey is conducted and when the resulting abundance estimate is agreed by the Committee, and because surveys, estimates and quota blocks need not be synchronised. For the sake of counting years, a survey is not considered to have occurred until the resulting abundance estimate is agreed. At that point, the 10-year time window is deemed to have begun in the year during which the survey was conducted. Then, ideally, the next survey would be conducted and the estimate approved within 10 years of the previous survey. However, other scenarios might occur. For example, the next survey might have occurred eight years after the previous one, but the corresponding abundance estimate not agreed until 13

Tables 1 and 2

Example schedules of surveys, block strike limits and so forth. See the text for a detailed explanation.

Yr	A	Clock		B	Clock	
1	SL			SL		
2						
3						
4	Surv	10				
5		9				
6	Est	8		Surv	10	
7	SL	7		Est/SL	9	
8		6			8	
9		5			7	
10		4			6	
11		3			5	
12	Surv	2	10		4	
13	SL	1	9	SL	3	
14	Est	0	8		2	
15			7		1	
16			6	Surv	0	10
17			5	Est	-1	9
18			4			8
19	SL		3	SL		7
20	Surv	10	2			6
21		9	1			5
22	Est	8	0			4
23		7				3
24		6				2
25	SL	5		SL		1
26		4		Surv	10	0

Yr	C	Clock		D	Clock		E	Clock	
1	SL			SL			SL		
2	Surv	10		Surv	10				
3		9			9				
4		8			8		Surv	10	
5	Est	7		Est	7			9	
6		6			6		Est	8	
7	SL	5		SL	5		SL	7	
8		4			4			6	
9		3			3			5	
10		2			2			4	
11		1			1			3	
12	Surv	0	10	Surv	0	10		2	
13	IASL	-1	9	IASL	-1	9	SL	1	
14		-2	8		-2	8		0	
15	Est/USL	-3	7	Est	-3	7		-1	
16			6			6		-2	
17			5			5	Surv	-3	10
18			4			4	Est	-4	9
19	SL		3	SL		3	SL		8
20	Surv	10	2	Surv	10	2			7
21		9	1		9	1			6
22	Est	8	0	Est	8	0			5
23		7			7				4
24		6			6				3
25	SL	5		SL	5		SL		2
26		4			4				1

years after the previous survey was conducted ('the 13th year'). In this case, a survey would be considered overdue during the 11th and 12th years. If the start of a new block occurred during that time, the grace period would be triggered and an interim relief provided. Otherwise, when the abundance estimate is agreed in the 13th year after the last survey was conducted, the fact that the survey actually took place eight years after the last agreed estimate would reset the clock so that the next deadline would be the 18th year, and a grace period would have been averted.

Tables 1 and 2 illustrate several scenarios about how strike limits might evolve with varying survey intervals and grace periods. In these tables, it is assumed for simplicity that the *Strike Limit Algorithm* would output a six-year block strike limit (SL) each time. For the sake of simplicity, carryover is ignored in these tables.

Five different scenarios (A-E) are shown in Tables 1 and 2. These tables cover more than four quota blocks (boxes), with surveys (Surv), abundance estimates (Est) and the establishment of block strike limits (SL) scheduled by year (Yr), The 'Clock' counts the number of years remaining before a survey will thereafter be overdue. Thus, when the clock set by the most recent estimate is negative, a survey is overdue and when a grace period quota is required an interim relief strike limit (IASL) is set.

Scenario A in Table 1 illustrates a situation with regular 8-year survey intervals and estimates two years later. Each strike limit is set using a timely survey; no surveys are overdue and no grace periods are required. Note that in year 13, a block strike limit is set using the survey from year 4. Although the more recent survey (year 12) has occurred, the corresponding abundance estimate has not yet been computed. Scenario B represents an unproblematic case with 10-year survey intervals.

Scenarios C and D illustrate cases where the grace period is invoked in year 13. In Scenario C, immediate revision of the interim relief strike limit (IASL) is assumed and an updated strike limit (USL) is computed. Scenario D presents the same schedule of surveys and estimates, but when the grace period is invoked, the IASL is retained for the entire block, with the year 12 survey first being used in year 19.

Scenario E illustrates that it is possible that surveys could be more than 10 years apart (in this case, 13 years) without triggering the grace period.

Appendix 9

SCIENTIFIC ASPECTS OF AN ABORIGINAL WHALING SCHEME

The Scientific Committee's Aboriginal Whaling Management Procedure (AWMP) applies stock-specific *Strike Limit Algorithms* (*SLA*s) to provide advice on aboriginal subsistence whaling (ASW) strike/catch limits.

ASW management (as part of an AWS, the aboriginal whaling scheme) incorporates several components, several of which have a scientific component:

(a) *Strike Limit Algorithms* (case-specific) used to provide advice on safe catch/strike limits;
(b) operational rules (generic to the extent possible) including carryover provisions, block quotas and interim relief allocations;
(c) Guidelines for *Implementation Reviews*; and
(d) Guidelines for data and analysis (e.g. guidelines for surveys, other data needs)

The scientific components are considered below.

1. CARRYOVER

Carryover is a provision to enable (some) strikes not used in one year to be used in a subsequent year or years, in order to allow for the inevitable fluctuations in the success of hunts (e.g. due to environmental conditions and/or whale availability). Whilst providing flexibility, carryover does not allow hunts to take more than the total number of strikes agreed by the Commission. This flexibility may produce additional benefits for the local management of the hunt. The concept is not new and *ad hoc* provisions incorporating carryover have been included in the Schedule for many years (see the summary provided in IWC, 2018b, p.169-72). As general guidance, the Commission has (in 2001 and 2016), approved examination by the Committee of scenarios incorporating a 50% interannual variation within blocks and 50% allowance to the next block, noting that this did not imply any commitment by the Commission that these values would be used in the Schedule.

1.1 The Committee's role

The Scientific Committee's role is not to recommend a particular carryover approach but rather to provide advice on the conservation and need performance of carryover options when asked by the Commission or ASW countries. Formal evaluation of the performance of options (see Item 1.2) by the Committee will allow a more consistent approach to carryover across hunts. The Committee's evaluation began in the year 2000 as the Committee began to develop its first recommended components of an AWS (IWC, 2001, p.18).

1.2 Examining conservation performance

The Committee examines the conservation performance of options using the same simulation testing approach used to develop *SLA*s. This allows the Committee to provide guidance as to the acceptable limits within which carryover provisions can be developed. In requesting guidance on carryover provisions, at least the following information should be provided by ASW countries or the Commission:

(a) an initial start date for the provision (e.g. 2003, start of new block);
(b) an expiration period (unused strikes cannot be carried over indefinitely); and
(c) limits on use (e.g. the maximum number of strikes allowed in any one year).

1.3 Additional provision

The Committee's *Implementation Review* process (see section 4 below) includes the monitoring of carryover provisions. Should new information (e.g. abundance data) lead an *SLA* to indicate a severe decrease in the quota then this will trigger an appropriate review of the existing carryover provisions and any implications for conservation performance. If necessary, the review may lead the Committee to recommend changes in carryover provisions that may, for example, result in a 'reset' of the starting year or other amendments to carryover provisions.

1.4 Schedule language

The Committee advises that the incorporation of carryover provisions in the Schedule should avoid ambiguity. Rather than try to encode general provisions in the Schedule, the Committee offers to assist the Commission in by providing the actual numbers for each hunt in a new quota block, based upon agreed general provisions.

1.5 Example

A request from the USA and Denmark/Greenland was to

> '…allow for the carry forward of unused strikes from the previous three blocks, subject to the limitation that the number of such carryover strikes used in any year does not exceed 50% of the annual strike limit'.

This request was tested using the *Bowhead SLA* (applicable to the Bering-Chukchi-Beaufort Seas stock) and the *WG-Humpback SLA* (applicable to West Greenland) and three types of options were examined:

(1) baseline case – all strikes taken annually (i.e. no need for carryover);
(2) 'frontload' case – strikes taken as quickly as possible within block (+50% limit annually until the block limit is reached); and
(3) two alternative scenarios where carryover strikes are accrued for one or three blocks, followed by a period of carryover usage subject to the +50% limit.

The three-block scenario considered in (3) served as a direct test of the provision described in the request of USA and Denmark/Greenland. The Committee agreed that the Commission's conservation objectives were met for both *SLA*s for all of the options above and would also be met for a proposal carrying forward strikes from the previous two blocks.

2. BLOCK QUOTAS

The Committee has advised the Commission (in the context of moving to biennial meetings) that block quotas of up to 8 years are acceptable (IWC, 2013, p.22), noting the requirement for abundance estimates every ten years (see Item 3).

3. INTERIM RELIEF

A variety of factors, including environmental conditions, beyond the control of the hunters may prevent the completion of a successful whale population abundance estimate. While recognizing such difficulties, the Committee notes that uncurtailed aboriginal whaling quotas cannot be continued indefinitely in the long-term absence of data. Therefore, the AWS must address what should be done in the event that efforts to obtain an agreed abundance estimate are unsuccessful after some time limit. For the purposes of applying AWMP *Strike Limit Algorithms*, the Committee has agreed that this limit is 10 years (IWC, 2016).

A third quota block begun after the 10-year limit has expired is termed a 'grace period' and the Committee has endorsed the use of an 'interim allowance', namely a grace period strike limit equal to the limit produced by the applicable *Strike Limit Algorithm*, without reduction, for a single block. This approach has been simulation tested for B-C-B bowheads and WG humpbacks to confirm that it meets the conservation and need satisfaction goals of the Commission (IWC, 2016, p.190-3, p.471-84; 2017a, p.498) and the results are summarised in IWC (2017b; 2018a, p.159). It will be tested for eastern NP gray whales at the next *Implementation Review* for that stock. Testing for the remaining ASW stocks will be added to the future workplan of the Committee.

The 10-year survey interval requirement is complicated by the fact that (a) there will usually be a delay between when a survey is conducted and when the resulting abundance estimate is agreed by the Committee and (b) because surveys, estimates and quota blocks need not be synchronised, as recognised in IWC (2003). For the sake of counting years between surveys, a survey is not considered to have occurred until the resulting abundance estimate is agreed. At that point, the 10-year time window is deemed to have begun in the year during which the survey was conducted. Further details and examples are given in IWC (2018a).

The Committee recommends that, during the grace period, a new strike limit is established immediately a new abundance estimate is agreed. this approach. However, it notes that if the Commission refrains from updating the strike limit until the grace period expires, this would not pose a conservation risk. If the strike limit is updated during a grace period block, the number of strikes taken to that point of the grace period should be subtracted from the updated quota, with the remainder being the strike limit for the rest of the grace period. Carryover is not affected.

The Committee emphasises that the interim allowance approach is intended to be applied only in the event that exceptional unforeseen circumstances had delayed obtaining an agreed abundance estimate beyond the end of the second quota block. It should not be interpreted as a routine approach for extending quotas for a third block without a concerted effort to obtain a successful survey prior to that time. Furthermore, the Committee would not recommend two consecutive interim allowances.

It is important to consider a scenario in which no acceptable abundance estimate is obtained by the end of the grace period. *SLA*s are not designed or intended to be applied if new abundance data are not forthcoming after such a long period. Given good faith efforts to obtain an abundance estimate, such a situation would probably have arisen from profound and unexpected environmental change (e.g. related to climate or a disaster such as a massive oil spill). Under such circumstances, an immediate *Implementation Review* (see Item 4.1.2) would probably have been initiated, irrespective of the timing of (un)successful surveys and quota blocks. As soon as it becomes apparent that an abundance estimate may not be obtained in time, researchers should immediately begin to develop alternative approaches to obtaining abundance estimates (or at least indices of abundance) that do not depend on the problematic circumstances. Nevertheless, if no abundance estimate is available the year before the end of the grace period, the Scientific Committee should immediately initiate an *Implementation Review*. The approach of the Committee in the absence of positive alternative evidence would be that the Committee could not provide advice on the quota using the *SLA* and the Commission should exercise great caution when agreeing any further strike limits. The level of caution will depend on the specifics of the situation.

4. *IMPLEMENTATION REVIEWS*

The concept of an *Implementation Review* is central to the functioning of the AWMP. The primary objectives of an *Implementation Review* are to:

(1) review the available information (including biological data, abundance estimates and data relevant to stock structure issues) to ascertain whether the present situation is as expected (i.e. within the space tested during the development of a *Strike Limit Algorithm* (*SLA*)) and determine whether new simulation trials are required to ensure that the *SLA* still meets the Commission's objectives; and
(2) to review information required for the *SLA*, i.e. catch data and, when available at the time of the *Review*, new abundance estimates (note that this can also occur outside an *Implementation Review* at an Annual Meeting).

4.1 Timing of *Implementation Reviews*

4.1.1 Regular Implementation Reviews

Implementation Reviews are undertaken regularly, normally every five to six years. This does not have to coincide with the renewal of catch/strike limits in the Commission. For logistical and resource reasons, only one major *Implementation Review* shall be undertaken at a time. The Committee shall begin planning for the *Review* at the Annual Meeting at least two years before the Annual Meeting at which the *Review* is expected to be finished. This is to enable the Committee to schedule additional work or Workshops if it believes that new information or analyses are likely to be presented that will necessitate the development of new simulation trials. Early planning will enhance the likelihood that the Committee will complete an *Implementation Review* on schedule. It is not expected that every *Implementation Review* will entail a large amount of work.

4.1.2 Special Implementation Reviews

In addition to regular *Implementation Reviews*, under exceptional circumstances the Committee may decide to call for special *Implementation Reviews,* should information be presented to suggest that this is necessary and especially if there is a possibility that the Commission's conservation objectives may not be met.

Calling such a *Review* does not necessarily mean revising the Committee's advice to the Commission, although it may do so. The Committee has not tried to compile a formal comprehensive list of what factors might trigger' such an early review, which implies unexpected/unpredictable factors. However, the following list is provided to give examples of some possible factors.

(1) Major mortality events (e.g. suggested by large numbers of stranded animals).
(2) Major changes in whale habitat (e.g. the occurrence of natural or anthropogenic disasters or changes, an oil spill, dramatic change in sea-ice, development of a major oil/gas field, etc.).
(3) Major ecological changes resulting in major long-term changes in habitat or biological parameters.
(4) A dramatically lower abundance estimate (although the *SLA* has been tested and found to be robust to large sudden drops in abundance, the Committee would review the potential causes of unexpected very low estimates).
(5) Information from the harvest and hunters (this might include very poor harvest results, reports of low abundance despite good conditions, reports of large numbers of unhealthy animals).
(6) Changes in biological parameters that may result in changes to management advice (e.g. reproduction, survivorship).
(7) If there are cases when need is not being satisfied, strong information that might narrow the plausibility range and allow an increase in block limits.

4.1.3 Outcomes of Implementation Reviews

There are a number of possible conclusions of *Implementation Reviews*:

(1) there is no need to run additional trials and that the existing *SLA* is acceptable;
(2) the results from the additional trials developed and run reveal that the existing *SLA* is acceptable;
(3) there is no need for any immediate additional trials or changes to management advice but work is identified that is required for consideration at the next *Implementation Review*; or
(4) the results of the additional trials require the development of a new (or modified and then retested) *SLA* in which case management advice will have to be reconsidered until that work is complete.

4.1.4 Data availability

Implementation Reviews fall under the Committee's Data Availability Agreement Procedure A (IWC, 2004). By the time of the Annual Meeting prior to that at which the *Implementation Review* is expected to be completed, the scientists from the country or countries undertaking the hunts, or others intending to submit relevant analyses, shall develop a document or documents that explains the data that will/could be used for the *Implementation Review*. Such a document will:

(a) outline the data that will be available, including by broad data type (e.g. sighting data, catch data, biological data): the years for which the data are available; the fields within the database; and the sample sizes;
(b) provide references to data collection and validation protocols and any associated information needed to understand the datasets or to explain gaps or limitations; and
(c) where available, provide references to documents and publications of previous analyses undertaken of data.

The data themselves shall be available in electronic format one month after the close of that Annual Meeting.

In the case of complex *Implementation Reviews* that may last more than one year and involve one or more workshops, new data can be submitted, provided that the data are described and made available at least nine months before the Annual Meeting at which the *Implementation Review* is expected to be completed.

4.1.5 Computer programs

Programs used in analyses submitted to the *Implementation Review* may be requested by the Committee, who may decide that the programmes need independent validation in accordance with its guidelines at the time. All *SLA* simulation testing and evaluation software shall be undertaken by the Secretariat using validated programmes.

5. GUIDELINES FOR SURVEYS

The Committee's general advice on surveys is applicable. Some more specific considerations are given below.

5.1 Survey/census methodology and design

Plans for undertaking a survey/census should be submitted to the Scientific Committee in advance of their being carried out, although prior approval by the Committee is not required. This should normally be at the Annual Meeting before the survey/census is carried out. Sufficient detail should be provided to allow the Committee to review the field and estimation methodology. Considerably more detail would be expected if novel methods are planned.

5.2 Committee oversight
Should it desire, the Scientific Committee may nominate one of its members to observe the survey/census to assess the scientific integrity of the process.

5.3 Data analysis and availability
Data to be used in the estimation of abundance will be made available to the Committee in accordance with Procedure A of the Data Availability Agreement (IWC, 2004). If new estimation methods are used in the data analysis, the Committee may require that computer programs (including documentation to allow such programs to be validated) be provided to the Secretariat for eventual validation.

5.4 Estimates to use in the *SLA*
The most recent estimate(s) accepted by the Committee for any year(s) should be incorporated in the *SLA* calculations. If there is more than one accepted estimate for a given year and the Committee agrees that the estimates are based on sufficiently independent data, then both estimates should be incorporated in the *SLA* calculations. If a revised estimate is obtained for a particular year, then the old one should be replaced before the *SLA* is next used.

6. GUIDELINES FOR DATA/SAMPLE COLLECTION

The Schedule states that data from each harvested animal should be collected and made available to the IWC. The following information should normally be provided for each harvest or individual whale as appropriate:

(1) species;
(2) number of animals;
(3) sex;
(4) season;
(5) location of catch (at least to the nearest village); and
(6) length of catch (to 0.1m).

The Committee recognises the importance of additional information, especially in the context of *Implementation Reviews* e.g. on reproductive status and health. It highlights the importance of collecting tissue samples for genetic studies in accordance with guidance provided by the Committee (e.g. *https://iwc.int/index.php?cID=60&cType=document*), especially in the context of stock structure issues. It notes that photo-identification data can be valuable for estimating biological parameters, assessing anthropogenic injuries, and encourages such research where possible. The value of traditional knowledge is also noted, and such information can also provide valuable input to conducting *Implementation Reviews*.

6.1 Revisions to the AWS
Revisions or additions to this AWS may be recommended by the Committee at any time, including during *Special Implementation Reviews*.

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