

Annex E

Report of the Standing Working Group on the Aboriginal Whaling Management Procedure

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1. INTRODUCTORY ITEMS

1.1 Convenor's opening remarks

Donovan welcomed the participants to the meeting. There had been a successful intersessional Workshop held in Copenhagen from 27-29 March 2009 (SC/61/Rep5) that focussed primarily on the development of an assessment method for common minke whales off West Greenland and consideration of abundance estimates for fin and common minke whales off West Greenland. The relevant aspects of that workshop are discussed under the appropriate agenda items below. He noted that the two days of pre-meeting had involved very technical discussions of the details of the two approaches to the sex ratio method for assessing common minke whales off West Greenland. These discussions were reported to the SWG under Item 2.1 and the work would be presented to (and continued within) the SWG. As the abundance estimates for eastern gray whales were not available, then little time was needed for the *Implementation Review* for gray whales (see Item 9) which would be postponed until 2010. Given this he noted that documents SC/61/AWMP1-3 would be discussed only within the sub-committee on bowhead, right and gray whales.

1.2 Election of Chair

Donovan was elected Chair.

1.3 Appointment of rapporteurs

Punt and Zeh were appointed rapporteurs with assistance from the Chair.

1.4 Adoption of Agenda

The adopted Agenda is shown in Appendix 1.

1.5 Documents available

The documents considered by sub-committee were SC/61/AWMP4-7 and SC/61/Rep5.

2. COMMON MINKE WHALES OFF WEST GREENLAND

2.1 Further discussion of sex ratio method

The Committee has been evaluating assessment methods for common minke whales off West Greenland that rely on the relationship between the observed sex ratio of catches and that inferred from population models parameterised in terms of carrying capacity, productivity, and how the distribution of males may have changed relative to that of females. This concept was introduced in 2005 (IWC, 2006; Witting, 2005). The major factor which suggests that sex-ratio data may be informative about population size is that catches have consistently been female-dominated. The broad lack of change in the catch sex-ratio for minke whales off West Greenland over time suggests that past catches have not markedly impacted this population of minke whales. This approach has not been used before within the Scientific Committee and developing the methods has involved considerable innovative thought and work to reach this stage of its potential implementation. Nonetheless, at this stage the SWG is still at the stage of determining whether it can be used in practice. The SWG's discussions thus far can be found in the reports of the SWG and intersessional workshops (IWC, 2006; 2007; 2008; 2009a; 2009c) and two teams of developers have been working: Witting and Schweder (Witting, 1997; 2006; Witting *et al.*, 2009; Witting and Schweder, 2008a; 2008b; 2009) and Brandão and Butterworth (Brandão and Butterworth, 2008; 2009). A number of priority topics for work to be undertaken before the present meeting were identified in (IWC, 2009b, pp. 21) and these were initially addressed at the intersessional workshop (SC/61/Rep5).

It has been agreed (IWC, 2009, pp. 21) that three (of an original six) models should form the focus for intersessional work (Fig. 1):

- (1) West Greenland is divided into two strata (NW+CW and SW), the data for the NW+CW and SW strata are included separately in the likelihood function, and allowance is made for time-dependent exchange of females and males between the NW+CW and SW strata (the 'Closed' model¹).
- (2) West Greenland is divided into two strata (NW+CW and SW), the data for the NW+CW and SW strata are included separately in the likelihood function, and the parameter determining the fraction of males in the SW stratum is assumed to change over time (the 'Influx' model).
- (3) The animals in the NW+CW and SW strata exhibit site fidelity. For computational simplicity, this model is implemented by treating the animals in the NW+CW and SW strata as separate populations (the 'Site Fidelity' model).

The Committee has been developing frequentist methods for estimating the lower 5% confidence bounds for key model outputs: carrying capacity, K , population size in 2007, N_{2007} and population depletion N_{2007}/K . Two implementations of each of the models have been made, although these two implementations have been based on somewhat different assumptions. SC/61/Rep 5 and meetings between Witting, Butterworth and Brandão have refined the specifications of these models so as to increase consistency, check that when the same assumptions are made the code implementing the models produces the same answers, and finalise the specifications of the approach for computing lower 5% bounds.

¹ The models have also been referred to by the numbers assigned to them in (IWC, 2009c): 148; respectively 3, 4b and 5 in papers. However, for clarity, the SWG agreed to use the descriptive names throughout this report.

Model	3	4b	5	
			<p>Closed . West Greenland is divided into two strata (NW+CW and SW), the data for NW+CW and SW strata are included separately in the likelihood function, and separate (and time-invariant) values for the parameters determining the degree of sex imbalance are estimated for each stratum. Allowance is made for time-dependent exchange of females and males between the NW+CW and SW strata.</p> <p>Influx . As for 'closed', except that there is no time-dependent exchange; rather the fraction of males in the SW stratum is assumed to change over time (or as a function of temperature).</p> <p>Site fidelity . The animals in the NW+CW and SW strata exhibit site-fidelity. For computational simplicity, this model is implemented by treating the animals in the NW+CW and SW strata as separate populations.</p>	
Data used	NW+CW, SW	NW+CW, SW	NW+CW, SW	
Estimable parameters	$v; \alpha^m, \alpha^f, \beta^m, \beta^f$	$v_1, v_2(t)$	v_1 (popn 1) v_2 (popn 2)	v determines the degree of sex imbalance α, β determines how v changes over time

Fig. 1. Sex-ratios models for common minke whales off West Greenland.

SC/61/AWMP7 applied the methodology advanced by Brandão and Butterworth (2008; 2007) for simulating catch sex sampling data in the process of computing lower confidence bounds for the abundance of the West Greenland minke whale population to the modelling scenarios developed at the IWC Workshop on Greenlandic Fisheries (IWC, 2009a, pp. 409), also taking account of suggestions made in SC/61/Rep5. Calculations were performed for MSYR values of 1% and 2%, and were implemented for the three models described above. For the site fidelity model, the SW stratum is treated as an independent stock, and the MLE of pre-exploitation abundance K is finite, so that standard likelihood profile estimates of lower confidence bounds for abundance were provided. An overdispersed Poisson and an overdispersed binomial likelihood formulation were considered.

SC/61/AWMP5 updated the Witting and Schweder model for the sex-ratio assessment of minke whales off West Greenland according to the guidelines in SC/61/Rep5. The updated model included a new and improved optimization routine based on gradients (The DFPMIN routine in Press *et al.*, 1986), and a likelihood estimator and data generation process based on the over-dispersed binomial distribution agreed upon in SC/61/Rep5. It estimated the degree of over-dispersion in all parameter optimizations, and it was shown that the simulated data of the model adequately captured the amount of sex ratio variation in the original data. There were still convergence problems for the closed model, and a new version of the closed model that solved this problem was introduced. This model had only one extra parameter relative to the influx model, while the old version of the closed model had two extra parameters. The frequency of non convergence for the optimizations on the simulated data was generally low (0-3%) although it was up to 5% in some cases. This problem, however, was largely solved at the present meeting resulting in optimizations with convergence problems in less than 0.1% of the cases.

The SWG noted that the management-related outcomes in SC/61/AWMP5 and SC/61/AWMP7 were markedly different even though considerable progress has been made towards making the two approaches as comparable as possible. The SWG therefore established a small group to identify the differences between the implementations of the influx model between SC/61/AWMP5 and SC/61/AWMP7, to determine which of these differences is most consequential in terms of the differences in the model outputs and make recommendations for further analyses. The report of this group is provided as Appendix 2. The SWG thanked the members of the small group for what was a considerable amount of work that made the deliberations of the SWG substantially easier.

The SWG was concerned that the SC/61/AWMP7 model for generating data sets led to less variation than the seemingly very similar SC/61/AWMP5 model. Further analysis based on simulations (Appendix 3) revealed that the two generation models lead to essentially identical distributions of total catch by sex, but that these models differ in terms of the generated distributions of sampled (i.e. sexed) catches by sex. Moreover, Appendix 3 shows that the generation model of SC/61/AWMP7 leads to lower standard deviations of catch by sex, with the extent to which the standard deviations being lower when the fraction of the catch that is unsexed is increased.

The SWG evaluated the recommendations from the small group and the results in Appendix 3 and agreed that:

- (1) A lower bound of 1 should be imposed on the overdispersion parameters (to avoid the possibility of estimated 'underdispersion')
- (2) The overdispersion parameters should be estimated whenever the model is fitted (i.e. both to the actual and the simulated data sets).
- (3) The optimisation scheme on which SC/61/AWMP7 is based is to be preferred because: (a) it is based on well-established software (AD Model Builder), (b) it is faster and fails to converge less often than the optimization scheme on which SC/61/AWMP5 is based, and (c) when differences in optimisation results between the SC/61/AWMP5 and SC/61/AWMP7 optimization methods have been found, the SC/61/AWMP7 optimization method obtained the lower value for the negative log-likelihood function.
- (4) The simulated data sets used to calculate the distributions for the deviance should be generated setting the values for the overdispersion parameters equal to those corresponding to $K=200,000$ (as agreed by IWC, 2009c, pp. 148).

- (5) Allowance should be made for uncertainty in the sex ratios of the catches for years when none of the actual catches were sampled for sex.
- (6) The simulated data sets should be based on the generation model of SC/61/AWMP5, primarily because the variability in the simulated data sets matches that in the actual data relatively well (Table 4 of SC/61/AWMP5) whereas previous analyses ((Brandão and Butterworth, 2007) have shown that the generation model of SC/61/AWMP7 leads to less variable data sets than the original data set.

The SWG recognised the importance of fully evaluating any new and novel approach for conducting assessments. It therefore appointed a small group to outline ways in which the robustness of the sex-ratio approach can be evaluated. The report of the small group is provided as Appendix 4. The SWG **endorsed** the recommendations of the small group and considered the specific calculations which should be conducted. The SWG identified the four types of calculations below:

- (1) Retrospective analyses (dropping off years of data one by one starting from the most recent year (for the 10 most recent years)).
- (2) Assessments based on different models (Closed, Site Fidelity, Influx) and MSYR rates.
- (3) Simulations based on different population models.
- (4) Model-free simulations (i.e. adjustment of existing data).

In relation to the simulations, the SWG **agreed** that the simulation-based approach to calculating lower 5% confidence bounds should be used even when it is possible to calculate confidence intervals without simulation, to ease the computational burden of the calculations. It also **agreed** that the model-free data sets (early Greenland, late-Greenland-north; late-Greenland-south) would be generated by changing the slope and mean sex-ratio of the data sets, but that the extent of variation in the data sets (characterised by the extent of overdispersion) and the sample sizes by year would be set to those in the actual data.

The SWG considered a preliminary set of robustness trials (Tables 1 and 2) and assigned each trial a priority ranking for intersessional work. The SWG noted that the values in Tables 1 and 2 (particularly those for K and the slopes in mean sex-ratio) were preliminary and may need to be refined once initial results are available. It noted that the intent of the values for K in Table 1 was that a range of stock status levels would be examined in the simulations.

Table 1. An initial list of robustness tests based on population models (unless specified otherwise the estimator should match the population model used to generate the data).

Case	Population model	K^1	Overdispersion	MSYR	Other	Priority
1	Influx	150,000	Estimated	2%		1
2	Closed	150,000	Estimated	2%		1
3	Model 5	150,000	Estimated	2%		2
4	Influx	75,000	Estimated	2%		2
5	Influx	50,000	Estimated	2%		2
6	Influx	20,000 ¹	Estimated	2%		1
7	Influx	150,000	Estimated	2%	Closed estimator	1
8	Closed	150,000	Estimated	2%	Influx estimator	1
9	Influx	150,000	2 x Estimated	2%		1
10	Influx	150,000	1	2%		2
11	Influx	150,000	Estimated	1%		1
12	Closed	150,000	Estimated	1%		2
13	Influx	150,000	Estimated	2%	+ 20 ys extra data	2
14	Closed	150,000	Estimated	2%	+ 20 ys extra data	2

¹ - To be reviewed once initial results are available.

Table 2. Specifications for the model-free robustness tests (separately for each data set and for all data sets at the same time).

Case	Slope	Mean	Priority
1	Unchanged	Unchanged	1
2	+0.05	Unchanged	2
3	-0.05	Unchanged	1
4	Unchanged	+0.05	2
5	Unchanged	-0.05	1

The SWG **agreed** that since the intention is that the ultimate goal is to use this approach for providing management advice, the assessment calculations and robustness evaluations should be conducted by the Secretariat. This will require the Secretariat to develop code (based on the current versions of the sex-ratio method) which implements the estimation methods, given the specifications for these methods and the decisions regarding the configuration of these methods outlined above, as well as code which allows the robustness tests to be conducted. The SWG recognised the past difficulty that the Committee has had specifying simulation tests and **agreed** that an intersessional workshop with Terms of Reference to refine the specifications and implementation of the assessment methods and robustness tests should be included in the budget. The importance of such a workshop will depend on whether the Intersessional Steering Group (see below) is able to resolve any key problems or not. In this respect, the SWG identified that the Secretariat should first implement trial 1 in Table 2 and trial 3 in Table 2, as these should allow major problems with the specifications to be identified.

The SWG established an Intersessional Steering Group (Donovan (convenor), Allison, Butterworth, Brandão, Punt, Schweder, Witting) to guide the intersessional work and to decide (and if necessary organise) an intersessional workshop.

The SWG considered whether the specifications of the closed model (see Appendix 5 for the current implementations of this model) should be modified to reduce the apparent parameter confounding. There was insufficient time to fully evaluate a newly-proposed version of the closed model (Appendix 6). This version could be explored further during the intersessional period and perhaps subjected to the robustness tests selected by the SWG if it is to be considered for adoption at the 2010 Annual Meeting.

In conclusion, the SWG **agreed** that considerable progress had been made during the meeting to overcome the technical difficulties related to the specification and implementation of sex-ratio-based methods of assessment. The SWG now has a method which is sufficiently well-developed that it can be evaluated using simulation testing. Completion of this testing is the goal of the SWG for the next Annual Meeting.

2.2 Other new information

2.2.1 Abundance

SC/61/AWMP4 reported on an aerial line transect survey for common minke whales conducted off West Greenland in August-September 2007. A total of 8,670 km of survey effort covered 14 strata in sea states <5 with a total stratum area of 213,996 km². The 27 sightings of minke whales were all within a strip width of 300m and the average time from first detection to when the sighting passed abeam was 1.7 sec. Due to the uniform and narrow distribution of the detections, strip census methods were used to analyse the survey. Two methods were deployed to correct the strip census estimates for whales missed by the observers and whales that were submerged during the passage of the plane.

At the intersessional workshop (SC/61/Rep5, Item 2.1) concern had been expressed that the two methods produced substantially different abundance estimates. The Workshop had recommended further investigation of the most appropriate way to address availability bias (i.e. the negative bias associated with the fact that some whales were submerged during the passage of the plane and thus not available to be seen by observers) and to adjust for this bias in the abundance estimate. The Workshop had agreed that both methods for correcting the strip census estimates were worthy of further investigation, and SC/61/AWMP4 considered both, applying them to sightings at sea states <3 (n=22) rather than to all sightings (n=27).

Method 1 included all 22 detections and obtained an uncorrected estimate of 1,866 (CV=0.30). A simple mark-recapture estimate was used to correct for whales at the surface missed by observers, resulting in a partially corrected estimate of 1,904 (CV=0.31). The correction for availability bias was based on 39 sequences of aerial photographs of surfacing and/or diving minke whales in Faxaflói Bay, Iceland. The photographs were taken, on average, 2.6 sec apart. The adjustment for availability bias obtained from these photographs resulted in a fully corrected abundance estimate of 17,307 (95% CI 7,628 to 39,270) minke whales.

Method 2 used only the 14 detections of minke whales that were observed to break the surface for the uncorrected estimate (1,208 with CV=0.36) and the partially corrected estimate of whales at the surface (1,233 with CV=0.37). The restriction to whales observed to break the surface was because the adjustment for availability bias in Method 2 was based on readings from satellite-linked recorders that could only occur when the whales were above the surface and the transmitters were dry. The fully corrected abundance estimate from Method 2 was 22,952 (95% CI 8,444 to 62,383).

There was some discussion within the SWG regarding the elimination of sea states 3 and 4 from the analyses; these sea states accounted for a third of the effort and 5 of 27 sightings. It was noted that (a) minke whales were more difficult to detect at sea states 3 and 4 than at sea states 1 and 2 and (b) the model used for analyses could not take into account sea state. It was also noted that the restriction matches up with the photographic data used to correct for availability bias in Method 1. Gunnlaugsson noted that Method 1 estimates included sightings of submerged whales as well as those that broke the surface. As submerged animals were harder to detect, the Method 1 estimates were more affected by heterogeneity in detection probabilities, leading to more negative bias in the abundance estimate. Thus he considered it not surprising that the Method 1 estimate was somewhat lower than the Method 2 estimate. Heterogeneity would upwardly bias the average forward detection distance and so negatively bias both abundance estimates.

Method 1 and Method 2 estimates in SC/61/AWMP4 were not substantially different. Discussion focused on which estimate was most appropriate to use for management purposes. The CI for both estimates were wide, reflecting the inclusion of the variance of forward detection time in the variance of the abundance estimate. However, the Method 1 estimate was more precise. It was based on more sightings, and the Method 1 photographic data used to correct for availability bias, although they included fewer surfacings than the corresponding Method 2 data, represented more whales than the five with satellite transmitters used for Method 2.

The SWG **agreed** that both methods were acceptable and encouraged the collection of telemetry data from more whales to strengthen the use of Method 2. On balance, the SWG concluded that, because the Method 2 estimate was less precise and involved extrapolation from a smaller number of survey sightings and a smaller number of whales contributing to the correction for availability bias, the Method 1 estimate, even though it might be more negatively biased, was the best estimate to use for management. The SWG therefore **recommended** the estimate of 17,307 (95% CI 7,628 – 39,270).

2.3 Management advice

2.3.1 Summary of previous season's catch data

The number of common minke whales struck from this stock shall not exceed 200 in each of the years 2008-2012, except that up to 15 strikes can be carried forward. A total of 146 common minke whales were landed in West Greenland (86 females; 55 males; 5 unidentified sex) and 5 were struck and lost during 2008 (SC/61/ProgRepDenmark). No information was available on the number of genetic samples taken from the harvested whales at this time. The SWG **recommended** that this information, along with any updated information on sex of the animals caught, be provided to the Secretariat.

2.4.2 Management advice

Last year, the Committee agreed an approach for providing interim management advice and this was confirmed by the Commission. It had agreed that such advice could be used for up to two five-year blocks whilst SLAs were being developed (IWC, 2009). Based on the application of the agreed approach (IWC 2009), and the lower 5th confidence interval for the 2007 estimate of abundance, 8,918), the SWG **agreed** that an annual strike limit of 178 will not harm the stock.

2.4 Progress with SLA Development

In recent years, the SWG has focused on the development of the sex-ratio method as a basis for providing management advice. Development of an SLA for the West Greenland minke whales will become a high priority topic for the future work of the SWG once this development work is completed. The SWG noted that the development of an SLA requires a 'need envelope' (e.g. see reference). The SWG **encourages** the Chair of the SWG to discuss this matter with the relevant delegation (Denmark and Greenland) as had been done previously with relevant delegations for the *Bowhead* and *Gray Whale* SLAs and report back next year.

3. FIN WHALES OFF WEST GREENLAND

3.1 Abundance estimates

3.1.1 Summary of discussions at intersessional workshop

The 2nd Intersessional AWMP Workshop on Greenlandic Fisheries (SC/61/Rep5) reviewed an analysis of the results of aerial line transect survey of fin whales conducted off West Greenland in 2007 (Heide-Jørgensen *et al.*, 2009). The revisions were made in response to past comments by the SWG. Results were presented in Heide-Jørgensen *et al.* (2009) based on conventional distance sampling (CDS) techniques and mark recapture distance sampling (MRDS) techniques. The Committee had previously recommended the CDS approach pending clarifications on some matters. The Workshop focused on comparisons between the CDS and MRDS approaches and which estimate should be recommended for use in assessments.

The Workshop focused on how pod size is incorporated. In the CDS analysis, the mean pod size is estimated by averaging over all strata, while in the MRDS analysis, mean pod sizes differ between strata. This is important for the MRDS analysis because there was a very large aggregation in one stratum. Despite the greater sample size for the MRDS, the Workshop concurred with the earlier view of the Committee that the amount of data available to support the approach was too limited and consequently recommended that the estimate of 4,359 whales with 95% confidence interval 1,879-10,114 should be used for the purpose of assessment.

3.1.2 Updated estimate

The SWG concurred with the Workshop conclusion that the CDS estimate of 4,359 fin whales (95% CI 1,879 to 10,114) was the best estimate and **recommended** that it be used for the purpose of assessment. It noted that this estimate was negatively biased because no correction was applied for whales submerged during the passage of the survey plane.

3.2 Management advice

3.2.1 Summary of previous season's catch data

A total of 11 (8 males; 3 females) fin whales were landed, and 5 struck and lost, in West Greenland during 2008 (SC/61/ProgRepDenmark). No information was available on the number of genetic samples taken from the harvested whales. The SWG **recommended** that this information be provided to the Secretariat when it becomes available.

3.2.2 Management advice

In 2007, the Commission agreed to a quota (for the years 2008-2012) of 19 fin whales struck off West Greenland. Last year, the Committee agreed an approach for providing interim management advice and this was confirmed by the Commission. It had agreed that such advice could be used for up to two five-year blocks whilst *SLAs* were being developed (IWC, 2009). Based on the application of the agreed approach (IWC 2009), as last year, the SWG **agreed** that an annual strike limit of 19 whales will not harm the stock.

3.3 Progress with *SLA* development

SC/61/Rep5 noted that simulation evaluation of *SLAs* requires the development and parameterisation of a set of operating models. It agreed that the set of trials developed to evaluate variants of the *CLA* for North Atlantic fin whales and those used last year to compare alternative methods for providing interim management advice are an appropriate starting point for developing trials for this case. The trials for the North Atlantic fin whales were focused on the areas likely to be subject to whaling off Iceland. These trials will need to be modified to focus more on the uncertainties pertinent to West Greenland if they are to form the basis for evaluation of *SLAs* for fin whales. The Workshop recommended that a short working paper on appropriate operating models for West Greenland fin whales be presented to the SWG in Madeira. Given the heavy workload and priority allocated to the work on the sex ratio method for common minke whales (Item 2 above), there had not been time to develop such a paper for this year's meeting. The SWG **reiterates** the Workshop recommendation that a short working paper on appropriate operating models for West Greenland fin whales be presented to the SWG at next year's meeting.

4. COMMON MINKE WHALES OFF EAST GREENLAND

4.1 Review of new information

One female common minke whale was struck (and landed) off East Greenland in 2008 (SC/61/ProgRepDenmark). The SWG noted that catches of minke whales off East Greenland are believed to come from the much larger Central stock of minke whales and that a survey that included strata off East Greenland had been conducted during 2007 (SC/61/RMP12).

4.2 Management advice

In 2007, the Commission agreed to an annual quota of 12 minke whales from the stock off East Greenland for 2008-2012, which the Committee stated was acceptable in 2007. The present strike limit represents a very small proportion of the Central Stock (see Table 3). The SWG **agreed** that the present strike limit would not harm the stock.

Table 3

Most recent abundance estimates for minke whales in the Central North Atlantic.

Small Area(s)	Year(s)	Abundance and CI / 95% CI
CG, CIP	2001	23,592 (CV = 0.26)
CM	2005	24,890 (CV = 0.45)
CIC	2007	See Annex D, item 3.3.1.2

5. REQUEST FOR MANAGEMENT ADVICE FOR HUMPBACK WHALES OFF WEST GREENLAND

5.1 Management advice

No new information was available for this stock since the thorough review that occurred last year. Last year, the Committee agreed an approach for providing interim management advice and this was confirmed by the Commission. It had agreed that such advice could be used for up to two five-year blocks whilst *SLAs* were being developed (IWC, 2009b). Using this approach, as last year, the SWG **agreed** that an annual strike limit of 10 whales will not harm the stock.

6. MANAGEMENT ADVICE FOR HUMPBACK WHALES OFF ST VINCENT AND THE GRENADINES

6.1 Review of new information

No catch report has been provided to the Scientific Committee by St Vincent and the Grenadines. Clapham advised the SWG that he had been informed that a whale had been taken on 27 April 2009. The SWG noted that St Vincent and Grenadines has submitted detailed catch information directly to the Secretariat during the Commission meeting over the past few years. It **encouraged** St Vincent and the Grenadines to also submit as much information as possible about any catches to the Committee via an annual progress report. The SWG again **strongly encouraged** collection of genetic samples for any harvested animals as well as fluke photographs, and submission of these to appropriate catalogues and collections. In respect of genetic samples, the SWG again **agreed** that the North Atlantic Whale Archive maintained by Per Palsbøll at Stockholm University was an appropriate facility.

6.2 Management advice

In recent years, the Committee has agreed that the animals found off St. Vincent and the Grenadines are part of the large West Indies breeding population. The Commission adopted a total block catch limit of 20 for the period 2008-12. The SWG **agreed** that this block catch limit will not harm the stock

7. SCIENTIFIC ASPECTS OF AN ABORIGINAL SUBSISTENCE WHALING SCHEME

7.1 Lessons learned from the bowhead *Implementation Review*

Last year, Donovan had agreed to assist George in developing a paper on this topic. However, George had been unable to attend this year's meeting and no paper was available. Donovan agreed to work with George to complete this work and he will present the paper at next year's meeting if George is unable to attend.

8. PREPARATIONS FOR AN IMPLEMENTATION REVIEW OF EASTERN GRAY WHALES

This issue was discussed in detail by the BRG sub-committee (annex F, item 4.2.3). The SWG noted that a list of required data for the ENP gray whales had been developed and will be available by the deadlines established for *Implementation Reviews*. The SWG noted that revised abundance estimates (SC/61/AWMP1) and the new data sources, assessment methodology, and operating models (SC/61/AWMP2, SC/61/AWMP3) may lengthen the time to conduct the *Implementation Review* and this may necessitate a pre-meeting prior to SC62. The SWG established a Steering Group under Donovan (members: Breiwick, Butterworth, Donovan, and Punt) to review the progress of any new analyses and make a decision on the need for a pre-meeting to facilitate completion of the *Gray Whale Implementation Review* at the 2010 Annual Meeting. ENP gray whales will be discussed at the proposed MSYR Workshop (annex D item 2.1.2) and the members of this SWG Steering Group will attend that workshop; this will be an appropriate mechanism to review progress and advise on analyses required for the *Implementation* and the need for a pre-meeting.

9. OTHER MATTERS

9.1 Method for estimating amounts of edible products for Greenland fisheries

The Greenlandic need statement is expressed in terms of tonnes, not numbers of animals. At last year's Commission meeting (reference), the Chair of the Commission asked the Scientific Committee to take note of a request from Argentina seeking clarification of factors used to convert whales to tonnes (e.g. whether and how this included edible products in addition to meat). Discussion within the SWG focussed on whether it was possible to estimate a conversion factor per strike per species from the available data and if not, how it should be done, rather than the way that it had been done within the Commission in the past. It noted that it had not been requested to review the conversion factors used when they had been accepted by the Commission previously.

SC/61/AWMP6 used length data from the Greenland aboriginal hunt and from the IWC catch database, along with a formula to convert length to weight developed by Lockyer (1976) to estimate average body weights of fin and minke whales, and the yield of edible products (meat and blubber) from these species. The authors found that the average lengths of minke whales in three data sets (Greenland hunt, IWC entire North Atlantic and IWC West Greenland) were in a small range from 6.9 to 7.2 m. Mean estimated body weight ranged from 4.4 to 5.0 tonnes. Meat (muscle) made up from 2.7 to 3.1 tonnes of body weight, and the yield of blubber was estimated at an average of 0.7 tonnes. The average lengths of fin whales were also quite consistent across four examined datasets (Greenland hunt, IWC Davis Strait/Baffin Bay, IWC entire North Atlantic, and IWC West Greenland), ranging from 17.8 to 18.6 m. Mean estimated body weight ranged from 34.2 to 39.1 tonnes. Meat (muscle) made up from 15.4 to 17.6 tonnes of body weight, and blubber from 8.2 to 9.4 tonnes. Overall, these figures are higher than the factors of 2 tonnes (minke whales) and 10 tonnes (fin whales) currently in use by Greenland, whose calculations involve the yield of only meat but not blubber or other edible products. The authors noted that logistical considerations may well affect actual yield in the hunt, but were unable to assess the extent to which this may be the case.

The SWG also received a working paper from Witting that incorporated an analysis of the edible product (meat, ventral grooves² and skin) yield of minke whales (n=1,875) and fin whales (n=134) reported by hunters over the period 1987-2007. Witting noted that the reported yields per whale were quite variable (e.g. ranging from 18-6,500kg for minke whales and 400-40,000kg for fin whales) but noted that it was not possible from the available information be able to know how much of the variation was real and how much may be due to misreporting. However, the conditions for hunting and flensing in Greenland varied considerably (including the possibility that whales are lost on the way back to shore) and thus such variability was not completely unexpected. The average yield of all products estimated from all catches was 1.96 tonnes (SD 1.17) for common minke whales and 9.51 (SD 5.40) tonnes for fin whales while that for meat alone was 1.37 (SD 0.85) for common minke whales and 6.14 (SD 4.84) tonnes for fin whales. Witting then used the above information and the actual landed catches of common minke and fin whales in recent years to estimate the total number of tonnes of meat obtained per year under the current strike limits (269 tonnes for common minke whales and 76 tonnes for fin whales). Point estimates of the conversion factors are thus 1.34 tonnes *per strike* for common minke whales and 4.02 tonnes *per strike* for fin whales (using yield per strike incorporates an estimate of actual efficiency). He also presented an approach for using this information to determine the probability that the current strike limits would satisfy need.

² Although termed 'blubber' it was clarified that in Greenland only the ventral grooves are consumed, not all of the blubber.

The SWG welcomed these papers but **agreed** that neither provided sufficient information to allow it to answer the question from the Commissioner from Argentina. The approach in SC/61/AWMP6, for example, treated the formula given by Lockyer (1976) as precise while some estimate of the uncertainty should be incorporated. Although the approach of Witting did use data from the Greenlandic hunt to calculate a yield per strike in order to examine the strike limit that would be needed to meet the need request from Greenland, Witting agreed that the reliability and representativeness of the data from the Greenlandic hunt that he obtained from the hunters' reports was unknown (e.g. whether weights are measured or estimates).

The SWG **agreed** that for it to be able to adequately address the question from the Commissioner from Argentina and to determine a conversion rate per strike, it would require reliable, representative data from the Greenlandic hunt. This would involve data on the measured weight of obtained edible products (meat, ventral grooves, skin) from an adequate sample of animals of each species and associated information on the individuals (sex, length, date of capture, position of capture). The SWG **requests** that Greenland collect such information and provide it, along with sampling and validation protocols as well as factors that may affect yield, to the SWG for its consideration.

10. WORK PLAN

The SWG **agreed** that its work plan for the 2010 Annual meeting would be as follows.

- (1) Brandão and Witting to provide the Secretariat with the codes for the sex-ratio estimation methods.
- (2) Secretariat to code (and hence validate) the sex-ratio method and the associated robustness tests.
- (3) Hold an intersessional workshop to refine the specifications and implementation of the sex-ratio methods and the associated robustness tests so that a decision can be taken at the 2010 Annual Meeting on whether the sex-ratio method can be used to provide management advice. Costs associated with travel and subsistence for this meeting are estimated to be £10,000. An intersessional Steering Group comprised of Donovan (Convenor), Allison, Butterworth, Brandão, Punt, Schweder, and Witting was appointed to guide the work and organise the meeting.
- (4) Punt and Donovan to develop a short working paper on appropriate operating models for West Greenland fin whales.
- (5) Conduct an *Implementation Review* for the Eastern North Pacific gray whales.
- (6) Review the progress on any new analyses and make a decision on the need for a pre-meeting to facilitate completion of the *Gray Whale Implementation Review* at the 2010 Annual Meeting.

11. ADOPTION OF REPORT

The report was adopted at 11:27 on 8 June 2009. The sub-committee thanked the chair for guiding them through a long agenda. The chair thanked the rapporteurs and the developers of the sex-ratio method.

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Appendix 1

AGENDA

1. INTRODUCTORY ITEMS

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

2. COMMON MINKE WHALES OFF WEST GREENLAND

- 2.1 Further discussion of sex ratio method
- 2.2 Other new information
 - 2.2.1 Abundance
- 2.3 Management advice
- 2.4 Progress with SLA Development

3. FIN WHALES OFF WEST GREENLAND

- 3.1 Abundance estimates
 - 3.1.1 Summary of discussions at intersessional workshop
 - 3.1.2 Updated estimate
- 3.2 Management advice
 - 3.2.1 Summary of previous season's catch data
 - 3.2.2 Management advice
- 3.3 Progress with SLA development

4. COMMON MINKE WHALES OFF EAST GREENLAND

- 4.1 Review of new information
- 4.2 Management advice

5. REQUEST FOR MANAGEMENT ADVICE FOR HUMPBACK WHALES OFF WEST GREENLAND

- 5.1 Management advice

6. MANAGEMENT ADVICE FOR HUMPBACK WHALES OFF ST VINCENT AND THE GRENADINES

- 6.1 Review of new information
- 6.2 Management advice

7. SCIENTIFIC ASPECTS OF AN ABORIGINAL SUBSISTENCE WHALING SCHEME

- 7.1 Lessons learned from the bowhead *Implementation Review*

8. PREPARATIONS FOR AN IMPLEMENTATION REVIEW OF EASTERN GRAY WHALES

9. OTHER MATTERS

- 9.1 Method for estimating amounts of edible products for Greenland fisheries

10. WORK PLAN

11. ADOPTION OF REPORT

Appendix 2

REPORT OF THE SMALL GROUP ON COMPARISON OF THE METHODS APPLIED IN SC/61/AWMP5 AND SC/61/AWMP7

Anabela Brandão, André Punt (Chair), Tore Schweder and Lars Witting

A. Background

The estimates of the lower 5% bound for the estimate of K and the abundance in 2007, N_{2007} , differ markedly between SC/61/AWMP5 and SC/61/AWMP7, even for the same population dynamics model and the same choice of likelihood function³ (Table 1).

Table 1

Lower 5% bounds for K and N_{2007} for the influx (4b) model and the "Schweder" likelihood function for the two values for MSYR and two estimation approaches.

MSYR	SC/61/AWMP5 ⁴		SC/61/AWMP7	
	K	N_{2007}	K	N_{2007}
1%	25,200	9,600	22,300	6,279
2%	19,300	9,100	17,800	6,536

Although the two sets of analyses in Table 1 are nominally the same, the small group identified a number of ways in which the approach in SC/61/AWMP5 differed from that in SC/61/AWMP7⁵.

1. SC/61/AWMP5 bounded the estimates of overdispersion (σ) to be at least 1. SC/61/AWMP7 did not impose this bound and the estimate of σ was less than 1 for at least one time-series of sex-ratios (Southwest Greenland; Table 5 of SC/61/AWMP7).
2. SC/61/AWMP5 estimated values for σ when computing the deviance profile. SC/61/AWMP7 set the values for σ when computing the deviance profile to the values obtained by fitting the model to the actual data with $K=200,000$
3. SC/61/AWMP5 and SC/61/AWMP7 used different parameter estimation schemes (i.e. different minimization methods and approaches for dealing with non-convergence).
4. When simulating data, SC/61/AWMP5 set the values for the σ s for each K to those obtained by fitting the population model to the actual data with K set to the value under consideration, while SC/61/AWMP7 used the values for the σ s obtained by fitting the population model to the actual data with K set to 200,000 for simulations all K s.
5. SC/61/AWMP7 allowed for uncertainty in the sex ratio of the simulated catches when no animals were sampled, i.e. their sex was recorded, SC/61/AWMP5 did not (these catches are only used to update the population dynamics and do not impact the data that are included in the likelihood function). SC/61/AWMP7 generated the catches by sex used to update the population dynamics using the algorithm in Adjunct 1, but set the sampled catches by sex to 0⁶.
6. SC/61/AWMP5 and SC/61/AWMP7 used different methods to generate data sets (see Adjunct 1⁷) for details.

The small group developed analyses (as outlined in the following sections) to identify the (major) causes for the differences in results between SC/61/AWMP5 and SC/61/AWMP7.

B. Differences in parameter estimation scheme

Twenty data sets for the influx (4b) model (2% MSYR) were generated using the methods in SC/61/AWMP5 and SC/61/AWMP7 when the true K was 20,000 (ten data sets for each method). The data sets for the SC/61/AWMP7 method were those which led to the largest deviances when the true K was 20,000. The methods of SC/61/AWMP5 (unchanged) and SC/61/AWMP7 (estimating the values for σ and constraining the σ s not be less than 1⁸) were applied to the 20 data sets. Table 2 compares the negative log-likelihood when K was set to 20,000 and when K was estimated, along with the estimate of K when it was estimated for each method, and the differences between the methods. The results from the two estimators are identical, except for only one of the data sets generated using the SC/61/AWMP7 method (Table 2b). Based on the results in Table 2, the small group concluded that potential cause 3 above was not a major reason for the differences in results between the two papers, but to find one notable difference in deviance in 40 cases means that there might be a non-negligible number of such cases in 1000 replicates. For the one case of notable difference, SC/61/AWMP7 found the more likely values for the parameters.

³ The group did not compare the results for the Closed (3) model because it is implemented differently in SC/61/AWMP5 and SC/61/AWMP7.

⁴ Including 'non converged' solutions.

⁵ Several minor differences due to programming errors were discovered (and corrected); these are not mentioned in this document.

⁶ The effect of this on the results is minor (results not shown).

⁷ Appendix A is based on the 'Schweder' (i.e. overdispersed binomial) likelihood function because that likelihood function formed the focus for the group's work.

⁸ The approach of SC/61/AWMP7 was thus modified to eliminate differences due to potential causes 1 and 2 in Section A.

Table 2. Comparisons of outputs from the two estimation methods.

(a) Data sets generated using the approach in SC/61/AWMP7

SC/61/AWMP7 (modified)			Estimation method			SC/61/AWMP5			Difference		
-LnL (K=20,000)	-LnL (K Est)	K Estimate	-LnL (K=20,000)	-LnL (K Est)	K Estimate	-LnL (K=20,000)	-LnL (K Est)	K Estimate	-LnL (K=20,000)	-LnL (K Est)	K Estimate
105.227	100.293	15007.6	105.227	100.293	15009	-0.0004	0.0003	-1.400			
112.058	107.612	15099.7	112.058	107.612	15101	0.0002	0.0001	-1.300			
103.930	100.210	15146.4	103.930	100.210	15148	0.0002	0.0000	-1.600			
97.877	89.634	14926.6	97.877	89.634	14928	0.0000	-0.0001	-1.400			
111.771	108.262	15101.6	111.771	108.262	15102	-0.0004	0.0002	-0.400			
106.988	101.832	14985.8	106.988	101.832	14987	0.0003	-0.0004	-1.200			
97.647	92.480	15149.8	97.647	92.480	15151	0.0000	0.0000	-1.200			
101.311	97.831	15124.9	101.311	97.831	15126	-0.0003	0.0000	-1.100			
107.251	103.387	15134.7	107.251	103.387	15136	0.0002	-0.0004	-1.300			
104.540	100.134	15276.4	104.540	100.134	15277	-0.0004	-0.0004	-0.600			

(b) Data sets generated using the approach in SC/61/AWMP5

SC/61/AWMP7 (modified)			Estimation method			SC/61/AWMP5			Difference		
-LnL (K=20,000)	-LnL (K Est)	K Estimate	-LnL (K=20,000)	-LnL (K Est)	K Estimate	-LnL (K=20,000)	-LnL (K Est)	K Estimate	-LnL (K=20,000)	-LnL (K Est)	K Estimate
111.309	111.308	20240.9	111.309	111.308	20241	0.0002	0.0003	-0.100			
120.322	116.798	15238.2	120.322	116.799	15239	-0.0002	-0.0005	-0.800			
106.872	106.701	17259.5	106.872	106.701	17260	-0.0002	0.0003	-0.500			
106.813	106.250	16810.5	106.814	106.250	16811	-0.0005	0.0001	-0.500			
109.454	108.211	16360.3	109.454	108.294	16638	0.0000	-0.0827	-277.700			
98.363	98.361	19672	98.363	98.361	19673	0.0000	0.0000	-1.000			
85.337	84.705	17243.5	85.337	84.705	17244	0.0000	0.0000	-0.500			
99.192	99.064	28021.2	99.192	99.064	28021	0.0000	0.0000	0.200			
90.340	90.261	25144.7	90.340	90.261	25147	0.0000	0.0000	-2.300			
96.259	96.018	27621.6	96.259	96.018	27622	0.0000	0.0000	-0.400			

C. Impact of potential causes 1, 2 and 4

Figure 1 and Table 3 compare the deviance function (i.e. based on the actual data) and the values for the upper 5% points of the deviance distribution (both as a function of K) based on the approach of SC/61/AWMP7 for three cases (2% MSYR):

- 'Original'. No bounds on the σ s; σ s set to those obtained from the fit of the model to the actual data when $K=200,000$; data sets generated setting the σ s to those obtained from the fit of the model to the actual data when $K=200,000$;
- 'Modified'. As for a), except that the σ s are bounded to be at least 1 and the σ s are estimated whenever the model is fitted.
- 'Modified-sig'. As for b), except that the data sets are generated setting the σ s to those for each value of K .

Table 3 also includes results from the original model of SC/61/AWMP5 and a modified version (where data are simulated with σ for $K=200,000$, there is simulated uncertainty when no catches were sampled for sex, and an improved optimisation routine that maintains the results of Table 2) that resemble the "modified" version of SC/61/AWMP7.

The impact of how the σ s are set when generating the data sets (i.e. 'Modified' vs 'Modified-sig') was minor (Figure 1; Table 3), suggesting that potential cause 4 in Section 4 was not a major cause for the differences in results between the two papers. However, the impact of placing bounds on the σ s and not estimating these parameters when computing the distributions for the deviance (potential causes 1 and 2 in Section A) was marked. The small group therefore concluded that the difference between the 'Original' and 'Modified' approaches was the major cause of the differences between the results in SC/61/AWMP5 and SC/61/AWMP7 (at least for the Influx (4b) model and Schweder likelihood function). Moreover, the estimates of the lower 5% bounds for K and N_{2007} from the 'Modified' version of SC/61/AWMP7 were very similar to those in SC/61/AWMP5.

Table 3.

Lower 5% bounds for K and N_{2007} for the influx (4b) model, the 'Schweder' likelihood function and MSYR=2% for three versions of the approach of SC/61/AWMP7, and the original and modified versions of the approach of SC/61/AWMP5.

Model	K	N_{2007}
Original	17,800	6,536
Modified	19,500	9,319
Modified-Sig	19,500	9,319
AWMP5-O	19,300	9,100
AWMP5-M	19,600	9,552

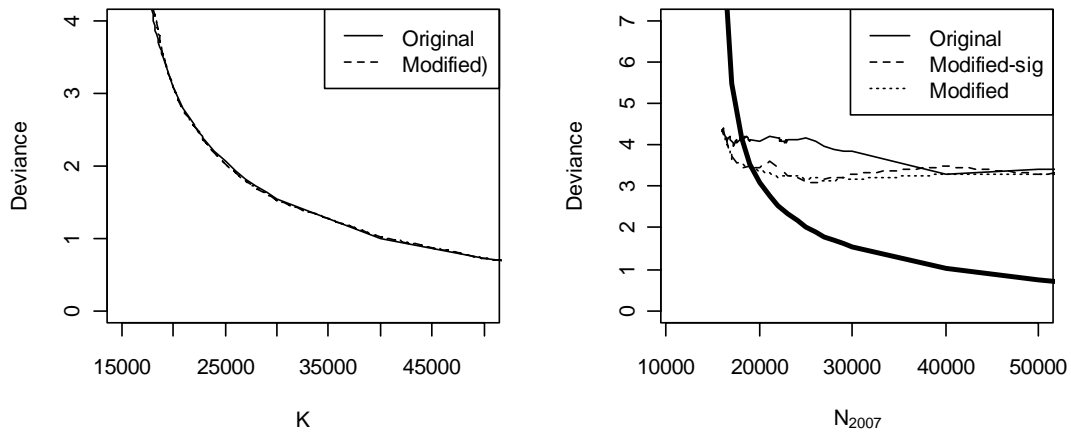


Fig. 1. Deviance function for the 'original' and 'modified' versions of the Influx (4b) model of SC/61/AWMP7 (left panel, the curves lie on top of each other) and the deviance function and the upper 5%iles of the distribution for the deviance from three variants of this model ('Original', 'Modified', and 'Modified-sig'). The deviance curves are the same in the two panels, while the right panels also show the upper 5%iles of the distribution for the deviance from three variants of this model.

D. Impact of method of data generation

The methods of data generation on which SC/61/AWMP5 and SC/61/AWMP7 are based differ in terms of how the data sets needed to compute the distributions for the deviance are generated (potential cause 6 in Section A). To investigate the impact of this difference, 1,000 data sets were generated using the original computer programs on which SC/61/AWMP5 and SC/61/AWMP7 were based. The σ s were set to the estimates when the model was fitted to the actual data and K was set to 24,593. The results are shown in Figure. 2. The results in Figure 2 are not consistent with the expectation (of the small group) that the distributions of catches by sex would be the same irrespective of which method is used to generate the data.

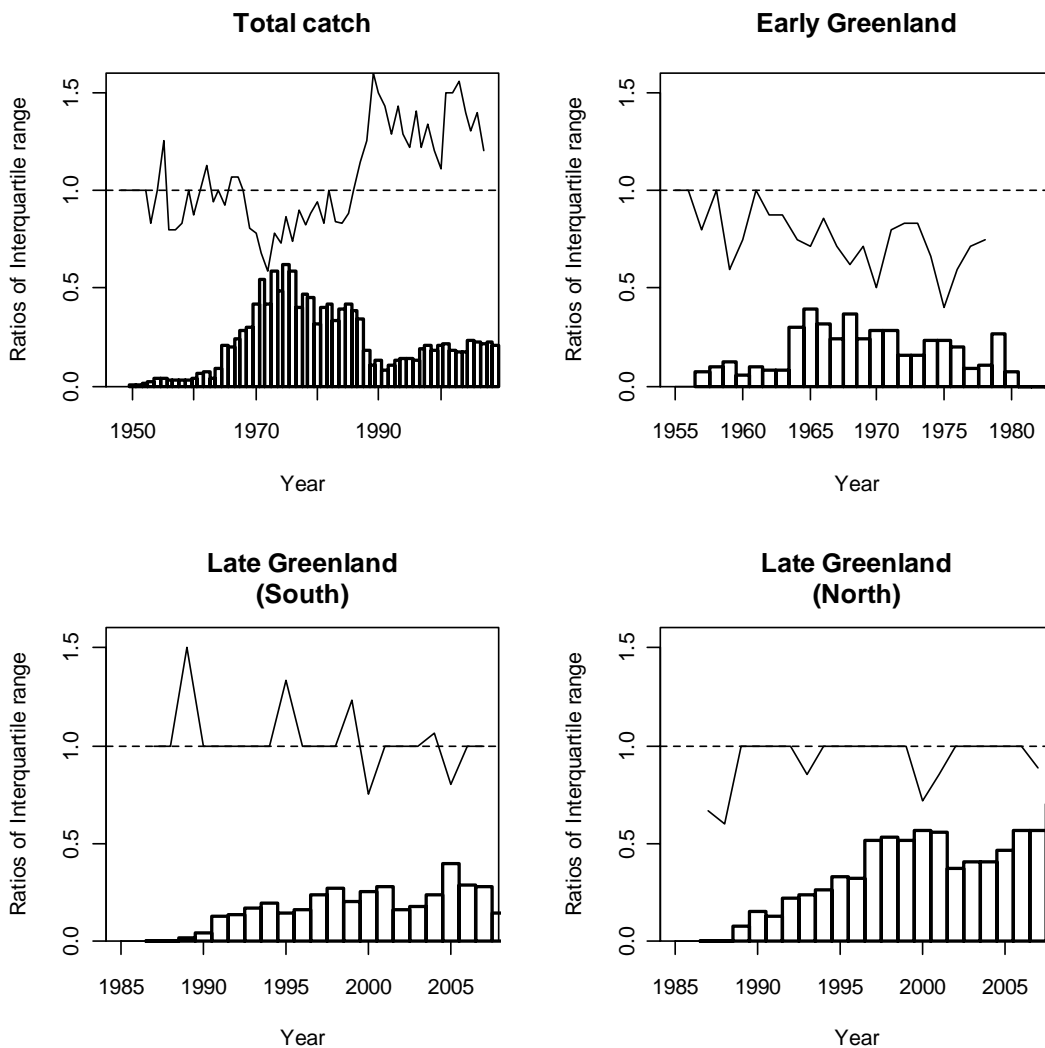


Fig. 2. The ratio of the interquartile range of the catch of females by year from the SC/61/AWMP7 approach to that from the SC/61/AWMP5 approach (i.e. SC/61/AWMP7 / SC/61/AWMP5). The bars denote the annual catches (divided by 800 for the upper left panel and by 200 for the remaining panels).

To further explore the patterns in Figure 2, particularly that in the upper right panel, which suggests that the method of SC/61/AWMP5 leads to more variable distributions of catch by sex than the method of SC/61/AWMP7, the model for generating data sets in SC/61/AWMP5 was implemented using the software on which SC/61/AWMP7 was based. This removed the possibility that the patterns in Figure 2 were due to differences in, say, how the random numbers were generated or programming errors. The results of this comparison are shown in Figure 3. The patterns in Figure 3 are qualitatively the same as those in Figure 2, which suggests that it is the differences in the model used to generate the data (Adjunct 1) and not how these data generation schemes are implemented that leads to the patterns in Figure 2.

The approach of SC/61/AWMP7 (modified) [and the associated software] was applied to data sets generated using the generation schemes on which SC/61/AWMP5 and SC/61/AWMP7 were based (see Adjunct 1) to explore the implications of the patterns in Figures 2 and 3. The values for the σ_s used when generating the simulated data sets were calculated for each K separately (rather than being set to those for $K=200,000$). The results still seem somewhat sensitive (a difference in the 5% bound for N_{2007} of roughly 1,000 animals) to the method used to generate the data (Table 4; Figure 4). However, the differences may well be a consequence of Monte Carlo uncertainty. For example, the 95% Monte Carlo interval for N_{2007} for AWMP5-M is [8,980-11,840].

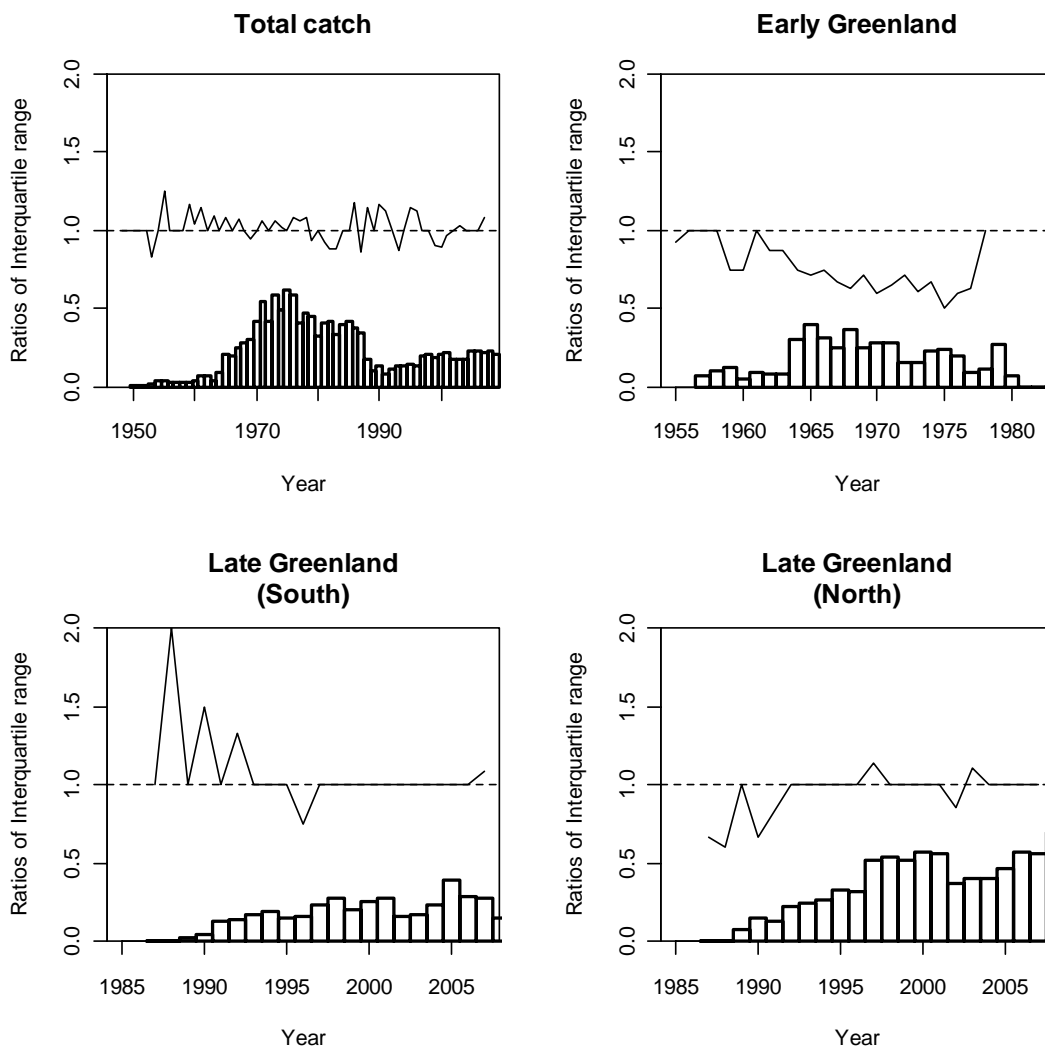


Fig. 3. As for Figure 2, except that all of the calculations were based on the software platform on which SC/61/AWMP7 is based.

Table 4

Lower 5% bounds for K and N_{2007} for the influx (4b) model, the 'Schweder' likelihood function and MSYR=2% for three versions of the approach of SC/61/AWMP7, and the modified version of SC/61/AWMP5.

Model	K	N_{2007}
AWMP7 Generation	19,500	9,319
AWMP5 Generation	20,500	10,841
AWMP5-M	19,600	9.552

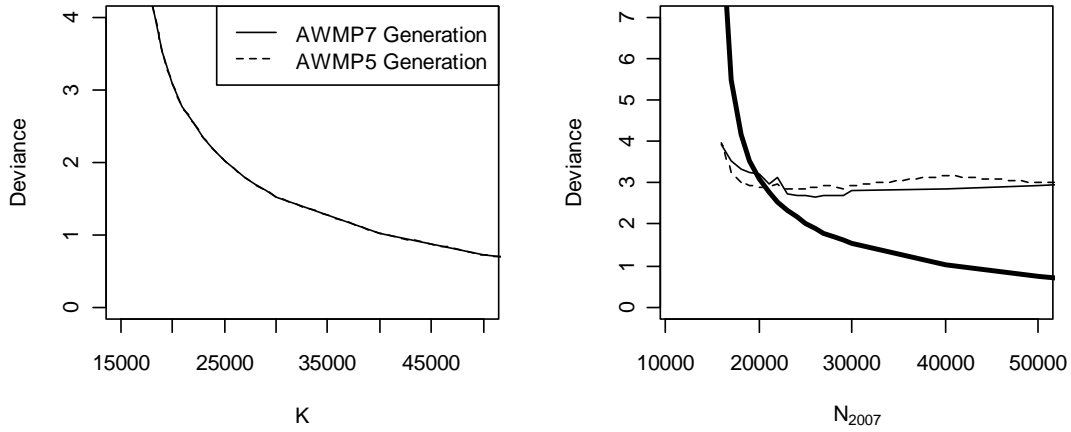


Fig. 4. Deviance function for the 'modified' versions of the Influx (4b) model of SC/61/AWMP7 (left panel) and the deviance function and the upper 5%iles of the distribution for the deviance when the simulated data sets are generated using the SC/61/AWMP5 and SC/61/AWMP7 approaches.

E. Conclusions and next steps

The small group concluded that the major reasons (of those in Section A) for the differences in results between the comparable analyses in SC/61/AWMP5 and SC/61/AWMP7 are caused by how the overdispersion parameters are treated when fitting the model to the data (actual and simulated). The small group makes the following recommendations regarding each of the potential causes:

1. Impose a lower bound of 1 on the σ_s (to avoid the possibility of estimated 'underdispersion').
2. Estimate the σ_s whenever the model is fitted (i.e. both to the actual and the simulated data sets).
3. Either optimization scheme is acceptable, although that implemented for SC/62/AWMP7 is faster.
4. Generate the data sets using the σ_s corresponding to $K=200,000$ (as agreed by JCRM 11:411).
5. Allow for sex uncertainty in the simulated catches when none of the actual catches were sampled for sex.
6. Either model for generating data sets is acceptable (although the approach in SC/61/AWMP5 rounded twice which may lead to more variability when the number of sampled animals is low).

Adjunct 1

The model for simulating the number of females among the sampled (i.e. recorded for sex) and the unsampled individuals in the catch

The numbers of sampled $C_y^{tot,samp}$ and unsampled $C_y^{tot,unsamp}$ individuals by year y and area (north and south for the late Greenlandic period; 1987-2007) are the same for all simulated data sets. The only difference between the two models for generating data sets, as detailed below, is that SC/61/AWMP7 simulates the sex for all the caught individuals, and then draws a random sample. In contrast SC/61/AWMP5 simulates the sexes among the sampled and the unsampled animals independently. The method of simulating sex is the same, but SC/61/AWMP5 carries out two roundings to integers compared to only one rounding in SC/61/AWMP7.

SC/61/AWMP5

SC/61/AWMP5 generates the catches by sex for the sampled animals (animals for which sex is known in the actual data) under the assumption that they are governed by an overdispersed binomial distribution. It then generates the catches by sex for the unsampled animals using the same approach. The removals by sex from the population are the sum (by sex) of the sampled and unsampled catches.

Sampled Catches

$$C_y^{fem,samp} \sim \min(C_y^{tot,samp}, \max(0, \text{round}(C_y^{tot,samp} p_y^{fem} + Z_y^{samp} \sigma \sqrt{C_y^{tot,samp} p_y^{fem} (1 - p_y^{fem})})))$$

$$C_y^{mal,samp} = C_y^{tot,samp} - C_y^{fem,samp}$$

where $C_y^{s,samp}$ is the (generated) number of animals that were sampled for sex during year y and found to be sex s ,

$C_y^{tot,samp}$ is the (known) total number of animals that were sampled for sex during year y ,

p_y^{fem} is the model estimate of the proportion of the catch that was female during year y ,

σ is the estimated extent of overdispersion, and

$Z_y^{s\text{amp}}$ is $N(0,1)$

Unsampled catches

$$C_y^{fem,unsamp} \sim \min(C_y^{tot,unsamp}, \max(0, \text{round}(C_y^{tot,unsamp} p_y^{fem} + Z_y^{unsamp} \sigma \sqrt{C_y^{tot,unsamp} p_y^{fem} (1 - p_y^{fem})})))$$

$$C_y^{mal,unsamp} = C_y^{tot,unsamp} - C_y^{fem,unsamp}$$

where $C_y^{s,unsamp}$ is the (generated) number of animals of sex s that were caught during year y but were not sexed,

$C_y^{tot,unsamp}$ is the (known) difference between the catch during year y and $C_y^{tot,samp}$, and

Z_y^{unsamp} is $N(0,1)$

Total catches (removed from the population)

$$C_y^{fem} = C_y^{fem,samp} + C_y^{fem,unsamp}; C_y^{mal} = C_y^{mal,samp} + C_y^{mal,unsamp}$$

SC/61/AWMP7

SC/61/AWMP7 first generates the catches by sex based on the total removals from the population. It then determines the catches by sex by sub-sampling from the total catches by sex.

Total catches (removed from the population)

$$C_y^{fem} \sim \min(C_y^{tot} \max(0, \text{round}(C_y^{tot} p_y^{fem} + Z_y \sigma \sqrt{C_y^{tot} p_y^{fem} (1 - p_y^{fem})})))$$

$$C_y^{mal} = C_y^{tot} - C_y^{fem}$$

where $C_y^{tot} = C_y^{tot,samp} + C_y^{tot,unsamp}$

Sampled catches

The values for $C_y^{fem,samp}$ and $C_y^{mal,samp}$ are generated by sampling $C_y^{tot,samp}$ animals at random and without replacement from C_y^{fem} females and C_y^{mal} males.

Appendix 3

FURTHER COMPARISONS OF THE GENERATION MODELS ON WHICH SC/61/AWMP5 AND SC/61/AWMP7 ARE BASED

André Punt

The ratios of the interquartile ranges are closer to one another when the fraction sexed is high. The fact that the results from the two models are very similar when the fraction sexed is high should not be a surprise because the two generation models are identical when all animals are sexed. Simulations were conducted to explore this further. The true sex ratio was 0.7 and the total number of caught ranged from 50 to 1000 for these simulations. The simulations varied the fraction of the catch sampled (20-90%) and the overdispersion parameter (1.5 and 2.0). The two generation models were specified as follows:

- AWMP7: (a) generate the number of females in the total catch using an overdispersed binomial, (b) sample the number of animals sexed without replacement from the total catch and record the number of females.
- AWMP5: generate the number of females by sex using an overdispersed binomial with 'n' equal to the number of animals sexed.

The patterns evident in Appendix 2 are evident in Figure 1, confirming that the two approaches are actually different when it comes to generating catches by sex.

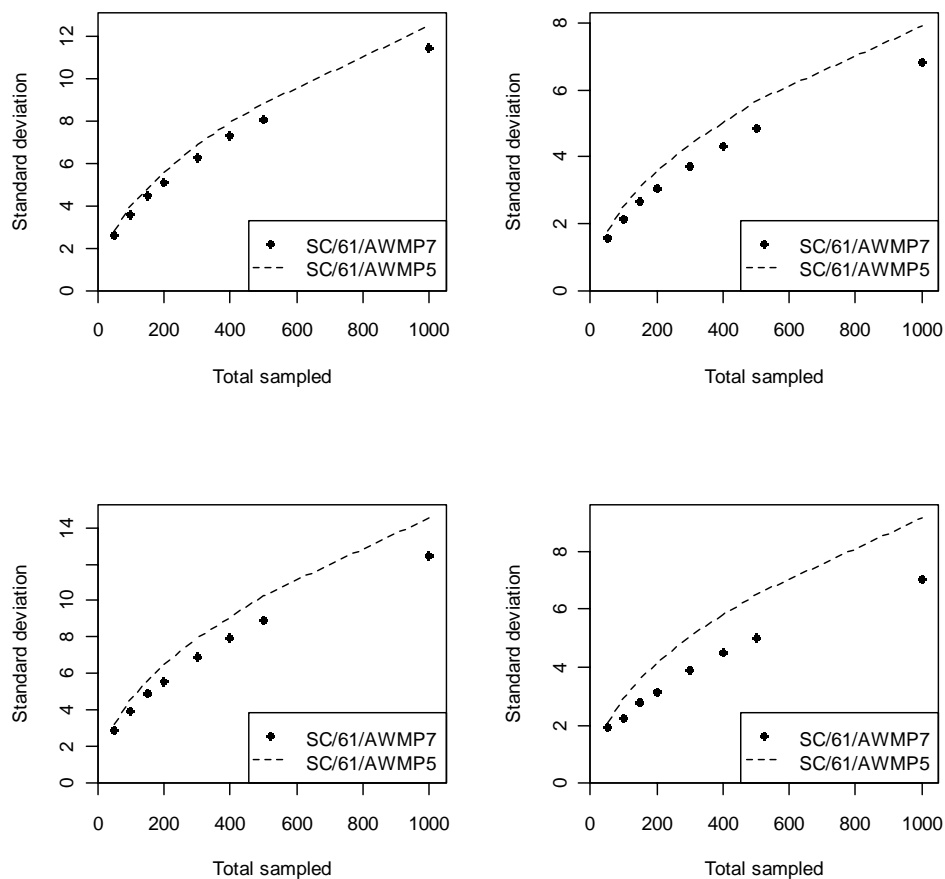


Fig. 1. Standard deviations of the number of females in the catch as a function of the total number in the catch. The true sex ratio is always 0.7: (upper left) 50% of the catch sampled; overdispersion=1.5; (upper right) 20% of the catch sampled; overdispersion=1.5; (lower left) 50% of the catch sampled; overdispersion=2.0; (upper right) 20% of the catch sampled; overdispersion=2.0.

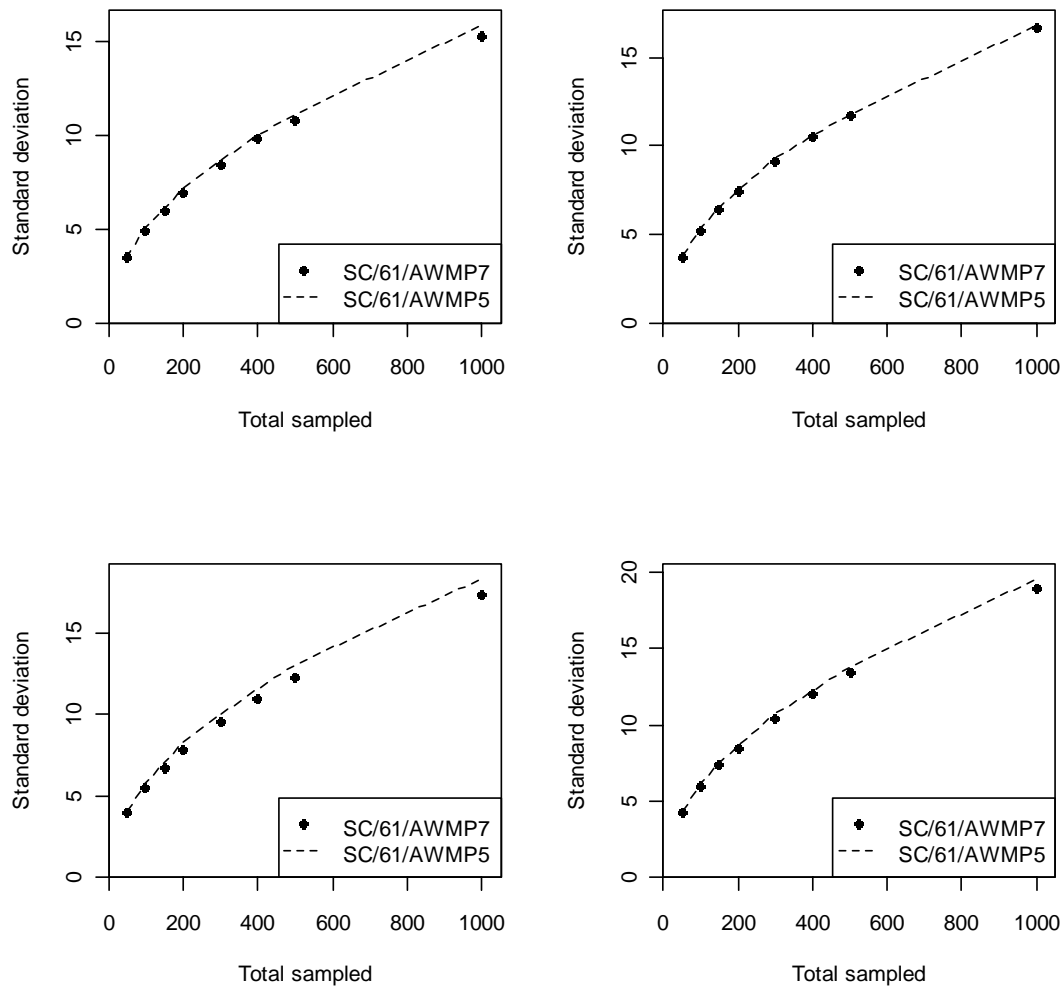


Fig. 2. As for Figure 1, except that the fractions sexed are 80% (left panels) and 90% (right panels).

Appendix 4

ROBUSTNESS TESTS FOR THE SEX-RATIO ESTIMATION METHOD

Allison, Apostolaki, Brandão, Givens, Punt (Chair), Schweder, Witting

The group suggests that robustness tests be based on two classes of data sets: (a) data sets generated using ad hoc algorithms to alter the observed data (model-free data sets), and (b) data sets generated using a population dynamics model under alternative sets of assumptions. The model-free data sets will explore the behaviour of the estimation method when the trend of the sex-ratios is changed in a systematic manner. The model-based robustness tests will be used to examine how the estimation results change in response to:

- (1) different 'true' K (and hence N_{2007}) values [when the population dynamics model is known];
- (2) different extents of overdispersion [when the population dynamics model is known];
- (3) model mis-specification [when the model used to generate the data sets differs from that on which the estimation method is based, such as an intentional confusion between models 3 and 4b, but not necessarily limited to these two models]; and
- (4) data sets that are longer than the current data set. The future data will be generated by projecting the population dynamics model forward under the average catch over the last 10 or 20 years.

'Adequate performance' will be evaluated for both types of robustness tests under the principle that changing the data should lead to changes in the model output in the expected direction and of the expected magnitude or that it should be possible to provide a qualitative explanation for any discrepancies between the model output and *a priori* expectations.

The following process for conducting and evaluating the results of model-based robustness trials is suggested.

- (1) Set a new 'true' value for K , the overdispersion parameters and any other parameters (e.g. based on fitting the population dynamics model to the actual data set given the chosen value of K).
- (2) Generate 1000 data sets taking account of uncertainty in the sex ratios of the catches, under the assumption that the 'true' K is correct.
- (3) For each data set
 - a. Calculate the deviance for the data set corresponding to the true value of K .
 - b. Generate a large number (e.g. 1,000) of data sets based on the true value of K and the values for the other parameters of the model (these would be obtained from step a) and compute the deviance for each of these data sets.
 - c. Record the percentile that the deviance from step a) represents in the distribution generated from step b).
- (4) Plot the collection of 1,000 percentiles (one for each simulated data set) and assess the frequency of the percentages being larger than 2%, 5%, 10%, etc (Fig. 1b).

The process for evaluating model-free robustness tests is similar. Specifically (see Fig. 1a):

- (1) Select a set of values for K . For each value of K :
 - a. Calculate the deviance for the original data set.
 - b. Generate a large number (e.g. 1,000) of data sets based on the true value of K and the values for the other parameters of the model (these would be obtained from step a) based on an overdispersed binomial distribution for both the sexed and unsexed component of the catch.
 - c. Record the percentile, P^* , that the deviance from step a) represents in the distribution generated from step b).
- (2) Repeat steps a-c above for each data set and value of K .
- (3) For each value of K plot the percentiles obtained at step 2 using a histogram and P^* using a vertical line.

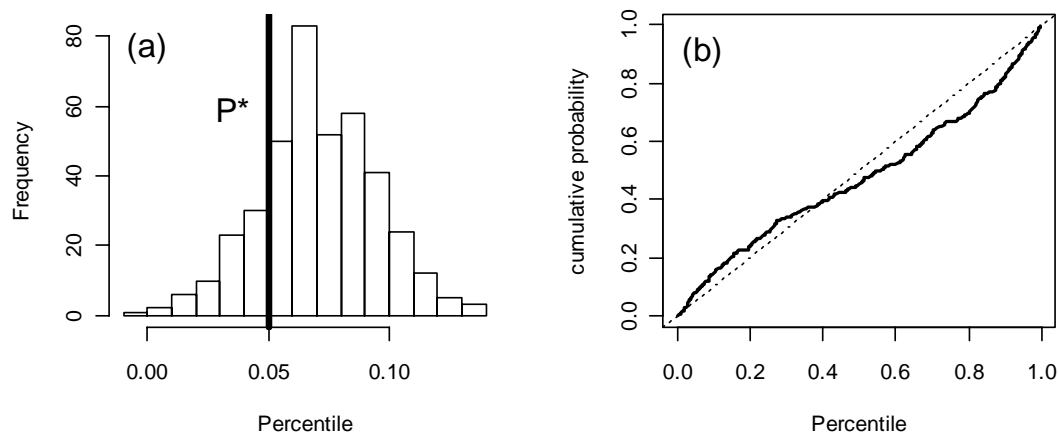


Fig. 1. (a) histogram of percentiles from 400 simulated data sets along with the P^* based on the actual data. (b) cumulative distribution of percentiles.

Appendix 5

CLOSED MODELS FOR WEST GREENLAND MINKE WHALES

Lars Witting and Anabela Brandão

The closed models describe the change in the difference in the sex ratios of minke whales in the northern and the southern areas in West Greenland as a function of a change in the way that the two sexes distribute themselves over the two areas. This effect is taken into account starting in 1987 because this is the first year where caught whales are allocated to the two areas. The model also includes an overall change in the sex ratio of minke whales in West Greenland as a function of the level of exploitation. This effect is a consequence of the sex specific harvest and the population dynamic trajectory that starts in 1948. Let the recruited number of female (f) and male (m) minke whales in the overall West Greenland area (w) in year t be

$$\begin{aligned} N_t^{w,f} &= N_t^f \\ N_t^{w,m} &= \lambda N_t^m \end{aligned} \quad (1)$$

where N_t^f and N_t^m are the recruited number of females and males in the total population, λ is AWMP7 notation, and $\mathcal{G} = 1 \setminus \lambda$ AWMP5 notation.

Assuming that the overall West Greenland area is closed, obviously

$$N_t^{n,g} = N_t^{w,g} - N_t^{s,g} \quad (2)$$

with $g \in \{m, f\}$ denoting gender, n the northern and s the southern area. Hence, given Eqns. (1) and (2), if we know the number of individuals of a sex in one of the two areas, we may calculate the number of individuals of that sex in the other area.

Original version

In the original version of the closed model, the numbers of individuals of gender g in the northern area is

$$N_t^{n,g} = r^g N_t^{w,g} \quad (3)$$

$$r^g = \frac{e^{\alpha^g + \beta^g \tilde{t}}}{1 + e^{\alpha^g + \beta^g \tilde{t}}} \quad (4)$$

with $\tilde{t} = t$ in AWMP7 and $\tilde{t} = t - 1987$ in AWMP5. With two genders, there are four parameters ($\alpha^m, \beta^m, \alpha^f, \beta^f$) to describe the allocation of the two sexes between the two areas.

New version

In the new version of the closed model in AWMP5 there are only three parameters (r, α, β ; note that these parameters are not the same as the r^g, α^g and β^g parameters above) to describe this process (r is denoted p^f in AWMP5, but is here denoted r for an easier comparison with the original version of the model). The first parameter r defines the number of females in the southern area as a function of the recruited number of females in the overall West Greenland area

$$N_t^{s,f} = r N_t^{w,f} \quad (5)$$

Hence, r is like the derived r^g parameters of Eqns. (3) and (4), except that it is time invariant in Eq. (5) and that it relates to the number of females in the southern area [$(1-r)N_t^{w,f}$ will give you the number of females in the northern area]. Furthermore, the fraction of females in the southern area is given as

$$\frac{N_t^{s,f}}{N_t^{s,f} + N_t^{s,m}} = \frac{e^{\alpha + \beta \tilde{t}}}{1 + e^{\alpha + \beta \tilde{t}}} \quad (6)$$

with $\tilde{t} = t - 1987$. Hence, by rearranging Eq. (6), the number of males in the southern area is

$$N_t^{s,m} = N_t^{s,f} / e^{\alpha + \beta \tilde{t}} \quad (7)$$

and knowing now the number of males and females in the total and the southern area, the number of males and females in the northern area is calculated from Eq. (2).

The main rationale for making the change from the original version of the closed model to the new version was 1) optimization conversion problems with the original version, 2) the understanding that four parameters was one more than the minimal number of parameters necessary to link the sex ratios in the two areas to one another, and the idea that optimization might be easier when the female fraction (which is a direct input to the likelihood function) in the area with the strongest trend was defined exclusively as a function of time (Eq. (6)) independently of the underlying population dynamics and cross linking of the two areas. The effect of the interaction between these two processes would then essentially be estimated by the r parameter and the resulting fraction of females in the northern area.

Appendix 6

SUGGESTIONS FOR PREFERRED CLOSED AND INFLUX MODELS FOR WEST GREENLAND MINKE WHALES

Lars Witting

This Appendix suggests small changes to the existing influx model and closed model used in the sex ratio based assessment of West Greenland minke whales. These changes are suggested in order to make the mathematics of the two models more similar and to correct a couple of less desirable features in the present models.

Closed model

Recall that the recruited number of female (f) and male (m) minke whales in the overall West Greenland area (w) in year t are

$$\begin{aligned} N_t^{w,f} &= N_t^f \\ N_t^{w,m} &= N_t^m / \mathcal{G} \end{aligned} \quad (1)$$

where N_t^f and N_t^m are the recruited number of females and males in the total population ($\mathcal{G} = 1 / \lambda$; with λ being AWMP7 notation, and \mathcal{G} AWMP7 notation). And with the overall West Greenland area being closed

$$N_t^{n,g} = N_t^{w,g} - N_t^{s,g} \quad (2)$$

with $g \in \{m, f\}$ denoting gender, n the northern and s the southern area. These basic constraints of the closed model are proposed to remain in place.

The proposed change refers only to the time trend in the relative allocation of male and female individuals between the two areas. Here, it is proposed that the total abundance of recruited whales in the southern area is

$$N_t^s = q N_t^w \quad (3)$$

(q is a time-invariant parameter) and that the female fraction in the southern area is

$$\frac{N_t^{s,f}}{N_t^{s,f} + N_t^{s,m}} = r_t \frac{N_t^{w,f}}{N_t^{w,f} + N_t^{w,m}} \quad (4)$$

where

$$r_t = \left(\frac{N_t^{w,f} + N_t^{w,m}}{N_t^{w,f}}, \frac{c e^{\alpha + \beta(t-1987)}}{1 + e^{\alpha + \beta(t-1987)}} \right) \quad (5)$$

with c being a scaling constant.

Relative to the original version of the closed model, the proposed model has only three parameters (q, α, β) instead of four to be estimated. Relative to the new version of the closed model in AWMP5, the proposed model let the population dynamic changes in the female fraction in the overall West Greenland area [$N_t^{w,f} / (N_t^{w,f} + N_t^{w,m})$] affect the female fraction not only in the northern area but also in the southern area. In AWMP5 the fraction in the southern area was assumed to be independent of this dynamics being given exclusively by an equation like Eq. (5).

By Eq. (3) the proposed model also assumes that it is the total number of whales that maintain a fixed ratio between the two areas [$N_t^n / N_t^s - (1 - q) / q$] and not just the females, as it is assumed in AWMP5.

[In order to finally connect the two areas for the proposed model, from Eqns. (3) and (4) note that number of females in the southern area is

$$N_t^{s,f} = q N_t^w r_t \frac{N_t^{w,f}}{N_t^{w,f} + N_t^{w,m}} \quad (6)$$

Hence, the number of males in the southern area is $N_t^s - N_t^{s,f}$ and, then, the number of males

and females in the northern area can be calculated by Eq. (2).]

Influx model

The influx model treats the northern and the southern areas independently with

$$\begin{aligned} N_r^{s,f} &\propto N_t^{w,f} & N_r^{s,m} &\propto N_t^{w,m} / \mathcal{G}_t^s \\ N_r^{n,f} &\propto N_t^{w,f} & N_r^{n,m} &\propto N_t^{w,m} / \mathcal{G}_t^n \end{aligned} \quad (7)$$

with $\mathcal{G} = 1 / \lambda$ parameter for each area, and the $\mathcal{G} = 1 / \lambda$ parameter for the southern area having the following time dependence

$$\mathcal{G}_t^s = \mathcal{G}_{1987}^s + (t - 1987)\beta \quad (8)$$

In order to avoid the potential problem of negative values imposed by linearity and in order to obtain a higher degree of mathematical similarity between the influx and the closed model, the time dependence of Eqns. (4) and (5) is proposed, so that the female fraction in the southern area of the influx model is

$$\frac{N_t^{s,f}}{N_t^{s,f} + N_t^{s,m}} = r_t \frac{N_t^{w,f}}{N_t^{w,f} + N_t^{w,m}} \quad (9)$$

where

$$r_t = \min \left(\frac{N_t^{w,t} + N_t^{w,m}}{N_t^{w,t}} \frac{c e^{\alpha + \beta(t-1987)}}{1 + e^{\alpha + \beta(t-1987)}} \right) \quad (10)$$

with c being a scaling constant.

When presenting parameter estimates, it may be desirable to re-parameterise this model to reflect simply the value of \mathcal{G}_t in 1987 and 2007 (\mathcal{G}_{1987} and \mathcal{G}_{2007}) by calculating the α and β parameters from the flowing constraint

$$r_{1987} = \frac{N_t^{w,f}}{N_t^{w,f} + N_{w,m} / \mathcal{G}_{1987}} \quad (11)$$

$$r_{2007} = \frac{N_t^{w,f}}{N_t^{w,f} + N_{w,m} / \mathcal{G}_{2007}} \quad (12)$$