Annex E

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

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1. INTRODUCTORY ITEMS

1.1 Convenor's opening remarks
Donovan welcomed the participants to the meeting. He noted that the major part of the work of the SWG this year is to build upon the progress made at the intersessional workshop (SC/65a/Rep02) held in Copenhagen in December 2012 on developing *SLA*s for the Greenlandic hunts, with an initial emphasis on humpback whales and bowhead whales. That Workshop dealt with a number of topics and they are dealt with where appropriate on the SWG's agenda. The SWG will also consider management advice for the hunts of Greenland and St Vincent and The Grenadines.

1.2 Election of Chair
Donovan was elected Chair.

1.4 Appointment of rapporteurs
Givens, Scordino, Butterworth and Punt acted as rapporteurs with assistance from the Chair.

1.5 Adoption of Agenda
The adopted agenda is given as Appendix 1.

1.6 Documents available
The new primary documents available to the SWG were SC/65a/AWMP01-07.

2. GRAY WHALES WITH EMPHASIS ON THE PCFG (PACIFIC COAST FEEDING GROUP)

2.1 Report of intersessional Workshop (SC/65a/Rep02)
In 2010, the Committee agreed that PCFG (Pacific Coast Feeding Group) whales should be treated as a separate management unit. PCFG whales are defined as gray whales observed (i.e. photographed) in multiple years between 1 June and 30 November in the PCFG area (IWC, 2011a, p.22). Not all whales seen within the PCFG area at this time will be PCFG whales and some PCFG whales will be found outside the PCFG area at various times during the year. The Makah tribe would like to take gray whales in the Makah usual and accustomed fishing grounds (U&A) in the future and the objective of the *SLA*s they proposed is to minimise the risk to the PCFG whales and meet the Commission's conservation objectives. An important component of this is to restrict hunting to the migratory season, i.e. prior to 1 June. The Committee began the evaluation process in 2011.

Last year, the Committee had agreed that two *SLA* variants (one with research provisions) met the conservation objectives of the Commission (IWC, 2013b, p.19). *SLA* variant 1 proposed that struck-and-lost whales did not count towards the APL (the 'allowable PCFG limit' – a protection level) i.e. there is no management response to PCFG whales struck but not landed. *SLA* variant 2 proposed that all struck-and-lost whales counted to the APL irrespective of hunting month, i.e. the number of whales counted towards the APL may exceed the actual number of PCFG whales struck. However, the Committee also noted that the two variants did not exactly mimic the proposed hunt and expressed concern that the actual conservation outcome of the proposed hunt had not been fully tested. The reason for this relates to how strikes in May are treated in *SLA* calculations. In the variants, the APL is adjusted to account for how many whales the Makah hunting plan would permit in May.

The two tested *SLA* variants bracketed the possible Makah hunting plans, assuming either 7 or 0 strikes in May for Variants 1 and 2, respectively. The Committee had approved Variant 2 but had stated that Variant 1 only met the Commission's conservation objectives if it was accompanied by a specific annual research programme (i.e. a photo-identification programme to monitor the relative probability of harvesting PCFG whales, the results of which are presented to the Scientific Committee for evaluation each year).

Donovan summarised progress made during the intersessional Workshop (SC/65a/Rep02). There are insufficient data to determine the proportion of strikes that would occur in May or prior to May, and the Workshop agreed to test six new variants to cover the full range of possible strikes occurring in May or prior to May, i.e. variants allowing x strikes prior to May where $x = 1,\ldots,6$. In particular, it had recommended that the full set of trials be repeated for these six variants (in addition to the two *SLA*s agreed by the Committee last year).

The Workshop also recommended that the photo-id catalogue for the eastern North Pacific gray whales (that will be used to assess whether landed whales are from the PCFG) be made publicly available as it is a key component of the management approach. It was pleased to be informed that funding is available to digitise the catalogue. Weller informed the SWG that NOAA still has funds available to digitise the catalogue of PCFG whales. Scordino noted that work is underway to compile photographs from a few key contributors for a photo catalogue of PCFG whales to be held at NOAA's National Marine Mammal Laboratory; this catalogue, at least initially, will not be publicly available.

2.2 New information and results
2.2.1 Further evaluation of proposed Makah Hunt
SC/65a/AWMP06 presented trial results for the six *SLA* variants discussed above. By examining the final depletion statistic for all evaluation and robustness trials for the six new *SLA* variants and Variants 1 and 2 used in the 2012 *Implementation Review*, the authors concluded that:

(1) the conservation performance of the new variants was intermediate between Variant 1 and Variant 2;
(2) there is not a uniform, linear increase in conservation performance caused by reducing the maximum number of strikes that occur prior to May;
(3) there is a point of saturation at which increasing the number of strikes prior to May does not lead to a decrease in conservation performance; and
(4) the results show that conservation performance changes as would be expected.

In summary, the performance of all the new variants was no worse than for Variant 1 and no better than for Variant 2. These conclusions also hold true for other conservation performance statistics examined.

The SWG thanked the authors for their work. The SWG recalled that the research requirement for Variant 1 had been imposed because its conservation performance was inferior to that of Variant 2 on a small number of trials. The SWG **agreed** that the newly tested *SLA*s performed acceptably and met the Commission's conservation objectives provided that they, like Variant 1, are accompanied by a photo-identification programme to monitor the relative probability of harvesting PCFG whales which is undertaken each year and the results presented to the Scientific Committee for evaluation.

SC/65a/AWMP03 presented an update on the availability of PCFG whales in the Makah U&A based on photo-identification surveys. With data collected from 1984 to 2011, strong evidence was found for PCFG whales being more available in the Strait of Juan de Fuca (56% of whales observed being PCFG whales) as compared to the Pacific Ocean (31%). This difference is statistically significant (Fisher's exact test, $p<0.01$). This finding supports the Makah Tribe's proposed prohibition of hunting in the Strait of Juan de Fuca. No significant differences were found for comparisons of the availability of PCFG whales by month in the Pacific Ocean. The updated availability of PCFG gray whales in Pacific Ocean waters of the Makah U&A presented in this paper was not appreciably different to the 30% availability used in the 2012 *Implementation Review*.

The SWG **welcomed** this update. It noted that the research program to monitor the availability of PCFG whales has the added benefit of collecting data that aids the assessment of risk that the Makah hunt would strike a whale identified in the western North Pacific (WNP) that has migrated to the US west coast discussed below. In response to the discussion, Scordino **agreed** to examine the possibility of trends in the data and include it in an updated paper for next year's meeting.

As noted last year (IWC, 2013b, p.20), observations of gray whales identified in the WNP migrating to areas off the coast of North America (Alaska to Mexico) raise concern about placing the WNP population at potential risk of being harmed or killed accidentally in the proposed Makah hunt. It was noted that the research programme to monitor the availability of PCFG whales has the added benefit of collecting data that aids the assessment of risk that the Makah hunt would strike a whale identified in the WNP that has migrated to the US west coast.

Given the ongoing concern about status of the gray whales in the WNP, in 2011 the Scientific Committee emphasised the need to estimate the probability of a western gray whale being killed during aboriginal gray whale hunts (IWC, 2012). Additionally, in the USA it is required that NOAA prepare an Environmental Impact Statement (EIS) pertaining to the Makah's request for a waiver under the US Marine Mammal Protection Act (MMPA) in order to hunt gray whales. The EIS will include an estimate of the likelihood of Makah hunters approaching, pursuing, and attempting to strike a WNP gray whale in addition to the likelihood of actual strikes (assumed to result in death or serious injury).

Moore and Weller (2013) estimated the probability that one or more whales identified in the WNP might be killed during the hunt proposed by the Makah Indian Tribe. This analysis updated the analysis of mortality risk provided to last year in Moore and Weller (2012) by incorporating Committee from feedback last year's meeting (IWC, 2013b, p.20). The probability of striking or taking a WNP gray whale during the proposed Makah hunt was estimated using four different sets of models (six models in total). The author's 'most plausible' model uses all available information and includes the least number of assumptions. Based on this model, the probability of striking at least one WNP gray whale in a single season ranged from 0.007 to 0.036, depending on whether the median or upper 95th percentile estimate is used and on which maximum is used for the total number of whales struck. The probability of striking at least one WNP gray whale during a five-year period ranges from 0.036 to 0.170 across the same scenarios. The expected number to be struck ranges from 0.01 to 0.04 for a single year and from 0.04 to 0.19 across 5 years.

Estimates from this analysis are considered by the authors to be precautionary since they assume that the Makah will achieve their proposed maximum strike limits. The results offer a conservative initial step in assessing the potential risk of WNP gray whales incurring mortality incidental to the proposed hunt on the ENP population by the Makah Indian Tribe.

The SWG **welcomed** this paper, recognising that it represents initial work. It notes that it will provide a contribution to the recommended workshop examining gray whales throughout the North Pacific (Annex F).

2.2.2 Other information

Mate summarised his recent satellite tagging work on PCFG gray whales. In 2012, Mate and his colleagues tagged nine additional gray whales off Oregon and northern California to those previously reported. Six of those continued transmitting until the whales visited the breeding grounds and returned to the Pacific Northwest; many are still providing data. In 2009, all of the satellite tagged whales visited the same lagoon, Ojo de Liebre, but in 2012 several whales travelled farther south to water offshore of San Ignacio Lagoon and Magdalena Bay. In 2009 and 2012 a tagged PCFG gray whale migrated as far north as Icy Bay, Alaska, beyond the management-defined range of the PCFG whales. Many of the tagged whales migrated further north initially in the spring than where they spent most of their PCFG feeding season. Considering the number of tags deployed and the success of their deployment, Mate noted that it will be possible to define home ranges and core areas for individuals. Mate also mentioned that ongoing research assessing the wound healing in tagged whales may be ready for presentation to the Scientific Committee next year. Finally, Mate reported on plans to deploy as many as 12 more tags in 2013. To the extent possible, attempts will be made to tag the same whales that were tagged in 2009 to see if those whales utilise the same home range, migration timing and routes, and breeding areas each year.

Weller briefly reported on a scientific task force (comprising eight NMFS scientists with expertise in fields relevant to stock structure assessment) workshop held by the US National Marine Fisheries Service (NMFS) to assess gray whale stock structure (Weller *et al.*, 2013). While the primary focus was to provide advice in terms of US domestic legislation, much of the work was also of scientific relevance to the IWC Scientific Committee. New information has suggested the possibility of recognising two additional stocks in US waters to the eastern North Pacific stock currently recognised: (1) the Pacific Coast Feeding Group (PCFG); and (2) the western North Pacific (WNP) stock. The task force reviewed new information relevant to gray whale stock structure, including the results of genetic, photo-identification, tagging and other studies. It agreed on a series of questions relevant to evaluating whether the PCFG and/or the WNP gray whales qualify as stocks under US guidelines and followed a structured decision-making process. The task force concluded that there was substantial uncertainty regarding whether the PCFG qualified as a separate stock and was unable to provide definitive advice. It did, however, advise that the WNP stock should be recognised as a stock. The task force provided recommendations for future work, including the continuation of field studies as well as additional analysis of the existing photo-identification and genetic data.

The SWG thanked Weller and noted that the report represented a thorough review of the current knowledge of PCFG and WNP gray whales. In response to a question on how the US defines a stock, Weller responded that the primary criterion is demographic independence. The SWG noted that the Scientific Committee continues to work on definitions relating to 'stock' and related terms and that this report will be of value to the working group on stock definition. It also **agreed** that it will provide valuable input to the recommended workshop examining gray whales throughout the North Pacific (see Annex F).

2.3 Summary and recommendations

The SWG **concluded** that the conservation performance of the proposed Makah whaling management plan has now been fully analysed within the *SLA* evaluation framework. It **agreed** that the proposed management plan meets the conservation objectives of the Commission provided that if struck and lost animals are not proposed to be counted toward the APL then a photo-identification research programme to monitor the relative probability of harvesting PCFG whales in the Makah usual and accustomed fishing grounds (U&A) is undertaken each year and the results presented to the Scientific Committee for evaluation. In other words, only Variant 2 was judged to meet the Commission's conservation objectives without the research requirement.

In regards to questions on whether the SWG should consider conducting an *Implementation Review* to evaluate the potential impacts of the Makah hunt on whales identified in the WNP, it was **agreed** that before an *Implementation Review* is conducted that the recommended workshop be held to review the range-wide population structure and status of North Pacific gray whales (see Annex F).

3. CONSIDERATION OF WORK REQUIRED TO DEVELOP *SLA*S FOR ALL GREENLAND HUNTS BEFORE THE END OF THE INTERIM PERIOD

3.1 Common minke whales and fin whales

3.1.1 Report from the intersessional Workshop (SC/65a/Rep02)

The Workshop noted the potential overlap between RMP and AWMP management with respect to common minke whales and fin whales in the North Atlantic. It agreed that the process of developing *SLA*s and RMP *Implementations* for stocks in regions where both commercial and aboriginal catches occur should include the following steps: (a) development of a common trials structure which adequately captures uncertainties regarding stock structure, mixing, MSYR, etc.; (b) identification of an *SLA* which performs as adequately as possible if there are no commercial catches; and (c) evaluation of the performance of RMP variants given the *SLA* selected at step (b). The work on RMP/AWMP-lite in this regard (see Item 3.1.3) was welcomed.

3.1.1.1 STOCK STRUCTURE

The Workshop recognised the need for consistency in stock structure hypotheses with RMP *Implementations.*

With respect to fin whales it had noted that the present hypotheses will be reviewed during the RMP *Implementation Review* scheduled for the 2013 meeting of the Scientific Committee. It also noted that it may be possible to base the *SLA* for fin whales off West Greenland on operating models which considered West Greenland only, i.e. in effect assuming that the animals found off West Greenland comprise a single stock that is adequately represented by the abundance estimates obtained off West Greenland. The rationale for this is that even if there are multiple stocks off West Greenland (as was suggested in some hypotheses considered during the RMP *Implementation*), it may be reasonable to assume that they are susceptible to capture in the aboriginal hunt proportionally to their abundance when the survey is conducted. In contrast, varying proportions of the multiple stocks over time would violate this assumption. The RMP *Implementation Review* should be asked to consider carefully any evidence that there may be more than one stock mixing off West Greenland.

With respect to common minke whales, the Workshop noted that it has been agreed that a joint AWMP/RMP stock structure workshop will be held in the intersessional period between the 2013 and 2014 annual meetings of the Scientific Committee (see Item 3.1.3 below). The results of this workshop will be essential to the *SLA* development process.

The SWG **endorsed** the conclusions and recommendations of the Workshop in this regard.

3.1.2 Joint RMP/AWMP Workshop(s) on stock structure

The SWG noted that the Steering Group for this meeting (which included SWG members including the Chair) had met to develop a work plan and that this had been reported to the sub-committee on the RMP (Annex D, Appendix 2). The SWG reiterated its support for this Workshop, first agreed last year (Donovan *et al.*, 2013), and the work plan developed.

3.1.3 AWMP/RMP-lite

SC/65a/Rep02 had introduced the idea of a new computer program called RMP/AWMP-lite, which is a platform written in R which implements a management strategy evaluation framework for evaluating the performance of catch and strike limit algorithms. The essence of RMP/AWMP-lite is the use of an age-aggregated model rather than an age-structured model to considerably speed up calculations; this will allow developers more easily to explore the properties of candidate *SLA*s before they are submitted to rigorous full testing. This framework can be used to evaluate management schemes where multiple stocks of whales are exploited by a combination of commercial and aboriginal whaling operations. The operating models can be conditioned to the actual data to allow an evaluation of whether stock structure assumptions and other hypotheses are comparable with the available data. The Workshop had suggested several improvements and extensions to the program. The SWG **endorsed** the conclusions and recommend-ations of the Workshop in this regard.

In discussion, Punt noted that all but one of the tasks had been completed (see SC/65a/RMP05). The ability to apply an *SLA* based on an independently-written routine has been implemented for the bowhead and humpback trials, but not in AWMP/RMP-lite. He noted that AWMP/RMP-lite had become complicated owing to the recent developments, which may warrant changing the way the code is implemented.

The Workshop recalled that the current approach to evaluating *SLA*s for the Greenlandic hunts treats each species independently even though need is expressed as a total amount of meat over multiple species. It was noted that once single-species *SLA*s are developed, a multispecies 'need surface' which expresses the trade-offs among need for several species in terms of a multi-dimensional inequality constraint could be considered because it should be easier to satisfy total need rather than satisfying maximum needs separately for several species.

The SWG **endorsed** the conclusions and recommend-ations of the Workshop in this regard, **reiterating** that work on single-species *SLA*s should be completed before multi-species considerations are examined.

The Workshop had also noted that the RMP and AWMP dealt with ship strikes and by-catch differently. The RMP catch limit is for all human-induced removals so that the commercial catch is the difference between the RMP catch limit and the expected removals due to, for example, ships strikes and bycatch. In contrast, the aim of the AWMP is not to maximize catch, but rather to satisfy need. Consequently, the strike limit is not reduced by ship strikes and by-catch. Rather, the trials used to select *SLA*s account for future levels of other human-caused removals, but the strike limit is still related only to need. Thus, the removals from the population in the case of aboriginal hunts would be the strike limit plus other human-caused removals.

The SWG **endorsed** the conclusions and recommend-ations of the Workshop in this regard, noting that this approach is used for other human-induced removals under Items 3.2 and 3.3 below.

3.1.4 Discussion and work plan

The work plan for SWG in relation to the development of *SLA*s for the hunts for fin and minke whales off West Greenland is partially dependent upon the associated work on RMP *Implementation Reviews* for fin and common minke whales. In terms of activity over the coming year the SWG will:

(1) examine the final modelling framework and trial specifications for North Atlantic fin whales being developed intersessionally including at an RMP intersessional workshop by a steering group (which includes AWMP members) and examine how this can be incorporated into *SLA* development;
(2) participate in the joint AWMP/RMP workshop on stock structure of common North Atlantic minke whales agreed last year to review stock structure hypotheses and review the results from the AWMP perspective an emphasis on Greenland;
(3) examine the discussions and results of the RMP *Implementation Review* for common North Atlantic minke whales that will start with a pre-meeting before SC/65b from an AWMP perspective; and
(4) receive need envelopes from Greenland for North Atlantic fin and common minke whale hunts off Greenland.

3.2 Humpback whales

3.2.1 Report from intersessional Workshop (SC/65a/Rep02)

Donovan briefly summarised the new information available for humpback whales off West Greenland from the Workshop (SC/65a/Rep02).

3.2.1.1 STOCK STRUCTURE

With respect to stock structure, the Committee agreed in 2007 that the West Greenland feeding aggregation was the appropriate management unit to consider when formulating management advice. Whales from this aggregation mix with individuals from other similar feeding aggregations on the breeding grounds in the West Indies (IWC, 2008, p.21).

The Committee also received valuable information from 30 satellite-tagged whales (Heide-Jørgensen, 2012). This found that few excursions were made outside the areas covered by the 2005 and 2007 aerial surveys which took place during August-September, although one animal left West Greenland in June and reached Newfoundland in July (i.e. would not have been available for counting). Two whales departed from West Greenland and took a route south along Labrador and Newfoundland. The Workshop recognised the value of such work to both stock structure and abundance and encouraged its continuation.

Photo-identification data are also valuable for stock structure and movement studies. Subsequent to the Workshop Witting confirmed that all photographs from West Greenland had been submitted to the North Atlantic humpback Catalogue who also informed the Chair that one match had been made with the Gulf of Maine in addition to matches from eastern Canada that confirmed the results from the telemetry studies.

The Workshop endorsed the previous Scientific Committee recommendation that the West Greenland feeding aggregation was the appropriate management unit and that it should be treated as a single stock in the trials.

3.2.1.2 ABUNDANCE

The Workshop reviewed the abundance estimates that had been received and adopted by the Scientific Committee. These are discussed further under Item 3.2.2.1 below.

The Workshop had agreed to use the estimates of relative abundance from aerial surveys to condition the trials. Since available abundance estimates from the mark-recapture studies covered a shorter period and were heavily correlated it was agreed that they would only be used in a *Robustness Trial*. However, the Workshop had also agreed that given that mark-recapture abundance estimates may become common in the future for both humpback and bowhead whales, efforts should be made to develop ways to better integrate them into the operating models for the *SLA* trials. It had also agreed that for future surveys, only absolute estimates of abundance would be generated.

3.2.1.3 REMOVALS

3.2.1.3.1 DIRECT CATCHES

Noting past difficulties in modelling the full western North Atlantic (including allocation of past catches) and the decision to treat the feeding aggregation as the appropriate management unit, it was agreed that trials would begin in 1960 under an assumption that the age-structure in that year is steady. The catch series for this period is known and this is treated as the best catch series and no alternatives are required. It can be found in the revised trial specifications to the present report (see Appendix 2).

None of the photographic recaptures of humpback whales from St. Vincent and the Grenadines have been made with animals from the West Greenland feeding aggregation, so these catches are not included in the catch series. However, given possible migration routes (e.g. from telemetry data), it was noted that known direct catches occurred from whaling stations off the east coast of Canada after 1960 that may have included some 'West Greenland' animals.

Making simple assumptions (Greenland whales are estimated to be off Newfoundland for ~1 month in comparison to Canadian whales which are there for ~ 6 months and taking the relative abundances of the two populations into account) leads to an estimated potential direct catch of Greenland humpbacks off Canada of up to 5% of the total direct catch. The Workshop agreed that this will be incorporated into the catch series in the revised trial specifications, but that no future direct catches off Canada will be simulated.

3.2.1.3.2 BYCATCHES AND SHIP STRIKES

The Workshop addressed the question of bycatches in both West Greenland and elsewhere. For West Greenland, noting that the crab fishery which was primarily responsible for bycatches has now peaked, it was agreed that future bycatches for Greenland will be generated assuming that the exploitation rate due to bycatch in the future equals that estimated for the trial in question over the most recent five-years. As no bycatches were reported for the 1960-2000 period for West Greenland, it was noted that this assumption is conservative in that bycatches will be assumed for the future.

With respect to bycatches of 'West Greenland' animals outside West Greenland, the Workshop agreed to an approach similar to that for direct catches, i.e. the estimated potential direct catch of Greenland humpbacks off Canada could be up to 5% of the total Canadian bycatch. Should ship strikes occur, the same approach would be used. The Secretariat agreed to investigate the available information on bycatch and ship strikes.

3.2.1.4 BIOLOGICAL PARAMETERS

The Workshop noted that prior distributions need to be specified for three biological parameters: (a) the non-calf survival rate; (b) the age-at-maturity; and (c) the maximum pregnancy rate. The objective is to develop priors (taken to be uniform for all three parameters) which are plausible based on the range of estimates in the literature. The values for these parameters used in the actual trials will encompass a narrower range than these priors because the priors will be updated by the data on abundance and trends in abundance during the conditioning process.

The Workshop agreed that the prior for non-calf survival, S_{1+}, will be U[0.9, 0.995]. The lower bound for this prior is the lower 95% confidence interval for the estimate of non-calf survival obtained by Larsen and Hammond (2004) while the upper bound is the upper 95% confidence interval for the estimate of non-calf survival rate for humpback whales in Prince William Sound, Alaska reported by Zerbini *et al.* (2010). Zerbini *et al*. (2010) based their estimates of maximum rates of increase on the non-calf survival rate estimate for this population.

The maximum pregnancy rate, f_{max}, is the pregnancy rate in the limit of zero population and thus is not measureable but is expected to be higher than observed pregnancy rates. Based on its review of the available information, the Workshop agreed that the prior will be U[0.4, 0.8]. The lower bound for this prior is close to the average of the estimates of pregnancy rate for humpback whale stocks reported by Zerbini *et al.* (2010). The upper bound was based on the view that the theoretical maximum (i.e. all mature females giving birth every year) is infeasible but that an estimate that involved a high proportion of animals on a one-year cycle (individuals have been observed to do this) should be considered.

The Workshop agreed that the prior for the age-at-maturity should be U[4, 12]. This is based on data from individually identified whales and incorporated the lower ages-at-first-parturition reported by Clapham (1992) and Gabriele *et al.* (2007) and the high value reported by Robbins (2007).

Recognising the great uncertainty in these priors given the paucity of data, the Workshop agreed that it was important to develop a *Robustness Trial* in which the priors for the biological parameters are modified by lowering the upper bounds for the priors for S_{1+} and f_{max} and increasing the lower bound for a_m.

The abundance data are not informative about carrying capacity and the Workshop agreed that trials should be based on the prior for carrying capacity, *K*, proposed in Punt (2012), U[0, 30,000], noting that the estimated total catch of North Atlantic humpback whales is approximately 30,000 (Reeves and Smith, 2002).

3.2.1.5 NEED

Need envelopes are an important component of developing a trial structure and are the responsibility of the relevant Governments. Need envelopes for humpback whales were submitted to the Workshop in Witting (2012) and these reflected the Greenlandic preference for humpback whales over fin whales and Greenland's desire for flexibility. The need envelope is summarised in Fig. 2. Reiterating that the determination of catch limits is a matter for the Commission but recognising that the Committee needs to be in a position to provide scientific advice on any need requests, the Workshop had agreed that need envelopes that increased over the initial three quota blocks from ten to twenty whales should capture this issue. Hence, the following three need envelopes were agreed [10, 15, 20-20], [10, 15, 20-40] and [10, 15, 20-60], with the middle envelope being considered the base case. Witting had also suggested consideration of an additional 'backup' scenario of initially adding ten humpback whales to the base case envelope (this was intended to compensate for any unforeseen decline in the common minke whale strike limits of up to approximately 60 minke whales).

3.2.1.6 *SLA*S TO BE CONSIDERED

The Workshop had agreed that all of the trials would be conducted for a bounding case and for two 'reference *SLA*s', in addition to any other *SLA*s which might be proposed by developers:

(1) the *Strike Limit* is set to the need;
(2) the *Strike Limit* is based on the interim *SLA* (IWC, 2009); and
(3) the *Strike Limit* is based on a variant of the interim *SLA* which makes use of all of the estimates of abundance, but downweights them based on how recent they are.

The Workshop had also agreed that the developers would be provided with:

(1) total need for the next block;
(2) catches by sex;
(3) mortalities due to bycatch in fisheries and ship strikes; and
(4) estimates of absolute abundance and their associated CVs.

3.2.1.7 TRIAL STRUCTURE

The Workshop developed proposed *Evaluation* and *Robustness* trials. These formed the basis for discussions under Item 3.2.3.

3.2.2 Discussion of the Workshop report and the results of intersessional work

The SWG **thanked** the Workshop for it comprehensive work and **broadly endorsed** its conclusions and recommendations; where appropriate they are either incorporated in the trial specifications (see Appendix 2) or provided the basis for further discussions under Item 3.2.3 below.

3.2.2.1 ABUNDANCE ESTIMATES

SC/65a/AWMP01 analysed surfacing time and availability bias for humpback whales in West Greenland, providing updated estimates of abundance. A total of 31 satellite-linked time-depth-recorders of three different types were deployed on humpback whales in West Greenland in May and July 2009-10. Over the period whales were tracked, the SLTDRs recorded the fraction of a 6-hour period that the whales spent at or above 2m depth. This depth is considered to be the maximum depth humpback whales are reliably detected on visual aerial surveys in West Greenland. Eighteen transmitters provided both data on the surface time and the drift of pressure transducer. The average surface time for these whales over the entire tracking period and during the two 6-hr periods with daylight was 28.3% (CV=0.06). Six whales that met data filtering criteria had reduced drift of the depth transmitter and their average surface time was 33.5% (CV=0.10). Previous analyses of visual aerial survey data have shown that the amount of time whales are available to be seen by observers is not an instantaneous process. Therefore the surface time needs to be corrected for a positive bias of about 10% when developing a correction factor for availability bias which increases the availability to 36.8% (CV=0.10). The most recent survey of humpback whales in West Greenland was conducted in 2007 and corrections with this availability factor provides fully corrected abundance estimates of 4,090 (CV=0.50) for mark-recapture distance sampling analysis and 2,704 (CV=0.34) for a strip census abundance estimate. These estimates are about 25% larger than previous estimates from the same survey. The annual rate of increase was 9.4% per year (SE 0.01) which was unchanged from the published paper.

The SWG noted that the methods behind the new estimates had been discussed fully at previous meetings when considering the 2007 survey. The revised estimate here was based on updated and improved information on the diving behaviour of whales from additional satellite tag data. It therefore **accepted** the new strip census abundance estimate as the best estimate. The full list of estimates accepted by the SWG is provided in Table 1. This information is also included in the trial specifications (see Appendix 2).

3.2.2.2 STOCK STRUCTURE

Noting the importance of information of photo-identification studies both to stock structure and the possibility of human-induced mortality outside the West Greenland area, the SWG **recommended** that Greenlandic scientists to work with the College of the Atlantic to develop a full overview of the available data and present this to the proposed intersessional Workshop.

3.2.2.3 REMOVALS

In the light of discussions at the workshop and at the present meeting, the SWG **agreed** that the Secretariat should continue to work with Canadian scientists and others to finalise the catch series (direct and indirect) following the guidelines agreed at the Workshop and present a final series to the proposed intersessional Workshop.

3.2.2.4 INITIAL INVESTIGATIONS OF *SLA*S

The SWG proceeded to discuss the results provided by the two sets of developers of candidate *SLA*s, which were based on trials as developed at the Intersessional Workshop. As the SWG discussed the results of this work for humpback and bowhead whales together, these are considered further under Item 3.4.

3.2.3 Trial structure

Based on the Workshop report and discussions above, the SWG revised the final trial structure for evaluation of *SLA*s for the West Greenland humpback whale hunt (also see Appendix 2).

During review of the trial specifications, it was noted that the prior distribution for f_{max} had been defined to be Unif[0.4,0.8], whereas data from Zerbini *et al.* (2010) included some lower estimates. In response to a question as to whether the lower end of the f_{max} prior should be adjusted downward accordingly, it was noted, however that the Zerbini *et al.* (2010) data referred to *observed* increase rates, whereas f_{max} referred to *theoretical maximum* rates. Values of f_{max} below 0.4 were regarded as very unlikely, and no change to the specifications was made.

The SWG **agreed** to replace need envelope D with C for trials 3A and 3B. The justification was that envelope D (involving pre-emptively higher initial need) would be very unlikely to be sought if the first survey was delayed until year 15. The SWG also agreed to add trials using need envelope C for all evaluation trials numbered 2A, 2B, and 4 or higher since it was important to consider the case when no initial jump in need was requested.

The SWG **agreed** that it was appropriate to include trials based on the environmental variability model for population dynamics developed by Cooke (2007) be included. This model reflects the impact of this variability on the population growth rate. The effect is not symmetrical because this growth rate is bounded for demographic reasons. This results in a qualitative difference being predicted in the behaviour of recovering populations. These first follow a steady exponential trend, but once somewhat higher abundance is reached much more variable behaviour can ensue (as indeed appears evident, for example, for the South West Atlantic right whale and Eastern North Pacific gray whale population). The SWG **agreed** that these environmental variability trials were plausible and thus should be considered *Evaluation Trials*. Since conditioning using this approach may prove problematic, it was also **agreed** that this model would be used only for future projections. These new trials are referred to as 'asymmetric environmental stochasticity'. Trial 8 will be parameterised intersessionally (Witting).

The factors considered in the trials are summarised in Table 1.

In preparation for evaluating *SLA*s for subsistence hunting of bowheads and humpback whales off West Greenland, the SWG reviewed the performance statistics, tables, and graphs used for past *SLA* evaluation and *Implementation Reviews*, to identify what methods were found most effective and informative.

Statistic D8 ('rescaled final population') was clarified in light of the fact that known or projected incidental removals will occur for some stocks hunted in West Greenland (e.g. Canadian hunting of bowhead whales). D8 has previously

Table 1

Factors tested in the trials.

Factors	Levels (reference levels shown bold and underlined)	
	Humpback whales	Bowhead whales
$MSYR_{1+}$	1%, 3%, **5%**, 7%	1%, **2.5%**, 4%
$MSYL_{1+}$	0.6	**0.6**, **0.8**
Time dependence in K*	**Constant**, halve linearly over 100 years	
Time dependence in natural mortality, M*	**Constant**, double linearly over 100 years	
Episodic events*	**None**, 3 events occur between years 1-75 (with at least two in years 1-50) in which 20% of the animals die. Events occur every five years in which 5% of the animals die.	
Need envelope	A: 10, 15, 20; 20 thereafter **B: 10, 15, 20; 20->40 over years 18-100** C: 10, 15, 20; 20->60 over years 18-100 **D: 20, 25, 30; 30->50 over years 18-100**	**A: 2, 3, 5; 5 thereafter** B: 2, 3, 5; 5 -> 10 over years 18-100 **C: 2, 3, 5; 5 -> 15 over years 18-100**
Future Canadian catches	N/A	**A: 5 constant over 100 years** B: 5-> 10 over 100 years C: 5-> 15 over 100 years D: 2.5 constant over 100 years?
Survey frequency	5 year, **10 year**, 15 year	
Historic survey bias	0.8, **1.0**, 1.2	0.5, **1.0**
First year of projection, τ	**1960**	**1940**
Alternative priors	$S_{1+} \sim U[0.9, 0.99]$; $f_{max} \sim U[0.4, 0.6]$; $a_m \sim U[5, 12]$	N/A
Strategic surveys	Extra survey if a survey estimate is half of the previous survey estimate	
Asymmetric environmental stochasticity parameters	To be finalised by an intersessional group	

*Effects of these factors begin in year 2013 (i.e. at start of management). The adult survival rate is adjusted so that if catches were zero, then average population sizes in 250-500 years equals the carrying capacity. Note: for some biological parameters and levels of episodic events, it may not be possible to find an adult survival rate which satisfies this requirement.

been defined as the ratio of the final abundance (either 1+ or mature females) after 100 years with removals given by the *SLA* to the final abundance 'under a scenario of zero strikes'. For over a decade of AWMP *SLA* development for several fisheries no incidental take has been considered, so the condition of 'zero strikes' has been equivalent to 'zero removals'. Indeed, some SWG members had believed incorrectly that D8 was calculated relative to zero removals. The possibility of non-zero incidental removals now highlighted this point of confusion.

Therefore, the SWG defined statistic D8(0) to represent rescaled final population relative to a scenario with zero removals *of any kind*, and D8=D8(inc) to refer to the existing statistic which is relative to a scenario with zero strikes but possibly non-zero incidental removals. Statistic D8(0) is boldfaced to indicate that it is 'considered …more important'.

The same confusion about incidental removals applies to the abundance in year t under a scenario of zero strikes, denoted P_t^*. The SWG defined $P_t^*(0)$ and $P_t^*(\text{inc})$ analogously to D8(0) and D8(inc).

The SWG promoted statistic N12 ('mean downstep') to the boldfaced 'more important' category, and demoted R1 ('relative recovery') to non-boldfaced.

Consistent with past efforts, the SWG **agreed** to produce two sets of output when evaluating candidate *SLA*s. The first is a comprehensive library of all output, including the 5%tile and median values of all statistics (boldfaced 'more important' or otherwise), and all graphs and other output listed in the trial specifications. The library will be available for inspection but not used as the primary basis for SWG discussion. The second output set is a subset of the comprehensive library. It contains only the tables and graphs anticipated to be the most useful for SWG evaluation of candidate *SLA*s. The elements of this review set are discussed below.

A table of 5%tile and median values of certain statistics will be included in the review set. The most important aspect of this table is that the same quantities for different *SLA*s should be arranged in a column with aligned decimal points, so that like numbers can be compared vertically. The next paragraph summarises the contents of the table and a possible format. Apart from the columnwise comparison requirement, the format may be adjusted to partition the contents and fit on the page(s) sensibly.

Columns of the table are 5%tile and median values for D1(1+), D1(mature females), D8(0), D8(inc), D9(1+), D10(1+), N9(20) and N9(100). Row blocks of the table correspond to trial scenarios. Rows within a block correspond to different strike limit rules. Within a block, there would be one row for each candidate SLA. Also included in the block would be rows for removals=0 (i.e. no strikes or incidental removals), strikes=0 (but incidental removals do occur), and strikes=need.

In addition to this table, the following plots will be included in the review set.

(1) The 'Zeh plots' (IWC, 2013c). The statistics to be displayed in the Zeh plots will be all those described for the table above, and N12 ('mean downstep'). Note that the Zeh plots rely on more quantiles of the statistics than just the 5th and 50th ones shown in the table.
(2) The plots defined as D6, i.e. abundance trajectory plots of P_t versus t ($t=0,\ldots,100$). All 100 simulated abundance trajectories for one algorithm are superimposed on this plot. Each plot pertains to a single *SLA* and a single trial scenario. Plots for 1+ abundance will be included in the review set, and analogous plots for the mature female component will be included in the comprehensive library.
(3) Plots of C_t versus t, as a step-function over 5-year blocks ($t = 0,\ldots,100$). All 100 simulated quota trajectories for one algorithm are superimposed on this plot. Each plot pertains to a single *SLA* and a single trial scenario. Superimposed in this plot (in a different color and heavier line type) will be the pointwise 5%tile trajectory of C_t.
(4) The plots defined as D7 (pointwise quantile abundance trajectories). In these plots, the three pairs of trajectory

lines (i.e. 5%tiles and medians for P_t, $P_t^*(0)$ and $P_t^*(\text{inc})$ will be superimposed on the same plot. Colour and line type will distinguish these.

(5) A new type of plot to compare depletion performance of several *SLA*s on a single graph. In this plot (one per trial scenario), the pointwise α^{th} percentile time trajectory of 1+ abundance is plotted, as in D7. However, the trajectories for all candidate *SLA*s are superimposed on the same plot. These are distinguished by color and line type. The three reference trajectories determined by assuming 0 strikes, 0 removals, and catch=need are *not* included in these plots. Two sets of such plots will be made, corresponding to α=5 and α=50.

3.3 Bowhead whales

3.3.1 Report from the intersessional Workshop (SC/65a/Rep02)

3.3.1.2 STOCK STRUCTURE

The current working hypothesis in the Scientific Committee is a single Baffin Bay-Davis Strait stock of bowhead whales (see Fig. 1). However, pending the availability of some genetic analyses, the Scientific Committee had agreed that the possibility that there are in fact two different stocks present in the overall area, with the second located in the Foxe Basin-Hudson Strait region, cannot be ruled out (e.g. see IWC, 2009, p.23).

No new information was available to the Workshop. Given that the objective was to develop an *SLA* for the Greenland hunt of bowhead whales, the Workshop had agreed to proceed first on a conservative basis that assumed that the absolute abundance of bowhead whales on the West Greenland wintering area would be informed by abundance estimates from data for that region only (see below). Only if such an *SLA* proved unable to meet need would abundance estimate information and stock structure considerations from the wider area shown in Fig. 1 be taken into account.

3.3.1.2 ABUNDANCE

The Workshop reviewed the available abundance estimates (SC/65a/Rep02, table 8). It is not possible to combine the Foxe Basin-Hudson Bay 2003 survey with the 2002 Prince Regent Inlet survey to obtain an estimate for the entire Davis Strait-Baffin Bay-Foxe Basin area. The Workshop therefore agreed to condition the operating model using data for Davis Strait-Baffin Bay stock only.

The 2002 survey in Prince Regent Inlet might not be conducted again whereas regular surveys will be conducted off West Greenland. The Workshop therefore agreed to conduct trials: (a) in which the estimate for Prince Regent Inlet is treated as an estimate of absolute abundance; and (b) in which the estimates from West Greenland are treated as estimates of absolute abundance.

While the sex ratio of animals in West Greenland is ~80:20 in favour of females (Heide-Jørgensen *et al.*, 2010b), it is expected that the sex ratio for the current whole population is 50:50 (based on historic catches over the whole region and present Canadian catches). The Workshop agreed that the trials will assume that the proportion of males available to the surveys will be the observed average male/female ratio in the biopsy samples.

Estimates of relative abundance from aerial surveys were also considered by the Workshop which agreed that an overdispersion parameter should be estimated for these sightings data under the assumption that the data are negative binomially distributed. Estimates of relative abundance are also available from genetic mark recapture studies. For similar reasons to those given for humpback whales above,

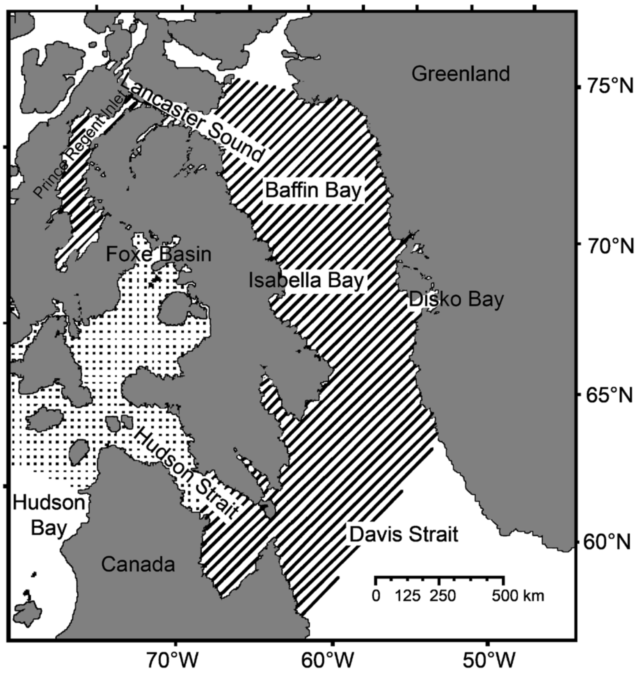

Fig. 1. Stock structure hypotheses for bowhead whales and place names referred to in the text. Hashed lines are for a Davis Strait-Baffin Bay stock while the dotted area refers to a Foxe Basin – Hudson Bay stock.

the Workshop agreed that these are not suitable for use now but that work should continue to enable these data to be used in the future; however, it accorded the work low priority at this time.

The Workshop agreed that the information provided to the *SLA* will be the results of surveys off West Greenland (relative indices if the operating model is conditioned to the estimate of abundance for Prince Regent Inlet and absolute if the operating model is conditioned to the estimate of abundance for West Greenland).

3.3.1.3 REMOVALS

For reasons similar to those agreed for humpback whales given above, the Workshop agreed that population projections should begin from a recent year (1940). This is earlier than for humpback whales because of the extended age-structure of the population.

The Workshop agreed that all the recent (post-1940) direct catches of bowhead whales by Canada and Denmark (Greenland) are known and thus that there was no need to consider an alternative catch series.

For 2011, Canada set an allowance of a maximum of four bowhead whales to be hunted in the Eastern Canadian Arctic. It is not known whether this allowance is for landed whales alone or whether it includes struck and lost whales; this is being investigated by the Secretariat.

The Workshop agreed that four scenarios regarding future Canadian catches should be considered (constant 5, 5 increasing to 10 over 100 years, 5 increasing to 15 over 100 years, constant 2.5; the last case reflects a situation in which half of the Canadian catches are taken from a different stock than the West Greenland catches). The sex-ratio for the West Greenland catches will be set to the sex ratio observed in the biopsy samples taken off West Greenland over the 2002-11 period while that for the Canadian catches should be set to the observed sex-ratio (the observed ratio for the Baffin Bay/Davis Strait whales taken by Canada is 4 male, 1 female, 4 unknown – this is being confirmed by the Secretariat).

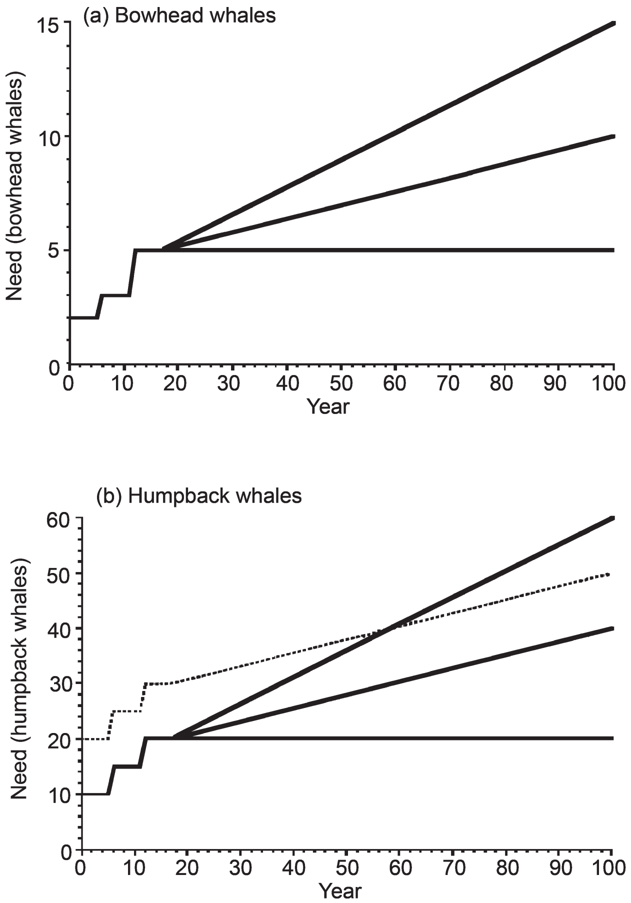

Fig. 2. Need envelopes A-D established for West Greenland bowhead and humpback whale trials.

Recent bycatches of bowhead whales by Denmark (Greenland) and any information for Canada that can be found by the Secretariat will be will be included in the revised trials specification. The Workshop noted that if the number of ship strikes increases as the Northwest Passage opens up, this could trigger an *Implementation Review*.

3.3.1.4 BIOLOGICAL PARAMETERS

In the absence of information for this region, the Workshop agreed to use the priors for f_{max}, S_{1+} and a_m used for the *Implementation* for the Bering-Chucki-Beaufort Seas bowhead whales, noting that these incorporate considerable uncertainty for all three parameters.

3.3.1.5 NEED

Brandon and Scordino (2012), presented to the Workshop, had suggested three scenarios, each of which involves an increase to the need from 2 to 5 at the start of the projection period followed by either: (1) no increase of need; (2) a doubling; and (3) a tripling of need in a linear fashion over the total time period. This is shown in Fig. 2.

3.3.1.6 TRIALS

The Workshop developed proposed *Evaluation* and *Robustness* trials. These formed the basis for discussions under Item 3.3.3.

3.2.2 Discussion of the Workshop report and the results of intersessional work

The SWG thanked the Workshop for it comprehensive work and **broadly endorsed** its conclusions and recommendations; where appropriate they are incorporated in the trial specifications (Appendix 2) or provided the basis for further discussion under Item 3.3.3 below.

3.3.2 RESULTS OF INITIAL WORK ON *SLA*S

The SWG received initial results provided by the two sets of developers of candidate *SLA*s, which were based on trials as developed at the Intersessional Workshop. As the SWG discussed the results of this work for humpback and bowhead whales together, these are considered further under Item 3.4.

3.3.3 Trial structure

The SWG finalised the trial structure (see Appendix 2) for evaluation of *SLA*s for the West Greenland bowhead whale hunt.

The SWG adopted the same planned evaluation strategies (statistics, tables, graphs) as described in Item 3.2.3 for the humpback case. This includes clarification of the abundance and depletion statistics in the situation of zero strikes and/or incidental removals.

SC/65a/Rep02 described *Evaluation Trials* 8A and 8B in which Canadian bowhead strikes tripled over 100 years. The SWG **agreed** to change these from *Evaluation Trials* to *Robustness Trials* (now 4A and 4B). It noted that a situation where Canadian bowhead strikes increased so much would trigger an *Implementation Review*, and therefore it was not necessary to incorporate such a scenario in the tested parameter space.

For the same reasons documented for humpback whales (see Item 3.2.3), the SWG **agreed** to add *Evaluation Trials* involving 'asymmetric environmental stochasticity'. It also **agreed** to include need scenario B in all *Evaluation Trials.*

A number of the preliminary results considered under Item 3.4 illustrated that it would be difficult to meet conservation objectives satisfactorily when the need level was high, especially if Canadian catches (which are taken by a non-IWC member country) increase. The SWG discussed whether it would be advisable to reconsider how strike quotas and incidental removals (i.e. by Canadian hunters) are accounted for in the *SLA* computations. However, it **agreed** to continue with the current framework but also **agreed** that this topic should be further considered at the next intersessional workshop.

3.4 Results from initial work on *SLA*s for humpback and bowhead whales

The SWG discussed the results provided by the two sets of developers of candidate *SLAs*, which were based on trials as developed at the intersessional Workshop.

Witting introduced SC/65a/AWMP04 which describes candidates *SLA*s for the West Greenland hunt on humpback whales. Two candidates based on the current interim *SLA* are proposed. They are both simple data based procedures with no internal population model, and they were selected from a total set of 48 examined procedures. All procedures were tested on a selected set of evaluation trials that included nearly all low production trials, and here they were set to pass a test of acceptable conservation performance (5th percentile of D10 larger than one) before they could be chosen as an acceptable procedure dependent upon their need satisfaction performance and other features. Both procedures estimate the strike limit as a function of 3% of the 2.5th percentile of an estimate of abundance. They put additional limits on the strike limit if the point-estimate of abundance is below 1,200, and one of the two procedures sets the strike limit to need if it exceeds 80% of need.

Witting then presented SC/65a/AWMP05 which describes candidates *SLA*s for the West Greenland hunt on bowhead whales. A similar approach to that taken in SC/65a/AWMP04 was followed. However, none of the 29

*SLA*s initially considered were able to pass the conservation criterion for the low production trials of the two alternative B and C scenarios for future Canadian catches, where annual Canadian catches are assumed to increase from 5 to 10, and from 5 to 15 over the simulation period. Not even a zero-*SLA*, which assumed zero Greenlandic catches for the whole period, was able to pass the conservation criterion when the Canadian catches increased from 5 to 15. Hence, the *SLA* development was restricted to trials where the annual Canadian catches were assumed to be no higher than five. The procedure with highest need satisfaction and acceptable conservation performance on these trials was then selected as a candidate *SLA*. This ($r_5N_{2.5}PS$) procedure sets the strike limit as a function of 0.5% of the 2.5th percentile of an estimate of abundance, it puts additional limits on the strike limit if the point-estimate of abundance is below 1,200, and it sets the strike limit to need if it exceeds 80% of need. Another candidate ($r_1N_{2.5}Pa$) was selected to optimise need satisfaction should annual need not exceed 5 in the future. This procedure provides higher need satisfaction than $r_5N_{2.5}PS$, and it sets the strike limit as a function of 1% of the 2.5th percentile putting additional limits on the strike limit if the point-estimate of abundance is below 800. While selected to have acceptable D10 conservation performance only on the low need trials, conservation performance for $r_1N_{2.5}Pa$ on the high need trials failed only marginally on trial B03BC.

Brandão presented results for four possible *SLA*s from SC/65a/AWMP02. One of the *SLA*s considered is the Interim *SLA* which is based on the most recent estimate of abundance, while the other three *SLA*s are variants of a weighted-average interim *SLA* which uses all abundance estimates, but earlier abundance estimates are downweighted compared to more recent ones. A simple integrative approach to provide a ready coarse comparison of the performance of each *SLA* across all the evaluation and robustness trials was put forward, based on the lower 5%-iles of the N9 (need satisfaction) and D1 (depletion) performance statistics. An index of depletion (D_{imp}) is first computed that measures the extent by which the *SLA* under consideration improves depletion compared to the *Strike Limit = Need SLA*. A statistic is put forward that gives a measure (Q) of the deviation from the ideal scenario of obtaining a result given values of the lower 5%-ile need satisfaction (N9) and of the index of depletion from a trial of both to be (close to) 1. There are two simple approaches to comparing the performance of *SLA*s under trials using this statistic, where averages are readily taken over all trials. These averages could apply either to the *Q* statistic itself or to a ranking for each trial based on the value of *Q* across the *SLA*s considered. There was generally little to choose between the four *SLA*s considered in terms of performance measured by these statistics. There was a qualitative difference between the two species: for humpback whales the *SLA* using the most recent abundance estimate only was preferred, whereas for bowheads the preference was to use all estimates with little downweighting for time since the survey. However, none of the *SLA*s considered performed adequately in terms of resource depletion for the lowest $MSYR_{1+}$ values considered.

In discussion both sets of developers responded to questions of clarification. The protection level concept introduced in the Witting *SLA*s was noted with interest, and it was suggested that this concept might be introduced to the Brandão *SLA*s to attempt to arrest the poor conservation performance on some trials. It was noted that at this stage, each set of developers had developed their own approaches to choose amongst the *SLA* candidates which they had tested. The SWG noted that this was an acceptable approach for developer to take when investigating the performance of their initial *SLA*s before deciding to put 'official' candidates forward but **re-iterated** that final choices would need to be based on the full set of performance statistics agreed for the trials.

3.5 Future consideration of multispecies advice

3.5.1 Report of intersessional Workshop (SC/65a/Rep02)

The Workshop referred to earlier discussions (IWC, 2011b; Witting, 2008) on this matter which have noted that Greenland's need is expressed in terms of tonnes of edible products, and for operational reasons some flexibility (to allow for temporal variability in the species composition of this tonnage) is important and would be preferred. The inclusion of such flexibility within a set of *SLA*s for a number of species, where these *SLA*s would need to be inter-linked, is a challenging scientific task in terms of designing the necessary simulation tests. The Workshop had re-iterated previous advice that this aspect is best pursued only after separate *SLA*s, which operate independently for each species, have been developed and accepted.

3.5.2 Conclusions and recommendations

The SWG endorsed the Workshop's conclusion and **re-iterated** previous advice (IWC, 2012) that this issue is best pursued only after separate *SLA*s, which operate independently for each species, have been developed and accepted.

4. ANNUAL REVIEW OF MANAGEMENT ADVICE

The SWG noted that the Commission had not reached agreement on strike limits for Greenland at the 2012 Annual Meeting (IWC, 2013a). It based its management advice on the same limits considered last year. In providing this advice it noted that the Commission has endorsed the interim safe approach (based on the lower 5th percentile for the most recent estimate of abundance) for providing advice for the Greenland hunts developed by the Committee in 2008 (IWC, 2009, p.16); it was agreed that that this should be considered valid for two blocks, i.e. up to the 2018 Annual Meeting.

4.1 Common minke whales off West Greenland

4.1.1 New information (incl. catch data and agreed abundance estimates)

In the 2012 season, 144 minke whales were landed in West Greenland and 4 were struck and lost. Of the landed whales, there were 109 females, 33 males and two of unknown sex. Genetic samples were obtained from 112 of these whales. Last year, the Committee has re-emphasised the importance of collecting genetic samples from these whales, particularly in the light of the proposed joint AWMP/RMP workshop (see Annex D). The SWG **welcomed** the fact that nearly 80% of the catch had been sampled in 2012 and encouraged continued sample collection.

This year, the SWG adopted a revised estimate of abundance for the 2007 survey. The revised published estimate (16,100 CV=0.43) was slightly lower than that first agreed in 2009. The SWG noted that this estimate is an underestimate of the total population by an unknown amount.

4.1.2 Management advice

In 2009, the Committee was for the first time able to provide management advice for this stock. This year, using the agreed

Table 2
Most recent estimates of abundance for the Central stock of common minke whales.

Small Area(s)	Year(s)	Abundance and CV
CM	2005	26,739 (CV=0.39)
CIC	2007	10,680 (CV=0.29)
CG	2007	1,048 (CV=0.60)
CIP	2007	1,350 (CV=0.38)

interim approach and the revised estimate of abundance given under Item 4.1.1, the SWG **advised** that an annual strike limit of 164 will not harm the stock. It **drew attention** to the fact that this is 14 whales lower than its advice of last year due to the revised 2007 abundance estimate.

4.2 Common minke whales off East Greenland

4.2.1 New information (incl. catch data and agreed abundance estimates)

Four female common minke whales were struck (and landed) off East Greenland in 2012. Two were females and the sex of the other two was unknown. The SWG was **pleased** to note that genetic samples were obtained from all minke whales caught in East Greenland (these could be used *inter alia* to determine the sex of the unknown animals). The Committee **again emphasised** the importance of collecting genetic samples from these whales, particularly in the light of the proposed joint AWMP/RMP workshop (see Annex D).

4.2.2 Management advice

Catches of minke whales off East Greenland are believed to come from the large Central stock of minke whales. The most recent strike limit of 12 represents a very small proportion of the Central Stock – see Table 2. The SWG **repeats** its advice of last year that the strike limit of 12 will not harm the stock.

4.3 Fin whales off West Greenland

4.3.1 New information (incl. catch data and agreed abundance estimates)

A total of four fin whales (all females) were landed, and one was struck and lost, off West Greenland during 2012. The SWG was **pleased** to note that genetic samples were obtained from three whales. The SWG **re-emphasised** the importance of collecting genetic samples from these whales, particularly in the light of the proposed work to develop a long-term *SLA* for this stock.

4.3.2 Management advice

Based on the agreed 2007 estimate of abundance for fin whales (4,500 95%CI 1,900-10,100), and using the agreed interim approach, the SWG **repeated** its advice that an annual strike limit of 19 whales will not harm the stock.

4.4 Humpback whales off West Greenland

4.4.1 New information (incl. catch data and agreed abundance estimates)

A total of seven (two males; four females; one unknown sex) humpback whales were landed (three more were struck and lost) in West Greenland during 2012. The SWG was **pleased** to learn that genetic samples were obtained from all of these whales and that Greenland was contributing fluke photographs to the North Atlantic catalogue – four have been submitted from whales taken since 2010. The SWG again **emphasised** the importance of collecting genetic samples and photographs of the flukes from these whales, particularly with respect to the MoNAH and YoNAH initiatives (Clapham, 2003; YoNAH, 2001).

This year, the SWG **endorsed** the revised fully corrected abundance estimate for West Greenland from the 2007 survey of 2,704 (CV=0.34) for the strip census abundance estimate (see Item 3 above). The agreed annual rate of increase of 0.0917 (SE 0.0124) remains unchanged.

4.4.2 Management advice

Based on the revised agreed estimate of abundance for humpback whales given above and using the agreed interim approach, the SWG **agreed** that an annual strike limit of 10 whales will not harm the stock.

4.5 Humpback whales off St Vincent and The Grenadines

4.5.1 New information (incl. catch data and agreed abundance estimates)

No new information or catch data were provided in time for consideration by the SWG although information has been requested by the Secretariat. Lang reported that there is one sample collected from a humpback whale taken on 11 April 2012 in the SWFSC tissue archive. The SWG **welcomed** this information.

Iñíguez reported information obtained from local newspapers on hunts on St Vincent and the Grenadines: a 35ft male (8 March 2013); a 41ft female and a 35ft male (both 18 March 2013); and another whale with no length or sex information (12 April 2013).

Regarding the same stock, he referred to reports that residents of Petite Martinique, Grenada, spent hours attempting to drive a mature whale onto a beach using five inflatable boatss, two large trader boats and a speedboat on 22 November 2012. The whale finally escaped but was harpooned four times. He has no further information on what happened with this whale.

4.5.2 Management advice

The SWG repeated its previous strong recommendations that St. Vincent and The Grenadines:

(1) provide catch data, including the length of harvested animals, to the Scientific Committee; and
(2) that genetic samples be obtained for any harvested animals as well as fluke photographs, and that this information be submitted to appropriate catalogues and collections.

The SWG has agreed that the animals found off St. Vincent and the Grenadines are part of the large West Indies breeding population (abundance estimate 11,570 95%CI 10,290-13,390). The Commission adopted a total block catch limit of 24 for the period 2013-18 for Bequians of St. Vincent and The Grenadines. The SWG **repeated** its advice that this block catch limit will not harm the stock.

The SWG draws the Commission's attention to the unofficial reports of attempts to land a humpback whale in Grenada; the Schedule specifies that the quota applies only to Bequians of St. Vincent and The Grenadines. The SWG requests that the Secretariat contact the Government of Grenada to obtain official information on this incident.

5. ABORIGINAL WHALING MANAGEMENT SCHEME

5.1 Guiding principles for *SLA* development and evaluation

The SWG noted that considerable effort had been put into general consideration of the development of *SLA*s at the beginning of the AWMP process (IWC, 2000; 2001; 2002).

It **agreed** that it would be useful to briefly outline some guiding principles for *SLA*s to assist developers of candidate *SLA*s for the Greenland hunts. These are summarised below.

(a) The primary objective of any *SLA* is to meet the objectives set by the Commission with respect to need satisfaction and conservation performance, with priority given to the latter.
(b) *SLA*s must incorporate a feedback mechanism.
(c) Once need has been met for the 'high' need envelope while giving acceptable conservation performance, then there is no need to try to improve the performance of an *SLA* further.
(d) Simple *SLA*s are to be preferred, providing this simplicity does not compromise achieving the Commission's objectives.
(e) With respect to (d), empirical procedures may prove preferable to population model based procedures because (1) they are more easily understood by stakeholders and (2) there is little chance for significant updating of population model parameters (e.g. MSYR) over time as the extent of additional data will probably be limited for populations subject to aboriginal whaling only. Nevertheless, the choice of the form for any candidate *SLA* lies entirely in the hands of its developer, with selection amongst candidates to be based only on performance in trials.
(f) If in developing *SLA*s, a situation arises where relatively simple *SLA*s fail on one or a few trials where the circumstances which might lead to the failure occur only many years in the future, rather than attempt to develop more complex *SLA*s to overcome this problem, a simpler *SLA* could be proposed despite this failure, and the difficulties dealt with by means of an *Implementation Review* should there be indications in the future that the circumstances concerned are arising. This principle applies only to: (1) circumstances in a scenario that are external and independent of the hunting/quota feedback loop, such as very high values of the future need envelope; and (2) are judged to be very unlikely to occur in the next few decades. Failure of an *SLA* to perform acceptably in some circumstance is not in itself a reason to apply this principle.

5.2 Scientific aspects of an aboriginal whaling scheme

In 2002, the Committee **strongly recommended** that the Commission adopt the Aboriginal Subsistence Whaling Scheme (IWC, 2003). This covers a number of practical issues such as survey intervals, carryover, and guidelines for surveys. The Committee has stated in the past that the AWS provisions constitute an important and necessary component of safe management under AWMP *SLA*s and it **reaffirms** this view as it has for the previous 11 years.

6. PROGRESS ON FOLLOW-UP WORK ON CONVERSION FACTORS FOR THE GREENLANDIC HUNT

6.1 New information

In 2009, the Commission appointed a small working group (comprising several Committee members) to visit Greenland and compile a report on the conversion factors used by species to translate the Greenlandic need request which is provided in tonnes of edible products to numbers of animals (Donovan *et al.*, 2010). At that time the group provided conversion factors based upon the best available data, noting that given the low sample sizes, the values for species other than common minke whales should be considered provisional. The group also recommended that a focused attempt to collect new data on edible products taken from species other than common minke whales be undertaken, to allow a review of the interim factors; and that data on both 'curved' and 'standard' measurements are obtained during the coming season for all species taken. The report was endorsed by the Scientific Committee (IWC, 2011a, p.21).

Since then the Committee has received progress reports but has commented that more detail and information is required. Last year the Committee recommended:

(1) the provision of a full scientific paper to the next annual meeting that details *inter alia* at least: a full description of the field protocols and sampling strategy (taking into account previous suggestions by the Committee); analytical methods; and a presentation of the results thus far, including information on the sex and length of each of the animals for which weight data are available; and
(2) the collection and provision of data on Recommendation No. 2 of Donovan *et al.* (2010) comparing standard versus curvilinear whale lengths. This should be done for all three species on as many whales as possible.

SC/65a/AWMP07 reports on the collection of weights and length measures from fin, humpback and bowhead whales caught in West Greenland. To improve the data collection process, information meetings involving biologists, hunters, wildlife officers and hunting license coordinators were held in the larger towns in 2012, and an information folder was produced and distributed to the hunters. The data collection process was also combined with an existing research project on hunting samples in order to get a stronger involvement of biologists. When researchers participate in hunts they train the hunters in measuring the lengths (curved and standard) and they make sure that the meat is weighed.

Until now the reporting rate has been lower than expected, with the data obtained in 2012 being from only one fin whale and one humpback whale, and the total number of reports since 2009 being from six bowhead whales, six humpback whales and three fin whales. These data provide preliminary yield estimates for all edible products of 9,014kg (SE:846) per humpback whale, of 6,967kg (SE:2,468) per fin whale, and of 8,443kg (SE:406) per bowhead whale. These numbers are all somewhat lower than the suggested yield in Donovan *et al.* (2010), and this is especially pronounced for fin whales. Nevertheless, the obtained estimates for fin whales fall within the range of previous yield weight estimates for fin whales in West Greenland.

A major reason for the low reporting rate has been the almost complete absence of weighing equipment where the whalers could weigh the different products. To increase the reporting rate, the Greenland Institute of Natural Resources has now purchased and distributed cranes to major towns for the hunters to use for weighing when landing a catch. It was also realised that the 'bin system' described in previous reports is more complicated than first anticipated because there is a large variation in the size of the bins used within the same hunt and between hunters. It is therefore now recommended that hunters weigh all edible products with the crane weight when they land the meat with the crane in the harbor. This approach will be investigated further in 2013 and discussed with the hunters. Owing to the logistical difficulties involved with whale hunts in Greenland (which

Table 3

Summary of absolute abundance estimates. Relative abundance estimates for use in the trials are given in Appendix 2 (Table 3).

Area	Year	Corr*	Estimate and approx. 95% CI and CV	IWC reference	Original reference
Common minke whale					
West Greenland	2007	A+P	16,100 (6,930-37,400) (CV:0.43)	IWC (2010); SC/65a	Heide-Jørgensen *et al.* (2010c)
West Greenland	2005	A+P	10,790 (3,400-34,300) (CV:0.59)	IWC (2008)	Heide-Jørgensen *et al.* (2008)
West Greenland	1993	A	8,370 (3,600-19,440) (CV:0.43)	IWC (1995)	Larsen (1995)
Fin whale					
West Greenland	2007		4,360 (1,810-10,530) (CV:0.45)	IWC (2009)	Heide-Jørgensen *et al.* (2010a)
West Greenland	2005	P	3,230 (1,360-7,650) (CV:0.44)	IWC (2008)	Heide-Jørgensen *et al.* (2008)
West Greenland	1988	A	1,100 (554-2,180) (CV:0.35)	IWC (1993)	IWC (1993)
Humpback whale					
West Greenland	2007	A+P	4,090 (1,690-9,880); (CV:0.45) MRDS	IWC (2009); SC/65a	Heide-Jørgensen *et al.* (2012); SC/65a/AWMP01
West Greenland	2007*	A+P	2,700 (1,390-5,270) (CV:0.34) strip census	IWC (2009); SC/65a	Heide-Jørgensen *et al.* (2012); SC/65a/AWMP01
Bowhead whale					
Prince Regent Inlet	2002	A+P	6,340 (3,119-12,906) (CV:0.36)	IWC (2009)	IWC (2009)
Foxe Basin – Hudson Bay	2003	A+P	1,525 (333-6,990) (CV:0.78)	IWC (2009)	IWC (2009)
West Greenland	2007	A+P	1,229 (489-3,090) (CV: 0.47)	IWC (2008)	Heide-Jørgensen *et al.* (2007);
Isabella Bay	2009	A+P?	1,105 (515-2,370) (CV: 0.39)	SC/65a/Rep02	Hansen *et al.* (2012)

*Indicates whether the estimate has been corrected for availability bias and/or perception bias.

are widespread along the coast and occur at unpredictable times during a long season) and the required change in the reporting system and subsequent need for training, it is likely that it will take several years to collect sufficient data on edible products.

6.2 Discussion

In response to questions, a number of clarifications were made. The original intention of weighing ten boxes had been so that an average weight per box could be developed to be multiplied by the total number of boxes to obtain an estimated total weight. However, with the efficient crane weights that are now in place in three cities, and with the finding that hunters may use different sized boxes even for the same whale, it has now been decided to weigh all boxes.

There were only five cases when scientists were able to be present at a humpback catch, and the low number illustrates the logistical difficulties in having scientists present at hunts. Witting did not have the precise details of this work or of the number of wildlife officers who may be able to assist in the work but will consult in Greenland. Efficient reporting requires not only training of hunters, but also the distribution of weighing equipment, so that hunters can report on their own.

In conclusion, the SWG **agreed** that the report was an advance on those previously received (and provided the first information on curvilinear lengths). However, it also **agreed** that it still did not provide sufficient information to fulfil the recommendations of last year. While aware of the logistical difficulties involved in obtaining these data, it **repeated its recommendations** of last year given in the second paragraph of this section. It **encouraged** Witting to assist in the writing of such a report to ensure that it better meets the request of the SWG next year.

7. CONSERVATION MANAGEMENT PLANS (CMPS)

The SWG noted the request for sub-groups to consider potential priority candidates for CMPs (SC/65a/SCP01). After considering the criteria given in that document the SWG **agreed** that it had no candidates for CMPs.

8. UPDATED LIST OF ACCEPTED ABUNDANCE ESTIMATES

The SWG noted the request to develop a list of accepted abundance estimates for consideration as part of an overall summary for all species to be developed by the Plenary. This was developed and has been forwarded for Plenary compilation. The abundance estimates agreed by this SWG are summarised above in Table 3.

9. WORK PLAN AND BUDGET REQUESTS

9.1 Work plan

The SWG **agreed** that the Chair should develop the work plan based upon the substantive items in the report. This is give in Table 4.

9.2 Budget requests

Intersessional Workshop on Developing SLA*s for the Greenlandic hunts*

The existing interim safe procedure for the Greenlandic hunts agreed in 2008 (IWC, 2009, p.16) was agreed to be valid for up to quota blocks so up to 2018. The Committee has identified completion of the development of long-term *SLA*s for these hunts as high priority work. In order to meet the proposed timeframe, an intersessional Workshop is required. The focus of the proposed Workshop is to: (1) to review the results of the developers of *SLA*s for humpback whales and bowhead whales; (2) finalise the modelling framework/trial structure for these hunts; (3) develop a work plan to try to enable completion of work on *SLA*s for these two hunts at the 2014 Annual Meeting; and (4) consider possible input (e.g. using AWMP/RMP-lite) for the joint AWMP/RMP workshop on North Atlantic common minke whale stock structure. The Workshop will be held in early 2014 in Copenhagen, Denmark, hosted by the Greenland representation; the costs are for IPs travel. It is intended to hold this back-to-back with and RMP Workshop on fin whales to save travel costs given some common membership.

AWMP Developers' fund

The developers fund has been invaluable in the work of *SLA* development and related essential tasks of the SWG.

Table 4

Work plan.

Item	Topic	Responsible persons	Deadline/target
3.1	Participate in the RMP North Atlantic fin whale RMP *Implementation* process and report back on the implications of this for *SLA* development for the Greenland hunt.	Donovan, Punt, Witting, Butterworth.	2014 Annual Meeting
3.1	Hold joint AWMP/RMP workshop on the stock structure of common minke whales in the North Atlantic (also see Annex D).	Joint Steering Group under Palsbøll.	Expected spring 2014
3.1	Submit need envelopes for West Greenland fin and common minke whales.	Witting.	Early Jan. 2014
3.2 and 3.3	Finalise the trials for the West Greenland humpback and bowhead whales (including coding) to allow developers to work intersessionally. Ensure that standard software is available to produce agreed performance statistics, as well as tabular and graphical output.	Steering Group convened by Donovan (Punt, Givens, Butterworth, Witting). Coding to be undertaken by Punt and Allison and developers.	(1) Agree specification and parameterisation by email and Skype: end Jul. 2013. (2) Complete coding and supply to developers: end Aug. 2013
3.2	Present overview of photo-identification work with respect to movements to inform stock structure and human induced mortality outside West Greenland.	Greenlandic scientists and College of the Atlantic (to be co-ordinated by Witting).	As soon as possible – ideally end of Aug. to assist Allison (see below), at latest in time for intersessional Workshop in early Jan. 2014
3.2 and 3.3	Finalise removals series including consideration of human-induced mortality outside the West Greenland area.	Allison.	End Aug. 2013
3.2 and 3.3	Continue initial exploration of potential *SLA*s for the Greenland humpback and bowhead whale hunts.	Developers.	For presentation at intersessional Workshop in early Jan. 2014
6.2	Produce full report on Greenlandic conversion factor programme.	Greenlandic authorities (assisted by Witting).	2014 Annual Meeting

It has been agreed as a standing fund by the Commission. The primary development tasks facing the SWG are for the Greenlandic fisheries. These tasks are of high priority to the Committee and the Commission. The fund is essential to allow progress to be made. It now stands at £8,000 and a request of £7,000 is made to restore it to the initial target level of £15,000.

10. ADOPTION OF REPORT

The report was adopted at 1900hrs on 11 June 2103. The SWG authorised the Chair to make editorial changes to the report as necessary to improve clarity. It also agreed that he should develop the work plan based upon the substantive items. The Chair thanked the participants for the constructive and co-operative attitude throughout these important discussions, some of which are highly technical. In particular, he thanked the developers for their work during the intersessional period that had greatly facilitated progress and the rapporteurs for their dedicated work. The SWG thanked the Chair for his efficient and good-humoured guidance.

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Appendix 1

AGENDA

1. Introductory items
   - 1.1 Convenor's opening remarks
   - 1.2 Election of Chair
   - 1.4 Appointment of rapporteurs
   - 1.5 Adoption of Agenda
   - 1.6 Documents available
2. Gray whales with emphasis on the PCFG (Pacific Coast Feeding Group)
   - 2.1 Report of intersessional Workshop (SC/65a/Rep02)
   - 2.2 New information and results
     - 2.2.1 Further evaluation of proposed Makah Hunt
     - 2.2.2 Other information
   - 2.3 Summary and recommendations
3. Consideration of work required to develop *SLAs* for all Greenland hunts before the end of the interim period
   - 3.1 Common minke whales and fin whales
     - 3.1.1 Report from the intersessional Workshop (SC/65a/Rep02)
     - 3.1.2 Joint RMP/AWMP Workshop(s) on stock structure
     - 3.1.4 Discussion and work plan
   - 3.2 Humpback whales
     - 3.2.1 Report from the intersessional workshop (SC/65a/Rep02)
     - 3.2.2 Discussion of the Workshop report and the results of intersessional work
     - 3.2.3 Trial structure
   - 3.3 Bowhead whales
     - 3.3.1 Report from the intersessional Workshop (SC/65a/Rep02)
     - 3.2.2 Discussion of the Workshop report and the results of intersessional work
     - 3.3.3 Trial structure
   - 3.4 Results from initial work on *SLA*s for humpback and bowhead whales
     - 3.5.2 Conclusions and recommendations
4. Annual review of management advice
   - 4.1 Common minke whales off West Greenland
     - 4.1.1 New information (incl. catch data and agreed abundance estimates)
   - 4.2 Common minke whales off East Greenland
     - 4.2.1 New information (incl. catch data and agreed abundance estimates)
     - 4.2.2 Management advice
   - 4.3 Fin whales off West Greenland
     - 4.3.1 New information (incl. catch data and agreed abundance estimates)
     - 4.3.2 Management advice
   - 4.4 Humpback whales off West Greenland
     - 4.4.1 New information (incl. catch data and agreed abundance estimates)
     - 4.4.2 Management advice
   - 4.5 Humpback whales off St Vincent and The Grenadines
     - 4.5.1 New information (incl. catch data and agreed abundance estimates)
     - 4.5.2 Management advice
5. Aboriginal Whaling Management Scheme
   - 5.1 Guiding principles for *SLA* development and evaluation
   - 5.2 Scientific aspects of an aboriginal whaling scheme
6. Progress on follow-up work on conversion factors for the Greenlandic hunt
   - 6.1 New information
   - 6.2 Discussion
7. Conservation Management Plans (CMPs)
8. Updated list of abundance estimates
9. Work plan and budget requests
   - 9.1 Work plan
   - 9.2 Budget requests
10. Adoption of report

Appendix 2

TRIAL SPECIFICATIONS FOR HUMPBACK AND BOWHEAD WHALES OFF WEST GREENLAND

[NB: Aspects of these specifications, including those highlighted, will be finalised prior to the 2014 Annual Meeting by an Intersessional Steering Group and Workshop]

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.

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

$R^{m/f}_{t,a}$ 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:

$$S_a = \begin{cases} S_0 & \text{if } a = 0 \\ S_{1+} & \text{if } 1 < a \le a_a \\ & \text{if } a > a_a \end{cases} \tag{A1.2}$$

S_0 is the calf survival rate;

S_{1+} is the survival rate for animals aged 1 and older; 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 humpback whales and 35 for bowhead 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:

$$B_{t+1} = b_{t+1} N^f_{t+1} \tag{A2.1}$$

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

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

a_m is the age-at-maturity (the convention of referring to the mature population is used here, although this actually refers to animals that have reached the age of first parturition);

b_{t+1} is the probability of birth/calf survival for mature females:

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

$$N^{1+}_t = \sum_{a=1}^{x} (R^f_{t,a} + U^f_{t,a} + R^m_{t,a} + U^m_{t,a})$$

$$K^{1+} = \sum_{a=1}^{x} (R^f_{-\infty,a} + U^f_{-\infty,a} + R^m_{-\infty,a} + U^m_{-\infty,a}) \tag{A2.4}$$

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:

$$B_t^f = 0.5 \;\; B_t \tag{A2.5}$$

The numbers of recruited/unrecruited calves is given by:

$$\begin{array}{ll} R_t^f = \alpha_0 \, B_t^f & R_t^m = \alpha_0 \, (B_t - B_t^f) \\ U_t^f = (1-\alpha_0) \, B_t^f & U_t^m = (1-\alpha_0)(B_t - B_t^f) \end{array} \tag{A2.6}$$

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

A.3 Catches

The historical (t<2013) removals are taken to be equal to the total reported removals (including struck and lost, by-catch, ship strikes, etc.) catches (Table 1). The sex-ratio of future aboriginal catches is assumed to be 50:50 F:M (bowheads) and 20:80 F:M (humpbacks) while the sex ratio of by catches, ship strikes and Canadian catches is assumed to be 50:50 F:M. Catches are taken uniformly from the recruited component of the population:

$$C_{t,a}^m = C_t^m \, R_{t,a}^m / \sum_{a'} R_{t,a'}^m \, ; \qquad C_{t,a}^{m/f} = C_t^f \, R_{t,a}^f / \sum_{a'} R_{t,a'}^f \tag{A3.1}$$

$C_t^{m/f}$ is the catch of males/females during year *t*.

The total catch 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; (b) bycatches in fisheries; (c) ship strikes; and (d) aboriginal catches in Canada (only bowheads).

The total bycatch during future year y is computed by applying the average exploitation rate during 2007-11 to the number of 1+ animals in year y, i.e.:

$$\tilde{C}_t = \tilde{F} \, N_t^{1+} \tag{A3.2}$$

$\tilde{F}$ is the average exploitation rate due to by-catch during 2007-11:

$$\tilde{F} = \sum_{t=2007}^{2011} (\tilde{C}_t^f + \tilde{C}_t^m) / \sum_{t=2007}^{2011} N_t^{1+} \tag{A3.3}$$

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 5 for humpbacks and 1 for bowhead 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:

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

Table 1

Total removals? of bowhead and humpback whales.

Year	M	F	Year	M	F	Year	M	F
(a) Bowhead whales								
1940	1	1	1970	0	0	2000	0.5	0.5
1941	0.5	0.5	1971	1	1	2001	0	0
1942	0	0	1972	0	0	2002	0	0
1943	0	0	1973	0.5	0.5	2003	0.5	0.5
1944	0	0	1974	0	0	2004	0.5	0.5
1945	1.5	1.5	1975	1.5	1.5	2005	0.5	0.5
1946	0.5	0.5	1976	0	0	2006	0	0
1947	0.5	0.5	1977	0	0	2007	0	0
1948	0	0	1978	0	0	2008	1.5	1.5
1949	0	0	1979	0.5	0.5	2009	3	3
1950	0	0	1980	0.5	0.5	2010	2.5	2.5
1951	0	0	1981	0	0	2011	0	1
1952	0	0	1982	0	0	2012	0	0
1953	0	0	1983	0	0			
1954	0	0	1984	0	0			
1955	0.5	0.5	1985	0.5	0.5			
1956	0.5	0.5	1986	0	0			
1957	0	0	1987	0	0			
1958	0	0	1988	0	0			
1959	0.5	0.5	1989	0	0			
1960	0	0	1990	0	0			
1961	0.5	0.5	1991	0	0			
1962	0	0	1992	0	0			
1963	0	0	1993	0	0			
1964	0.5	0.5	1994	0.5	0.5			
1965	0.5	0.5	1995	0	0			
1966	0	0	1996	0.5	0.5			
1967	0.5	0.5	1997	0	0			
1968	0	0	1998	0.5	0.5			
1969	0	0	1999	0	0			
1935	0	0						
1936	0	0						
1937	0	0						
1938	0	0						
1939	0.5	0.5						
(b) Humpbacks								
1960	0	1	1980	8	8	2000	0	2
1961	0	1	1981	6	6	2001	1	1
1962	1	1	1982	6	6	2002	2	1
1963	0	0	1983	7	9	2003	0	1
1964	0	0	1984	8	8	2004	2	1
1965	0	1	1985	4	4	2005	2	3
1966	2	2	1986	0	0	2006	0	0
1967	2	2	1987	0	0	2007	1	1
1968	2	3	1988	0	1	2008	1	2
1969	1	2	1989	1	1	2009	0	0
1970	0	0	1990	0	1	2010	4	6
1971	2	2	1991	0	1	2011	3	5
1972	1	2	1992	0	1	2012	4	9
1973	5	6	1993	0	0			
1974	4	5	1994	0	1			
1975	4	5	1995	0	0			
1976	4	5	1996	0	0			
1977	8	9	1997	0	0			
1978	12	12	1998	0	1			
1979	7	8	1999	0	1			

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

$U^{m/f}_{-\infty,a}$ 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:

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

In common with the trials for the Eastern North Pacific gray whales (IWC, 2013), the trials are based on the assumption that the age-structure at the start of year τ is stable rather than that the population was at its pre-exploitation equilibrium size at the start of (say) 1600, the first year for which catch estimates are available. 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 a 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, $N^*_{\tau,a}$, is therefore given by the equation:

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

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).

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

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.

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 and z, where $f_{\max}$ is the maximum theoretical 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, 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, $MSYR_{1+}$, $MSYL_{1+}$, K^{1+}, P_Ψ, CV_{add} (the additional variance for the estimates of 1+ abundance in Ψ) from the priors in Table 2. The additional variance for the estimates of absolute abundance and indices of relative abundance are assumed to be the same. 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 and z to find values for S_0, A and z.
(c) Calculate the likelihood of the projection which is given by[1]:

$L=L_1L_2$ (L_2 applies only to the sighting rates for bowheads) where:

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

$$L_2 = \prod_t (\rho \hat{P}_t)^{N_t^{obs}} e^{-\rho \hat{P}_t} \tag{A8.1a}$$

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 pertain to the survey estimates of abundance at the start of year t;:

$$\hat{P}_t = \tilde{S}^f \sum_{a=1}^{x} (R^f_{t,a} + U^f_{t,a}) + \tilde{S}^m \sum_{a=1}^{x} (R^m_{t,a} + U^m_{t,a}) \tag{A.8.2}$$

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

$\tilde{S}^f, \tilde{S}^m$ is the relative selectivity for females and males (1:1 for humpbacks and 1:0.25 for bowheads);

$E(CV^2_{add2,t})$ is the square of the actual CV of the additional variation for year t:

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

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

N_t^{obs} is the number of animals counted during year t (a relative index of abundance; Table 3b),

ρ is the constant of proportionality between the number of 1+ animals and the population counts, and

B_c is the bias associated with a relative index of abundance (different for each relative index).

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 are unique.

The bulk of the trials for humpbacks are conditioned on the estimate of absolute abundance (Table 3a) and the time series of relative abundance based on aerial surveys (Table 3b). The relative indices of abundance based on mark-recapture are used when conditioning one of the *Robustness Trials*.

Table 2

The prior distributions.

Parameter	Prior distribution (humpbacks)	Prior distribution (bowheads)
Non-calf survival rate, S_{1+}	U[0.90, 0.995]	N(1.059, 0.0378^2), truncated at 0.995
Age-at-maturity, a_m	U[4, 12]	N(20,32) truncated at 13.5 and 26.5
Transition age	0	U[1,9]
K^{1+}	U[0, 30,000]	U[0, 40,000]
$MSYL_{1+}$	Pre-specified	Pre-specified
$MSYR_{1+}$	Pre-specified	Pre-specified
Maximum pregnancy rate, $1/f_{max}$	U[1.25, 2.5]	U[2.5, 4]
Additional variation (population estimates), CV_{add}, in year Ψ	U[0, 0.35]	U[0, 0.35]
Abundance in year Ψ, P_Ψ	$\ell n P_{2007} = N(\ell n 2{,}154, (0.36^2 + CV^2_{add}))$	A: $\ell n P_{2002} = N(\ell n 6{,}340; (0.38^2 + CV^2_{add}))$ B: $\ell n P_{2007} = N(\ell n 1{,}229, (0.47^2 + CV^2_{add}))$
Additional variation (relative indices), CV_{add2}	U[0.2, 0.6]	U[0.2, 0.6]
Bias of relative abundance indices, B_c	$\ell n B_c \sim U[-\infty, \infty]$ (see[1])	$\ell n B_c \sim U[-\infty, \infty]$ (see[1])

[1]This is the non-informative prior for a scale parameter.

Table 3

Estimates of absolute abundance (a) and estimates of relative abundance (b).

Year	Estimate	CV
(a) Estimate of absolute abundance		
Bowhead whales		
2002	6,340	0.38
2007	1,229	0.47
Humpback whales		
2007	2,700	0.34

(b) Estimates of relative abundance

Bowhead whales						*Humpback whales*					
Year	Estimate	CV	Year	Effort L, (km)	Count	Year	Estimate	CV	Year[1]	Estimate[1]	CV[1]
2006	1229	0.47	1981	951	1	1984	99	0.40	1982	271	0.13
2012	829	0.35	1982	2,273	1	1985	177	0.44	1989	357	0.16
			1990	591	1	1987	220	0.62	1990	355	0.12
			1991	1,088	3	1988	200	0.74	1991	566	0.42
			1993	577	0	1989	272	0.75	1992	376	0.19
			1994	1,092	0	1993	873	0.53	1993	348	0.12
			1998	1,184	5	2005	1,158	0.35			
			1999	1,104	0	2007	1,020	0.35			
			2006	791	9						
			2012	1,574	25						

[1]Not used in the *Evaluation Trials*.

B. Data generation

B.1 Absolute abundance estimates

The historic (t<2013) abundance estimates (and their CVs) are provided to the *SLA* and are taken to be those in Table 3a for humpback whales and the relative indices of abundance for bowhead whales in Table 3b. An estimate of abundance together with an estimate of its CV is generated, and is provided to the *SLA,* once every F years during the management period (starting in year 2017 for humpbacks and 2022 for bowheads; F=10 years beyond the year with the last estimate of abundance). The CV of the abundance estimate (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 size of $\hat{P}_t$).

The steps used in the program to generate the abundance estimates and their CVs are given below[2].

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

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

$E(CV_{est,t}^2)$ 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. The value of η 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:

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

C. Need

The level of need supplied to the *SLA* is the total need for the 6-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 *Robustness Trials* in Table 6.

[2]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 3). Generate values of CV_{add}^2 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 and 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.

Table 4

Factors tested in the trials.

Factors	Levels (reference levels shown bold and underlined) Humpback whales	Bowhead whales
$MSYR_{1+}$	1%, 3%, **5%**, 7%	1%, **2.5%**, 4%
$MSYL_{1+}$	0.6	**0.6**, 0.8
Time dependence in K*	**Constant**, Halve linearly over 100yr	
Time dependence in natural mortality, M*	**Constant,** Double linearly over 100yr	
Episodic events*	**None**, 3 events occur between years 1-75 (with at least 2 in years 1-50) in which 20% of the animals die, Events occur every 5 years in which 5% of the animals die	
Need envelope	A: 10, 15, 20; 20 thereafter B: 10, 15, 20; 20->40 over years 18-100 C: 10, 15, 20; 20->60 over years 18-100 D: 20, 25, 30; 30->50 over years 18-100	**A: 2, 3, 5; 5 thereafter** B: 2, 3, 5; 5 -> 10 over years 18-100 C: 2, 3, 5; 5 -> 15 over years 18-100
Future Canadian catches	N/A	**A: 5 constant over 100 years** B: 5-> 10 over 100 years C: 5-> 15 over 100 years D: 2.5 constant over 100 years?
Survey frequency	5 yr, **10 yr**, 15 yr	
Historic survey bias	0.8, **1.0**, 1.2	0.5, **1.0**
First year of projection, τ	1960	1940
Alternative priors	S_{1+} ~ U[0.9, 0.99]; f_{max} ~ U[0.4, 0.6]; a_m ~ U[5, 12]	N/A
Strategic surveys	Extra survey if a survey estimate is half of the previous survey estimate	
Asymmetric environmental stochasticity parameters	To be finalised by an intersessional group	

*Effects of these factors begin in year 2013 (i.e. at start of management). The adult survival rate is adjusted so that in catches were zero, then average population sizes in 250-500 years equals the carrying capacity. *Note*: for some biological parameters and levels of episodic events, it may not be possible to find an adult survival rate which satisfies this requirement.

Table 5

The *Evaluation Trials*. Values given in bold type show differences from the base trial.

Trial	Description	$MSYR_{1+}$	Need scenarios	Survey freq.	Historic survey bias	Conditioning option
(a) Humpback whales						
1A	$MSYR_{1+}$=5%	5%	A, B, C, D	10	1	Y
1B	$MSYR_{1+}$=3%	**3%**	A, B, C, D	10	1	Y
1C	$MSYR_{1+}$=7%	**7%**	A, B, C, D	10	1	Y
2A	5 year surveys	5%	B, C, D	**5**	1	1A
2B	5 year surveys; $MSYR_{1+}$=3%	3%	B, C, D	**5**	1	1B
3A	15 year surveys	5%	B, C	**15**	1	1A
3B	15 year surveys; $MSYR_{1+}$=3%	3%	B, C	**15**	1	1B
4A	Survey bias = 0.8	5%	B, C, D	10	**0.8**	Y
4B	Survey bias = 0.8; $MSYR_{1+}$=3%	**3%**	B, C, D	10	**0.8**	Y
5A	Survey bias = 1.2	5%	B, C, D	10	**1.2**	Y
5B	Survey bias = 1.2; $MSYR_{1+}$=3%	**3%**	B, C, D	10	**1.2**	Y
6A	3 episodic events	5%	B, C, D	10	1	1A
6B	3 episodic events; $MSYR_{1+}$=3%	**3%**	B, C, D	10	1	1B
7A	Stochastic events every 5 years	5%	B, C, D	10	1	1A
7B	Stochastic events every 5 years; $MSYR_{1+}$= 3%	**3%**	B, C, D	10	1	1B
8A	Asymmetric environmental stochasticity	5%	B, C, D	10	1	??
8B	Asymmetric environ. stochasticity; $MSYR_{1+}$=3%	**3%**	B, C, D	10	1	??

Trial	Description	$MSYR_{1+}$	Need scenario	Survey freq.	Canadian catches	Historic survey bias	Conditioning option
(b) Bowhead whales (each conducted conditioning to the estimate of abundance for West Greenland, treating it as absolute abundance)							
1A	$MSYR_{1+}$=2.5%	2.5%	A, B, C	10	A	1	Y
1B	$MSYR_{1+}$=1%	**1%**	A, B, C	10	A	1	Y
1C	$MSYR_{1+}$=4% (and $MSYL_{1+}$=0.8)	**4%**	A, B, C	10	A	1	Y
2A	5 year surveys	2.5%	A, B, C	**5**	A	1	1A
2B	5 year surveys; $MSYR_{1+}$=1%	**1%**	A, B, C	**5**	A	1	1B
3A	15 year surveys	2.5%	A, B, C	**15**	A	1	1A
3B	15 year surveys; $MSYR_{1+}$=1%	**1%**	A, B, C	**15**	A	1	1B
4A	Survey bias = 0.5	2.5%	A, B, C	10	A	**0.5**	Y
4B	Survey bias = 0.5; $MSYR_{1+}$=1%	**1%**	A, B, C	10	A	**0.5**	Y
5A	3 episodic events	2.5%	A, B, C	10	A	1	1A
5B	3 episodic events; $MSYR_{1+}$=1%	**1%**	A, B, C	10	A	1	1B
6A	Stochastic events every 5 years	2.5%	A, B, C	10	A	1	1A
6B	Stochastic events every 5 years; $MSYR_{1+}$=1%	**1%**	A, B, C	10	A	1	1B
7A	Alternative future Canadian catches	2.5%	A, B, C	10	**B**	1	1A
7B	Alternative future Canadian catches; $MSYR_{1+}$=1%	**1%**	A, B, C	10	**B**	1	1B
9A	Alternative future Canadian catches	2.5%	A, B, C	10	**D**	1	1A
9B	Alternative future Canadian catches; $MSYR_{1+}$=1%	**1%**	A, B, C	10	**D**	1	1B
10A	Asymmetric environmental stochasticity	2.5%	A, B, C	10	A	1	??
10B	Asymmetric environ. stochasticity; $MSYR_{1+}$=1%	**1%**	A, B, C	10	A	1	??

Table 6

The *Robustness Trials*.

Humpback whales				Bowhead whales			
Trial no.	Factor	Need scenario	Conditioning option	Trial no.	Factor	Need scenario	Conditioning option
1A	Linear decrease in K; $MSYR_{1+}$=5%	B, D	1A	1A	Linear decrease in K; $MSYR_{1+}$=2.5%	A, C	1A
1B	Linear decrease in K; $MSYR_{1+}$=3%	B, D	1B	1B	Linear decrease in K; $MSYR_{1+}$=1%	A, C	1B
2A	Linear increase in M; $MSYR_{1+}$=5%	B, D	1A	2A	Linear increase in M; $MSYR_{1+}$=2.5%	A, C	1A
2B	Linear increase in M; $MSYR_{1+}$=3%	B, D	1B	2B	Linear increase in M; $MSYR_{1+}$=1%	A, C	1B
3A	Strategic Surveys; $MSYR_{1+}$=5%	B, D	1A	3A	Strategic Surveys; $MSYR_{1+}$=2.5%	A, C	1A
3B	Strategic Surveys; $MSYR_{1+}$=3%	B, D	1B	3B	Strategic Surveys; $MSYR_{1+}$=1%	A, C	1B
4A	Alternative priors; $MSYR_{1+}$=5%	B, D	4A*	4A	Canadian catch 'C'; $MSYR_{1+}$=2.5%	A, C	1A?
4B	Alternative priors; $MSYR_{1+}$=3%	B, D	4B*	4B	Canadian catch 'C'; $MSYR_{1+}$=1%	A, C	1B?
4C	Alternative priors; $MSYR_{1+}$=7%	B, D	4C*				
5D	$MSYR_{1+}$=1%	B, D	5D*				
6A	Include mark-recapture estimates in the conditioning; $MSYR_{1+}$=5%	B, D	6A*				
6B	Include mark-recapture estimates in the conditioning; $MSYR_{1+}$=3%	B, D	6B*				

*Trial which needs to be conditioned.

F. 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≥2013 (defined as t=0 below) Note that incidental removals may still occur in the absence of strikes. To emphasize 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^* (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 harvest or incidental 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. Hence, there are gaps in the numbers where some statistics have been deleted.

F.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 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 population level: min(P_t): t=0,1,…,T.

D10. Relative increase P_T/P_0.

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

F.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.

H. References

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