Report of the Fourth AWMP Workshop on the Development of *SLA*s for the Greenlandic Hunts

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NOTE: some modifications will be made to Annexes E and F in mid-April due to some additional intersessional work being undertaken.

The Workshop was held at the Grønlands Repræsentation, Copenhagen from 15-18 December 2012. The list of participants is given as Annex A.

1. INTRODUCTORY ITEMS

1.1 Convenor's opening remarks
Donovan welcomed the participants to the Workshop. He noted that the focus of the Workshop would be to:

(1) progress work on the development of a trial structure for the Greenlandic humpback and bowhead whale hunts such that candidate *SLA*s can be evaluated and if possible adopted at the 2013 Scientific Committee meeting;
(2) review RMP/AWMP-lite and develop some preliminary scenarios in order to allow developers to begin to consider the more difficult cases of common minke and fin whales prior to the 2013 Scientific Committee meeting, recognising that final *SLA* development will be considered in the context of the relevant RMP *Implementation Reviews* and the forthcoming (after the 2013 Annual Meeting) workshop on common minke whale stock structure that will occur; and
(3) finalise the trials for the Makah hunt so that the *Implementation Review* can be completed at the 2013 Scientific Committee meeting.

1.2 Election of Chair
Donovan was elected Chair.

1.3 Appointment of rapporteurs
Allison, Butterworth, Punt, and Witting were appointed as rapporteurs.

1.4 Adoption of Agenda
The adopted agenda is given as Annex B.

1.5 Documents available
The documents available to the meeting were SC/D12/AWMP1-5 (see Annex C).

2. SUMMARY OF DISCUSSIONS AT SC64 AND INTERSESSIONAL PROGRESS
Donovan summarised the discussions at the 2012 Scientific Committee meeting with respect to the Greenlandic hunts (IWC, 2013a).

The Committee had re-emphasised the importance of developing long-term candidate *SLA*s for the Greenlandic hunts as soon as possible and certainly before the Commission's biennial meeting in 2018, given that the interim approach for providing management advice had been agreed (IWC, 2009a) to be valid for up to two blocks. It had agreed that it should be possible to develop an appropriate trial structures and operating models for the more straightforward cases of the humpback and bowhead whale hunts before the 2013 Annual Meeting to enable candidate *SLA*s to be evaluated. To assist in this process it had agreed a research project (IWC, 2013c) to be undertaken by Punt to develop a draft approach for consideration at an intersessional workshop.

The Committee had also emphasised the importance of developers beginning to consider the development of candidate *SLA*s for fin whales and common minke whales, recognising that this needed to be in the context of the work being undertaken on stock structure with the RMP sub-committee and the joint AWMP/RMP proposal for work on the stock structure of North Atlantic common minke whales (Donovan *et al.*, 2013). To assist this process, the Punt research project noted above also incorporated the development of an AWMP/RMP-lite program.

The Workshop noted that papers SC/D12/AWMP1 and AWMP2 presented the contract work undertaken by Punt. They are discussed below under the relevant agenda items. It thanked Punt for his usual prompt and thorough work, recognising that without this, the Workshop would not have been able to complete its agenda on time.

3. GENERAL ISSUES

3.1 Candidate *SLA*s including guiding principles
The Workshop noted that considerable effort had been put into general consideration of the development of *SLA*s at the beginning of the AWMP process (e.g. (International Whaling Commission, 2000; IWC, 2001a; 2001b; 2002). It also recognised that a document (co-ordinated by Donovan, Punt and Scordino) that provides advice on the development of *SLA*s and their evaluation will be presented at the 2013 Scientific Committee meeting.

However it agreed that it would be useful at this workshop to briefly outline some guiding principles for *SLA*s to assist developers of candidate *SLA*s prior to the 2013 annual meeting. 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) the low likelihood of much 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.

More specifically with respect to the Greenlandic hunts, the Workshop recalled (IWC, 2009c) that the agreed 'interim' approach is 2% of the lower 5% confidence interval for the most recent estimate of absolute abundance. The 'interim' *SLA* will form the basis of at least one of the candidate *SLA*s (to be chosen, alternative candidate *SLA*s must at least show improved performance compared to this). However, it was also **agreed** to modify the 'interim' *SLA* to include a variant that allowed additional abundance estimates by using an approach similar to that used under the *catch-cascading* option of the RMP (this is discussed further below and see Annex D).

The Workshop also noted that under the aboriginal subsistence whaling scheme (IWC, 2003a; 2003b; 2003c) agreed by the Committee (although not yet adopted by the Commission), if an acceptable new abundance estimate (relative or absolute as pertinent to the case concerned) is not obtained by the 10th year after the previous such estimate, a 'grace period' of up to 5 years applies during which the strike limit allowed previously is reduced by 50% until an acceptable new abundance estimate is obtained. After 5 further years, the allowed strike limit will drop to zero. This will be incorporated as necessary into the trial structure (see Annex D).

3.2 Component of the population to which MSYR refers
During the development of *SLA*s for the Bering-Chuckchi-Beaufort Seas (BCB) bowhead and Eastern North Pacific (ENP) gray whale populations, there had been considerable discussions within the Scientific Committee as to what was the appropriate 'currency' in which to express MSYR. Given the case-specific AWMP approach and the nature of the data available on bowhead and gray whales, the Scientific Committee **agreed** that it was most appropriate to express MSYR in terms of the 1+ component of the population (i.e. non-calves). This differed from the approach adopted for the generic Revised Management Procedure approach for commercial whaling of baleen whales which has expressed MSYR in terms of the mature component of the population. The Committee has discussed and accepted these two different approaches in the past (International Whaling Commission, 2000; IWC, 1998).

The Workshop reiterated that use of different 'currencies' did not imply any differences in biology/productivity.

For species/populations not subject to commercial whaling (i.e. bowhead, gray and humpback whales), the Workshop **agreed** that the 1+ currency remains the most appropriate.

However, the Workshop noted that for North Atlantic populations of common minke and fin whales, the situation arises in which species within the same ocean basin are subject to commercial whaling (for which RMP *Implementations* and *Implementation Reviews* have been carried out) and aboriginal subsistence whaling off Greenland. The most appropriate approach to take here requires further consideration by the Scientific Committee. One option is that provided appropriate currency conversions are used to ensure that assumptions about biology and productivity are the same, then the AWMP process can still evaluate performance in the context of 1+.

3.3 Presentation of results and selection of *SLA*s
The Workshop **agreed** that the existing presentation style for the results of AWMP trials and the procedures used in the past to select amongst candidate *SLA*s remain appropriate (e.g. see IWC, 2008b)

4. DEVELOPMENT OF TRIAL STRUCTURE FOR HUMPBACK WHALES OFF WEST GREENLAND

4.1 Stock structure hypotheses

4.1.1 Present hypothesis/es

In 2007, the Committee had noted that the humpback whales found off West Greenland belong to a separate feeding aggregation whose members mix on the breeding grounds in the West Indies, with individuals from other similar feeding aggregations (IWC, 2008a, p. 21). It therefore had agreed that the West Greenland feeding aggregation was the appropriate management unit to consider when formulating management advice.

4.1.2 New information

SC/D12/AWMP5 provided maps of tracks of 30 humpback whales tagged with satellite linked radio transmitters on their feeding grounds in Disko Bay, West Greenland, in June 2008, 2009 and 2010. The whales used the continental shelf areas along West Greenland between 60 and 70ºN extensively and made few excursions outside the areas covered by aerial surveys in 2005 and 2007 during August-September. Two whales departed from West Greenland and took a route south along Labrador and Newfoundland. One of them had already departed from West Greenland in June and reached Newfoundland in July.

The Workshop thanked Heide-Jørgensen for his work and encouraged him to continue tagging whales as it may provide information on early migration, movement between feeding areas and behaviour during the survey period. It was noted that the animal that left West Greenland in June might indicate that some animals leave the West Greenland area before the time of surveys (August), leading to a negative bias in the abundance estimates.

The Workshop recognised the potential of photographs to provide alternative evidence of movement between feeding areas and it **agreed** that Witting should confirm that all photographs from West Greenland have been submitted to the North Atlantic humpback Catalogue; Donovan **agreed** to check with Carlson to see whether any matches have been made.

4.1.3 Hypothesis/es for use in trials

The Workshop **endorsed** the previous Scientific Committee recommendation that the West Greenland feeding aggregation was the appropriate management unit. Therefore it **recommended** that it should be treated as a single stock in the trials, noting that there is no evidence to suggest other hypotheses should be tested.

4.2 Abundance estimates and trends

Table 1

Estimates of absolute abundance for West Greenland humpback whales from an aerial survey in 2007.

Year	*n*	CV	Remarks	Reference
2007*	2,154	0.36	Initial strip census analysis (Heide-Jørgensen *et al.*, 2008) accepted by the Committee in 2008 (IWC, 2009a) was 3,039 (CV=0.45) – see text	(Heide-Jørgensen *et al.*, 2012)
2007	3,272	0.50	The initial MRDS estimate accepted by the Committee was 3,299 (CV=0.57)	Heide-Jørgensen *et al.*, 2008

* agreed for use in the trials

4.2.1 Review of estimates for use in conditioning and trials

The Committee has agreed absolute abundance and trend estimates for West Greenland humpback whales (Heide-Jørgensen *et al.*, 2008; IWC, 2009a). The absolute estimates were obtained from aerial survey data using two different analytical methods: strip census and mark-recapture distance sampling (MRDS). As both estimates were similar, the Committee had accepted both estimates (although noting that the sample size was rather low for undertaking a MRDS analysis) but had adopted the strip census estimate as the 'best' estimate *inter alia* given its smaller CV. The Workshop noted that the subsequently published version of the paper (Heide-Jørgensen *et al.*, 2012) had a revised strip census estimate (2,154, CV=0.36 versus the original 3,039, CV=0.45) in response to comments from the referees. The Workshop **requested** Heide-Jørgensen to provide a short working paper for discussion at the 2013 Annual meeting documenting the changes such that the Committee can agree a 'final' best estimate. For the present purposes, the Workshop **agreed** to use the published strip census value (see Table 1). The agreed annual rate of increase was 9.4% per year (SE 0.01) which was unchanged in the published paper.

The Workshop **agreed** to use the estimates of relative abundance from aerial surveys given in Table 2a to condition the trials. By contrast, the abundance estimates from the mark-recapture studies (Table 2b) cover a shorter period and are heavily correlated so it was **agreed** that at present these will only be used in a *Robustness Trial*. However, the Workshop **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 operating models.

Table 2

Estimates of relative abundance for West Greenland humpback whales.

Year	Estimate	CV	Year	Estimate	CV
(a) Aerial surveys			**(b) Photo-ID mark-recapture**		
1984	99	0.4	1982	271	0.13
1985	177	0.44	1989	357	0.16
1987	220	0.62	1990	355	0.12
1988	200	0.74	1991	566	0.42
1989	272	0.75	1992	376	0.19
1993	873	0.53	1993	348	0.12
2005*	1,158	0.35			
2007	1,020	0.35			

*In 2009 the Committee had agreed that this uncorrected estimate was suitable for use in assessments

Both absolute and relative estimates of abundance are expected in the future. The next aerial survey is planned for 2015 to cover a similar area to the previous survey and with humpback whales as one of the priority species. Given present abundance and the a**greed** estimated rate of increase (insert value), the Workshop **agreed** that future sample sizes should be sufficient to allow absolute abundance estimates to be obtained from future surveys. In view of this, only absolute estimates will be generated into the future.

4.2.2 *Conclusions*

The Workshop **agreed** that both the absolute estimates of abundance given in Table 1 and the relative estimates of abundance from aerial surveys given in Table 2a will be used to condition the trials. In addition, it **agreed** that the relative abundance estimates from the mark-recapture studies (Table 2b) will be used in a *Robustness Trial*. Only absolute estimates will be generated into the future.

4.3 Removals history

4.3.1 Direct catches

The full historic catch series for North Atlantic humpback whales was reviewed in Smith and Reeves (2010). There is considerable uncertainty concerning the level of catches prior to 1930. However, because of known difficulties with fitting a population model for the western North Atlantic from its pre-exploitation level, the inability to assign many of the past catches to feeding aggregations and the decision to treat the West Greenland feeding aggregation as the appropriate management unit, it was **agreed** that trials would begin in the year 1960, under the assumption that the age structure at the start that year is steady. Thus the catch series used in the trials (and see Annex E) is provided from 1960 onwards, since when the catches are known reliably and there is no need for an alternative series to be considered.

None of the photographic recaptures of humpback whales from St. Vincent and the Grenadines have been 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), the Workshop noted that Greenland animals may have been subject to direct catches outside the West Greenland area. In particular, it was noted that known direct catches occurred from whaling stations off the east coast of Canada after 1960 (see Annex E).

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. No future direct catches off Canada will be simulated

4.3.2 Bycatches

Bycatches of humpback whales are known to occur both off West Greenland; Table 3 presents the information available in National Progress reports since 2000. It was **agreed** that Allison will ensure that animals incorporated into the direct catch series (some were reported as shot for humane reasons) are not double counted; bycaught animals will be considered separately. Heide-Jørgensen noted that many of the bycaught animals were taken in the crab fishery which has now peaked. The Workshop **agreed** that future bycatches 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.

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.

As was the case for direct catches, the Workshop noted that animals may be subject to bycatches outside the West Greenland area outside the feeding season. In particular it was noted that known bycatches occur down the east coast of Canada and especially Newfoundland/Labrador.

In order to account for this possibility in the trials, it was **agreed** that Donovan and Allison would try to obtain data for bycatches off eastern Canada. These will be incorporated into the trial specifications and will be included in Annex E developed after the Workshop. As for direct catches, it was **agreed** that the estimated potential bycatch of Greenland humpbacks off Canada could be up to 5% of the total Canadian bycatch.

Table 3 (being checked)

List of bycatches and ship strikes of West Greenland humpback whales since 2000 (taken from the national progress and infractions reports)

Year	Bycatch	Ship strike	Also reported as an Infraction?
2000	2	0	
2001	2	0	
2002	3	0	
2003	1	0	
2004	?	?	
2005	5	0	
2006	3	0	
2007	3	0	
2008	3	0	
2009	0	0	
2010	1	0	

4.3.3 Ship strikes

There are no known reports of ship strikes off West Greenland. Donovan and Allison will examine whether there are reports of ship strikes of humpback whales off Canada and if so, the same approach as for direct catches and bycatches will be used to generate ship strike series. Information will be included in Annex E developed after the Workshop.

4.3.4 Conclusions with respect to series to use

A single direct catch series will be used. The historic bycatch series will be finalised by Donovan and Allison and will be included in Annex E developed after the Workshop. Future bycatches will be generated assuming that the exploitation rate due to bycatch in the future equals the mean value over the most recent five-years.

4.4 Biological parameters

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 will 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* (see Item 4.7) in which (IWC, 2005) 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. The Workshop **agreed** that trials should be based on the prior for carrying capacity, *K*, proposed in SC/D12/AWMP2, U[0, 30,000], noting that the estimated total catch of North Atlantic humpback whales is approximately 30,000 (Smith and Reeves, 2010).

The **agreed** priors are summarised in Table 4.

Table 4

The prior distributions for humpback and bowhead whales for use in the trials

Parameter	Humpback	Bowhead
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(20,3^2) truncated at 13.5 and 26.5
K^{1+}	U[0, 30,000]	U[0, *sum appropriate historic catches*]
$MSYL_{1+}$	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	$\ell nP_{2002} = N(\ell n3,270;(0.50^2 + CV_{add}^2))$	A: $\ell nP_{2002} = N(\ell n6,340;(0.38^2 + CV_{add}^2))$ B: $\ell nP_{2006} = N(\ell n1229,(0.47^2 + CV_{add}^2))$
Additional variation (relative indices), CV_{add2}	U[0.2, 0.6]	U[0.2, 0.6]
Bias of relative abundance indices, B_c	$\ell nB_c \sim U\left[-\infty,\infty\right]$ (see[1])	$\ell nB_c \sim U\left[-\infty,\infty\right]$ (see[1])

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

4.5 Need

SC/D12/AWMP4 presented need envelope considerations following internal discussions in Greenland and proposed a way forward for the purposes of the trials. Development and consideration of need envelopes is the pragmatic approach used in the *SLA* development process to enable management advice to be provided to the Commission for possible increases in agreed need over time (e.g. due to increasing human populations) without requiring that additional trials be developed and run. It should be stressed that the size and shape need envelopes (which are proposed by those representing the subsistence hunters) do not imply that need requests will necessarily increase or that the Commission will accept such requests. Any need requests that are for scenarios outside the need envelopes tested will require additional trials and may require further *SLA* development. Need envelopes that are very wide may mean that candidate SLAs that fully meet need objectives cannot be developed.

For the ENP gray whales and BCB bowhead whales, three need envelopes were considered that started at current need levels: one remained constant through time, one increased linearly over the 100-year period to twice the present level and one increased linearly over the 100-year period to three times the current level. SC/D12/AWMP4 suggested a similar approach for West Greenland humpback whales but with some modifications to account for (a) the preference of the hunters for humpback whales rather than fin whales (see below) and (2) the multispecies nature of the fishery and the overall expression of need in terms of edible products.

That Greenlanders would generally rather catch humpback whales than fin whales is reflected in the historical catches. It was only in the 1980s that concerns over the status of humpback whales led to the move to catches of fin whales and the removal of the traditional exemption allowing Greenlanders to take humpback whales despite its protected status in the North Atlantic. Recently, the Commission has allowed a resumption of the hunt on humpback whales and Witting explained that the currently expressed need for ten humpback whales is to some degree a compromise between the historical limits agreed for fin and humpback whales. To allow for more flexibility in the expression of actual need on fin and humpback whales in the near future, he suggested that the starting level of the need envelopes on humpback whales should be around twenty whales. 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 **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 (Fig. 1).

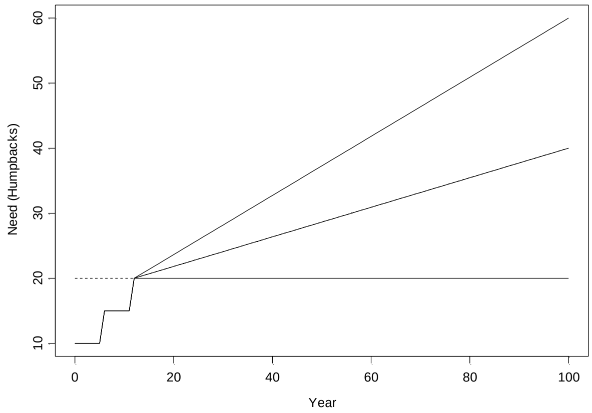

Fig 1. Need Envelope for humpback whales (with the backup envelope shown by the dotted line).

Witting also proposed that a further case be examined to cope with unforeseen circumstances that may result in the allowable catch of especially minke whales being reduced. Using the interim conversion factors developed in IWC/62/9, the amount of edible products from 50, 75 or 100 minke whales corresponds to the amount of edible products from 8, 12 and 16 humpback whales. He suggested consideration of an additional 'backup' scenario of initially adding ten humpback whales to the base case envelope (this would compensate for a decline in the minke whale strike limits of up to approximately 60 minke whales).

Witting agreed to discuss these need envelopes once again with managers in Greenland, and to report any suggested changes back to the AWMP Steering Group before the annual meeting.

4.6 *SLA*s to be considered

The general issue of the design of *SLA*s is discussed under item 3.1. The Workshop **agreed** that all of the trials would be conducted for three 'reference *SLA*s', in addition to any other *SLA*s which might be proposed by developers (Annex D):

(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 **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.

Witting and Butterworth/Brandao **confirmed** that they will be developing candidate *SLA*s.

4.7 Development of *Evaluation* and *Robustness* Trials

SC/D12/AWMP2 had provided a set of draft specifications for *Evaluation* and *Robustness* trials for humpback whales off West Greenland based on those developed for the Eastern North Pacific stock of gray whales (IWC, 2005) One key feature was that the population dynamics model is initiated in a recent year (1960 for most of the trials) rather than under the assumption that the population was at carrying capacity at the start of the first year with catches. The Workshop **endorsed** this approach as suggested previously (IWC, 2013b) given the past difficulties to find population dynamics models which capture the entire period of exploitation and are able to fit the abundance data for the North Atlantic humpback whales adequately (Punt *et al.*, 2006) and the difficulties in assigning past catches to the West Greenland feeding aggregation. The operating model is conditioned to estimates of absolute and relative abundance. The trials proposed in SC/S12/AWMP2 explored the implications of uncertainty about $MSYR_{1+}$, the first year considered in the operating model, episodic events, need, survey frequency, and changes over time in natural mortality and carrying capacity.

The Workshop considered the proposals in SC/S12/AWMP2 in light of its discussions above and the uncertainties involved. In particular, it **agreed**:

(a) trials will incorporate an assumption that additional variance is the same for all sighting surveys given that there are insufficient data to update the prior for additional variance by individual survey;
(b) *Strike Limits* will be updated every six years rather than every five years to reflect the move to biennial Commission meetings;
(c) $MSYR_{1+}$ of 3%, 5%, and 7% will be examined (3% is low compared to observed rates of increase for other humpbacks stocks and well as humpback whales off West Greenland, 5% is close to the best estimate of the current rate of increase for West Greenland humpback whales and 7% is consistent with the rates of increase for other stocks of humpback whales of 10+%);
(d) trials for which the survey period is every 15 years should be conducted with and without application of the rule related to the grace period (such trials also examine the situation in which the intention is to conduct surveys every 10 years, but a survey estimate cannot be produced that frequently).

With respect to *Robustness Trials* the Workshop **agreed** that *inter alia* these should include**:**

(a) trials in which the priors for the biological parameters exclude more productive values because the combination of the upper ends of the priors for S_{1+} and f_{max} along with the lower end of the prior for the age-at-maturity may be unlikely;
(b) at least one trial in which $MSYR_{1+}$=1%;
(c) a 'strategic survey' trial which assumes that a survey will be conducted in year *y*+1 if the survey in year *y* led to an estimate which is less than half of that from the preceding survey;
(d) a trial in which the operating model is conditioned also to the mark-recapture estimates of abundance under the assumption that the estimates are independent.

Table 5 summarises the factors the Workshop **agreed** should be considered in the trials. Tables 6 and 7 summarise the **agreed** *Evaluation* and *Robustness Trials*. Annex F (to be completed after the Workshop) provides the full specifications for the trials.

Table 5

Factors to be tested in the trials for humpback and bowhead whales

Factors	Other Levels (Reference levels shown bold and underlined)	
	Humpback whales	Bowhead whales
MSYR $_{1+}$	1%, 3%, **<u>5%</u>**, 7%	1%, **<u>2.5%</u>**, 4%
Time dependence in *K* *	**<u>Constant</u>**, Halve linearly over 100yr	
Time dependence in natural mortality, *M* *	**<u>Constant,</u>** Double linearly over 100yr	
Episodic events *	**<u>None</u>**, 3 events occur between yrs 1-75 (with at least 2 in yrs 1-50) in which 20% of the animals die, Events occur every 5 years in which 5% of the animals die	
Need in final year (linear change from 5/10 in 2011)	**A:** **<u>B:</u>** **C:** **<u>D:</u>**	**<u>A: 5 -> 5 over 100 years</u>** <u>B: 5 -> 10 over 100 years</u> **<u>C: 5 -> 15 over 100 years</u>**
Survey frequency	5 yr, **<u>10 yr</u>**, 15 yr	
Historic survey bias	0.8, **<u>1.0</u>**, 1.2	0.5, **<u>1.0</u>**
First year of projection, τ	**<u>1960</u>**	**<u>1940</u>**
Alternative Priors	S_{1+} ~ U[0.9, 0.99]; f_{max} ~ U[0.4, 0.6]; a_m ~ U[5, 13]	N/A
Strategic surveys	Extra survey if a survey estimate is half of the previous survey estimate	
Canadian catches	N/A	A: 5 -> 5 B: 5-> 10 C: 5-> 15 D: 2.5 -> 2.5

* Effects of these factors begin in year 2011 (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 6

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

Trial	Description	*MSYR*$_{1+}$	Need Scenarios	Survey freq.	Historic Survey Bias	Conditioning Option
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, D	**5**	1	1A
2B	5 year surveys	**3%**	B, D	**5**	1	1B
3A	15 year surveys	5%	B, D	**15**	1	1A
3B	15 year surveys; MSYR$_{1+}$ =3%	**3%**	B, D	**15**	1	1B
4A	Survey bias = 0.8	5%	B, D	10	**0.8**	Y
4B	Survey bias = 0.8; MSYR$_{1+}$ =3%	**3%**	B, D	10	**0.8**	Y
5A	Survey bias = 1.2	5%	B, D	10	**1.2**	Y
5B	Survey bias = 1.2; MSYR$_{1+}$ =3%	**3%**	B, D	10	**1.2**	Y
6A	3 episodic events	5%	B, D	10	1	1A
6B	3 episodic events; MSYR$_{1+}$ =3%	**3%**	B, D	10	1	1B
7A	Stochastic events every 5 years	5%	B, D	10	1	1A
7B	Stochastic events every 5 years; MSYR$_{1+}$ = 3%	**3%**	B, D	10	1	1B

Table 7

The *Robustness Trials* for humpback whales

Trial No.	Factor	Need Scenario	Conditioning option
1A	Linear decrease in *K*; MSYR=5%	B, D	1A
1B	Linear decrease in *K*; MSYR=3%	B, D	1B
2A	Linear increase in *M*; MSYR=5%	B, D	1A
2B	Linear increase in *M*; MSYR=3%	B, D	1B
3A	Strategic Surveys; MSYR=5%	B, D	1A
3B	Strategic Surveys; MSYR=3%	B, D	1B
4A	Alternative priors; MSYR=5%	B, D	4A
4B	Alternative priors; MSYR=3%	B, D	4B
4C	Alternative priors; MSYR=7%	B, D	4C
5D	MSYR=1%	B, D	5D
6A	Include mark-recapture estimates in the conditioning; MSYR=5%	B, D	6A
6B	Include mark-recapture estimates in the conditioning; MSYR=3%	B, D	6B

4.8 Consideration of results and/or future work

The code implementing the trials will be updated intersessionally and provided to potential developers. The full Workplan and timeline is outlined in Item 9.

5. DEVELOPMENT OF TRIAL STRUCTURE FOR BOWHEAD WHALES OFF WEST GREENLAND

5.1 Stock structure hypotheses

The current working hypothesis in the Scientific Committee is a single Baffin Bay-Davis Strait stock of bowhead whales (see Fig. 2). However, pending the availability of some genetic analyses, the Committee has 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, 2009d).

No new information was available to the Workshop to revise this understanding of stock structure with its current uncertainties. Given that the Workshop's objective was to develop an *SLA* for the Greenland hunt of bowhead whales, it **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. 2 be taken into account. This is discussed further under Item 5.7.

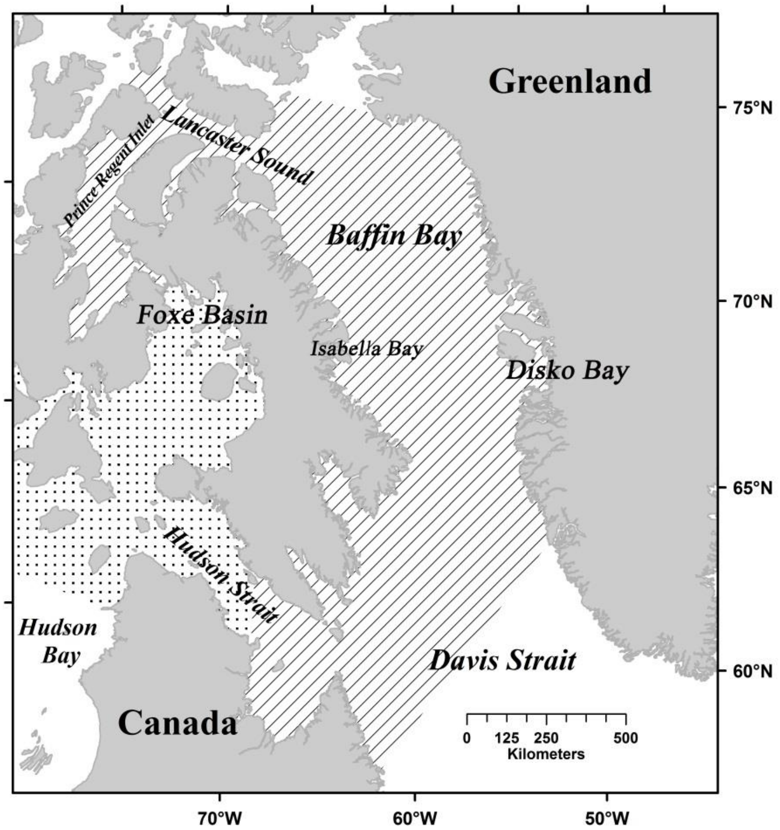

Fig.2. Stock structure hypotheses for bowhead whales and place names referred to in the text. Hashed lines are for a Davis Strait- Baffin Bay stock while the dotted area refers to a Foxe Basin- Hudson Bay stock.

5.2 Abundance estimates and trends
Table 8 lists the abundance estimates for North Atlantic bowhead whales.

It is not possible to create an estimate of abundance for the entire Davis Strait-Baffin Bay-Foxe Basin area as would be required to model the total population as a single stock because the survey in Prince Regent Inlet was conducted in 2002 whereas the Foxe Basin-Hudson Bay survey was conducted in 2003: combining estimates from the two surveys could risk double counting animals. The Workshop agreed to condition the operating model using data for Davis Strait-Baffin Bay stock only (see Items 5.1 and 5.6).

The Workshop noted that 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.

The sex ratio data from ~600 biopsy samples taken off West Greenland over the past 13 years show that the ratio of female:male animals in this area is ~80:20 (Heide-Jørgensen *et al.*, 2010). There is no reason to expect that the current whole population does not have a 50:50 sex ratio since the large numbers of historical (pre-1900) catches were taken over the entire range and the catch ratio of recent Canadian catches is close to 50:50. Thus it is assumed that there is sex segregation on the feeding grounds. In view of this 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 are given in Table 9. The Workshop **agreed** that an overdispersion parameter should be estimated for these sightings data under the assumption that the data are negative binomially distributed.

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).

Estimates of relative abundance are also available from genetic mark recapture studies (Table 10). The potential of these mark recapture estimates (which are expected to continue in the future) was noted, but since time-series are not independent estimates, it will take some work to incorporate them into the trials. The Workshop **recommends** that work continue to enable these data to be used in the future, however, it accorded the work low priority at this time.

Table 8

Aerial survey estimates of bowhead whales

Stock-Region	Year	*n*	CV/95%CI	Remarks	Reference
Prince Regent Inlet	2002	6,340	CI=3,119-12,906	Agreed to be used for management advice under alternative hypothesis	(IWC, 2009d)
Foxe Basin-Hudson Bay	2003	1,525	CI=333-6,990	Agreed to be used for management advice under alternative hypothesis	(IWC, 2009d)
West Greenland	2007	1,229	CV=0.47	Winter season – Agreed to be used for management advice under alternative hypothesis	(Heide-Jørgensen *et al.*, 2007)
West Greenland	2012	829	CV=0.35	Preliminary (March-April survey) – agreed for use in conditioning	Hansen (2012)
Isabella Bay	2009	1,105	CV=0.39	Summer season	(Hansen *et al.*, 2012)

Table 9

Estimates of relative abundance from aerial surveys. Data from 2012 are preliminary.

Year	Effort (units)	Sightings	Year	Effort (units)	Sightings
1981	951	1	1994	1,092	0
1982	2,273	1	1998	1,184	5
1990	591	1	1999	1,104	0
1991	1,088	3	2006	791	9
1993	577	0	2012	1,574	25

Table 10

Estimates of relative abundance from genetic mark-recapture studies. Data from 2011 and 2012 are preliminary.

Year	Estimate	CV
2010	1,410	0.23
2011	1,681	0.28
2012	1,219	0.23

5.3 Removals

All the recent known direct catches of bowhead whales by Canada and Denmark (Greenland) are listed in Table 11. The catch series is believed to be complete for the period since 1940 (when the trials begin – see below) and the Workshop **agreed** 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. Allison will investigate this further.

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 should 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- Cherry to double check).

Recent bycatches of bowhead whales by Denmark (Greenland) and any information Donovan and Allison may find for Canada will be will be included in Annex E developed after the Workshop. It was noted that in future, if the number of ship strikes increases as the Northwest Passage opens up, this could trigger an *Implementation Review*.

5.4 Biological parameters

The Workshop received no new information on biological parameters. It therefore **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.

5.5 Need

SC/D12/AWMP3 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 (and see Fig. 3).

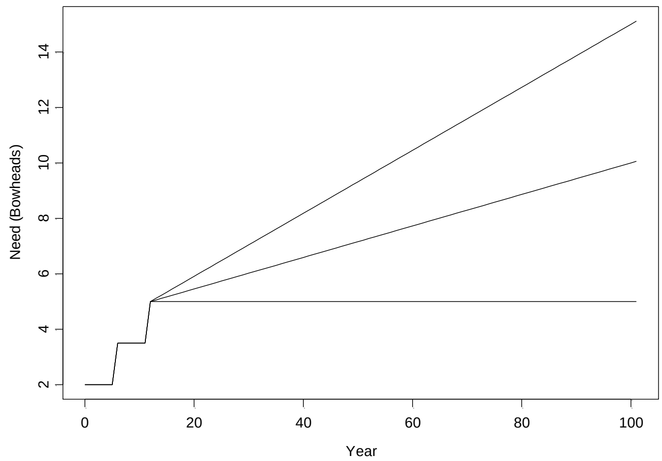

Fig 3. Need envelope for bowhead whales

5.6 *SLA*s to be considered

The Workshop **agreed** that the *SLA* developers will be provided with the total need for the next block, the catches by sex (separated into commercial and aboriginal catches [combined] and catches due to bycatch in fisheries and ship strikes [also combined], and catches by Canada), and the estimates of absolute abundance and their associated CVs. The *SLA* for bowhead whales may also wish to make use of the estimate of absolute abundance for Prince Regent Inlet of 6,340 (CV 0.38), noting that it cannot be assumed that abundance estimates from other than the West Greenland wintering area will be available in the future.

Witting and Butterworth/Brandao **confirmed** that they will be developing candidate *SLA*s.

5.7 Development of *Evaluation* and *Robustness* Trials

SC/D12/AWMP2 also provided a set of draft specifications for *Evaluation* and *Robustness* trials for bowhead whales off West Greenland. As for humpback whales and for similar reasons, the Workshop **endorsed** the approach 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.

Given the uncertainty in stock structure (Item 5.1), trials could be conducted for one-stock and two-stock scenarios. Neither scenario is straightforward to model, *inter alia* because: (a) no estimate of abundance for the entire Davis Strait-Baffin Bay-Foxe Basin area is available (the Prince Regent Island and Foxe basin surveys were surveyed in different years and cannot therefore be added together); (b) it is difficult to assign catches to stocks under the two-stock hypotheses; and (c) there is no guarantee that Canadians will undertake future abundance surveys.

The Workshop therefore **agreed** to condition the operating model using abundance data for the Davis Strait-Baffin Bay area only and remove all catches from the modelled Davis Strait-Baffin Bay-Foxe Island population. Both assumptions are conservative.

With respect to the Prince Regent Inlet survey estimate of 6,340 (CV 0.38), it was **agreed** to conduct trials initially only for the case in which the estimate of 1,229 (CV 0.47) off West Greenland is treated as an estimate of absolute abundance (after adjusting for the sex ratio), recognising that this clearly is an underestimate. The rationale is that if an *SLA* performs adequately when the operating model is conditioned to the West Greenland estimate alone, the *SLA* will perform adequately even in the absence of future surveys in Prince Regent Inlet. The information provided to the *SLA* will be the results of surveys off West Greenland. If it does not possible to develop an acceptable *SLA* under this assumption, then scenarios can be considered where the operating model is conditioned to the estimate of abundance for Prince Regent Inlet and estimates of abundance for West Greenland are considered to be relative.

The Workshop **agreed** that an overdispersion parameter should be estimated for the sightings data under the assumption that the data are negative binomially distributed, and 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 not taken from the same stock as the West Greenland catches). The sex-ratio for future West Greenland catches should be set to the sex ratio of the biopsy samples off West Greenland over 2002-11 while that for future Canadian removals should be set to the observed sex-ratio.

The historical catches of bowhead whales were taken throughout the entire Davis Strait-Baffin Bay-Foxe Basin area, so it is reasonable to assume that the sex ratio of the entire population(s) at the start of 1940 is 50:50, despite the recent female-biased catches off West Greenland. The latter reflects the sex ratio of the animals found in the West Greenland wintering area as determined from over 600 biopsy samples. Clearly not all males in the population(s) are available when the survey is conducted.

The Workshop noted the factors that had been agreed for humpback whales, recognising that most of these were also appropriate for bowhead whales. Table 5 summarises the factors the Workshop **agreed** should be considered in the trials. Tables 11 and 12 summarise the **agreed** *Evaluation* and *Robustness Trials*. Annex E provides the full specifications for the trials.

Table 11

The *Evaluation Trials* for bowhead whales (each conducted conditioning to the estimates of abundance for Prince Regent Inlet and West Greenland as absolute). Values given in bold type show differences from the base trial.

Trial	Description	$MSYR_{1+}$	Need Scenarios	Survey freq.	Historic	Survey Bias	Conditioning Option
1A	$MSYR_{1+}$ = 2.5%	1%	A,B,C	10	A	1	Y
1B	$MSYR_{1+}$ = 1%	**2.5%**	A,B,C	10	A	1	Y
1C	$MSYR_{1+}$ = 4%	**4%**	A,B,C	10	A	1	Y
2A	5 year surveys	2.5%	A, C	**5**	A	1	1A
2B	5 year surveys; $MSYR_{1+}$ =1%	**1%**	A, C	**5**	A	1	1B
3A	15 year surveys	2.5%	A, C	**15**	A	1	1A
3B	15 year surveys; $MSYR_{1+}$ =1%	**1%**	A, C	**15**	A	1	1B
4A	Survey bias = 0.5	2.5%	A, C	10	A	**0.5**	Y
4B	Survey bias = 0.5; $MSYR_{1+}$ =1%	**1%**	A, C	10	A	**0.5**	Y
5A	3 episodic events	2.5%	A, C	10	A	1	1A
5B	3 episodic events; $MSYR_{1+}$ =1%	**1%**	A, C	10	A	1	1B
6A	Stochastic events every 5 years	2.5%	A, C	10	A	1	1A
6B	Stochastic events every 5 years; $MSYR_{1+}$ = 1%	**1%**	A, C	10	A	1	1B
7A	Alternative future Canadian catches	2.5%	A, C	10	**B, C, D**	1	1A
7B	Alternative future Canadian catches; $MSYR_{1+}$=1%	**1%**	A, C	10	**B, C, D**	1	1B

Table 12

The *Robustness Trials for* bowhead whales

Trial No.	Factor	Need Scenario	Conditioning option
1A	Linear decrease in *K*; MSYR=2.5%	A,C	1A
1B	Linear decrease in *K*; MSYR=1%	A,C	1B
2A	Linear increase in *M*; MSYR=2.5%	A,C	1A
2B	Linear increase in *M*; MSYR=1%	A,C	1B
3A	Strategic Surveys; MSYR=5%	A,C	1A
3B	Strategic Surveys; MSYR=3%	A,C	1B

5.8 Consideration of results and/or future work

The code implementing the trials will be updated intersessionally and provided to potential developers. The full Workplan and timeline is outlined in Item 9.

6. PROGRESS WITH RESPECT TO COMMON MINKE WHALES AND FIN WHALES

6.1 Use of RMP/AWMP-lite

SC/D2/AWMP1 provided the specifications for RMP/AWMP-lite, which is a platform written in R which implements an MSE (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 framework is applied for illustrative purposes to fin whales in the North Atlantic.

The Workshop welcomed SC/D2/AWMP1, which will help the Committee as it designs a trial structure for the North Atlantic common minke and fin whales, and will assist potential developers prepare for the development process. The Workshop **agreed** that the following modifications should be made to RMP/AWMP-like prior to the *Implementation Review* for the North Atlantic fin whales, which is scheduled to start during a pre-meeting prior to the 2013 meeting of the Scientific Committee:

(a) allow the *SLA*s to be coded as an executable file which is called from RMP/AWMP-lite so that developers do not need to be familiar with R;
(b) add headers to all output files;
(c) replace the Schaefer production model by a Pella-Tomlinson model so that MSYL can be specified to occur at 0.6K;
(d) allow MSYR to be a parameter of the model (instead of the intrinsic growth rate).
(e) simplify the use of folders so that it is easy for users to implement the software on their machines;
(f) add a tagging likelihood so that the tagging data can be used to inform the values in the mixing matrices;
(g) allow the population model to be initiated in a recent year and apply this version of the model to data for the North Atlantic fin whales;
(h) extend the model to allow for dispersal among breeding stocks and use this extension of the model to implement Stock Structure Hypotheses I, II, III, V, and VI for the North Atlantic fin whales (IWC, 2009b).

The Workshop **agreed** that this work should be funded from the AWMP Developers Fund.

The Workshop recognised that production models can be biased compared to age-structured models. However, it **agreed** that any such bias was unlikely to be marked for baleen whales because the age-at-recruitment and the age-at-maturity are often similar and are usually not very different from age 1. The MSYR parameter in RMP/AWMP-lite should therefore be treated as being effectively in the $MSYR_{1+}$ currency. The Workshop noted that RMP/AWMP-lite can make use of 'minimum estimates' of abundance; minimum estimates are those for which coverage and precision are such that true abundance will certainly be larger than the point estimate from the survey.

6.2 Stock structure

The Commission has agreed that in cases of overlap, achievement of aboriginal need has a higher priority than allowing for commercial catches. Therefore, the process of developing *SLA*s and RMP *Implementations* for stocks in regions where both commercial and aboriginal catches occur should be: (a) development of a 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).

6.2.1 Fin whales

Six stock structure hypotheses were identified during the *Implementation* (IWC, 2009b). These hypotheses will be reviewed during the *Implementation Review* scheduled for the 2013 meeting of the Scientific Committee.

The Workshop had an initial discussion regarding whether it would 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 Workshop **agreed** that the RMP *Implementation Review* should be asked to consider carefully any evidence that there may be more than one stock mixing off West Greenland.

6.2.2 Common minke whales

The trials structure for North Atlantic minke whales was developed for the 199x RMP *Implementation* (ref). The stock structure hypotheses considered at that time (and in subsequent *Implementation Reviews*) focused on the central and eastern stocks. Clearly additional focus on the western end of the range is required to adequately capture the range of hypotheses regarding stock structure for the minke whales hunted off West Greenland. Information on, for example, changes over time in catch sex ratios (or the lack thereof) confirms that the minke whales hunted off West Greenland do not comprise an entire stock. The Committee has recognised the need for a full evaluation of common minke whale stock structure in the North Atlantic in both an AWMP and RMP context. It has therefore agreed that a joint AWMP/RMP stock structure workshop be held in the intersessional period between the 2013 and 2014 Annual meetings. The results of this workshop will clearly be essential to the *SLA* development process.

6.3 Abundance estimates

The abundance estimates agreed by the Committee for the West Greenland fin and minke whales are listed in tables x and y. The Workshop noted that the published paper (ref.) had updated the estimates originally accepted by the Committee; the Workshop **recommends** that the published estimates be accepted by the Committee.

6.4 Removals

The removals due to commercial and subsistence whaling are well documented for West Greenland fin and minke whales. However, the RMP *Implementation Reviews* will need to document and include information on bycatches and ship strikes.

6.5. Biological parameters

Unless new information becomes available, the existing biological parameter values used in the RMP should also be used for the AWMP.

6.6 Need

6.6.1 Fin whales

Witting advised the Workshop that the three scenarios (Fig. 4) regarding the need envelope were:

(1) 19 whales in each year over the 100-year projection period;
(2) 19 whales each year increasing to 38 over the 100-year projection period;
(3) 19 whales each year increasing to 57 over the 100-year projection period.

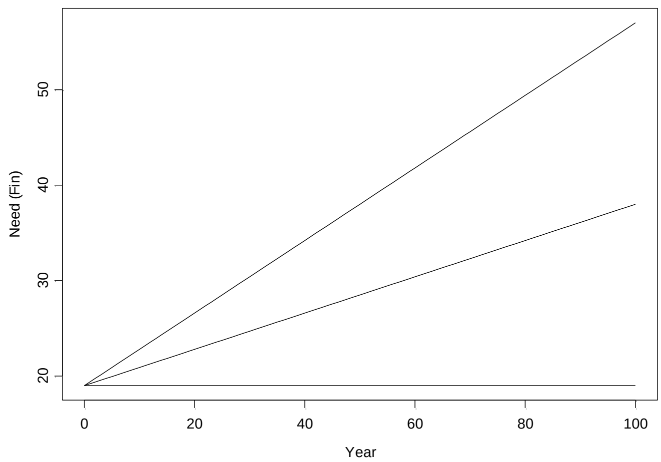

Fig. 4. Need envelope for fin whales

6.6.2 Minke whales

Witting advised the Workshop that the three scenarios (Fig. 5) regarding the need envelope were:

(1) 200 whales in each year over the 100-year projection period;

(2) 200 whales each year increasing to 400 over the 100-year projection period;
(3) 200 whales each year increasing to 600 over the 100-year projection period.

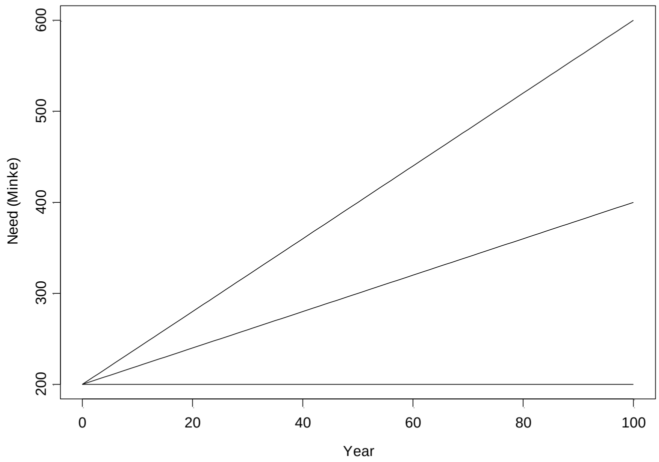

Fig. 5. Need envelope for common minke whales.

6.7 Candidate *SLA*s/developing teams

Witting and Brandão / Butterworth indicated that they were likely to develop candidate *SLA*s for common minke and fin whales.

6.8 Potential trials structure

6.8.1 Fin whales

The residual pattern for the fit of the operating model to the abundance estimates is common across areas, which suggests that there is model mis-specification. Future trials should consider alternative model structures such as initialising the population dynamics model more recently that the year corresponding to the first catches. The Workshop **recommends** that this matter be further considered by at the forthcoming *Implementation Review.*

6.8.2 Minke whales

The trials structure needs to account for the sex-ratio of past and future catches during the aboriginal and commercial hunts. Consideration should be given to sex-biased migration. A structure to allow for such migration is given in SC/64/AWMP15.

7. FUTURE CONSIDERATION OF OPERATIONAL MULTISPECIES ASPECTS IN THE PROVISION OF MANAGEMENT ADVICE

Earlier discussions (e.g. IWC, 2011; Witting, 2008) on this matter 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 re-iterated previous advice (IWC, 2012) that this aspect is best pursued only after separate *SLA*s, which operate independently for each species, have been developed and accepted.

8. COMPLETION OF GRAY WHALE *SLA* EVALUATION FOR THE MAKAH HUNT (VIA SKYPE)

Following the discussions at the 2012 Scientific Committee meeting, SC/D12/AWMP3 noted that two *SLA* variants (one with research provisions) were agreed by the Committee to meet the conservation objectives of the Commission. 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 was not fully tested. The reason that an exact variant was not tested was because there is a temporal rule in the proposed hunt, such that all struck and lost whales from December through April are not counted against the Allowable PCFG Limit (APL), whereas any struck and lost whales in May are counted against the APL. There are insufficient data to determine the proportion of strikes that would occur in May or prior to May, and hence the two variants of the hunt were developed to bracket the range of possible monthly strikes. SC/D12/AWMP3 proposed the testing of the following six variants to span the full range of possible strikes occurring in May or prior to May.

(1) Allow only one strike prior to May.
(2) Allow two strikes prior to May.
(3) Allow three strikes prior to May.
(4) Allow four strikes prior to May.
(5) Allow five strikes prior to May.
(6) Allow six strikes prior to May

The Workshop **endorsed** the approach outlined in SC/D12/AWMP3 and **recommended** that the full set of trials be repeated for these six variants (in addition to the two *SLA*s agreed by the Committee [1 and 2]). Annex G summarises the performance for the eight trials used by the Committee during 2012 to contrast *SLA*s 1 and 2 for these six variants.

The Workshop also **recommends** that the PhotoID 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.

9. WORKPLAN

The Workshop **agreed** to the workplan given in Table 13.

Task	Species	Who	When
Get final catch series (to 2012) [by sex]	Both	CA	15 April 2013
Get bycatches	Both	GD, LW	15 April 2013
Get Canadian catches [by sex]	Bowheads	CA	15 April 2013
Scenarios for ship strikes	Both	GD, LW	15 April 2013
Specifications for grace period	Both	GD?	15 April 2013
Negative binomial likelihood implemented	Bowheads	AEP	12 January 2013
Estimate overdispersion parameter (in R)	Bowheads	AEP	12 January 2013
Implement and test grace period	Both	AEP	12 January 2013
Generate “q” for relative index	Bowheads	AEP	12 January 2013
Additional variance the same for relative and absolute indices	Both	AEP	12 January 2013
Pass additional catch series to the SLA code	Both	AEP	12 January 2013
Add switch to select among default SLAs	Both	AEP	12 January 2013
Read in historical and future Canadian catches (assign future catches to sex)	Bowheads	AEP	12 January 2013
Read in historical and future bycatches and ship strikes	Both	AEP	12 January 2013
6-year Strike Limit	Both	AEP	12 January 2013
Implement Strategic surveys	Both	AEP	12 January 2013
SLA coded as executable option	Both	AEP	12 January 2013
Distribute all conditioning files, runstreams, etc,	Both	AEP	12 January 2013
Update graphs	Both	AEP	12 January 2013
Specifications document updated	Both	AEP	12 January 2013
All runstreams checked	Both	AB/CA	31 January 2013
Check whether all photographs from West Greenland have been submitted to the College of the Atlantic catalogue and confirm whether any matches have been made	Humpback whales	GD/LW	15 April 2013
Produce short paper documenting any changes in published abundance estimates from papers presented to Scientific Committee meetings	All (especially humpback)	MPHJ	1 May 2013
Further discussion of need envelopes with managers in Greenland	All (especially humpback)	LW	1 May 2013
Develop an approach for simulating the availability of future mark-recapture estimates of abundance	General	AEP/CA/AB	‘low priority’

10. ADOPTION OF REPORT

The report was adopted at 1545 on 18 December 2012 apart from some editorial work and fact checking. The Chair thanked the participants for a constructive and successful workshop. In particular, he thanked Mads-Peter Heide-Jørgensen and the staff of the Grønlands Repræsentation for the excellent facilities, Alice Heide-Jørgensen for helping out so efficiently at the weekend and the rapporteurs. Finally he thanked Jette Donovan Jensen for acting as social secretary. The Workshop thanked the Chair for his usual effective and good humoured chairing of the workshop.

REFERENCES

These can be found on the last page of the report.

Annex A
Agenda

1. Introductory items
    - 1.1 Convenor's opening remarks
    - 1.2 Election of Chair
    - 1.3 Appointment of rapporteurs
    - 1.4 Adoption of Agenda
    - 1.5 Documents available
2. Summary of discussions at SC64 and intersessional progress
3. General issues
    - 3.1 Candidate *SLA*s including guiding principles
    - 3.2 Component of the population to which MSYR refers
    - 3.3 Presentation of results and selection of *SLA*s
4. Development of Trial structure for humpback Whales off West Greenland
    - 4.1 Stock structure hypotheses
        - 4.1.1 Present hypothesis/es
        - 4.1.2 New information
        - 4.1.3 Hypothesis/es for use in trials
    - 4.2 Abundance estimates and trends
        - 4.2.1 Review of estimates for use in conditioning and trials
    - 4.3 Removals history
        - 4.3.1 Direct catches
        - 4.3.2 Bycatches
        - 4.3.3 Ship strikes
        - 4.3.4 Conclusions with respect to series to use
    - 4.4 Biological parameters
    - 4.5 Need
    - 4.6 SLAs to be considered
    - 4.7 Development of *Evaluation* and *Robustness Trials*
    - 4.8 Consideration of results and/or future work
5. Development of trial structure for Bowhead Whales off West Greenland
    - 5.1 Stock structure hypotheses
    - 5.2 Abundance estimates and trends
    - 5.3 Removals
    - 5.4 Biological parameters
    - 5.5 Need
    - 5.6 SLAs to be considered
    - 5.7 Development of *Evaluation* and *Robustness Trials*
    - 5.8 Consideration of results and/or future work
6. Progress with respect to common minke whales and fin whales
    - 6.1 Use of RMP/AWMP-lite
    - 6.2 Stock structure
        - 6.2.1 Fin whales
        - 6.2.2 Common minke whales
    - 6.3 Abundance estimates
    - 6.4 Removals
    - 6.5. Biological parameters
    - 6.6 Need
        - 6.6.1 Fin whales
        - 6.6.2 Minke whales
    - 6.7 Candidate *SLA*s/developing teams
    - 6.8 Potential trials structure
        - 6.8.1 Fin whales
        - 6.8.2 Minke whales
7. Future consideration of operational multispecies aspects in the provision of management advice
8. Completion of gray whale *SLA* evaluation for the Makah hunt (via Skype)
9. Workplan
10. Adoption of report

Annex B
Participants

Denmark

Mads-Peter Heide-Jorgensen

Lars Witting

Japan

Toshihide Kitakado

USA (via Skype)

Jonathan Scordino

John Brandon

Dave Weller

Steve Stone

Secretariat

Greg Donovan

Cherry Allison

Invited Participants

Doug Butterworth

Anabela Brandão

André Punt

Annex C
List of Documents

SC/D12/AWMP1. PUNT, A.E. A Full Description of RMP/AWMP-lite

SC/D12/AWMP2. PUNT, A.E. Trial specifications for humpback and bowhead whales off west Greenland

SC/D12/AWMP3. BRANDON, J. and SCORDINO, J. Suggested additional *SLA* variants to further evaluate the proposed Makah hunt

SC-D12-AWMP4. WITTING, l. Suggestions for need envelopes

SC-D12-AWMP5. HEIDE-JØRGENSEN, M-P. Maps of humpback whales tracked by satellite in West Greenland 2008-2010

Annex D

A weighted-average interim-*SLA*-like *SLA*

ANDRÉ E. PUNT

The interim-*SLA* determines the *Strike Limit* as the lesser of need and

$$0.02\hat{N}e^{-1.645CV} \tag{1}$$

where $\hat{N}$ is the most recent estimate of abundance and *CV* is the coefficient of variation of $\hat{N}$.

Equation 1 has the disadvantage of ignoring all the estimates of abundance except for the most recent estimate. An alternative estimator which uses all of the abundance estimates (but ignores any trend in the population size) would replace $\hat{N}$ and *CV* in Equation 1 by:

$$\hat{N} = \exp[\sum_i \frac{0.9^{t_i}\,\ell n N_i}{CV_i^2} / \sum_i \frac{0.9^{t_i}}{CV_i^2}] \qquad CV = \frac{\sqrt{\sum_i 0.9^{2t_i} / CV_i^2}}{\sum_i 0.9^{t_i} / CV_i^2} \tag{2}$$

where N_i is the i^{th} estimate of abundance, CV_i is the coefficient of variation of N_i, and t_i is the time (in years) between when the i^{th} estimate of abundance was obtained and the first year of the block for which a *Strike Limit* is needed.

Annex E
To be provided when available after the Workshop (by mid-April) Direct catches, bycatches and ship strikes to be included in the trials for humpback and bowhead whales

Annex F

Trial specifications for humpback and bowhead whales off West Greenland (will be updated to include data from Annex E)

A. The population dynamics model

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

A.1 Basic dynamics

Equations A1.1 provide the underlying 1+ dynamics.

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

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

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

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

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

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

$$S_a = \begin{cases} S_0 & \text{if } a = 0 \\ S_{1+} & \text{if } a > 0 \end{cases} \qquad \text{(A1.2)}$$

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:

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

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

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

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

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

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

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

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

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

A is the resilience parameter; and

z is the degree of compensation.

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

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

The numbers of recruited/unrecruited calves is given by:

$$\begin{array}{ll} R_{t,0}^f = \alpha_0 B_t^f & R_{t,0}^m = \alpha_0 (B_t - B_t^f) \\ U_{t,0}^f = (1-\alpha_0) B_t^f & U_{t,0}^m = (1-\alpha_0)(B_t - B_t^f) \end{array} \tag{A2.6}$$

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

A.3 Catches

The historical (*t*<2013) catches are taken to be equal to the reported 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 bycatches, 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 2007-2011 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 2007-2011:

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

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.:

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

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:

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

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

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

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

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

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

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:

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

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)

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

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]:

$L = L_1 L_2$ (L_2 applies only to the sighting rates for bowheads) where

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

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

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

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

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

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

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

$\tilde{S}^f, \tilde{S}^m$ 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*:

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

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).

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

(e) 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*.

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

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: $\phi \sim N[0;\sigma^2_\phi]$ and $\sigma^2_\phi = \ell n(1+\alpha^2)$ (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 $\hat{P}_t$).

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

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[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^2_{add} for year Ψ.

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

(iii) Set θ^2 using equation B1.6 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^2_n distribution using equation B1.5.

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

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

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

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

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

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

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

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

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:

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

The values of α and β are then computed as:

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

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.

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 $t \geq 2013$ (defined as t=0 below), and K^* is the population size in year t if there had never been any harvest.

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^*

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 *x*th percentile of the distribution of $V_t = C_t / Q_t$

N8. Plots of V_t for simulations 1-100.

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

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

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

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

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 for each trial:

- 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.
- Individual time-trajectories of 1+ population size and of strikes

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Table 1
Catches of bowhead and humpback whales

(a) Bowheads

Year	M	F	Year	M	F			
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	0
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

Year	M	F	Year	M	F	Year	M	F
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	0	0
1972	1	2	1992	0	1	2012	0	0
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			

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(20,3^2) 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	$\ell nP_{2007} = N(\ell n2154, (0.36^2 + CV_{add}^2))$	A: $\ell nP_{2002} = N(\ell n6,340; (0.38^2 + CV_{add}^2))$ B: $\ell nP_{2007} = N(\ell n1229, (0.47^2 + CV_{add}^2))$
Additional variation (relative indices), CV_{add2}	U[0.2, 0.6]	U[0.2, 0.6]
Bias of relative abundance indices, B_c	$\ell nB_c \sim U[-\infty, \infty]$ (see[1])	$\ell nB_c \sim U[-\infty, \infty]$ (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)

(a) Estimate of absolute abundance

Year	**Estimate**	**CV**
Bowhead whales		
2002	6340	0.38
2007	1229	0.47
Humpback whales		
2007	2154	0.36

(b) Estimates of relative abundance

Bowhead whales						Humpback whales					
Year	Estimate	CV	Year	Effort	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	2273	1	1985	177	0.44	1989	357	0.16
			1990	591	1	1987	220	0.62	1990	355	0.12
			1991	1088	3	1988	200	0.74	1991	566	0.42
			1993	577	0	1989	272	0.75	1992	376	0.19
			1994	1092	0	1993	873	0.53	1993	348	0.12
			1998	1184	5	2005	1158	0.35			
			1999	1104	0	2007	1020	0.35			
			2006	791	9						
			2012	1574	25						

1 – Not used in the *Evaluation Trials*

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 yrs 1-75 (with at least 2 in yrs 1-50) in which 20% of the animals die, Events occur every 5 years in which 5% of the animals die	
Need envelope	A: 10, 15, 20; 20->20 over years 18-100 **B: 10, 15, 20; 20->40 over years 18-100** A: 10, 15, 20; 20->60 over years 18-100 **D: 20, 25, 30; 20->50 over years 18-100**	**A: 5 -> 5 over 100 years** B: 5 -> 10 over 100 years **C: 5 -> 15 over 100 years**
Future Canadian catches	N/A	**A: 5 -> 5 over 100 years** B: 5 -> 10 over 100 years C: 5 -> 15 over 100 years D: 2.5 -> 2.5 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	

* 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.

(a) Humpback whales

Trial	Description	*MSYR*$_{1+}$	Need Scenarios	Survey freq.	Historic Survey Bias	Conditioning Option
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, D	**5**	1	1A
2B	5 year surveys; MSYR$_{1+}$ =3%	**3%**	B, D	**5**	1	1B
3A	15 year surveys	5%	B, D	**15**	1	1A
3B	15 year surveys; MSYR$_{1+}$ =3%	**3%**	B, D	**15**	1	1B
4A	Survey bias = 0.8	5%	B, D	10	**0.8**	Y
4B	Survey bias = 0.8; MSYR$_{1+}$ =3%	**3%**	B, D	10	**0.8**	Y
5A	Survey bias = 1.2	5%	B, D	10	**1.2**	Y
5B	Survey bias = 1.2; MSYR$_{1+}$ =3%	**3%**	B, D	10	**1.2**	Y
6A	3 episodic events	5%	B, D	10	1	1A
6B	3 episodic events; MSYR$_{1+}$ =3%	**3%**	B, D	10	1	1B
7A	Stochastic events every 5 years	5%	B, D	10	1	1A
7B	Stochastic events every 5 years; MSYR$_{1+}$ = 3%	**3%**	B, D	10	1	1B

(b) Bowhead whales (each conducted conditioning to the estimates of abundance for Prince Regent Inlet and West Greenland as absolute)

Trial	Description	*MSYR*$_{1+}$	Need Scenario	Survey freq.	Canadian Catches	Historic Survey Bias	Conditioning Option
1A	MSYR$_{1+}$ = 2.5%	1%	A,B,C	10	A	1	Y
1B	MSYR$_{1+}$ = 1%	**2.5%**	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, C	**5**	A	1	1A
2B	5 year surveys; MSYR$_{1+}$ =1%	**1%**	A, C	**5**	A	1	1B
3A	15 year surveys	2.5%	A, C	**15**	A	1	1A
3B	15 year surveys; MSYR$_{1+}$ =1%	**1%**	A, C	**15**	A	1	1B
4A	Survey bias = 0.5	2.5%	A, C	10	A	**0.5**	Y
4B	Survey bias = 0.5; MSYR$_{1+}$ =1%	**1%**	A, C	10	A	**0.5**	Y
5A	3 episodic events	2.5%	A, C	10	A	1	1A
5B	3 episodic events; MSYR$_{1+}$ =1%	**1%**	A, C	10	A	1	1B
6A	Stochastic events every 5 years	2.5%	A, C	10	A	1	1A
6B	Stochastic events every 5 years; MSYR$_{1+}$ = 1%	**1%**	A, C	10	A	1	1B
7A	Alternative future Canadian catches	2.5%	A, C	10	**B**	1	1A
7B	Alternative future Canadian catches; MSYR$_{1+}$=1%	**1%**	A, C	10	**B**	1	1B
8A	Alternative future Canadian catches	2.5%	A, C	10	**C**	1	1A
8B	Alternative future Canadian catches; MSYR$_{1+}$=1%	**1%**	A, C	10	**C**	1	1B
9A	Alternative future Canadian catches	2.5%	A, C	10	**D**	1	1A
9B	Alternative future Canadian catches; MSYR$_{1+}$=1%	**1%**	A, C	10	**D**	1	1B

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$_{1+}$=5%	A,C	1A
3B	Strategic Surveys; MSYR$_{1+}$=3%	B, D	1B	3B	Strategic Surveys; MSYR$_{1+}$=3%	A,C	1B
4A	Alternative priors; MSYR$_{1+}$=5%	B, D	4A*				
4B	Alternative priors; MSYR$_{1+}$=3%	B, D	4B*				
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

Annex G

Summary results from additional runs requested for the proposed Makah hunt of gray whales

SLA Variant	Final Depletion		Rescaled Final Depletion		Final Depletion		Rescaled Final Depletion	
	Low 5%	Median	Low 5%	Median	Low 5%	Median	Low 5%	Median
	Trial GB01C				**Trial GB08B**			
SLA 1	0.259	0.343	0.314	0.383	0.357	0.458	0.505	0.594
6 Strikes before May	0.259	0.343	0.314	0.383	0.357	0.458	0.505	0.594
5 Strikes before May	0.259	0.342	0.314	0.383	0.357	0.460	0.505	0.596
4 Strikes before May	0.262	0.344	0.317	0.383	0.359	0.462	0.512	0.598
3 Strikes before May	0.267	0.346	0.323	0.386	0.365	0.463	0.509	0.601
2 Strikes before May	0.273	0.349	0.330	0.394	0.371	0.468	0.525	0.611
1 Strike before May	0.280	0.356	0.338	0.403	0.384	0.484	0.542	0.628
SLA 2	0.290	0.365	0.352	0.414	0.396	0.504	0.560	0.656
	Trial GP01C				**Trial GB10B**			
SLA 1	0.382	0.461	0.400	0.472	0.492	0.556	0.492	0.557
6 Strikes before May	0.382	0.461	0.400	0.472	0.492	0.556	0.492	0.557
5 Strikes before May	0.382	0.460	0.400	0.472	0.492	0.556	0.492	0.557
4 Strikes before May	0.390	0.464	0.406	0.476	0.487	0.560	0.487	0.562
3 Strikes before May	0.396	0.468	0.414	0.479	0.508	0.566	0.510	0.567
2 Strikes before May	0.405	0.476	0.424	0.488	0.533	0.584	0.535	0.584
1 Strike before May	0.417	0.494	0.439	0.509	0.550	0.604	0.552	0.606
SLA 2	0.438	0.515	0.460	0.528	0.575	0.633	0.576	0.635
	Trial GP02C				**Trial GP08B**			
SLA 1	0.231	0.272	0.255	0.295	0.330	0.442	0.475	0.578
6 Strikes before May	0.231	0.272	0.255	0.295	0.330	0.442	0.475	0.578
5 Strikes before May	0.231	0.272	0.256	0.295	0.330	0.442	0.475	0.582
4 Strikes before May	0.234	0.276	0.260	0.299	0.341	0.441	0.486	0.579
3 Strikes before May	0.241	0.281	0.267	0.304	0.343	0.443	0.489	0.582
2 Strikes before May	0.258	0.297	0.284	0.319	0.345	0.451	0.497	0.595
1 Strike before May	0.274	0.320	0.303	0.345	0.360	0.466	0.517	0.610
SLA 2	0.299	0.347	0.334	0.372	0.364	0.482	0.528	0.635
	Trial GI01C				**Trial GP10B**			
SLA 1	0.378	0.446	0.399	0.459	0.475	0.536	0.476	0.538
6 Strikes before May	0.378	0.446	0.399	0.459	0.475	0.536	0.476	0.538
5 Strikes before May	0.378	0.449	0.399	0.46	0.475	0.537	0.476	0.538
4 Strikes before May	0.381	0.451	0.401	0.465	0.475	0.542	0.476	0.543
3 Strikes before May	0.387	0.455	0.407	0.469	0.482	0.549	0.483	0.549
2 Strikes before May	0.395	0.465	0.416	0.478	0.508	0.566	0.510	0.567
1 Strike before May	0.414	0.477	0.433	0.491	0.528	0.587	0.530	0.588
SLA 2	0.434	0.497	0.457	0.513	0.556	0.619	0.557	0.621

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