Report of the 2016 AWMP Intersessional Workshop on Developing *SLA*s for the Greenland Hunts and the AWS

Report of the 2016 AWMP Intersessional Workshop on Developing *SLA*s for the Greenland Hunts and the AWS[1]

The Workshop was held at the Greenland Representation, Copenhagen, from 17-22 December 2016. The list of participants is given as Annex A.

1. INTRODUCTORY ITEMS

1.1 Convenor's opening remarks

Donovan welcomed the participants to Copenhagen. He thanked the Greenland Representation for once again hosting an AWMP Workshop in their excellent facilities. The main tasks of the Workshop were to: (1) review new abundance estimates off Greenland; (2) advance the development of *SLA*'s for the Greenlandic fin and common minke whale hunts; and (3) consider various issues related to the Aboriginal Whaling Scheme (AWS).

1.2 Election of Chair

Donovan was elected Chair.

1.3 Appointment of rapporteurs

Butterworth and Givens acted as rapporteurs, assisted by Donovan.

1.4 Adoption of Agenda

The adopted agenda is given as Annex B.

1.5 Documents available

The list of documents is given as Annex C.

2. NEW ABUNDANCE ESTIMATES OFF GREENLAND

2.1 Presentation of the results of the 2015 surveys

Heide-Jørgensen and Hansen introduced SC/D16/AWMP06. An aerial line transect survey of whales in East and West Greenland was conducted in August-September 2015. The survey covered the area between the coast of West Greenland and offshore (up to 100km) to the shelf break. In East Greenland, the survey lines covered the area from the coast up to 50km offshore crossing the shelf break. The survey was conducted as a double platform experiment with two front and two rear observers in a *Twin Otter* equipped with bubble windows following previous protocols (e.g. Heide-Jørgensen *et al.*, 2010; IWC, 2009, item 3.1, p.413). A total of 423 sightings of 12 cetacean species was obtained and abundance estimates were developed for common minke whales (32 sightings), fin whales (129 sightings), humpback whales (84 sightings), harbour porpoises (55 sightings), long-finned pilot whales (42 sightings) and white-beaked dolphins (50 sightings).

The at-surface abundance estimates were corrected for perception bias[2] with point independence models where it is assumed that only detections at zero distance from the trackline were independent between the two platforms. Separate detection functions were fitted for the mark-recapture data and the distance sampling data. Conditional detection functions for the mark-recapture data were developed where heterogeneity between observers was modelled with covariates (perpendicular distance to sightings, sea state, group size and observers) and the best model selected based on AIC (Akaike Information Criterion). The mark-recapture detection function was used to estimate the correction for perception bias ($p(0)$). With respect to large whales, data on surface corrections for five common minke whales and a single fin whale were collected from whales instrumented with satellite-linked time-depth-recorders. Only the sample size for common minke whales was considered adequate to develop a correction factor. The instruments provided data on the proportion of time the whales are at the surface (considered 0-2m) for common minke whales (16%, CV=0.08). The final correction for availability bias (19.5%, CV=0.26) was adjusted for the time the whales can be potentially seen from the aircraft (time-in-view).

The fully corrected abundance estimates for the species subject to aboriginal subsistence whaling considered best by the authors were: common minke whales: 4,204 (CV=0.48, 95% CI: 1,732-10,204) in West Greenland and 2,681 (CV=0.46, 95% CI: 1,139-6,312) in East Greenland, humpback whales: 1,321 (CV=0.44, 95% CI: 578-3,022) in West Greenland and 4,012 (CV=0.35, 95% CI: 2,044-7,873) in East Greenland. No corrections for availability bias could be applied for the fin whales, but the estimates corrected for perception bias were 465 (95% CI: 233-929) in West Greenland and 1,932 (95% CI: 1,204-3,100) in East Greenland. The abundance of cetaceans in such coastal areas of East Greenland has not been estimated before, but despite the lack of previous estimates from the area, the achieved abundance estimates were higher than expected.

The use of dive and surface time information from satellite-linked time-depth-recorders was preferred over previous methods and recalculation of the 2007 minke whale abundance estimate with the availability correction factor from 2015 (including time-in-view adjustment) gives an estimate of 9,853 (cv=0.43, 95% CI: 4,433-21,900) common minke whales in West Greenland in 2007. A comparison of the point estimates from 2015 in West Greenland with a similar survey conducted in 2007 suggests that the three baleen whale species (and white-beaked dolphins) were present in much lower densities in 2015; however, only fin whales showed a significant difference in abundance. Harbour porpoises and pilot whales, however, did not show a similar decline. The authors suggested that the decline in baleen whale and white-beaked dolphin abundance was probably due to emigration to the East Greenland shelf areas where recent climate-driven changes in pelagic productivity may have accelerated favourable conditions for baleen whales.

2.2 Discussion

Discussion focused on the substantial (and in the case of fin whales, statistically significant) changes in abundance estimates for common minke, fin and humpback whales from the 2007 to the 2015 surveys off West Greenland. There are various possible explanations for this, which have implications for the specification of projections in *SLA* testing (for example as regards whether these changes reflect variability in the factors that underlie them, or rather a permanent shift). These matters are discussed further below and under Item 3.

[1]Presented to the Scientific Committee as SC/67a/Rep06.

[2]Perception bias reflects the probability of sighting a whale (school) given that it is sufficiently close to the surface to potentially be seen. Availability bias accounts for the proportion of time a whale school is not sufficiently close to the surface to be potentially sighted from (in this case) an aircraft.

2.2.1 Survey areas, methods (field and analytical)

The Workshop noted that the design and implementation of the 2007 and 2015 surveys had been consistent and at least some of the same observers were used. From this perspective, the Workshop **agreed** that results from the two surveys are comparable.

2.2.2 Estimates for large whales subject to ASW

SC/D16/AWMP06 had suggested that reduced abundance estimates for various species off West Greenland in 2015 compared to 2007 might in part reflect a movement from west to east Greenland given the relatively high abundance estimates evident in the east in 2015. There are insufficient data (e.g. photo-identification data from East Greenland for humpback whales) to evaluate this hypothesis.

An addendum to SC/D16/AWMP06 summarises results for abundance estimates for fin, minke and humpback whales from the 2007 and 2015 surveys for a number of analytical methods and assumptions needed in their implementation. These were examined at considerable length during the Workshop from the perspective of deciding the most appropriate estimates for use in *SLA* development and implementation. Table 1 summarises the selections from that addendum for input to *SLA* analyses. Such selections are not intended to imply that those choices are the only possible, but rather that for the reasons given below they are considered to be the most appropriate for that purpose.

2.2.2.1 FIN WHALES INCLUDING DISCUSSION OF CORRECTION FACTORS

The Workshop noted that there is an approximate halving in the average fin whale school size from the 2007 to the 2015 survey with its much lower estimate of abundance. Perception bias is small (i.e. estimates of this multiplicative factor to adjust abundance estimates are all only slightly below 1). No attempt has been made to adjust for availability bias (i.e. whales unable to be seen as they were below the surface) because the telemetry sample size is only one animal.

The selected estimate for the 2015 survey (see Table 1) was based on a line transect rather than a strip census approach to adjust for the negative bias in the latter as a result of a drop in the detection function with perpendicular distance from the trackline. The mark recapture distance sampling approach (MRDS) was preferred to conventional distance sampling (CDS) so that account could be taken of perception bias (although the difference was minimal). East as well as West Greenland sightings were included for more precise estimates of the detection function and hence also of abundance.

The reasons for the much lower abundance estimate for 2015 compared to 2007 are discussed further below in sub-sections 3.2 and 3.3.

2.2.2.2 COMMON MINKE WHALES INCLUDING DISCUSSION OF CORRECTION FACTORS

Both perception and availability bias estimates are available for the minke whale abundance estimates for West Greenland from the 2007 and 2015 surveys, and for East Greenland for the 2015 survey (see SC/D16/AWMP06 addendum). Perception bias corrections are generally small. In contrast, as one would expect for diving animals and a plane travelling at around 100 knots, the availability bias correction (this is based on detectability of whales down to a depth of 2m, which is considered more realistic than assuming detection only when on the surface), is large and leads to increasing estimates by a multiplicative factor of about 5.

For the 2015 West Greenland survey, after inspection of the data, the estimate provided by the strip census method for a width of 300m was selected (see Table 1) as most appropriate. There was an evident drop in detection at the increased distances (see SC/D16/AWMP06 and addendum). Preference over MRDS estimates arose from these being broadly similar to corresponding strip estimates, suggesting minimal negative bias in the latter, as well as avoidance of the complex computational task of taking covariance of estimates for different years into account if sample size was increased to provide more precise estimation of the detection function and hence abundance for comparable CVs to the strip-based approach.

For similar reasons, the strip survey estimate for a strip width of 240m was selected for the 2007 survey off West Greenland. However, for East Greenland in 2015, the MRDS estimate was selected given clear indication of a negative bias in the strip-based estimate.

Heide-Jørgensen introduced SC/D16/AWMP07. The time series of aerial surveys of large cetaceans off West Greenland conducted at regular intervals since 1984 was used to construct an index of the relative abundance of common minke whales in the area. The effort was corrected for varying detection probabilities but no correction could be applied for the lack of coverage in south Greenland in 1984 and 1985 (south of 62°N). To account for this, an alternative series covering the areas north of 62°N was developed. The resulting indices of relative abundance showed considerable variation, suggesting that there is not a consistent fraction of common minke whales from the North Atlantic that use the West Greenland banks as a summer feeding ground.

Some variation had already been taken into account in conditioning the RMP *Implementation Simulation Trials* (IWC, 2017c). The single further year's datum now available for a fairly long series made no qualitative difference to the broad features on this series; hence it was not deemed necessary to revise the conditioning of the RMP *Implementation Simulation Trials* to take this information from a single further year into account. Trial development for *SLA* testing is discussed under Item 4.

2.2.2.3 HUMPBACK WHALES INCLUDING DISCUSSION OF CORRECTION FACTORS

The estimated perception bias for humpback whales result in rather small adjustments to the abundance. There were no new data to inform availability bias; survey-specific calculations were made to provide an estimate of 0.42 by which to divide to adjust 2015 abundance estimate (see the addendum to SC/D16/AWMP06 and Table 1).

As for fin whales, line transect estimates of abundance were preferred to strip-based estimates. Furthermore, MRDS estimates were preferred to CDS estimates as the former took perception bias into account without greatly prejudicing estimates of precision. The final selections preferred global to stratum based adjustments because the very small sample sizes in some strata led to higher estimates of variance.

2.3 Conclusions

The Workshop **recommended** that the abundance estimates in Table 1 were appropriate for use in *SLA* development and implementation. It also **recommended** that the Scientific Committee review the estimates of abundance provided in SC/D16/AWMP06 for the other species.

3. DEVELOPMENT OF AN *SLA* FOR THE GREENLANDIC FIN WHALE HUNT

3.1 Review of discussions at SC/66b including progress made

At its 2016 Annual Meeting, the Scientific Committee had recommended that the Workshop should consider the reasons

Table 1

Summary of new agreed abundance estimates (see text) for common minke, fin and humpback whales in West and East Greenland. Detection depth was assumed to be up to 2m apart from for fin whales which was not corrected for availability bias. Availability bias takes into account time in view. For the MRDS for humpback whales a combined mean group size was used.

			Perception bias					
Method	ESW	N	Model	Value	Availability bias	Abundance	CV	95% CL
Common minke whale – east 2015								
LT	450m	23 E+W	MRDS 2015	0.97 (0.04)	0.20 (0.26)	2,681	0.45	1,153; 6,235
Common minke whale – west 2015								
SC	300m	12	Chapman	0.94 (0.06)	0.18 (0.32)	5,241	0.49	2,114; 12,992
Common minke whale – west 2007								
SC	240m	18	Chapman	0.98 (0.02)	0.18 (0.32)	9,853	0.43	4,433; 21,900
Fin whale – west 2015								
LT	700m	75 E+W	MRDS 2015	0.99 (0.001)	-	465	0.35	233; 929
Humpback whale – east 2015								
LT	1,200m	76 E+W	MRDS 2015	0.98 (0.02)	0.42 (0.14)	4,288	0.38	2,097; 8.770
Humpback whale – west 2015								
LT	1,200m	76 E+W	MRDS 2015	0.98 (0.02)	0.42 (0.14)	1,008	0.38	493; 2,062

Key: LT=line transect; SC=strip census; ESW=effective search width; *N*=number of sightings, E+W indicates that sightings from East and West Greenland were pooled to estimate the detection function.

for the sensitivity of the values for the performance metrics to small changes to the specifications of the *SLA* trials (IWC, 2017d, section 2.3, p.175). Brandão had examined the precision with which estimates of 5th percentiles from these trials could be obtained as the number of replicates was increased beyond the customary choice of 100. Example results for two of the fin whale trials are shown in Fig. 1.

This examination yielded no clear result for a single number of replicates that would provide sufficient precision, as the extent of precision required for a particular trial depended on the expected value and performance threshold for the performance statistic under consideration - the importance of running a large number of trials is high only if the value of performance statistic is close to a threshold value.

In these circumstances, the Workshop took an operational decision to:

(a) increase the initial number of replicates for *Evaluation Trials* to 400;
(b) maintain the number of replicates for stochastic *Evaluation Trials* and *Robustness Trials* at 100; and
(c) when evaluating results, should the value of the 5th percentile for a key performance statistic be close to the associated threshold for an *Evaluation Trial*, perform sufficient additional replicates for that trial before accepting (or rejecting) performance for that trial.

Consideration of the number of trials used in the previous Greenlandic *SLA* developments is given under Item 5.3.

3.2 New abundance estimate

The fin whale abundance estimate from the 2015 survey off West Greenland of 465 (see Table 1 and Item 2) is significantly less than that from the 2007 survey of 4,470. Previous *SLA* testing procedures, as well as candidate *SLA*'s, have assumed that all surveys provide abundance estimates of the total number of whales subject to aboriginal strikes that are either unbiased, or at least that the bias is consistent over time. The difference between the 2007 and 2015 estimates is certainly too large to attribute to catches made over the intervening period, and there is no other evidence to suggest a real decline in abundance of the population of whales subject to these strikes. Consequently the possibility arises that only a part of this population is present off West Greenland in at least some years. If this is the case, this aspect needs to be reflected in the manner in which future survey abundance estimates for this region are generated when testing *SLA*'s and which retains a conservative and realistic testing scenario to manage the Greenland hunts.

3.3 Updated density-regulated assessment

Witting presented SC/D16/AWMP02 which modelled West Greenland fin whales as a single population. The 1987, 2005 and 2007 surveys indicated a population that increased from about 1,000 animals in 1987 to 3-4,000 animals around 2005/2007, with no direct evidence of larger fluctuations between years. However, as discussed under Item 2, with only 465 (CV: 0.35) fin whales at the surface during an aerial survey in 2015 (SC/D16/AWMP06), and no indication of problems with the survey, the author believed that it was prudent to reconsider whether the simulation framework for West Greenland fin whales remained adequate.

This was examined by the development of density-regulated assessment models. The first approach resembled the present framework, where it is assumed that all the whales in the population migrate to West Greenland waters each year. It was fitted to three time series of abundance: (1) the 2005/07 estimates; (2) the 1987/2005/07 estimates; and (3) the 1987/2005/07/15 estimates. The model was able to reconcile the abundance data for the two shorter time series with no additional variance, while this was possible for series 3 only with a high level of additional variation (additional CV estimate of 1.2 with 90% CI: 0.52-2.2).

A second approach transformed the additional variation into a simple model for fluctuations in the number of whales that move to the West Greenland area during years of survey. This was achieved by assuming that the high abundance estimates from 2005 and/or 2007 reflected the total number of whales in the population in those years, while the additional variation in the abundance estimates around the expected trajectory was taken to reflect variation in the fraction of whales that moved to the West Greenland area in those years. This process estimated an average negative bias of 0.4 (90% CI:0.11-0.88) across all the abundance estimates when the 2005/07 estimates were assumed to be absolute, with an additional CV of 1.1 (90% CI:0.5-2.2) reflecting inter-annual variation in the fraction of whales that move to the West Greenland area.

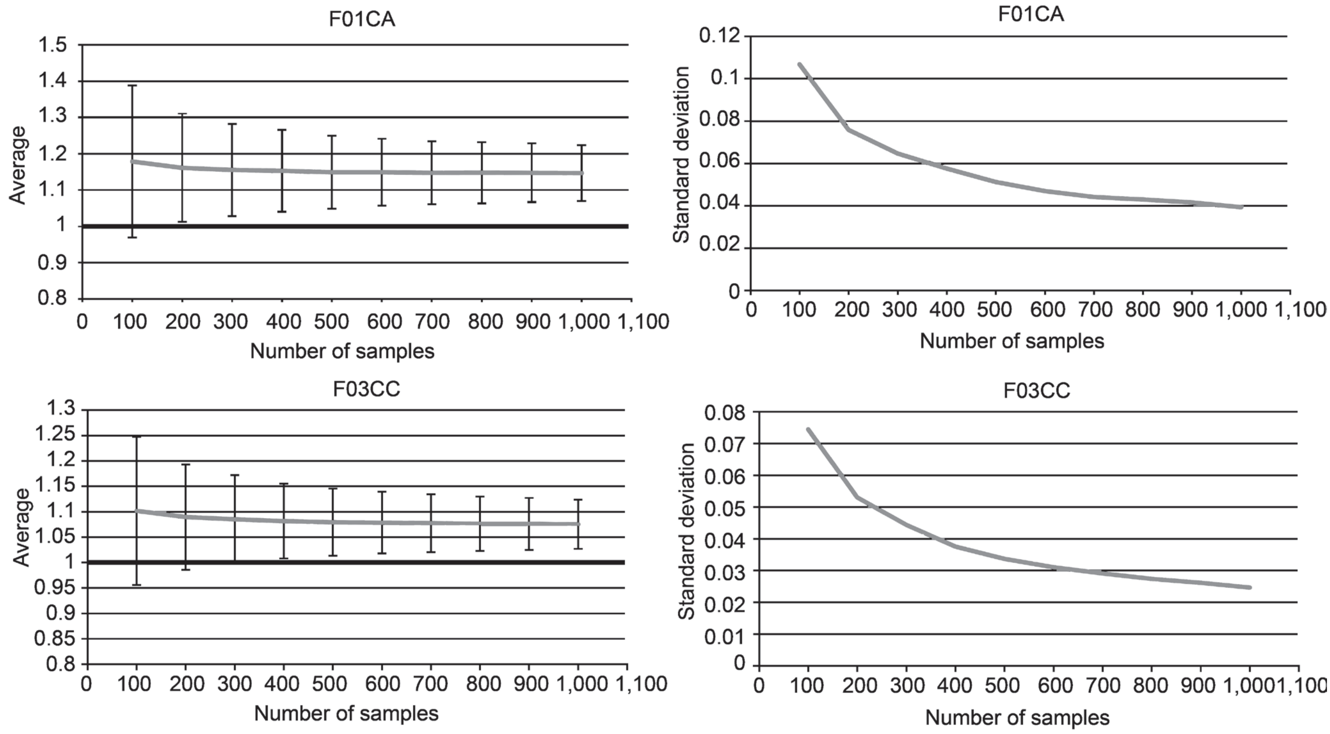

Fig. 1. Average (with 95% confidence intervals) and the standard deviation of the 5-%tile for various numbers of draws samples with replacement from 1,000 values of the conservation performance statistic D10 (the relative increase of 1+ population size) over 1,000 simulations for two fin whale *SLA Evaluation Trials.*

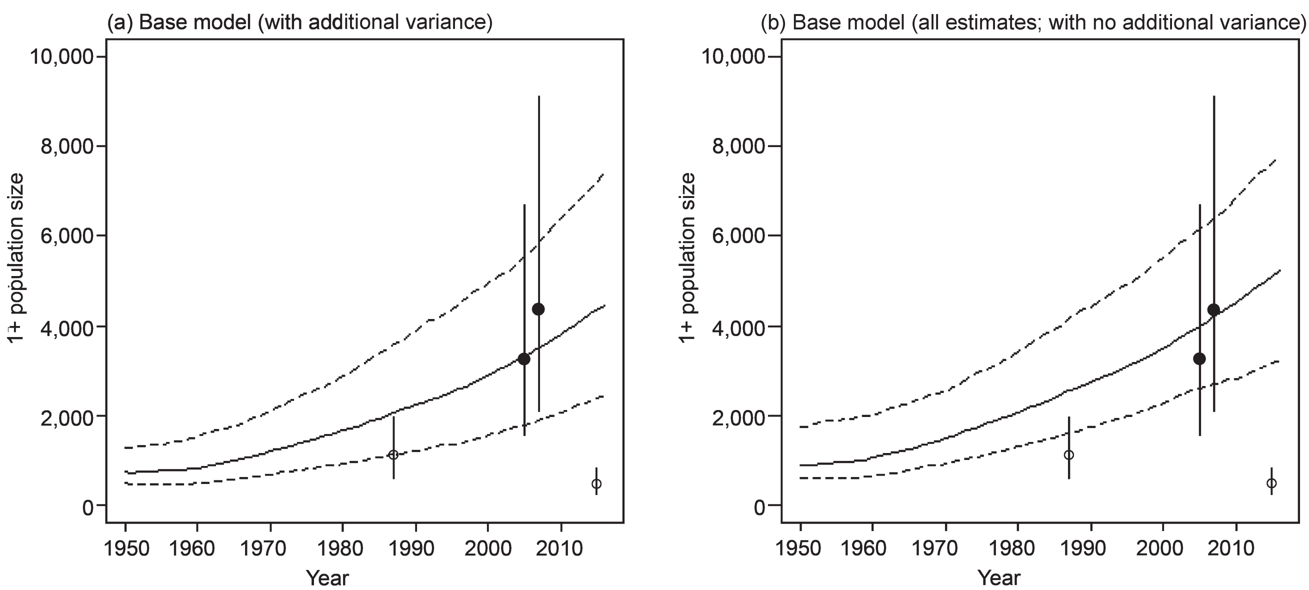

Fig. 2. Posterior distributions (medians and 90% intervals; solid and dotted lines respectively) for 1+ population size for fin whales off West Greenland. Results are shown when the operating model is fitted: (a) to the estimate of abundance for 2005 (indirectly) and 2007; and (b) to the estimates of abundance for 1987, 2005 (indirectly), 2007, and 2015 (b). The prior for the population size in 2005 is lognormal, parameterized using the estimate of abundance for 2005, with the point estimate taken as the mean of the prior.

Figs 1-4 of the addendum to SC/D16/AWMP02 show the results from a population model fit to the abundance estimates from all four years assuming no additional variance. The Workshop **agreed** that it is clear from this that given their survey sampling variances, those estimates taken together are not compatible with such a model, so that further approaches need to be considered, in particular with a view towards realistic generation of future abundance estimates for *SLA* trials.

3.4 Discussion of implications of new information for finalising the *SLA*

The Workshop **agreed** that it was not an acceptable approach to obtaining a statistically adequate fit to the four fin whale survey estimates of abundance by adding further additional variance of estimable magnitude to the survey sampling variances for each estimate. This is because in this case the point estimates differ so substantially that the resultant model fit would imply that in some years substantially more whales than the actual number in the population entered the West Greenland region. It was therefore **agreed** to model these abundance estimates by means of a two-component process whereby each year either all whales in the population entered the West Greenland region, or only a proportion of those whales, where the proportion was drawn from a distribution. Given that abundance estimates were available for four years only, the Workshop **agreed** that no purpose would be served by attempting other than a fairly simple model. Hence the two years 2005 and 2007 (with the highest estimates of abundance) were considered to be instances where all whales had entered the West Greenland region and were available to be surveyed. The probability in a future year that this would occur is to be modelled by a Beta(3;3) distribution, which reflects the posterior resulting from the assumption of a uniform prior over [0; 1], updated by data indicating that this had occurred in two out of four instances.

In years for which only a proportion of the whales enter the region, that proportion is to be modelled by a Beta(3;7) distribution. This implies a proportion of 30% on average, but importantly allocates nearly equal likelihood to the values of 0.1 and 0.5, which correspond roughly to the proportions estimated to be present to best account for the 2015 and 1987 survey results respectively for a scenario with an $MSYR_{1+}$ value of 2.5%.

Annex D specifies how the operating model for the trials is fitted to the survey data for this model, with results (a) excluding and (b) including the survey data for 1987 and 2015 in the fit shown in Fig. 2. The latter case reflects proportions of 11% and 53% of the whales being present in 2015 and 1987 respectively, thus indicating reasonable compatibility with the two Beta distribution forms assumed for the model developed.

Given the weak basis in data for the model assumed, together with its important influence on results for candidate *SLA* acceptability through effectively specifying an average multiplicative negative bias of abundance estimates of 0.65, the Workshop **recommended**:

(a) an *Implementation Review*, which is to include re-specification of these Beta distributions, take place once a further survey of the West Greenland region has been conducted; and
(b) robustness trials be conducted for fixed proportions of years for which all whales are present in the West Greenland region, set equal to the 5^{th} and 95^{th} percentile of the Beta(3;3) distribution.

3.5 Conclusions and recommendations

Given the operating model revisions specified above, the Workshop **agreed** that the fin whale trials would need to be reconditioned. Punt was thanked for already having updated the code to incorporate the recently agreed modification of the link between survey frequency and rules for phasing out strike limits otherwise permitted under an *SLA*.

The existing trials (IWC, 2017a, Annex E, pp. 17-23) were reviewed and modified, as set out in Annex E. A complete list of the trials is shown as Table 2. Important changes to previous lists of trials include survey frequencies of 5, 10 and 15 years linked to *SLA* applications every 6 years (as agreed at last year's Scientific Committee meeting); the use of two CV values for generating abundance estimates; and robustness tests for high and low probabilities that all whales are to be found in the West Greenland region each year.

3.6 Work plan

Updates of the trials code incorporating the changes reflected in Annex E will be completed shortly by Punt.

The Workshop **agreed** that if possible the results from re-runs of the revised candidate fin whale *SLA*s should be made available for comment by the Steering Group some six weeks before the 2017 Annual Meeting of the Scientific Committee.

The tests of sensitivity to the number of replicates of the results from the *WG-Bowhead SLA Evaluation Trials* will be completed by Brandão in consultation with the Steering Group and submitted to the 2017 Annual Meeting of the Scientific Committee.

4. DEVELOPMENT OF AN *SLA* FOR THE GREENLANDIC COMMON MINKE WHALE HUNTS

4.1 Review of discussions at SC/66b and the RMP intersessional Workshop

At its last meeting, the Scientific Committee had reaffirmed the value of the ongoing RMP *Implementation Review* to its work to develop an *SLA* for the common minke whale hunts off Greenland (IWC, 2017b, item 8.1.2, p.21). It therefore agreed that the present AWMP intersessional workshop should take place immediately after the RMP Workshop to complete the RMP *Implementation Review* of common minke whales in the North Atlantic. This would allow the AWMP workshop to benefit from the results of that review.

The Workshop reviewed the RMP Workshop discussions (SC/67a/Rep05). That Workshop had finalised agreements on all outstanding issues with respect to the completion of the common minke whale RMP *Implementation Simulation Trials*; the results for those trials will become available before the 2017 Annual Meeting of the Scientific Committee and will facilitate the development of an *SLA* for the Greenlandic common minke whale hunts by 2018.

4.2 New abundance estimate

SC/D16/AWMP06 provided further minke whale abundance estimates for areas off Greenland from the 2015 survey. These are discussed under Item 2.2 above, which specifies the reasons for choosing the particular estimates selected (see Table 1) for input to conditioning further trials.

The Workshop noted that Item 2 of SC/67a/Rep05 detailed an approach to ensure that future variability in the number of common minke whales present each year off West Greenland would be modelled in a more realistic manner.

4.3 Initial modelling and trial structure

Given results for abundance estimates from the 2015 survey which were suggestive of movement of whales from the west to the east coast of Greenland, the Workshop **agreed** that Punt and Allison will check whether the covariance in the relative proportions of common minke whales present in these regions in the existing RMP trials was consistent with the 2015 results. They will also to check the implication of the results from close-kin genetic data in this regard so as to determine whether or not the existing trials need amendment in this respect to provide a more realistic representation of common minke whale distribution patterns off Greenland. The Workshop noted that the results from this investigation would not have implications for conclusions to be drawn from the existing RMP trials for North Atlantic minke whales, as those were intended to inform in regard to commercial whaling in the Eastern and Central regions of the North Atlantic, and the stocks which dominated in those regions were not considered to be present off West Greenland in other than relatively small numbers.

Table 2a

The *Evaluation Trials* for fin whales. Values given in bold type show differences from the base case values. For all trials the probability *p* that all animals are off West Greenland when a survey takes place = 0.5; if some whales are not off West Greenland, the proportion off West Greenland is generated from a beta distribution with parameters (3,7).

Trial	Description	$MSYR_{1+}$	Need scenarios	Survey freq.	Historical survey bias	No of replicates	Future survey CV
01-4	$MSYR_{1+}$ = 4%	4%	A, B, C	10	1	400	0.40
01-2	$MSYR_{1+}$ = 2.5%	2.5%	A, B, C	10	1	400	0.40
01-1	$MSYR_{1+}$ = 1%	**1%**	A, B, C	10	1	400	0.40
01-7	$MSYR_{1+}$ = 7%	**7%**	A, B, C	10	1	400	0.40
02-4	5 year surveys	4%	A, B	**5**	1	400	0.40
02-2	5 year surveys; $MSYR_{1+}$ =2.5%	2.5%	A, B, C	**5**	1	400	0.40
03-4	15 year surveys	4%	A, B	**15**	1	400	0.40
03-2	15 year surveys; $MSYR_{1+}$ =2.5%	2.5%	A, B, C	**15**	1	400	0.40
03-1	15 year surveys; $MSYR_{1+}$ =1%	**1%**	A, B, C	**15**	1	400	0.40
04-4	Survey bias = 0.8	4%	A, B	10	**0.8**	400	0.40
04-2	Survey bias = 0.8; $MSYR_{1+}$ =2.5%	2.5%	A, B	10	**0.8**	400	0.40
05-4	Survey bias = 1.2	4%	A, B	10	**1.2**	400	0.40
05-2	Survey bias = 1.2; $MSYR_{1+}$ =2.5%	2.5%	A, B	10	**1.2**	400	0.40
06-4	3 episodic events	4%	A, B	10	1	400	0.40
06-2	3 episodic events; $MSYR_{1+}$ =2.5%	2.5%	A, B, C	10	1	400	0.40
06-1	3 episodic events; $MSYR_{1+}$ =1%	**1%**	A, B, C	10	1	400	0.40
07-4	Stochastic events every 5 years	4%	A, B	10	1	**100**	0.40
07-2	Stochastic events every 5 years	2.5%	A, B	10	1	**100**	0.40
08-4	Asymmetric environmental stochasticity	4%	A, B	10	1	**100**	0.40
08-2	Asymmetric environmental stochasticity	2.5%	A, B, C	10	1	**100**	0.40
08-1	Asymmetric environmental stochasticity	**1%**	A, B, C	10	1	**100**	0.40
09-2	$MSYR_{1+}$ = 2.5% with future survey CV 0.35	2.5%	A, B, C	10	1	**400**	**0.35**
10-2	$MSYR_{1+}$ = 2.5% with future survey CV 0.45	2.5%	A, B, C	10	1	**400**	**0.45**

Table 2b

The *Robustness Trials* for fin whales.

Trial no.	Factor	$MSYR_{1+}$	Need scenario	No of rep	Future survey CV
21-4	Linear decrease in *K* in future	4%	A, B	100	0.40
21-2	Linear decrease in *K* in future	2.5%	A, B	100	0.40
22-4	Linear increase in *M* in future	4%	A, B	100	0.40
22-2	Linear increase in *M* in future	2.5%	A, B	100	0.40
23-4	Strategic surveys	4%	A, B	100	0.40
23-2	Strategic surveys	2.5%	A, B	100	0.40
24-4	*p*=0.5; Propn generated from beta (7,3)	4%	A, B	100	0.40
24-2	*p*=0.5; Propn generated from beta (7,3)	2.5%	A, B	100	0.40
25-4	*p*=0.5; Propn generated from beta (2,10)	4%	A, B	100	0.40
25-2	*p*=0.5; Propn generated from beta (2,10)	2.5%	A, B	100	0.40
26-4	*p*=0.189 (Propn generated from beta (3,7)	4%	A, B	100	0.40
26-2	*p* =0.189 (Propn generated from beta (3,7))	2.5%	A, B	100	0.40
27-4	*p* =0.811 (Propn generated from beta (3,7))	4%	A, B	100	0.40
27-2	*p* =0.811 (Propn generated from beta (3,7))	2.5%	A, B	100	0.40
28-2	Baseline with future survey CV 0.2	2.5%	A, B	100	**0.20**
29-2	*p*=0.5; Propn generated from beta (2,10)	2.5%	A, B	100	**0.20**

The Workshop **agreed** that the AWMP Steering Committee should receive the report from Punt and Allison and examine whether the further information that has become available should be taken into account in conditioning the planned new trials. The Workshop noted further that information about the need envelopes to be considered in developing an *SLA* for the Greenlandic minke whale hunts was detailed in IWC (2014, p.443); further analyses would be based on these envelopes unless Greenland provided revised information in regard to need.

4.4 Conditioning issues
Additional conditioning of operating models will be required if these change from those adopted for the current North Atlantic common minke whale RMP *Implementation Review*.

4.5 Advice on initial testing using 'preliminary' *SLA*s
Given the limited time available, discussion of this issue was deferred to the 2017 Annual Scientific Committee Meeting.

4.6 Conclusions and recommendations
The development of this *SLA* for Greenlandic minke whale hunts will be progressed further during the 2017 Annual Meeting of the Scientific Committee with a view to completion at the 2018 Annual Meeting. The Steering Group will request the provision of further papers concerning the stock structure of western North Atlantic minke whales for discussion at the 2017 meeting.

4.7 Work plan
The Workshop **agreed** that the following should be addressed before the 2017 Scientific Committee Meeting:

(1) completion of the RMP *Implementation Review* for North Atlantic common minke whales to serve as a basis for developing the operating models for *SLA* testing;
(2) submission of the report by Allison and Punt to the Steering Group with respect to the relative proportions of different stocks/sub-stocks off Greenland as detailed under Item 4.3; and
(3) request for further information to contribute to the conditioning of those operating models as set out in the sub-sections immediately above.

5. GENERAL MATTERS INCLUDING THE ABORIGINAL WHALING SCHEME (AWS)

5.1 AWS

AWS provisions are one of the last major remaining components of the comprehensive indigenous whaling management framework first requested by the Commission in 1994 and developed with an enormous expenditure of scientific effort and resources over the last two decades. The Commission has agreed that the AWS is a key component of this framework. Accordingly, in consultation with the Commission and its ASW sub-committee, the Scientific Committee informed the Commission in 2015 that it intends to develop recommendations for all scientific components and aspects of an AWS. Ideally, this work will be completed during the 2017 Scientific Committee meeting, i.e. well in advance of the 2018 Commission meeting when new aboriginal whaling limits are due to be established.

5.1.1 Carryover specification

A proposed AWS provision for the carryover of unused strikes has been considered recently by the Scientific Committee. During the initial development of *Strike Limit Algorithms*, the Commission had agreed (IWC, 2001a, p.20):

> '…that blocks of five years with an inter-annual variation of fifty percent were satisfactory in terms of allowing for the likely variability in hunting conditions. It therefore agreed that these values are appropriate for use in trials. It was recognised that this does not commit the Commission to these values in any final aboriginal whaling management procedure.'

At that time, the Committee also agreed that the same 50% allowance could be carried over between the last year of one block and the first year of the next. The rationale for this limitation has not changed: from a scientific perspective, *SLA*s are robust with respect to this carryover provision.

The Committee had reported last year (IWC, 2017b, item 8.2, p.22) that it is continuing to develop these ideas and intends to provide final advice on carryover provisions before the 2018 Commission meeting and ideally in 2017.

Givens presented SC/D16/AWMP05 that reviewed the current carryover provisions in the Schedule and proposed a scheme that does not rely on multi-year block boundaries or inconsistent application across stocks. Specifically, unused strikes would be accumulated annually, available for use as soon as the next year, and expire after 12 years. The number of carryover strikes that could be used in a year would be limited to 50% of the annual strike limit if given, or the annualized strike limit if only a block limit is given. Tracking this scheme was suggested to be the responsibility of the IWC Secretariat.

In discussion, the Workshop noted a number of desirable features of this scheme and also developed a possible alternative scheme based upon the fifty percent criterion cited above. Denoting the block-to-block carryover as Ct this proposed scheme was:

$$C_t = \min \{ 0.5Q_t, 0.5Q_{t-1}, U_{t-1} \}$$

where

Q_t is the strike limit for the *t*th block, not counting any carryover;
U_t is the unused strikes during the *t*th block, namely X_t-S_t;
X_t is the total strikes allowed for the *t*th block, namely Q_t+C_t; and
S_t is the total strikes used during the *t*th block.

Additionally, no more than $1.5Q_t/6$ strikes may be taken in any single year. The division by 6 is intended to 'annualise' a 6-year block quota. The choices of 0.5 and 1.5 reflect the 50% interannual variation limit referred to in IWC (2001b). This approach draws unused strikes from both the previous block strike limit itself and from any unused carryover in that same block.

One notable difference between these two options is that the SC/D16/AWMP05 does not depend on a 'blocks' structure, whereas 'blocks' are a central concept underlying the second approach. The latter reflects the way in which the Commission currently establishes block limits for ASW hunts.

Table 3 provides an example of both options. The left hand portion of the table illustrates the block-based approach, including instances where carryover is limited to 50% of the previous or next block strike limit. The right hand portion of the table illustrates the approach of SC/D16/AWMP05, showing how carryover strikes are accumulated, used, and expired after 12 years. The Workshop welcomed the development of additional options and recommended that any such options be submitted to the Scientific Committee in advance of its 2017 meeting.

The Workshop **agreed** that whatever approach is used to calculate carryover limits, the manner in which the Scientific Committee recommends carryover limits to the Commission should be as simple as possible to facilitate inclusion in any Schedule amendment. Example language for each option is as follows. For the SC/D16/AWMP05 approach:

> '...in addition, unused strikes from previous years may be added as carryover to the strike limit in any year(s) of the new block provided that the additional strikes are not more than 12 years old at the time of usage and the total strikes taken in any year does not exceed Z.'

In the above, Z is replaced by a number equalling 150% of the annualised strike limit before carryover.

For the second approach:

> '...in addition, Y unused strikes from the previous block may be added as carryover to the block strike limit for the new block provided that the total strikes taken in any year does not exceed Z.'

In the above, Y is replaced by the number C_t and Z is as previously defined.

5.1.2 Interim allowance approach: extending testing to other SLAs

The Workshop recalled the development of the 'interim allowance' strategy, which deals with the situation where an abundance estimate is temporarily and unintentionally delayed more than 10 years from the previous survey. The interim allowance strategy was first tested using the *Bowhead SLA* and found to be acceptable in that case.

The Workshop thanked Punt for developing code for testing the interim allowance strategy for West Greenland bowhead, humpback and fin whales. The results of testing for the West Greenland humpback whale case will be reviewed at the 2017 Scientific Committee meeting. Testing for West Greenland bowhead whales will occur only after the evaluation of the number of replicates is completed.

Table 3

Illustration of two options for carryover (CO). This table is initialised (prior to the tabled years) as follows: (i) for the block-based option, 24 strikes carried forward from the previous block; (ii) for the annual expiration option, 24 strikes carried forward from the previous block, with 2 of these of each age from 12 to 1 years old. Although no annual strike limit is assumed, the block strike limit is annualised for the 'annual expiration' option to determine the number of strikes allocated to carryover usage. This mimics the situation when there is both a block and annual strike limit, as is the case for B-C-B bowheads.

Block strike limit	Strikes used during year	Block-based option		Annual extirpation option						
		CO at start of block[H]	Strikes available at end of year[I]	Taken from block limit[A]	Taken from CO[B]	CO at start of year[C]	Expired CO[D]	CO added[E]	CO at end of year[F]	Remainder of block limit at end of year[G]
360	50	24	334	50	0	24	2	10	32	310
	35		299	35	0	32	2	25	55	275
	70		229	60	10	55	2	-10	43	215
	48		181	48	0	43	2	12	53	167
	60		121	60	0	53	2	0	51	107
	82		39	60	22	51	2	-22	27	47[1]
360	23	39	376[2]	23	0	27	2	37	62	337
	75		301	60	15	62	2	-15	45	262
	62		239	60	2	45	2	-2	41	200
	51		188	51	0	41	2	9	48	149
	49		139	49	0	48	2	11	57	100
	65		74	60	5	57	2	-5	50	35
360	21	74	413	21	0	50	10[3]	39	79	339
	25		388	25	0	79	25	35	89	314
	30		358	30	0	89	0[4]	30	129	284
	17		341	17	0	129	12	43	160	267
	32		309	32	0	160	0	28	188	235
	38		271	38	0	188	0	22	210	197
360	60	180[5]	480	60	0	210	37	0	173	300
	60		420	60	0	173	0	0	173	240
	60		360	60	0	173	0	0	173	180
	60		300	60	0	173	9	0	164	120
	60		240	60	0	164	11	0	153	60
	60		180	60	0	153	0	0	153	0
200		100[6]				153[7]				

Key: [A]minimum of the block strike limit divided by six and the number of strikes in the year; [B]difference between the number in A and the block strike limit divided by six (or zero is negative); [C]equal to the value F from the previous year; [D]equal to the C added (column E) 10 years before; [E]minimum of 0 and difference between the block strike limit divided by six and the value in column A; [F]value in column C less than value in column D plus the value in column E; [G]block strike limit less the cumulative number of strikes in the block; [H]carrying over from the previous block; [I]block strike limit plus (allowed) carryover from the previous less cumulative strikes in the block to the year concerned.

Footnotes: [1]These 47 are not added to carryover at the end of the block. They have been spent as follows: net 35 allocated to 'CO added' and 12 allocated to 'Expired CO'. [2]Calculated as 360+39-23. [3]The 10 CO in the first year of the first block have expired after 12 years. [4]No strikes expire because no were accumulated as CO in the third year of the first block. [5]Reduced from 271 due to requirement that block-to-block carryover does not exceed half the previous (or next) block quota. [6]Reduced from 180 due to requirement that block-to-block carryover does not exceed half of the next block quota. [7]This is greater than the final carryover on the left hand side because strikes from the severely underutilised third block persist using the annual expiration scheme. They will expire during the next block.

Similarly, testing for fin whales will be occur after the Scientific Committee has agreed on a West Greenland fin whale *SLA*. Application of the interim allowance strategy for the *SLA* for eastern north Pacific gray whales will be tested during the next *Implementation Review* for this stock.

5.2 Use of minimum abundance estimates

SC/D16/AWMP04 described an opportunity that had arisen to estimate the abundance of Bering-Chukchi-Beaufort Seas bowhead whales. A set of five flights from the US Bureau of Ocean Energy Management (BOEM) and the National Marine Fisheries Service's Marine Mammal Laboratory (MML) project termed Aerial Surveys of Arctic Marine Mammals (ASAMM) found unprecedented large numbers of bowhead whales in the Alaskan Beaufort Sea in late August, 2016. There were 183 sightings of 676 animals seen during transect flights and circling. Although not explicitly designed to estimate absolute population abundance, the survey protocols and design, data collected and encounter rates could enable abundance estimation of bowhead whales within the survey region (extending to the 200m isobath) during a short 5-day sampling period. However, data from past surveys, satellite tags, opportunistic encounters and traditional knowledge all indicated that the bowhead whales in the survey region during these days are likely to constitute only a portion of the overall population. The authors posed two questions. First, could an abundance estimate of a portion of a population, and therefore known to be negatively biased, be used alongside the series of absolute abundance estimates when applying the *Bowhead SLA*, and if so, how? Second, if such an abundance estimate were used, would it 'reset the clock' so that the next abundance estimate would be due within ten years of 2016? They noted that answers to these questions would provide guidance about the timing of upcoming traditional ice-based or aerial photo-id surveys which were originally planned for 2017, but are now unlikely due to poor ice conditions and lack of sufficient funding.

In discussion, the Workshop **encouraged** the research team to use these data to derive an estimate of the abundance of bowhead whales in the survey region during the five-day sampling period. This estimate would be an important scientific contribution regardless of whether it was used with the *Bowhead SLA*.

With respect to use of such an estimate with the *Bowhead SLA,* the Workshop noted that the *Bowhead SLA* is robust to abundance estimates with large CVs. It had also been tested with several levels of constant survey bias, for which performance had been found acceptable. A single negatively biased abundance estimate is unlikely to change the advice provided using the *Bowhead SLA*.

The Workshop noted that the situation above differs from that of 'strategic surveys' considered during RMP and AWMP development. The latter related to a hunting country discarding the results of a good survey that produced a low estimate that might reduce the strike limit. In the case considered here, it is known in advance that the estimate will be substantially negatively biased, likely to be imprecise, and potentially unsuitable for use with the *SLA*.

The decision as to whether to submit an estimate for consideration for use with the *SLA* rests with the USA. If a estimate submitted is deemed suitable by the Scientific Committee for use with the *Bowhead SLA*, the Workshop **agreed** that this would 'reset the clock' so that the next abundance survey would then be due by 2026.

In terms of developing an estimate, the Workshop noted the importance of examining the extent to which the spatio-temporal layout of tracklines and survey blocks might prevent or reduce instances of double-counting individuals. It also suggested that the researchers examine whether survey-independent data (e.g. telemetry data) might be used to develop a less negatively-biased estimate by estimating the proportion of the population in the survey area at that time. However, it recognised that the August 2016 bowhead distribution was clearly unusual, making such an approach problematic. The Workshop suggested that a variety of analytical options and approaches be considered and reported in any paper submitted to the Scientific Committee. This would assist the Committee in deciding whether an estimate is suitable for use with the *Bowhead SLA*.

5.3 Number of replicates used in Greenland trials

As discussed under Item 3.1, the Workshop had examined the issue of the number of replicates used in the development of an *SLA* for the West Greenland fin whale hunt and developed an operational approach to deal with this issue. It recognised that this issue should also be investigated for the other West Greenland hunts.

During the workshop, Brandão undertook these computations for all the *Humpback SLA Evaluation Trials* and for some *WG-Bowhead SLA Evaluation Trials*. The results showed that the problem did not arise for the humpback whale trials but for one of the bowhead trials, even for 1000 simulations, the estimated probability interval for the D10 performance statistic included the threshold. It was therefore **agreed** that Brandão would extend this exercise for all the *WG-Bowhead SLA Evaluation Trials***.** The results will be examined during the 2017 meeting of the Scientific Committee.

During discussion, it was also noted that the *WG-Bowhead SLA* had been tested using only the abundance estimates from West Greenland, although it was recognised that this region covered only part of the Eastern Canada-West Greenland stock (catches from Canada were included). Last year it was agreed that the Scientific Committee will review a new estimate from Canada. The Workshop agreed that the AWMP Steering Group will consider whether preliminary use of this abundance estimate should also be considered in the runs undertaken by Brandão.

5.4 Work plan

The Workshop **agreed** to the following work plan:

(1) Punt and Brandão will conduct trials of the interim allowance approach for West Greenland humpback case (see Item 5.1.2) and submit the results to the 2017 Annual Meeting; and

(2) Brandão (in conjunction with the Steering Group) will rerun the full set of *WG-Bowhead SLA Evaluation Trials* and submit these to the 2017 Annual Meeting as discussed under Item 5.3.

6. ANY OTHER BUSINESS

There were no matters raised for discussion under this item of the agenda.

7. ADOPTION OF REPORT

The report was adopted by correspondence on 25 January 2017. Before the Workshop ended, the Chair thanked the staff of the Greenland Representation for the usual excellent facilities. He also thanked the participants for their co-operation and the quality of the debate in addressing complex issues. In particular, he thanked the rapporteurs and especially Witting and Brandão for their exceptionally hard work to progress *SLA* development for the Greenlandic hunts, and Punt and Allison for work on computational aspects. The Workshop thanked Jette Donovan Jensen for her customary cheerful assistance with logistics, especially with respect to dining.

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International Whaling Commission. 2017d. Report of the Scientific Committee. Annex E. Report of the Standing Working Group on Aboriginal Subsistence Whaling Management Procedures. *J. Cetacean Res. Manage. (Suppl.)* 18:174-84.

Annex A

List of Participants

DENMARK

Rikke Hansen
Mads-Peter Heide-Jørgensen
Lars Witting

ICELAND

Thorvaldur Gunnlaugsson

NORWAY

Nils Øien

INVITED PARTICIPANTS

Anabela Brandão
Doug Butterworth
Geof Givens
André Punt
Lars Walløe

IWC

Cherry Allison
Greg Donovan

Annex B

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. New abundance estimates off Greenland
   - 2.1 Presentation of the results of the 2015 surveys
   - 2.2 Discussion
     - 2.2.1 Survey areas, methods (field and analytical)
     - 2.2.2 Estimates for large whales subject to ASW
   - 2.3 Conclusions
3. Development of an *SLA* for the Greenlandic fin whale hunt
   - 3.1 Review of discussions at SC/66b including progress made
   - 3.2 New abundance estimate
   - 3.3 Updated density-regulated assessment
   - 3.4 Discussion of implications of new information for finalising the *SLA*
   - 3.5 Conclusions, recommendations
   - 3.6 Work plan
4. Development of an *SLA* for the Greenlandic common minke whale hunts
   - 4.1 Review of discussions at SC/66b and the RMP intersessional Workshop
   - 4.2 New abundance estimate
   - 4.3 Initial modelling and trial structure
   - 4.4 Conditioning issues
   - 4.5 Advice on initial testing using 'preliminary' *SLA*s
   - 4.6 Conclusions and recommendations
   - 4.7 Work plan
5. General matters including the Aboriginal Whaling Scheme (AWS)
   - 5.1 AWS
     - 5.1.1 Carryover specification
     - 5.1.2 Interim allowance approach: extending testing to other *SLA*s
   - 5.2 Use of minimum abundance estimates
   - 5.3 Number of replicates used in Greenland trials
   - 5.4 Work plan
6. Any other business

Annex C

List of Documents

SC/D16/AWMP

01. Witting, L. Density regulated model for west Greenland humpback whales.
02. Witting, L. Density regulated models for west Greenland fin whales.
03. NO PAPER.
04. Givens, G., Ferguson, M., Clarke, J., George, J. and Suydam, R. Can *SLA*s use minimum population size estimates?
05. Givens, G. On the simple carryover of strikes.
06. Hansen, R., Boye, Larsen, T., Nielsen, R., Tervo, O., Nielsen, R., Singing, M. and Heide-Jørgensen, M.P. Abundance of whales in east and west Greenland in 2015.
07. Heide-Jørgensen, M.P. and Hansen, R.G. An index of the relevant abundance of minke whales in west Greenland.

Annex D

Accounting for a Time-Varying Proportion off Fin Whales of West Greenland

André E. Punt

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

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

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

Where L_y is the likelihood for the i^{th} abundance estimate, I_y is the estimate of abundance for year y, N_y is the total (1+) number of animals in year y, and σ_y is the standard error of the log of I_y.

Data generation for each future year y will be based on first generating a value from U[0,1]. If this value is less than p, the bias, β, is assumed to be equal 1 otherwise β is generated from Beta (3,7).

Annex E

West Greenland Fin Whale *SLA* Trial Specifications

Please see *J. Cetacean Res. Manage. (Suppl.)* 18: 501-510 for the latest version of these specifications. This should be read in conjunction with Punt, 2018, p.559 in this volume (see above) which details updates in the model used. A final version of the specification will be published in next year's *Supplement*.